UNIVERSITY OF REGINA

Canada Foundation for Innovation

Outcome Measurement Study on Energy Research at the University of Regina

Institutional Roll-up Report 2009

(with edits and addenda – updated May 21, 2009)

Office of Resource Planning
University of Regina
April 8, 2009

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SUMMARY OF EDITS

Changes made to April 8, 2009 report

- Page 16, Section 1.3
  Third paragraph

- Page 42, Figure 8
  Footnote added

- Page 53, Section 5.1
  First paragraph and "partnership agreement" and "five top end-user" partner organizations" lists

- Page 56, Section 5.4
  Third paragraph

- Page 65, Appendix E
  Table – one organization deleted and two organizations added

SUMMARY

Overview: University of Regina

The University of Regina has its roots in Regina College, a small residential high school established in 1911. It became an independent degree-granting institution in 1974 and has expanded to nine faculties and 25 academic departments, which have established reputations for excellence and innovative programs leading to bachelors', masters', and doctoral degrees. Located in the heart of Regina's Wascana Centre, one of the largest urban parks in North America, the University of Regina offers an attractive work and study environment for more than 11,500 full- and part-time students, 1,540 faculty and staff, and approximately 750 casual employees.

Over the past 25 years, the University of Regina has developed into an international university, signing partnership agreements with more than 90 institutions in 22 different countries. This focus on internationalization has helped attract students and faculty from around the world, bringing global perspectives to a University that had its beginnings with only 27 students nearly a century ago, and now has 52,900 alumni worldwide.

The past decade has seen unprecedented growth at the UofR, with the physical capacity of the campus more than doubling over that time. This growth is a reflection of the University's development into one of Canada's leading comprehensive universities – a dynamic institution with a strong national and international reputation for teaching and research.

Since 2000, external research funding at the UofR has doubled to more than $22M and our graduate enrolment has increased to more than 1,400 students (18 percent of whom are international). Its specialized academic programs provide hands-on training to future scholars and professionals. The undergraduate petroleum engineering program is the largest in the country. The institution's strong industry and government partnerships, including Innovation Place Regina, advance innovative applied research and development to help foster technology transfer and commercialization.

Our world-class scholars significantly advance five thematic areas – culture and heritage, energy and the environment, health, informatics and social justice. We conduct leading-edge research in carbon capture and storage, green energy technologies, cancer research, data mining, climate change adaptation, pain and aging, and other areas of traditional strength. Ten Canada Research Chairs and more than 60 research laboratories, centres and institutes are foci for internationally-renowned innovative research.

The History of Energy Research at the University of Regina

The province of Saskatchewan is the second largest producer of oil in Canada. It is also a major producer of coal and natural gas. Some of these resources are difficult to produce, for example, our heavy oil deposits where primary production may be as low as 5% of the oil in place, leaving 95% of the oil in the ground if we did not move to technology development.

In the 1980s, the province and the federal government created the Canada-Saskatchewan Heavy Oil-Fossil Fuels Agreement. This provided a substantial amount of money to be used to develop the capacity in the province to access its fossil fuel resources. Much of the money was spent supporting pilot projects, but a significant amount was also spent developing capacity at the University of Regina. At the time, the Energy Research Unit at the University was built up, and work on CO_2 capture from the combustion of fossil fuels was initiated.

Developing capacity at a university is as much about individuals with foresight as it is about need. Fortunately, these two aspects were in alignment. The provincial government and senior researchers in the University worked together to continue the development of energy research capacity even in the years that federal/provincial funding programs were not available. This was the situation in the mid 90s. The ongoing efforts of individuals were recognized in the late 90s with three significant events occurring. The first of these was the creation of the Petroleum Technology Research Centre (PTRC) and the second was the start up of the IEA GHG Weyburn-Midale CO_2 Monitoring and Storage Project (the Weyburn Project). The third component was the start of the International Test Centre for CO_2 Capture (ITC).

The creation of the PTRC was significant in that it provided the funding necessary to form the Petroleum Systems Engineering group, which rapidly became the largest petroleum engineering program in the country. The PTRC also provided resources for applied research, money to build a new petroleum research facility and to move in the Saskatchewan Research Council's petroleum research group to work closely with the University. The first director of the PTRC was hired in 1999. In the decade of its existence, the PTRC has grown in terms of industry support, global recognition and most recently government funding with the award of a $10.5 million Business-Led Network of Centres of Excellence.

The Weyburn Project was also initiated in 1999 to evaluate the use of CO_2 Enhanced Oil Recovery for the safe storage of CO_2. While the project was not looking directly at enhanced oil recovery, the evaluation of the movement of CO_2 in the ground inevitably led to a better understanding of this type of oil recovery process. More than this, it made Saskatchewan and Regina the centre of a high profile research initiative with global outreach. This was, in fact, one of the best examples of a collaborative research program, bringing together researchers from six countries on two continents. Ten years later, this project is into its second phase.

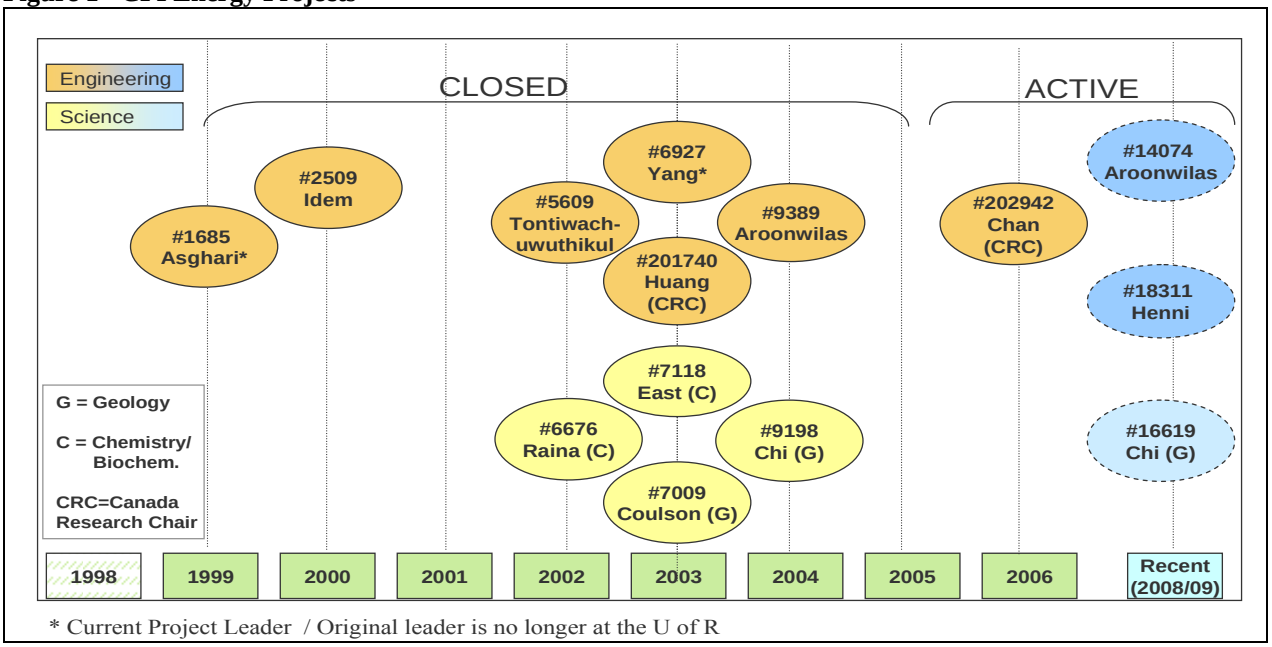
The third element was the creation of the ITC. This highly successful project focused on the capture of CO_2 from anthropogenic sources. Without CO_2 capture, enhanced oil recovery with CO_2 requires the use of natural CO_2 sources, resulting in additional CO_2 emissions rather than significant reductions. The investment in the ITC included the financial resources from government to build a new pilot plant for capture tests, re-commission an existing pilot plant in Estevan and to establish a new building with capacity for the pilot plant and new laboratories. At this point, the University was also successful in obtaining CFI funding (totaling $1.8 million) to equip the new Greenhouse Gas Technology Building laboratories with state-of-the-art analytic equipment. Work at ITC was initiated in 2001, with funding coming predominantly from industry.

As a final note, in 2001, the University created the Office of Energy and Environment in recognition that this research area was going to be a significant part of the University's future research direction and that effort was going to be required to maintain direction, focus and funding.

CFI Energy Projects at the University of Regina

Since 1999, the UofR has received CFI funding or a commitment of funding for fourteen infrastructure projects geared towards enabling and enhancing *Energy* research (see Figure 1). All but four of the projects are now complete. One of the four active projects (#202942) has been underway since 2006 while the other three were only just initiated in 2008 or later[1]. These fourteen projects represent CFI investments of just under $4.4 million[2] and a total investment of almost $9.5 million when matching funding and other sources of funding are taken into consideration.

Figure 1 - CFI Energy Projects



The key outcomes summarized in this report are based on information collected from 17 Principal Users of one or more of 11 Energy-focused CFI projects that were 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. All of the projects, by year, include:

1999

- Project # 1685 - **Sustainable Heavy Oil Research Facility (SHORF)**; Faculty of ENGINEERING, Program area - PETROLEUM SYSTEMS; Project Leader - Dr. Koorosh Asghari (Since 1999; initially Dr. Amit Chakma). This project received about $1 million in CFI funding and $1.6 million from PTRC to develop four new laboratories. The facilities were developed to enable research into some of the problems associated with developing environmentally acceptable, economically viable petroleum recovery techniques.

[1] Based on the fiscal year, ending on April 30th.
[2] Includes $700,250 in Infrastructure Operating Fund (IOF) allocations.

- *Key infrastructure: Research infrastructure to equip the Innovation Laboratory, CO_2 Utilization Laboratory, Production Laboratory, and Explosion-Proof Special Purpose Laboratory.*

2000

- Project # 2509; **Scanning Electron Microscope for Materials Characterization in Energy and Environmental Research**; Faculty of ENGINEERING, Program area - INDUSTRIAL SYSTEMS; Project Leader - Dr. Raphael Idem. This project received about $50,500 in CFI funding and just over $77,000 in partner contributions. The infrastructure has contributed to research in three areas: (1) in generating clean energy from biomass materials, waste vegetable oils and diesel; (2) in developing more cost-effective, efficient and safe methods of capturing CO_2; and (3) in aiding in the development of safe, economical and environmentally sustainable heavy oil recovery.
    - *Key infrastructure: scanning electron microscope*

2002

- Project # 5609; **International Test Centre for Carbon Dioxide Capture (ITC)**; Faculty of ENGINEERING, Program area - INDUSTRIAL SYSTEMS; Project Leader - Dr. Paitoon Tontiwachwuthikul. This project received $1.8M in CFI funding and just over $1.84M in partner contributions. The funding was used to equip the ITC with advanced research tools, equipment and instruments to enhance research activities in CO_2 capture and separation. Prior to the initial CFI request, commitments by industry and government (federal and provincial) to fund the infrastructure (pilot plants and the ITC building) were in excess of $10M.
    - *Key infrastructure: research tools to equip the ITC, including LC-NMR, fiber optic probe, EDS, XPS, XRD, surface area and porosity analyzer, X-ray tomography unit, vapor-liquid equilibrium unit with high pressure circulation cells, high temperature autoclave reactors*

- Project # 6676; **Inductively Coupled Plasma Mass Spectrometer (ICP-MA) for Analysis in Energy and Environment Research**; Faculty of SCIENCE, Department of CHEMISTRY AND BIOCHEMISTRY; Project Leader - Dr. Renata Raina. This project received just over $60,000 in CFI funding and more than $106,000 in partner contributions. While the project leader utilizes the infrastructure primarily for non-energy based research, the infrastructure is widely used by faculty from Engineering for research related to CO_2 separation and the remediation of petroleum-contaminated sites.
    - *Key infrastructure: inductively coupled plasma mass spectrometer*

2003

- Project # 6927; **Enhanced Oil Recovery Research Infrastructure (EORRI)**; Faculty of ENGINEERING, Program area - PETROLEUM SYSTEMS; Project Leader - Dr. Tony Yang (since 2007; formerly Dr. Mingzhe Dong). This project received over $75,000 in CFI funding and $116,000 in partner contributions. Funding from this project was used to build up key facilities for enhanced oil recovery research. The infrastructure is housed in the Innovation Lab of the PTRC building adjacent to the UofR campus.
    - *Key infrastructure: fluid-rock ultracentrifuge and spinning-drop interfacial tensiometer*

- Project # 201740; **Energy and Environmental Research Laboratory**; Faculty of Engineering, Program area - ENVIRONMENTAL SYSTEMS; Project Leader - Dr. Guo (Gordon) Huang – CRC Chair. This project received just over $150,000 in CFI funding and about $225,000 in partner contributions. Funding from this project has enabled extensive experimental, modeling and process-control studies in the area of energy and environment. From an energy research perspective, the infrastructure is particularly useful in enhancing research geared towards addressing subsurface contamination and site remediation related to petroleum-production.
    - *Key infrastructure: integrated experimental-modeling system*

- Project # 7118; **Simulation of Complex Chemical Reactions**; Faculty of SCIENCE, Department of CHEMISTRY AND BIOCHEMISTRY; Project Leader - Dr. Allan East. This project received just under $57,000 in CFI funding and just over $85,300 in partner contributions. The infrastructure has enabled, through computer simulation, the examination of energy at the molecular level in an attempt to lower the input cost of petroleum refining.
    - *Key infrastructure: QuantumCluster™ supercomputer platform*

- Project # 7009; **High-resolution cathodoluminescence imaging and spectroscopy research facility**; Faculty of SCIENCE, Department of GEOLOGY; Project Leader - Dr. Ian Coulson. This project received just over $82,000 in CFI funding and just over $121,500 in partner contributions. The infrastructure supported the enhancement of existing CFI funded equipment. It supports research in multiple disciplines (geology, chemistry, biology, and engineering) and is used at the UofR by the Department of Geology and the Faculty of Engineering (to support petroleum exploration based research).
    - *Key infrastructure: high-resolution cathodoluminescence instrumentation for installation on existing scanning electron microscope*

2004

- Project # 9389; **High-pressure/ High-temperature Continuous Flow Stirred and Tubular Reactor System for Greenhouse Gas Mitigation Research**; Faculty of ENGINEERING, Program area - INDUSTRIAL SYSTEMS; Project Leader - Dr. Adisorn Aroonwilas. This project received just under $58,500 in CFI funding and just over $95,000 in partner contributions. The infrastructure is housed in the International Test Centre for Carbon Dioxide Capture at the UofR. The infrastructure supports and enhances research aimed at developing cost-effective CO_2 capture technologies and reducing greenhouse gas emissions.
    - *Key infrastructure: continuous flow reactors, gas feed system, liquid feed system, product handling system, temperature controller and furnace, control and data acquisition system*

- Project # 9198; **Geofluids characterization and modeling facilities**; Faculty of SCIENCE; Department of GEOLOGY; Project Leader - Dr. Guoxiang Chi. This project received just over $44,800 in CFI funding and just under $133,400 in partner contributions. The infrastructure is located in the Geofluids Laboratory in the Department of Geology at the UofR. The infrastructure supports research in the feasibility of CO_2 storage in geological formations, as well as developing strategies for enhancing petroleum and mineral exploration.
    - *Key infrastructure: three microthermometric systems and Visual MODFLOW software*

2006

- Project # 202942; **Visualization Infrastructure for Energy Informatics Laboratory**; Faculty of ENGINEERING, Program area - SOFTWARE SYSTEMS; Project Leader - Dr. Christine Chan – CRC Chair. This project received just over $82,000 in CFI funding and just over $121,500 in partner contributions. This project provides the UofR with state-of-the-art infrastructure for visualization studies related to energy production and pollution mitigation, and is the only infrastructure of its kind in Western Canada. It is housed with and augments analytical equipment and facilities at the Energy Informatics Laboratory of UofR that had been previously acquired.
    - *Key infrastructure: DepthCube and Perspecta spatial 3D visualization systems*

New Projects (2008 / 2009) – Not yet Implemented

- Project #14074; **Integrated Energy-Flux Monitoring System**; Faculty of ENGINEERING, Program area - INDUSTRIAL SYSTEMS; Project Leader - Dr. Adisorn Aroonwillas. This project received just over $52,000 in CFI funding and almost $78,500 in partner contributions. This state-of-the-art infrastructure will be housed in the PTRC, and will greatly enhance research aimed at developing cost-effective methods of mitigating greenhouse gas emissions. It will also support renewable energy production research, particularly in the area of affordable biodiesel production from both high quality feedstock and waste cooking oil.
    - *Key infrastructure: integrated energy-flux monitoring system*

- Project #18311; **Measurements of the Heat of Reactions of CO_2 in New Promising Chemical Solvents;** Faculty of ENGINEERING, Program area - INDUSTRIAL SYSTEMS; Project Leader - Dr. Amr Henni. This project received almost $84,000 in CFI funding and over $125,500 in partner contributions. The infrastructure will be housed in the International Test Centre for CO_2 Capture at the UofR. It will complement and enhance ongoing research at the ITC aimed at mitigating greenhouse gas emissions through the development of cost-effective strategies to capture CO_2.
    - *Key infrastructure: flow calorimeter*

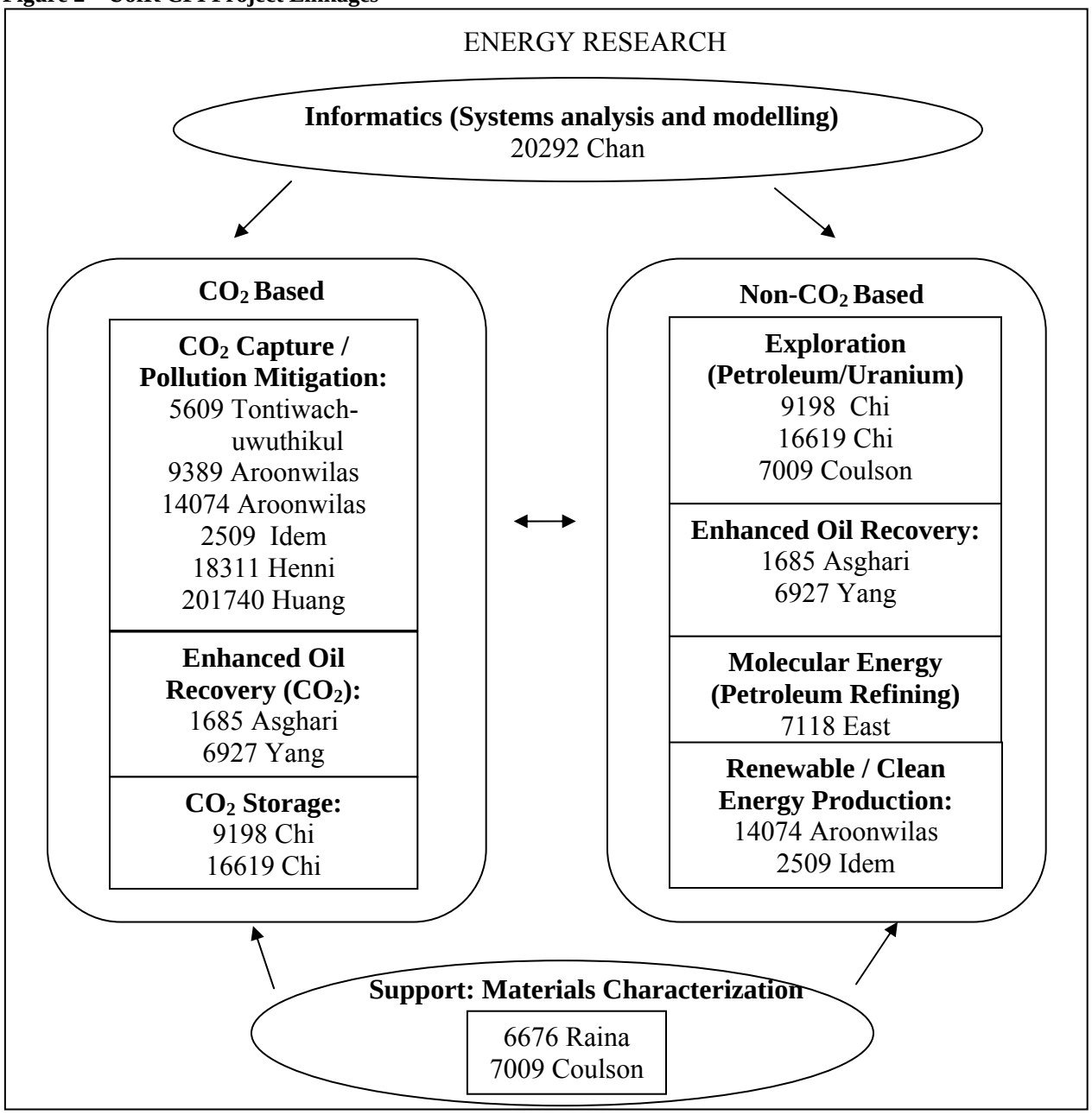
- Project #16619; **Laser Raman Spectroscopy and Energy Dispersive Spectrometry for Compositional Analysis of Geological Fluids;** Faculty of SCIENCE; Department of GEOLOGY; Project Leader - Dr. Guoxiang Chi. This project received $96,500 in CFI funding and almost $145,000 in partner contributions. This infrastructure complements earlier CFI funded infrastructure received by Chi, in that while both are used for the characterization of geological fluids, each measures distinct aspects of the fluids. Both are used for research into reservoirs and carrier beds of petroleum, as well as uranium deposits.
    - *Key infrastructure: energy dispersive spectroscopy and cryogenic system to be combined with an existing scanning electron microscope*

CFI Project Linkages

The linkages between the fourteen CFI projects are illustrated thematically in Figure 2 below, and are further depicted in Appendix A - "Matrix of CFI Projects and Users." In combination, these projects address a comprehensive array of energy related issues, spanning both CO_2 based and non- CO_2 based energy related problems. Among these are energy exploration, recovery and refining; CO_2 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 and through materials characterization support provided by Dr. Coulson and Dr. Raina.

The linkages between the projects are also demonstrated by the involvement of the project leaders in projects other than their own. As shown in Appendix A, twelve of the fourteen projects are used by multiple users. In ten cases, one or more of the additional users is a Project Leader of another project.

Figure 2 – UofR CFI Project Linkages



1.0 IMPACTS ON STRATEGIC RESEARCH PLANNING

1.1 Changes to the University of Regina's SRP

By the mid-1990's the UofR had developed research foci in environmental (prairie ecology), energy (petroleum technology) and informatics research, with emergent clusters in health-related, social justice, aboriginal, and culture and heritage research. These were developing, however, without reference to a fully articulated institutional planning strategy for the University. In 1996, in response to the MacKay Report commissioned by the Saskatchewan Minister of Post-Secondary Education and Skills Training and the resulting paper 'Public Interest and Revitalization of Saskatchewan's Universities', the UofR undertook a review of its mission. Following an internal consultation process, in 1999, the Board of Governors approved a 'Direction Statement for the University of Regina' drawn from 'Shaping Our Future: Academic Planning Toward the Second Quarter Century (vision, mission and goals)'[3]. Through another consultation process, a document entitled 'Shaping Our Future: Principles and Emphases to Guide Decision-Making'[4] was finalized in the fall of 2000.

In the context of the above planning and the development of research foci, the advent of the CFI program in 1997 allowed the UofR to target the development of selected major areas of research, particularly in prairie ecology, energy and informatics. The CFI program was therefore an important mechanism for the University to refine its research foci. The University's first four applications to CFI focused on those three areas and were successful in 1999 in building research capacity in prairie environmental quality, informatics, sustainable heavy oil research, and aquatic ecosystems, particularly associated with the University's Faculties of Science and Engineering. Since that time a total of 44 CFI grants totaling approximately $8.6 M have been awarded by CFI to UofR scholars.

The advent of the CRC Program in 2000 and the requirement for a Strategic Research Plan (SRP) moved the University to more directly identify its areas of strategic research emphases. Building upon the earlier planning documents and the CFI investments and employing a consultative process that engaged all Faculties and research centres / institutes, under the direction of the Vice-President (Research and International), the initial SRP identified five strategic research areas: culture and heritage, energy and environment, health, informatics, and social justice. Energy research was a natural fit within the University's SRP given the previous investments in energy research, the success in creating industry / government partnerships (see 1.2 below), and support from CFI. A subsequent renewal of the SRP for the period 2006-1010[5] continued the emphasis on energy research with further refinement identifying the development of carbon management technologies, the search for alternative energy sources, and the development of energy and environment related policy options. CFI investments have

[3] http://www.uregina.ca/presoff/issues/AcademicPlanning/AcademicPlansAndPrioritiesFinal.html
[4] http://www.uregina.ca/presoff/issues/AcademicPlanning/shaping%20our%20future.pdf
[5] (http://www.uregina.ca/presoff/vpresearch/documents/20062010CRCStrategySummary.pdf)

been valuable in facilitating integration of research interests among disciplines, focusing the scope of energy R&D (e.g. on carbon capture and storage technologies), and improving the speed of implementation of research programs.

Under its new President, the University is currently engaged in a renewal of its institutional strategic plan, expected to be completed by Fall 2009. The institutional strategic planning process involves consultations with faculty, staff and students throughout the University, as well as with members of the Board of Governors, Senate, the external community, Government partners, and other stakeholders.

As well, the Office of the Vice-President (Research and International) has initiated a renewal process for the institutional strategic research plan (SRP) in tandem with the overall institutional strategic planning process. The renewed SRP is intended to be completed by Spring 2010 to coincide with the end of the current SRP (2006-2010). The renewal process for the SRP involved the establishment of a working committee of scholars from across campus to review the existing SRP and develop a draft table of contents for the renewed SRP. In addition, the University's Executive of Council[6] has a Council Committee on Research with representatives from across the campus who are providing direction on the development of the renewed SRP. The renewal process for the SRP will involve consultations external to the academy with research partners and clients. Integral to those planning processes, CFI programs continue to be a major influence on University research strategy, particularly through the Leaders Opportunity Funds and the recent competition under the New Initiatives and Leading Edge Fund programs.

1.2 External influences on the University of Regina's SRP

In support of the University of Regina's emphases on developing energy R&D, the Government of Saskatchewan has established a mechanism to provide matching funding for CFI grants to the UofR. The UofR works closely with Government to insure support for UofR applications to CFI. The process of application for CFI allows UofR researchers to work with industry and governments to examine federal and provincial science and technology alignments that serve multiple interests. In particular, the University research on energy aligns well with provincial and federal science and technology priorities, as the following examples indicate.

Entrepreneurial and Knowledge Advantages

The University took a major step forward on its energy-related research with the establishment of the Petroleum Technology Research Centre (PTRC) in 1998, a partnership among Natural Resources Canada, the Saskatchewan Department of Industry and Resources, the Saskatchewan Research Council and the University of Regina, with support from the western Canadian oil and gas industry. That partnership was further enhanced by the development of the International Test Centre for Carbon Dioxide (CO_2) Capture through partnerships with SaskPower, EnCana, HTC Purenergy, E.ON|UK,

[6] Council at the UofR is equivalent to the Senate at many other Canadian universities, while the Senate is a forum for representatives of alumni and professional and community organizations.

Saudi Aramco, Research Institute of Innovative Technology for the Earth (RITE), Alberta Energy Research Institute (AERI), RWEnpower, Babcock & Wilcox, Natural Resources Canada, and Saskatchewan Industry & Resources. CFI investments were critical for the University to be able to engage with industry and government as a partner in those developments.

CFI investment has also been beneficial in allowing a critical mass of R&D to be developed that facilitated the internal development of the University's Industry Liaison Office (UILO). The technology transfer and commercialization potential of energy R&D, particularly in relation to carbon capture and storage (CCS) technology, provided the impetus for the University to work with the Regina Regional Economic Development Authority (RREDA) and the federal and provincial governments in 2007 to establish SpringBoard West Innovations Inc. (SBWI), a non-profit organization designed to help innovators transform an idea into a commercial reality and to help organizations access important new innovations. The development of that partnership in turn has led to the construction of a new building in the University's Research Park to house SBWI and the UILO. That new building provided the opportunity to co-locate a number of centres / institutes focused on energy and environment research as well as the University's Office of Energy and Environment (OEE) in an integrated cluster named the Consortium for Global Change Management (CGCM).

In December 2008, the University finalized a partnership agreement with Royal Dutch Shell ($5M) and the Government of Saskatchewan ($5M) to establish the International Performance Assessment Centre for Geological Sequestration of Carbon Dioxide (IPAC-CO_2). IPAC- CO_2 will be housed in the new SpringBoard building and will leverage an additional $15M from industry partners in support of research on performance assessment. IPAC is negotiating with centres in other countries for the establishment of an international network of centres focused on performance assessment. CFI investment in UofR research was instrumental in allowing the development of procedures that form the core of the assessment underlying IPAC.

The UofR is currently in discussions with the Government of Saskatchewan for the formation of a Sustainable Energy Institute as an umbrella organization that will include IPAC- CO_2, and a carbon capture and storage demonstration plant. This $200M project will link Saskatchewan with government and industry interests in Montana for the use of carbon for enhanced oil recovery.

People Advantage

One example of the University's efforts to foster innovation and growth with our industry partners in support of graduate students was to establish a Graduate Student Support Fund associated with our Petroleum Systems Engineering (PSE) Program. Established in partnership with the Petroleum Technology Research Center, this fund allows PSE professors to recruit top-quality graduate students in anticipation of R&D contracts for energy research with PTRC.

The University also adapted its administrative emphasis on energy research by establishing the Office of Energy and Environment (OEE). That administrative office resulted in the hiring of two permanent staff as well as three term staff to advance the University's interests in energy research and development.

CRC Program

In addition to the impact of provincial and federal priorities, the CRC program has had a direct impact on institutional planning. Although the University has identified five strategic areas of research emphases in its SRP, six of the University's 10 CRC's are engaged in energy and environment research, with two Tier 1 Chairs directly focused on energy research. The designation of one of the Tier 1 Chairs to energy led to the creation of the University's Centre for Studies on Energy and the Environment (CSEE) which is now forming a core part of the Consortium for Global Change Management.

1.3 External effects of the University of Regina's SRP

Investments by the CFI in energy research at the University have been directly responsible for the University's ability to collaborate effectively with external industry, government and other academic partners.

The International Test Centre for CO_2 Capture was founded in 1999 to conduct fundamental, bench, pilot, and demonstration scale research and development on carbon capture technologies for the energy industry. ITC is a $12M centre that includes a $3.3M CO_2 capture pilot plant located in-house and a $5.2M pre-commercial capture demonstration plant located at SaskPower's Boundary Dam coal-fired power plant near Estevan, Saskatchewan.

At start-up, ITC received a $3.7M CFI equipment grant to help furnish its state-of-the art laboratories. In fact, ITC has been described as one of the "best-equipped laboratories in North America." ITC receives $700K/year from industry and $300K/year from the UofR. Approximately 5% is spent on operations and the remainder supports research. The equipment furnished by the CFI funding has enabled ITC to attract some of the top researchers and graduate students in energy and greenhouse gas research. It has also enabled ITC to attract considerable industry and government funding and to participate in some of the most advanced carbon capture projects and research programs in the world. Finally, it has enabled our researchers to secure a number of patents and the University to sign licensing agreements with industry to use and distribute these patented technologies.

In mid-2008, for example, the ITC's commercialization partner, HTC Purenergy, signed a technology licensing agreement with Doosan Babcock Energy, UK, and its parent company, Doosan Heavy Industries, Korea, to produce and distribute ITC's patented CO_2 capture technology internationally. Doosan designs, supplies, and constructs advanced steam generation technology for the power industry and has constructed more than 300 plants worldwide.

Currently, the ITC is involved in several international collaborations and research demonstration projects. In January 2008, the ITC and commercialization partner HTC Purenergy were one of a limited number of pre-qualified suppliers identified worldwide to respond to a tender issued by StatoilHydro in Norway, the first country to commit to and then tender CO_2 capture on its natural gas burning plants. Norway has been joined by other nations and organizations that have announced they will undertake CO_2 capture, including Great Britain, OPEC, and Australia. In late February, HTC Purenergy and ITC were awarded a feasibility tender in Australia to capture CO_2 from Australian coal-powered plants. On March 5, 2008, HTC Purenergy and the UofR were qualified as able to carry out front-end engineering and design work for the Norwegian government's Gassnova SF on another larger Norway-based power station.

All of the above accomplishments are a direct result of the ITC's research and development capacity, which, in turn, was largely furnished by the initial CFI equipment grant. Start-up and operational funding was also supplied by the federal government through Western Economic Diversification and by the Government of Saskatchewan.

Carbon capture is not the only energy initiative at the UofR. Since carbon capture would not be advantageous without the capacity to store or otherwise dispose of the captured CO_2, the UofR has also invested heavily in developing a leading research program in CO_2 storage. This research is strongly associated with the UofR's research in oil production since one of the most effective and financially sound means of storing large quantities of CO_2 is to use it in enhanced oil recovery projects in which the CO_2 is injected into the reservoir to boost oil production. Sufficient CO_2 can be injected into the reservoir to more than compensate for the CO_2 produced from utilizing the additional oil. Many of the EOR research projects conducted by the UofR Faculty of Engineering focus on either optimizing the CO_2 storage/EOR process, evaluating and minimizing the risk of CO_2 leakage from the reservoir, or developing and testing new ways of utilizing captured CO_2 and other greenhouse gases in EOR projects, such as in heavy oil production.

The UofR's focus on both oil production and CO_2 capture is greatly enhanced by our partnership with the Petroleum Technology Research Centre (PTRC). PTRC is the managing organization of the world's first and largest CO_2 geological storage project – the IEA GHG Weyburn-Midale CO_2 Monitoring and Storage Project – operated in association with large-scale commercial CO_2 EOR operations at EnCana Corp.'s Weyburn field in southern Saskatchewan. PTRC is a not-for-profit research organization established in 1998 to facilitate collaboration between the federal and provincial governments, the University of Regina, the Saskatchewan Research Council, and the oil industry operating in the province and internationally. In addition to the Weyburn Project, PTRC is managing the multi-million dollar VAPEX project, which is demonstrating the feasibility of using greenhouse gases such as CO_2 to extract heavy oil. PTRC is also managing the Aquistore Project, the first large-scale CO_2 saline aquifer storage project in North America and the second largest in the world. The project has received $5M in funding from SDTC (Sustainable Development Technology Canada). PTRC uses government funding to leverage industry support (and *vice versa*) for major enhanced oil recovery and sustainable production pilot and demonstration projects.

The UofR's Petroleum Systems Engineering group (PSE) receives PTRC funding for specific projects, and every year, the UofR runs several projects related to both oil production and CCS through PTRC, including projects related to the major programs such as Weyburn and VAPEX. The UofR leases 5,390 sq. ft. of research/lab space and 4,543 sq. ft. of office space in the PTRC building for the PSE faculty and graduate students, and many of the UofR's PTRC laboratories have been furnished with CFI grants. The availability of this equipment enables the UofR researchers to continue to leverage PTRC support and industry and government funding via PTRC for their work.

The IEA GHG Weyburn-Midale CO_2 Monitoring and Storage Project (the Weyburn Project) is a $40 million, 8-year study to demonstrate the technical and economic feasibility of CO_2 geological storage using CO_2 EOR as the economic driver. The expected outcomes are the world's most comprehensive storage dataset, best practices, and successful monitoring and modeling techniques for identifying and operating large-scale CO_2 EOR and storage projects. The UofR was instrumental in establishing the project and is its major research provider. PTRC, through the Weyburn Project, has established the world's most comprehensive data set on CO_2 geological storage. The Weyburn Project has also produced some of the best modeling and performance assessment technologies in the petroleum industry.

Implementing CCS as a means of managing CO_2 emissions will require more than just capture and CO_2 injection research. In recognition of issues concerning performance and risk assessment, independent verification of CO_2 captured and stored, and public policy development, the University, the Province of Saskatchewan, and Royal Dutch Shell launched a new UofR research centre, the International Performance Assessment Centre for CO_2 Geological Storage (IPAC-CO_2), to address these research areas. Initial start-up funding of $5M each is provided by the Province and Shell, with similar amounts of funding being garnered from other industry partners. Risk management, quality assurance, and storage quantification techniques are the key planned outcomes. IPAC-CO_2 will serve as the world's first independent body for assessment and verification of CO_2 storage projects. While IPAC- CO_2 itself has not received CFI support as yet, the entire centre is ultimately an outcome of the outstanding research already accomplished at the UofR in CCS; much of this research was supported by CFI funding, including the initial ITC equipment grant.

As all of these research programs demonstrate, the UofR has made major investments in energy production with a particular emphasis on clean utilization of fossil fuels. However, the University's efforts are not limited to clean coal energy production and sustainable oil production. The UofR is also heavily invested in developing clean and green fuels, including hydrogen and biofuels. For example, the Greenhouse Gas Technology Centre (GGTC) is a $25M building that houses the ITC as well as the Faculty of Engineering's hydrogen production and biofuels research programs. This facility will also house two multi-million dollar hydrogen production pilot plants, which are under construction. Plans to expand to a second GGTC facility (GGTC Phase 2) are in the final approval phase. GGTC 2, at a capital cost of $50M, will enable significant expansion of the University's greenhouse gas control technology research including the

CCS and hydrogen and biofuels programs. While the hydrogen plants are to be supported with SDTC funding, some of the preliminary research and fundamental and bench-scale equipment has been supported and furnished with CFI funding, including part of the initial ITC equipment grant.

Industry sponsors of the UofR's CCS research include: SaskPower, EnCana Corp., HTC Purenergy, Doosan Babcock/Heavy Industries, E-ON|UK, Saudi Aramco, RWEnpower, Babcock & Wilcox, BP Exploration (Alaska) Inc, Canadian Natural Resources Limited, ConocoPhillips, Husky Energy Inc., Nexen, Inc., Penn West Energy Trust, Royal Dutch Shell, Shell Canada Limited, Total, Apache Canada, Aramco Services Company, Chevron, Dakota Gasification Company, OMV, Schlumberger, and Devon Canada. Government sponsors include: Natural Resources Canada, United States Department of Energy, Natural Sciences and Engineering Research Council of Canada, Western Economic Diversification Canada, Canadian Foundation for Innovation, Government of Saskatchewan, Saskatchewan Ministry of Energy and Resources, and IEA GHG R&D Programme. Other research organizations include: University of Waterloo, Saskatchewan Research Council, Alberta Research Council, Research Institute of Innovative Technology for the Earth (RITE) - Japan, and Alberta Energy Research Institute (AERI). These partnerships are in place not only to sponsor the research but also to guide its development and ensure wide dissemination/transfer of results. Multiple industry and government sponsors and partners are secured for each research program.

1.4 Linkages of SRP to Complementary Investments

Human Resources

Two of the University of Regina's ten Canada Research Chair (CRC) appointments are allocated to researchers in the energy theme. Together they account for 26 % of CFI's $990,000 in investments allocated to CRCs at the University of Regina.

The two Tier 1 CRCs in the theme area are:

- **Guo (Gordon) Huang, Tier 1 Canada Research Chair (2003)** in Natural Sciences and Engineering (Energy and Environment); Dr. Huang specializes in environmental systems analysis in the areas of subsurface contamination and air pollution caused by a wide range of petroleum-related practices.
- **Christine Chan, Tier 1 Canada Research Chair (2006)** in Natural Sciences and Engineering (Energy and Environmental Informatics), specializes in developing and applying artificial intelligence and knowledge-based system technologies for analysis and decision support in energy and environmental systems; Dr. Chan's research is directed towards improving the productivity of energy processes and the management of environmental pollution caused by the production and use of petroleum.

The faculty members conducting energy research at the UofR are generally either from the Faculty of Engineering or the Faculty of Science. Among new faculty hired between 1999 and 2008 in Engineering and Science (Geology and Chemistry / Biochemistry), over half (54%) are involved in energy research[7] (see Table 1 below). Not unexpectedly, all of the new faculty members in the Petroleum Systems Engineering program are in the thematic area. In addition, 50% of the new hires in the Environmental Systems and over one third (38%) of the new hires in the Industrial Systems programs are also involved in energy research. In the Faculty of Science, all four of the new hires in Geology are working in the theme area or are collaborating (through joint publication or data provision) with faculty who are more actively involved in energy research. The same applies to two out of seven (29%) new hires in Chemistry.[8]

Table 1 - New Faculty Hires in the Theme Area Since 1999, by Faculty and Dept.

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	11	8	3	38%
	Petroleum	8	8	8	100%
	Software Systems	5	3		0%
ENGINEERING Total		**36**	**24**	**13**	**54%**
SCIENCE	Chemistry / Biochem	9	7	2	29%
(selected departments)	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 terms of CFI's investment at the UofR, over two-fifths (43%) of the almost $9M allocated to researchers at the institution has been awarded to researchers involved in energy research (see Table 2 below). 43% of the $3.7M in CFI funding for energy infrastructure went to new faculty hired between 1999 and 2008. By far the largest share of "energy" funds went to faculty in Engineering, $3.4M compared to just over $282,000 in funding that went to the Faculty of Science. Of the total CFI investment provided to Project Leaders in the Faculty of Engineering, 77% went to energy-focused Project Leaders. Although there are equal proportions of pre-CFI and since-CFI energy-focused faculty in Engineering (4 and 4), a much larger share of the energy infrastructure funds went to the longer-term faculty, with only 38% having been allocated to new hires. In Science, 68% of CFI funding allocated specifically to faculty in the departments of Chemistry/Biochemistry and Geology went to energy researchers, all of whom were hired after 1998.

[7] Professors only; lecturers and lab instructors are excluded.

[8] It should be noted that the degree of energy-related research among the new hires in the theme area is highly variable, ranging from 100% for some to only a moderate amount (often on the basis of collaboration) for others. Thus, while most of the new hires could be described as "Energy Hires", there are a few, particularly in the Sciences, who would be better described as "Energy Collaborators".

Table 2 - Value of CFI Investment awarded to Faculty at the University of Regina

CFI Award Recipients	All UofR Projects		Energy Projects		% Energy	
	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

Additional Investments in the Theme Area:

- Multi-million dollar investments in developing infrastructure to support energy research include[9]:
    - a $13 million Greenhouse Gas Technology Centre (2001)
    - a $8.5 million International Test Centre for Carbon Dioxide Capture (2003)
    - 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)
    - a $12 million International CO_2 Storage Assessment Centre (announced November 2008)
- UofR co-funding of CFI Awards: To date, UofR contributions to CFI infrastructure total $541, 233.
- UofR funding / co-funding of energy research projects: Since CFI funding, the Principal Users of CFI energy projects have also contributed $763,884 to energy research through funds secured internally from the institution.
- CFI Infrastructure Operating Funds (IOF): Ten out of the fourteen CFI energy focused projects are eligible for IOF funds . The other four were not eligible, either because the CFI project was awarded to a CRC or the project was approved prior to July 1, 2001.
    - Overall IOF = $700,250
    - Eligible IOF = $653,727
    - IOF Received = $575,225

[9] These examples of complementary funding include funding from all sources. The majority of the funding has come from external sources.

    - Three projects received IOF funds: #5609, #9389 and #6676 (totaling $575,225).
    - Four projects -- #7009, #7118, #6927 and #9198 (total funding $78,502) -- have been advised of the CFI IOF funding but have not made a request.
    - Funding requests for CFI IOF have not been finalized for projects #14074, #16619 and #18311.

- NSERC Equipment Grants: Additional investments in the theme area include NSERC equipment grants totaling $995,397 allocated to ten out of the seventeen Principal Users of Energy CFI infrastructure between 1998 and 2008. The vast majority of these investments were received between 2001 and 2004 (87%), while 8% was received pre-CFI and 5% was received after 2004.

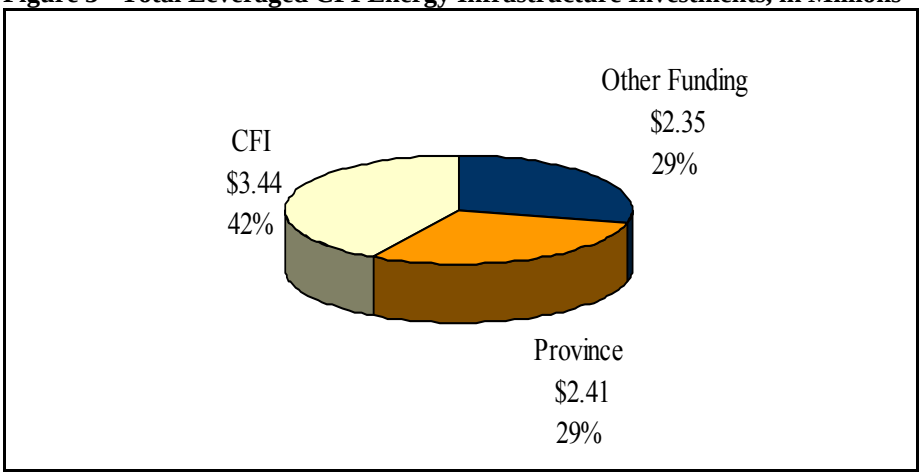
2.0 IMPACTS ON RESEARCH CAPACITY

The ensuing assessment of the impact of CFI infrastructure at the UofR is based on eleven of fourteen CFI projects in the energy theme. These eleven projects have been substantially implemented, whereas the other three CFI projects (#14074, #18311 and #16619) have just recently been or are in the process of being implemented and are therefore considered as outcomes of earlier CFI investments.

2.1 Infrastructure Investment Value

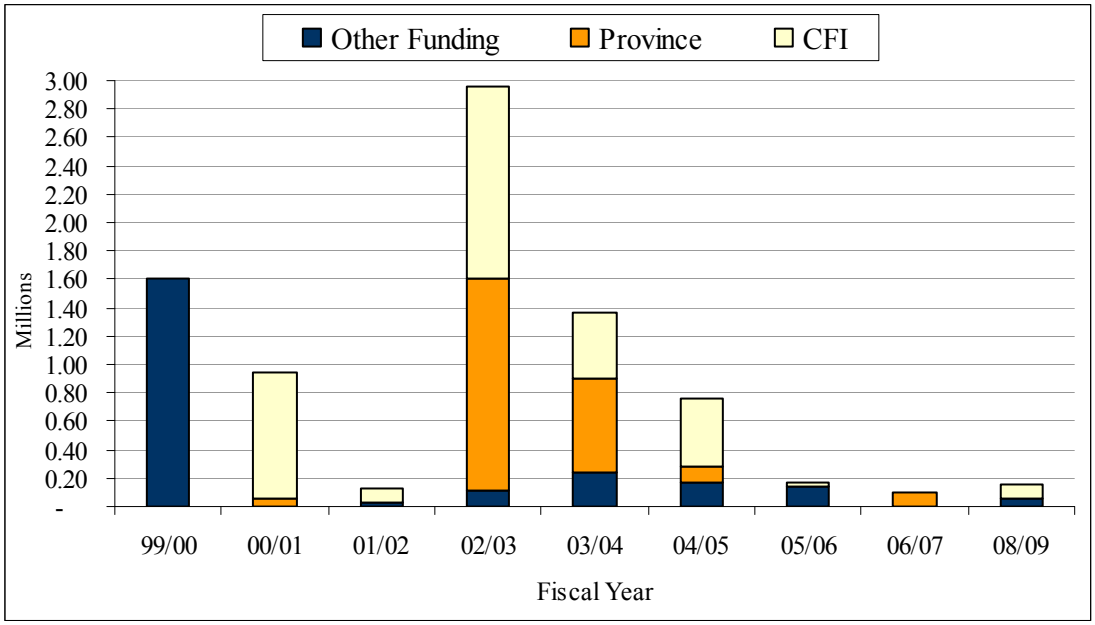
With partner contributions, the total investment in CFI energy infrastructure, among projects that were implemented prior to 2007, is $8.2 million. The CFI contributions have been substantially augmented by partner contributions, which account for 58% of the total investment (Figure 3). These partner contributions are shared equally by the Province of Saskatchewan and other funding sources, largely from industry and to a lesser extent from UofR contributions.

Figure 3 - Total Leveraged CFI Energy Infrastructure Investments, in Millions



Source: Records from Financial Services and Research Services

Figure 4 - Cumulative Leveraged CFI Energy Infrastructure Investments



Source: Records from Financial Services and Research Services

Early contributions in 1999 of about $1.6 million from PTRC set in motion the development of the Sustainable Heavy Oil Research Facility (SHORF) housed at the PTRC in Regina's Research Park (see Figure 4 above). This initial contribution was complemented by $1 million in funding from CFI. These funds enabled the development of four world-class laboratories, which have made possible research geared towards developing innovative, environmentally acceptable and economically viable methods of recovering oil.

The next major influx of funding for CFI energy infrastructure occurred in 2002 in conjunction with the International Test Centre for Carbon Dioxide Capture (ITC). This project received almost $3.7 million in combined funding ($1.8M from CFI and almost $1.9M from partners).

The extent of the existing infrastructure for energy research at the UofR is predominantly the result of the substantial contributions of CFI and other funding partners. Prior to 1999, very little infrastructure for energy research was available at the UofR and funds received for these purposes were nominal. For example, the total value of NSERC equipment grants awarded to the Principal Users of Energy CFI projects pre-CFI was only $108,042. This represents only 5% of the total investments for infrastructure received from CFI for the 11 projects that have been substantially implemented and 2% of the total investments when partner contributions are considered.

2.2 Infrastructure Capabilities

Not only was there very little infrastructure available prior to the CFI funding, but what was available was no better than average quality. In terms of the total value of all CFI projects in the energy theme, the Project Leaders rated 29% of the pre-CFI funded infrastructure as "very low", 8% as "below average" and 63% as just "average". With the CFI funding, the overall technical capacity of energy research infrastructure was boosted to "like the best in the world" for 85% of the infrastructure and an additional 7% was rated "like the best in Canada". No longer was more than one third deemed to be "very low." In fact, only a small proportion of the pre-CFI infrastructure (8%) remained "average" or "below average" in technical capability. Similar ratings were also provided with respect to the operational capability of infrastructure for energy research in the pre- and post-CFI funding periods. An exception is that the ratings of operational capacity for pre-CFI infrastructure in comparison to ratings of technical capacity were more optimistic in that only 2% (instead of 29%) was rated as "very low."

Table 3 - Technical and Operational Capability of the Infrastructure

	% of CFI Energy Projects (by $ Value)			
	Technical Capability		Operational Capability	
Rating	Pre-CFI	Now	Pre-CFI	Now
Like the Best in the World	0%	85%	0%	84%
Like the Best in Canada	0%	7%	0%	6%
Average	63%	6%	62%	11%
Below Average	8%	2%	36%	0%
Very Low	29%	0%	2%	0%

Source: Interviews with Project Leaders; the ratings are based on the 11 CFI projects implemented prior to 2007; the value of the project is based on CFI funding only (excluding IOF).

For most of the Project Leaders, the advent of CFI funding has vastly improved their ability not only to conduct energy research, but to conduct leading edge research. While the infrastructure improvements paved the way for a couple of the Project Leaders to compete with other institutions, for a number of others it placed them ahead of their competitors. The improvements were described by one Project Leader as follows: "The equipment that was available prior to the CFI equipment was below average. The CFI equipment that was installed was the best. There was very little research before having the CFI infrastructure in place and right now we are rated as one of the best places to do this type of work." In the words of another Project Leader: "Before CFI, it was average, like any other university. Once the CFI was installed it was the best in the world. It is still the best in the world and then some."

A couple of the Project Leaders indicated that while the equipment made available through CFI funding serves a valuable role in that it has enabled them to do fundamental research, and even compete with other institutions, the equipment itself was average when first installed and will remain so. There were also a couple of the Project Leaders

who noted that the equipment, when first installed, was "like the best in Canada" but is now out-of-date. Looking ahead, at least one of the three new (post-2006) CFI projects will overcome the limitations of infrastructure obtained previously and is expected to raise the technical capacity of the Project Leader's infrastructure from just average to be like the best in the world. Yet another Project Leader is hoping to get some upgrades for equipment that when first purchased was like the best in Canada, but is now only average; it is anticipated that the upgrades would boost the equipment back to its original "best in Canada" status.

In a number of cases the operational capability of the CFI funded infrastructure was greatly enhanced by earlier and complementary funding from the University and other sources. The existence of, and/or commitments to, earlier infrastructure like the Sustainable Heavy Oil Research Facility (SHORF), the International Test Centre for Carbon Dioxide Capture (ITC), and the PTRC played a pivotal role in ensuring that the operational requirements of CFI equipment would be met. One Project Leader explained that while the CFI has had an "important effect on developing operational capability at the University," many of the necessary components (including lab space) were already provided through the University. Similarly, another Project Leader suggested, in regards to CFI equipment used to upgrade earlier equipment, that, "Prior to CFI involvement [the infrastructure] was about average, but after the update was installed we had other sources of money for operation and maintenance, and other things from industry support. So, it became the best in the world and still is, but not because of purely CFI funding."

Among the Project Leaders whose infrastructure's operational capacity is ranked just average, the chief limitations are space (having enough of it or having dedicated space) and a lack of technical support. To overcome the support gaps, these Project Leaders have had to largely assume responsibility for the operational aspects of the infrastructure, and they do so at the expense of time that could otherwise be spent conducting research.

2.3 Research funding

Since 1996, the UofR has received over $19.5 million in research funding from external sources for energy research (see Table 4 below). Almost all of this (96%) was received since the initial CFI infrastructure awards were granted in 1999. The largest share of funding received since the start of CFI has come from industry (42%) and the second largest portion (37%) is from the federal government's NSERC program. Close to equal proportions of provincial and other federal funding account for an additional 19% of total sponsored funding obtained by the University. A very small proportion (3%) was provided from sources either outside of the Province of Saskatchewan or outside the country. These include Alberta Science and Research, the Alberta Energy Research Institute and the University of Texas, USA.

Table 4 - Sponsored Energy Research by Source

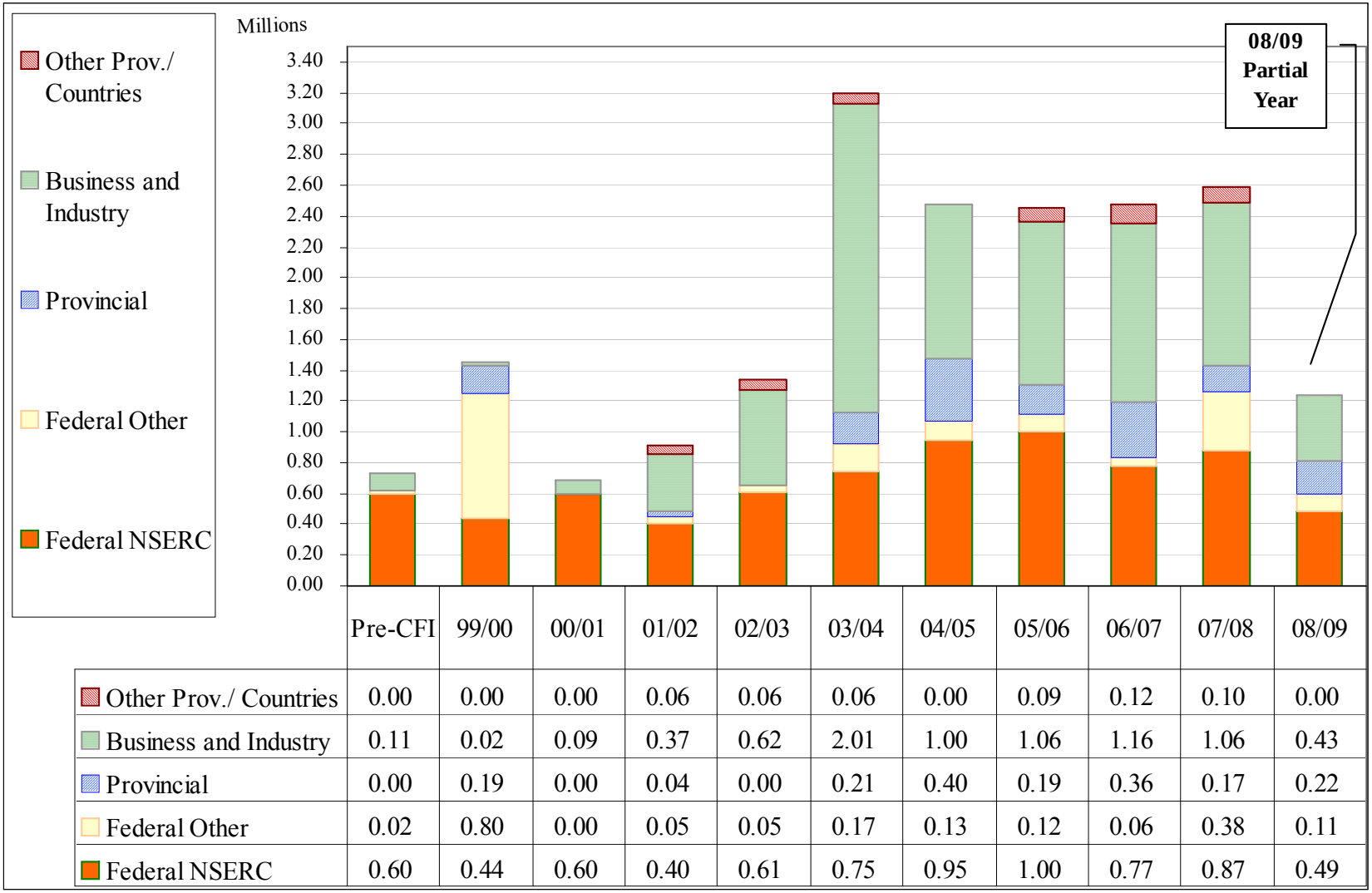
Funding Source	All Funding	Pre-CFI Funding	Since CFI Funding	Since CFI Funding % of All Funding	Since CFI Funding % of Total Since CFI Funding
Federal NSERC	$ 7,475,200	$ 601,006	$ 6,874,194	92%	37%
Federal Other	$ 1,885,491	$ 17,500	$ 1,867,991	99%	10%
Provincial	$ 1,764,700	$ -	$ 1,764,700	100%	9%
Business and Industry	$ 7,926,891	$ 114,000	$ 7,812,891	99%	42%
Other Prov./ Country	$ 491,349	$ -	$ 491,349	100%	3%
Total	**$ 19,543,632**	**$ 732,506**	**$ 18,811,126**	**96%**	**100%**

Source: Financial Services, vetted by PUs to include only "Energy" funds
"Pre-CFI" includes fiscal year 1996/97 to 1998/99;
"Since CFI" includes fiscal year 1999/00 to approx. the first 8 months of fiscal year 2008/09

In addition to sponsored funding obtained by the UofR, the CFI energy Principal Users have also contributed to energy research through funds secured internally from the institution. These have come primarily from faculty research accounts, although President's awards and other sources have also added to the sum of funds contributed by the institution. These internal funds total $763,884. Combined with contributions from external sources the total amount of research funding obtained from 1996 to 2008 is in excess of $20.3 million. Of note is that these contributions reflect funding that has been received to date. Several hundred more research dollars have been committed through various awards and agreements and are yet to be received.

Looking at trends in sponsored funding, notwithstanding the 2000/01 fiscal year, annual sponsored funding for energy research has exceeded the three-year cumulative pre-CFI amount of $732,506 (see Figure 5 and Table 5 below). While NSERC has been a constant and generally increasing source of funds over the past decade, the biggest gains have been made as a result of industry partner contributions. While industry contributions to energy research predate CFI investments, the value of contributions has increased substantially since the CFI investments began, starting with an $80 thousand contribution in 1997 to an annual high of over $2 million in 2003 and over $1million each year thereafter.

Figure 5 - 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 year 1996/97 to 1998/99; "Since CFI" includes fiscal year 1999/00 to approx. the first 8 months of 2008/09)

Smaller, yet still significant contributions have been made by the Province of Saskatchewan following initial CFI investments, as well as recent contributions from the public sector outside of the province.

Increases in sponsored funding for energy research since the implementation of CFI funded infrastructure have been paralleled by increases in the number of researchers working in the theme area (see Table 5 below). Just as sponsored research funding in the 07/08 fiscal year is 3.5 times greater than the cumulative dollar amount of all sponsored research funding received for fiscal years 96/97 to 98/99, so too has the number of Principal Users more than tripled from 4 in the pre-CFI years to 13 in the 07/08 fiscal year. In line with these changes, the average funding per researcher has also increased pre-CFI to more recent years, starting from almost $21 thousand in 96/97 to a high of more than $266 thousand in 03/04.

Table 5 - Sponsored energy research funding and number of Principal Users

Fiscal Year	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

There was general consensus among the Project Leaders that despite the limited number of faculty at the UofR, the group did indeed constitute critical mass[10]. Most agreed that reaching a point of critical mass with respect to energy research at this institution could certainly not be measured by the strength in numbers, but by the diverse backgrounds and areas of expertise among a limited number of the faculty and the extent to which these researchers work in coordination with one another. One Project Leader described the situation as follows: "We have all these faculty members in different aspects that constitute the energy theme and we can say we have critical mass, but, on the other hand, if you separate them into smaller groups this may not be the case." The collaborative aspect was further iterated by one Project Leader, who stated, "There is a wide list of people who come from different backgrounds and contribute in their respective area, but they also come together to contribute."

The CFI has been integral in this process as it has brought researchers together from a variety of disciplines and faculties. For example, the involvement of faculty with the initial CFI funded project, SHORF (# 1685), has not been restricted to petroleum professors, but involves collaborative research with engineering professors from other areas, as well as with faculty from Computer Science and Geology. Even among the researchers within Petroleum Engineering, backgrounds are diverse. They have backgrounds in not only Petroleum Engineering, but also Chemical and Mechanical Engineering.

At least a couple of the Project Leaders are of the view that the low population of both staff and students at the UofR is a limiting factor, resulting in a lower impact than could otherwise be obtained with a larger faculty. While some of the Project Leaders are concerned that the low population is an impediment, another sees this as being offset by the number of dedicated faculty positions, at least in the area of CO_2 capture. This Project Leader explained that "when you look at CO_2 capture, the University of Regina is the only institution where faculty positions are dedicated to this area (up to 5 people). There is no place in Canada that does CO_2 capture per se. If you go to the University of Texas in Austin there is one professor involved in CO_2 capture but I would say they have critical mass because they have [a large number of] students, staff and technicians. We are becoming better off because we have different people with different backgrounds doing different things and working towards a common goal…. we have become a centre of excellence in the sense that, not only are we able to do what [the director of the UofTexas] does, but we have different people with different backgrounds adding more to what one person can do."

[10] Based on CFI's definition whereby a "critical mass" of faculty members is defined as having sufficient number of faculty members, from a sufficiently broad range of disciplines, that all types of expertise required to make significant progress in the theme are available.

2.5 Faculty Recruitment and Retention

The majority of the Principal Users concur that the investments in CFI infrastructure for energy research have had a very positive impact on faculty recruitment. One Project Leader, speaking on behalf of the Petroleum group, indicated that the University routinely incorporates tours of the group's labs and facilities as part of the interview process and the result is that "everyone is positively impressed with the quality and type of equipment and infrastructure that is there." Another indicated that when a position opens up they receive a "flood of applications" and that the CFI infrastructure now allows them to "recruit internationally recognized people because they know the value of the infrastructure." As expressed by another Project Leader: "In the past, no one knew where Regina was, but now the UofR has a world renowned reputation for its CO_2 capture research. It is known for its energy and environmental projects."

In the Faculty of Science, at least three out of the four Project Leaders in this faculty were attracted by the CFI infrastructure, and its availability was pivotal in their decision to come to the institution. One was attracted, in particular, by a recruiting ad highlighting the Petroleum Technology Research Centre. The lack of recruitment to Science in more recent years, they claim, is not a problem of attraction, but is due to budget constraints.

Within the Faculty of Engineering and the departments of Geology and Chemistry / Biochemistry in the Faculty of Science, there has been a number of new faculty working in the energy theme that were hired between 1999 and 2008, and the majority of these new hires have been retained. All but two of the new faculty hired since the first CFI project were retained. The losses were in Petroleum Engineering, which also gained the greatest number of new hires. The retention rate among new faculty hires working in the energy theme is slightly higher than the rate of retention among all new faculty in Engineering and the two "energy" departments in Science, 90% compared to 85%.

Table 6 - New Professors (Hired Between 1999-2008) in Selected Faculties / Depts.

Faculty	Dept./Program	ALL New Hires	ALL New Hires Retained	% All New Hires Retained	**ENERGY** New Hires	**ENERGY** New Hires Retained	% **ENERGY** New Hires Retained
ENGINEERING	Electronic Systems	1	1	100%			
	Environmental Systems	5	4	80%	2	2	100%
	Industrial Systems	10	8	80%	3	3	100%
	Petroleum	10	8	80%	10	8	80%
	Software Systems	3	3	100%			
ENGINEERING Total		**29**	**24**	**83%**	**15**	**13**	**87%**
SCIENCE (Geol / Chem)	Chemistry / Biochem	8	7	88%	2	2	100%
	Geology	4	4	100%	4	4	100%
SCIENCE (Geol / Chem) Total		**12**	**11**	**92%**	**6**	**6**	**100%**
Grand Total		**41**	**35**	**85%**	**21**	**19**	**90%**

* excludes lecturers and lab instructors

The vast majority of the new hires in the energy theme (18 out of 21) were attracted from abroad at some point along their educational or career trajectory. Most came from China and the US, fewer numbers (up to two each) came from Thailand, Iran, Nigeria, and the UK.

In some cases these new faculty members came directly after completing their graduate work and in some cases after having accumulated faculty experience in academia or other research experience in industry. For instance, Dr. Asghari came directly from the University of Kansas and Dr. Zhou came from the University of Tulsa, Oklahoma. A number of others were attracted to the University of Regina from abroad as graduate students, and having completed their doctoral work they continued on as faculty. Dr. Yang, for example, came from China four years ago to complete his second Ph.D at the UofR and then chose to stay. He was attracted by the research opportunities that the CFI infrastructure and training at the UofR offered in his research area of interest, and then stayed despite having good offers from other institutions because he recognized that this is among, if not, the best place in the world to pursue research in CO_2 EOR storage.

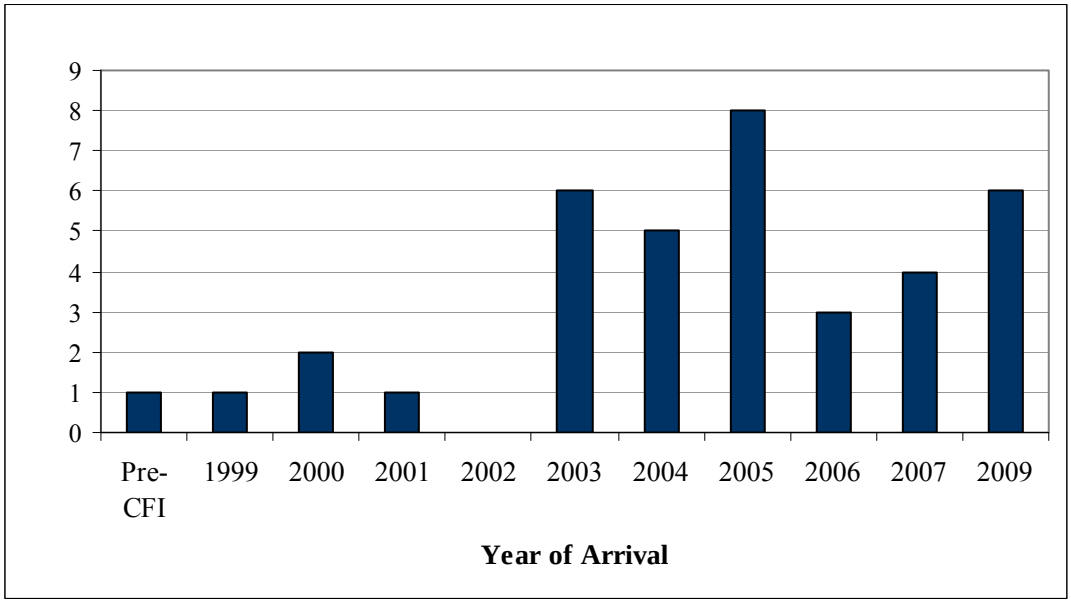
CFI investments on energy research infrastructure have not only been a boon to attracting and retaining highly qualified faculty in recent years, but they have also contributed greatly to retention among faculty members that have a longer history with the University of Regina. One of the few Project Leaders who pre-dates the first CFI investments claimed: "I myself would have left. When we first started here, there was not too much in terms of equipment. Compared to other universities where they have [a long] history…, the University of Regina and the Faculty of Engineering are quite new… Without the money from CFI, a lot of the new faculty members would have looked somewhere else for support."

Other faculty members that are newer to the institution echoed similar sentiments about the impact of the CFI infrastructure on retention. One Project Leader in Science expressed it as follows: "Personally, the infrastructure is a major factor for staying. If my CFI infrastructure was not approved I would have to consider moving somewhere else to carry on my research." For this researcher the limited number of faculty in his department is in and of itself a major limitation. The CFI infrastructure helps to make up for the disparity in faculty numbers and without it he would have left. Another Project Leader, this one in the Petroleum Engineering group, also commented on the small size of the department and the extent to which the CFI infrastructure helps to compensate for this. In his words: "It is a small department, but given the size of the department and the number of people doing work in this area it is big. In Engineering, there are many people who have been retained because of the infrastructure we have. Some people argue it would be useless to go to a bigger institution because they would have to start from scratch to build this kind of infrastructure."

2.6 Visiting Researchers

Of the 63 visiting researchers that have come to the University of Regina in connection with energy research, 37 have stayed or plan to stay for more than a week. All but one of these 37 longer-term visiting researchers arrived after the first CFI energy infrastructure project was implemented in 1999 (see Figure 6 below).

Figure 6 - Visiting Researchers by Year of Arrival



While the length of stay among the 37 visiting researchers (lasting more than a week) ranged from two to 54 months, close to three quarters of them (26 or 70%) stayed for six months or longer. On average, the length of stay among these visiting researchers is nine months. The majority came from China (32), with the remaining visitors from Great Britain (4) and India (1). See Appendix B for a detailed list of visiting researchers and their origins (institution and country).

There is no doubt that the CFI facilities are a major drawing card for visiting scientists. Not only is the ITC "the main attraction for visiting professors as well as politicians and everyone else," according to one Project Leader, but it is also "the biggest draw in Regina in general and the origin is the CFI grant…. [It] puts us on the map. I think there is nothing like it in North America." The significance and uniqueness of the infrastructure, particularly for CO_2 capture research, has and continues to attract visiting researchers. Oftentimes they come to see what the UofR has and does, with the intention of trying to duplicate it at their own institutions.

To date, most of the visiting researchers attracted to the University of Regina's energy research related facilities are associated with the Faculty of Engineering, a growing number researchers are visiting with faculty in Science. In particular, Dr. Chi's Geofluids lab in the Department of Geology is becoming a world-known centre for fluid inclusion studies. So far, his lab has received two visiting researchers, with two more on their way and a number of others who are in the process of applying to come.

2.7 Multidisciplinarity

A high level of interdisciplinary work is conducted by energy researchers at the University of Regina. The multidisciplinary approach is made evident in Appendix C, which shows the various users of each project and their corresponding discipline, and in Appendix D, which lists other UofR energy researchers, who collaborate with one or more of the Project Leaders or Principal Users. The energy researchers who use the infrastructure at the UofR come from one of eight disciplinary backgrounds in one of two faculties[11].

- In the Faculty of Engineering, the program areas include:
    - Environmental
    - Electrical
    - Industrial
    - Petroleum
    - Software
- In the Faculty of Science, the program areas include:
    - Biology
    - Chemistry / Biochemistry
    - Geology

Virtually all of Dr. Chan's research (Project #202942) is inter-disciplinary, blending informatics with environmental, petroleum and process systems engineering. As well, many of the energy focused researcher projects led by researchers in Petroleum Engineering are done in collaboration with faculty from Industrial, Electronic, Software and Environmental Systems Engineering, as well as with faculty in Science (Computer Science, Chemistry/Biochemistry and Geology). Similarly, coming from a chemistry background, Dr. East (Project #7118) collaborates with a number of faculty members from Geology, as well as with faculty from two program areas in Engineering.

One specific example of the benefits of multidisciplinary collaborative efforts was provided by Dr. Asghari (Petroleum Systems Engineering) (Project #1685) in regards to research he has undertaken with Dr. Paranjape (Electronics Systems Engineering). In this case, the latter contributed knowledge of digital signal process, while the former contributed knowledge and expertise in CO_2 and Enhanced Oil Recovery. By combining their distinct areas of expertise, they were able to monitor and gain better insight into where CO_2 goes when it is injected into a reservoir. This has implications for both enhanced oil recovery as well as CO_2 storage applications. These collaborative endeavours have, according to Dr. Asghari, added greatly "to our knowledge and [have]

[11]This is based on interviews with project leaders and data derived from CFI applications forms.

expanded our understanding of how the research in the energy area could be improved." The importance of the CFI equipment in fostering opportunities for multidisciplinary work is also recognized. In Dr. Asghari's case, because all of the experimental work is conducted in their PTRC labs using CFI funded equipment, "there is always a direct or indirect contribution of CFI into the collaborative research."

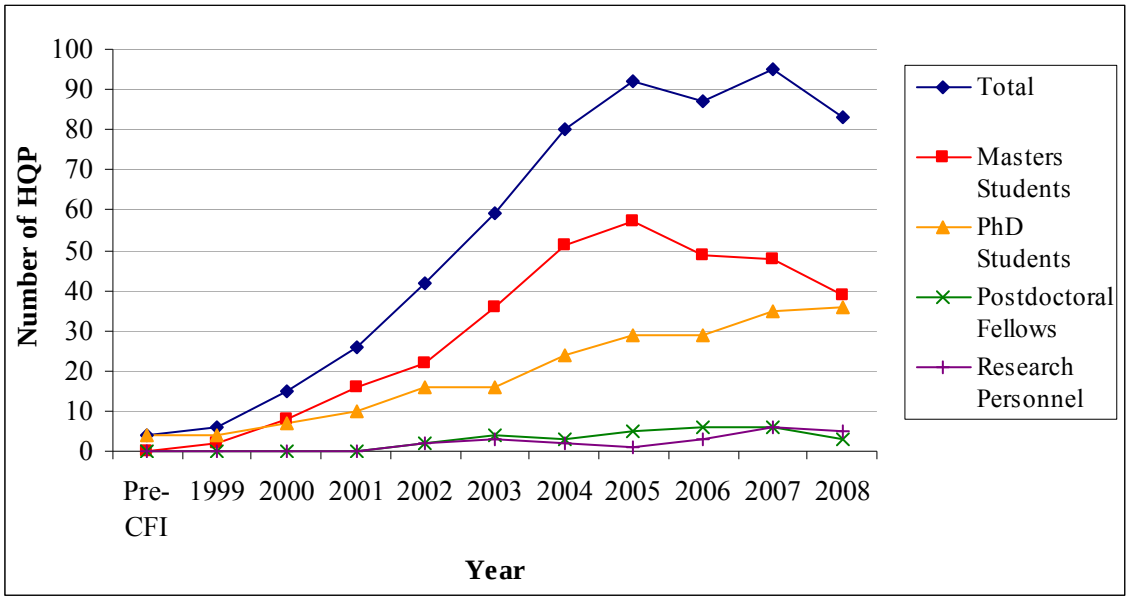
The benefit of the collaborative approach is further described by Dr. Idem (Project #2509): "Bringing people together adds value to the research because one person will have a particular set of skills but the overall project requires skills that are broader than just that individual person." In fact, he asserts that they actively seek out individuals from different disciplines to complement existing skills and expertise in order to ensure a complete array of skills required for a particular project, "whether it's the infrastructure project itself or projects that grow out of the CFI infrastructure." At the University of Regina, a project might be done in coordination with "five or six people with different backgrounds, each person contributing, [and] filling in the gap left by the other person. … We have a complete set of people who can embark on a complete project…. We have all the skills we need to do anything we want to do. From the onset, we are looking for a disciplinary group that contributes towards the outcome of the whole project. That is intentional, not just because we wanted representation from different people, but we wanted to make use of the different skill sets."

3.0 IMPACTS ON HIGHLY QUALIFIED PERSONNEL (HQP)

3.1 Number of Research trainees

Since the beginning of the CFI projects at the University of Regina in 1999, 155 individual students have worked in energy-focused research with the Project Leaders and Principal Users of the CFI projects considered in this assessment. Only four of the students started their programs just prior to 1999 which they completed either in 2002 or 2003. Over a dozen of the students were guided through more than one graduate program, generally first a Masters program followed by a Doctoral program, and in a few instances these were supplemented with further guidance as a post-doctoral fellow or other researcher. At the program level, these students account for 98 Masters students, 52 PhD students, 12 Post-doctoral fellows, and 9 research personnel. Figure 7 illustrates the dramatic increase in the number of energy-focused students under the direction of the Project Leaders and Principal Users from the onset of the CFI to the present, with six in training in 1999 to a peak of 95 in 2007.

Figure 7 - Number of Highly Qualified Personnel in training annually with Principal Users in the Energy Theme



Source: NSERC Form 100 with confirmation from PL's and PU's

3.2 Quality of training and trainees

Since the implementation of the CFI funded infrastructure there has been a dramatic increase in the number of graduate student applicants, to the point that, at least in the Petroleum Systems Engineering program, now only about 10% of applicants are accepted; whereas, virtually all qualified students were accepted pre-CFI. Moreover, among the pool of applicants are higher quality students, coming in with higher GPAs. These changes are attributed in large part to the CFI infrastructure. The scenario is described by one Project Leader as follows: "…these days, some of the top students, who a few years ago would have gone somewhere else, are coming and asking to join the group because they heard of the research that is going on [here]. We can pick and choose. The Faculty of Graduate Studies is giving them awards because of their grades, something that in my case has never happened before. I am getting people who are lecturers at other universities who are attracted to the University.... We know the reputation and quality of the program is making that possible."

There has also been an increase in the number of international students attracted to the UofR in both Engineering and Science. While this trend might in part be due to the strong local labour market, which is enticing domestic students into the job market, there is evidence of growing interest in the UofR programs by students from abroad as a result of the CFI infrastructure. According to one Project Leader in Engineering, "Students are actually contacting [us] by email, [indicating] that they read about [the UofR] and the infrastructure and would like to come and work with [us]. We have more emails now than before the CFI. It becomes more competitive. Now you have more students to select from and can go to the best applicants instead of just taking anyone you see." Another Project Leader in Science indicated that many of the students he receives have come here on the recommendation of academic supervisors from back home who are familiar with the faculty and facilities at the UofR.

The quality of training has also been enhanced since the advent of CFI funding, as evidenced in the development of new programs and courses. The Petroleum Systems Engineering (PSE) program, for instance, was offered only as an undergraduate program prior to the CFI funding. Within a few years of receiving the initial CFI funded infrastructure, a graduate level program in PSE was developed and first offered in 2002. Another new graduate program in Process Systems Engineering (at the Masters level) was developed in 2006. Both of the new Engineering programs rely heavily on the CFI funded infrastructure. In Science a graduate course in fluid inclusions has also been developed by Dr. Chi and would have been very difficult to offer without the CFI infrastructure. In addition to the development of on-campus programs and courses, new workshops and training courses, in areas like CO_2 storage and EOR, have been developed and delivered worldwide.

The high caliber of training offered at the UofR is attributed to the wide range of expertise, combined with hands-on training in state-of-the-art facilities. Not only is the CFI funded infrastructure pivotal in the training of students, but it also provides them with the ability to produce research data for publication and ultimately makes them more marketable in the labour market.

3.3 Knowledge Transfer through HQP

Since 2001, the CFI Energy Principal Users have guided 86 energy-focused graduate students through to completion. The majority of these graduates (48%) have taken up jobs with Canadian companies in the private sector, in companies like Harvard Oil, Nexen Oil Company, Schlumberger Canada Ltd., and Skystone Engineering. Just over one quarter of the students hired into the Canadian private sector (11) obtained employment with partner organizations,[12] including HTC Purenergy and Husky Energy. As well, out of the six graduates who went on to jobs in Canadian government, four were hired by public sector partner organizations, namely the Saskatchewan Research Council and Environment Canada. Another public sector organization that has benefited from UofR trained HQP is the Saskatchewan Ministry of Environment.

Table 7 - Initial Career Destinations of graduates and PDFs

Career / Training Destinations	Number of Graduates	% 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%**

Source: NSERC Form 100 with confirmation from PL's and PU's

An additional 12% of graduates found employment abroad. Among the countries that have gained these students are Thailand, China, Saudi Arabia, Iran, the United Arab Emirates, Libya, Nigeria, and Australia.

[12] A partner organization is defined as any private or public sector financial contributor that has complemented CFI investments in infrastructure. For a complete partner organization list, refer to Appendix E. This list was compiled and approved through the assistance of University of Regina Research Services and the Faculty of Engineering.

Close to one quarter did not stray from academia – 9% pursued employment in academia and 14% chose to further their academic training. Of students continuing with further academic training, five out of twelve graduates (42%) chose to remain at the UofR after completing their Masters degree to seek their PhD. Of those who were hired into jobs in Canadian academia, five out of eight graduates (63%) were hired at the University of Regina.

The impact of the CFI on training of HQP is readily apparent by the eagerness of partner organizations to hire UofR graduates who have trained in the CFI-funded facilities. In fact, it is not out of the ordinary for Project Leaders to be approached by partner organizations for student referrals, even long before the student has completed his or her program. The scenario described by one Project Leader is as follows: "Some of our partner organizations come to us and want to recruit any students we have and want us to identify the good ones so they can have them as soon as they are finished their program here…. In some cases we can't supply the number of people they are looking for because we simply don't have them." The hands-on training with the CFI infrastructure that students receive plays a tremendous role in making them highly sought after by industry: "They prefer to have students who have had hands on experience in the job they are doing so they can fit in quickly and make in-roads in the industry…. They know the kind of work they are doing and the kind of products we are getting out and they feel the students are very [well] trained, not just in Canada but also world wide. Generally we [hear] from employers that the students do very well where they are."

4.0 IMPACTS ON RESEARCH PRODUCTIVITY

4.1 Competitiveness

The CFI funded infrastructure has made it possible for the UofR to undertake leading-edge research, making it the primary competitor in energy-focused research. In listing their competitors and in describing the nature of the competition, there was no indication from the Project Leaders of any "strong" competition (see Table 8 below). Competition with the Saskatchewan Research Council, for instance, was described as friendly. Similarly, competition with academic institutions within Canada tended to be described as minor, or confined to very specific areas of research. The University of Saskatchewan and the University of Calgary were seen as competitors, not so much in terms of the quality of energy research, but primarily in terms of the sheer size of some of their departments (e.g., Geology) relative to the UofR.

Table 8 - Main Competitors and Collaborators by Scale

Main Competitors & Collaborators	Competitor	Collaborator
Provincial		
Saskatchewan Research Council	Y	Y
University of Saskatchewan	Y	Y
Petroleum Technology Research Centre		Y
SaskEnergy / Transgas		Y
SaskPower		Y
Prairie Hunter Energy Corporation		Y
HTC Purenergy		Y
Saskatchewan Energy & Resources		Y
National		
University of Calgary	Y	
University of Alberta	Y	
Alberta Research Council	Y	
University of Waterloo	Y	
University of British Columbia	Y	
Geological Survey of Canada		Y
International		
University of Texas in Austin	Y	Y
Norwegian University of Science and Technology (NTNU) in Norway	Y	Y
University of Melbourne, Australia	Y	Y
China University of Petroleum		Y
China National Petroleum Corporation		Y
International Energy Agency		Y
University of Vienna		Y
Institut francais du petrole (IFP)	Y	
** Other collaborators from industry are included among the research consortium of the International Test Centre for CO2 Capture (see page 47 for a listing).		

Even relative to international institutions -- like the Norwegian University of Science and Technology (NTNU) in Norway, the University of Texas, and the University of Melbourne -- there is general consensus that what the University of Regina offers is not replicated at any other university institution when factors like scope and scale are considered.

The UofR offers a full spectrum of infrastructure for CCS research ranging from small-scale labs to very large demonstration plants and is equipped in some cases with equipment that is unique in the world. The range and scale of the energy research infrastructure and resources has enabled the development of the largest Petroleum Systems Engineering (PSE) program in Canada and the ability to conduct some of the best research in the area of CCS in the world.

The impact of some of the larger CFI funded projects on competitiveness is described in section 1.3. The following are a couple of examples associated with smaller CFI projects. One example is a high pressure pendant drop interfacial tension unit designed and built by Dr. Gu and Dr. Yang's group. The unit makes it possible to observe CO_2, water and oil in reservoir conditions. It is a unique piece of equipment that has contributed to several projects and published papers and has given the UofR dominance in that domain over other groups[13]. Another example is work that Dr. East has undertaken in collaboration with the University of Vienna, which was made possible by the CFI funded equipment for his project #7118. This equipment has allowed Dr. East to make substantial progress in understanding chemical mechanisms for petroleum cracking. He and his collaborator at the University of Vienna are now leading this field and are optimistic that this infrastructure will lead to the development of a new theory that will aid future catalyst design.

In more recent years there have been a number of visitors from competitor institutions to the energy research facilities at the UofR, many of whom are taking closer stock of the UofR's situation and are attempting to duplicate what is being done here. Given the increasing competition, there was a sense among a few of the Project Leaders that in order to maintain an edge, the UofR will require more funding in the future.

4.2 Research Productivity

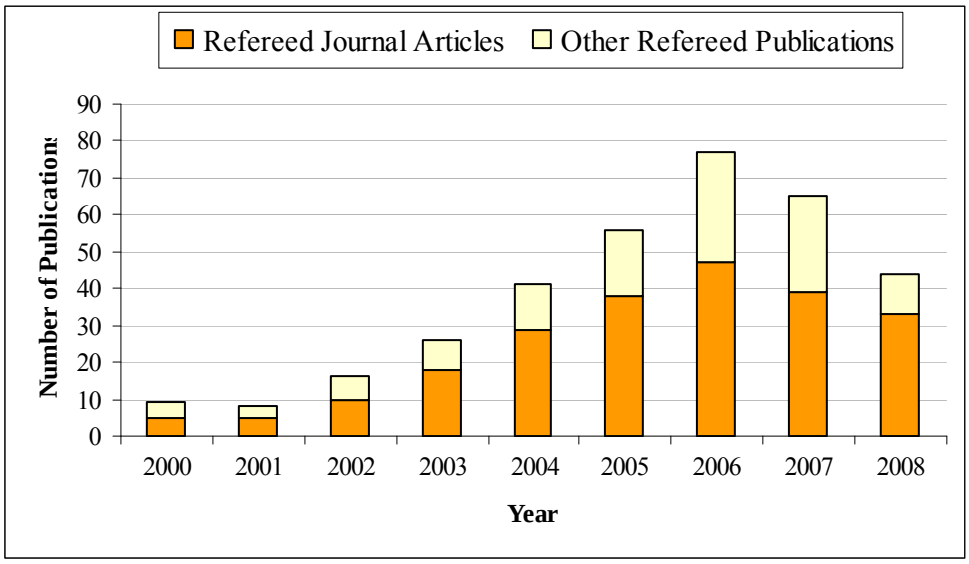
A Web of Science search with the UofR Principal Users as an identified author identified a total of 642 publications from 1999-2008. Within this number, not all publications will be specifically energy related. As well, there will be some duplication as it is common for the Principal Users to co-author articles together. At the same time, this search would not have found all publications as Web of Science does not index all journals, but it does include those considered most significant in each field.

CV mining and vetting for the energy theme area within publications by the Principal Users revealed 224 unique refereed journal articles and 118 unique other refereed publications for a total of 342 publications pertaining to energy. As Figure 8 illustrates,

[13] Example provided by Dr. Asgahri.

in 2000, just after the initiation of CFI projects at the UofR, the total number of refereed publications in the energy theme was 9; this grew to a peak of 77 in 2006. Not only has the quantity of publications increased, but the perceived quality has also improved. As one Project Leader confirmed, "We are able to publish in highly reputable journals and are invited to contribute to publications."

Figure 8 - Refereed Publications in the Energy Theme



Source: NSERC Form 100 vetted by PL's and PU's[14]

In addition to the above numbers, there have been seven refereed journal articles accepted for publication and another 19 submitted for consideration in recent years. Principal Users have also prepared over 300 non-refereed publications, such as conference presentations and posters and computer software packages. As well, in theme areas other than energy but which utilized CFI infrastructure, there have been 30 refereed journal articles published from 1999 to 2008, 2 accepted in 2005, and a further 10 submitted in the last two years, demonstrating the broad benefits resulting from CFI.

Most Significant Scientific Publications Dependent on CFI

As selected by the Principal Users with a description of the importance:

- Akande, AJ; Idem, RO; Dalai, AK. 2005. Synthesis, characterization and performance evaluation of Ni/Al2O3 catalysts for reforming of crude ethanol for hydrogen production, *Applied Catalysis A-General*, 287 (2): 159-175.
    - This was the first time in the world the idea of catalytically extracting hydrogen from fermentation broth was demonstrated and reported.

[14] The apparent decrease in publications in more recent years is due at least in part to the non-inclusion of more recent publications not captured in the data source used (most recent NSERC 100 forms which are not updated annually).

- Aroonwilas, A; Veawab, A. 2004. Characterization and comparison of the CO_2 absorption performance into single and blended alkanolamines in a packed column, *Industrial & Engineering Chemistry Research*, 43 (9): 2228-2237.
    - It is the most comprehensive source of CO_2 absorption performance data.
- Aroonwilas, A; Veawab, A. 2007. Integration of CO_2 capture unit using single- and blended-amines into supercritical coal-fired power plants: Implications for emission and energy management, *International Journal of Greenhouse Gas Control*, 1 (2): 143-150.
    - It is the first work that: (1) uses rigorous design approach and in-house models to simulate the integration of CO_2 capture unit to the power plant; and (2) provides comparative information on the integration of CO_2 capture unit using various amines.
- Cai, YP; Huang, GH; Yang, ZF; Lin, QG; and Tan, Q. 2009. Community-scale Renewable Energy Systems Planning under Uncertainty – an Interval Chance-constrained Programming Approach, *Renewable and Sustainable Energy Reviews*, 13, 721-735.
    - This is the first Canadian Community-Scale Renewable Energy Systems Planning Model.
- Chi, G., Lai, J., Tong, A. and Pedersen, P.K. 2006. Potential use of petroleum inclusions in the study of hydrocarbon degradation in oil sands and heavy oils in the Western Canada Sedimentary Basin – examples from western Saskatchewan. In Gilboy, C.F. and Whittaker, S.G. (eds.), Saskatchewan and Northern Plains Oil and Gas Symposium. *Saskatchewan Geological Society Special Publication 19*: 270 – 280.
    - The biodegradation of oil in oil sands in the Western Canada Sedimentary Basin has been conventionally studied through analysis of oils or solid bitumen from the reservoirs. These oil and bitumen represent the petroleum that has experienced biodegradation. We proposed a new way of studying the degradation process by analyzing oil inclusions entrapped in minerals. These inclusions represent samples of the oil before biodegradation and in different stages of degradation. This is the first case of this kind of study in the Canadian oil sands and provides a reference for future studies.
- East, ALL; Bucko, T; Hafner, J. 2007. Carbocation branching observed in a simulation, *Journal of Physical Chemistry A*, 111 (27): 5945-5947.
    - This paper reports a breakthrough in the understanding of the branching rearrangement steps of hydrocarbons. We achieved the first unbiased simulation of a branching event.
- Gessner, O; Lee, AMD; Shaffer, JP; Reisler, H; Levchenko, SV; Krylov, AI; Underwood, JG; Shi, H; East, ALL; Wardlaw, DM; Chrysostom, ET; Hayden, CC; Stolow, A. 2006. Femtosecond multidimensional imaging of a molecular dissociation, *Science 311* (5758): 219-222.

- Pump-probe spectroscopy probes the fate of excess energy pumped into a molecule from laser light. The novelty in this work was in presenting a new and useful technique for how the probing can be done, both experimentally and computationally. This collaboration between experimentalists and theorists should be considered a landmark in femtosecond pump-probe spectroscopy; it led to improved understanding of the fate of excess energy in molecules. This paper has been cited 34 times in three years.

- He, L; Huang, GH; and Lu, HW. 2008. Health-risk-based groundwater remediation system optimization through clusterwise linear regression, *Environmental Science & Technology* (American Chemical Society), 42(24), 9237-9243.
    - An innovative optimization system for managing and controlling site remediation at petroleum-contaminated groundwater systems.

- Hunter, KC; East, ALL. 2002. Properties of C-C bonds in n-alkanes: Relevance to cracking mechanisms, *Journal of Physical Chemistry A*, 106 (7): 1346-1356.
    - This paper was the first to look at the trends in C-C bond properties of ordinary n-alkanes with position on the alkane, and with length of chain.

- Idem, R; Wilson, M; Tontiwachwuthikul, P; Chakma, A; Veawab, A; Aroonwilas, A; Gelowitz, D. 2006. Pilot plant studies of the CO_2 capture performance of aqueous MEA and mixed MEA/MDEA solvents at the University of Regina CO_2 capture technology development plant and the Boundary Dam CO_2 capture demonstration, *Industrial & Engineering Chemistry Research*, 45 (8) 2414-2420.
    - This was the first world reported demonstration of this technology at the pilot/demonstration plant levels with detailed analyses of the effects of various parameters on plant performance. This provided information for industry to examine the cost effectiveness of the post combustion capture process.

- Kumar, P; Sun, Y; Idem, RO. 2007. Nickel-based ceria, zirconia, and ceria-zirconia catalytic systems for low-temperature carbon dioxide reforming of methane, *Energy & Fuels*, 21: 3113-3123.
    - This was the first time in the world this process has been performed practically at conditions of commercial importance.

- Qin, XS; Huang, GH; Zeng, GM; and Chakma, A. 2008. Simulation-based optimization of dual-phase vacuum extraction to remove nonaqueous phase liquids in subsurface, *Water Resources Research* (American Geophysical Union), 44(4), Art. No. W04422.
    - An innovative optimization system for simulating and managing petroleum-contaminated site through dual-phase vacuum extraction systems.

- Sakwattanapong, R; Aroonwilas, A; Veawab, A. 2005. Behavior of reboiler heat duty for CO_2 capture plants using regenerable single and blended alkanolamines, *Industrial & Engineering Chemistry Research*, 44 (12):4465-4473.
    - It is the first work that reports reboiler heat duty data of both single and mixed amines.
- Uraikul, V; Chan, CW; Tontiwachwuthikul, P. 2007. Artificial intelligence for monitoring and supervisory control of process systems, *Engineering Applications of Artificial Intelligence*, 20 (2): 115-131.
    - This is a very up-to-date and comprehensive survey of applications of AI technology in monitoring and control of process systems.
- Walz, C., Chi, G., Pedersen, P.K. 2009. Petrographic, stable isotope and fluid inclusion characteristics of the Viking sandstones: implications for sequence stratigraphy, Bayhurst and surrounding areas, SW Saskatchewan, Canada. In Linking Diagenesis to Sequence Stratigraphy of Sedimentary Rocks (edited by S. Morad and M. Ketzer), *International Association of Sedimentologists Special Publication*.
    - Sequence stratigraphy model is important in identifying and characterizing petroleum reservoirs. Sequence boundaries are relatively easy to recognize in basin margins such as in western Alberta, and more difficult to study toward basin center such as in Saskatchewan. This paper used stable isotopes and fluid inclusions as tools to help recognize the sequence boundaries within the Viking Formation in western Saskatchewan. It is the first study of this kind in western Saskatchewan, and provides an example for sequence stratigraphic models in the region.
- Xu, Q., Chi, G. and Bend, S.L. 2008. Diagenesis of the Mannville Group in the Lloydminster area, western Saskatchewan: A preliminary petrographic study in Summary of Investigations 2008, Volume 1, Saskatchewan Geological Survey, *Saskatchewan Industry Resources, Misc. Rep*. 2008-4.1, CD-ROM, Paper A-7.
    - The petroleum in the Mannville Group in the Lloydminster area of western Saskatchewan is heavy oil, unlike the counterparts in the Athabasca and Cold Lake areas in Alberta, which are oil sands. The reason for this difference was not clear. This study reveals that there may have been two episodes of oil charging, with the later charging event of higher temperatures and the oil less likely to be biodegraded. This finding will help for further exploration in the area, especially in searching for higher quality, less degraded oil.
- Yang, DY; Gu, YA; Tontiwachwuthikul, P. 2008. Wettability determination of the crude oil-reservoir brine-reservoir rock system with dissolution of CO_2 at high pressures and elevated temperatures, *Energy & Fuels*, 22 (4):2362-2371.
    - The world's first analysis of wettability for the crude oil-reservoir brine-reservoir rock-CO_2 system under reservoir conditions.

- Yang, DY; Tontiwachwuthikul, P; Gu, YG. 2005. Interfacial interactions between reservoir brine and CO_2 at high pressures and elevated temperatures, *Energy & Fuels*, 19 (1): 216-223.
    - The world's first analysis of interfacial interactions between reservoir brine and CO_2 at high pressures and elevated temperatures.
- Yang, DY; Tontiwachwuthikul, P; Gu, YG. 2006. Dynamic interfacial tension method for measuring gas diffusion coefficient and interface mass transfer coefficient in a liquid, *Industrial & Engineering Chemistry Research*, 45 (14): 4999-5008.
    - Novel technique for studying mass transfer at high pressures and elevated temperatures.
- Zhou, Q; Chan, CW; Tontiwachiwuthikul, P. 2009. A monitoring and diagnostic expert system for carbon dioxide capture, *Expert Systems with Applications*, 36 (2): 1621-1631.
    - Carbon dioxide capture is now an important issue given the global concern on greenhouse gas. This paper presents work on developing an expert system that automates monitoring and control of the CO_2 capture process.
- Zhou, Q; Chan, CW; Tontiwachiwuthikul, P. 2009. Regression analysis study on the carbon dioxide capture process, *Industrial & Engineering Chemical Research*, 47 (14): 4937-4943.
    - Given the importance of carbon dioxide capture, this is the first time an in-depth regression study was done to investigate relationships among parameters in the process.
- Henni, A; Li, J; Tontiwachwuthikul, P. 2008. Reaction kinetics of CO_2 in aqueous 1-amino-2-propanol, 3-amino-1-propanol, and dimethylmonoethanolamine solutions in the temperature range of 298-313 K using the stopped-flow technique, *Industrial & Engineering Chemical Research,* 47 (7):2213-2220 2008
    - The manuscript completes the most comprehensive screening study of a large number of promising primary and tertiary amines/diamines. The best amines found had a reaction rate three to thirty times higher than the reaction rates of industry "standard" amines (monoethanolamine and methyldiethanolamine).
- Mundhwa, M; Henni, A. 2007. Molar excess enthalpy (H-m(E)) for various {alkanolamine (1) plus water (2)} systems at T = (298.15, 313.15, and 323.15) K, *Journal of Chemical Thermodynamics* 391439-1451 2007 .
    - This is the most comprehensive study of the heat of mixing aqueous alkanolamine solutions. A large number of rules of thumb based on group contribution were introduced to account for the heat of mixing. For the first time, an analogy was found between the hydrophobicity of the alkanolamines and their rates of the reaction with CO_2.

- Henni, A; Tontiwachwuthikul, P; Chakma, A. 2005. Solubilities of carbon dioxide in polyethylene glycol ethers. *Canadian Journal of Chemical Engineering* 83 (2): 358-361 2005
    - This study represents the most comprehensive comparison of the most promising physical solvents used in the gas sweetening industry.
- Henni, A; Hromek, JJ; Tontiwachwuthikul, P; Chakma, A. 2003. Volumetric properties and viscosities for aqueous AMP solutions from 25 degrees C to 70 degrees C. *Journal of Chemical and Engineering Data* 48 (3): 551-556 2003.
    - This manuscript compares the viscosity deviations of different amines widely used in the gas industry, and reveals the changes in the types of forces (attraction/repulsion) involved at the molecular level as the concentration changes. This change in the type of forces explains many anomalies found in the analysis of concentrated and dilute concentrations of the aqueous solutions.

Key Scientific Issues Addressed with CFI

The Principal Users agree that the CFI infrastructure is essential for their research in the energy theme area. As one Project Leader simply explained, "Without CFI infrastructure we could not have done anything." Examples of key research problems and scientific issues that could not have been addressed without the CFI infrastructure include:

- cost-effective technologies – particularly a new solvent that has an improved performance of CO_2 absorption and stripping (solvent regeneration), while offering minimum or no operational problems – used to capture carbon dioxide from low to high pressure industrial gas streams
- corrosion inhibition during solvent absorptive separation of CO_2
- study of geofluids to investigate the feasibility of long-term greenhouse gases (CO_2) storage in geological formations
- production of clean energy, such as biodiesel, from biomass materials, waste vegetable oils and petroleum fractions
- computer simulations of complex chemical reactions at the molecular level, including reactions important to energy storage and retrieval
- enhanced petroleum recovery techniques that are economically viable and environmentally acceptable
- ability to determine the formation conditions of energy resources

Excellence Awards to Principal Users

- 2 Canada Research Chairs, Tier 1, 2006-2013; 2003-2010

- 2 Awards of Innovation, Regina Chamber of Commerce, 2008
- 2 NSERC Synergy Awards for Innovation, 2006
- 1 HTC Clean Energy Chair, 2006
- 1 President's Scholar Award, University of Regina, 2004-2006
- 1 NSERC University Faculty Award, 2000-2005
- 1 Award of Excellence, Petroleum Technology Research Centre, 2003
- 1 University of Regina Inspiring Teaching Award, 2003
- 1 NSERC Postdoctoral Fellowship, 2002
- 1 Performance Award, Petroleum Technology Research Centre, 2002
- 1 Society of Petroleum Engineers Scholarship, USA, 2001-2002

National & International Research Programs involving Principal Users

- Co-chair of CO_2 research review meeting at the University of Texas at Austin
- Member of the Expert Review Team for the Intergovernmental Panel on Climate Change which was a co-recipient of the Nobel Prize for Peace, 2007.
- Track Chair/Member Technical Committee: Engineering Institute of Canada Climate Change Conference
- Member of Organizing Committee (Chair – Publications): 19th Canadian Symposium on Catalysis
- Member of the IEA GHG Expert Group on Risk Assessment of Underground Storage of CO_2. (2 PUs)
- Member, 2006 SPE Annual Technical Conference and Exhibition committee on Fluid Mechanics and Recovery Processes
- One of the key organizers of the 7th Greenhouse Gas Control Technology (GHGT-7) and the 9th Greenhouse Gas Control Technology (GHGT-9) hosted by International Energy Agency (IEA)
- Organizer of International Symposium on Separation with 49th Canadian Chemical Engineering Conference
- Session Chair & Organizer for Environmental/Analytical Session of 87th and 88th CSC (Canadian Society of Chemistry) Conference
- Elected Membership Director for AWMA (Air and Waste Management Association) CPANS (Canadian Prairies and Northern Section)
- Invited Expert Peer Review Panel Member for Canada/US Great Lakes Integrated Atmospheric Deposition Network (IADN), 2008 (5 member international expert panel, only Canadian member).

4.3 Networking and collaboration

The establishment in the late 90's of the PTRC -- a partnership among Natural Resources Canada, the Saskatchewan Department of Industry and Resources, the Saskatchewan Research Council and the University of Regina, with support from the western Canadian oil and gas industry -- paved the way for a multi-disciplinary and collaborative approach to energy and environment research and development. It is described by one Principal User as "a product of unprecedented collaboration among many federal, provincial, academic and private sector entities." The level of collaboration and partnership in the theme area was further amplified by the subsequent establishment of the IEA GHG Weyburn-Midale CO_2 Monitoring and Storage Project and the International Test Centre for Carbon Dioxide (CO_2) Capture. The nature and impact of these key partnerships are outlined in section 1.3 of this report (see pages 15 - 18).

CFI investments have had a tremendous impact in fostering these external linkages. These grants have contributed greatly to the development of the technical capacity required to undertake leading edge research and the sheer presence of this infrastructure has been a boon to attracting some of the best researchers in the field and in leveraging industry and government support. The direct experience of the project leaders is that virtually each and every CFI funded infrastructure has fueled and expanded their own or others opportunities for research collaboration and networking. Moreover, the general consensus among project leaders is, that while networking and collaborations have tended to be targeted to specific research interests, they have all had a positive impact on the overall quality, depth and scope of energy research, and on the ability of the researchers to publish. Furthermore, these external connections have also served to raise the profile of the work undertaken by UofR researchers, and in many cases to a level warranting international recognition.

The following are specific examples of collaborative research endeavours in the theme area undertaken by the Principal Users that have been made possible as a result of CFI investments:

- Dr. East's CFI funded equipment for simulating complex chemical reactions has enabled collaborative work with a group of researchers from the University of Vienna, and this has resulted in important discoveries in the area of petroleum refining chemistry. It has also been pivotal in fostering collaboration with the National Research Council of Canada and the University of Southern California.

- Dr. Couslon's CFI infrastructure fostered a collaboration with Dr. H. Qing (Dept. of Geology, University of Regina), the Petroleum Technology Research Centre (a University- Provincial Government funded initiative) and several, Calgary-based, petroleum exploration companies. The collaborative work is aimed at investigating the stratigraphic and diagenetic histories of petroleum source and reservoir rocks in southern Saskatchewan.

- Dr. Chan has undertaken a number of collaborative initiatives with researchers within the UofR, as well as with external researchers, to construct decision support systems (DSS) to support research in petroleum waste management and pollution control. Dr. Chan has worked in collaboration with SaskEnergy / Transgas on various projects; one aimed at predicting petroleum production using artificial intelligence techniques, and another aimed at developing artificial intelligence and knowledge-based systems for the detection of gas pipeline ruptures and confirmation of stress corrosion cracking.

- Dr. Torabi has worked in collaboration with researchers from the Saskatchewan Research Council on various projects; including one to develop a new method for improving productivity of the Viking Reservoirs of West-Central Saskatchewan.

- Dr. Aroonwilas' CFI funded infrastructure supports greenhouse gas mitigation research. It also strengthens interdisciplinary research because it can be used by researchers in a variety of disciplines such as chemical engineering, petroleum engineering, corrosion science, environmental engineering, process engineering and chemistry. The infrastructure has strengthened research collaborations and partnerships between the University of Regina, the Petroleum Technology Research Center (PTRC), and Saskatchewan Research Council (SRC). More specifically, Dr. Arronwilas has taken part in various collaborative research activities conducted out of the International Test Centre for CO_2 Capture, in the areas of climate change and the exploration and development of cost-effective technologies for CO_2 capture. These projects have brought together stakeholders from academia (University of Waterloo), government (Saskatchewan Industry and Resources, Natural Resources Canada, and US Department of Energy), oil and gas (Nexen and EnCana), coal (Luscar), and power generation (SaskPower and TransAlta).

- Dr. Wee has collaborated with the Greenhouse Gas Technology group, Faculty of Engineering, University of Regina in the design, synthesis and development of novel amino alcohol solvents for CO_2 capture technology.

- Dr. Veawab has collaborated on a number of projects undertaken through the International Test Centre for CO_2 Capture (ITC) in the theme area. Specific projects include: solvent formulation, development of effective corrosion control, optimum design for absorber and regenerator, and reduction of energy consumption.

- Dr. Tontiwachwuthikul has worked collaboratively on a number of research projects in the theme area. Those aimed at developing intelligent and knowledge-based system technologies to support research in the theme area, in particular, are highly interdisciplinary, merging expertise from software engineering and computer science, as well as process engineering. The results of these collaborative research projects have benefited industry and research partners, including: the Petroleum Technology Research Centre, TR Labs, ISM Corp., SaskEnergy Inc., the City of Regina, and Saskferco Inc.

- Dr. Asghari has received support from Natural Resources Canada, the Petroleum Technology Research Centre and IEA GHG Weyburn-Midale Monitoring and Storage Project. The colleagues with whom he collaborates are Drs. Raman Paranjape, Christine Chan, Nader Mahinpey, Mingzhe Dong, Don W. Green, G.P.Willhite, S. Vossoughi, and C.S. McCool.

- Dr. Huang's CFI funded Energy and Environmental Research Laboratory has fostered provincial and national collaborations with TransGas, SaskEnergy, Communities of Tomorrow, National Research Center and Saskatchewan Environment, as well as international collaborations with the China University of Petroleum and China National Petroleum Corporation. These international collaborations have contributed significantly to research in the area of petroleum waste management.

- Dr. Dong's use of the CFI funded infrastructure for Enhanced Oil Recovery research strengthened research collaborations established internally among faculty at the University of Regina, as well as externally with the Saskatchewan Research Council, NRCan Western Research Centre, the University of New Brunswick, and the University of Waterloo. Joint research with researchers from the University of Waterloo led to several publications which are of significance in reservoir simulation and enhanced oil recovery.

Formal Research Networks

- STEPS (Sustainable Technologies for Energy Production Systems): 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

4.4 Sharing of infrastructure

The majority of the CFI funded projects for energy research are used almost exclusively by researchers within the institution, with only periodic or minimal external usage. In four of the eleven cases there is more routine and extensive sharing of infrastructure with researchers from outside the University of Regina. In these cases, the level of usage among external researchers ranges from 15% to 40% depending on the project. Overall, most of the external users are from other academic institutions, and a smaller number are from the public and private sectors. Projects with more substantial external usage include:

- #5609 (Tontiwachwuthikul) - **International Test Centre for Carbon Dioxide Capture (ITC);** Usage - 60% internal, 40% external; external users are mostly from other academic institutions and industry; the scheduling of use among users is based on a queuing systems, except when time sensitive or high priority analysis takes precedence. The external industry users of this infrastructure are affiliated with the following organizations: RITE, E.ON., SaskPower, Babcock & Wilcox, Saudi Aramco, HTC Purenergy, EnCana, AERI, SIR, NRCan, and RWE Npower.
- #2509 (Idem) - **Scanning Electron Microscope for Materials Characterization in Energy and Environmental Research;** Usage – 70% internal, 30% external; external users are from other academic institutions within Canada.
- #9198 (Chi) - **Geofluids characterization and modeling facilities;** Usage – 85% internal, 15% external; key external users include researchers from the Geological Survey of Canada and Memorial University of Newfoundland.

5.0 IMPACTS ON LOCAL, REGIONAL, NATIONAL AND INTERNATIONAL INNOVATION

5.1 Partnerships

The following is a summary of the formal partnerships signed or pending between the University of Regina and "end-user" organizations[15] since 2001[16]. See Appendix E for a detailed list of end-user organizations.

- 136 partnership agreements (with partner cash contributions of $31,962,397)
    - 78 Completed ($14,874,800)
    - 44 Active ($6,900,936)
    - 10 Approved ($186,628)
    - 2 Pending ($1,000,000)
- The five top "end-user" partner organizations, accounting for 80% (almost $26M) of the total cash contributions from all end-user organizations, include:
    - Saskatchewan Economic and Co-operative Development,
    - Petroleum Technology Research Centre (PTRC),
    - Royal Dutch Shell
    - Crown Investments Corporation
    - Saskatchewan Industry & Resources, and
- The ITC Future Cap industry consortium, an industry cluster, is made up of over 10 research organizations in the public and private sector in Canada and from abroad. Canadian companies include Saskatchewan Power Corporation (SaskPower), EnCana Corporation, HTC Purenergy, and Stantec. Foreign companies include E.On Engineering (UK), Saudi Aramco (Saudi Arabia, world's largest oil producer), Babcock & Wilcox (USA), and RWE nPower (UK). Government organizations include Saskatchewan Industry & Resources, Alberta Energy Research Institute, Natural Resources Canada, and the Research Institute of Innovative Technology for the Earth (RITE) of Japan.

For examples of the nature of collaborations between the UofR and external partners (and the impact of CFI investments on the partnerships), see Section 1.3 of this report.

[15] CFI defines end-users as "Individuals or organizations outside the academic community (typically in industry or government) who will use the research results to develop practical applications."

[16] Source: Office of Resource Planning, and http://www.uregina.ca/news/newsreleases.php?release=520 for pending partnership with ESSO

5.2 Technology Transfer

Table 9 - Summary of Direct Technology Transfer

Indicator	Total Number
Invention Disclosures	38
Patents Filed[17]	36
Licenses Granted	2 (+ 2 pending)
Royalties and Licensing Revenue	$644,512
Material Transfer Agreements	N/A
Start-ups or Spin-offs	0

Source: University of Regina University Industry Liaison Office

Most of the patents filed in the energy theme area have been the result of collaboration among University of Regina researchers. Examples from 2004 to 2007 include:

- Aroonwilas, A.; Veawab, A. "Heat-Recovery Gas Absorption Process" US patent application 90114 (2006) and PCT application PCT/CA2007/000461 (2007)
- Tontiwachwuthikul, P.; Idem, R.; Wee, A.; Chakma, A.; Veawab, A.; Aroonwilas, A.; Henni, A.; Maneeintr, K. "Method for capturing carbon dioxide from gas stream" US provisional patent application 60/823,314 (2006) and PCT application PCT/CA2007/001435 (2007)
- Asghari, K.; Wilton, R. "Methods of Improving Conformance Control in Fractured Hydrocarbon Reservoirs" US Patent Application (2004)
- Idem, R. O.; Kumar, P.; Sun, Y. "Catalysts for Hydrogen Production" US Provisional Patent application US60/664,641 (2005) and PCT Patent Application PCT/CA2006/000353 (2006) – License granted
- Idem, R; Tontiwachwuthikul, P; Gelowitz, D. "Process Integration – Method for Capturing C02 from Gas Stream" US Provisional Patent Application 60/940,529 (2007) – License granted (with below)
- Idem, R.O.; Tontiwachwuthikul, P.; Saiwan, C.; Supa, T; Pitipuech, P. "Chemical Additives To Inhibit Oxygen And Sulfur Dioxide Induced Degradation Of Amine Solvents During CO_2 Capture From Flue Gas Streams" US Provisional Patent Application 60/989,269 (2007) – License granted (with above)

[17] Based on the length of time normally required for a patent to be awarded, none of the patents filed have yet been awarded.

5.3 Knowledge Transfer of Other Types

Table 10 - 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 impacts of energy research at the U of R

As a result of the breadth and collaborative nature of energy research undertaken at the University of Regina, a vast number of issues pertaining to energy have being addressed by the Principal Users of the CFI infrastructure. An overarching focus among the researchers is on generating economic and environmental improvements. From an economic perspective, the development of lower cost technologies helps Saskatchewan and Canada both in terms of using the technology locally and selling the technology to the rest of the world. From an environmental perspective, effective and efficient CO_2 capture and storage reduces harmful greenhouse gas emissions, which in turn helps to prevent the effects of global warming. Overall, this leads to the sustainable development of local energy resources.

The research occurring at the International Test Centre for Carbon Dioxide has resulted in some important industrial applications that demonstrate the above benefits. For example, the researchers reported on mass transfer studies using high efficiency structured packing that is ten to thirty times better than conventional packing. An industrial partner used this research to build and design a more efficient CO_2 production system. As well, the ITC research group designed and constructed a highly compact and efficient industrial-scale CO_2 production unit for the food processing industry in the Canadian Arctic region. As a positive spin-off, this led directly to the creation of a number of jobs for local Aboriginal workers. Furthermore, the ITC's pilot plant facility at SaskPower's Boundary Dam Power Station near Estevan, Saskatchewan applies the group's development of lower cost methods for CO_2 capture from flue gases produced by the coal-fired power station to remove four tonnes of CO_2 per day from the emissions. (Source: ITC website www.co2-research.ca)

The Enhanced Oil Recovery (EOR) program, at the Petroleum Technology Research Centre, which began in 1998, has engaged scientists and faculty at the University of Regina to conduct research into developing both more environmentally sustainable and economical technologies, that in turn have helped the industry in Saskatchewan produce more oil. This U of R research has contributed towards not just improved environmental and economic performance, but in turn has assured a sustained and increasing royalty stream to the Saskatchewan government, which surpassed 1 billion dollars annually in recent years. In addition, the PTRC's Weyburn-Midale CO_2 Monitoring and Storage Project, launched in 2000 as the world's first CO_2 measuring, monitoring and verification initiative, has benefitted from the EOR research conducted by the University of Regina, as well as by other universities, to help realize the goal of reducing CO_2 emissions in conjunction with increased oil production. A total of 8000 tonnes a day of CO2 is injected into the field at Weyburn-Midale, as part of two commercial enhanced oil recovery operations, and over the life of the project it is projected that over 40 million tonnes of CO_2 will be stored underground; this is equivalent to removing over 8 million cars off the road for a year. (Source: PTRC website www.ptrc.ca).

6.0 CHALLENGES

Most of the Project Leaders are struggling with ongoing human and physical (space) resource constraints. Despite considerable physical expansion on campus, such as the Greenhouse Gas Centre which increased its physical capacity by 50-60%, some researchers are constrained by insufficient space. In some cases, newer and larger facilities and updated equipment are required, not only to accommodate expansion, but also to maximize current research capacities. One Project Leader indicated that in his area of research, while there has been substantial growth in research productivity and the number of researchers (from two to seven people), the space has not increased. Another indicated that many of the researchers want to expand on what they have, but "at this point, there is no room to put any expansion or modification, or any upgrade on any of the equipment even if [they] wanted to."

For much of the infrastructure, dedicated lab technicians are needed to ensure, at a minimum, that the equipment is properly maintained. Finding the right person to maintain the equipment is a big challenge, particularly in light of more recent labour market trends in Saskatchewan. As one Project Leader described it, "the type of energy research we do is specific and in the past few years, with the job market being this good, it is a challenge to recruit and retain technical people in the university environment. On the research side, we try to utilize and train our graduate students and get more PhD students so that when we train them in the lab they will stay for a bit longer and pass on the training to future graduate students."

Despite the value they bring, a number of Project Leaders are of the view that students are not the best resource for the technical upkeep of CFI infrastructure and other equipment. The problem with relying on students, as one Project Leader explains, is that "students come and go and you have to spend time training them. By the time they are good, they are ready to go." Not only that, but there is a lot at stake given the cost of the equipment. It is not a good idea explained another Project Leader to start training students on very costly equipment. Instead, there needs to be a highly qualified person responsible for the equipment and for training students to utilize it properly. While the Faculty of Engineering has few funds that can be freed up for these positions, they have been fortunate enough, to this point, to have received funding from industry to hire some technical staff. Of note, is that these resources are made possible only for larger projects in which the industry partners have a stake. For other projects, a significant amount of effort is still required on the part of Project Leaders to try and secure additional funds from various external sources for these purposes.

In Science, the maintenance needs of the CFI infrastructure are not extensive enough, at least on a per CFI project basis, to require a full-time technical staff person. Having only a part-time position increases the difficulties in trying to secure highly qualified technical personnel. Like Engineering, the Project Leaders in Science struggle to keep the technicians they attract and train, even the lesser skilled ones. In the words of one Project Leader: "We can't train a technician and keep them here. Lower level technicians can be recruited, but I must take the time to train them and give them the skills they need. Once

they are trained, it can be difficult to keep them because they can get more money [elsewhere]." Most of these Project Leaders are forced to take on the technical upkeep of the CFI infrastructure themselves. The time they spend in this capacity is significant and takes away from time that could otherwise be spent on research. At least one of these PLs is reluctant to acquire more infrastructure until these technical support gaps are addressed. Because of the smaller scope of their projects, the energy-focused researchers in the Faculty of Science could benefit from having a centralized lab facility equipped with highly skilled technicians.

Additional to space and personnel resource constraints are the costs of maintaining the equipment -- repairs and service contracts are expensive. A number of the Project Leaders are finding that the CFI start-up funds for operation are insufficient in the long run. Moreover, they do not address resource needs, like the need for a qualified technician to maintain the infrastructure. Equipment upgrades are another issue. A number of Project Leaders are ready for upgrades. One Project Leader, for instance, explained that their infrastructure is now five to ten years old, and they have "reached a point, in terms of research, [where they] need to go to another phase… [and they] need another influx of funding to go to another step. We know very well our area of expertise, but there is new technology. … What we have, we have utilized very well. We are very happy with what we have, but now there is more expensive equipment than what we have right now that will take us to another step, but we don't have the funds to go to the next step."

APPENDIX A - Matrix of CFI Projects and Users (*NOTE: Project Leaders are also Principal Users of their own infrastructure.)

Last Name	Highest User Type	Aroonwilas #14074	Aroonwilas #9389	Asghari #1685	Chan #202942	Chi #16619	Chi #9198	Coulson #7009	East #7118	Henni #18311	Huang #201740	Idem #2509	Raina #6676	Tontiwachwuthikul #5609	Yang #6927	# Project Linkages per User
Aroonwilas	PL	PU	PU							OU						3
Asghari	PL	OU		PU											OU	3
Chan (CRC)	PL				PU											1
Chi	PL					PU	PU									2
Coulson	PL					PU	OU	PU								3
East	PL								PU							1
Henni	PL	OU								PU				PU		3
Huang (CRC)	PL			PU							PU		OU	PU		4
Idem	PL	OU			PU					OU		PU	PU	PU		6
Raina	PL												PU			1
Tontiwachwuthikul	PL	OU	OU		PU					PU			OU	PU		6
Yang	PL														PU	1
Dong	PU	OU		OU									OU		PU	4
Gu	PU			PU								PU	OU	PU	OU	5
Veawab	PU	OU	OU							OU		PU		PU		5
Wee	PU	OU								OU				PU		3
Chakma	PU													PU		1
Torabi	PU				PU											1
Ayub	OU			OU												1
Bend	OU					OU	OU									2
Bethune	OU					OU	OU									2
Dahms	OU					OU										1
Dale	OU					OU										1
de Montigny	OU	OU								OU						2
Dube	OU						OU									1
He	OU										OU					1
Mahinpey	OU	OU								OU						2
Muhammad	OU														OU	1
Murphy	OU					OU										1
Pedersen	OU						OU									1
Qin	OU										OU					1
Qing	OU					OU	OU									2
Shirif	OU			OU						OU					OU	3
Wilson	OU			OU												1
Yost (CRC)	OU					OU										1
# Principal Users (PUs)		**1**	**1**	**3**	**4**	**2**	**1**	**1**	**1**	**2**	**1**	**3**	**2**	**8**	**2**	**32**
# Other Users (OUs)		**9**	**2**	**4**	**0**	**7**	**6**	**0**	**0**	**7**	**2**	**0**	**4**	**0**	**4**	**45**
Total Users		**10**	**3**	**7**	**4**	**9**	**7**	**1**	**1**	**9**	**3**	**3**	**6**	**8**	**6**	**59**

APPENDIX B - Visiting Researchers

Researcher	Institution	Country
Dr. Zhang Yufu	China University of Petroleum	P.R. China
Dr. Guha Saumyen	Indian Institute of Technology	India
Mr. Qin Hua Peng	Peking University	P.R. China
Dr. Xue Chunji	East China Institute of Technology	P.R. China
Dr. Liu Shuwen	Chang'an University	P.R. China
Mr. Duan Xuchuan*	Tianjin Institute of Geology & Mineral Resources	P.R. China
Dr. Feng Caixia	Institute of Geochemistry	P.R. China
Professor Ni Jin Ren	Peking University	P.R. China
Professor Tu Mingqiang	Wuhan University of Hydraulic & Electrical Engineering	P.R. China
Mr. Liang Zhiwu	Hunan University	P.R. China
Dr. Yuan Xingzhong	Hunan University	P.R. China
Dr. Li Caiting	Unknown	P.R. China
Dr. Fu Xudong	Tsinghua University	P.R. China
Professor Hu Yuegao	Hunan University	P.R. China
Dr. Chen Jierong	Xi'an Jiaotong University	P.R. China
Dr. Nie Songlin	Huazhong University of Science & Technology	P.R. China
Dr. Zhou Qiting	Zhengzhou University	P.R. China
Ms Liu Xiangdong	Chinese Research Academy of Environmental Science	P.R. China
Ms Zhang Jialin	Hunan University	P.R. China
Mr. Li Yu	Jilin University	P.R. China
Dr. Wang Shuguang	Shandong University	P.R. China
Dr. Lai Jianqing	Central South University	P.R. China
Mr. Ma Jianhua	Changjian Scientific Research Institute	P.R. China
Mr. Hu Jiajun	Changjian Scientific Research Institute	P.R. China
Mr. Chen Songsheng	Changjian Scientific Research Institute	P.R. China
Mr. Zhou Liangjing	Changjian Scientific Research Institute	P.R. China
Mr. Yang Wenjun	Changjian Scientific Research Institute	P.R. China
Mr. Yin Shiyong	Changjian Scientific Research Institute	P.R. China
Dr. Liu Hong	Congqing University of Science & Technology	P.R. China
Dr. Fengjun Nie	E. China Inst. Of Technology	P.R. China
Mr. Liu Hongtao	Daqing Oildfield Company Ltd.	P.R. China
Ms. Zhang Haiyan	China University of Petroleum-Beijing	P.R. China
Ms. Gardiner Rebecca	Doosan Babcock	Great Britain
Mr. Hume Scott	Doosan Babcock	Great Britain
Mr. Kerr Stuart	Doosan Babcock	Great Britain
Mr. Bowden Stuart	Doosan Babcock	Great Britain
Mr. Chen Chunmao	China University of Petroleum	P.R. China

*** Arrived prior to initial CFI funding.**

APPENDIX C - Principal Users (PU) and Other Users (OU) of CFI Energy Projects in Chronological Order

* EVSE = Environmental Systems Engineering
ISE = Industrial Systems Engineering
PSE = Petroleum Systems Engineering
SSE = Software Systems Engineering

** User of CFI infrastructure for non-energy related research.

Project Leader	CFI Project	Name of User	Dept.*	User Type
1999				
Asghari, Koorosh PSE	1685 - Sustainable Heavy Oil Research Facility (SHORF)	Asghari, Koorosh	PSE	PU
		Huang, Guo (Gordon)	EVSE	PU
		Gu, Yongan (Peter)	PSE	PU
		Wilson, M.	EVSE	OU
		Shirif, Ezeddin	PSE	OU
		Ayub, Muhammad	PSE	OU
		Dong, Mingzhe	PSE	OU
2000				
Idem, Raphael PSE	2509 - Scanning Electron Microscope for Materials Characterization in Energy & Environment Research	Idem, Raphael	ISE	PU
		Gu, Yongan (Peter)	PSE	PU
		Veawab, Amornvadee	EVSE	PU
2002				
Raina, Renata CHEM	6676 - Inductively Coupled Plasma Mass spectrometer (ICP-MA) for Analysis in Energy & Environment Research	Raina, Renata	CHEM	PU
		Idem, Raphael	PSE	PU
		Chen, Zhi**	ENG	OU
		Dong, Mingzhe	PSE	OU
		Huang, Guo (Gordon)	EVSE	OU
		Gu, Yongan (Peter)	PSE	OU
		Tontiwachwuthikul, Paitoon	ISE	OU
Tontiwachwuthikul, Paitoon ISE	5609 - International Test Centre for Carbon Dioxide Capture (ITC)	Tontiwachwuthikul, Paitoon	ISE	PU
		Chakma, Amit	PSE	PU
		Gu, Yongan	PSE	PU
		Henni, Amr	ISE	PU
		Huang, Guo (Gordon)	EVSE	PU
		Idem, Raphael	PSE	PU
		Veawab, Amy	EVSE	PU
		Wee, Andrew	CHEM	PU
2003				
Coulson, Ian GEOL	7009 - Establishment of a new high-resolution cathodoluminescence imaging and spectroscopy research facility	Coulson, Ian	GEOL	PU
East, Allan CHEM	7118 - Simulation of Complex Chemical Reactions	East, Allan	CHEM	PU

Project Leader	CFI Project	Name of User	Dept.*	User Type
Yang, Daoyong PSE	6927 - Enhanced Oil Recovery Research Infrastructure (EORRI)	Yang, Daoyong	PSE	PU
		Dong, Mingzhe	PSE	PU
		Asghari, Koorosh	PSE	OU
		Ayub Muhammad	PSE	OU
		Gu, Yongon (Peter)	PSE	OU
		Shirif, Ezeddin	PSE	OU
Huang, Guo (Gordon) EVSE	201740 - Energy & Environmental Research Laboratory	Huang, Guo (Gordon)	EVSE	PU
		He, Li (PDF)	ENG	OU
		Qin, David (PDF)	ENG	OU
2004				
Aroonwilas, Adisorn PSE	9389 - High pressure/High-temperature continuous flow stirred & tubular reactor system for greenhouse gas mitigation research	Aroonwilas, Adisorn	PSE	PU
		Tontiwachwuthikul, Paitoon	ISE	OU
		Veawab, Amy	EVSE	OU
Chi, Guoxiang GEOL	9198 - Geofluids Characterization and Modeling Facilities	Chi, Guoxiang	GEOL	PU
		Bend, Stephen	GEOL	OU
		Bethune, Kathryn	GEOL	OU
		Coulson, Ian	GEOL	OU
		Dube, Benoit Geological Survey Canada	Ext. User	OU
		Pedersen, Per Subsurface Geo Lab	Ext. User	OU
		Qing, Hairuo	GEOL	OU
2006				
Chan, Christine SSE	202942 - Visualization Infrastructure for Energy Informatics Laboratory	Chan, Christine	SSE	PL
2008				
Aroonwilas, Adisorn PSE	14074 - Integrated Energy – Flux Monitoring System	Aroonwilas, Adisorn	PSE	PU
		Asghari, Koorosh	PSE	OU
		de Montigny, David	ISE	OU
		Dong, Mingzhe	PSE	OU
		Henni, Amr	ISE	OU
		Idem, Raphael	PSE	OU
		Mahinpey, Nader	EVSE	OU
		Tontiwachwuthikul, Paitoon	ISE	OU
		Veawab, Amornvadee	EVSE	OU
		Wee, Andrew	CHEM	OU

Project Leader	CFI Project	Name of User	Dept.*	User Type
Chi, Guoxiang GEOL	16619 - Cryo-SEM>EDS system for compositional analysis of geological fluids	Chi, Guoxiang	GEOL	PU
		Coulson, Ian	GEOL	PU
		Bend, Stephen	GEOL	OU
		Bethune, Kathryn	GEOL	OU
		Dahms, Tayna**	CHEM	OU
		Dale, Janis**	GEOL	OU
		Murphy, Scott**	CHEM	OU
		Qing, Hairuo	GEOL	OU
		Yost, Christopher**	BIOL	OU
Henni, Amr ISE	18311 - Measurements of the Heat of Reactions of CO_2 in New Promising Chemical Solvents	Henni, Amr	ISE	PU
		Tontiwachwuthikul, Paitoon	ISE	PU
		Aroonwilas, Andy	PSE	OU
		deMontigny, David	ISE	OU
		Idem, Raphael	PSE	OU
		Mahinpey, Nader	EVSE	OU
		Shirif, Ezzedin	PSE	OU

APPENDIX D - Other Energy Researchers at UofR

Name	Department
Paranjape, Raman	Engineering – Electronic Systems
Kybett, Brian	Science - Chemistry
Lee, Donald	Science - Chemistry
Mihichuk, Lynn	Science - Chemistry
Azam, Shahid	Engineering – Petroleum
Islam, Rafiqul	Engineering – Petroleum
Zeng, Fanhua	Engineering – Petroleum
Zhao, Gang	Engineering – Petroleum

APPENDIX E - Number and value of formal *energy focused* partnerships

(e.g., collaborative, joint, research projects) with <u>end users</u>

End User **Partner Organizations**	**# of contracts**	**value of contracts ($)**
Saskatchewan Economic and Co-operative Development	3	7,460,000
Petroleum Technology Research Centre (PTRC)	80	6,733,370
Royal Dutch Shell *	1	5,000,000
Crown Investments Corporation *	1	5,000,000
Saskatchewan Industry & Resources	11	1,535,813
HTC Purenergy **	5	1,474,586
Shell Global Solutions International B.V.	1	525,000
EnCana Corporation (formerly Pan Canadian Petroleum Ltd.)	2	382,860
Saskatchewan Power Corporation	2	313,360
Alberta Energy Research Institute (AERI)	1	300,000
Neill & Gunter	1	280,825
Research Institute of Innovative Technology for the Earth (RITE)	1	265,995
Natural Resources Canada	1	260,000
RWE Npower plc	1	250,000
National Research Council (NRC)	1	250,000
EON-UK	1	235,920
Aramco Services Company (ASC)	1	233,420
The Babcock & Wilcox Company	1	230,720
Alberta Science and Research Authority (ASRA)	1	182,500
Public Works and Government Services Canada	1	166,000
TransAlta Utilities Corporation	1	150,000
Petroleo Brasileiro, S.A.	1	150,000
International Energy Agency Greenhouse Gas R & D Programme	1	150,000
Fluor Canada Ltd.	1	150,000
Husky Oil Operations Limited	1	67,200
Saskatchewan Research Council (SRC)	4	62,200
EPCOR	1	50,000
AUTO21	2	39,028
Environment Canada	3	34,000
Profico Energy Management Ltd.	1	15,000
Communities of Tomorrow	1	14,600
Grand Total	134	31,962,397

* pending / conditional

** includes agreements with Hydrogen Thermochem Corp. and BTC BioEnergy

APPENDIX F - Timeline of Major Awards (2003 – 2009)

(unless otherwise noted, information comes from the University of Regina website: http://www.uregina.ca/news/newsreleases.php?viewarchives=1)

Media Release Date		Awards and Events
January 20	**2009**	Government of Canada announces the establishment of a new Business-Led Network of Centres of Excellence (BL-Network) in Regina. Government of Canada support for the Sustainable Technologies for Energy Production Systems (STEPS) Network will help to improve access to hydrocarbon resources in Canada and around the world by developing advanced technologies and innovations in an environmentally sustainable and economically viable way. The STEPS program builds on and significantly expands the Enhanced Oil Recovery Research Program at the Regina-based Petroleum Technology Research Centre (PTRC). The STEPS Network will receive $10.5 million over four years. http://www.rce-nce.gc.ca/media/newsrel/2009/200109_e.htm
December 15	**2008**	The Regina-based Petroleum Technology Research Centre (PTRC) will receive $1.5 million this fiscal year and each of the next two fiscal years to continue its leading-edge research on behalf of the province's and country's oil industry. http://www.gov.sk.ca/news?newsId=7539bb74-7b67-4629-9dae-f7275b029090
November 28	**2008**	The University of Regina has been granted the right to hold a session to profile its world-wide reputation as a leader in Carbon Capture and Storage (CCS) technology at the United Nations Framework Convention on Climate Change (UNFCCC) in Poznań, Poland on December 3, 2008.
November 6	**2008**	$5 million from the Government of Saskatchewan and $5 million from Royal Dutch Shell creates the International Performance Assessment Centre for Geologic Storage of CO_2 (IPAC-CO_2) which is located at the University of Regina.
September 3	**2008**	International Test Centre for Carbon Dioxide Capture (ITC), the University of Regina and Innovation Norway co-sign a Memorandum of Understanding (MOU) intended to enhance both organizations' development of climate change technologies. The MOU outlines the University of Regina and Innovation Norway's mutual commitment to such initiatives as research partnerships, joint commercial development activities, student research exchanges, and visiting lecturers.
May 30	**2008**	NSERC awards U of R researchers and students over $2.9 million to support research and scholarships including Nader Mahinpey (Engineering). Mahinpey's research supports the development of a long-term greenhouse gas mitigation technology with a specific focus on the energy sector through production of biofuels from thermo-chemical and bio-chemical conversion.
April 17	**2008**	NSERC awards a total of just under $600,000 to Amy Veawab, Adisorn Aroonwilas and Raphael Idem. Veawab and Aroonwila' funding totals $400,000 over three years and involves using low-quality feedstock such as cooking oil and animal fat to produce biodiesel. Idem's three-year Strategic Project Grant is valued at $197,000 for research involving finding an economically viable way of producing hydrogen fuel from renewable and non-purified biomass sources.
April 4	**2008**	The PS-Eng group, which consists of Raphael Idem, Paitoon Tontiwachwuthikul and Don Gelowitz, received the Award of Innovation from the Regina Chamber of Commerce for developing a variety of CO2 capture technologies and processes. The Award of Innovation includes a monetary award as well as a trophy for each recipient. (amount not provided in media release.)

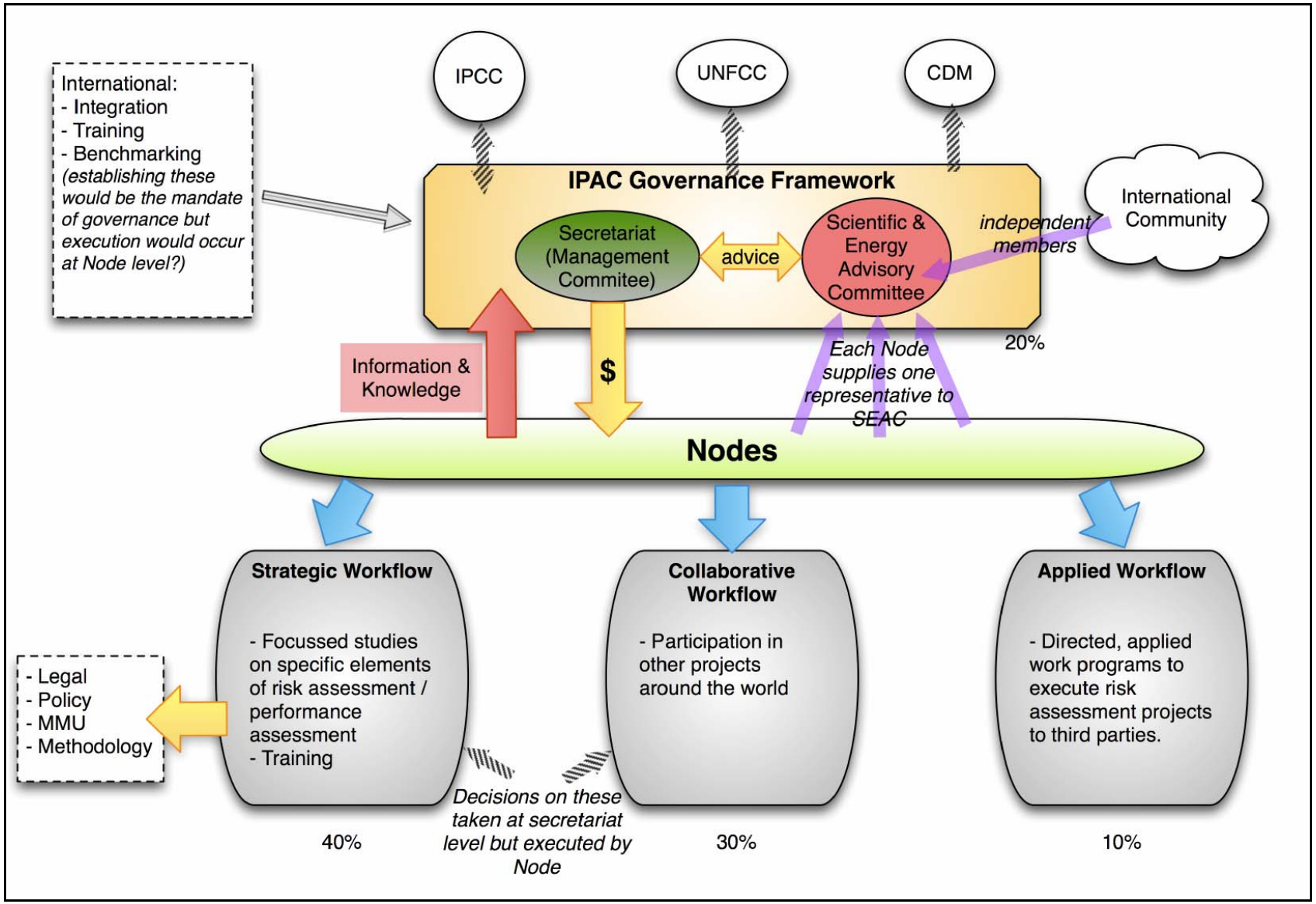
Media Release Date		Awards and Events
February 12	**2008**	Four new research projects at the University of Regina will receive more than $500,000 through the Innovation and Science Fund. The Innovation and Science Fund will provide: • $52,327 to purchase equipment for the Development of Energy Efficient Technologies for Mitigating Greenhouse Gas Emissions; • $144,000 to develop a Meso-scale Oedometer Test System, which will help scientists understand and improve the engineering behaviour of soils and rocks in the evolving climate; • $137,400 to purchase equipment for the Centre for Irrigation Water Protection and Microbial Ecology of Foods; and • $200,000 to establish a Canada Research Chair Position in Microbes, The Environment and Food Safety. http://www.gov.sk.ca/news?newsId=770bee82-99a1-42ed-99fe-b2f76652fd53
October 12	**2007**	Dr. Malcolm Wilson, is a co-recipient of the 2007 Nobel Peace Prize. As a contributing author to the Intergovernmental Panel on Climate Change, Dr. Wilson shares in the honours of the 2007 Nobel Peace Prize that was awarded jointly to the IPCC and Al Gore for their efforts to promote awareness of the impacts of and potential solutions for climate change and global warming.
July 19	**2007**	Shahid Azam, receives $114,000 from the CFI Leaders Opportunity Fund (LOF) for developing a testing system to study earthen materials affecting in-ground storage, transportation infrastructure and pipelines. Andy Aroonwilas receives $52,327 from the CFI LOF for developing an energy monitoring system to be used for greenhouse gas reduction research.
May 3	**2007**	Aramco Services Company, a subsidiary of Saudi Aramco commits to be a co-sponsor of the final phase of the IEA GHG Weyburn-Midale CO2 Monitoring and Storage Project. The project is a two-phase, eight-year, $80 million international study investigating long-term storage of CO2 in conjunction with enhanced oil recovery in oil fields. http://www.ptrc.ca/archive.php?f_action=news_detail&news_id=9325
March 26	**2007**	The Government of Saskatchewan is investing $23.6 million to fund continuing construction of the University of Regina's Laboratory Building addition. The state-of-the-art facility, which will house more than 30 research teams including over 100 graduate students, will be an important means of attracting top researchers, teachers and students to the University. When completed, the new Laboratory Building will be one of the most modern teaching and research facilities in Canada, featuring state-of-the art laboratory space for students and faculty, as well as modern audio-visual and conferencing capabilities. http://www.gov.sk.ca/news?newsId=4075e5c5-8b5d-42ad-884c-3e8a63ece66a
January 9	**2007**	Gordon Huang receives two Strategic Project Grants from NSERC which total $560,000 over three years and are for two different projects. One is to develop a risk management system for natural and human-induced disasters, and the other is for watershed management under changing climatic conditions.
October 18	**2006**	NSERC awards the Synergy Award for Innovation in the two or more companies category to the University of Regina, Energy INet, SaskPower, HTC Purenergy, EnCana Corp., Babcock & Wilcox, Neill & Gunter, E.On, Saudi Aramco, Research Institute of Innovative Technology for the Earth, Saskatchewan Industry and Resources, Alberta Energy Research Institute, Natural Resources Canada and University of Waterloo. Winning universities receive a $200,000 NSERC research grant. Industrial partners receive the prestigious Synergy sculpture and an opportunity to hire an NSERC Industrial R&D Fellow for two years (NSERC will bear the cost of the industrial portion of the fellow's salary). (http://www.nserc-crsng.gc.ca/Prizes-Prix/Synergy-Synergie/Index-Index_eng.asp)

Media Release Date		Awards and Events
April 4	**2006**	Saskatchewan is investing $1.8 million over three years in the Petroleum Technology Research Centre (PTRC) to help develop a more environmentally sensitive and energy-efficient enhanced oil recovery process for heavy oil reservoirs. The JIVE (Joint Implementation of Vapour Extraction) Project, will use the funds to further develop, demonstrate and evaluate vapour extraction technology that uses solvent gases instead of steam to extract heavy oil. The $9.6 million three-year JIVE Project comprises the PTRC, Canadian Natural Resources Limited, Husky Energy, and Nexen Inc. The research will be conducted by Saskatchewan Research Council, **University of Regina** and the Alberta Research Council. The partners will pool their intellectual property and have it managed by the PTRC. (http://www.ptrc.ca/archive.php?f_action=news_detail&news_id=8709)
June 6	**2005**	NSERC awards over $2.35 million to U of R faculty and students in grants and scholarships. Twenty-four faculty members received grants totaling $1,812,796 and 12 graduate students received scholarships totaling $411,900. The University also received $135,000 in Undergraduate Student Research Awards, to be awarded to 30 students. The NSERC grants will fund research at the University in areas such as physics, geology, computer science, engineering, mathematics and statistics, biology, chemistry and biochemistry.
September 15	**2004**	The PTRC and the University of Regina have signed four agreements with organizations in Australia, Europe and the United States as direct result of work presented at 7th International Conference on Greenhouse Gas Control Technologies. PTRC and the U of R are partners in two of the Memorandums of Understanding, reflecting the growth of their global reputation and expertise into the science of climate change. The University of Regina, the Norwegian University of Science and Technology, the University of Melbourne and the University of Texas at Austin have agreed to collaborate on research into the post-combustion capture of carbon dioxide. The PTRC, University of Regina and the recently established Cooperative Research Centre for Greenhouse Gas Technologies (CO_2CRC) in Australia, agreed to work together on the capture and storage of carbon dioxide. The PTRC and Netherlands Organization for Applied Scientific Research (TNO) agreed, among other things, to work together to develop software packages for assessing the storage of carbon dioxide in geological formations such as oil fields. PTRC and the European Network of Excellence, known as CO_2 GeoNet, will focus their efforts on risk assessment methods and procedures. This agreement includes an exchange of data and staff.
June 21	**2004**	HTC Hydrogen Thermochem Corp. is investing $500,000 in the creation of a new industrial research chair in engineering at the University of Regina. The endowment was announced today at the official signing of a memorandum of understanding between the company and the University, held in the greenhouse gas laboratory at the University's International Test Centre for Carbon Dioxide Capture (ITC). The chair will focus on development of new hydrogen production technologies, including extraction of hydrogen from natural gas and ethanol, and the capture and/or use of related carbon dioxide. Under the agreement HTC Hydrogen Thermochem Corp. will contribute $100,000 per year between now and 2009. The University, in addition to providing laboratory space and infrastructure support, will recruit other researchers in the hydrogen engineering field, creating a critical mass of researchers to contribute toward the success of the research.

Media Release Date		Awards and Events
July 30	**2003**	Dr. Guo (Gordon) Huang is appointed to the Canada Research Chair in Energy and Environment. He will receive $200,000 per year for seven years with $150,402 for research infrastructure development from CFI.
June 25	**2003**	HTC Hydrogen Thermochem Corp. (now HTC Purenergy) and the University of Regina have entered a three-year, $480,000 collaborative research agreement to study the cost-effective production of hydrogen as an alternative fuel. The intellectual property developed under the collaboration will be owned by the University, and licensed exclusively to HTC Hydrogen Thermochem for commercial product development.
June 19	**2003**	Five University of Regina researchers have been awarded a total of more than $300,000 by the Canada Foundation For Innovation (CFI). $77,609 was awarded to Mingzhe Dong for purchase of equipment for the study of interaction between fluids and rock surfaces, chemical loss due to adsorption, and oil recovery efficiency.
June 2	**2003**	Twenty-four researchers claim grants including Adisorn Aroonwilas who receives $84,000 for four years for fundamental studies of mass-transfer with chemical reaction for CO2 separation processes. Nader Mahinpey receives $88,000 over 4 years for an investigation of hydrodynamics, heat and mass transfer of oxygen enhanced coal combustion in a carbon dioxide atmosphere.
March 3	**2003**	The Government of Canada invests a total of $6 million in the Weyburn CO_2 Monitoring Project. The project is managed and coordinated by the Petroleum Technology Research Centre at the Regina Research Park on the University of Regina campus. The International Test Centre for Carbon Dioxide Capture (ITC) opened today.

ADDENDA TO THE INSTITUTIONAL ROLL-UP REPORT DATED APRIL 8, 2009

IPAC CO_2 Governance



Energy Project Linkages