Natural Resources Canada | Ressources naturelles Canada

CLEAN ENERGY FUND

SUMMARY REPORT – FEDERAL R&D

Office of Energy R&D **May 2014**

Canada

Contents

At a Glance

- 561 projects were funded, covering basic research to pre-demonstration pilot-scale tests.
- 7 federal departments and agencies participated.
- Leverage was $22.82 million for total CEF funding of $26.4 million, a ratio of 0.87:1.
- As reported by project leaders:
  - More than 100 non-federal researchers from over 80 different organizations participated in projects.
  - the R&D projects contributed, in whole or in part to:
- the publication of 84 peer-reviewed articles in scientific journals;
- 86 technical reports and 58 client reports;
- 171 presentations at national and international conferences, workshops and symposia;
- over 500 months of training and developing of highly qualified personnel (HQP) – students and postdoctoral fellows;
- 2 patents issued and several patent applications submitted; and
- creation or revision of 11 Canadian codes and standards.

1. Introduction

The Government of Canada announced the Clean Energy Fund (CEF) in January 2009 as part of its actions to ensure a healthy environment, by supporting clean energy research, development and demonstration (RD&D) projects, including carbon capture and storage. The objective of CEF was to support the development of the new, cutting-edge energy technologies that are essential for reducing greenhouse gas (GHG) and other air emissions in energy production, transmission, distribution and use. Initially announced as a $1 billion investment, that was reduced by $205 million in Budget 2010 to provide additional funds to the ecoENERGY Retrofit-Homes initiative.

The major part of the funding was allocated for large scale carbon capture and storage projects. Approximately $146 million was provided for smaller scale demonstration projects in renewable and clean energy systems technologies.

$26.4M million over two years was allocated for clean energy R&D conducted by federal departments and agencies, in a range of activities from basic research up to and pre-demonstration pilot projects. The goal was to address gaps that required further advancements in knowledge and understanding, and testing of concepts, before emerging technologies could be brought to the stage of “real world” trials. Federal scientists from 7 departments and agencies participated, as well as over 100 non-federal participants from more than 80 different organisations – industry, other levels of government, academia, non-government organisations and associations.

The R&D component was conducted over an 18 month period ending on March 31, 2012. This report provides a summary of that component.

[1] Some projects had components undertaken in different federal laboratories; if those components are counted separately the number is 89.
[2] All financial and statistical information in this report has been taken from the individual Project Status Reports.

2. R&D Areas

Projects were funded in four priority technology areas within the nine technology Portfolios under which OERD managed its funding programs at the time.

- Renewable and Clean Energy (with sub-components in renewable energy, bioenergy and integration in the built environment);
- Environmental Challenges Facing Oil Sands Production;
- Carbon Dioxide ($CO_{2)}$ Capture and Storage; and
- Hydrogen and Fuel Cells

The scope of R&D in each of these is described in Appendix 1.

3. Achievement Highlights and Statistics

Note: further information on these projects can be found in Appendix 2, identified from the project code in the format 001XY.

3.1 Project Highlights

- A Smart Grid Standards Task Force was established to provide Canadian input into standardisation efforts being spearheaded by the U.S. National Institute of Standards and Technology and at the International level by the Electrotechnical Commission (077CE).
- In support of the deployment of marine renewable energy systems, a preliminary review of site characterisation requirements and methodology at a number of sites with high wave and tidal energy potential was completed, and a best practices document developed. This was the first attempt to summarise the range of geological and geophysical information that is required for characterising the seabed and identifying geohazards at a marine renewable energy site. (113CE)
- A project focussed on expediting wind energy development through improved and more efficient environmental assessment produced a compilation of all publically available pre- and post-construction wildlife monitoring data from operational wind projects in Canada, and production of a centralised database. The project also produced a literature review detailing the various impacts of wind farms on migratory birds and Species At Risk to better inform proponents and regulators involved in the environmental assessment of wind projects on possible and likely impacts to birds. (041CE)
- A project aimed at advancing the design, development and fabrication of the next generation combined building-integrated solar electric and thermal power generating technologies and systems, and their integration in net- or near-zero energy high performance buildings, led to the publication of a Technology Assessment Report that, *inter alia,* provided an overview of the barriers to the market uptake of the PV-T technology in Canada. These findings will help to orient future R&D on this technology and remove the barriers to its market uptake. (068CE)

- Three housing archetype energy models for three different Canadian regions were developed and validated. Using the developed models, simulations as well as optimisations were carried out to determine the most promising combination of heat pump (HP) systems and renewable energy resources for the Canadian housing market in regards to energy savings and life cycle cost. The results provide a strategic orientation for future heating and cooling technology developments in Canada and support Canadians in the decision process of acquiring cost efficient, clean heating and cooling systems for existing and new houses. (079CE)
- Data were generated for gasification of a range of Canadian forestry biomass feedstocks under a broad range of operating conditions. The data will assist industry in moving forward with future applications of the production and utilisation of renewable natural gas (RNG) from gasification of biomass (081CE)
- A new technique for distinguishing between natural background sources of naphthenic acids and those arising from oil sands production was developed and applied. Naphthenic acids are toxic compounds therefore the oil sands industry is particularly concerned because of the high concentrations in tailings ponds, the “zero discharge” policy which prohibits release of extraction wastes from their leases, and the eventual need to restore these waters to viable habitats. Methods that can differentiate sources of naphthenic acids in the environment are essential to assess the overall environmental impact of bitumen extraction activities. (111OS)
- A proof of concept process to recover the bitumen from mature fine tailings (MFT) taken from a tailings pond was developed. This bitumen typically cannot be processed due to high levels of surfactants. The project showed that the industry can re-introduce tailings pond bitumen into their extraction plant with a suitable chemical additive using the same principles as is used in bitumen extraction from ore. Any project that improves the efficiency of the extraction process reduces green-house gas emissions by virtue of “free” bitumen recovery without the associated mining costs. Reducing bitumen in MFT is also beneficial to landscape reclamation. (101OS)
- A project to develop a set of tools and models to assess the performance of solvent-based versus aqueous extraction processes for bitumen recovery was undertaken. Five performance criteria were used; bitumen recovery, water usage, solvent recovery/losses, tailing management, and bitumen product quality. Solvent-based extraction processes offer strong evidence that fluid fine tailings could be reduced or eliminated, while maintaining high bitumen recovery (>80-90%) and producing good quality diluted bitumen product with low solids and water contents. The diluted bitumen produced could potentially be shipped directly to refineries, thereby eliminating the requirement of upgrading the bitumen to a synthetic crude oil. (088OS)
- Polymer Electrolyte Membrane Fuel Cell (PEMFC) technologies are a viable and innovative option for future worldwide energy needs. Proton exchange membranes (PEMs) play a central role in PEMFCs, serving as both electrolyte and gas separator. However, technical challenges such as cost and durability are still hindering their commercialization. A new transformative manufacturing process to prototype PEMs was developed which improves the durability and lowers the manufacturing cost without sacrificing performance. (022HF)
- Several classes of new hydrogen storage materials with improved properties were created, backed up with fundamental experimental and modeling insight into the micro-structural features responsible for the improvements. (051HF)

- A full process simulation was undertaken for capture of CO_2 from a 600 MW coal- fired power plant. The study was a full simulation at 12 combinations of feed and vacuum pressures. For the optimum feed pressure the overall capture cost was $25.6US/ton CO_2 captured at a purity of 99% and 90% recovery. The energy demand was 40.4% of a 600 MW coal fired plant. (038CCS)
- A post-combustion CO_2 capture test rig was developed, designed and built to test green and hybrid solvents for CO_2 capture. This pilot-scale test unit will serve as a unique test platform for post-combustion CO_2 capture research and will generate valuable data for the research community (046CCS).

3.2 Performance Statistics

Table A shows performance statistics to which the CEF R&D projects contributed, in whole or in part. Note: Some interpretation and correction of reported results has been necessary in some cases in response to the variety of ways in which the standard Project Status Report templates were completed. However, any variance from the statistics in the table is considered to be minor. Highly Qualified Training (HQP) is for undergraduate and post-graduate students, and for post-doctoral fellows.

Table A - Performance statistics, as reported by project leaders, to which the projects contribute in whole or in part

R&D Area	No. of projects	Publications (peer-reviewed)	Conference presentations	Technical reports	Client reports	Patents issued	Codes	HQP training (months)	Leverage (Sk)
Smart Grid - Renewables	13	22	45	30	18	0	3	96	3,643.5
Smart Grid - Buildings	13	15	15	7	9	0	4	72	4,601.0
Smart Grid - Bioenergy	4	19	50	12	2	0	0	139	5,696.0
CO_2 Capture and Storage	6	2	16	7	0	0	0	2	1,788.5
Hydrogen and Fuel Cells	7	22	18	14	13	2	4	56	3,068.2
Oil Sands	13	4	27	14	15	0	0	142	3,656.6
Total	**56**	**84**	**171**	**84**	**57**	**2**	**11**	**507**	**22,453.8**

3.3 Project Type

Projects spanned a significant part of the innovation spectrum, from basic research, up to pilot scale demonstrations of technologies at an early stage of development. Further, a significant number of projects were focussed on, or had a substantial component of, new knowledge generation, in support of policy development, codes and standards.

Figure 1 below shows the breakdown. Note that some projects covered more than one part of the spectrum, so the numbers in the figure sum to more than the actual number of projects funded.

Table 1 - Funding Breakdown by Innovation Spectrum

Innovation Spectrum	Funding Percentage
Basic Research	19%
Applied Research	36%
Field Tests	5%
Pilot Tests	5%
Knowledge Generation	18%

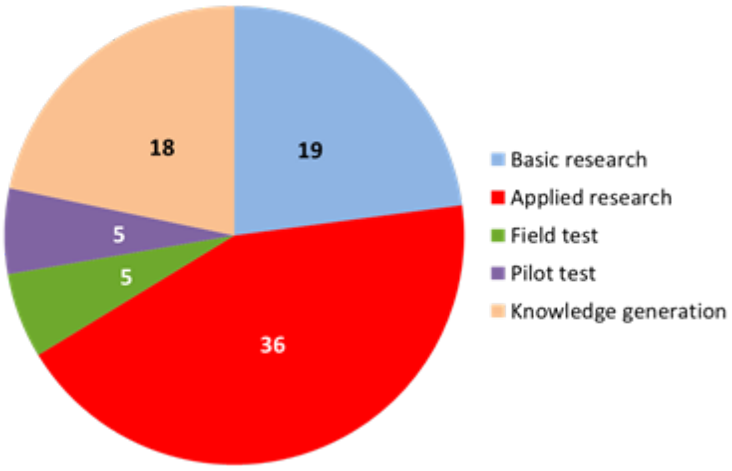

Figure 1: Coverage of the innovation spectrum by number of projects

4. Funding

Figure 2 below shows the distribution of funding by R&D area.

Table 2 - Distribution of Funding by R&D Area

R&D Area	Funding Breakdown
Oil Sands	4.366M (16%)
H2 And Fuel Cells	2.895M (11%)
Ccccs	5.935M (22%)
Renewables - Bioenergy	3.460M (13%)
Renewables - Built Environment	7.008M (26%)
Renewables - Integration	3.193 (12%)

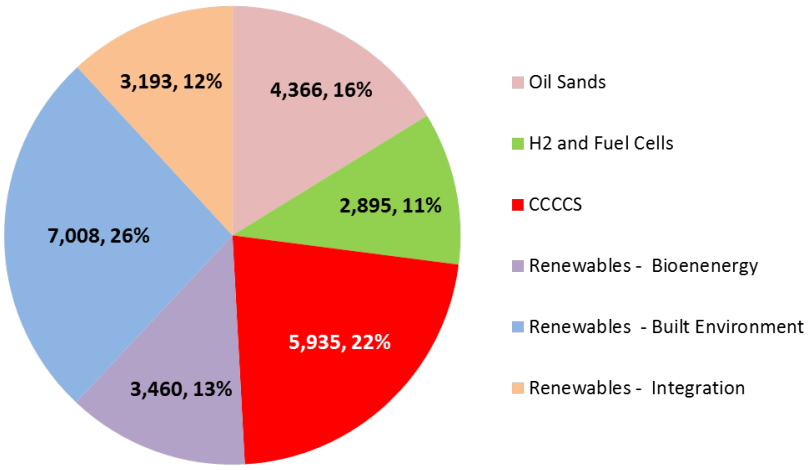

Figure 2: Funding by R&D Scope (and technology Portfolio) - $k and percentage of total

7 departments and agencies participated in the R&D component:

- Agriculture and Agri-Food Canada
- Environment Canada
- Fisheries and Oceans Canada
- Industry Canada
- National Research Council
- NRCan (four sectors: Canadian Forest Service, Earth Sciences, Minerals and Metals, Innovation and Energy Technology)
- Public Works and Government Services Canada

Figure 3 show the distribution of funding to these organisations.

Table 3 - Distribution of Funding to Participating Organisations

Participating Organizations	Funding Breakdown
Agriculture and Agri-Food Canada	277K (1.0%)
Environment Canada	1.653M (6.2%)
Fisheries & Oceans Canada	277K (1.0%)
Industry Canada	132K (0.5%)
National Research Council Canada	6.972M (26.2%)
Public Works & Government Service	26K (0.1%)
NRCan, Canadian Forest Service	1.132M (4.3%)
NRCan, Earth Sciences	1.575M (5.9%)
CanmetENERGY	13.590M (51.0%)
NRCan, Minerals & Metals	999K (3.8%)

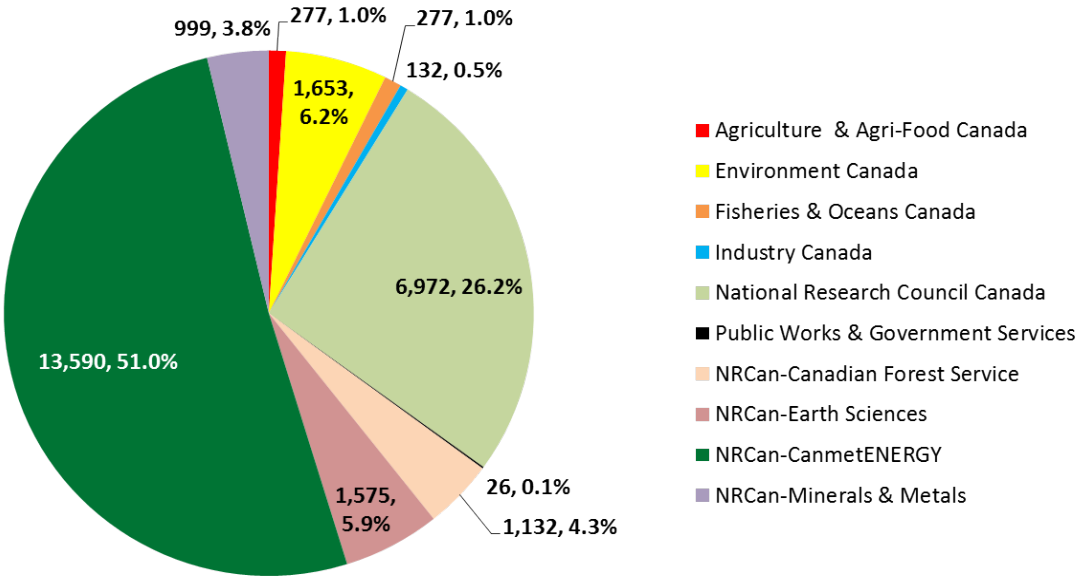

Figure 3: Funding by recipient organisation - $k and percentage of total

Appendix 1 – R&D Scope

A1.1 Renewable and Clean Energy

Projects in this component addressed the integration, at the community level, of renewable and clean energy, defined as wind, marine, low head hydro (less than 15m), solar thermal, low-enthalpy heat to produce power from geothermal and industrial sources, solar photovoltaic, biomass and biogas. It included Smart Grid concepts – using information gathered automatically, such as supply and demand information, to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity. Projects were to be focused on the examination of systems for the increased integration and deployment of renewable and clean energy into both the power grid and the built environment.

Priority was placed on the investigation of a full system approach that would maximise renewable energy deployment. Activities could include simulation, energy mapping, techno-economic and regulatory studies, and technology development up to the pre-demonstration pilot project and proof-of-concept field trial phase.

Proposals were requested in 3 areas:

- Smart Grid concepts, including innovative facilitative technologies, such as smart controls, diagnostic tools, and sensors; demand response concepts; and renewable energy forecasting tools;
- projects to assist in the accelerated commercialisation of renewable technologies that could have the greatest deployment potential in Canada up to 2020 and beyond; and
- new concepts in integrating renewable energy technologies into the built environment, including biomass and biogas used to generate power and/or heat, as well as reducing electrical peak demands, in the context of the drive towards net zero buildings and communities, and the particular needs of rural and remote communities.

The projects in this area spanned three of the Technology Portfolios under which the Office of Energy R&D managed its programs during the period of CEF: Integrated Renewable Energy Systems, Built Environment, and Bio-based Energy Systems.

A1.2 Environmental Challenges Facing Oil Sands Production

Projects in this component addressed the environmental challenges facing oil sands production and the conversion of bitumen. Oil Sands are a strategic resource that provides Canada with both a sustainable and secure source of energy, as well as a prosperous position in the global energy economy. Oil sands development and operations however, have environmental consequences for air, land and water. It is important to address certain key environmental issues across the entire spectrum of the oil sands, from production through to end use.

Wise use of Canada's limited water resources is high on the environmental agenda and is one of the major limiting factors for production and growth of the oil sands operations. One of the pressing oil sands mining issues is the impact of process water on regional water quality and the fate of contaminants from seepage of tailings ponds on local hydrological systems.

An addition environmental concern is air emissions from oil sands development, which consist of CO_2 from producing the energy required for operations; nitrogen oxides (NOx) and sulphur oxides (SOx) from plant operations; and volatile organic compounds (VOCs) from solvents used in the extraction process and sent to the tailings ponds. Efforts to reduce losses of organic solvents to tailings will reduce VOC emissions.

Project proposals were requested in three areas:

- Evaluation and predictive models to enable step change technologies in oil sands operations, including computational fluid dynamics, thermodynamics and physico-chemical interactions and integrated life cycle analysis;
- Monitoring and measurement protocols for improving water quality, including modeling, monitoring and measurement to help gain a detailed understanding of the water quality issues in both oil sands mining and in situ operations on hydrological systems, aquifers along with surface water; and
- Understanding air and water impacts from tailings, including determining the processes that would allow for discharge of treated process water to the river, reducing the loss of organic solvents to tailings, and understand the distribution and fate of metals, chemical amendments, and residual flocculant (chemical agents that clarify the water) in tailings streams.

Projects fell under the Bitumen, Oil and Gas Portfolio.

A1.3 Hydrogen and Fuel Cells

Hydrogen and fuel cell technologies present a viable and innovative option for our future energy mix, and Canada is well positioned for their adoption. Firstly, Canada is the largest per capita hydrogen producer in the OECD, producing approximately 3 million tonnes of hydrogen annually for industrial applications. Secondly, Canada is a world leader in technology development including fuel cells, hydrogen infrastructure systems and hydrogen storage. The focus of the CEF was to address the key technical challenges associated with fuel cells and hydrogen production, delivery and storage.

In spite of the promise of hydrogen and fuel cell technologies, there remain significant technical challenges that need to be addressed. For example, due to hydrogen's low volumetric energy density - the amount of energy stored per unit volume – compared to other energy carriers, it is more costly and less efficient as an energy carrier. For fuel cells, both for stationary and transportation use, there is a need to reduce the level of system complexity, to increase reliability and, particular for use in transportation, to reduce size and weight.

The R&D priorities were therefore to reduce cost and improve efficiency, including by reducing weight and volume, improving performance, and developing advanced materials.

Project proposals were requested in two areas:

- Hydrogen production, delivery and storage, addressing cost and system efficiency and, for hydrogen storage, reducing weight and volume, improving performance, and developing advanced materials and systems;
- Fuel cell technologies, focussing on identifying and developing new materials and systems that will reduce the cost and improve the durability and efficiency of fuel cell technologies.

Projects fell under the Clean Transportation Systems Portfolio.

A1.4 CO_2 Capture and Storage

Carbon dioxide capture and storage (CCS) has been identified both internationally and nationally as being a key GHG mitigation technology, especially in light of the current forecasts regarding the continued use of fossil fuels in meeting global energy needs to 2050.

There are several reasons for Canada's interest in CCS. Firstly, Canada is endowed with an abundance of fossil fuels, around which a very strong set of industry sectors already exist. Secondly, CCS has the potential to contribute to increasing energy reserves by using the captured CO_2 for enhanced oil, natural gas, and coal bed methane recovery. Thirdly, reducing all atmospheric emissions is an important federal government priority. Fourthly, Canada has significant CO_2 storage opportunities with an abundance of geological formations that are potentially well-suited to the safe and permanent storage of CO_2.

The R&D priorities focussed on lowering the costs and improving the performance of CCS systems, including developing technology that can be retrofitted to existing plant assets and new designs for future near-zero emission plants for a variety of different applications and industry sectors, including oil sands operations; and addressing environmentally acceptable and reliable CO_2 storage in support of broad deployment.

Projects proposals were requested in two areas:

- Innovative capture technologies, including lower cost and higher efficiency capture systems applicable to different energy sectors, CO_2 separation technologies, and more efficient and cost-effective ancillary systems (e.g., air separation, compression)
- Innovative R&D in environmentally acceptable and reliable CO_2 storage, including monitoring, measurement, and verification technologies, assessments of storage capacity and injection rates, and the impact of CO_2 injection on reservoir fluids and rocks.

Projects fell under the Clean Coal & Carbon Capture and Storage Portfolio.

Appendix 2 – Project Summaries

A2.1 Renewable and Clean Energy

A2.1.1 Smart Grid and Renewable Energy

Supporting an efficient regulatory framework for ocean renewable and clean energy initiatives (011CE)

Lead: Fisheries and Oceans Canada

Partners / Collaborators: Natural Resources Canada

CEF Funding: $384,000

Other Funding: $141,500

Objectives:

To develop a strategic science and research plan to address future regulatory information needs related to the granting of project approvals for the construction, operation and decommissioning of offshore renewable energy devices (wave, wind, tidal, in-stream) in Canadian marine and aquatic ecosystems.

Key Achievements:

- Pathways of Effects logic models for each major form of renewable energy (wave, wind, tidal, in-stream) were developed, following a science-industry peer review workshop. Many of the potential environmental effects of marine renewable energy have not been fully documented. As a first step, the pathways of effects will demonstrate potential socio-economic and environmental interactions based on our understanding of marine renewable energy activities in Canada and similar projects in other jurisdictions. The supporting strength of evidence document provides a current overview of our understanding of potential effects.
- A Framework for Environmental Risk Assessment and Decision-Making for Tidal Energy Development in Canada (discussion document) was prepared, as well as a summary report on major Canadian science/research needs.

Next Steps:

The research needs identified through this project will be used as a tool for evaluating future project proposals as it will ensure they are aligned appropriately with science priorities.

Development of a short term wind forecasting system to support the Maritime Consortium's Clean Energy Fund demonstration project (013CE)

Lead: Environment Canada

Partners / Collaborators: Hydro Quebec
University of New Brunswick

CEF Funding: $293,000

Other Funding: $240,000

Objectives:

- Develop an innovative modeling strategy for local applications of a short-term wind forecasting system (horizontal resolution: 2.5km)
- Develop surface-layer and boundary-layer versions of Environment Canada's weather prediction models for wind energy applications (horizontal resolution: ~100m)

Key Achievements:

The most important achievement of this project is the development of an innovative modeling strategy for local application of the Wind Energy Forecasting System (SPEO in its French acronym). The local version of SPEO has been applied for real-time tests in Gaspé region (in collaboration with Hydro-Quebec) and in the Atlantic Provinces (in collaboration with University of New Brunswick (UNB) and NB Power for the Atlantic PowerShift demonstration project).

Validation results revealed that the local version of the SPEO gives a forecast statistically equivalent to a full version of SPEO. UNB has gone a step further in the framework of PowerShift demonstration project: EC's forecasts are compared with those from a commercial service provider (AWS TrueWind). Preliminary results (based on one month data) show that EC's forecasts outperform the commercial forecasts. UNB is working on the comparison for longer period (1 -2 years). If comparisons based on longer term support the preliminary results, the immediate outcome, improved competitive capacity (of Canadian companies using Canadian technology), will be archived.

Next Steps:

- Continue the real-time tests in Quebec and the Atlantic provinces
- Collaborate with UNB in comparison with commercial products in the framework of the Atlantic PowerShift demonstration project
- Extend the application and real-time tests to other provinces (e.g. British Columbia, Manitoba Hydro, etc.)

Expediting wind energy development through improved and more efficient environmental assessment (014CE)

Lead: Environment Canada

Partners / Collaborators: Ontario Ministry of Natural Resources,
Acadia University
Simon Fraser University
Golder Associates Limited
Long Point Waterfowl
Canadian Wind Energy Association

CEF Funding: $364,000

Other Funding: $969,000

Objectives:

To develop standards and guidelines for novel and cutting edge tools and technologies to expedite the environmental assessment process for wind power projects in Canada.

Key Achievements:

- Compilation of all publicly available pre- and post-construction wildlife monitoring data from operational wind projects in Canada and entry of relevant data into a centralised database.
- Completion of a literature review detailing the various impacts of wind farms on migratory birds and Species at Risk to better inform proponents and regulators involved in the environmental assessment of wind projects on possible and likely impacts to birds.

Next Steps:

Environment Canada (EC) and its collaborators will build upon the results and linkages created by the CEF project and continue to expedite the environmental assessment process for wind power projects in Canada through focused research. Examples:

- Additional modified marine radars provided by project partners within migratory corridors identified by the CEF-supported project will be deployed.
- EC and its partners will operate and maintain the modified marine radars and acoustic microphones continuously during the spring and fall migration seasons (2012 and 2013), when collision rates are predicted to be highest.
- Data from the modified marine radars, weather radar, automated digital radio receivers and acoustic microphones will be combined with local spatially-explicit habitat and weather data to model the temporal and spatial factors that influence wildlife collision risks.

Forecasting and Estimating Atmospheric Icing on Wind Turbines (015CE)

Lead: Environment Canada

Partners / Collaborators: none

CEF Funding: $102,000

Other Funding: $45,000 (EC A-base)

Objectives:

To continue the applied research started by a PERD project (" Rime Icing Modeling" to investigate the use of NWP (numerical weather prediction) meso-scale models along with rime icing models to simulate and forecast the occurrence and amount of rime ice accretion on structures such as wind turbines at specific locations.

Key Achievements:

- Environment Canada's meso-scale numerical weather prediction model, GEM-LAM, was adapted for simulating in-cloud (rime) icing at the surface (lower 100 m or so of the atmosphere).
- This provides significant advancement of the modelling environment that would likely not have occurred without the support of this CEF project..

Next Steps:

The meso-scale modelling work will be g merged and directly continued as part of Environment Canada's ecoEII and PERD projects and collaboration with Hydro Quebec.

Environmental Health and Safety of Photovoltaic Technology (019CEF)

Lead: Environment Canada

Partners / Collaborators: NRCan (CanmetENERGY)

CEF Funding: $135,000

Other Funding: $185,000 (EC and NRCan A-base + $5,000 from industry

Objectives:

- To enhance the scientific and technical understanding of PV technologies.
- To support effective public policy, regulations and federal investment decisions that advance PV and other clean energy technologies in Canada.
- To provide an understanding of the relative environmental impacts of various electrical power sources.
- To identify knowledge gaps and essential information for development of sound energy policy and allocation of funds to strategic research priorities.

Key Achievements:

The key output of the project was the technology assessment report entitled "Environmental Health and Safety of Photovoltaic Technology" that examines the environmental benefits and impacts of solar photovoltaic technology across its full life cycle (from cradle to grave), including energy payback, greenhouse gas emissions and criteria air contaminants, toxic releases, water quality and use, and landscape and ecology. The report also provides a comparison of solar photovoltaic technology to other conventional energy-generating technologies and discusses areas for further research. By providing a better understanding of environmental benefits and challenges of solar photovoltaic technology, the project results will enhance scientific and technical understanding of environmental issues and priorities and could support the development of effective policy, regulations and federal investment decisions.

The project was introduced at the Annual Photovoltaic Industry Forum held by the National Science and Engineering Research Council's Photovoltaic Innovation Network (May 2011). The forum offered an opportunity to discuss the planned assessment of the environmental and health issues surrounding solar Photovoltaic technology with industry stakeholders. Stakeholders at the forum expressed support for an assessment of this type.

Next Steps:

The uptake of the report will be monitored by counting the number of times the report is downloaded from the Environment Canada Web site.

Enhancement of solar panel performance using integrated plastic waveguides, optical filters and micro-optics (024CE)

Lead: National Research Council Canada

Partners / Collaborators:
Active Burges Ltd.
Arc Solar Inc.
B-Con Engineering Inc.
COM DEV Ltd.
indelWorks Inc.
Redoe Mold Ltd.
SolGate Inc.
Tyco Electronics

CEF Funding: $336,000

Other Funding: $266,500

Objectives:

To enhance the performance of solar panels through the integration of specific optical micro/nano structures on the top surface of the panels.

Key Achievements:

The project showed that integration of micro-optical structures on solar panels significantly improves the delivery of sunlight at the solar panels and therefore increases the incident power.

- Simulation results showed that a solar panel without micro-optical structures receives a total incident power of 0.25 W at 90º of light source orientation. It means that 75% of the incoming power is reflected away from the solar panel light receiving surface significantly reducing photovoltaic efficiency and performance.
- Five different micro-optical structures were intensively analysed. Experimental evaluation of PV cell performance results has shown an improvement of between 5.1% and 10.2% in maximum power.

Next Steps:

- Continue with the next stage of R&D focused on the design, numerical simulation, fabrication and performance testing of novel optical structures for enhancing performance of solar cells and panels.
- Continue with a scale-up design, fabrication and field studies, where optical structures for the enhancement of PV cell performance will be enlarged from 3 cm x 3 cm area (used in this completed project) to a real size of the solar cells (e.g. 20 cm x 20 cm area).

An Overview and Assessment of the Progress of Standardisation Development for Low Impact Renewable Energy Generation Technologies and Services in Canada (064CE)

Lead: Industry Canada

Partners / Collaborators: Standards Council of Canada (non-funding participant)

CEF Funding: $71,100

Other Funding: $55,500

Objectives:

Develop a map of the renewable energy generation technology (REGT) standardisation (standards development and conformity assessment) work accomplished to date.

Key Achievements:

Through this initiative, 480 REGT standards and 101 draft standards were identified. Canadian Standard development organisations (SDOs) have 23 REGT standards, and 235 international standards have been developed either by the International Standards Organisation (ISO) or the International Electrotechnical Commission (IEC). All the standards were categorised in an excel inventory based on geographical location, technology, standard type, and draft. The standards inventory is an excellent tool for government and industry to understand the current suite of REGT standards in Canada and internationally.

This work included industry and government outreach to collect views on current standards development processes and to identify gaps in REGT standards. The findings of the industry consultation are presented in the "REGT standards review: lessons-learned report". Recommendations resulting from this work include:

- Improvements to the standards development process
- a need for better process-content management and integration during the standardisation process.
- Standards processes need to be more agile in order to update requirements to keep pace with changing technology and changing user-market needs.

Next Steps:

The outputs of this project are knowledge products and recommendations. The follow-up steps will include dissemination of the work among the standards development community including Natural Resources Canada and standards development organisations.

Marine Renewable Energy Technology Roadmap (072CEF)

Lead: NRCan CanmetENERGY

Partners / Collaborators: Broad range of industry and university participants

CEF Funding: $210,000

Other Funding: $320,000

Objectives:

To strengthen the likelihood of success of the Marine Renewable Energy Technology Roadmap and to ensure that there is on-going support to complete, disseminate and commence the implementation of the roadmap, including:

- Ensuring key stakeholder participation and input in workshops and providing support for an additional workshop to solidify the development of the content of the Roadmap;
- Supporting the publication of the Roadmap report.

[Note: the Roadmap was developed with funding from the ecoENERGY Technology Initiative and PERD]

Key Achievements:

More than 100 experts contributed ideas through a series of 3 workshops to produce a national vision and strategy for Canada's marine renewable energy sector through this Roadmap.

The Roadmap was released. See http://www.marinerenewables.ca/technology-roadmap/

Next Steps:

Implementation of the Roadmap.

Flexible Resources Integration in Smart Grid (077CE)

Lead: NRCan CanmetENERGY

Partners / Collaborators: Electro-Federation of Canada
Communication Research Centre of Canada
University of Sherbrooke
Standards Council of Canada
IREQ-Hydro-Quebec

CEF Funding: $420,000

Other Funding: $215,000

Objectives:

- Undertake the necessary research in support of study groups within the CNC/IEC Task Force on Smart Grid Technology and standards.
- Assess innovative combinations of communications for demand response and renewable balancing.
- Clarify the technological options and requirement for Smart Grid development with flexible resources.

Key Achievements:

- A national Smart Grid Technology and Standards Task Force was established in collaboration with the Standards Council of Canada and supported the preparation of the Smart Grid Standard Roadmap.
- Key standard priority areas and recommendation during the implementation phase were documented.
- An innovative combination of communications for demand response and renewable balancing was successfully tested.

Next Steps:

Under this one year project, the focus was on building the hardware and the test bench and automating the exchange of information among loads to feed a load reduction algorithm. The concept, as pre-patented, allows the dynamic creation of a load community that will be able to self-regulate their load level within a power system. The next steps will be a major focus of the load management solution developed by University of Sherbrooke and on its improvement to balance renewable, electric car charging and to be used by smart inverters. Standardisation work will also continue with the development of “use-cases”.

Smart Microgrid Optimal Operation Research and Development (083CEF)

Lead: NRCan CanmetENERGY

Partners / Collaborators: Pulse Energy
Village of Hartley Bay, B.C.
B.C. Government

CEF Funding: $194,000

Other Funding: $371,000

Objectives:

The objective of this project is to develop and validate, through simulations and field tests, advanced methods and techniques to operate and manage active distribution networks with high penetration of distributed energy resources to improve the operational performance of the distribution network and increase the system reliability. The R&D will provide the knowledge base to support the development of intelligent, self- healing distribution systems.

Key Achievements:

- Documented and analysed the existing energy situation of the community through existing information, hands-on system identification and historical measurements.
- Provided training, service and employment to remote communities, where high quality green collar jobs will be particularly valuable. Work created will involve assisting with the installation of hardware, setting up and managing internet connectivity, on-going energy management and hardware service.
- The knowledge base generated through this Project will provide guidelines that will help other remote communities in Canada reduce their dependence on diesel, save energy, and maximise the use of renewable sources of electricity as these are integrated into their supply..

Next Steps:

To follow up and build on the developed knowledge and lessons learned from this project to conduct applied R&D on remote smart microgrids, including detailed studies on load control, remote microgrid monitoring and renewable resources assessment. The follow-up work will include case studies that support the development of optimisation and load control tools for remote smart microgrids.

Geohazard Barriers to Extensive Deployment of Marine Renewable Energy Systems (113CE)

Lead: NRCan Geological Survey of Canada (GSC)

Partners / Collaborators: none

CEF Funding: $106,000

Other Funding: $105,000

Objectives:

- To broadly engage the marine energy community to compile and evaluate the range of conditions that should be assessed as part of future marine energy projects.
- To refine the national marine energy estimates by defining the potential geohazards that could limit the environmental feasibility of marine energy development.

Key Achievements:

A preliminary review of site characterisation requirements and methodology at a number of sites with high wave and tidal energy potential was completed, and a best practices document developed. This was the first attempt to summarise the range of geological and geophysical information that is required for characterising the seabed at a marine renewable energy site.

The project was successful in pulling together the various elements that are required for development of a best practice guide. This guide was 90% complete at the termination of the CEF funding and due to be completed by August 2012. The results provide a starting point for development of standards for site characterisation at both national and international levels. An immediate outcome of the work is that the industry is interested in seeing the best practices converted into standards. The project leader has joined the Canadian sub-committee of IEC-TC114 and is considering submission of a proposal to the committee for a new standard development. This proposal would be brought forward to IEC at the annual plenary meeting in Oslo in October 2012. Such a standard would be used by industry to reduce development risks and by regulators to improve regulatory efficiency.

Next Steps:

To convert the information and best practices identified in this project into standards for industry and regulators.

Integrated Seabed Suitability Assessment for Marine Renewable Energy Development in Canada (114CE)

Lead: NRCan Geological Survey of Canada (GSC)

Partners / Collaborators: Fisheries and Oceans
Universities

CEF Funding: $210,000

Other Funding: $590,000 (GSC A-base)

Objectives:

To integrate information on surficial geology and sediment dynamics and to develop a new predictive model for seabed substrate stability assessment that can be applied to renewable energy developments in offshore areas across Canada.

Key Achievements:

- Increased data and knowledge of site-specific assessment of near-bed flow and seabed stability through deployments of instrumented landers at strategically selected sites in Bay of Fundy.
- Through collaboration with DFO and universities, 3D tidal model data were coupled with a sediment transport model for regional predictions of seabed shear stress, sediment transport pattern, and sediment mobilisation magnitude and frequency in the Bay of Fundy. This regional prediction for the existing tidal current regime provides the foundation for the assessment of far-field effects on sediment transport by tidal energy extraction
- Production of an innovative regional seabed suitability map (Seascape map) for the Bay of Fundy.

Next Steps:

GSC is transitioning out of marine renewable energy research. With the support of minimum A-base funding, the follow-up activities in the transitioning year 2012-13 will include:

- Complete the model predictions of impacts on sediment transport by tidal energy extraction in the Bay of Fundy as this is an integrated part of the modelling component of the project and the results will have direct applications in assessing the far-field impact of commercial scale tidal energy development in Bay of Fundy.
- Refining of the Bay of Fundy Seascape map so that the innovative methodology and results for integrated assessment of seabed suitability achieved in Bay of Fundy can be integrated into the standards and best practices guide initiated under a separate CEF project.

Geothermal Energy Potential for Northern Communities (115CE)

Lead: NRCan Geological Survey of Canada (GSC)

Partners / Collaborators: Northern Geothermal
U of Calgary

CEF Funding: $140,000

Other Funding: $140,000

Objectives:

To assess the potential for geothermal energy to offset non-renewable energy usage in remote northern Communities with a view to determining opportunities to reduce greenhouse gas emissions and reduce the use of imported diesel in remote communities by converting to local renewable energy resources.

Key Achievements:

The project clearly defined high potential geothermal areas in northern Canada that could be of benefit to isolated northern communities. The work conducted under this project will provide a first order view of what northern communities have the geological potential that would warrant investment in further investigation of local geothermal potential. This should aid regulators and decision makers in focusing investment in the renewable and clean energy resource.

A secondary outcome is that this work has drawn interest from the Department of National Defence, which that are examining options for lower cost local energy resources to support northern military bases in order to protect Canadian sovereignty. This led to some additional cooperative work to assess potential in areas of specific interest to DND, including discussion of drilling thermal gradient wells.

Next Steps:

Geothermal research had been phased out at the GSC so there is no likely direct follow up steps to be conducted. However, the result of the work remain important and relevant and may be explored in a future program.

A2.1.2 Bioenergy

Development of guidelines for assessing the sustainability of using biomass in heat and/or electricity production (017CE)

Lead: Environment Canada

Partners / Collaborators: Agriculture and Agri-Food Canada
Canadian Environmental Assessment Agency
Ontario Ministry of Natural Resources
Ontario Power Generation
B.C. Ministry of Environment
National Council for Air and Stream Improvement

CEF Funding: $800,000

Other Funding: $207,000

Objectives:

To produce a first iteration of an environmental life cycle analysis (LCA) on the combustion of biomass for heat or electricity production in Canada including GHG emissions and sinks, other air pollutants, impacts on water quality, water use, indirect impacts on surface and groundwater levels, impacts on biodiversity, impacts on soils, energy consumption, and efficiency as well as impacts on ecosystem services, natural habitat, land use and its conversion will also be considered.

- To produce a first-iteration list of criteria to be considered when evaluating environmental impacts of biomass production and combustion for heat or electricity production.

Key Achievements:

- A first iteration LCA model was developed, and provided a comprehensive, quantitative and transparent assessment of the environmental impacts of forest-based biomass production and combustion, in comparison to coal.
- The LCA study identified data limitations including: environmental emissions related to aquatic and terrestrial ecotoxicity, freshwater eutrophication, terrestrial acidification, natural land transformation, and fossil fuel depletion.
- A tool was also developed for quantifying changes in forest structure as indicators of potential impacts to biodiversity.

Next Steps:

Follow up steps include an internal review of the LCA model, data, and results, followed by the development of a publication plan for public release of the results. Furthermore, continued development and updating of the LCA is necessary as improved data becomes available.

Anaerobic Digestion and membrane separation for renewable methane (037CE).

Lead: National Research Council Canada

Partners / Collaborators: Air Science Technologies
Novozymes North America Inc.

CEF Funding: $786,000

Other Funding: $1,012,000

Objectives:

To reduce the cost and improve the performance of biomass-based conversions for combined heat and power (CHP).

The anaerobic digestion (AD) component of the project aimed to improve the conversion of biomass to methane and focused on demonstrating and optimising at pilot-scale the main findings of the previous projects under ecoENERGY Technology Initiative and the National Research Council of Canada's National Bioproducts Program.

Key Achievements:

More than 200 membrane modules were produced and characterised with pure and mixed gases allowing for improved membrane performance.

Preliminary assays showed that micro-aeration has a positive impact on the hydrolytic potential of anaerobic digestion resulting in less solid wastes to be disposed of, and in turn, less GHG emissions.

Next Steps:

As a result of the work in this project a private sector company is interested in using membranes for biogas upgrading. Based on the economic study/process simulation they see a large market potential for systems in the 200 to 600 m3/hr range.

Production and Utilisation of Renewable Natural Gas (RNG) From Gasification of Biomass (081CE)

Lead: NRCan-CanmetENERGY

Partners / Collaborators: National Research Council,
FP Innovations,
Canadian Gas Association,
Enbridge Gas Co.

CEF Funding: $790,000

Other Funding: $714,000

Objectives:

To address technical gaps related to the conversion of biomass feedstocks to Renewable Natural Gas suitable for distribution through the existing natural gas grid infrastructure and utilisation of both the product RNG and intermediate process gases for combined heat and power.

Key Achievements:

The project led to the generation of gasification data for a broad range of Canadian forestry feedstocks under a broad range of particle size, bulk density, fluidising medium (air; steam/oxygen mixture) and temperature. The data will assist industry in moving forward with future applications of the production and utilisation of renewable natural gas from gasification of biomass.

Syngas trace contaminant sampling and analysis techniques were developed, as well as a new hot syngas clean-up system comprised of filtering, catalytic tar cracking and desulphurisation for both bench and pilot-scale biomass gasification.

Next Steps:

Follow up work will include:

- Survey and evaluation of methods to determine trace contaminant levels in syngas (i.e. best methods to go about measuring HCN, NH3, COS etc.) and implementation at CanmetENERGY in order to further enhance the capability of the existing equipment.
- Pilot plant testing of tar cracking (tar reforming with homologous compounds using commercial catalysts) and desulphurisation approaches for syngas cleaning

The overall performance and coordination of this research project will be led by CanmetENERGY with industrial review/input from Nexterra, Enerkem, G4 Insights and the Canadian Gas Association (CGA). CGA and member utilities, Nexterra, FP Innovations will provide industrial context for natural gas infrastructure and biomass feedstock assessment.

Addressing Key Barriers and Issues to the Extensive Deployment of Short-Rotation Plantation/Agroforestry Energy Systems in Canada (106CE)

Lead: NRCan-Canadian Forest Service

Partners / Collaborators:
Agriculture and Agri-Food Canada
Canadian Wood Fibre Centre
University of Guelph
University of British Columbia
University of Alberta, Edmonton
Université Laval
Université de Sherbrooke
Réseau Ligniculture Québec
Institut de recherche en biologies végétale
Agro Énergie
Six Nations

CEF Funding: $1,087,000

Other Funding: $3,559,400

Objectives:

To address key large-scale deployment barriers and issues pertaining to the deployment of short-rotation Plantation/Agroforestry Energy Systems in Canada, such as the uncertainties on yield opportunities, sustainability of systems, and cost; the lack of standardised methods to assess biomass yield prior to harvest; and uncertainties on the opportunity for systematic biomass harvest and on environmental consequences resulting from this harvest.

Key Achievements:

Characterised biomass production and quality traits in and promising native willows, and developed a data base for planted willow and several native species observed in eastern Canada.

Assembled regional and national datasets on yields and production cost of fast-growing woody crops on agricultural lands, updated biophysical yield estimates and verified price and volatility projections based on historical estimates.

Next Steps will include:

- Assessing the ease-of-propagation and biomass productivity on highly disturbed sites associated with coal mining, base metals and gold mining, oil sands production, and oil and gas exploration activity, and to develop protocols for site reclamation and restoration of forest cover.
- Assessing the feasibility and costs of wood-based bioenergy from non-agricultural lands, such as forest harvest residuals from managed forests.

A2.1.3 Built Environment

Solid-State Lighting in the Office of the Future (02CE)

Lead: National Research Council of Canada

Partners / Collaborators:
NRCan-CanmetENERGY
BC Hydro
University of British Columbia
Northeastern University, Boston USA
University of Essex, UK

CEF Funding: $170,000

Other Funding: $597,000

Objectives:

To bridge the gap between basic development of high-efficacy solid-state lighting (SSL) sources and their successful wide-scale adoption, including field testing an SSL system to address installation, operation and maintenance issues in a real office environment.

Key Achievements:

A portable demonstration of LED lighting scenarios with a scale model and associated LED lighting and controls gear was developed and successfully road-tested at two conferences in 2012.

An SSL system offering tunable spectrum was installed and demonstrated at the CanmetENERGY facility at Bells Corners to show the potential of LEDs and what the future of lighting may look like. Over 800 people viewed the demonstration units over a six month period.

Next Steps:

A follow-up project will focus on experiments on colour issues:

- to address further issues related to LED flicker, in support of standards development, to further examine colour-tunable lighting, both for individual control and automatic control, and to examine the issue of colour quality and possible illuminance reductions.
- High-resolution SSL controls for energy efficiency - development of fine-tuned controls with various scenarios to facilitate improved energy efficiency and increased usability.

Exploring the Performance of Roof Integrated Photo Voltaic Systems for Potential Integration in Canadian Residential Roofing (03CE)

Lead: National Research Council of Canada

Partners / Collaborators: NRCan-CanmetENERGY
Six Nations

CEF Funding: $224,000

Other Funding: $253,000

Objectives:

To improve the understanding of roof-integrated photovoltaic (RIPV) systems, and develop the expertise and facilities necessary to assess the performance of these systems.

- To investigate the clean energy generation of RIPV systems.
- To determine the system performance of RIPV including: heat and moisture transfer and durability, and also provide comparison with traditional shingle systems.
- To calibrate and use 3D heat and moisture transfer model to determine how RIPV has an impact on the roof system energy balance (attic airspace, insulation).
- To identify the most promising climates and construction types for the deployment of these products.
- To identify technical barriers that could prevent the uptake of these new technologies.

Key Achievements:

- The RIPV system has been installed and operating since 2011 on the InfoCentre roof at the Canadian Centre for Housing Technology (CCHT). Over the eight month trial period, the 2 kW RIPV system generated over 1MWh of electricity and had a measured efficiency of 5.3.
- Wind intrusion, wind uplift, and water-tightness laboratory tests were performed. Wind uplift performance testing revealed the interface between the PV film sheet and roofing membrane as the weakest link.
- The impact of snow cover and shadows on energy consumption has been fully analysed. Snow cover resulted in a 90% loss of potential energy production in January. Shadowing resulted in a reduced system output by 3-5%, equivalent to a loss of 0.55 kWh on sunny evenings.
- A simplified PV energy model has been developed.

Next Steps will include:

It is planned to develop a standard for roof-integrated PV evaluation, and to develop guidelines for the implementation of roof-integrated PV in Canada.

NRC has signed an MOU with a private sector company to compare performance of shingle type products with microinverters and central string inverters (as part of a $2M grant from Sustainable Development Technology Canada). This project will examine shading issues as well as the performance of solar panels in different orientations.

Solar and Meteorological Information for Solar and Building Energy Applications, Codes and Standards (016CE)

Lead: Environment Canada

Partners / Collaborators: none

CEF Funding: $120,000

Other Funding: $90,000

Objectives:

To provide updated and geographically expanded solar radiation and meteorological data sets required in various technology areas to accurately assess the solar resource and other climatic conditions, and thus be able to simulate the performance of solar energy collection systems and building energy systems for specific locations and for integrated community energy applications.

Key Achievements:

The project successfully leveraged linkages to two other projects (one of them an ecoENERGY Innovation Initiative R&D project) to produce Canadian Weather Energy and Engineering Datasets (CWEEDS) and Canadian Weather year for Energy Calculation (CWEC) file updates based on 14 years of satellite-based SUNY (State University of New York) gridded data. It was originally planned to use seven years of SUNY data. The data are now as recent as 2011, and not 2008 as originally planned.

The project provides a very good base upon which annual updates can be made to keep the information current for the renewable and building energy sector.

Next Steps:

The project has led to follow-on work funded under the Program of Energy R&D (PERD) cycle to update, improve and expand the solar irradiance and meteorological files to 2015, and to improve the model to estimate hourly solar irradiance from standard meteorological observations and the earth-sun geometry where in-situ solar radiation observations and satellite-derived solar irradiance values are not available.

Smart Power Management for Renewable Energy (Solar PV) Uptake applied to a Multi-Unit Town-Home Cluster (026CE)

Lead: National Research Council of Canada

Partners / Collaborators: Defence Research and Development Canada
Carleton University
Electrovaya
Panasonic
Hyteon

CEF Funding: $810,000

Other Funding: $546,000

Objectives:

- To develop a total energy management system for a town-home cluster to maximize renewable uptake.
- To optimise the components of the system with respect to sizing and operational strategies.
- To calibrate ESP-r sub models using test data so scenarios can be developed.
- To encourage Panasonic to analyse and participate in the Canadian market for energy management.
- To reduce the cost and complexity of multi-residential and community scale electrochemical storage.

Key Achievements:

- The Canadian Centre for Housing Technology FlexHouse (townhouse unit) has been retrofitted with the Energy Management System, new energy efficiency appliances, an attendant house-sized-UPS system, and power metering equipment, and is operational to enable investigation of a range of simulated occupancy scenarios.
- Models describing the operational benefits of a fuel cell and Li-ion battery have been developed and evaluated against real operating units. This has been critical to implementing proper protocols inside the test home to optimise the Smart Power Management system.
- The electric demand patterns of a cluster of townhouses (11 homes) were measured at a time resolution of one-minute over the period of one year. This data was used for developing representative energy usage scenarios for the project and could be beneficial to other projects in the future.

Next Steps:

A private sector partner plans to use the results of initial testing to continue product development and attempt to improve both performance and economic feasibility of the energy storage system.

The equipment installed within the FlexHouse test home will be maintained after the completion of this CEF project, thus serving as a highly useful "living lab" for future projects.

Next generation combined building-integrated solar photovoltaic and thermal (BIPV-T) energy generating systems for net-zero-energy buildings (068CE)

Lead: NRCan-CanmetENERGY

Partners / Collaborators: Canadian Mortgage and Housing Corporation

CEF Funding: $472,000

Other Funding: $35,000

Objectives:

To advance the design, development and fabrication of the next generation combined building-integrated solar electric and thermal (BIPV-T) power generating technologies and systems and their integration in net- or near-zero energy high performance buildings (new and retrofit commercial/institutional, and residential).

To build the knowledge to engage industry and national research networks to design, develop and fabricate cost-effective combined solar heat and power cogeneration technology for optimal integration in net-zero energy-efficient homes and high performance commercial and institutional buildings.

Key Achievements:

A PV-T Technology Assessment Report was produced that, inter alia, provided an overview of the barriers to the market uptake of the PV-T technology in Canada. These findings will help to orient future R&D on this technology and remove the barriers to its market uptake. The report confirmed the interest of the solar industry towards the PV-T and BIPV-T technologies, identified specific R&D needs, and provided an overview of the barriers to the market uptake of the PV-T technology in Canada.

An analytical model of a BIPV-T using air as the heat transfer fluid was developed and validated.

Next Steps:

The external ecoENERGY Innovation Initiative project, “Plug and Play Building-Integrated Photovoltaic and Thermal Technologies” will enable a stronger linkage with Industry as part of the 2012-2016 research program effort, especially with the NRCan-led project “Next-Generation Dynamic builds envelope systems”. The PV-T test bench and the results from the report on optimal BIPV-T designs will both be used in these EcoEII projects.

Development of Solar Seasonal Storage Technologies for Net-Zero Community and Building Applications (069CE)

Lead: NRCan-CanmetENERGY

Partners / Collaborators:
Sterling Homes
Qualico Communities
ATCO Gas
Enermodal Engineering
Thermal Energy Systems Specialists
Ecole Polytechnique
SAIC Canada
Queen's University

CEF Funding: $350,000

Other Funding: $260,000

Objectives:

To build on the previous successful work on high solar fraction solar seasonal storage technologies for space heating funded by the Program of Energy R&D and ecoENERGY Technology Initiative in order to advance Canada's knowledge and understanding of the potential of high solar fraction seasonal storage technologies for large scale community space heating applications. In particular, to provide key technical input to the development of a demonstration project 10-20 times larger than the award-winning Drake Landing Solar Community project.

Key Achievements:

Demonstrated that the capital cost of a solar Borehole Thermal Energy Storage (BTES) system for a 1000+ home community size can be reduced by approximately 53% from that of the Drake Landing Solar Community project (52 homes).

The simulation study demonstrated that the annual BTES efficiency increases with size and that an efficiency of 77% can be achieved for the 1000+ home community (600 100m deep boreholes), compared to 45% for 52 homes (144 35m deep boreholes).

Next Steps:

The methodology and analysis model used in the study is currently being used to determine the feasibility of the solar/BTES technology concept for several other locations across Canada, in particular for those regions where natural gas is not readily accessible (Yukon and Nova Scotia) and residential heating costs are >$30 per GJ.

Enabling Building Systems Technologies for Smart Grid Integration (070CE)

Lead: NRCan-CanmetENERGY

Partners / Collaborators: Public Works and Government Services Canada
Ontario Power Authority
Delta Controls
Northam Realty Advisors
Lawrence Berkeley National Laboratory

CEF Funding: $1,194,000

Other Funding: $100,000

Objectives:

The overarching objective of the project is to develop the knowledge and tools required to achieve high performance and net zero energy buildings that are capable of self-diagnostics, self-optimisation and of responding in a dynamic way to their external environment through the Smart Grid. Specific objectives include developing advanced control strategies for the use of thermal storage systems in demand responsive buildings, and developing a performance monitoring and assessment tool for identifying problems with on-site PV generation systems.

Key Achievements:

Two successful workshops were organised:

- Towards Intelligent Net Zero Energy Buildings Workshop, on June 30, 2011, was attended by 40 participants from academia (US and Canada), industry, and government. The workshop included presentations along the four themes of the Zero Energy Building Systems Integration Program (ZEBSIP) followed by round table discussions. Collaborative research activities were identified through the discussions.
- Model Predictive Control in Buildings Workshop, on June 24-25, 2011, was attended by 75 scientists from 9 countries. This was the first of its kind in the field of model predictive controls and was a highly successful workshop.

Next Steps:

An automated software tool that will monitor the performance of the PV system using the fault detection and diagnosis methods developed in this project is under development. The diagnostic methods will be validated on-line on a real system. This tool will then be used as a building block for a generalised fault detection and diagnostic tool that will be easily customised to any PV system provided that a small set of measurements is available.

Integration of Heat Pump Technologies and Renewable Sources in Northern Communities (071CE)

Lead: NRCan-CanmetENERGY

Partners / Collaborators: Defence R&D Canada

CEF Funding: $310,000

Other Funding: $990,000

Objectives:

- To identify innovative integration strategies of sea water heat pumps at the Canadian Forces Station (CFS) Alert, located at the northern tip of Ellesmere Island, in order to reduce air shipments of diesel fuel and the associated environmental and economic footprint of this practice.
- To conduct an evaluation of heat pump technologies, driven mechanically, electrically and-or by heat recovered from on-site cogeneration units.
- To perform a state of the art assessment for similar applications where they can be found.
- To determine energy efficiency strategies which demonstrate the best prospect for Alert as well as for replication across northern communities.

Key Achievements:

A station energy model was developed comprised of over 100 buildings of which detailed energy models for the fifty heated buildings were developed. The energy model was validated to the station's recorded fuel consumption and electrical sub metering data and used for detailed analysis on identifying the energy flows of buildings as well as quantifying the impact of key energy efficiency measures.

A sea water heat pump system was assessed for the station. Due to the station's dependence on the on-site cogeneration system to provide electricity and heat, the sea water heat pump system was found to be most suitable for a small cluster of buildings located at the airfield.

Next Steps:

Further work will be undertaken at CFB Alert. Follow-on work under PERD will extend the analysis of using sea-water as a renewable energy source to other Northern Communities. It is proposed to evaluate the integration of cogeneration with heat pumps in a Northern community.

Affordable Net-Zero Energy Homes – Optimisation and Integration of Renewable Energy Systems (075CE)

Lead: NRCan-CanmetENERGY

Partners / Collaborators: National Research Council of Canada

CEF Funding: $775,000

Other Funding: $740,000

Objectives:

To define the maximum energy performance that can be achieved in affordable, cost-constrained housing design. Where this performance falls short of the Net Zero Energy (NZE) target, the research will identify key technology gaps where further research is required to achieve NZE performance. Specific objectives include:

- To analyse and evaluate the performance of existing and emerging innovative energy technologies (including high performance insulation and glazing, envelope-integrated renewable systems and heat pumps) in Canadian NZE-housing.
- To identify key barriers to market uptake of net-zero housing related to: technology gaps, construction practices, and further improving affordability, and identify ways in which industry can overcome these gaps.

Key Achievements:

The project successfully identified cost optimal solutions for production NZE-home builders at 30% lower cost than current practice, and gained key insights into the optimal design of production NZE housing, which will provide valuable guidance to industry leaders, and serve as a foundation for future research.

Next Steps:

As part of the PERD-funded Deep Energy Retrofit for Housing research, the optimisation tool will be applied to develop retrofit strategies for achieving energy savings of 60% or more for major segments of the housing stock.

Integrated Community Energy Modelling: Barriers and Knowledge Gaps (078CE)

Lead: NRCan-CanmetENERGY

Partners / Collaborators:
Ontario Power Authority
BC Ministry of the Environment
Canadian Urban Institute
Canadian Institute of Planners
BC Ministry of Community & Rural Development
New Brunswick Climate Change Hub
Community Energy Association
Federation of Canadian Municipalities
University of British Columbia
University of New Brunswick
Carleton University
BC Hydro
GeoBC

CEF Funding: $410,000

Other Funding: $425,000

Objectives:

To enable the effective delivery of relevant and timely energy, GHG and cost information to inform policy making at various levels of government, in support of the reduction of Canadian GHG emissions and the co-benefits derived from the optimised energy management in Canadian communities.

To reduce or eliminate the technical barriers and knowledge gaps to enable the creation of an NRCan-led Integrated Community Energy Modelling (ICEM) best practices guide.

Key Achievements:

Thought to be a Canadian first, TaNDM (Tract and Neighbourhood Data Modelling) project partners identified standard building categories across BC Assessment, BC Hydro, Fortis BC and NRCan that enable a coherent relationship between building attribute, measured and modelled data to be developed.

Next Steps:

Project findings provide both technical and collaborative models for other provinces, and a benchmark in terms of level of effort and costs involved in 'repurposing' existing datasets for community energy inventory and model development purposes.

New Generation of Integrated Heat Pumps and Renewable Sources for GHG Minimisation in Canadian Houses (079CE)

Lead: NRCan-CanmetENERGY

Partners / Collaborators: Concordia University
LTE-Hydro Québec
École Polytechnique de Montréal
Canadian GeoExchange Coalition

CEF Funding: $1,021,000

Other Funding: $175,000

Objectives:

- To identify the most promising combinations of heat pump (HP) systems and renewable energy sources through a systematic techno-economic comparison for the reduction of GHG emissions in different houses and climates in Canada using simulation based optimisation tools.
- To investigate three new generation-integrated HP and renewable energy technologies for the orientation of future R&D activities.

Key Achievements:

Three housing archetype energy models for three different Canadian regions were developed and validated. Using the developed models, simulations as well as optimisations were carried out to determine the most promising combination of heat pump systems and renewable energy resources for the Canadian housing market in regards to energy savings and life cycle cost. The results provide a strategic orientation for future heating and cooling technology developments in Canada and support Canadians in the decision process of acquiring cost efficient, clean heating and cooling systems for existing and new houses.

Next Steps:

The housing archetype database will be expanded to include additional regions as well as housing vintages to continue exploring and determining the most suitable combinations of heat pumps and renewable energy systems within Canada.

Work on the identification of the most promising combinations of heat pump systems and renewable energy sources for the reduction of GHG emissions in different houses and climates in Canada will be extended to commercial, residential and institutional buildings.

A Process Methodology for Optimising Renewable Energy Solutions Integrated within the Community (080CE)

Lead: NRCan-CanmetENERGY

Partners / Collaborators: Public Works and Government Services Canada
National Research Council Canada
Technical University of Denmark
Hydro Ottawa
Enbridge
City of Ottawa
National Capital Commission, Ottawa
Carleton Sustainable Energy Research Centre (CSERC)

CEF Funding: $799,000

Other Funding: $155,000

Objectives:

To develop a methodology that communities and utilities across Canada may use to assess the optimal mix of renewable energy technologies, demand side management (DSM) activities and municipal policies to apply at a community-wide scale to achieve their longer term energy and greenhouse gas reduction strategies.

Key Achievements:

Gaps in understanding the impact of human behaviour as regards the uptake of DSM activities or the environment were identified. The research highlighted the need to refine the categories of future research to include behavioural issues that enhance the potential for technological uptake and community change.

Next Steps:

The concepts examined and developed within the project will form the basis for further research work under PERD. In particular, the development of district energy / urban clusters is being advanced in a number of communities across Canada and the development of economic strategies to support their development will be a prime component of this new research.

Archetypes Library for Residential / Commercial-Institutional Energy Models (082CE)

Lead: NRCan-CanmetENERGY

Partners / Collaborators: NRCan Office of Energy Efficiency
Public Works and Government Services Canada

CEF Funding: $360,000

Other Funding: $235,000

Objectives:

To define housing and building thermal and geometric archetypes representing various regions (climate zones), vintage groups and types of buildings in order to establish energy efficiency baselines for representative new and existing residential and commercial buildings that can form the datum/base for various renewable energy technology assessments, emerging technologies and policy tools.

Key Achievements:

For commercial buildings, archetype libraries were developed using the ongoing activities in the development of energy models as standardised representations of different classes of buildings. The library of models is intended for use by designers at the pre-design phase and by authorities having jurisdiction or policy makers in the analysis of energy efficiency scenarios at a variety of scales from the individual building to the community level.

For low-rise residential buildings, a detailed set of low-rise residential archetypes has been developed from the EnerGuide for Houses database using the thermal characteristics and geometric information from 630,000 actual Canadian houses. The sample was presented in 280 archetypes formed from 35 provincial code-specific administrative regions in seven age categories.

Next Steps:

This project initiated the assembly of models with an intention to carry them forward under different projects and funding sources. Future outcomes arising from use of the models may benefit Canadian building performance and inform Canadian building codes. The preparation of the archetype library enables this potential.

A2.2 Environmental Challenges Facing Oil Sands Production

A weight of evidence approach to assess the cycling of oil sands relevant metals in a man-made (tailings ponds) and natural (Athabasca River) environment (035OS)

Lead: NRCan-CANMET Mining and Mineral Sciences

Partners / Collaborators: Environment Canada
Institut National de la Recherche Scientifique - Eau Terre Environnement

CEF Funding: $499,000

Other Funding: $613,700

Objectives:

To investigate the distribution and fate of metals in tailings streams and receiving environments, in order to assess:

- The fate of metals - by determining the type of metals in both tailings ponds and the Athabasca River and the abiotic and biotic factors influencing their fate in various environmental compartments (water, sediment and suspended solids).
- The impact – by assessing the potential environmental impact of these various compartments using a multi-trophic toxicity testing regime.

Key Achievements:

Provided a comprehensive examination of the current state of the environment with respect to trace metals in areas of the Athabasca River basin adjacent to oil sands development.

Employed in-situ methods including Diffusive Gradient in Thin Films (DGTs), a novel ion-exchange method and ultra-filtration to assess the bio-available fraction of metals in the water.

Highlighted the potential use of isotopic signatures as a future tool for tracing metals from groundwater to the river.

Next Steps:

To be determined, on the premise that given the proposed scale of future oil sands development, and the atmospheric deposition of coke particles observed in this study, the continual year-round monitoring of metals in the Athabasca watershed seems warranted.

Real-time chemical analysis of process water used for oil sand extraction (036OS)

Lead: National Research Council of Canada

Partners / Collaborators: Canadian Natural Resources Ltd. (CNRL)

CEF Funding: $299,000

Other Funding: $588,000

Objectives:

To develop an on-line sensor that can measure the concentration of four elements, Na, Mg, Ca, and K in solution in the process water by using laser induced breakdown spectroscopy (LIBS) sensing technology. An oil sands producer has determined that the extraction rate of bitumen from oil sands could be improved if the chemical composition of the water used in the froth flotation process could be monitored.

Key Achievements:

Using a filter to remove all particles from the process water allows the LIBS technology to measure Na concentration along with the concentration of the three additional elements.

The LIBS measurement can still be achieved with simulated process water and real process water containing some particles in suspension although it is more difficult.

Next Steps:

Currently negotiating a contract with CNRL to continue the project.

The goals are:

1) Repeat measurements on process water obtained from a filter being developed by AITF,
2) Build and install a permanent LIBS system next to the filter unit, and
3) Install the filter + LIBS sensor online.

Reduction of GHG emissions through hydrodynamic studies of process fluids in bitumen/heavy oil treatment (042OS)

Lead: National Research Council of Canada

Partners / Collaborators: NRCan-CanmetENERGY
Fractal Systems

CEF Funding: $345,000

Other Funding: $480,900

Objectives:

To develop an understanding of hydrodynamic cavitating flows and examine the influence of cavitations on bitumen heavy oil upgrading during in-line processing.

Key Achievements:

- Using in-house expertise, advanced imaging tools were developed for quantifying cavitation intensities.
- Gaps in cavitation theory and the absence of correlation between numerical and empirical methods were addressed through the development of a rheological model that explains cavitating nozzle performance.
- The development tools were applied and validated on industrial-prototype cavitation nozzle systems.

Next Steps:

Through experimental work and model development, stresses in heavy oil and/or solvent mixtures need to be better understood during in-line processing.

Development of Predictive Models to Forecast Bitumen Recovery, Extraction Performance and Environmental Impacts of Solvent-based versus Aqueous Extraction Processes in Producing Bitumen from Oil Sands (088OS)

Lead: National Research Council of Canada

Partners / Collaborators: Syncrude
Titanium Corporation
Canada's Oil Sands Innovation Alliance

CEF Funding: $435,000

Other Funding: $1,148,000

Objectives:

To develop a set of tools and models to forecast bitumen recovery, extraction, performance and environmental impacts of solvent based versus current aqueous extraction processes.

Key Achievements:

Solvent-based extraction processes offer strong evidence that fluid fine tailings could be reduced or eliminated, while maintaining high bitumen recovery (>80-90%) and producing good quality diluted bitumen product with low solids and water contents.

The diluted bitumen produced could potentially be shipped directly to refineries, thereby eliminating the requirement of upgrading the bitumen to a synthetic crude

Next Steps:

Next stage of R&D resulting from this project will be conducted as part of a project between NRC and the University of Alberta. An additional two years of research has been approved for this work with associated funding levels at $390,536.55 for 2012-2013 and $397,659.65 for 2013-2014

Technology Improvements for Ebullated Bed Bitumen Conversion (089OS)

Lead: NRCan-CanmetENERGY

Partners / Collaborators: Laval University

CEF Funding: $209,000

Other Funding: $50,000

Objectives:

To improve the efficiency and performance of the ebullated bed bitumen conversion process (which is the least understood process in bitumen conversion) using computational fluid dynamics (CFD) based modeling in order to reduce the process energy intensity and GHG emission while maintaining the high quality of bitumen products.

Key Achievements:

The simulation results showed that the flow dynamics in the ebullated bed bitumen hydroconverter are strongly dependent on operational conditions and fluid properties. Solid catalyst particles moving upward in the center of the reactor and downward close to the reactor wall, causing three phase turbulent flow, which greatly affects the bitumen conversion in the reactor.

It was shown that to achieve higher product selectivity, reactor performance and efficiency, backmixing of liquid should be avoided while at the same time better mixing of solid catalyst particles is preferred. This requires optimisation of operating conditions. Such optimisation can only achieved through modeling and simulation.

Next Steps:

The proposed next phase of the project would be further systematic simulation of industrial scale reactors. Pilot plant experiments would also be needed to further validate the simulation results.

Advanced Modeling and in situ Characterisation of Hydro processing Catalysts for Bitumen Conversion (091OS)

Lead: NRCan-CanmetENERGY

Partners / Collaborators: National Research Council of Canada

CEF Funding: $218,000

Other Funding:

Objectives:

To identify the desirable active metal species and understand their functioning mechanism by using in-situ surface characterisation techniques validated by density function theory (DFT) modeling and simulation to enhance commercial and in-house developed hydro-processing catalyst activity and process efficiency, which has the potential to reduce process energy intensity and GHG emission.

Key Achievements:

Density functional theory (DFT) modeling and simulation tools were applied to provide theoretical understanding to validate/verify the experimental results. New insights and knowledge was gained in areas such as; structures of carburised molybdenum sulfides, adsorption on carburised molybdenum sulfides, the effect of carburisation on molybdenum sulphide hydrodesulphurisation reaction, and the stability and structure of Pt encapsulated zeolite, to be used to develop more efficient catalysts.

Next Steps:

Follow up work includes:

- Development of new hydro-treating and hydrocracking catalysts based on the modelling results, including carburised Ni-Mo hydro-treating catalyst and zeolite incorporated noble metal hydrogenation catalyst.
- A pilot scale test will be conducted to evaluate the performance of the catalysts.

Synergic Integration of Renewable Biomass Products into Oil Sands Processing to Reduce Emissions of Carbon and other Harmful Elements (100OS)

Lead: NRCan-CanmetENERGY

Partners / Collaborators:

CEF Funding: $293,000

Other Funding:

Objectives:

To identify suitable and sustainable biomass resources such as forestry and agro-residues, assess raw biomass conversion technologies along with process analysis and modeling of biomass integration into bitumen extraction and upgrading operations.

Key Achievements:

The study proposed a novel 3-step methodology to estimate energy and emissions involved in biomass hauling and densification.

A new process model was proposed for integrated gasification of torrefied (densified) biomass to produce heat, power, and hydrogen.

Integrated models were developed that will be instrumental in calculating the mass and energy balances for different case-scenarios and can help quantify the effective renewable biomass contributions and corresponding reductions in emissions in oil sands operations, compared to the base case scenarios.

Next Steps:

The integrated models developed in this phase of study will be instrumental in calculating the mass and energy balances for different case-scenarios and can help quantify the effective renewable biomass contributions and corresponding reductions in emissions in oil sands operations, compared to the base case scenarios. In his context, the tools developed and knowledge generated will be further refined through in-house experiments and stake holder consultation/input to optimise the outputs for multiple scenarios for the purpose of reductions in GHG emissions and cost.

Eliminating environmental issues around residual bitumen in tailings ponds (101OS)

Lead: NRCan-CanmetENERGY

Partners / Collaborators:

CEF Funding: $245,000

Other Funding: $10,000

Objectives:

To undertake research to recover bitumen from tailings ponds as this bitumen typically cannot be added to the extraction process due to the presence of high levels of surfactants.

Key Achievements:

A method to recover bitumen from mature fine tailings (MFT) was developed. This bitumen typically cannot be recovered. Chemically treating the resultant bitumen allows it to be introduced into an existing froth plant stream without deleterious effects due to high surfactant loading. Any process that improves the efficiency of the extraction process reduces green-house gas emissions by virtue of “free” bitumen recovery without the associated mining costs. Decreasing the amount of bitumen in MFT is also beneficial to landscape reclamation.

Next Steps:

Methods and processes developed in this study will be used in cost recovery projects as bitumen recovery from tailings ponds is an important issue for the oil sand mining operations.

Impact of in situ oil sand extraction methods on water quality (102OS)

Lead: NRCan-CanmetENERGY

Partners / Collaborators:

CEF Funding: $230,000

Other Funding:

Objectives:

To understand what happens to the chemistry of water that is pumped into an oil sand formation during in situ thermal operations as well as understand the groundwater chemistry in the formation already, by either adapting existing, or designing new equipment to carry out experiments that will mimic actual temperature and pressure conditions.

Key Achievements:

An autoclave cell was designed, constructed and tested and used to study mineral-water-organic reactions at temperatures and pressures consistent with in situ oil sand thermal operations. It was demonstrated that this apparatus could be used to study reactions of specific interest given possible deleterious changes to groundwater quality, especially the use of solvent in solvent-assisted steam assisted gravity drainage, an extraction method being tested as a way to reduce water use.

Next Steps:

The autoclave cell developed for the project will be stored in hopes that the project can be revived in the next PERD funding cycle. Understanding the impacts of in-situ oil sand thermal operations on groundwater quality will become increasingly important as more and more operations are built.

Fate of soluble organics from oil sand process water and volatile organic compounds in tailings (103OS)

Lead: NRCan-CanmetENERGY

Partners / Collaborators:

CEF Funding: $273,000

Other Funding:

Objectives:

To understand what happens to the chemicals in oil sand process water once that water enters the tailings ponds or ecosystem, looking at factors that determine the water quality in oil sands process water, the implications of this water quality on oil sands extraction processes and issues related to the impact of this water on reclamation. Also understanding how volatile hydrocarbons will be lost to the air once tailings are pumped to the tailings ponds, how fast they partition to the air, and do any remain in the settled minerals.

Key Achievements:

Results indicate that two oilfield chemicals prefer to stay in the soil since they partition more into the solid phase while naphthenic acids (NA) and sulphonates would likely be mobile since they partition more into the water phase. As a consequence, NAs and sulphonates could elute into the groundwater and can be carried away through the water cycle given sufficient time.

Discovered that Heptane release from water is not affected by salinity at levels below 10,000 mg/L. Therefore, variation in salinity of tailings process water (typically much lower than this) will not affect solvent release.

Obtained evidence suggesting that mass transfer is the most important factor in volatile organic compound (VOC) release and that any mechanical disturbance of the mature fine tailings-water interface could lead to increased solvent release from the tailings ponds.

Next Steps:

The methods and results from this project will be used as the foundation for a continuation in an ecoENERGY Innovation Initiative project to study the environmental fate of other chemicals, such as polymers that are used in tailings treatment in oil sand operations.

Understanding opportunities for willow clones in remediation of end pit lake shoreline and watershed development (108OS)

Lead: NRCan-Canadian Forest Service

Partners / Collaborators: Syncrude
Environment Canada

CEF Funding: $250,000

Other Funding: $251,000

Objectives:

To understand the role of willows in end pit lake shoreline development, shoreline stabilisation, and the hydrological consequences of their use in mitigating mature fine tailings impacts from oil sands extraction processes.

Key Achievements:

It was determined that the tolerance of willows to oil sands process affected water varies by clones (genetically different individuals) both within and between species. Process affected water not only has high levels of naphthenic acid but also has high concentrations of salts like sodium. Prior to this work it was generally believed that tolerance to salts was a species related difference, not clone related, at least with willows.

A major oil sands operator expressed interest to test the tolerant willow clones in the field and also promote the testing of other species using the methodology developed for this project..

Next Steps:

The next steps are the continued testing and monitoring of native willow clones for biomass production and for reclamation of disturbed sites. Follow-up will also include establishment of a field trial testing the most tolerant willow clones. Additionally the methodology will be used to screen native balsam poplar clones.

Properties and transformation processes of organic contaminants in oil sands tailings ponds (111OS)

Lead: NRCan-Geological Survey of Canada

Partners / Collaborators: Environment Canada

CEF Funding: $385,000

Other Funding: $85,000

Objectives:

To develop and apply new isotopic methods that can directly distinguish between natural background and oil sands production –related sources of naphthenic acids (NAs) in environmental samples and the application of novel molecular level natural abundance radiocarbon analyses to directly assess in-situ microbial carbon sources and biodegradation of naphthenic acids in tailings ponds.

Key Achievements:

The successful development and application of a novel technique for use in source apportionment of naphthenic acids

Insight into the sources of acid extractable organics through analysis of its radiocarbon (14C) content around the Athabasca oil sands operations.

Critical understanding of the fate of residual petroleum hydrocarbon contamination in tailings ponds sediment as it is critical to the successful implementation of remediation strategies.

Next Steps:

Subject to funding additional R&D would include the applicability of the novel technique developed to evaluate sources of naphthenic acids in other types of bitumen mining-impacted environments, as well as the examination of additional “naphthenic acid” isotopic fingerprinting techniques. The methods and protocols developed will also be adopted for use in evaluating carbon cycling in microbial communities exposed to petroleum hydrocarbons in environments where shale gas exploration
is set to occur.

Transport of natural and anthropogenic contaminants in groundwater from oil sands to the Athabasca River: a local study (112OS)

Lead: NRCan-Geological Survey of Canada

Partners / Collaborators: Environment Canada
Alberta Environment and Water
Institut national de recherche scientifique – Eau Terre Environnement

CEF Funding: $560,000

Other Funding: $430,000

Objectives:

- To identify, quantify and model the flux of oil-sand related chemicals in groundwater along two alignments of well clusters selected to include open mining sites within the Athabasca oil-sand region.
- To address the key issue of distinguishing and quantifying the oil sand related contaminant loads that are released naturally from those produced by anthropogenic activities using newly-developed cutting-edge geochemical and isotopic analytical procedures.

Key Achievements:

A numerical contaminant transport model to quantify the fluxes of organic and metal contaminants from a large tailings pond into surrounding groundwater and surface water was developed.

It was demonstrated that non-traditional metal isotopes can help distinguish oil sand operation-related from naturally present metals.

Next Steps:

Subject to the availability of funding, follow-up will include:

- Developing new metal and naphthenic acid isotopic fingerprints, and using them along the currently tested suite of indicators for identifying contaminant sources near oil sands developments.
- Producing a quantitative assessment of the groundwater transport of oil sand-related contaminants from shallow aquifers to surface water (contaminant flux).
- Identifying the processes that control the concentration and distribution of oil sand-related organic (biodegradation) and metal contaminants in groundwater.

A2.3 Hydrogen and Fuel Cells

Innovative Processes for Prototyping of High Volume, Low-Cost, Durable Membrane-Electrode-Assemblies for Stationary and Automotive Fuel Cells (022HF)

Lead: National Research Council Canada

Partners / Collaborators: General Motors-EERL
Ballard Power Systems

CEF Funding: $496,000

Other Funding: $291,000

Objectives:

To develop unique, high-volume manufacturing processes that will produce low-cost, durable proton exchange membranes and membrane-electrode-assemblies.

Key Achievements:

A new transformative manufacturing process to prototype proton exchange membranes (PEMs) was developed. Polymer Electrolyte Membrane Fuel Cell (PEMFC) technologies are a viable and innovative option for future worldwide energy needs. However, technical challenges such as cost and durability are still hindering their commercialisation. PEMs play a central role in PEMFCs, serving as both electrolyte and gas separator.

Electrolytes with improved durability and lower manufacturing cost without sacrificing performance were developed.

A testing facility unique in Canada was realised.

Next Steps:

Completion of performance and durability assessment by industrial partners.

Assessment of in-situ fuel cell tests and durability results obtained by GM and Ballard for joint publications.

Validation of performance and durability of novel proton exchange membranes against a benchmarked commercial perfluorosulphonic acid (PFSA) membrane.

Novel and improved electrodes for sustainable, alkaline hydrogen electrolysers (040HF)

Lead: National Research Council Canada

Partners / Collaborators: confidential

CEF Funding: $172,500

Other Funding: $364,500

Objectives:

The preparation of improved electrodes for the sustainable production of hydrogen in alkaline solutions.

Key Achievements:

Established deposition methods for the alloy coating process.

Established controlled deposition of various thicknesses of alloy coatings.

Characterised the samples and correlated the physiochemical properties to Hydrogen Evolution Reaction (HER) activities.

Established higher HER activity of these coatings due to extrinsic properties of the catalysts..

Next Steps:

Further work will depend on the interest of the collaborators and identification of methods to carry out further R&D.

Bimetallic Catalysts Yielding Improved Kinetics in Magnesium Hydride and Magnesium Borohydride Hydrogen Storage Materials (051HF)

Lead: National Research Council Canada

Partners / Collaborators: Simon Fraser University

CEF Funding: $384,000

Other Funding: $20,000

Objectives:

To develop new hydrogen storage materials.

Key Achievements:

Several classes of new hydrogen storage materials with remarkable properties were created. This research provided fundamental experimental and modeling insight into the key micro-structural features responsible for improving hydrogen storage materials.

Next Steps:

None identified.

Advanced ORR cathodes using nano-scale non-carbon supported electrocatalysts for high temperature PEM fuel cells (053HF)

Lead: National Research Council Canada

Partners / Collaborators: Automotive Fuel Cell Corporation
Ballard Power Systems
Canadian Light Source University of Saskatoon

CEF Funding: $499,600

Other Funding: $1,017,600

Objectives:

To develop competitive cathodes for Proton Exchange Membrane (PEM) fuel cells with enhanced durability and 2-3 times higher catalytic activity than that of a commercial prototype.

Key Achievements:

A novel hybrid core-shell support with low carbon content for PEM fuel cell Oxygen Reduction Reaction (ORR) catalysts was developed and patented.

A hybrid core-shell supported platinum-palladium catalysts with 3 times higher ORR activity (300mA/mgPt) versus best commercial prototypes was developed and patented.

Next Steps:

The achieved results, developed methods, and modelling tools will be used for further investigation and development of various supported catalysts and supports.

Scale up of Platinum Alloy Catalysts on Non Carbon Supports for PEM Fuel Cells (056HF)

Lead: National Research Council Canada

Partners / Collaborators: Automotive Fuel Cell Corporation
Ballard Power Systems

CEF Funding: $498,800

Other Funding: $942,600

Objectives:

To establish an intermediate scale -up capability in NRC for the manufacture of Proton Exchange Membrane (PEM) fuel catalysts and catalyst supports for the Canadian fuel cell industry to increase the competiveness of its products.

Key Achievements:

A technological line for the intermediate scale-up of catalysts and catalyst supports for the Canadian fuel cell industry was established at the National Research Council Canada.

An electrochemical test set up was built for the simultaneous testing of the durability testing of eight synthesised catalysts.

Next Steps:

The developed chemical-engineering protocols developed will be improved, permitting an increase in productivity.

The scale up facility will also be used to make and test pilot quantities of industrial catalysts for uses outside of the fuel cell industry, for instance, for manufacturers of rechargeable batteries.

PEM fuel cell contamination research - effect of chlorine and ammonia on performance and durability of PEM fuel cells (059HF)

Lead: National Research Council Canada

Partners / Collaborators: confidential

CEF Funding: $374,200

Other Funding: $276,000

Objectives:

To study the contamination effects of chlorine and ammonia on Proton Exchange Membrane (PEM) fuel cells.

Key Achievements:

Tests were undertaken that will aid the collaborator in its future work.

Next Steps:

The collaborator will use the experimental data and the performance degradation predictor generated from this project.

High current density enabling technologies for Generation 4 automotive fuel cell stacks (063HF)

Lead: NRCan-CanmetENERGY

Partners / Collaborators: Automotive Fuel Cell Cooperation
University of Alberta
University of Toronto
Simon Fraser University
McGill University

CEF Funding: $499,000

Other Funding: $521,000

Objectives:

To develop supporting tools, fundamental understanding and models to enable high current density fuel cell operation in the 2-3 A/cm^2 range for automotive applications.

Key Achievements:

A small scale, zero gradient hardware system was designed, and built by the Automotive Fuel Cell Cooperation.

Using Electron Tomography, substantial progress was made in the three-dimensional reconstruction of a catalyst layer in the nanometer scale.

A fuel Cell Simulation Toolkit (FCST) was developed at the University of Alberta. FCST is the first OpenSource fuel cell simulator available in the literature. Currently, the program contains mathematical models for two-dimensional analysis and optimisation for a fuel cell anode, cathode and Membrane Electrode Assembly (MEA).

Next Steps:

The focus will be on increasing the knowledge of the individual materials and extending collaborations. If this technique advances it will be a key technique for the further improvement of best performing materials.

A2.4 CO_2 Capture and Storage

Hydrate Technology for CO_2 capture and storage (05CCS)

Lead: National Research Council Canada

Partners / Collaborators: University of British Columbia

CEF Funding: $405,000

Other Funding: $362,500

Objectives:

To address knowledge gaps and clarify the role of impurities in flue gas when hydrate technology is applied to CO_2 capture and sequestration as gas hydrates (ice-like structures in which gas is trapped inside water molecules).

Key Achievements:

Calculations suggest that hydrogen sulphide and sulphur dioxide impurities should not need to be removed from flue gas before CO_2 removal by hydrate technology.

Next Steps:

Laboratory experiments to improve conditions for CO_2 capture in order to increase feasibility will continue. Actual applications of this kind of technology are unlikely to be developed unless carbon sequestration will be legislated. At that point scale up applications would need to be tested.

Materials property evaluation for CO_2 Capture, Transportation and Storage Infrastructure (06CCS)

Lead: NRCan-CanmetMATERIALS

Partners / Collaborators: NRCan-CanmetENERGY

CEF Funding: $500,000

Other Funding: $330,000

Objectives:

To address critical challenges associated with corrosion, crack initiation, and crack propagation resulting from phase instabilities that are exacerbated by impurities in CO_2 streams captured from power generation and other combustion operations.

To establish materials performance and CO_2 phase stability databases. These will guide the development of engineering specifications, new materials and lifetime predictive models, and will help to evolve national and international standards, which will form the basis for regulations.

Key Achievements:

It was determined that:

- Interaction between material and environment is not an issue, even in the presence of several impurities as long as free water is not present.
- With current knowledge and experience, transportation and injection into the well can be safely carried out; however material-environmental issue with different capture systems and long-term behaviour under storage condition are not well understood.

Laboratory and field experiences were collected and incorporated into a searchable database.

Next Steps:

Additional tests are ongoing to further knowledge on the material behaviour.

Extensive industrial experience is already available in CO_2 pipelines for enhanced oil recovery (EOR) operations, but further experience is needed for transporting CO_2 in presence of impurities resulting from some capture processes. Work will continue to address this knowledge gap.

Improved membranes for CO_2 capture and O_2/N_2 separations (O38CCS)

Lead: National Research Council Canada

Partners / Collaborators: Air Science

CEF Funding: $539,000

Other Funding: $564,000

Objectives:

To improve further the performance of membranes for the capture of CO_2 from fossil fuel based energy sources, including seeking improvements in the cost of the separation process (membrane or adsorption based) which can be linked to the selectivity and flux of the membranes.

Key Achievements:

A full process simulation was undertaken for capture of CO_2 from a 600 MW coal- fired power plant. The study was a full simulation at 12 combinations of feed and vacuum pressures. For the optimum feed pressure the overall capture cost was $25.6US/ton CO_2 captured at a purity of 99% and 90% recovery. The energy demand was 40.4% of a 600 MW coal fired plant.

Next Steps:

No direct follow-up planned.

Emerging Low-cost Capture Processes and Technologies at Atmospheric Pressure for Conversion or Storage of CO_2 (046CCS)

Lead: NRCan-CanmetENERGY

Partners / Collaborators: Carleton University
University of Waterloo
University of Regina
McGill University
National Research Council Canada

CEF Funding: $1,527,400

Other Funding: $204,500

Objectives:

To develop low-cost CO_2 capture technology options for Canadian fossil fuel industry to accelerate their move towards near-zero emission performance, including developing new concepts, models, processes, solvents, materials, and know-how.

Key Achievements:

A post-combustion CO_2 capture test rig was developed, designed and built to test green and hybrid solvents for CO_2 capture. This pilot-scale test unit will serve as a unique test platform for post-combustion CO_2 capture research and will generate valuable data for the research community.

The modelling study into design concepts for full-scale oxy-fuel combustion systems has provided insight that will help guide future research in the area. Results indicate that the need for flue gas recycling (RFG) can be reduced (from the generally accepted level of 70%) by a combination of operating and design choices: reducing incoming O_2/CO_2 temperatures, modifying oxidant/fuel staging and firing circle, and increasing heat transfer surface area in the boiler.

Next Steps:

The research work and pilot-scale testing will be continued under projects that are funded by PERD and the ecoENERGY Innovation Initiative.

CO_2 Storage (049CCS)

Lead: NRCan-CanmetENERGY

Partners / Collaborators: Saskatchewan Ministry of Energy and Resources
Manitoba Geological Survey
Manitoba Water Stewardship
Alberta Innovates
Energy and Environment Research Centre, University of North Dakota.

CEF Funding: $779,000

Other Funding:

Objectives:

- To design and construct laboratory-scale facilities to test the effects of CO_2 and impurities on geologic core samples. This will be an integrated facility where capture technology (gasification, oxy-fuel, etc.) tested to determine the effects of CO_2 streams produced on site at CanmetENERGY labs from various capture equipment.
- To provide contribution funding and participate in a joint Canada-US project studying the Prairie Basal Aquifer, which has been identified as the most promising potential CO_2 storage formation in the Western Canadian Sedimentary Basin.

Key Achievements:

The principle achievements have been the extension of CanmetENERGY's high pressure CO_2 test unit to allow materials testing under precise flue gas composition ,pressure (up to 200 bar) and temperature (up to 300^{o}C) and the construction of a high-pressure and temperature lab to conduct static testing of rock-fluid-CO_2 systems.

The project provided that are data essential for evaluating the feasibility, safety, and security of storing significant amounts of CO2 (thousands of megatonnes) for long time periods (thousands of years) in the regionally extensive Basal Aquifer of the Prairie Region / Northern Plains of North America.

Next Steps:

The next steps for this project are to continue to evaluate rocks, caprocks, and wellbore materials from other prospective storage formations under a range of CO_2 stream scenarios and geologic conditions pertinent to the CO_2 sources and storage formations being tested with a view to building up a database/ list of publications that will be used by geo-storage proponents in evaluating the suitability of a site for the long-term storage of significant amounts of CO_2 and associated impurities.

The next steps for the Basal Aquifer project are to complete detailed numerical modeling of the fate and effects of CO_2 injected in the Basal Aquifer, and to evaluate the effects of potentially leaking CO_2.

High Pressure Energy Conversion Technologies for CCS (050CCS)

Lead: NRCan-CanmetENERGY

Partners / Collaborators: NRCan-CanmetMATERIALS
SaskPower
Canadian Clean Power Coalition
Carleton University
Babcock Power

CEF Funding: $2,000,000

Other Funding: $327,250

Objectives:

To develop, integrate and evaluate high-impact CCS processes and technologies for power generation, oil sands and large industrial emitters (LFEs).

- To prove the technology concepts at the pilot-scale to bring the technologies to demonstration stage and eventually commercialise the leading technology. The components of the technologies are presently at various stages of development. Some are at the pilot level development stage, while others are still in the conceptual stage.
- Too generate the data that will be required for commercial design and construction of the technologies under investigation, including feedstock characteristics, capital and operating costs, resource availability.

Key Achievements:

The study into design concepts for full-scale high-pressure oxy-coal combustion systems has yielded information that will be useful in helping to guide future research and design optimisation studies. Results include general findings on burner configuration, combustor configuration, heat transfer surfaces, and overall process layout. Some of these findings show a strong coupling between burner and combustor design which has a significant impact on performance and overall system sizing implications.

Bench scale tests were successfully carried out on two coals, before and after beneficiation. Neither hydrothermal processing nor impaction changed the sulphur content of the fuels. The hydrothermally processed Boundary Dam was found to have increased ash fusion temperatures in a reducing atmosphere, higher ash content and similar reactivity to the untreated lignite. The washed Coal Valley bituminous coal was found to have lower as fusion temperature in a reducing atmosphere, lower ash content and higher reactivity.

Next Steps:

The research work will be continued under projects that are funded by PERD program and the ecoENERGY Innovation Initiative.