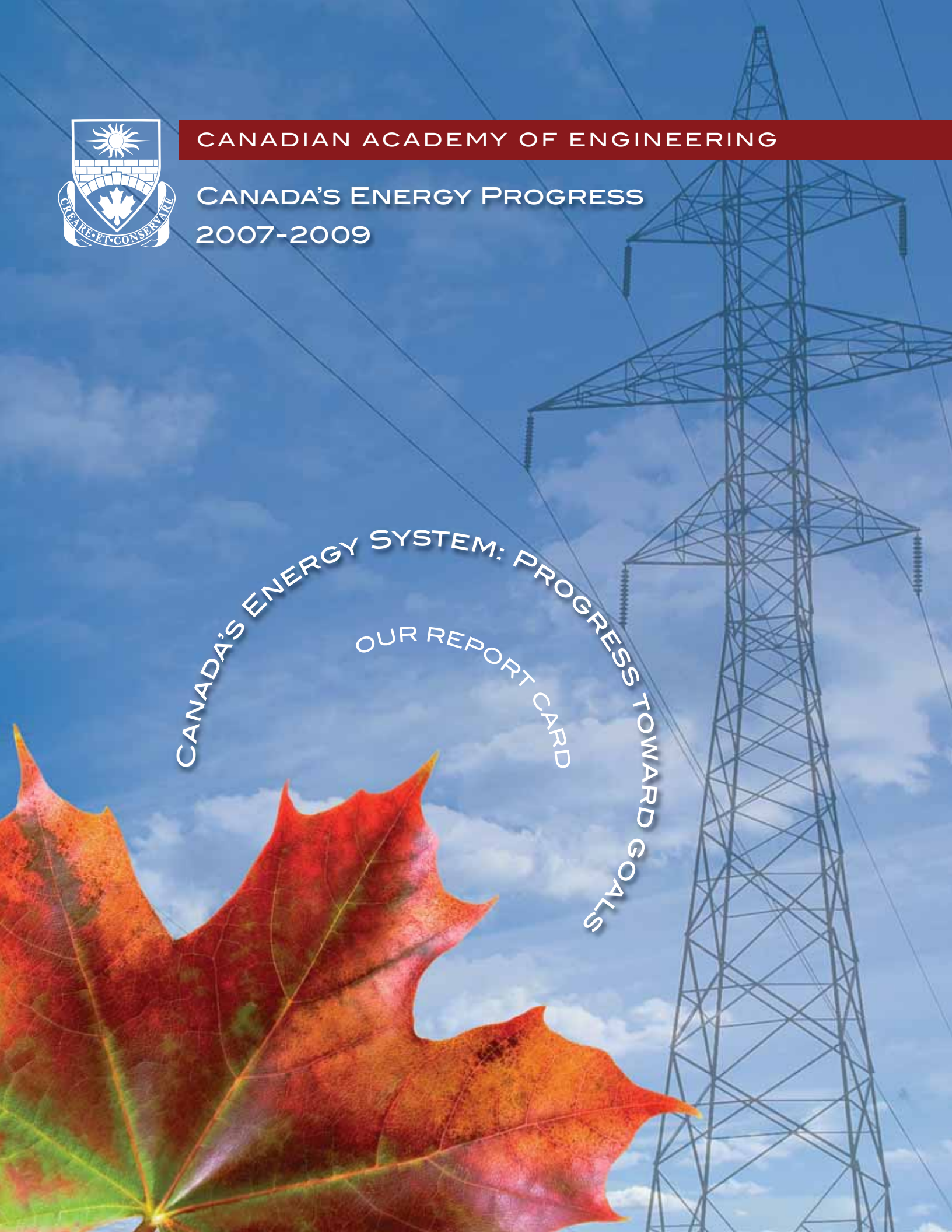
CANADIAN ACADEMY OF ENGINEERING
CANADA'S ENERGY PROGRESS
2007-2009
CANADA'S ENERGY SYSTEM: PROGRESS TOWARD GOALS
OUR REPORT CARD

Canadian Academy of Engineering

Canada's Energy Progress 2007-2009

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Preface

The Canadian Academy of Engineering (CAE) is the national institution through which Canada's most distinguished and experienced engineers provide strategic advice on matters of critical importance to the nation. The Academy is an independent, self-governing and non-profit organization established in 1987 to serve the nation in matters of engineering concern. Fellows of the Academy are committed to ensuring that Canada's engineering expertise is applied to the benefit of all Canadians.

The Canadian Academy of Engineering works with other senior academies in Canada and abroad. It is a founding member of the Council of Canadian Academies (CCA), along with the Royal Society of Canada and the Canadian Academy of Health Sciences. It is a member of the International Council of Academies of Engineering and Technological Sciences (CAETS), which includes some 26 similar national bodies around the world.

The Academy also collaborates with the constituent members of the Canadian Engineering Leadership Forum, i.e., Engineers Canada, the Engineering Institute of Canada, the Association of Consulting Engineering Companies – Canada, the National Council of Deans of Engineering, and the Canadian Federation of Engineering Students. Jointly, we are all committed to ensuring a safer, cleaner, healthier and more competitive Canada.

In 2007, the Academy published the *Energy Pathways Task Force Phase 1 – Final Report* which made four recommendations:

Recommendation 1 –
Canada should proceed with three National Technology Projects:
- Gasification of fossil fuels and biomass.
- GHG emission reduction (carbon dioxide capture followed by transportation, long term storage and/or use).
- Upgrades to electrical infrastructure, with improved access by wind and solar sources, and capacity for energy storage.

Recommendation 2 –
Establish a network for bioconversion demonstration processes.

Recommendation 3 –
Pursue technology development on many other energy opportunities and challenges.

Recommendation 4 –
Maintain a watching brief on magnetic confinement fusion and initiate a university-based laser fusion project as an international contribution.

Canada's Energy Progress 2007-2009 – Canada's Energy System: Progress Toward Goals – Our Report Card is an evaluation of the progress that Canada has made with respect to the above recommendations.

Although it is recognized that this report is not a complete evaluation of all the energy research and development projects underway in Canada, it does provide an indication of the progress made in many important energy areas. However, much remains to be done.

On behalf of the Canadian Academy of Engineering, I wish to thank the authors and the many other contributors to this most valuable report.

Dr. Axel Meisen, FCAE
President, Canadian Academy of Engineering

April 2010

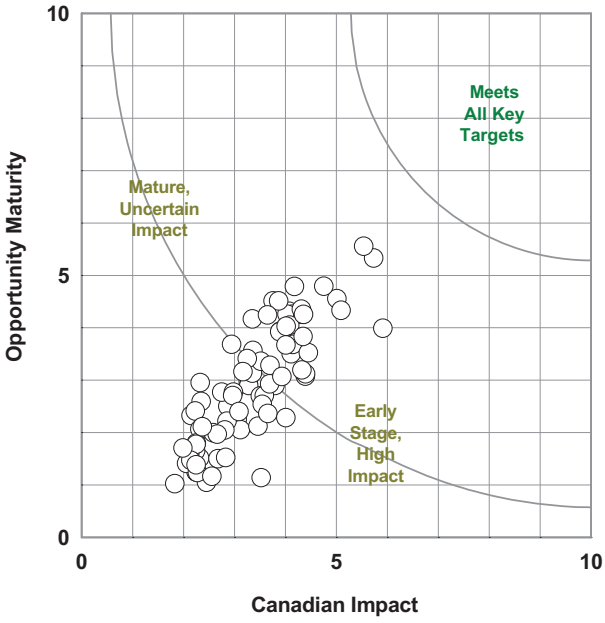
1. Executive Summary

"Canada – an emerging energy superpower" is a vision articulated by Prime Minister Stephen Harper on numerous occasions[1, 2]. In 2006, the Canadian Academy of Engineering initiated an examination of various Canadian energy pathways to define the opportunities and challenges implicit in this vision. The Energy Pathways Task Force established by the Academy has prepared two energy reports[3, 4] and has sponsored two workshops[5, 6] on specific energy topics.

In particular, the Canadian Academy of Engineering in its Energy Pathways report of 2007[3] proposed recommendations related to:

- Three national technology projects (fossil fuel/biomass gasification, greenhouse gas emission reduction, electrical infrastructure upgrades)
- Network for the demonstration of bioenergy processes
- Pursuit of specific Canadian energy opportunities
- Fusion energy contributions

The purpose of the present study is to evaluate the progress in energy technology development that Canada has made since the publication of the 2007 report. Such progress is illustrated in the accompanying figure where the circles represent the current status of over eighty research opportunity areas, measured against the Opportunity Maturity (essentially commercial readiness) and the Canadian Impact (economic and environmental).



With respect to the three recommended national technology projects:

- Several coal and biomass gasification projects are underway, but a national gasification demonstration project has not yet been established.
- Funding and projects have been defined which will result in an important national capability for greenhouse gas capture and storage.
- No significant progress has been made on three electrical transmission system challenges (a high voltage interprovincial grid system, improved connectivity for renewable energy sources and cost-effective energy storage).

[1] Prime Minister Stephen Harper, St. Petersburg, Russia, 2006 G8 Summit

[2] Clean Energy for Tomorrow: Investing in Carbon Capture and Storage in Alberta, Wabamun, Alberta, 14 October, 2009

[3] Energy Pathways Task Force, Phase 1 – Final Report, Canadian Academy of Engineering, May, 2007

[4] Electricity: Interconnecting Canada – A Strategic Advantage, Report of the Canada Power Grid Task Force, Canadian Academy of Engineering, December, 2009

[5] Three National Technology Projects, Calgary, October, 2007

[6] Report on Bio-Conversion Workshop, Sarnia, May, 2008

With respect to bioenergy, a network has been established but there is no evidence of a plan to organize, fund and undertake demonstration projects for the most promising bioenergy applications.

With respect to the many other Canadian energy opportunities:

- Advances in solar heating and power are ready for wider application, which could provide the basis for a rejuvenated Canadian manufacturing sector.
- Wind power in Canada has expanded to close to 4,000 MW, but progress on grid integration, load forecasting, cost-effective electrical energy storage and the development of a Canadian design and fabrication capability is limited.
- Projects are in place to upgrade oil sand bitumen to higher value products, but will require major funding to move from pilot to field demonstration.
- Hydrogen is an active research area, including several demonstration projects related to British Columbia's Hydrogen Highway and an inter-university program on the production of hydrogen through the thermochemical splitting of water.
- A Canadian laser fusion project linked to international programs has been defined but not yet funded.

There are two key conclusions from this evaluation.

1. Although Canada is at the forefront in early stage innovation, we have not been as successful in 'crossing the chasm' and getting new ideas demonstrated on a commercial scale and into the marketplace.

2. As noted in NRCan's 2006 report *Powerful Connections – Priorities and Directions in Energy Science and Technology in Canada,* a systems approach is essential to maximize the benefits of energy technologies and effectively manage energy innovation. Examination of the research and technology currently under development indicates that there is limited evidence that Canada has the framework, policy or networks to manage energy sources and processes as an integrated system.

By its nature, this is not a complete analysis of all the energy research and development activities underway in Canada. However, it does provide an indication of the progress made in many important energy areas. It is apparent that the pace of development must be accelerated if Canada is to achieve its energy superpower vision.

It is believed that this is the first time that an attempt has been made to provide an independent and integrated 'Energy Report Card' for Canada. We urge that this effort be continued by a funded and dedicated research team.

The CAE Energy Pathways Task Force wish to acknowledge the contributions of the University of Western Ontario Research Park in providing the services of Dr. Katherine Albion as Project Manager, in acquiring and setting up the ProGrid database software used in the evaluations, and in providing support to the Task Force throughout the project.

2. Introduction

Energy is a cornerstone of civilization and is essential for Canada's economic and social well-being. Canada has been endowed with huge, unequalled energy resources; however, Canada lacks a compelling national energy vision. Can Canada produce upgraded energy products at reasonable prices with acceptable environmental impacts? New technology will be required, and success will depend on effective public policy and new concepts of risk sharing. Transformational changes must be made through collaborative efforts of government, industry and academia.

In 2007, the Energy Pathways Task Force established by the Canadian Academy of Engineering completed an examination of various pathways connecting energy sources to the final end user. This analysis was the result of the growing concern related to the collision between energy and the environment, the intersection of which is the dominant issue facing the planet this century. The focus of the project was on technology options that would allow Canada to achieve its greenhouse gas emission targets while continuing to provide an adequate supply of energy, at competitive prices, to meet the growing demand for energy.

The *Energy Pathways Task Force Phase 1 – Final Report,* issued in May 2007, included four recommendations:

Recommendation 1 –
Canada should proceed with three National Technology Projects:

- Gasification of fossil fuels and biomass.
- GHG emission reduction (carbon dioxide capture followed by transportation, long term storage and/or use).
- Upgrades to electrical infrastructure, with improved access by wind and solar sources, and capacity for energy storage.

Recommendation 2 –
Establish a network for bioconversion demonstration processes.

Recommendation 3 –
Pursue technology development on many other energy opportunities and challenges.

Recommendation 4 –
Maintain a watching brief on magnetic confinement fusion and initiate a university-based laser fusion project as an international contribution.

This current study is an evaluation of the progress that Canada has made with respect to these recommendations. Requests for project updates and information were sent to a broad list of energy researchers and technology developers, located at Canadian:

- Engineering Schools
- University Research Labs (other than Faculties of Engineering)
- Government Research Labs
- Research Agencies and Organizations
- Energy Associations
- Industry

Requests were sent to more than 250 researchers and developers, resulting in the receipt of over 80 status reports representing over 140 researchers. These reports cover the following energy opportunities:

- Gasification of Fossil Fuels and Biomass
- GHG Emission Reduction
- Upgrades to the Electrical Infrastructure (including hydro electric)
- Network for Bioconversion Demonstration Processes
- Wind
- Solar
- Natural Gas Hydrates
- Mineable Oil Sands
- Bitumen Upgrading
- Hydrogen Production
- Nuclear Power for Alberta
- Bituminous Carbonates
- Geothermal
- Tidal
- Wave
- Inertial Confinement Fusion
- Energy Use

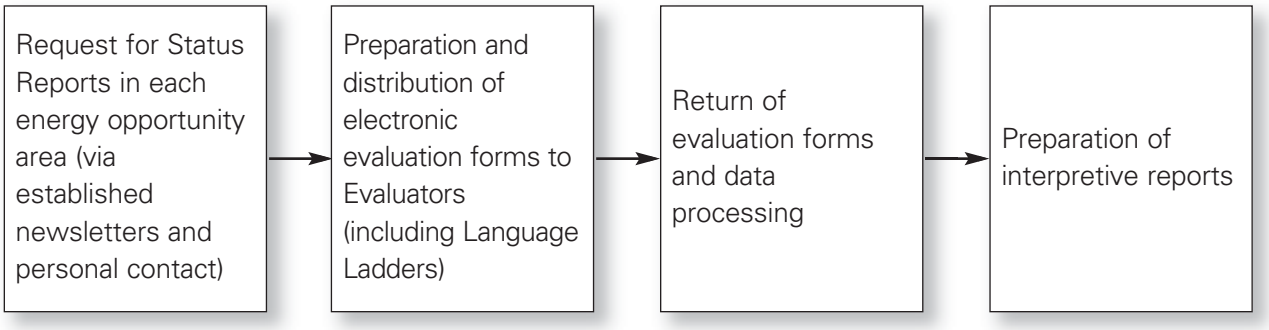
It is realized that this report is not a complete evaluation of all the research and development projects in Canada for these energy opportunities. The projects included are the result of requests sent to energy researchers and technology developers who kindly submitted information and updates of their projects for this report. For future reports, it is expected that additional participants will respond which will provide a more comprehensive view of the energy research and technology development activities in Canada. Participants in this year's report are highly commended for their contributions and support.

3. Evaluation Methodology

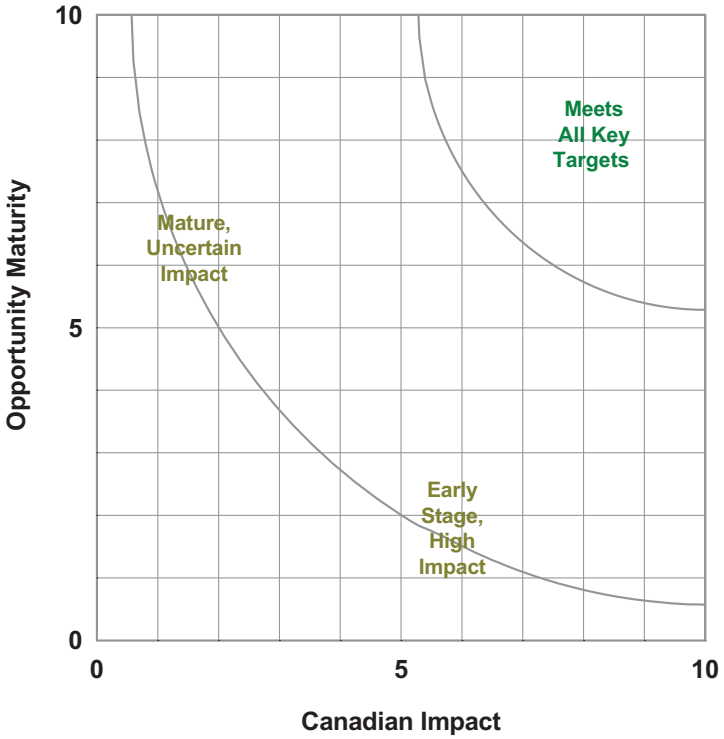
The projects included in this report were evaluated using the ProGrid evaluation methodology. The ProGrid evaluation process implemented was analogous to that used by the Canadian Academy of Engineering's *Energy Pathways Task Force Phase 1 – Final Report,* which is available at www.acad-eng-gen.ca. The criteria used in this evaluation are shown in the following evaluation matrix, which are a sub-set of those used in the original 2007 study. These were felt to focus on factors that are more closely under the control of the researchers and developers and are necessary for the successful deployment of the technology. Language Ladders were prepared to provide metrics for the evaluation and are provided in Appendix A. Language Ladders are a set of statements which represent performance levels, beginning at 'A' and progressing to 'D'. A team of evaluators independently reviewed each project submission according to the Language Ladders.

Opportunity Maturity	**Enablers**	**Canadian Impact**
Science	Funding	Economic
Technology	Collaboration	Environment
		Sustainability

The work flow is illustrated below:



The prime output chart from the evaluation process is a grid showing the progress towards commercialization with respect to the two overarching objectives, Opportunity Maturity and Canadian Impact, as illustrated below.



Early stage opportunities with the potential for a significant impact have high x-axis ratings and low y-axis ratings. Opportunities for which the science and technology are mature but whose application and impact are uncertain, have high y-axis ratings and low x-axis ratings. In either case, a trajectory for improved ratings can readily be defined.

4. Summary of Energy Opportunity Areas

This section provides an estimate of the progress that Canada has made regarding the various recommendations and messages provided in the CAE *Energy Pathways Task Force Phase 1 – Final Report.*

The analysis of each energy opportunity includes the recommendation/message from the 2007 Energy Pathways Report, the summary of the progress made based on the information received from the energy researchers and technology developers, and the resulting opportunity grid positions. The Opportunity Grid provides the status of all projects submitted in terms of their positions along the path to commercialization. The positions of the projects involved in each energy opportunity area are shown as grey circles. Projects related to the other energy opportunities are shown as white circles. Each circle on the chart is the average of the rankings determined by the Evaluators' reviews. Within the energy opportunities there is overlap in the position of some projects represented by the circles.

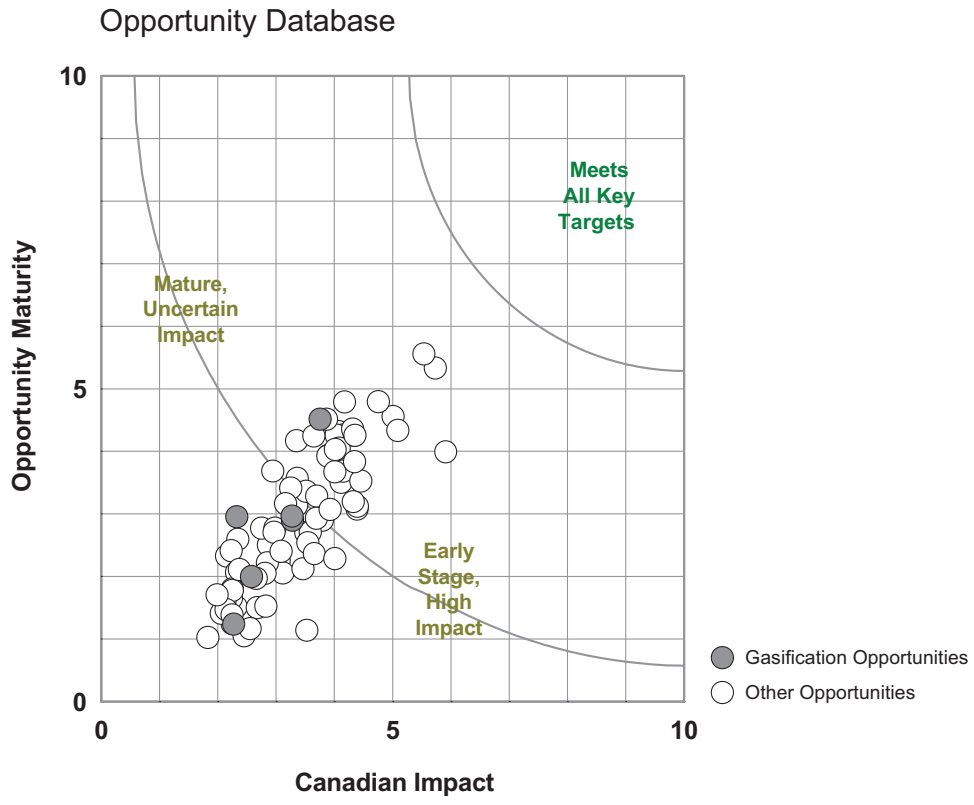
Gasification of Fossil Fuels and Biomass

The 2007 Message

Canada should undertake the gasification of fossil fuels and biomass as a national technology project. Gasification technology is proven but not clearly economic in Canada at present. Demonstration scale projects including CO_2 capture using Canadian low rank coals and coke and next generation technology improvements are needed. While gasification will largely be regional using coal, a successful demonstration project could lead to a platform for gasification of biomass country-wide.

The Progress

Information on six projects was submitted. The highest rated project involves university researchers along with government and industry partners in a large bioenergy research program. This project targets the co-firing and gasification of biomass and peat for power generation and the beneficial utilization of biomass derived fly ash. The additional five projects are related to the demonstration of a small scale combined heat and power system to determine energy production feasibility, the design and development of fluidized bed gasification systems using various feedstocks, the removal of hydrogen from syngas produced in a fluidized bed gasifier, and thermal and catalytic gasification of bio-oil for the production of syngas. A national gasification demonstration project has not yet been established.



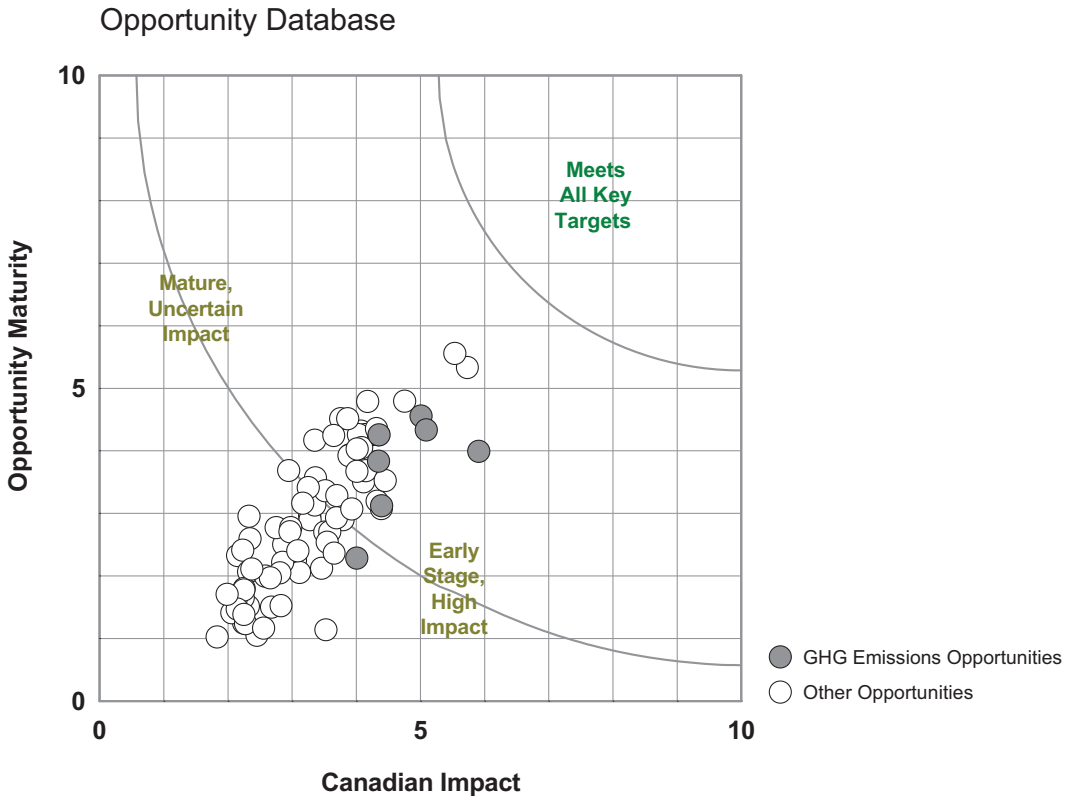
Greenhouse Gas Emission Reduction

The 2007 Message

Canada should undertake greenhouse gas emission reduction (through CO_2 capture followed by transportation, long-term storage and/or use) as a national technology project. Effective and economical CO_2 capture, collection and storage will be an enabler for many other pathways. While there is a major pilot in Weyburn, Saskatchewan, using CO_2 for enhanced recovery, major and immediate efforts are needed at the national level to develop the related technologies for both new projects and to retrofit some existing large emitters.

The Progress

Information on seven projects was collected. Three projects can be grouped as the highest rated project in this category. Alberta announced a $2 billion Carbon Capture and Storage (CCS) Fund with recommendations on how to best implement carbon capture and storage technology in the province. The top rated projects have been awarded funding from this initiative for the storage of 3.5 millions of tonnes of CO_2 annually from upgrading activities and retrofitted coal-fired power generation. Other projects awarded funding include in-situ gasification of coal in inaccessible reserves and the construction of a pipeline to transport CO_2 to depleting oil wells for enhanced oil recovery. Additional projects examine the suitability of a geological site for CO_2 storage, and modeling and feasibility studies of the injection of enriched flue gas into saline aquifers for efficient dissolution. These projects represent a significant attempt to develop a national capability in this area.



Upgrades to Electrical Infrastructure

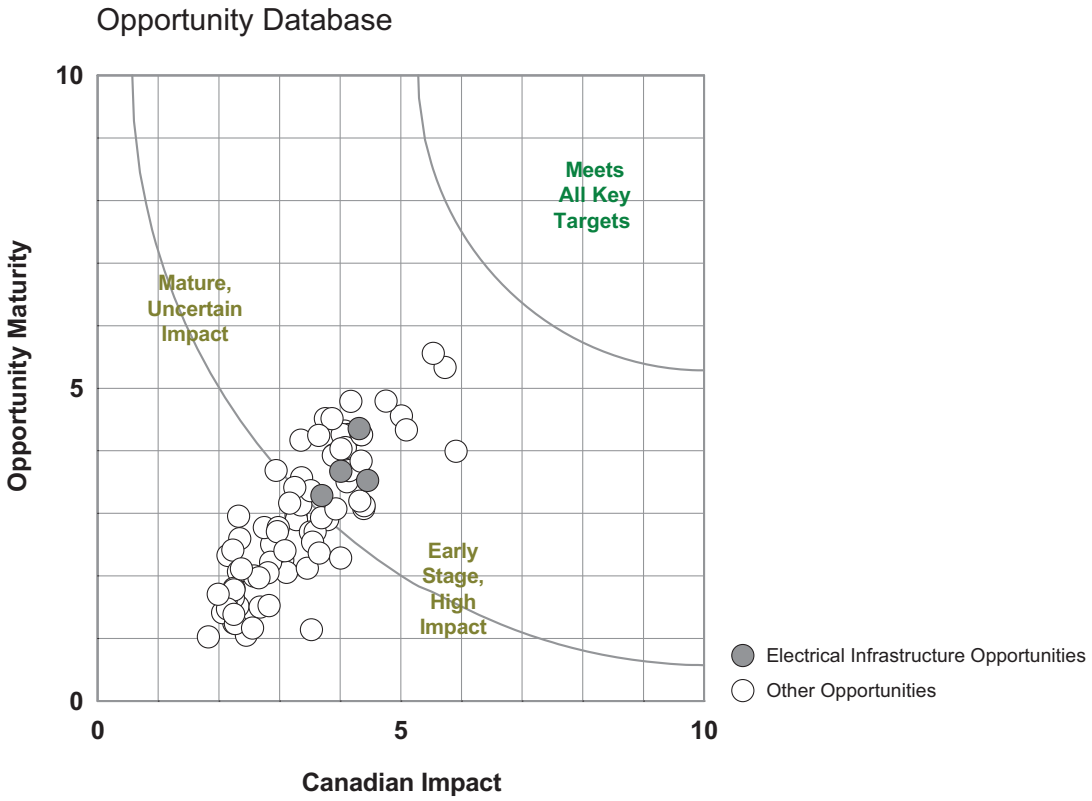
The 2007 Message

There are three challenges related to a national electrical grid system:

1. A national grid system linking most or all of the provinces with high voltage transmission lines capable of transmitting relatively significant amounts of power.
2. Technology to allow more effective connection of larger amounts of intermittent renewable-based generation to the local grid without compromising system operations.
3. Technology to allow more cost effective storage of the energy from electricity produced from intermittent sources and off-peak base loads.

The Progress

Information on four projects was submitted. Three of the projects were hydro electric projects in Manitoba that are either under construction or in the planning stage. These are likely representative of many other hydro electric developments underway in Canada. As noted in the fourth project, the report of the Canadian Academy of Engineering Power Grid Task Force, Canada has huge undeveloped hydro electric potential. However, the three challenges noted in the 2007 Message need to be addressed if Canada is to achieve its potential in this energy area. The International Energy Agency has estimated that Canada's electricity sector will require $190 US billion in new investment by 2030 which will provide an opportunity to adopt new, advanced technologies.



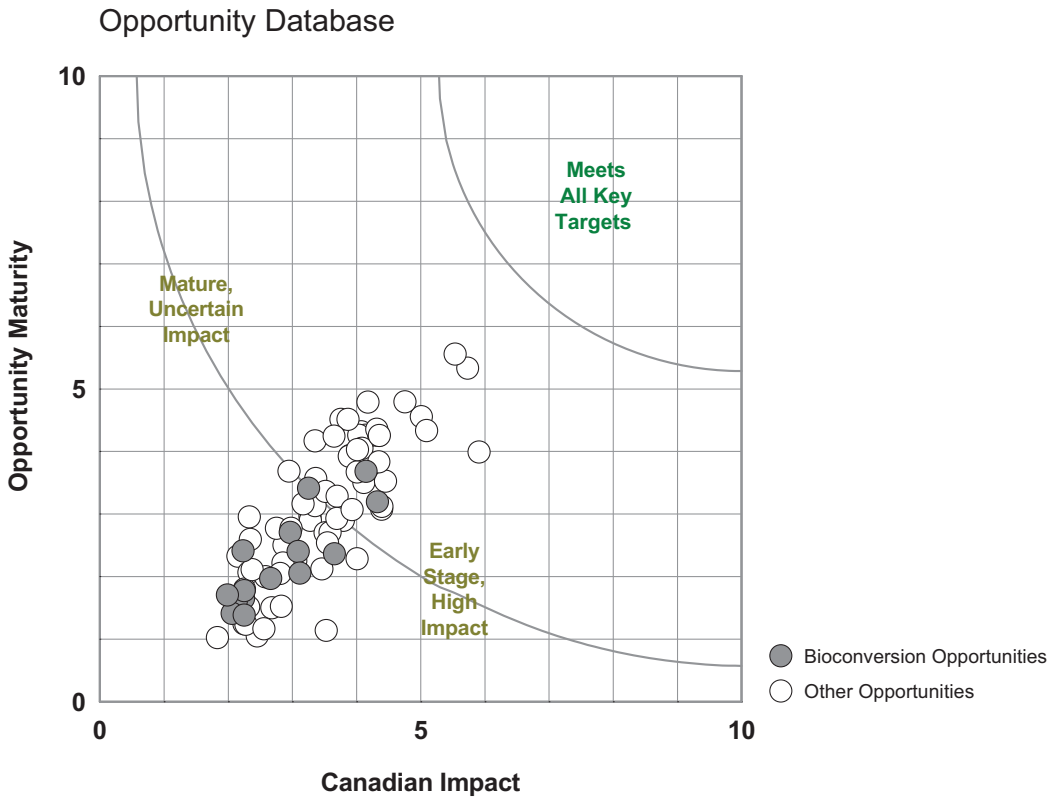
A Network for Bioconversion Demonstration Processes

The 2007 Message

There are a large number of directions that could be taken in producing energy products from both agricultural and forestry feedstocks. In many cases, regional factors would be key drivers. A national coordinated network is needed to incent and share information on a series of regional demonstration projects that could result in significant upgrades to current technologies.

The Progress

Information was submitted on fifteen projects. The highest rated project in this opportunity area was undertaken by a group involved in 'feedstock engineering' to integrate processes and management strategies from the biomass harvest up to the feedstock conversion to bioenergy and bioproducts. Additional projects include the optimization of continuous fermentation systems for direct fermentation of cellulosic biomass to biofuels, research activities for the development of biorefinery processes emphasizing systems analysis of biorefinery concepts, the creation of an institute dedicated to the production of chemicals and fuels from alternative resources which has launched a major pyrolysis program, and a study of the kinetics and mechanisms of the hydrothermal conversion of biomass to biofuel. A network has been established, however there is no evidence of a plan to organize, fund and undertake demonstration projects for the most promising bioenergy applications.



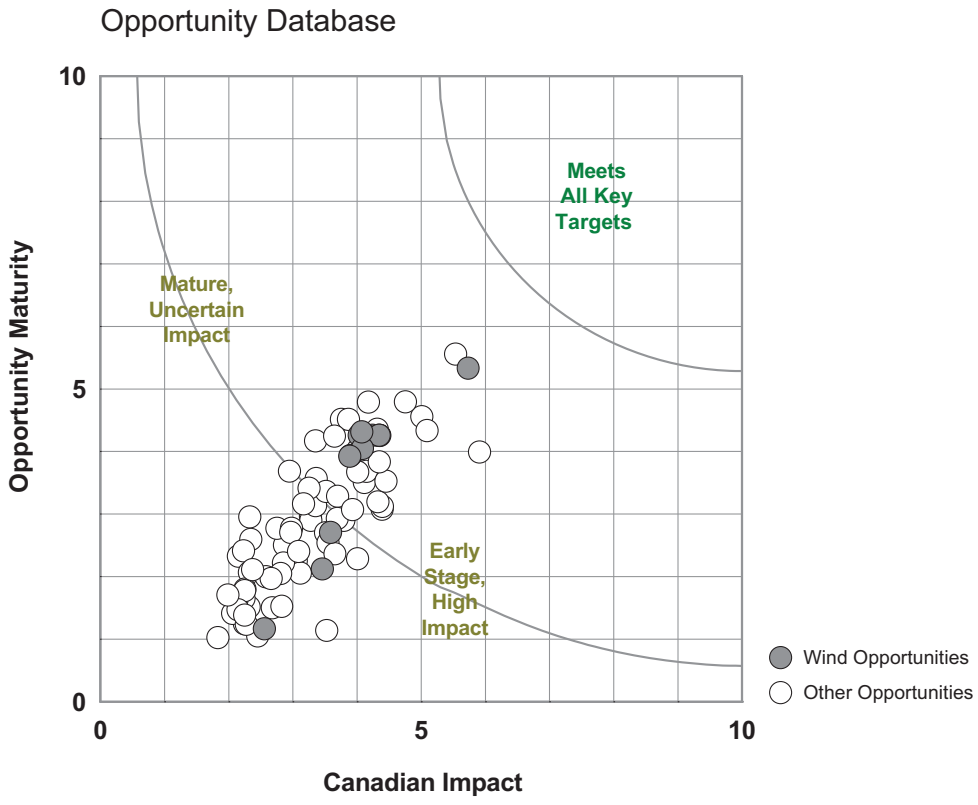
Wind

The 2007 Message

The technology for producing electricity by wind turbines has increased rapidly in recent years to the point that wind power is a growing component of most power systems that have good wind profiles. However, this technology has a large footprint relative to the power output and studies and technology improvements are needed to address issues of integration with power grids and more effective storage of the energy generated to mitigate the intermittency of the resource.

The Progress

Information on thirteen projects was collected, with nine clustered and overlapping around point (4, 4) on the grid. These nine projects represent individual wind farm installations across Canada, particularly in Atlantic Canada. The top rated project provided by the Canadian Wind Energy Association represents the current situation after all current wind energy farms are installed and operating, which will bring the installed capacity to 4,000 MW. The three lower rated projects are early stage studies of different turbine designs, structural life measurements and wind energy storage. Thus, significant progress has been achieved in increasing Canadian wind energy capacity. However, progress on grid integration, cost-effective electrical storage and development of a Canadian design and fabrication capability is limited.



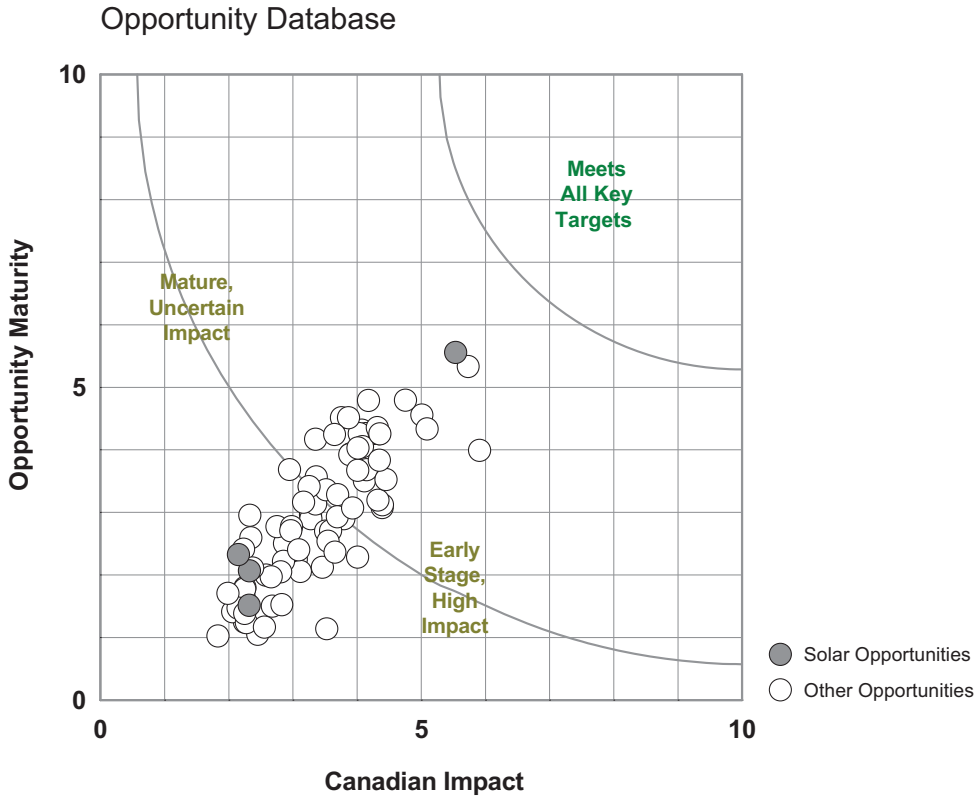
Solar

The 2007 Message

It is likely that Canada will not be a leader in the massive technology development efforts that will be needed to achieve the potential of this pathway. However, work on issues such as integration with the grid and storage could contribute to the effectiveness of this pathway.

The Progress

Information on four projects was submitted. The highest rated project in this energy opportunity area, and all areas included in our evaluation, was undertaken by a network of 26 researchers at 12 universities, supported by several government and industry partners. The network coordinated work on both thermal and electric power applications. Field demonstration of advances included a prize-winning demonstration house constructed using a photovoltaic/thermal prefabricated roof module. With a better definition of the economics, this energy opportunity area appears to be ready for wider application. The other three projects are early stage investigations of the application of nanotechnology for the development of new and advanced solar cells.



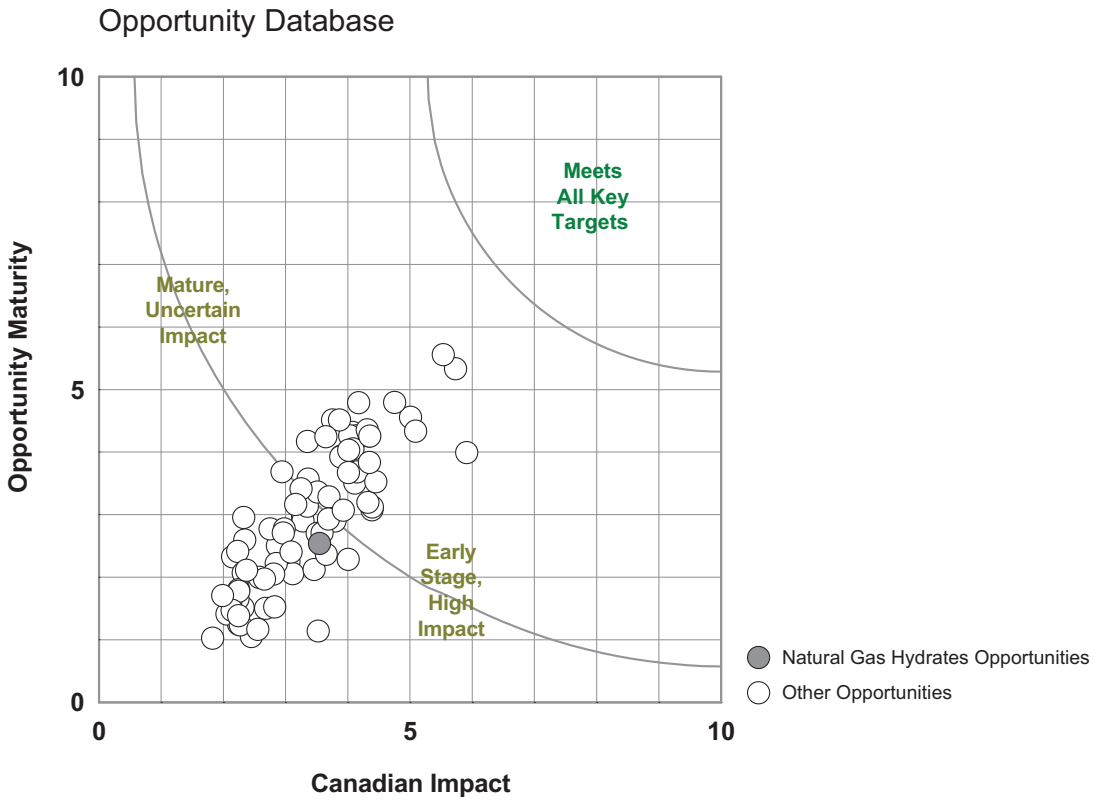
Natural Gas Hydrates

The 2007 Message

While it is believed that we have a massive resource, little detailed information is available and there is currently no technology for the large scale, practical recovery of this resource. Canada should expand its research efforts in this area, starting with mapping and delineating the resource base and assessing the potential and risks involved in future exploitation. Due to the widespread global occurrence of gas hydrates, there is a potential for technology export.

The Progress

Information on one project was submitted. This project noted that in Canada, natural gas hydrates are located beneath the permafrost in the Arctic and along the offshore continental margins. Natural gas hydrates are a vast energy source for Canada with the potential to provide decades worth of energy to the Canadian supply mix. A successful production test has been completed and work is underway to complete the data analysis. Future work includes locating hydrate reserves and determining the technical feasibility for extraction and commercial production in an environmentally conscious manner. Therefore, this project is targeted to meet the CAE 2007 recommendation.



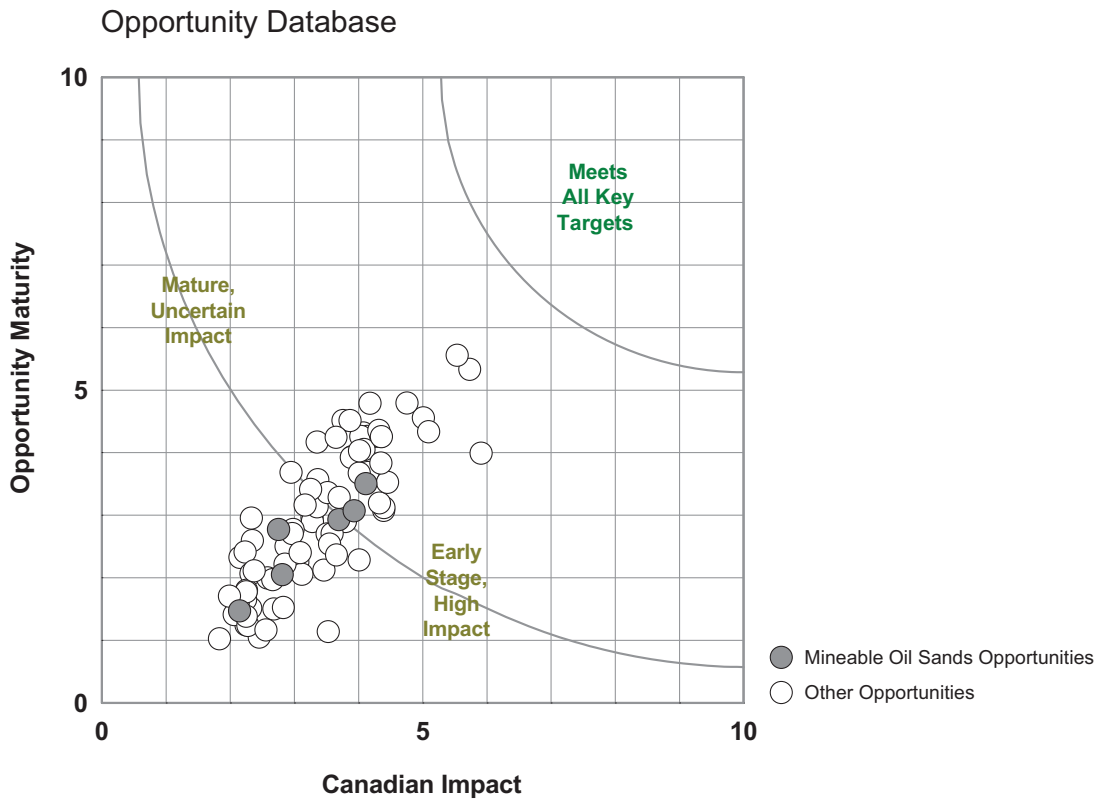
Mineable Oil Sands

The 2007 Message

The current approach to extracting and processing our surface mineable oil sands resource is not environmentally acceptable. Work is needed to identify step changes to the 40-year old technology that is now being used.

The Progress

Information on six projects was submitted. The highest rated project was a major joint university-industry program designed to reduce the environmental impact of oil sands mining, extraction and upgrading processes through the development of breakthrough technologies. This program has the potential for advancement toward the 'Ready for Commercialization' zone depending upon its success in the development of new processes. Four of the remaining projects were related to better management of and reclamation of tailings ponds through improved technologies, which when ready for application will show higher ratings in the future. One project was a report on the benefits, risks and issues associated with oil sands development which identified three scenarios which could help guide oil sands development.



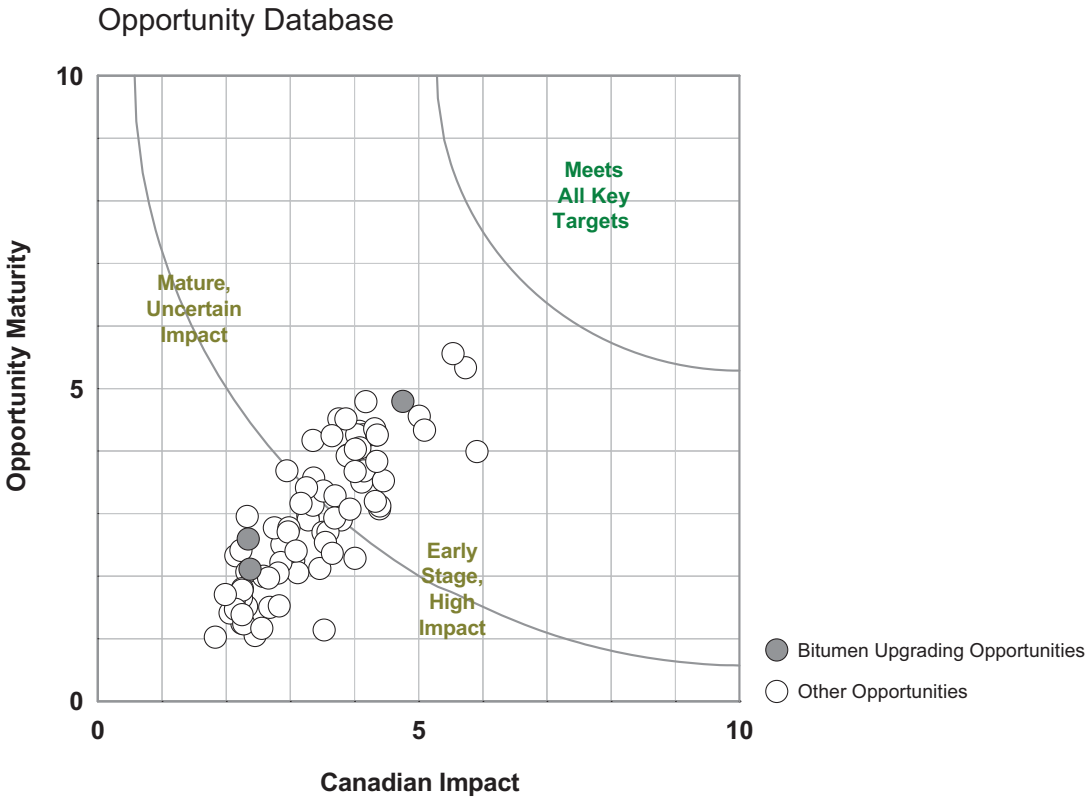
Bitumen Upgrading

The 2007 Message

Research is needed on technologies to use in local processing of the raw materials extracted from our oil sands to make the best use of the outputs based on their chemical structures. New science is needed in this area.

The Progress

The top rated project submitted in this energy area is the Hydrocarbon Upgrading and Demonstration Program initiated by an Alberta Government research agency. The goal is to upgrade oil sands bitumen and heavy oil into higher value products with reduced carbon dioxide emissions. The Alberta Government has invested $40 million in the program which has been more than matched by a number of industrial partners. Several new technologies have advanced to the pilot stage of development. Advancement to the full pre-commercial demonstration stage will require considerably more investment by government and industry, and there are short term economic factors which may slow the pace of this program. The two additional projects relate to improvements of existing upgrading processes and have the potential for early application if successful.



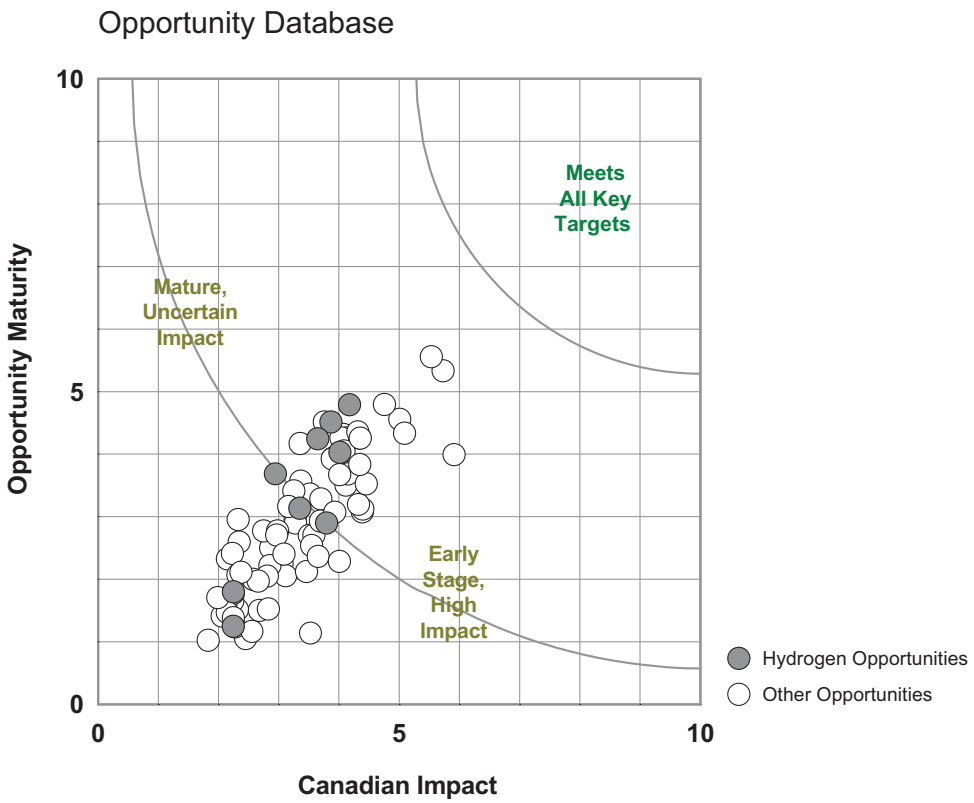
Hydrogen Production

The 2007 Message

Continued reliance on natural gas to produce hydrogen for use in oil sands upgrading is a questionable use of our natural gas resource and is environmentally unacceptable. Research is needed on alternative technologies that could combine Canada's existing strengths in nuclear power and hydrogen production.

The Progress

Information on nine projects was submitted. The top rated project was British Columbia's Hydrogen Highway, which includes a number of fueling stations and end use equipment applications. The next rated project is a five car hybrid electric vehicle test, fueled from BC's Hydrogen Highway. The next two projects relate to the development of fuel cells – a solid oxide fuel cell network coordinated by the University of Calgary and an integrated hydrogen and fuel cell technology pilot program in the Toronto area. Three closely rated projects were a major inter-university program for the production of hydrogen by the thermochemical splitting of water, and testing of hydrogen fueled vehicles in a bus fleet and airport environment. The final two projects were early stage testing of the catalytic and microbial conversion of biomass to hydrogen. Thus, six of the submitted projects related to the use of hydrogen in mainly mobile applications. Three projects were focused on the search for alternative sources for hydrogen supplies and are at a very early stage.



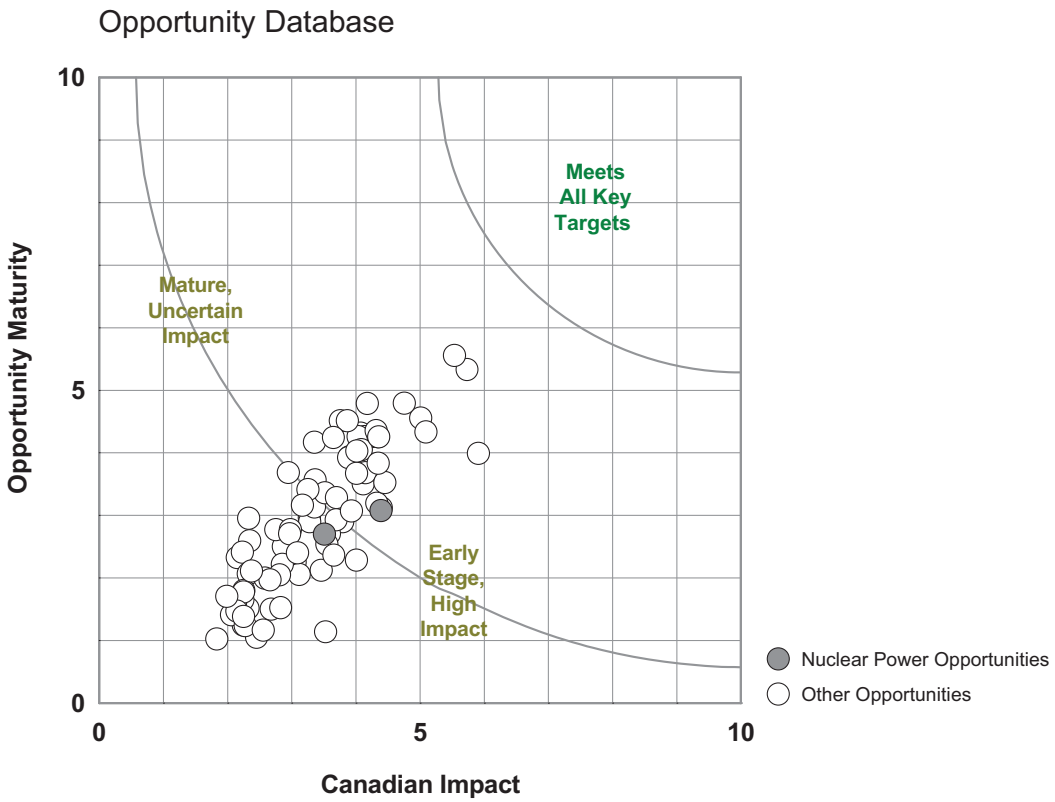
Nuclear Power for Alberta

The 2007 Message

Our world leadership in the SAGD process combined with our proven nuclear power plant technology could be leveraged to greatly reduce environmental impacts of the current oil sand processes. Research is needed on effective integration of centralized steam production with dispersed well injection (to overcome long distance steam transportation challenges), electricity production and water/air cooling requirements.

The Progress

Information on two projects was collected. The highest rated project in this energy opportunity area is the initial phase of planning with regards to the possible construction of a nuclear plant in Alberta. This plant may include as many as 4 nuclear reactors to meet Alberta's growing energy demand. The next phase is contingent on the province's announcement as to whether nuclear energy will be included in Alberta's energy mix. The second project was a report prepared by an Expert's Panel providing information to Alberta on nuclear energy and soliciting feedback from the public for the government to consider in its decision on the inclusion of nuclear power. On December 14, 2009, the results of the public consultation were released.



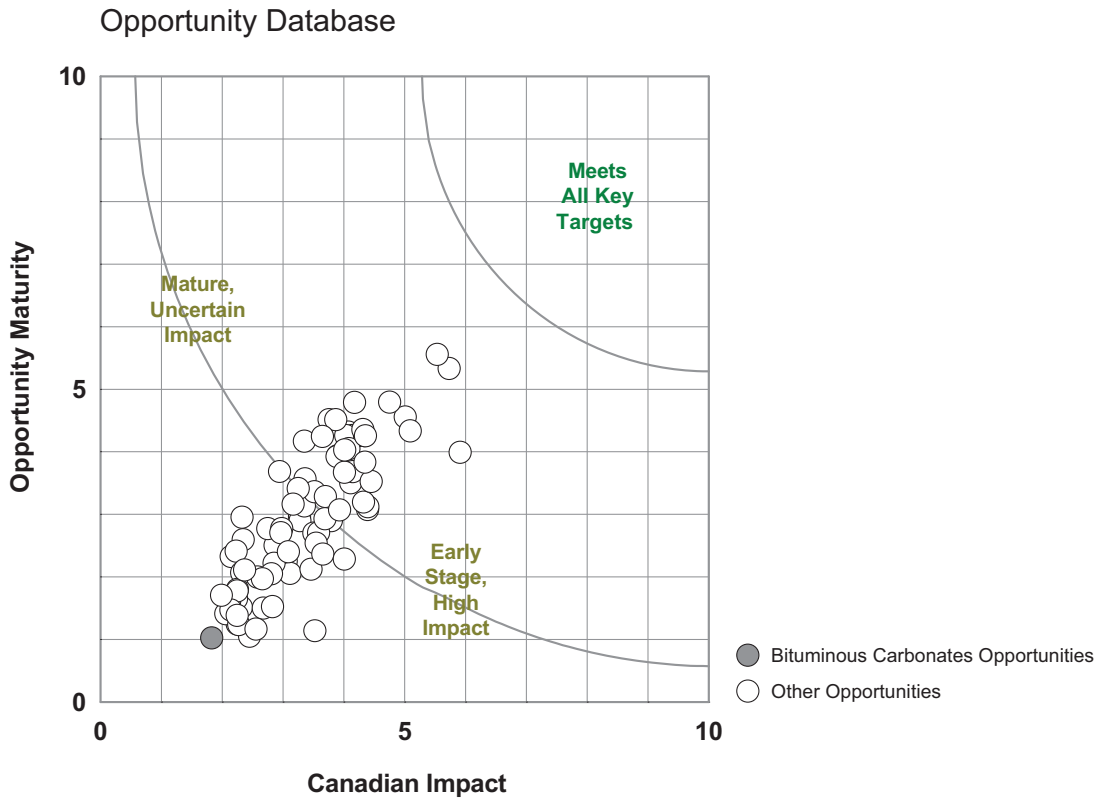
Bituminous Carbonates

The 2007 Message

Previous recovery efforts related to this large resource base have not been encouraging. Knowledge about the geology and effective and economic extraction methods is limited. More work is needed on reservoir characterization and improved recovery approaches before this resource will have any significant impact.

The Progress

Information on only one project was submitted, which confirms the early stage of development. This project noted that there are approximately 2 trillion barrels of viscous oil in such reservoirs worldwide. There are as yet no specific extraction technologies that have been identified as being optimum, although a general consensus is that thermal methods, gravitationally dominated, will be preferred. It is expected that suitable screening criteria will evolve, as well as the identification of technical and geoscience issues that need further study resolution. There have been a number of field trials in these reservoirs and interest by leaseholders continues.



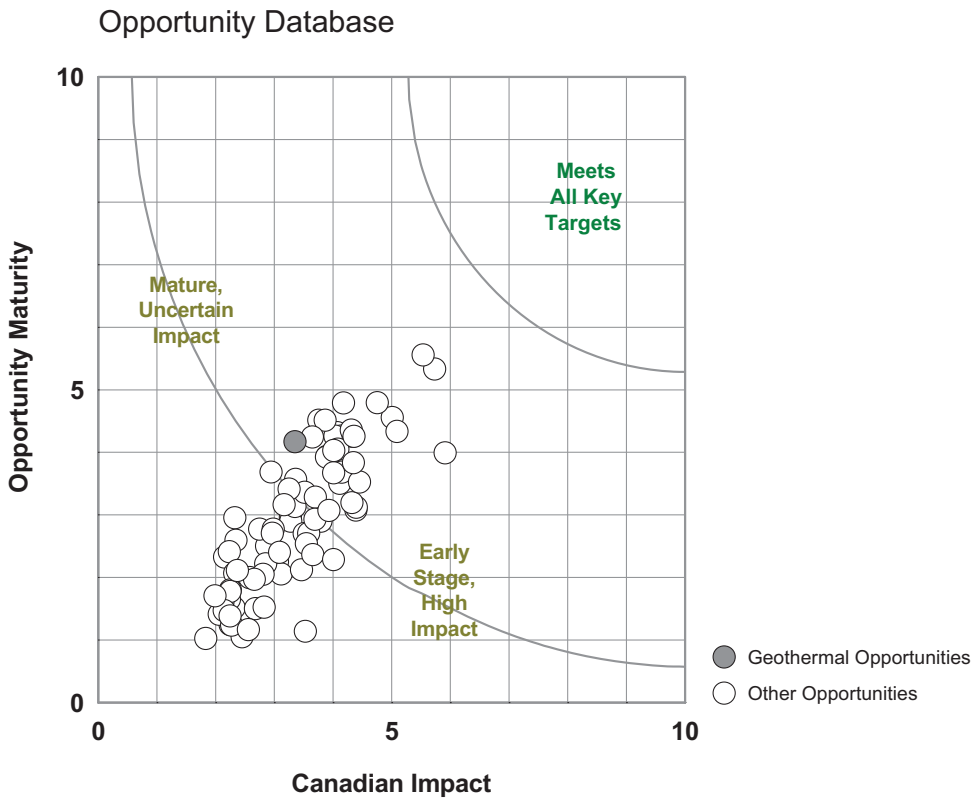
Geothermal

The 2007 Message

The technology for this is not highly developed and we do not have a national survey of the resource base. Trials of heat exchanger technology could be carried out using existing oil wells in Western Canada.

The Progress

Information on one project was submitted which confirms that the technology is ready for development. This project entails the use of the largest geothermal pump in Manitoba installed in a new, state-of-the-art, energy efficient office building. This office building, in combination with additional energy saving features, has exceeded the expected energy reductions. The energy savings allows for the sale of energy to export markets.



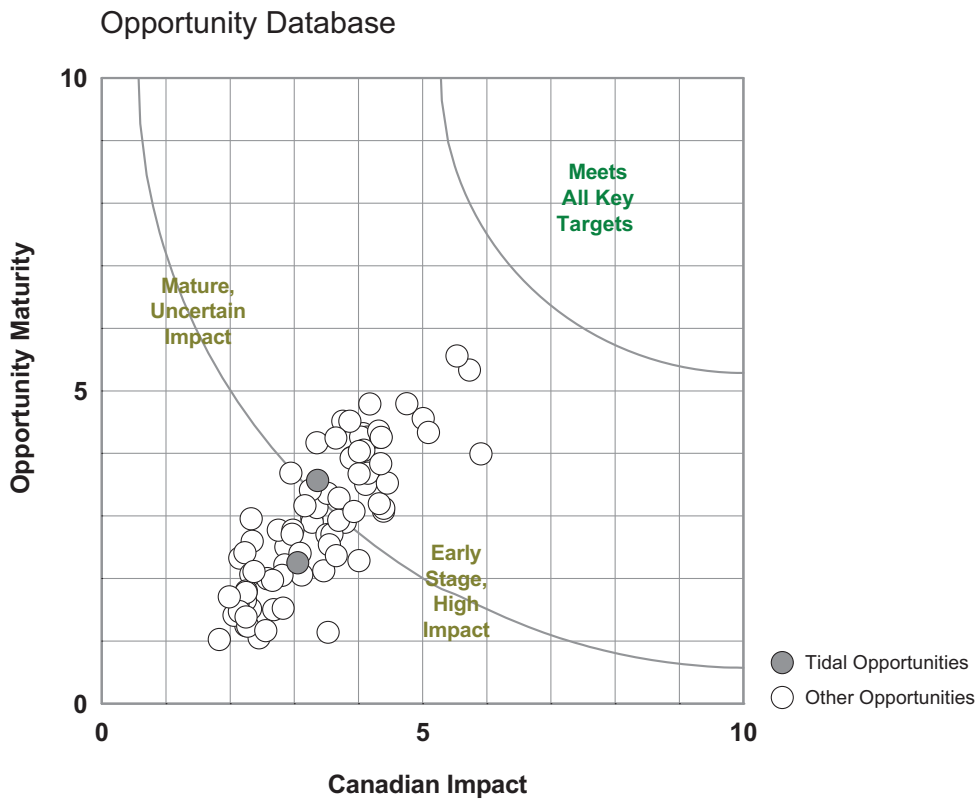
Tidal

The 2007 Message

While the idea is not new, modern technology for this is in its early stages of development. Our candidate sites are typically in areas where other energy sources are limited and thus this technology could make a significant contribution. Demonstration projects would be needed to confirm the potential.

The Progress

Information on two projects was collected. The highest rated project in this energy opportunity area is a turbine commercialization project. This project will demonstrate the feasibility of grid connections, identify issues regarding power quality and reliability, and validate the operation of the turbine in a marine environment. The second project is the construction and operation of a research centre for tidal energy.



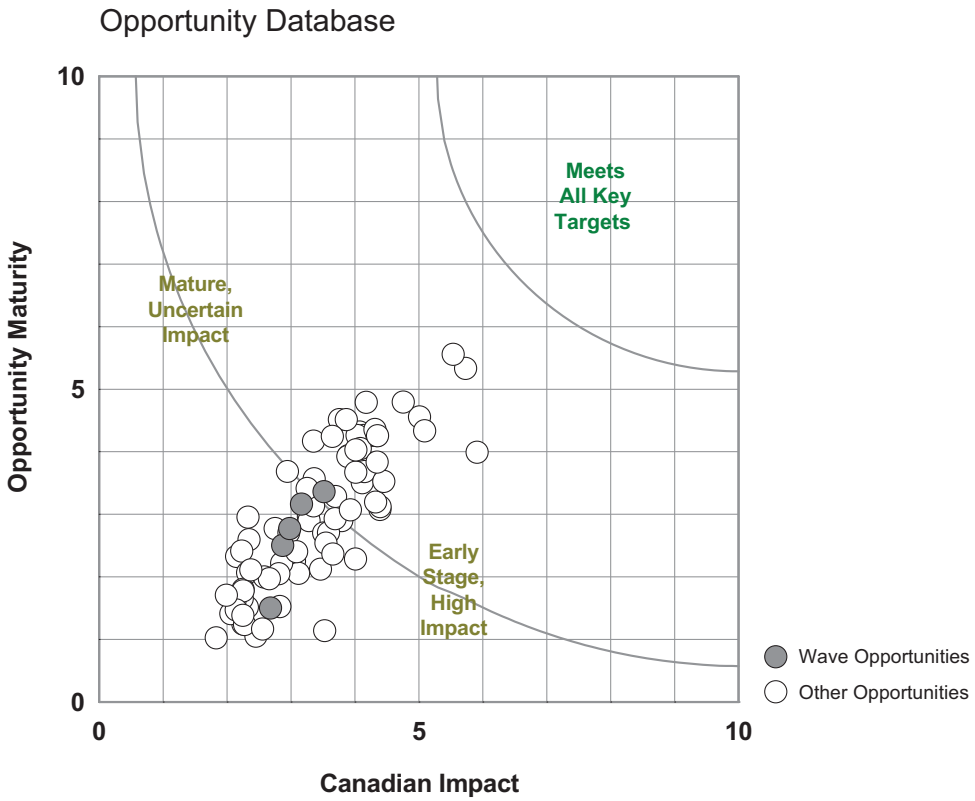
Wave

The 2007 Message

While the idea is not new, modern technology for this is in its early stages of development. Our candidate sites are typically in areas where other energy sources are limited and thus this technology could make a significant contribution. Demonstration projects would be needed to confirm the potential.

The Progress

Information on five projects was collected. The top two projects in this energy opportunity were awarded funding by the BC Innovative Clean Energy Fund. The highest rated project is a wave energy technology demonstration. This system adapts to ocean conditions for optimized power generation. The second highest rated project is a demonstration underwater submerged buoy technology which is less vulnerable to weather conditions. The other projects include a horizontal axis turbine pilot installation and development of experimental and numerical processes to collect wave statistics. The Ocean Renewable Energy Group supports the development of wave and tidal energy technologies.



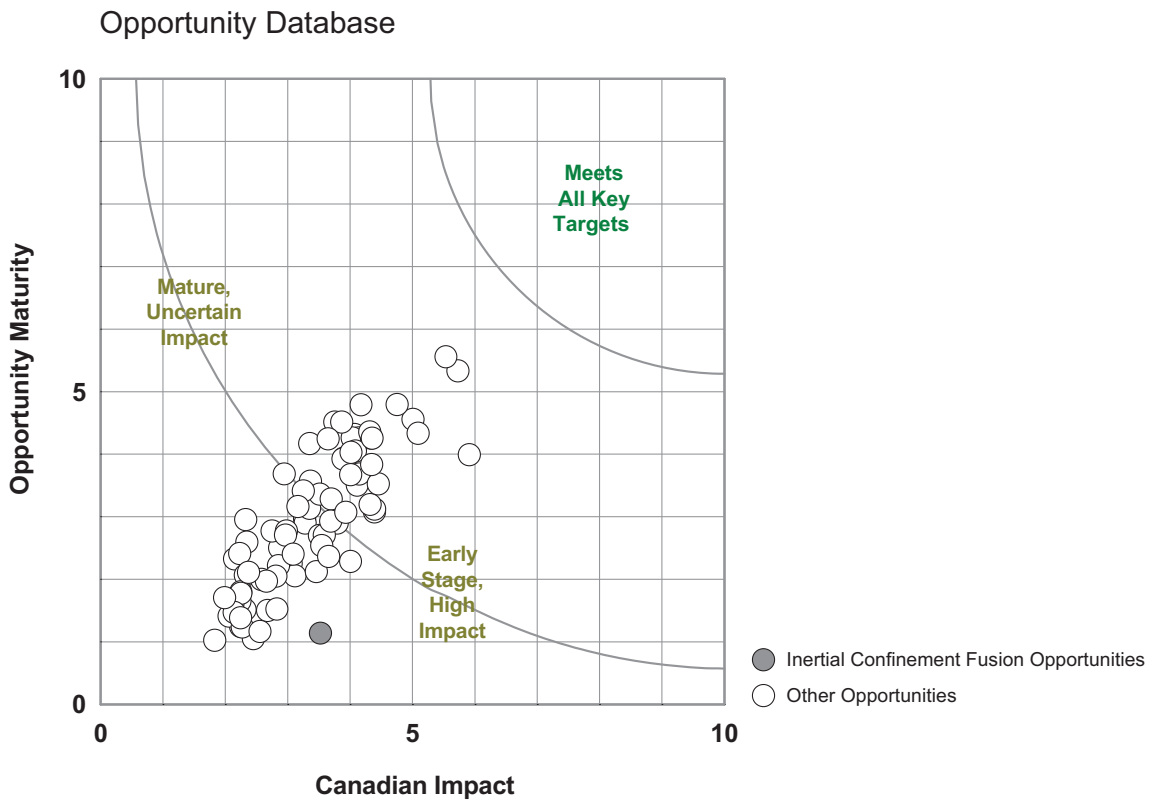
Inertial Confinement Fusion

The 2007 Message

Inertial confinement fusion, once considered to be decades away in application, has made recent advances and it is recommended that a university-based effort in Canada be defined and supported as a contribution to the international effort.

The Progress

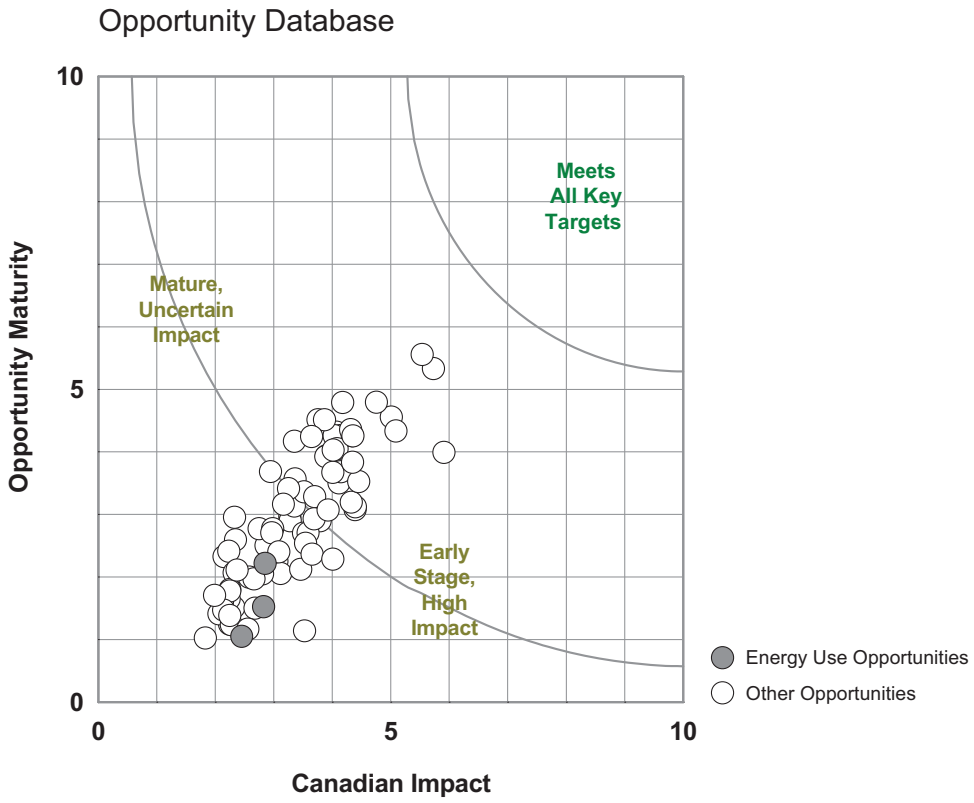
Information on one project was submitted. Canada is the only developed country not involved in an inertial confinement fusion program. In particular, the United States, France and Japan have experienced significant progress and rapid advancement of their technologies. International key players have assisted in the development of a 5-year plan that has identified opportunities for Canada to become involved in international programs and have provided training for Canadian researchers and technicians. Progress has been through the creation of reports recommending research and development programs, white papers, economic studies, presentations to stakeholders and the creation of a steering committee to develop initiatives for consideration by the Alberta government. This project is not yet funded.



Energy Use

The Progress

Information on three projects was submitted. The highest rated project is the development of a university-industry partnership program to conduct energy audits on industrial facilities. Recommendations are provided to the business for cost reductions through energy conscious infrastructure modifications. Development of a database will allow for pattern recognition of energy usage across various facilities and industries which will result in enhanced energy and process planning. The second project is the development of a university-based professional certificate in energy management which involves the study of energy theory, case studies and a practical in-field implementation project. The third project is energy consumption monitoring (components and overall) of a machine or process through time series signals which are decomposed to identify individual components and results in a reduced number of monitoring points.



5. Appendix A – Language Ladders

A1. Science

Description of the state of scientific advance.

A	The scientific principles of this specific application are not yet fully understood, or information is not adequate to make an evaluation.
B	The scientific principles of this specific application have been clarified through work completed to date.
C	The scientific principles of this specific application have been significantly expanded in new areas through work completed to date ...
D	... THAT will guide future work along unique new pathways.

A2. Technology

Description of the state of the technology advance.

A	Progress in the advancement of the technology has not proceeded beyond preliminary studies, or information is not adequate to make an evaluation.
B	Progress in the advancement of the technology has involved the undertaking of clearly defined projects.
C	Progress in the advancement of the technology has involved the launch of major programs which are meeting critical milestones.
D	Progress in the advancement of the technology has involved the completion of demonstration projects under commercially relevant conditions.

B1. Funding

Description of the state of the acquisition of funding.

A	Funding for this energy opportunity has been acquired from traditional discretionary funding sources.
B	Funding for this energy opportunity has been acquired for new initiatives from external funding sources which has expanded R&D capacity.
C	Funding for this energy opportunity has been acquired from industry or government programs that have enabled major increases in human resources and/or infrastructure for this opportunity.
D	Funding for this energy opportunity has been acquired from major new missions established to meet nationally endorsed energy goals with sustainable funding.

B2. Collaboration

Description of the degree of collaboration among R&D organizations in this Opportunity.

A	The R&D work is being performed primarily by the initiating organization.
B	The R&D work has included a number of organizations who have established agreed upon goals.
C	The R&D work is being carried out by a network of Canadian organizations who periodically meet to share progress on agreed upon goals ...
D	... AND the network is linked to similar international organizations with active ongoing collaboration.

C1. Economic

An outline of current expectations for the economic impact of this Opportunity.

A	Information of the impact on the Canadian economy is preliminary, or information is not adequate to make an evaluation.
B	Work completed on this opportunity has confirmed that the expected impact on the Canadian economy will be significant to at least one specific geographic region.
C	Work completed on this opportunity has provided validated quantitative information of a sustained economic impact across the Canadian economy ...
D	... THAT will be equivalent to that achieved by other major Canadian national energy undertakings such as the first trans-Canada pipeline.

C2. Environment

An outline of the current expectations of the environmental impact of this Opportunity.

A	Successful development of this opportunity will have possible adverse affects on the environment that would be of concern to well-informed citizens.
B	Successful development of this opportunity will have no adverse effect on the environment, or any possible affect could be readily addressed through appropriate practices.
C	Successful development of this opportunity will have a positive effect on the environment which would be accepted as a strong reason for actively pursuing this line of investigation.
D	Successful development of this opportunity would provide a unique approach for overcoming a dominant environmental concern facing Canada.

C3. Sustainability

An assessment of the robustness and sustainability of the Opportunity.

A	This opportunity when ready for development will have limited durability and/or geographical scope in Canada.
B	This opportunity when ready for development will have short to medium term application, and be significant in at least one major geographic region.
C	This opportunity when ready for development will have sustained and long term impact in Canada beyond the initial commercial applications ...
D	... AND will become embedded as a major and important feature of the Canadian energy economy.

6. Appendix B – R&D Project Submissions

The Canadian Academy of Engineering's Energy Task Force would like to thank the energy researchers and technology developers in Canada for their contributions to, and support of, this report.

Opportunity Area	Project Number	Project Title	Contributor
Gasification of Fossil Fuels and Biomass	1	Demonstration of Small Scale Biomass Gasification for Combined Heat and Power Production	Brent Lakeman Alberta Research Council
Gasification of Fossil Fuels and Biomass	2	Fluidized Bed Gasification Pilot Plant	Todd Pugsley University of Saskatchewan
Gasification of Fossil Fuels and Biomass	3	Gasification of Meat and Bone Meal	Todd Pugsley University of Saskatchewan
Gasification of Fossil Fuels and Biomass	4	Fluidized Bed Membrane Gasifier	Todd Pugsley University of Saskatchewan
Gasification of Fossil Fuels and Biomass	5	Co-Firing of Biomass, Peat and Coal for Power Generation	Charles Xu Lakehead University
Gasification of Fossil Fuels and Biomass	74	Thermal and Catalytic Gasification of Bio-Oil to Produce Syngas	Franco Berruti University of Western Ontario
Greenhouse Gas Emission Reduction	6	Carbon Dioxide Sequestration Based on Differential Solubility of Flue Gases	Maurice B. Dusseault University of Waterloo
Greenhouse Gas Emission Reduction	44	Heartland Area Redwater Project	Stefan Bachu Alberta Research Council
Greenhouse Gas Emission Reduction	63	Accelerating Carbon Capture and Storage Implementation in Alberta	Alberta Carbon Capture and Storage Development Council
Greenhouse Gas Emission Reduction	77	Alberta Carbon Trunk Line	Government of Alberta
Greenhouse Gas Emission Reduction	79	Swan Hills In-Situ Coal Gasification	Government of Alberta
Greenhouse Gas Emission Reduction	80	Quest Project	Government of Alberta
Greenhouse Gas Emission Reduction	81	Project Pioneer	Government of Alberta
Upgrades to Electrical Infrastructure	7	Electricity: Interconnecting Canada, A Strategic Advantage	The Canadian Academy of Engineering, Canada Power Grid Task Force
Upgrades to Electrical Infrastructure	49	Conawapa Generating Station	Robert Parsons Manitoba Energy, Science and Technology Energy Development Initiative
Upgrades to Electrical Infrastructure	56	Keeyask Generating Station	Robert Parsons Manitoba Energy, Science and Technology Energy Development Initiative
Upgrades to Electrical Infrastructure	57	Wuskwatim Generating Station	Robert Parsons Manitoba Energy, Science and Technology Energy Development Initiative
A Network for Bioconversion Demonstration Processes	8	Bioengineering for Third Generation Biofuels	David Levin University of Manitoba
A Network for Bioconversion Demonstration Processes	36	Project not identified at this time	
A Network for Bioconversion Demonstration Processes	37	Biomass and Bioenergy Research Group	Tony Bi University of British Columbia

Opportunity Area	Project Number	Project Title	Contributor
A Network for Bioconversion Demonstration Processes	50	The Clean Energy Research Centre	John Grace University of British Columbia
A Network for Bioconversion Demonstration Processes	51	Institute for Chemicals and Fuels from Alternative Resources	Franco Berruti University of Western Ontario
A Network for Bioconversion Demonstration Processes	52	Techniques for the Separation of Char and Sand in a Fluidized Bed	Franco Berruti University of Western Ontario
A Network for Bioconversion Demonstration Processes	53	Production and Separation of Valuable Chemicals from Pyrolysis Bio-Oils	Franco Berruti University of Western Ontario
A Network for Bioconversion Demonstration Processes	54	Intermittent Biomass Pulse Feeding System	Franco Berruti University of Western Ontario
A Network for Bioconversion Demonstration Processes	55	A Novel Gas-Solid Separator for Pyrolysis in Downer Reactors	Franco Berruti University of Western Ontario
A Network for Bioconversion Demonstration Processes	69	Chemical Analysis of Pyrolysis Bio-Oils for Pesticide Activity	Franco Berruti University of Western Ontario
A Network for Bioconversion Demonstration Processes	70	Mobile Pyrolysis Technology for the Conversion of Biomass into Bio-Oil and Bio-Char	Franco Berruti University of Western Ontario
A Network for Bioconversion Demonstration Processes	71	Pyrolysis of Agricultural and Forestry Residues	Franco Berruti University of Western Ontario
A Network for Bioconversion Demonstration Processes	72	Pyrolysis of Biomass	Franco Berruti University of Western Ontario
A Network for Bioconversion Demonstration Processes	73	Biomass Pyrolysis: Experimental and Modelling Studies	Franco Berruti University of Western Ontario
A Network for Bioconversion Demonstration Processes	78	Hydrothermal Conversion of Wet Biomass in Biofuel	Zhongchao Tan University of Calgary
Wind	9	Vertical Axis Wind Turbine	David S-K Ting University of Windsor
Wind	10	Federal and Provincial Wind Initiatives	Canadian Wind Energy Association
Wind	11	Installed Wind Farms in 2008-2009	Canadian Wind Energy Association
Wind	12	Ontario Becomes Wind Power Leader in Canada	Ontario Ministry of Energy and Infrastructure
Wind	13	Acciona to Construct 64.5 MW Wind Farm in Aulac	New Brunswick Department of Energy
Wind	14	New 49.5 MW Wind Farm to be Constructed in Lameque	New Brunswick Department of Energy
Wind	15	Second Wind Contract Announced for Northern New Brunswick	New Brunswick Department of Energy
Wind	16	Huron Wind Churns Out Strong Performance in 2008	Bruce Power
Wind	17	Canada's Largest Wind Farm Slated for Development in Southern Manitoba	Robert Parsons Manitoba Energy, Science and Technology Energy Development Initiative

Opportunity Area	Project Number	Project Title	Contributor
Wind	18	NSP Reaches Goal with Independent Wind Producers	Nova Scotia Power
Wind	19	Expanding Our Use of Renewable Energy	Nova Scotia Power
Wind	40	Structural Health Monitoring and Life Extension Control of an Ontario Wind Farm	Rupp Carriveau University of Windsor
Wind	41	A Study of the Feasibility of Compressed Air Energy Storage for Ontario	Rupp Carriveau University of Windsor
Solar	21	Nanocrystalline Titania Based Dye-Sensitized Solar Cells	George Demopoulos McGill University
Solar	22	NSERC Solar Buildings Research Network	Andreas Athienitis Concordia University
Solar	23	Flexible Organic Photovoltaic Solar Cells	Paul Charpentier University of Western Ontario
Solar	24	Using Nanotechnology for Heat and Light Selective Plastics for Solar Thermal and Greenhouses	Paul Charpentier University of Western Ontario
Natural Gas Hydrates	43	The Natural Gas Hydrate Program	Cathryn Bjerkelund Natural Resources Canada
Mineable Oil Sands	25	The Centre for Oil Sands Innovation	Murray Gray University of Alberta
Mineable Oil Sands	45	Microbially Enhanced Oil Production and Recovery	Gerrit Voordouw University of Calgary
Mineable Oil Sands	64	Growth in the Canadian Oil Sands: Finding the New Balance, IHS CERA Special Report	Ed Borst Shell Canada Limited
Mineable Oil Sands	65	Water Capping of Fine Tails	Syncrude Canada Ltd.
Mineable Oil Sands	66	Oil Sands Fen Reclamation Research	Syncrude Canada Ltd.
Mineable Oil Sands	67	Tailings Management and Reclamation	Syncrude Canada Ltd.
Bitumen Upgrading	68	Studies of the Injection of Heavy-Oil into Fluid Cokers: Process Improvements	Franco Berruti University of Western Ontario
Bitumen Upgrading	76	Development of Attrition Technologies for Particle Size Reduction in Fluid Bed Coker Reactors	Franco Berruti University of Western Ontario
Bitumen Upgrading	82	Alberta/AERI's Upgrading Program	Duke du Plessis Alberta Energy Research Institute
Hydrogen Production	20	Thermo-Mechanical Design of Nuclear Based Hydrogen Production	Greg Naterer University of Ontario Institute of Technology
Hydrogen Production	26	Canadian Hydrogen Airports	Pierre Gauthier Air Liquide Canada Inc.
Hydrogen Production	27	Converting Low Value Biomass to Hydrogen	Jerald Lalman University of Windsor

Opportunity Area	Project Number	Project Title	Contributor
Hydrogen Production	28	Hydrogen from High Organic Waste Streams Utilizing Supercritical Water Gasification	Paul Charpentier University of Western Ontario
Hydrogen Production	58	NSERC Solid Oxide Fuel Cell Canada Strategic Research Network	Sharon Thomas University of Calgary
Hydrogen Production	59	Hydrogen Fuel Cell Buses	Stephen Brydon BC Transit
Hydrogen Production	60	Vancouver Fuel Cell Vehicle Program	Canadian Hydrogen and Fuel Cell Association
Hydrogen Production	61	BC Hydrogen Highway	Canadian Hydrogen and Fuel Cell Association
Hydrogen Production	62	Ontario's Hydrogen Village	Canadian Hydrogen and Fuel Cell Association
Nuclear Power for Alberta	29	Nuclear Consultation Begins in Alberta	Government of Alberta
Nuclear Power for Alberta	30	Nuclear Power for Alberta	Bruce Power Alberta
Bituminous Carbonates	35	Heavy Oil Production Technologies for Fractured Carbonates	Maurice Dusseault University of Waterloo
Geothermal	48	Manitoba Hydro Head Office	Robert Parsons Manitoba Energy, Science and Technology Energy Development Initiative
Tidal	31	Canoe Pass Tidal Energy Commercialization Project	Ocean Renewable Energy Group
Tidal	32	Fundy Ocean Research Centre for Energy	Ocean Renewable Energy Group
Wave	33	Ocean Renewable Energy Group	Ocean Renewable Energy Group
Wave	34	West Coast Wave Collaboration Project	Ocean Renewable Energy Group
Wave	46	Cornwall Ontario River Energy Project	Ocean Renewable Energy Group
Wave	47	SyncWave Demonstration	Ocean Renewable Energy Group
Wave	75	Pacific Coastal Wave Energy Demonstration Project	Ocean Renewable Energy Group
Inertial Confinement Fusion	83	Alberta/Canada Fusion Energy Initiative	Allan Offenberger University of Alberta
Energy Use	38	The Union Gas – University of Windsor EnerSmart Research Partnership	Rupp Carriveau University of Windsor
Energy Use	39	The University of Windsor Advanced Professional Certificate in Energy Management	Rupp Carriveau University of Windsor
Energy Use	42	Energy Profiling Through Time Series Signal Analysis	Rupp Carriveau University of Windsor

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