CANADIAN ACADEMY OF ENGINEERING

ENERGY PATHWAYS TASK FORCE

PHASE 1 – FINAL REPORT

Acknowledgements

Canadian Academy of Engineering

Energy Pathways Task Force
Phase 1 – Final Report

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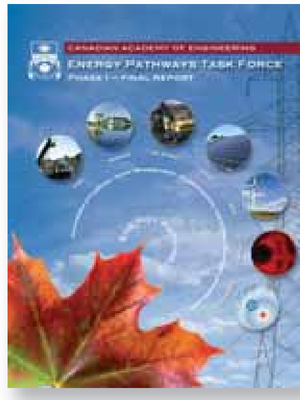
The eight sponsors of this initiative provided significant financial and in-kind support without which this project would never have been attempted. This report, however, does not represent the views of organizations, rather it reflects the opinions of knowledgeable individuals in both the public and private sector concerning the enormous energy opportunities available to Canada.

There were more than a hundred people involved in the project, including members of the Academy Task Force



who led the activity, the Proponents of 27 energy pathways, and the Evaluators who matched their judgements against those of the Proponents. The Proponents deserve an extra measure of praise; they agreed at the request of the Academy to prepare pathway descriptions and to carry out their own assessment, an act of some courage.

The authors of this report thank all those involved in the project, with special mention to:

- **Philip Cockshutt,** Past Executive Director of CAE who provided support at every stage
- **Fraser Barnes** of ProGrid Solutions who provided the software for the analysis and personally managed the complex set of file uploads and downloads.

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Preface

The Canadian Academy of Engineering (CAE) comprises many of the country's most accomplished engineers, who have expressed their dedication to the application of science and engineering principles in the interests of the country and its enterprises. The Academy is an independent, self-governing and non-profit organization established in 1987 to serve the nation in matters of engineering concern.

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It is an active member of the *International Council of Academies of Engineering and Technological Sciences (CAETS),* which involves 24 other leading countries.

Members of the Academy are nominated and elected by their peers to honorary Fellowships in recognition of their outstanding contributions, their distinguished achievements and leadership in the Profession of Engineering in Canada and in the wider community of the country. There are at present some 300 active members, plus 90 emeritus members. Members work closely with the other national engineering associations in Canada, and with the other Canadian academies that comprise the *Council of Canadian Academies* (CCA). Fellows of the Academy are committed to ensuring that Canada's engineering expertise is applied to the benefit of all Canadians.

So what led the Academy to undertake an examination of the various pathways connecting energy sources to final end users? Put simply, it has risen out of a growing concern related to the collision between energy and the environment, the intersection of which represents the dominant issue facing the planet over the present century.

Where is Canada positioned with respect to this issue? Here is our assessment:

1. Canada does not have a "national narrative" that describes a common vision for the country in which all regions participate. Where are the successors to the visionary leaders who built the national railways, the St Lawrence Seaway, energy pipelines and our universal health care system?
2. Several of our major, long-standing sectors, such as the automotive and forestry industries, face serious challenges, in spite of intensive efforts to resolve the problems.
3. Energy is one of the cornerstones of civilization and is central to Canada's economic and social well-being, but we lack a compelling national energy vision. With huge unequaled energy resources, will Canada be able to produce upgraded energy products at reasonable prices with acceptable environmental impacts? New technology will be

needed, but success will also require effective public policy and new concepts of risk sharing. Transformational changes will not be made through the efforts of individual companies, nor governments acting alone.

If we are able to bring about such transformational changes, it has been suggested that Canada would become a "sustainable energy superpower". The Canadian Academy of Engineering represents engineers who build things. Engineers build to a design specification, for the benefit of all Canadians. What are the design specifications for a Canada that is a "sustainable energy superpower"? Energy experts, politicians and citizens will have varying views on an appropriate definition.

Regardless of the precise definition, as engineers, it is our role to ensure that we have the technological capacity to make the following contributions to a new and expanded domestic and international energy role for Canada:

- To enable a planned and consistent shift to economic renewable energy resources.
- To make significant reductions in the environmental impacts from energy recovery, processing and use.
- To meet the current and future energy demands of all Canadians on a sustainable basis.
- To export valued-added energy products and thus be able to maintain balanced trade relations with our major trading partners.

It should be stressed that this report is not a "policy document" but rather an examination of some 27 energy pathways tracing the principal routes from our rich endowment of energy sources to their ultimate end use.

It is particularly important to note here that the energy pathways assessed are by no means a complete listing of all potential pathways. Rather, each pathway studied was selected by an individual experienced and knowledgeable engineer who considered it sufficiently important to make the effort to act as a proponent and prepare a submission. While perhaps not as exhaustive in scope as a commissioned study might have been, the collection of resulting assessments is an important achievement of Canadian engineering in identifying what needs to be done to move towards a desirable future.

This Energy Pathways Report should be positioned with two other related studies: the CCA study on *The State of Science & Technology in Canada* and the Report of the National Advisory Panel on Sustainable Energy Science and Technology, *Powerful Connections: Priorities and Directions in Energy Science and Technology in Canada*. All three reports are in large measure complementary. The CCA study identifies Canadian scientific strength in certain areas, e.g. oil sands, but then shows the perceived shortcomings in the capacity to build sustainable dominance in the area. The 'pathways' are quite specific about what needs to be done to get there. The National Advisory Panel stresses the need for a systems approach to dealing with the energy issues they identify, and the 'pathways' clearly call for a systems approach in the challenges they identify. This is a most fortunate conjunction of circumstances, as the three reports taken together constitute a much stronger statement about what needs to be done than any one of them taken alone.

On behalf of the Canadian Academy of Engineering I am confident that this report will make a meaningful contribution to the continuing dialogue on the directions needed if Canada is to become a sustainable and environmentally sound energy superpower.

Sincerely,

Dr. John D. McLaughlin, FCAE
President, Canadian Academy of Engineering
May 2007

1. Executive Summary

Can Canada become a Sustainable Energy Superpower? The answer to this question may come from the Canadian Academy of Engineering's examination of 27 energy pathways, tracing the principal routes from our rich endowment of energy sources to their ultimate end use. Using an objective, disciplined evaluation methodology over 100 energy experts were engaged to evaluate the potential of new and advanced technologies to achieve economic, environmental, efficiency and value-added targets. The resulting evaluations lead to the following recommendations:

RECOMMENDATION 1

National Technology Projects

Canada should undertake the following 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)

A National Technology Project is considered to be a commitment by Canada to plan and implement major energy programs which have both economic and environmental benefits, involving significant public/private sector participation, at federal, provincial and regional levels. These three projects will provide an integrated approach to provide higher valued energy products, reduce carbon dioxide emissions and facilitate the entry of additional renewable energy sources into the Canadian electrical grid.

Gasification involves the reactions of carbon-based fuels with steam and oxygen to produce electricity, hydrogen and other value-added products. Although commercial in other countries, it has not been demonstrated for Canadian low rank coals and biomass, and has not been integrated with carbon dioxide capture, transportation, use and storage technologies. The latter is the second of the three National Technology Projects. Hydrogen is needed now for upgrading hydrogen-deficient fossil fuels and as a potential future transportation fuel. It is also one of the options for storing the electrical energy from intermittent renewable energy sources such as solar and wind, whose capacity to feed into the electrical grid is restricted, as well as from baseload nuclear sources during off peak hours. These and other limitations of the national energy grid are the subject of the third National Technology Project.

It is recommended that these projects be each funded for a ten year period, and be managed by a national cross-sectoral board. This board should set objectives, allocate resources, and track performance against the objectives. The mandate of the Board should also include Life Cycle Assessments to assess both the net energy gain and the net environmental impacts for each energy initiative. It is worth noting the success that the Alberta Government had, commencing in 1975, in the establishment of the Alberta Oil Sands Technology and Research Authority (AOSTRA). This body carried out major innovative programs over fifteen years with combined private/public sector funding in the order of one billion dollars. A similar commitment in each of the above three national projects would put Canada on the path to a sustainable energy superpower and would attract the skilled people needed to achieve this vision.

The Canadian Academy of Engineering would be pleased to cooperate with other stakeholders to help define the scope of these National Technology Projects as Phase 2 of this energy pathways project. With recognition that future phases will be much more demanding, both in terms of cost and management – at least an order of magnitude larger.

RECOMMENDATION 2

Network for Bioconversion Demonstration Processes

There are many opportunities across Canada for distributed and environmentally friendly processes for generating energy products from agricultural, forestry, meat and fish waste processing and municipal solid waste feedstocks, which in total would make a significant contribution to Canada's energy requirements. Existing organizations such as BIOCAP Canada and CBIN (Canadian Biomass Innovation Network R&D Program) will be able to assist in the identification of priority feedstocks and processes. A national network to conduct regional demonstration projects should be formed and funded.

RECOMMENDATION 3

Pursuing Energy Opportunities and Challenges

There are challenges in the Canadian energy sector which need new or advanced technology. In some areas, Canada has significant opportunities related to unique energy resources and should lead in carrying out basic and applied research leading to future commercial applications and technology export opportunities. In other areas, there will be opportunities to adapt technologies developed elsewhere for application in Canada. Organizations active in these areas should prioritize and coordinate their activities with the objective of significantly accelerating the pace of progress.

Examples of these challenges are:

- Water supply, treatment and management
- Wind and solar
- Natural gas hydrates
- Lower impact surface mineable oil sands
- Higher valued products from heavy oil and bitumen
- Alternative hydrogen supplies
- Potential for nuclear power for insitu oil sand production
- Advanced nuclear fission reactors, including nuclear waste management
- Bituminous carbonates
- Geothermal
- Tidal and wave

RECOMMENDATION 4

Fusion Energy

Canada should maintain sufficient expertise in fusion research to monitor and periodically assess the progress made by the international community.

- The international effort in magnetic confinement fusion is very large and commercialization is many decades in the future. Canada should maintain a watching brief on ongoing international efforts and contribute in areas where we have appropriate expertise, such as in the production and handling of tritium.
- Inertial confinement fusion, once considered to be even further 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.

2. Introduction

The Canadian Academy of Engineering (CAE) 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. This mission is fulfilled by:

- promoting increased awareness of the role of engineering in society
- speaking out with an independent voice on issues relevant to engineering in Canada and abroad
- promoting industrial competitiveness while preserving the environment, in Canada and abroad
- recognizing and celebrating excellence in engineering contributions to the Canadian economy
- advising on engineering education, research, development and innovation
- developing and maintaining effective relations with other professional engineering organizations, academies and learned societies, in Canada and abroad.

Clean Energy Innovation is an issue that is of critical importance for the future well-being and prosperity of Canadians. In March 2002, responding to the challenges being faced by the global energy industry, including regional instability, depleting conventional resources, climate change and price volatility, the CAE released a study titled, *Energy and Climate Change*. It concluded that, "A long-term, sustainable energy strategy needs to be developed, which will necessarily require a larger choice of energy sources and technologies than [are] presently available". The Report noted that the CAE could play an important role in the assessment of technologies that are already available or entirely new energy technologies.

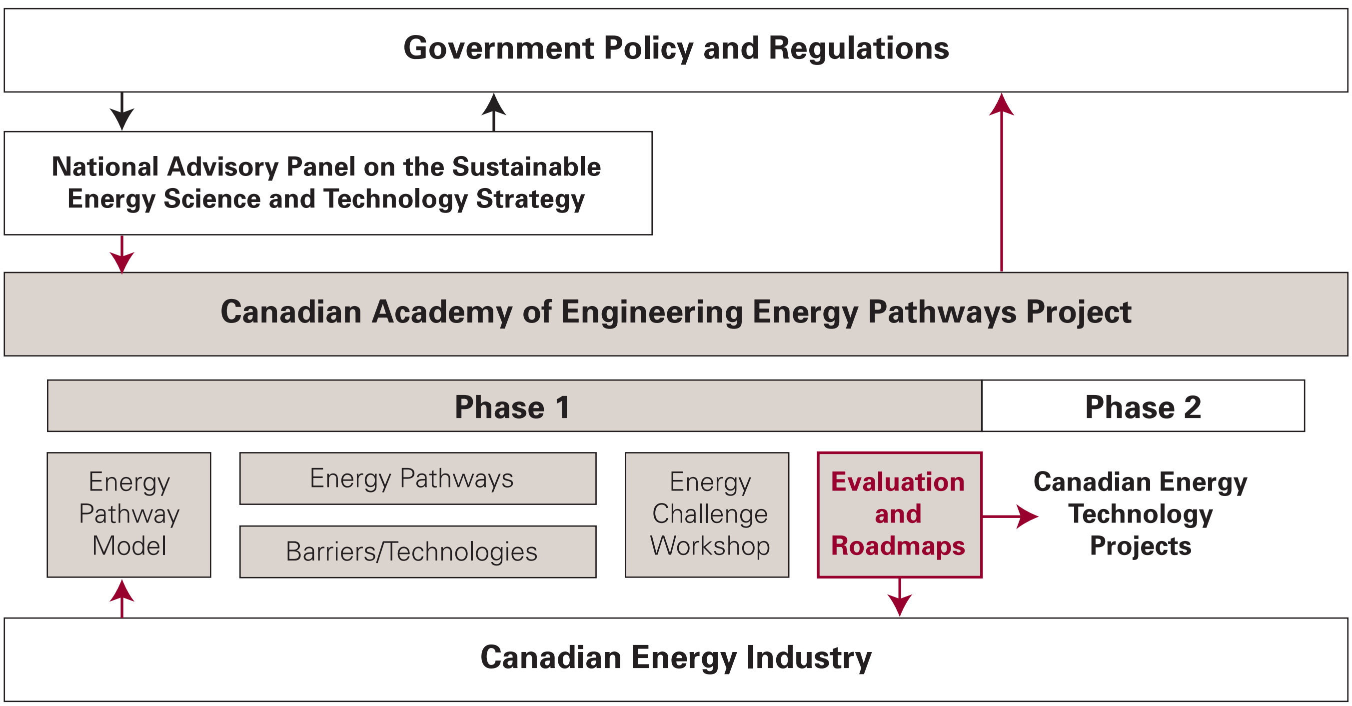
With support from a group of Sponsors (Appendix 1) a Task Force was formed (Appendix 2) to continue the work of the Academy on this subject, with the specific goal to define the barriers that are preventing the development of economic and environmentally acceptable energy sources and carriers in Canada and to identify the technologies that can overcome these barriers. The focus of this project has been on technology options that would permit Canada to achieve its greenhouse gas (GHG) emission targets, while continuing to provide an adequate supply of energy, at competitive rates, to meet the growing demand for energy.

Chart 1 illustrates how the Academy has positioned itself between the government and the energy industry. The foci of the Academy's efforts are to assist governments in laying out their policies and strategies and to provide options for industry to achieve production targets while meeting future environmental regulations. The process began with the development of an Energy Pathways Model, an examination of prospective pathways against that model, a workshop with key stakeholders to obtain additional input, leading to the evaluation effort described in this report. The goal is to define major Canadian Energy Technology Projects that have the potential to achieve the vision previously described.

While this project was in its final stage of data gathering, *Powerful Connections: Priorities and Directions in Energy Science and Technology in Canada* was issued by the National Advisory Panel on Sustainable Energy Science and Technology. The Panel report recommends an integrated systems approach to the development of our many energy sources, and calls for a dedicated commitment by all stakeholders to provide the financial and innovative resources to put Canada in a world leadership position in sustainable energy development. The energy pathways evaluated in our CAE Project will be examined against the excellent recommendations in the Panel report. It is considered appropriate and desirable that the energy pathways also be treated as a system so that the appropriate level of funding might be made available at the appropriate time, without the need to interrupt the flow of work to search for possible funding sources for the next stage.

CHART 1

Energy Pathways Project Process Model



3. Energy Pathways

The building blocks for Phase 1 of the project are the energy pathways available to Canada, as shown in Chart 2. They can be divided into three groups, Fossil Fuels, Renewables and Nuclear. Our concept was not just to focus on energy sources, but rather to emphasize the entire pathway from the energy source, through a conversion process, then a carrier to the final end use. But some pathways depend upon other pathways and these linkages have to be identified and understood. It was also recognized that some pathways in themselves are links embedded in other pathways.

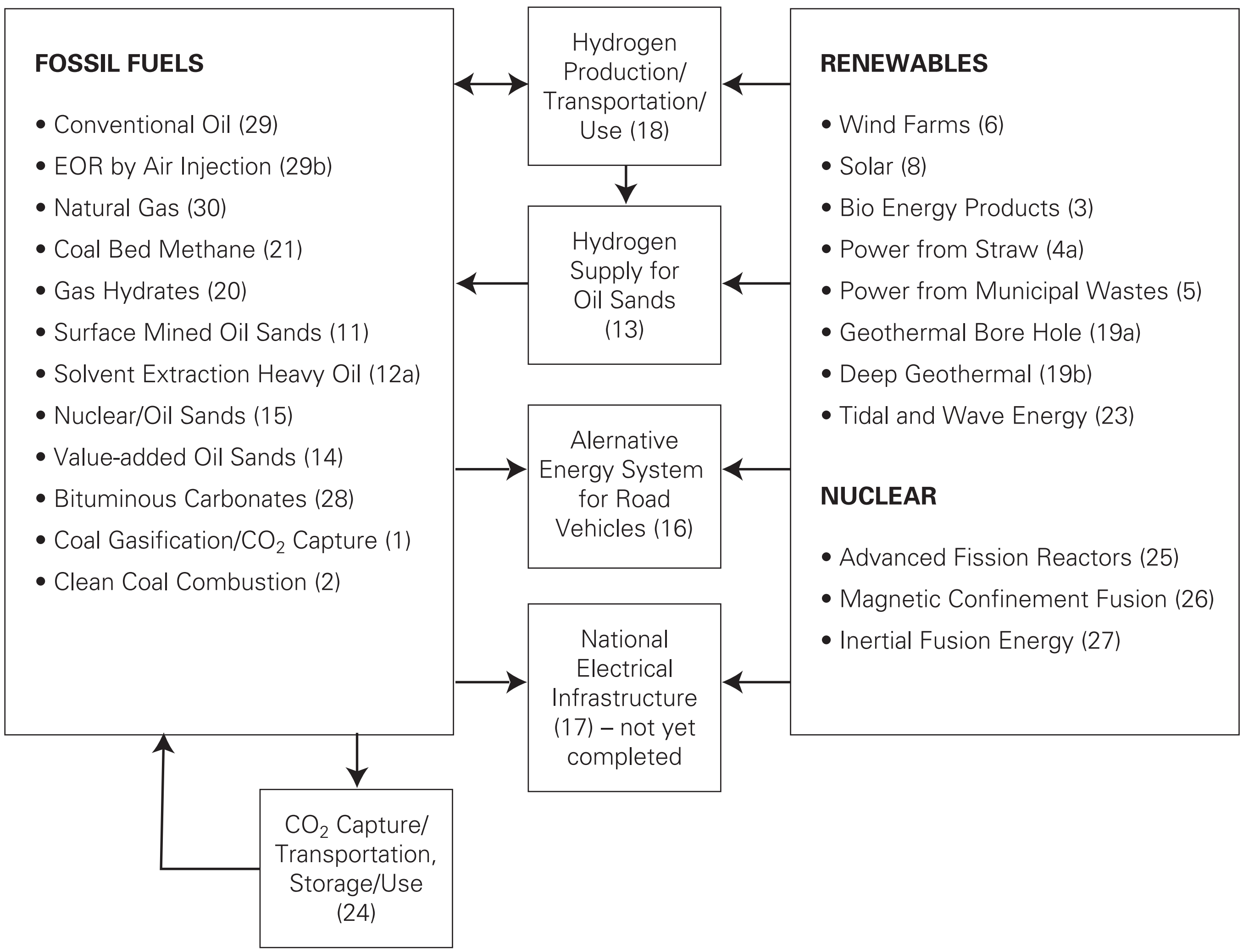
There are two important materials, hydrogen and carbon dioxide, that interact with both fossil fuels and renewable energy sources. The vast resources of oil sands require hydrogen to produce a usable product. Canada has world leading technology for producing hydrogen from natural gas and is competitive in producing hydrogen by the electrolysis of water. Carbon dioxide is a by-product of many energy conversion processes, and is a major contributor to greenhouse gases in the atmosphere. Technologies are needed to capture, store and use this gas without release to the atmosphere.

Clearly, there are major challenges in understanding Canada's energy options as an integrated system. The decision on which pathways to include in the project was made by the members of the Task Force. At the request of the Task Force, a description of the pathways was provided by knowledgeable individuals (called 'Proponents') identified in Appendix 3. The evaluation of the pathways against a set of criteria determined by the Task Force was undertaken by individuals (called 'Evaluators') identified in Appendix 4. Although the project had eight sponsors, these organizations did not participate formally in the selection of pathways, the selection of proponents, or the selection of evaluators. The evaluators were self-selected, responding individually to an invitation to participate on the public web site of the Canadian Academy of Engineering.

We had hoped to include a pathway on the National Electrical Infrastructure, but were unsuccessful in finding a Proponent to tackle the topic. However, the issue arose in several other pathways and is addressed in our suggestion for a National Technology Project in this area.

CHART 2

Energy Pathways



The contribution of these energy sources to Canada's current energy consumption is summarized in Chart 3, with some possible future targets. The pace of a shift from fossil fuels to renewable or nuclear energy sources will depend on our ability to capture and store carbon dioxide, and our ability to generate hydrogen economically from sources other than natural gas.

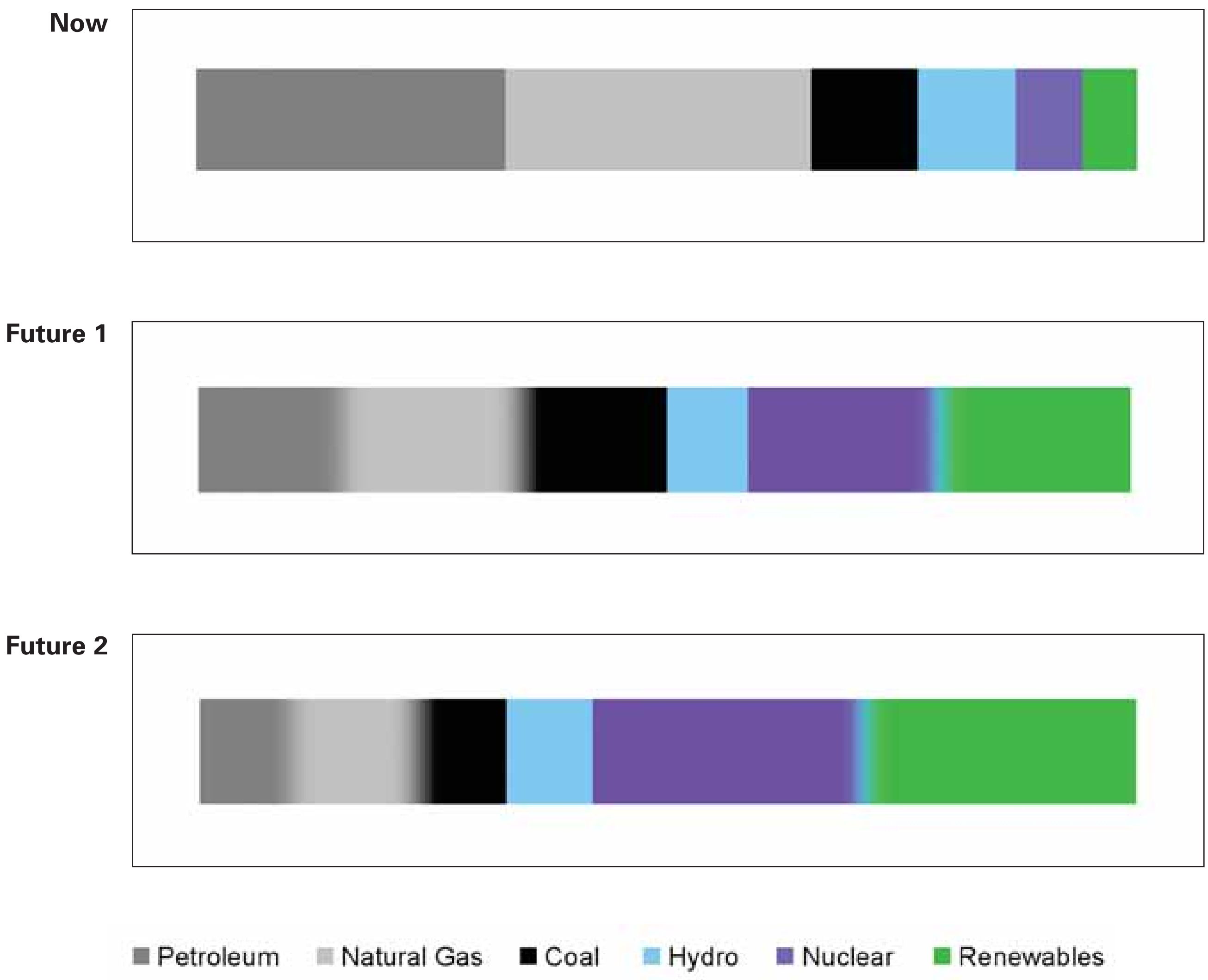
CHART 3

Energy Demand inside Canada[1]

The energy demand inside Canada, excluding exports, is about 75% derived from fossil fuels. This is lower than many industrialized countries, due to major contributions from hydro and nuclear.

There is clearly a global desire to shift away from fossil fuels. For Canada, technology is being developed that could reduce the dependence on fossil fuels, as illustrated in Future 1 below. If Canada can develop and apply the technology to recover and sequester the carbon dioxide produced from fossil fuels, the pressure and timing to replace fossil fuels may diminish and lengthen.

What might be a reasonable long term target? Fossil fuels will be source of aircraft fuel and for many chemical products for the foreseeable future. It is only conjecture at this time but 33% from fossil fuels might be a reasonable long term steady state contribution as illustrated in Future 2.



[1] Based on Canada's Energy Flows, 2002, Natural Resources Canada

4. Setting the Stage

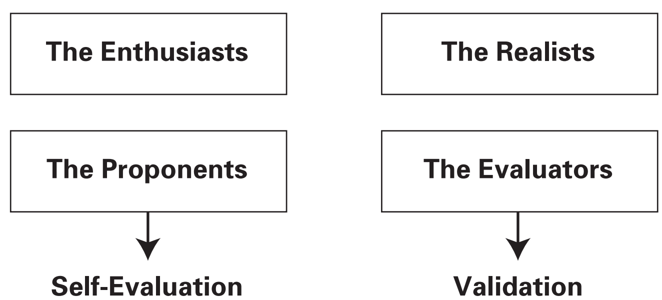
Previous roadmap studies have identified a large number of barriers that are restricting the development of energy sources. Some of these barriers are economic but increasingly they are related to adverse environmental impacts.

The innovative talent of many researchers has led to a plethora of new and improved technologies that have the potential to overcome these barriers. The researchers demonstrate a high level of enthusiasm for their advances and are active in soliciting support for further development and commercialization. Industry by its nature prefers to rely on proven technology and is reluctant to take the risks needed to incorporate new ideas and approaches. This leads to a dynamic tension between "Enthusiasts" and "Realists", terms we use for convenience without wishing to cast any negative connotation to either. It is the Realists that keep our economy humming with minimum disruption. Without the Enthusiasts, however, we would forever be 'hewers of wood and drawers of water'.

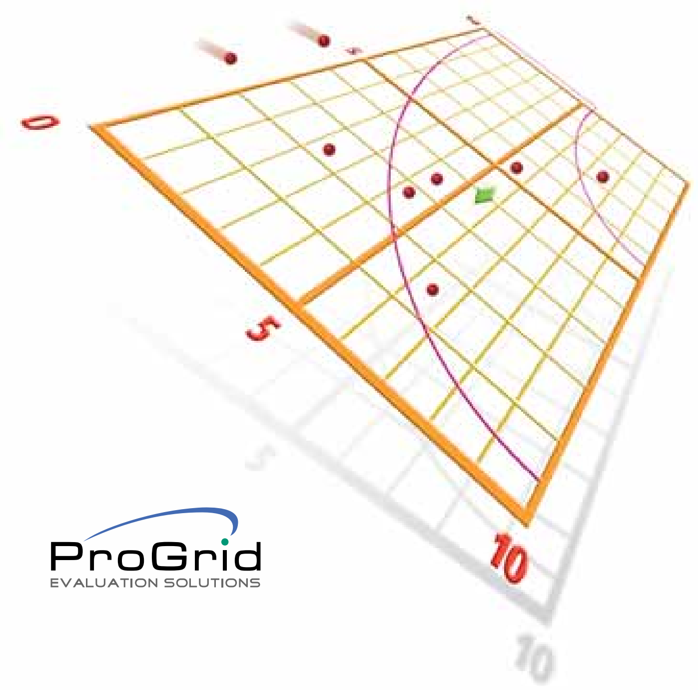
A process is needed to enable each group to deploy its talents for the benefit of the country. For this purpose the Academy employed ProGrid methodology which is used extensively by Canadian research organizations in evaluating proposals. The Enthusiasts become the Proponents for a particular energy pathway and present the merits of their pathway and undertake a self-evaluation against an established set of criteria. Other knowledgeable people play the role of the Realists by undertaking evaluations against the same criteria. This is illustrated in Chart 4.

CHART 4

The Dynamic and Constructive Tension



5. The Evaluation Matrix



The first key step in the evaluation is to establish the criteria for the evaluation through an Evaluation Matrix as shown in Chart 5. There is a flow in this matrix from Inputs in Column A (Pathway Assets) to Outputs in Column C (Expected Impact), connected by Enablers in Column B (Canadian Capacity).

This matrix was established to include all of the key factors that would be critical in deciding on the importance of the pathways in the near term, the medium term and the long term.

For our particular purpose, the Inputs are considered to be the cumulative assets of a pathway. These include the scientific, technical and commercial readiness, societal acceptability and the fit as a Canadian national initiative. The Outputs are the desired economic and environmental impacts and the contribution to efficiency and value-added products (upgrading). The Enablers are the factors needed to convert assets into desired impacts.

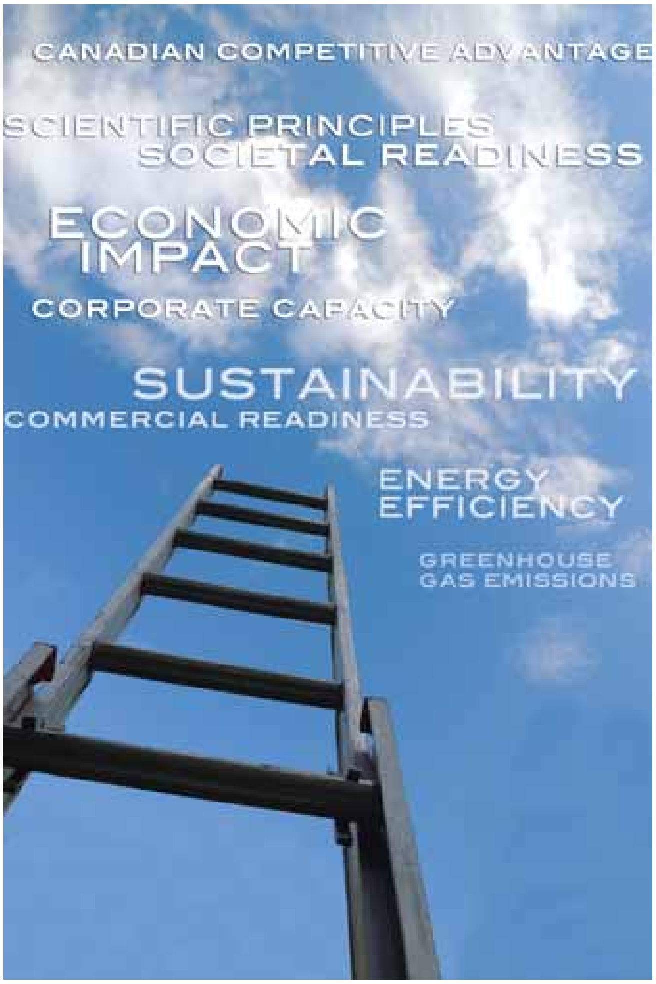
Pathways would not be expected to rank highly in all criteria in this matrix. Some pathways may excel in some criteria to an extent that would offset a weak, or non-relevant, position in other criteria. In fact, a medium ranking in all criteria has been found to represent the least desirable set of ratings in previous uses of the methodology employed in this project (leading to a term called 'stalled technologies', well known by those involved in the venture capital field).

CHART 5

Energy Pathway Evaluation Matrix

A. INPUTS **Pathway Assets**	**B. ENABLERS** **Canadian Capacity**	**C. OUTPUTS** **Expected Impact**
Scientific Principles	Corporate Capacity	Economic
Technology Validation	Canadian Competitive Advantage	Environmental (ex GHG)
Commercial Readiness	Sustainability	GHG Emissions
Societal Acceptability	Enabler for Another Pathway	Energy Efficiency
Fit to Canadian National Initiative	Delivery/Infrastructure Issues	Value-Added

6. Language Ladders



A key component of the evaluation methodology is the development of a communication language between the Proponents and the Evaluators. This need led to the preparation of a Language Ladder, as illustrated in Chart 6 for the first cell in the matrix, Scientific Principles. It may look deceptively simple. The establishment of a credible set of Language Ladders is a very difficult task, but once done, is very rewarding.

The full set of Language Ladders used in the project is provided in Appendix 5.

Experience has shown that a Language Ladder with an even number of "rungs" is preferable to one with an odd number, to avoid evaluators seeking the 'safe' middle rung. It has also been found that four is an optimum number of rungs, balancing the need for ease of use and comprehensiveness.

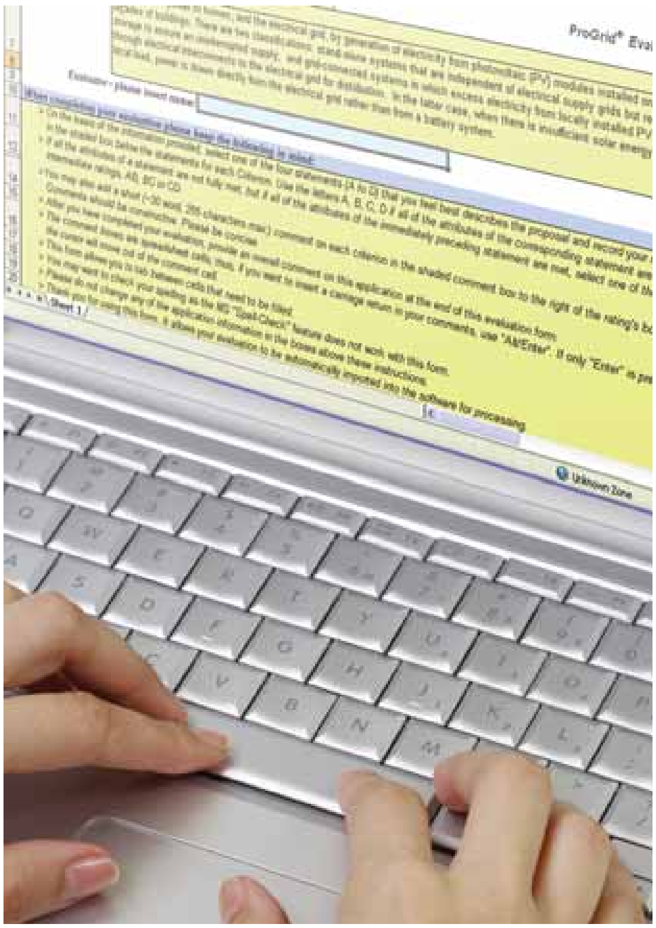
CHART 6

Language Ladder for Scientific Principles

A	The scientific principles involved in the pathway are not yet fully understood.
B	The scientific principles involved in the major steps in the pathway are well understood and all relevant information has been disseminated to the scientific community.
C	The scientific principles involved in all steps in the pathway are well understood and have been validated by independent research teams …
D	… AND no significant scientific questions remain to be answered in this pathway.

7. Proponent Documents & Self-Assessments

The 12-page Proponent Pathway documents were accessed from the CAE Web site (http://www.acad-eng-gen.ca/). As part of this document, each Proponent prepared a 100 word summary of the pathway, in addition to a more detailed description of the barriers and technology solutions. These summaries are shown in Appendix 6. A companion Evaluation Form was also provided on this web site.



The following procedure was provided to Evaluators to assist in completing their evaluations.

1. Select the Pathway that you wish to evaluate and download the 'Proposal', a Word file, as well as the corresponding Evaluation Form, an MS Excel file. Remember where you saved these forms on your computer.

2. Print the Proposal or read it on screen. Note the 15 evaluation criteria and read the description of the Pathway on the next 2 or 3 pages.

3. On the page titled 'Language Ladder Evaluation', review the rating and justification provided by the Proponent for 'A1 Scientific Principles'. Make a mental decision on whether you agree with the rating provided by the Proponent, based on the justification provided AND your own knowledge of the field.

4. Open the Excel Evaluation Form and read the instructions provided for completing the Evaluation form. Record your name in the box provided. Insert your own rating (A, AB, B, BC, C, CD, D) and a short comment in the boxes provided. You can select a rating the same as the Proponent, a lower rating or a higher rating. If you have selected a rating significantly different from the rating of the Proponent, a brief explanation in the comment box will be very helpful.

5. Return to the Proposal form and review the rating and justification provided by the Proponent for 'A2 Technical Validation'. Once you have decided on your own rating, return to the Excel form to insert your rating and comments. Continue until you have rated all 15 criteria. Add concluding comments on the Pathway Assets and Expected Impacts in the two boxes at the bottom of the Evaluation Form.

6. Send your completed Evaluation Form to cae-project@progrid.info, indicating in your e-mail message if you do not want your name to appear in the reports on this initiative.

8. Explanation of the Output Reports

The standard ProGrid mathematics were used in generating the Output Reports shown in Appendix 6, namely:

- The fifteen criteria in the Evaluation Matrix were rated equally.
- The Language Ladder steps (A, B, C, D) were expressed as a linear scale
- Ratings for the criteria in column A of the Evaluation Matrix were allocated to the Y axis of the grid chart, for column C to the X axis and for Column B equally to both axes.
- R-value, a percentage representing the progress in achieving maximum ratings on the X and Y axes.

One-page reports were generated for each Pathway, based on the information provided by the Proponents and the Evaluators. These include the following information:

1. The Pathway Summary provided by the Proponent (called Opportunity Summary in the reports).
2. The Opportunity Grid comparing the opinion of the Proponent with the opinions of each Evaluator, with the Pathway Assets and Expected Impact as the axes.
3. An R-value, as described above.
4. An Opportunity Profile comparing the Proponent rating with the average rating of the Evaluators for the 15 criteria in the Evaluation Matrix.

The Opportunity Grid has two curves concentric to the position 10, 10. The upper curve has an R-value of 66.7%, which on the diagonal of the grid would occur when all criteria were rated as C. The lower curve has an R-value of 33.3%. Points above the upper curve meet most of the requirements of the variables in the Evaluation Matrix, related to Pathway Assets and to Expected Impact. In some cases, this might mean that the Pathway is sufficiently well developed that further development will occur as a result of market forces.

Pathways which are now below the upper curve may have the potential for substantial benefits to the country, either by overcoming current weaknesses in the near term or by laying the foundations for advances in the longer term. The Opportunity Grid can only be interpreted in conjunction with the Opportunity Profile, which identifies the strengths and weaknesses.

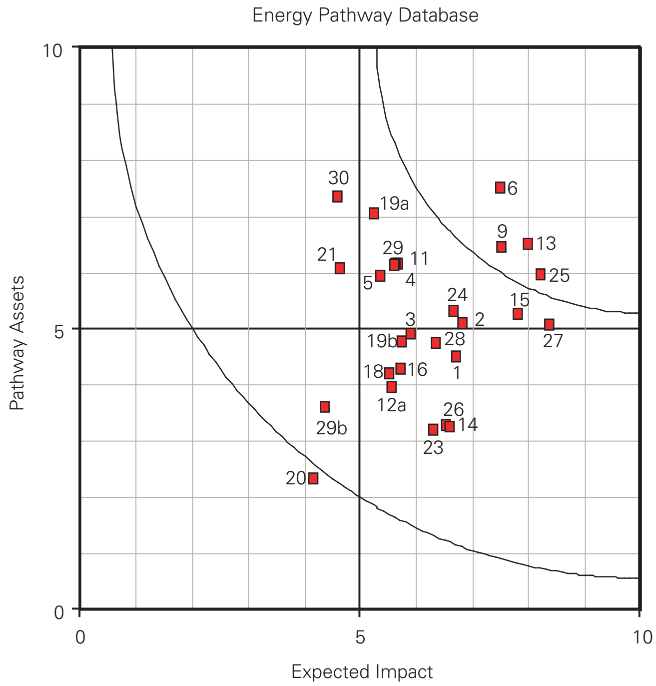
More detailed reports will be accessible from the CAE web site, including:

1. Evaluator comments for Pathway Assets and Expected Impact
2. Bar charts comparing Proponent and Evaluator ratings for the fifteen criteria with associated comments by the Evaluators.

The Evaluator comments are particularly useful when there is a high degree of variance in the evaluator ratings. The additional knowledge that the 'outlier' possesses may be of crucial significance in reaching the best understanding of the potential of a pathway.

CHART 7

Relative Positions of the Pathways



1 Coal Gasification with CO_2 Capture
2 Clean Coal Combustion
3 Energy Products from Agricultural and Forestry Feedstocks
4 Power from Agricultural Feedstocks (Straw)
5 Power and Heat from Municipal Solid Waste
6 Wind Farms for Grid Supply
9 Solar Energy for Electricity
11 Low Impact Surface Mineable Oil Sands
12a Solvent Vapor Extraction Process Heavy Oil
13 Alternative Hydrogen Supply for Oil Sands Development
14 Value-Added Products From Oil Sands
15 Nuclear Fission Energy for Oil Sands Development
16 Alternative Energy System for Road Vehicles
18 Hydrogen Production Transportation and Use
19a Geothermal Borehole Thermal Energy Storage
19b Mid-depth and Deep Geothermal
20 Natural Gas Hydrates
21 Development of Coal Bed Methane
23 Tidal and Wave Energy for Electrical Power
24 CO_2 Capture, Transportation, Storage & Use
25 Advanced Fission Reactors for Electrical Power
26 Magnetic Confinement Fusion for Electrical Power
27 Inertial Fusion Energy for Electricity
28 Recovery of Bitumen from Carbonate Deposits
29 Increased Conventional Oil Recovery
29b Enhanced Oil Recovery by Air Injection
30 Increased Natural Gas Recovery

Before examining the individual pathway reports, Chart 7 provides the X, Y grid positions of the 27 pathways evaluated in this project.

The chart provides the average rating of the evaluators with respect to the two overarching objectives of Pathway Assets and Expected Impact. Four pathways are above the “C-curve”.

Having a position lower in the chart indicates that there are weaknesses in either pathway assets or expected impact that would need to be overcome. The technology effort can be focused on those areas where there is a strong Canadian fit and the potential for technology advance.

This chart helps to position a pathway with respect to the 15 critical variables but is not one on which decisions can be made without the knowledge of the underlying strengths and weaknesses.

10. Pathway Reports

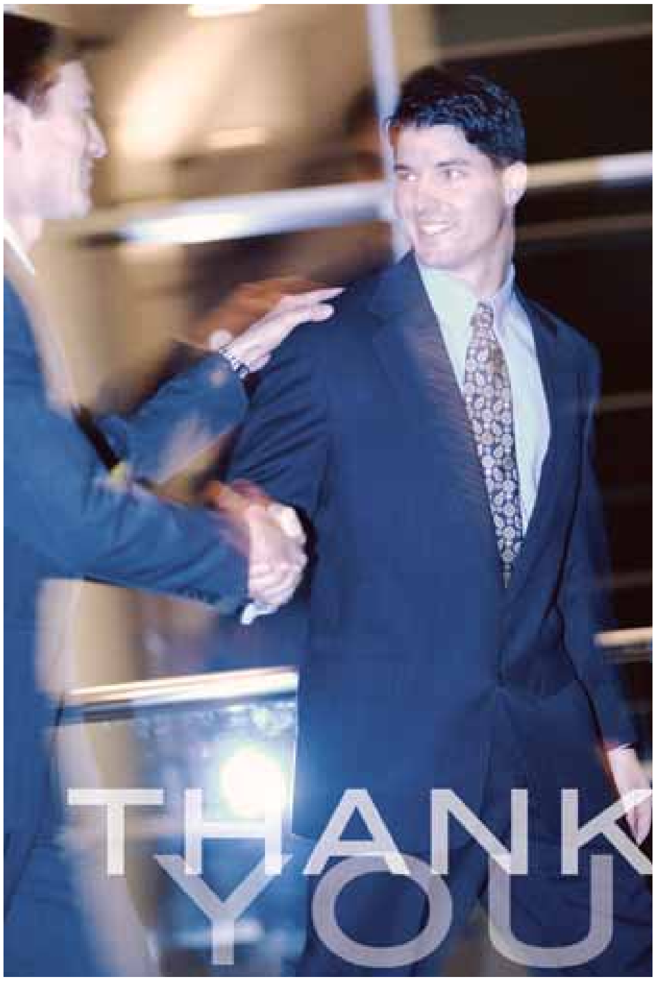
One-page reports for each Pathway are included in Appedix 6; the grid and profile charts present the opinions of the Proponents and the Evaluators. The following are summaries of the messages learned for each pathway, as understood by the Task Force.

No.	Pathway	Message
1	Coal Gasification with CO_2 Capture	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.
2	Clean Coal Combustion (including CO_2 capture)	This is an alternative route to gasification to utilize our coal reserves to produce electricity. This combustion process avoids the operational complexities of gasification but also does not produce the ancillary feedstocks. The key area on which work is needed relative to our most recent cleaner coal plants (Genesee) is CO_2 capture.
3	Energy Products from Agricultural & Forestry Feedstocks	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.
4	Power from Agricultural Feedstocks (Straw)	This pathway would be a candidate for one of the nodes of the national network identified for Pathway 3.
5	Power and Heat from Municipal Solid Waste	Current technology in use in Europe and the US avoids the emissions problems of the incinerators of the past. This pathway is inherently CO_2 neutral (and would be CO_2 positive if long distance garbage haulage was displaced) and could be a feedstock for gasification technology. Regional demonstration projects as part of the national network of Pathway 3 would be appropriate as a means of encouraging use of this pathway.
6	Wind Farms for Grid Supply	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.
9	Solar Energy for Electricity	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 referred to above for wind energy could contribute to the effectiveness of this pathway.

No.	Pathway	Message
11	Low Impact Surface Mineable Oil Sands	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.
12a	Solvent Vapor Extraction Processed Heavy Oil	The technology for this is immature and financial support is needed for field testing processes that look promising based on bench scale testing.
13	Alternative Hydrogen Supply for Oil Sands Development	Continued reliance on natural gas to produce hydrogen for use in oil sands upgrading is a questionable use of our natural gas resource and environmentally unacceptable. Research is needed on alternative technologies that could combine Canada's existing strengths in nuclear power and hydrogen production.
14	Value-added Products from Oil Sands Development	Research is needed on technologies to use in local processing of the raw materials extracted from our oil sands such as to make the best use of the outputs based on their chemical structures. New science is needed in this area.
15	Nuclear Fission Energy for Oil Sands Development	Our world leadership position in the SAGD process combined with our proven nuclear power plant technology could be leveraged to greatly reduce environmental impacts of the current process. 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
16	Alternative Energy System for Road Vehicles	As automobile designs are controlled outside Canada, we are not likely to play a lead role in developing this technology. However, research on the cold climate aspects of the technologies and on battery technology would be beneficial and could secure an advantage for the Canadian auto parts industry. Widespread adoption would have impacts on power system operations by increasing overnight load levels and this warrants assessment.
17	Upgrades to Electrical Infrastructure (was not undertaken as a separate pathway but related issues were raised in other pathways)	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.
18	Hydrogen Production, Transportation and Use	Production of hydrogen for industrial use is important on a regional basis. Improvements in the technology for hydrogen production are needed (see Pathway 13).
19a	Geothermal Borehole Thermal Energy Storage (BTES) System	The basic technology for this is in place and use of this technology can reduce strain on electricity grids and bring significant reductions in GHG depending on the fuel being displaced. Work to reduce materials and installation costs would be beneficial.

No.	Pathway	Message
19b	Mid-depth and Deep Geothermal Energy	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.
20	Natural Gas Hydrates	While it is believed 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.
21	Development of Coal Bed Methane	These resources are currently being recovered in a number of wells in Alberta. Incremental improvements in the technology will take place driven by the market. R&D on mitigating the environmental aspects, particularly water use, is needed.
23	Tidal and Wave Energy for Electrical Power	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.
24	Carbon Dioxide Capture, Transportation, Storage and Use	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 in 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. Such efforts are recommended as a national priority.
25	Advanced Fission Reactors for Electrical Power	Nuclear power is a very important component of a reduced carbon world. Continuing support for development of advanced generation reactors is desirable and would build on our leadership in providing proven nuclear power technology. In addition, work on developing technology for recycling nuclear waste could result in a world leadership position.
26	Magnetic Confinement Fusion for Electrical Power	Canada should maintain a watching brief on ongoing international efforts and contribute in areas where we have appropriate expertise, such as in the production and handling of tritium. This will give us a "seat at the table".
27	Inertial Fusion Energy for Electricity	In view of recent more promising outlooks for inertial confinement fusion, it is suggested that Canada's academic community provide support to ongoing international efforts in this field.
28	Recovery of Bitumen from Carbonate Deposits	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.
29	Increased Conventional Oil Recovery	Increased recovery is an important near-term objective to ensure effective resource utilization. Development of the technology is likely to be incremental and largely market driven. This technology is a primary application for CO_2 captured in energy production facilities (such as coal gasification plants).
29b	Enhanced Oil Recovery by Air Injection Processes	This technology is likely to be applicable in niche applications and improvements will likely be incremental and largely market driven.
30	Increased Natural Gas Recovery	Technology improvements will be incremental and largely market driven.

Sponsors



Ian Potter
Vice-President
Alberta Research Council

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Gordon	Slemon	Canadian Academy of Engineering
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William	Smith	University of Ontario Institute of Technology
Bert	Wasmund	Hatch
Roger	Yates	Hatch

Pathways and Proponents

No.	Pathway	Proponent(s)
1	Coal Gasification with CO_2 Capture	Duke Duplessis, Senior Advisor, Alberta Energy Research Institute and David Lewin (Senior Vice President Environment, EPCOR and Co-Chair of the Canadian Clean Power Coalition).
2	Clean Coal Combustion	Bob Stobbs, Saskatchewan Power
3	Energy Products from Agricultural & Forestry Feedstocks	Ron Crotogino and Tom Browne, Paprican
4	Power from Agricultural Feedstocks (Straw)	Amit Kumar and Peter Flynn, Department of Mechanical Engineering, University of Alberta
5	Power and Heat from Municipal Solid Waste	Rory Hynes, Hatch Energy
6	Wind Farms for Grid Supply	Michael Morgenroth, Hatch Energy
9	Solar Energy for Electricity	Steve Harrison, Queen's University
11	Low Impact Surface Mineable Oil Sands	Clem Bowman, former Chair of AOSTRA and Eddy Isaacs, Executive Director of Alberta Energy Research Institute
12a	Solvent Vapor Extraction Processes Heavy Oil	Bernard Tremblay, Saskatchewan Research Council
13	Alternative Hydrogen Supply for Oil Sands Development	William Smith, Dean of Science, University of Ontario Institute of Technology and Alistair Miller of AECL
14	Value-added Products from Oil Sands Development.	Catherine Laureshen, Hydrocarbon Upgrading Manager, Alberta Energy Research Institute
15	Nuclear Fission Energy for Oil Sands Development	Ron Oberth, AECL and Ted Heidrick, University of Alberta
16	Alternative Energy System for Road Vehicles	Robert L. Evans, Methanex Professor, Department of Mechanical Engineering, & Director, Clean Energy Research Centre, The University of British Columbia
18	Hydrogen Production, Transportation and Use	Ramseh Sadhankar and Ron Oberth of AECL and William Smith, Dean of Science, University of Ontario Institute of Technology
19a	Geothermal Borehole Thermal Energy Storage (BTES) System	William Smith, Dean of Science, University of Ontario Institute of Technology and Greg Naterer, Faculty Engineering and Applied Science, University of Ontario Institute of Technology
19b	Mid-depth and Deep Geothermal Energy	Doug James, EnergyINet

No.	Pathway	Proponent(s)
20	Natural Gas Hydrates	William Smith, Dean of Science, University of Ontario Institute of Technology Sandy Colvine, NRCan Bruce Peachey PTAC/EnergyINet Director, Increased Recovery
21	Development of Coal Bed Methane	Bruce Peachey, EnergyINet/PTAC Director, Increased Recovery
23	Tidal and Wave Energy for Electrical Power	Chris Campbell, Executive Director, Ocean Renewable Energy Group
24	Carbon Dioxide Capture, Transportation, Storage and Use	Surindar Singh, Senior Manager, CO2 Management Alberta Energy Research Institute
25	Advanced Fission Reactors for Electrical Power	AECL, Chalk River, and George Bereznai, University of Ontario Institute of Technology
26	Magnetic Confinement Fusion for Electrical Power	Rick Sydora, Professor, Department of Physics, University of Alberta
27	Inertial Fusion Energy for Electricity	Allan Offenberger, University of Alberta
28	Recovery of Bitumen from Carbonate Deposits	Ted Heidrick, Poole Professor in Technology Management, Faculty of Engineering and School of Business, University of Alberta Dzung Nguyen, Senior Advisor/Manager, Emerging Technologies, Alberta Energy Research Institute Dr. Jose Alvarez, Senior Research Scientist, Heavy Oil & Oil Sands, Alberta Research Council
29	Increased Conventional Oil Recovery	Bruce Peachey, EnergyINet/PTAC Director, Increased Recovery
29b	Enhanced Oil Recovery by Air Injection Processes	Norman Freitag, Saskatchewan Research Council
30	Increased Natural Gas Recovery	Bruce Peachey, EnergyINet/PTAC Director, Increased Recovery

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Doug	Soveran	Saskatchewan Research Council
Bert	Wasmund	Hatch
Eric	Wasmund	Inco
Paul	Watkinson	University of British Columbia
Richard	West	Hatch Energy
Malcolm	Wilson	University of Regina
Anonymous 1		
Anonymous 2		
Anonymous 3		

Language Ladders

A1. Scientific Principles

As part of the justification for your rating, please include a description of the major scientific issues involved in this pathway, and the state of knowledge on these at this time.

Please select which of the following statements best represents the Pathway.

A. The scientific principles involved in the pathway are not yet fully understood.

B. The scientific principles involved in the major steps in the pathway are well understood and all relevant information has been disseminated to the scientific community.

C. The scientific principles involved in all steps in the pathway are well understood and have been validated by independent research teams…

D. …and no significant scientific questions remain to be answered in this pathway.

A2. Technology Validation

As part of the justification for your rating, please include an overview of each of the primary technologies involved in the pathway, the scale-up steps required and the degree of validation.

Please select which of the following statements best represents the Pathway.

A. The technologies involved in this pathway have not been tested beyond the laboratory bench scale.

B. The technologies involved in this pathway have been successfully tested at the first logical scale beyond the laboratory bench.

C. The technologies involved in this pathway have been successfully tested on a demonstration scale under commercially relevant conditions…

D. …and external stakeholders have been involved in the demonstration and have accepted or validated the results.

A3. Commercial Readiness

"Integrated" in this Language Ladder means that all major technology components have been coupled together in a manner equivalent to that which would occur in a commercial operation.

Please select which of the following statements best represents the Pathway.

A. The technologies involved in the pathway have not been tested as an integrated process.

B. The major technologies involved in the pathway have been successfully tested as an integrated process but not yet under conditions relevant to a commercial operation.

C. The major technologies involved in the pathway have been tested as a integrated process under conditions relevant to a commercial operation…

D. …and any remaining commercialization risks are expected to be acceptable to organizations operating in this sector.

A4. Societal Acceptability

Please select which of the following statements best represents the Pathway.

A. Commercialization of this pathway would encounter significant societal resistance which will not be readily overcome.

B. Commercialization of this pathway would encounter societal concerns and it will be a challenge to address these in a clear and convincing manner.

C. Societal concerns arising from the commercialization of this pathway would be minimal and are expected to be relatively easy to address.

D. Commercialization of this pathway would not encounter societal concerns.

A5. Fit to Canadian National Initiative

A Canadian National Initiative is one that has the potential to have an economic and/or social impact equivalent to past Canadian projects such as building the national railway. It may include a high level of participation in a major international project.

Please select which of the following statements best represents the Pathway.

A. The pathway is not yet ready to be considered as a potential Canadian National Initiative.

B. This pathway has high potential to be a Canadian National Initiative but there is minimum evidence of support by Canadian public and/or private stakeholders.

C. This pathway is an important Canadian National Initiative which has been supported by Canadian public and/or private stakeholders.

D. This pathway is a major Canadian National Initiative in which there is clearly demonstrated sustaining support by Canadian public and/or private stakeholders.

B1. Corporate Capacity

Please describe the corporate capacity required to fully commercialize this pathway in all its aspects. Provide names of companies where appropriate and indications of their experience and strengths relevant to the pathway.

Please select which of the following statements best represents the Pathway.

A. There are no Canadian companies who have the capacity to be leaders in the development of this pathway within Canada.

B. There are one or more capable Canadian companies who will be leaders in commercialization of this pathway within Canada but the supporting industrial infrastructure will require significant enhancement.

C. There are many capable Canadian companies who will be leaders in the commercialization of this pathway. The supporting industrial infrastructure is more than adequate to achieve effective commercialization.

D. This pathway is in an area of major Canadian industrial strength and the full commercialization of this pathway will ensure that many Canadian companies will be able to achieve and maintain a world leadership position.

B2. Canadian Competitive Advantage

Please provide a description of the specific competitive advantages (including examples) that commercialization of this pathway would provide for Canada, both in energy related markets and in the global economy as a whole.

Please select which of the following statements best represents the Pathway.

A. Commercialization of this pathway would not contribute to any unique Canadian strength in international energy markets.

B. Commercialization of this pathway would fit well with existing Canadian strengths in international energy markets.

C. Commercialization of this pathway would add significantly to existing Canadian strengths in international energy markets…

D. …and would give Canada an important and sustainable competitive advantage in wider aspects of the global economy.

B3. Sustainability

Please describe how full commercial development of this pathway would extend the life of existing sources of energy and/or create new sources with the potential to substitute for non-renewable sources. Include specific examples and estimates of substitution potential where possible.

Please select which of the following statements best represents the Pathway.

A. Development of this pathway would neither
   i) extend the expected commercial life span of an existing energy source, nor
   ii) introduce a new energy source with a life span over 30 years.

B. Development of this pathway would measurably (by at least 30 years) extend the expected commercial life span of an existing energy source, or would introduce a new energy source with an equivalent life span.

C. Development of this pathway would extend the expected commercial life span of an existing energy source well beyond any current societal planning horizon (100 years plus), or would introduce a new source with the same long term potential.

D. Development of this pathway would result in an essentially unlimited energy supply.

B4. Enabler for Another Pathway

As part of the justification for your rating, please describe the specific interactions and interdependencies of this pathway with other existing or potential energy pathways.

Please select which of the following statements best represents the Pathway.

A. Commercialization of this pathway is dependent on the successful commercialization of another energy pathway but will not contribute in itself to the successful commercialization of that pathway.

B. Commercialization of this pathway is not dependent on the successful commercialization of another pathway and will not contribute in a measurable way to the successful commercialization of another energy pathway.

C. Commercialization of this pathway will contribute in a measurable way to the successful commercialization of another energy pathway.

D. Commercialization of this pathway is essential to the effective commercialization of another energy pathway and will substantially enhance the effectiveness of both.

B5. Delivery/Infrastructure Issues

As part of the justification for your rating , please describe issues related to the delivery of the energy source in this pathway (such as, for instance, integration into an existing grid, storage, backup, etc.) and their means of resolution where appropriate.

Please select which of the following statements best represents the Pathway.

A. Little or no infrastructure exists for delivery of this energy source and/or there are significant unresolved issues related to delivery which must be dealt with before commercial introduction.

B. Some unresolved delivery/infrastructure issues exist but these can reasonably be expected to be dealt with before commercial introduction.

C. This energy source is part of a commercial delivery system in at least one major market in Canada and the experience in that market is completely transferable across Canada.

D. The delivery/infrastructure system for this energy source is well established in most regions across Canada.

C1. Economic Impact

Please select which of the following statements best represents the Pathway.

A. Successful commercialization of this pathway would have a limited or short term economic impact on the Canadian economy.

B. Successful commercialization of this pathway would contribute to the Canadian economy, and possibly would have major impact in a specific geographic region.

C. Successful commercialization of this pathway would have a major positive and sustained impact across the Canadian economy …

D. …and would be equivalent to other significant Canadian undertakings such as building the first gas pipeline across the country.

C2. Environmental (other than GHG emissions) Impact

Please identify the major environmental impacts (other than greenhouse gas emissions) affecting land, air and water that you have considered in arriving at your rating and provide explanatory comments.

Please select which of the following statements best represents the Pathway.

A. Commercialization of this pathway would have significant negative overall environmental impacts that would be perceived as unacceptable by well-informed citizens.

B. Commercialization of this pathway would have small negative overall impacts on the environment and well-informed citizens would seek evidence that those impacts would be acceptable.

C. Commercialization of this pathway would have small positive overall environmental impacts in the view of well-informed citizens.

D. Commercialization of this pathway would have significant positive overall environmental impacts in the view of well-informed citizens.

C3. Greenhouse Gas (GHG) Emissions Impact

Please select which of the following statements best represents the Pathway.

A. Commercialization of this pathway would result in significant increases in Canada's total GHG emissions.

B. Commercialization of this pathway would result in moderate increases in Canada's total GHG emissions.

C. Commercialization of this pathway would result in moderate reductions in Canada's total GHG emissions.

D. Commercialization of this pathway would result in significant reductions in Canada's total GHG emissions.

C4. Energy Efficiency Impact

Please select which of the following statements best represents the Pathway.

A. Commercialization of this pathway would result in a reduction in the overall efficiency with which energy is produced/converted/delivered/used in Canada.

B. Commercialization of this pathway would not have a material impact on the level of efficiency with which energy is produced/converted/delivered/used in Canada.

C. Commercialization of this pathway would increase the overall efficiency with which energy is produced/converted/delivered/used in Canada.

D. Successful commercialization of this pathway would result in major improvements in the efficiency with which energy is produced/converted/delivered/used in Canada.

C5. Value-Added Impact

Canada has expressed concern for many years about the low level of recovery and upgrading of our natural resources. This has led to a strong national goal of adding value to our raw resources, either by increasing yield/recovery or product value.

Please select which of the following statements best represents how the Pathway would increase the yield/recovery or value of the involved energy stream above that achieved by current commercial practice.

A. Commercialization of this pathway would not increase the yield or value of products derived from this energy pathway, in comparison to current commercial practice.

B. Commercialization of this pathway would moderately increase the yield or value of products derived from this energy pathway, in comparison to current commercial practice.

C. Commercialization of this pathway would significantly increase the yield or value of products derived from this energy pathway, in comparison to current commercial practice.

D. Commercialization of this pathway would result in a major transformation in how Canada's resources are recovered and upgraded within our borders.

ProGrid Output Reports

Opportunity No : 1 **Proponent : Duke Duplessis, David Lewin** **Page : 1**

Opportunity Title : Coal Gasification with CO2 Capture

Opportunity Summary:

Canada has abundant coal resources; enough to meet the country's energy needs for hundreds of years. Gasification and the associated shift reaction convert coal in the presences of oxygen and steam into CO2 and hydrogen. The hydrogen can be used for generating "clean" power, for refining oil, upgrading bitumen and for producing petrochemicals ("poly-generation") while the carbon dioxide can be captured and used in enhanced oil recovery and coal bed methane applications or sequestered in saline aquifers. Gasification economics depend on the quality of the coal and little is known about gasifying low rank (quality) Canadian coals. Canada's pathway consists of evaluating, improving, demonstrating known and emerging gasification technologies.

The Opportunity was assessed by 9 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 4.5

Expected Impact = 6.7

R Value = 55%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

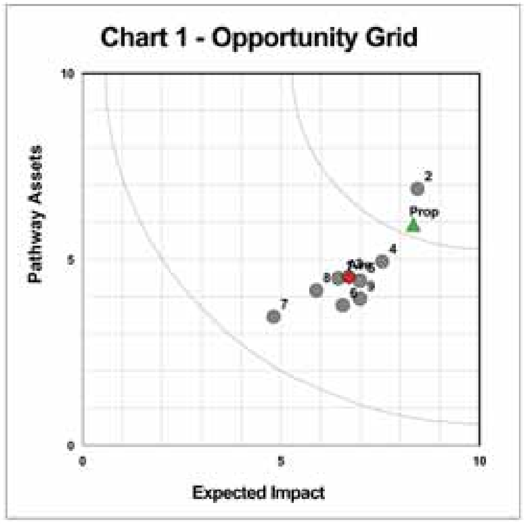
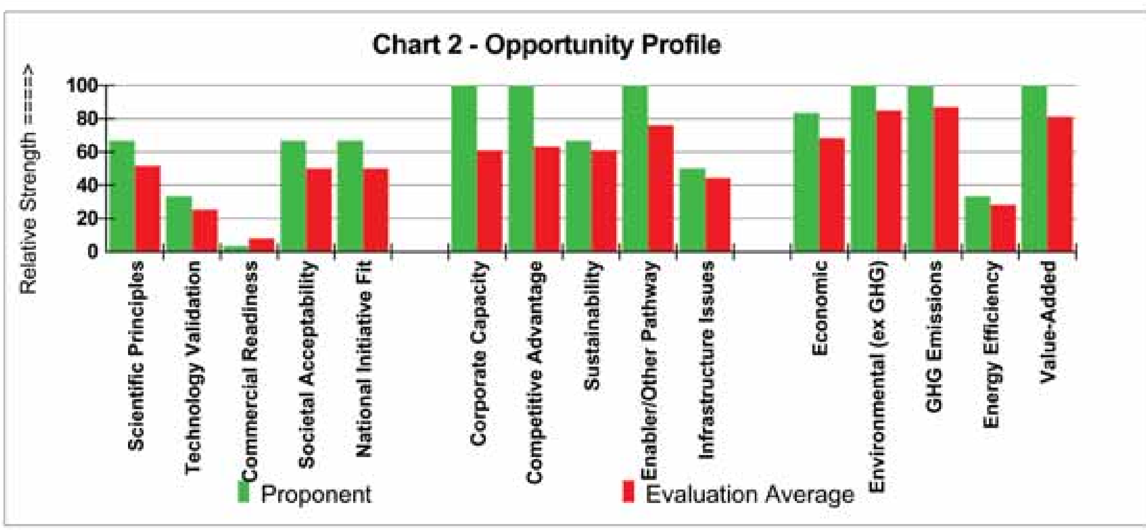


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 2 **Proponent : Bob Stobbs** **Page : 1**

Opportunity Title : Clean Coal Combustion

Opportunity Summary:

Canada has abundant coal resources. Clean coal combustion can make this resource a Canadian asset for future energy sources and remove the perception that coal is an environmental liability. Clean coal combustion will reduce emissions of NOx, SO2, particulates and mercury to very low levels as well as capture most of the CO2.

The Opportunity was assessed by 9 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

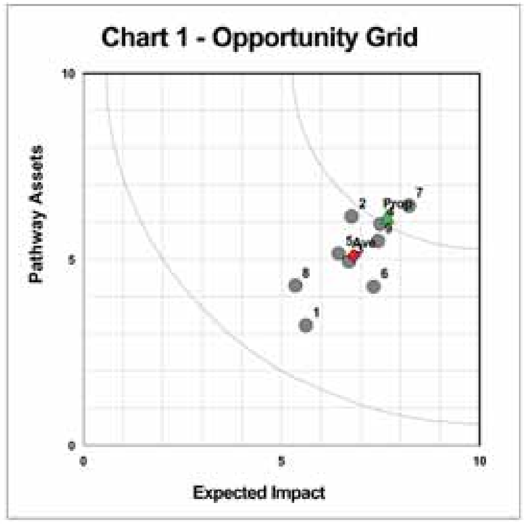
The Opportunity ratings have the following characteristics:

Pathway Assets = 5.1

Expected Impact = 6.8

R Value = 59%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)



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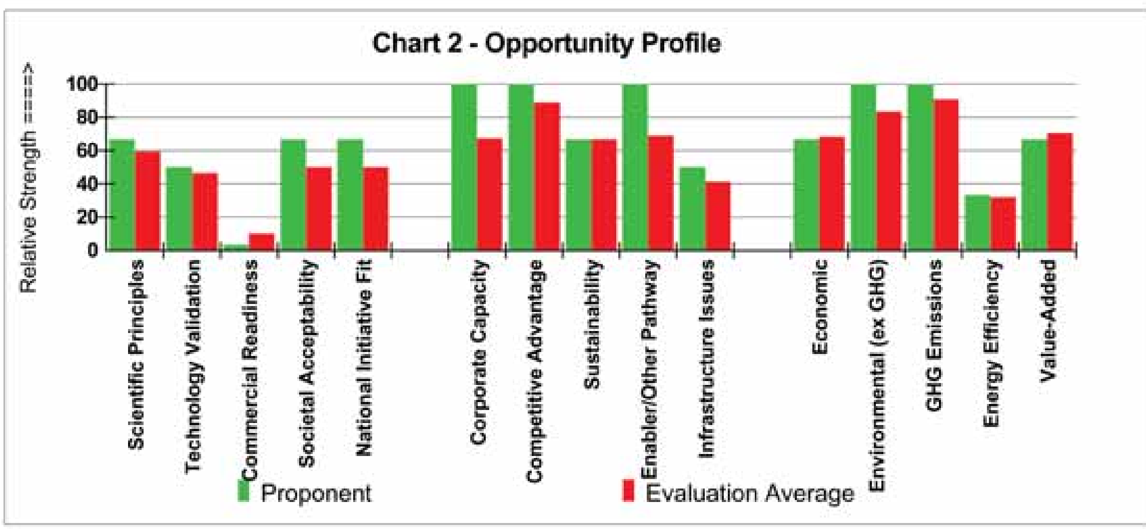


Opportunity No : 3 **Proponent : Ron Crotogino, Tom Browne** **Page : 1**

Opportunity Title : Energy Products from Agriculture and Forestry Feedstocks

Opportunity Summary:

On an annual basis, the renewable resource residues available from forestry, agriculture and related manufacturing industries are equivalent to approximately 25 percent of the energy Canada derives from fossil fuels. The pine beetle infestation in the forests of British Columbia, will add a substantial amount of forest bio-mass that will need to be disposed off during the next 10-20 years. Marginal agricultural land can be used to produce bio-energy crops in harmony with farming and ranching to maintain a sustainable source of biological energy feed-stocks. Proven technologies exist for converting these feed-stocks into a broad range of fuels such as wood pellets, fuel oils, bio-diesel, and ethanol. Canada can become a world leader.

The Opportunity was assessed by 7 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 4.9

Expected Impact = 5.9

R Value = 54%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

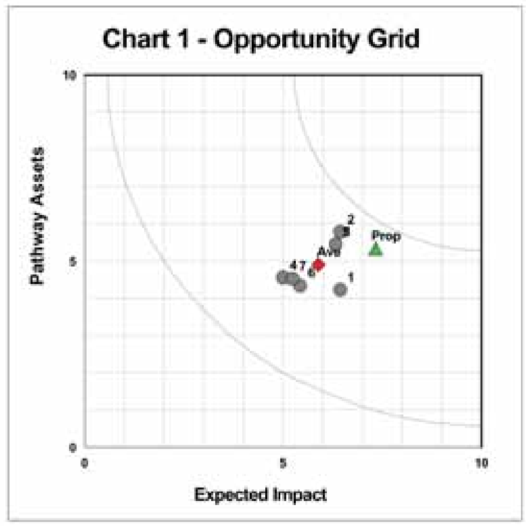
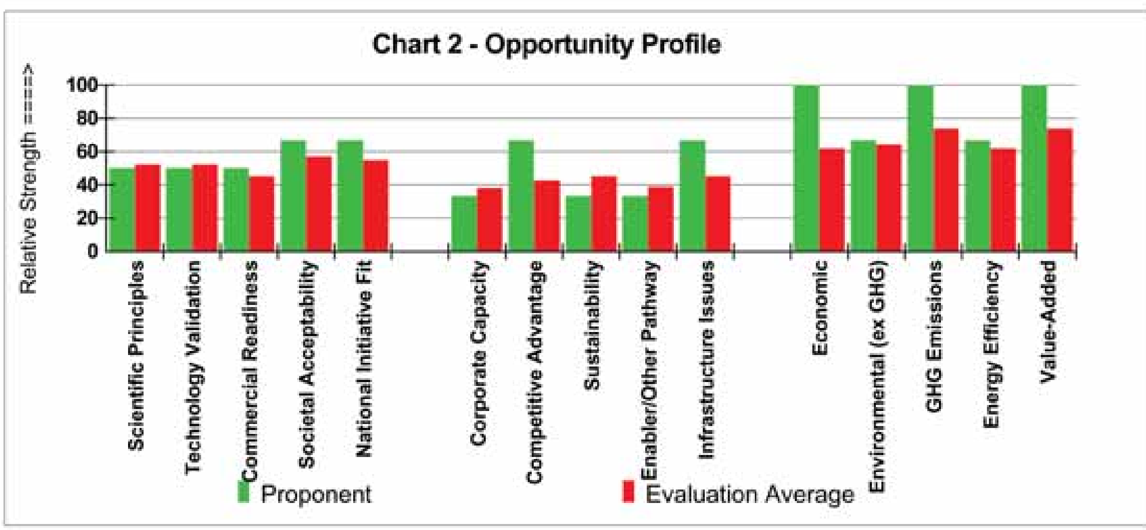


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 4 **Proponent : Amit Kumar, Peter Flynn** **Page : 1**

Opportunity Title : Power from Agricultural Feedstocks (Straw)

Opportunity Summary:

Biomass is considered carbon neutral i.e. the amount of carbon released during its combustion is nearly the same as taken up by plant during its growth. Power from straw is not economic today in western Canada, where power is generated from a large base of hydroelectric, gas fired, and coal fired plants. Cost of power from a large-scale straw fired power plant (more than 300 MW) is in the range of C$65- $75 per MWh. Numerous studies, including a detailed study based on western Canada straw, confirm that the optimum size of a straw based power plant is 250 to 450 MW. Straw is being used to produce heat and power in several plants in Europe on a commercial scale, and is also being co-fired with coal. Technology is mature.

The Opportunity was assessed by 8 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 6.1

Expected Impact = 5.6

R Value = 59%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

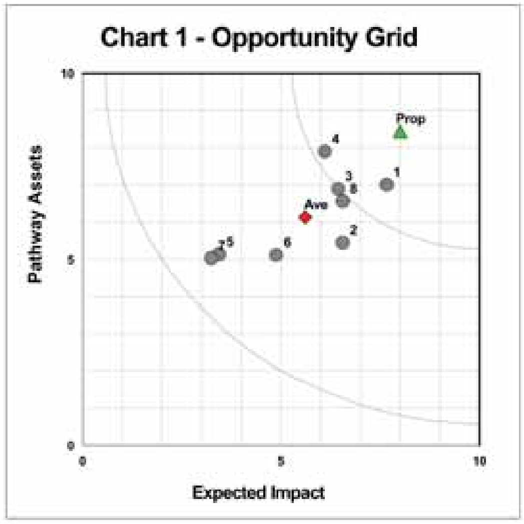
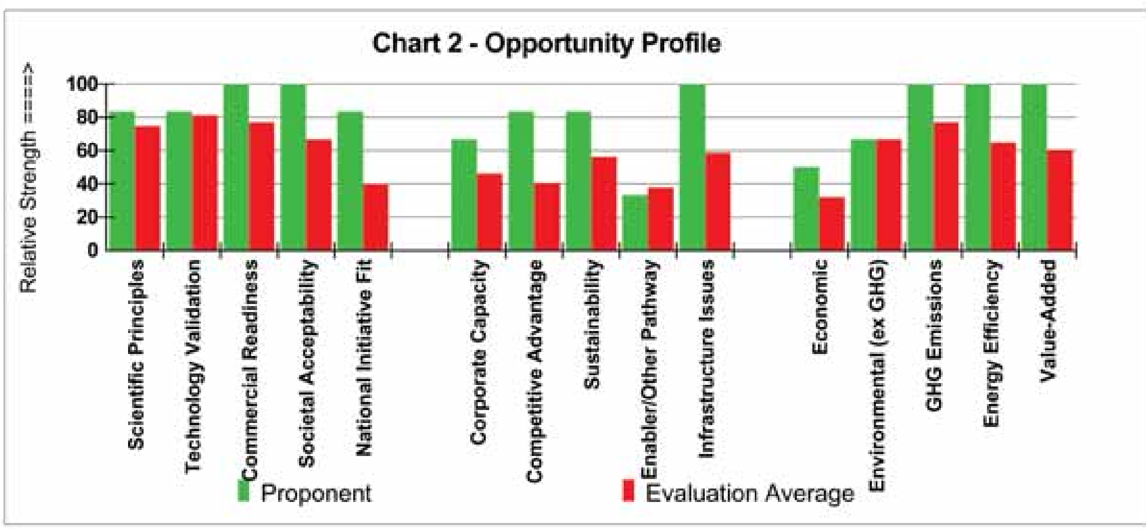


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 5 **Proponent : Rory Hynes, Bob Griesbach** **Page : 1**

Opportunity Title : Power and Heat from Municipal Solid Waste

Opportunity Summary:

Supply of electricity to the grid or directly to end users and supply of thermal energy to end users by combined heat and power (CHP) plants using Municipal Solid Waste (MSW) as the energy source.

The Opportunity was assessed by 4 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 5.9

Expected Impact = 5.4

R Value = 56%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

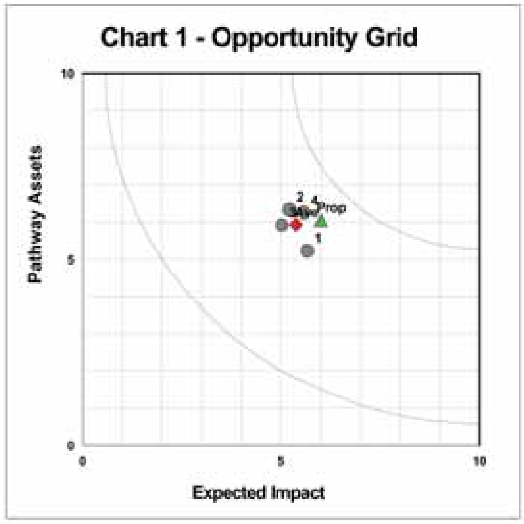
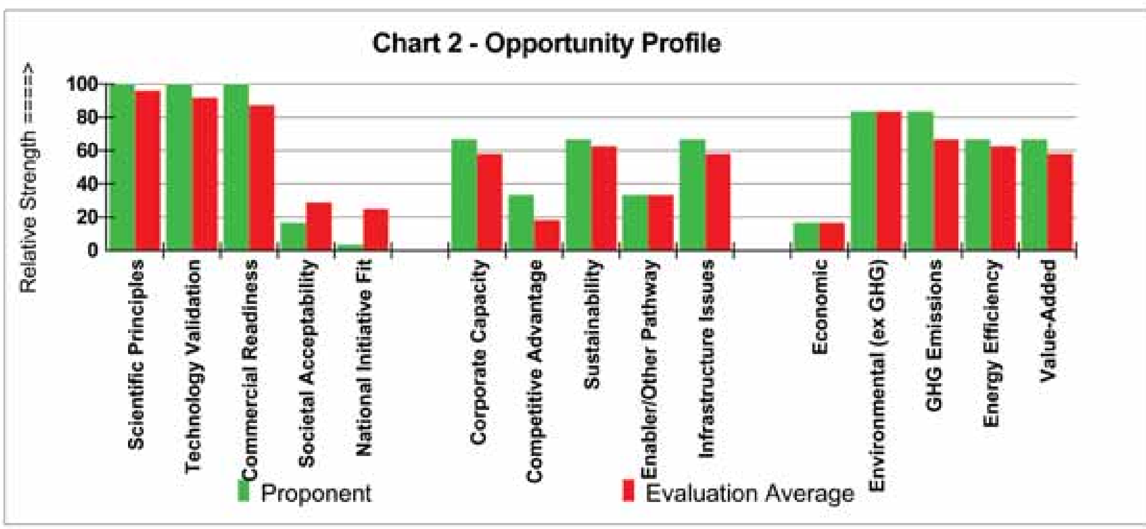


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 6	Proponent : Dr. Michael Morgenroth	Page : 1

Opportunity Title : Wind Farms for Grid Supply

Opportunity Summary:

Wind farms consist of an array of factory built wind turbines and the balance of plant infrastructure to collect the electricity and feed it into the electrical grid. Wind turbines are driven by zero-cost, non-polluting fuel, the wind. Technology development in the last 20 years for the rotor, drive train and electrical power conditioning equipment, have made wind power economically competitive and desirable as a replacement for other forms of generation that are environmentally less benign. Wide spread public support has created a regulatory environment where wind farm development is favoured through a relatively rapid permitting and environmental assessment process.

The Opportunity was assessed by 9 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 7.5

Expected Impact = 7.5

R Value = 75%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

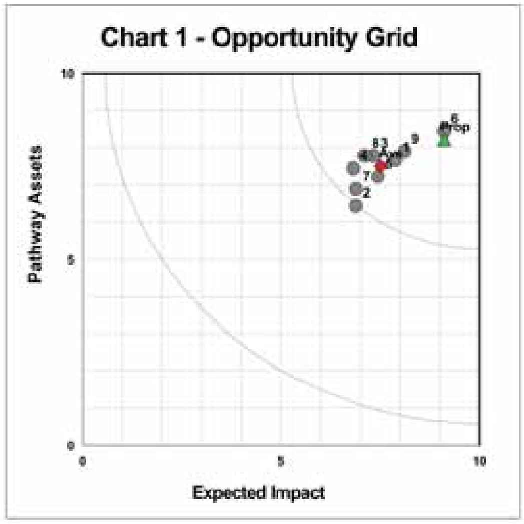
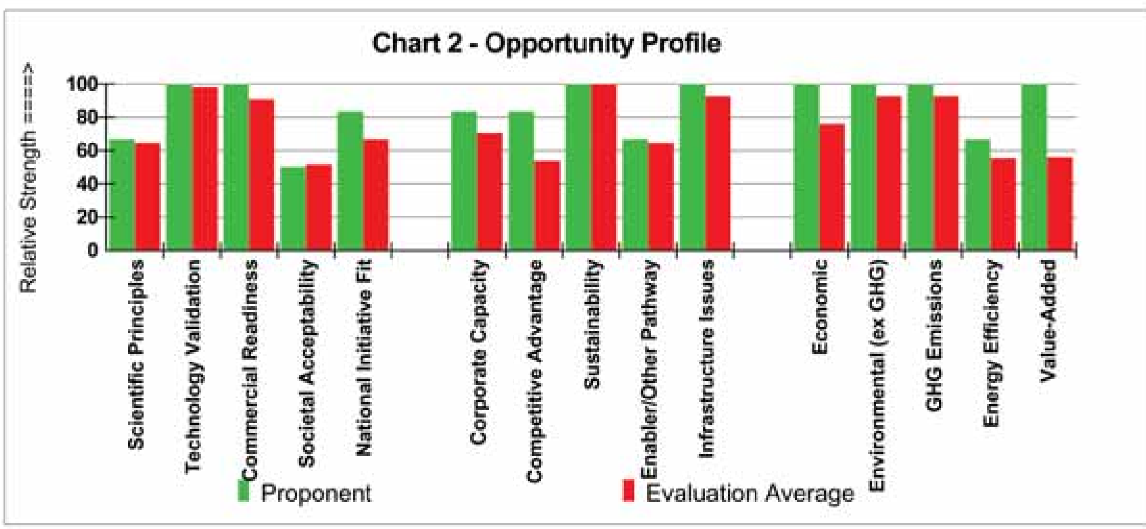


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 9 **Proponent : Dr. Steve Harrison** **Page : 1**

Opportunity Title : Solar Energy for Electricity

Opportunity Summary:

The supply of power to homes, and the electrical grid, by generation of electricity from photovoltaic (PV) modules installed on the roofs or façades of buildings. There are two classifications: stand-alone systems that are independent of electrical supply grids but require an energy storage to ensure an uninterrupted supply; and grid-connected systems in which excess electricity from locally installed PV panels is fed through electrical interconnects to the electrical grid for distribution. In the latter case, when there is insufficient solar energy to meet the local load, power is drawn directly from the electrical grid rather than from a battery system.

The Opportunity was assessed by 7 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 6.4

Expected Impact = 7.5

R Value = 69%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

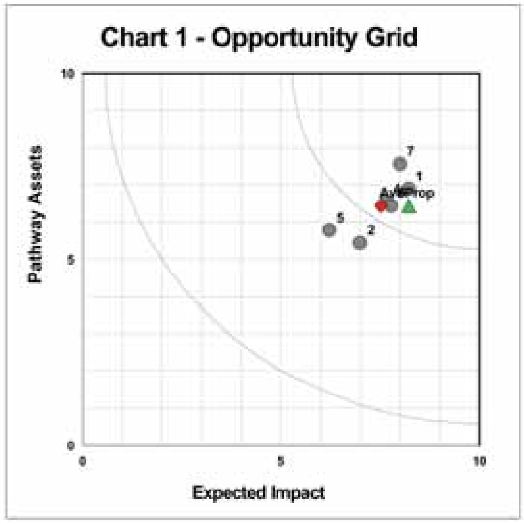
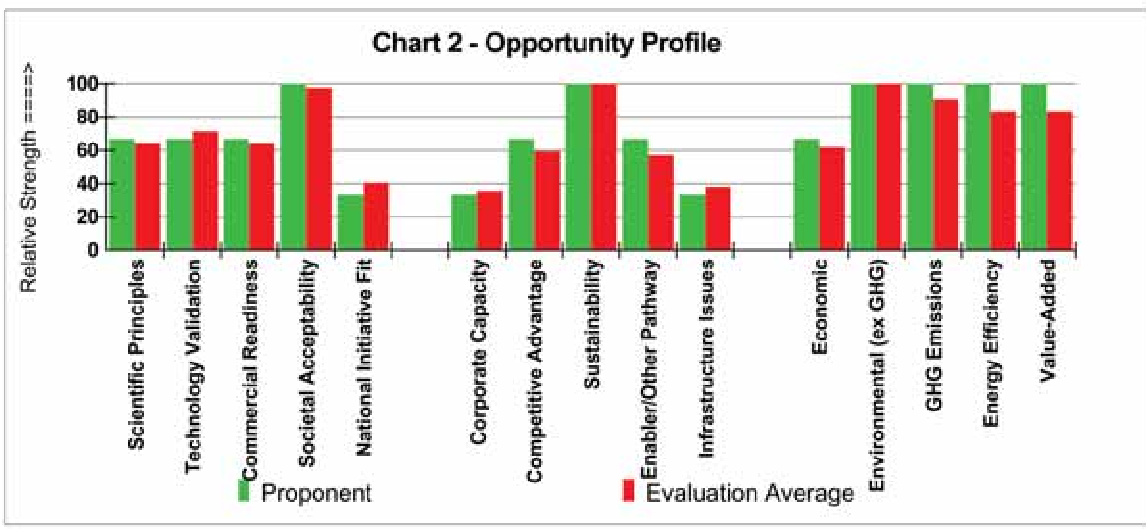


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 11 **Proponent : Clem Bowman, Eddy Isaacs** **Page : 1**

Opportunity Title : Low Impact Surface Mineable Oil Sands

Opportunity Summary:

The Canadian Oil Sands have a total in place resource of over 2 trillion barrels, of which roughly 10% can be recovered by surface mining technology. Beginning with the pioneering work of the Alberta Research Council in the late 1920s and early 1930s, followed by the Alberta Government demonstration plant at Bitumount in the late 1940s, commercial production began with the Great Canadian Oil Sands Plant in the late 1960s and the Syncrude Canada plant in the 1970s. Many other companies are now involved and production of synthetic crude is expected to be about 2 million BPD of bitumen and synthetic crude in aggregate by 2012. The Oil Sands Technology Roadmap produced by the Alberta Chamber of Resources identified many of the challenges.

The Opportunity was assessed by 5 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 6.1

Expected Impact = 5.7

R Value = 59%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

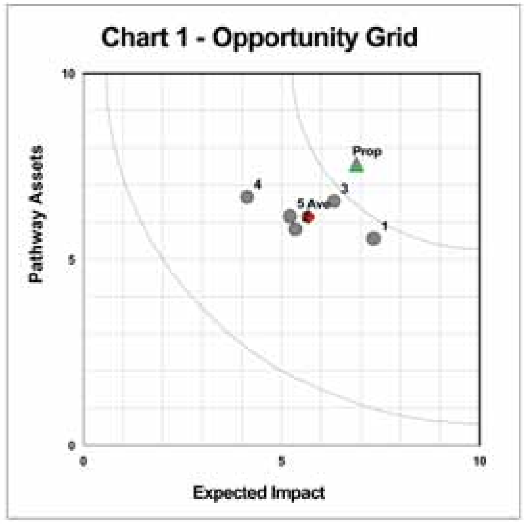
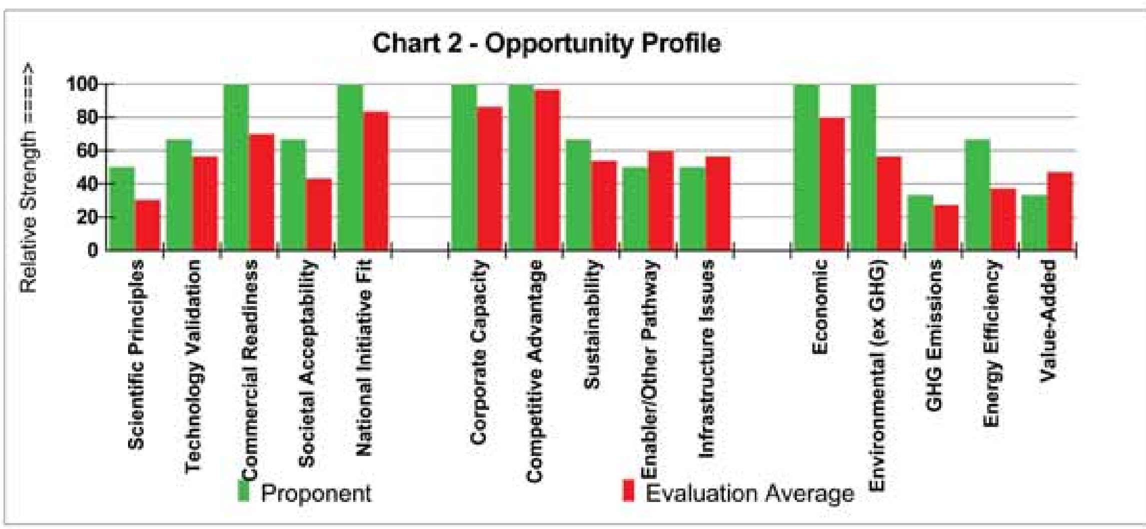


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 12a **Proponent : Dr. Bernard Tremblay** **Page : 1**

Opportunity Title : Solvent Vapor Extraction Process Heavy Oil

Opportunity Summary:

Solvent vapour extraction processes are less energy intensive, use less water, and are more suitable for thinner, partially-depleted reservoirs than are thermal recovery processes. In addition, these processes should reduce CO2 emissions by 90% compared to steam injection. A major concerted effort between research organizations and industry will be required to make the solvent extraction process successful. A series of well defined laboratory studies, scaled and mechanistic physical modeling, and numerical simulations coordinated with ongoing field pilot operations will provide the technical and economical de-risking required for industry acceptance and wide-spread commercial application.

The Opportunity was assessed by 10 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 4.0

Expected Impact = 5.6

R Value = 47%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

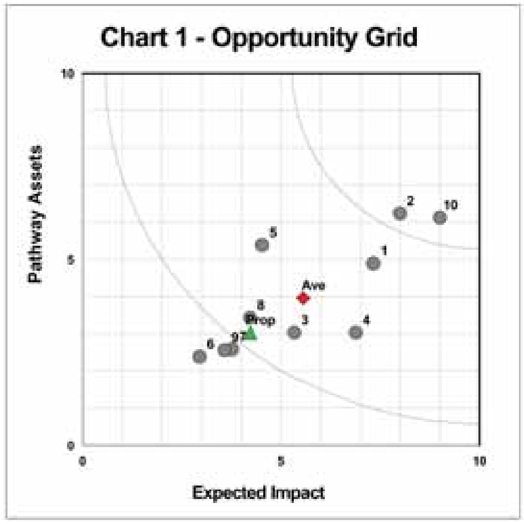
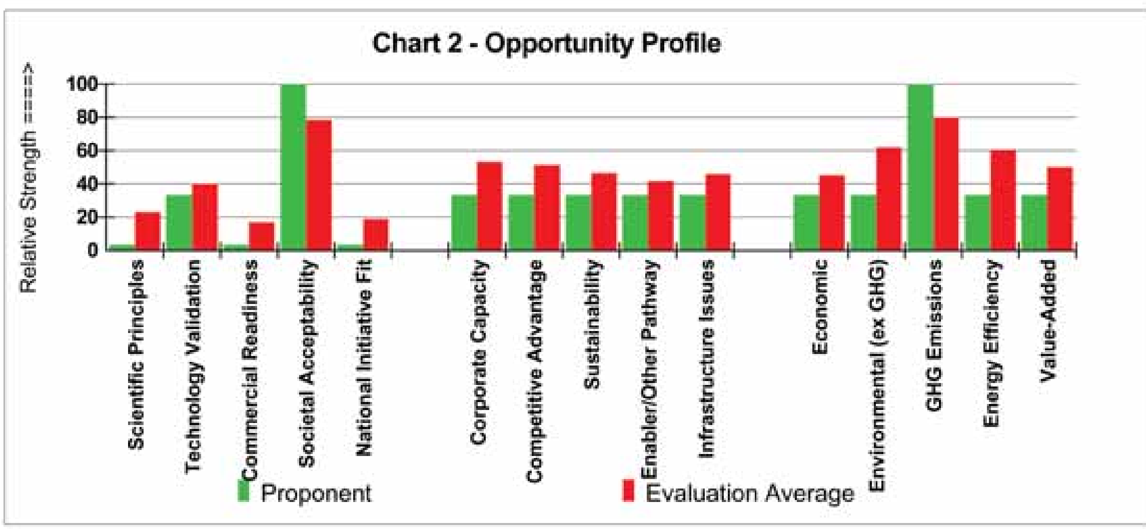


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 13 **Proponent : Dr. William Smith Alistair Miller** **Page : 1**

Opportunity Title : Alternative Hydrogen Supply for Oil Sands Development

Opportunity Summary:

Hydrogen is a key additive in the transformation of oil sands bitumen into synthetic crude oil (SCO). The current method of producing it is Steam-Methane Reforming (SMR), which consumes an increasingly expensive and scarce resource (natural gas) and co-produces substantial CO2. Although other hydrogen production methods are potentially feasible (see Pathway 13 - Hydrogen Production by New Technologies, Transportation and Use), production by electrolysis is a mature technology. Hydrogen by electrolysis with the electricity produced by a nuclear reactor is now an economically attractive alternative, especially if it can be produced intermittently using off-peak electricity. It has the added benefit of long-term price stability.

The Opportunity was assessed by 6 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 6.5

Expected Impact = 8.0

R Value = 72%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

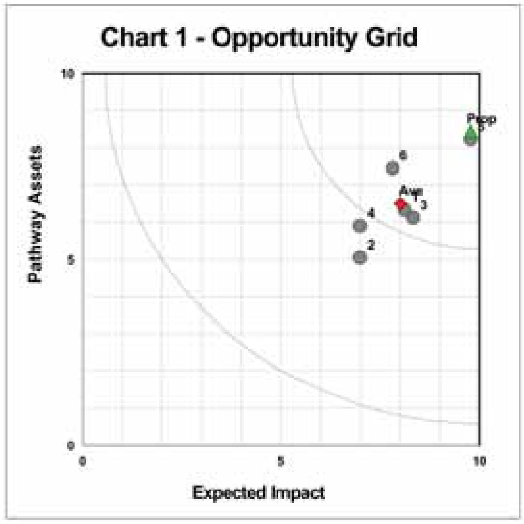
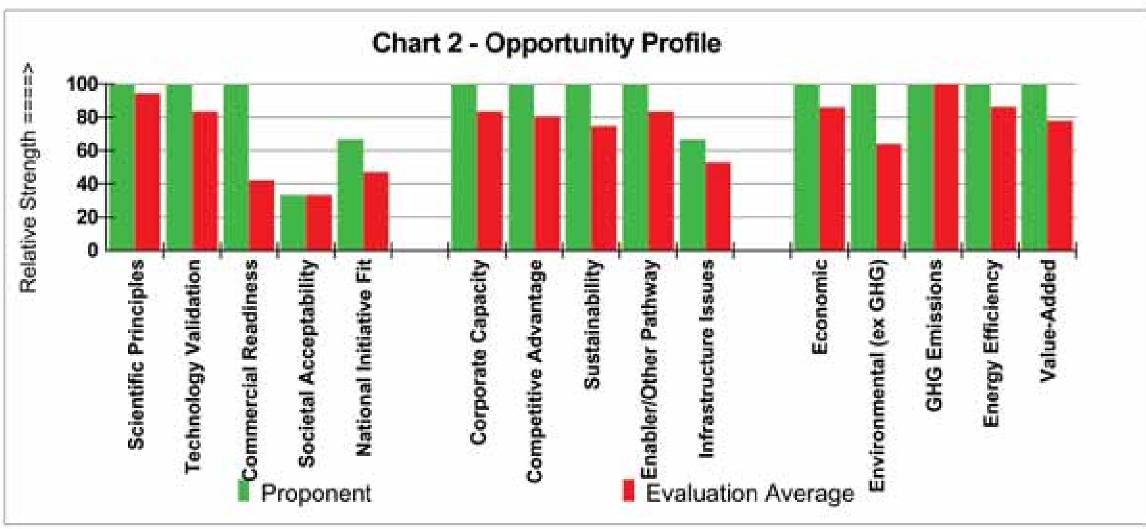


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 14 **Proponent : Dr. Catherine Laureshen** **Page : 1**

Opportunity Title : Value-Added Products From Oil Sands

Opportunity Summary:

Alberta has very large recoverable reserves in the oil sands - more than those of Saudi Arabia. Current production levels of approximately 1 million barrels per day of bitumen and synthetic crude oil will more than triple by 2030, provided costs of recovery and upgrading can be continuously reduced through improved technology. An expanded mix of products and new markets must be developed, to avoid long term depressed netbacks on unprocessed bitumen. Canada's pathway to value-added products from oil sands bitumen will focus on improved bitumen characterization, new separation technologies, new catalysts, and integration of upgrading and refining processes, including gasification.

The Opportunity was assessed by 9 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 3.3

Expected Impact = 6.6

R Value = 47%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

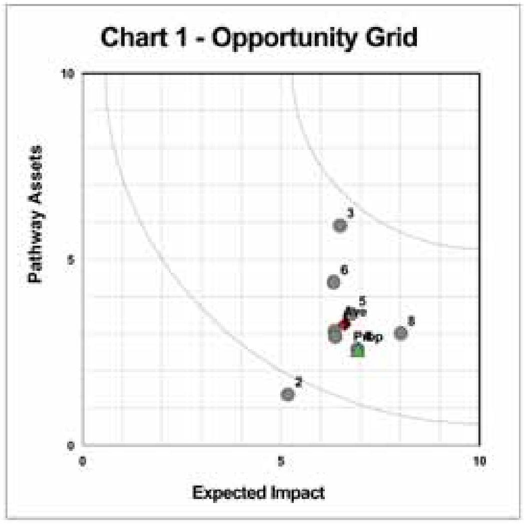


Chart 2 - Opportunity Profile.

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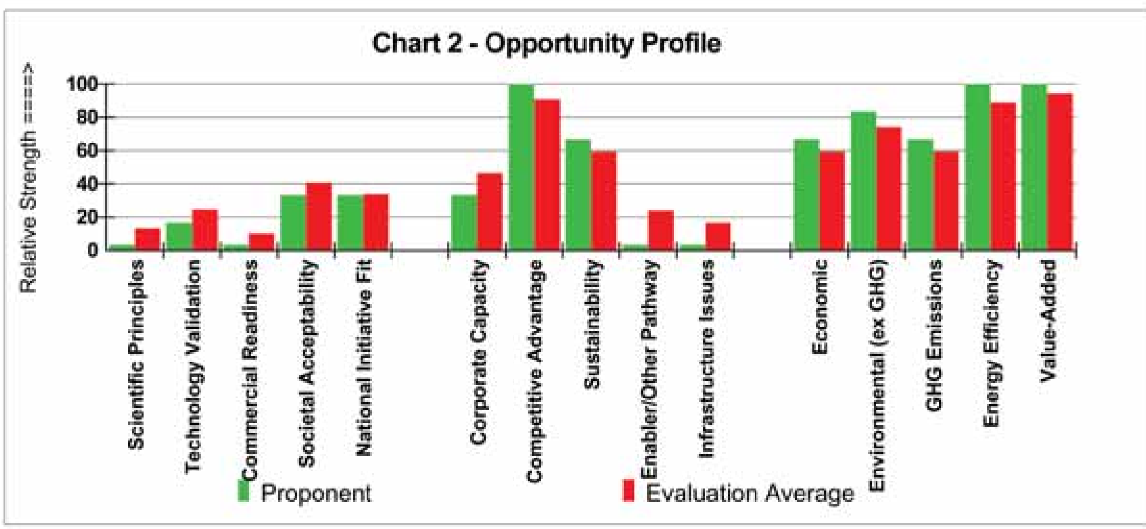


Opportunity No : 15 **Proponent : Ron Oberth AECL Ted Heidrick UofA** **Page : 1**

Opportunity Title : Nuclear Fission Energy for Oil Sands Development

Opportunity Summary:

The SAGD process injects medium pressure steam into an oil sand reservoir to reduce the viscosity of the bitumen in order to enable its extraction. SAGD operations currently represents only about 10% of total oil sands production but is expected to become the dominant recovery process due to large underground reserves, improving technology / recovery performance and generally lower environmental impact than surface mining. Once through steam generators (OTSG), occasionally backed up by combined-cycle gas turbines, are the most commonly used energy source to generate steam for the SAGD process. This pathway outlines the use of nuclear energy to generate injection steam at a competitive and stable price while reducing CO2 emissions.

The Opportunity was assessed by 7 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 5.3

Expected Impact = 7.8

R Value = 63%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

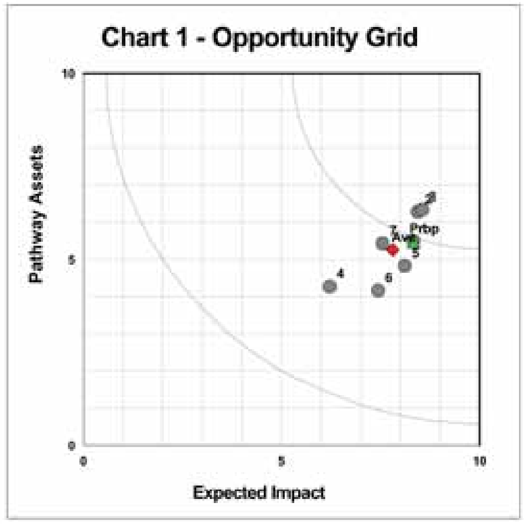
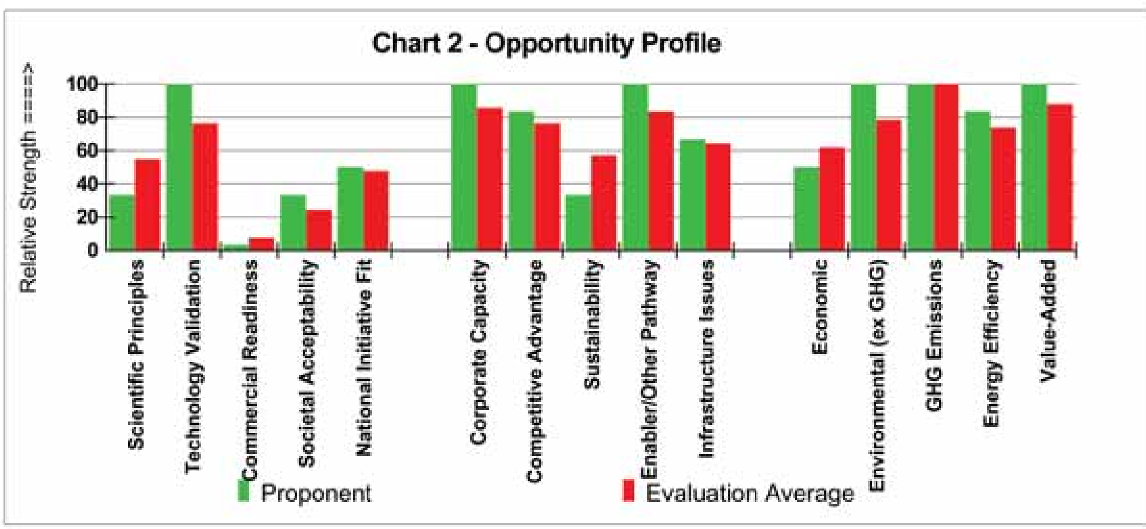


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 16 **Proponent : Dr. Robert L. Evans** **Page : 1**

Opportunity Title : Alternative Energy System for Road Vehicles

Opportunity Summary:

This pathway would use electricity as the main energy carrier for light and medium duty road vehicles, by using " plug-in hybrid", or "grid-connected" hybrid vehicles. A vehicle range of up to 100 km would be obtained using the energy stored in a battery which has been charged from the electricity grid. A small, efficient, engine would be used to extend the range when required, and to provide power "assist" on steep hills, for example. The primary energy could then be obtained from any zero greenhouse gas source, including renewable energy and nuclear power.

The Opportunity was assessed by 10 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 4.3

Expected Impact = 5.7

R Value = 49%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

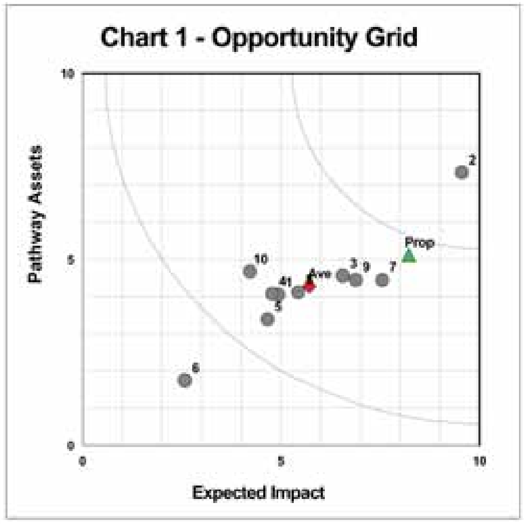
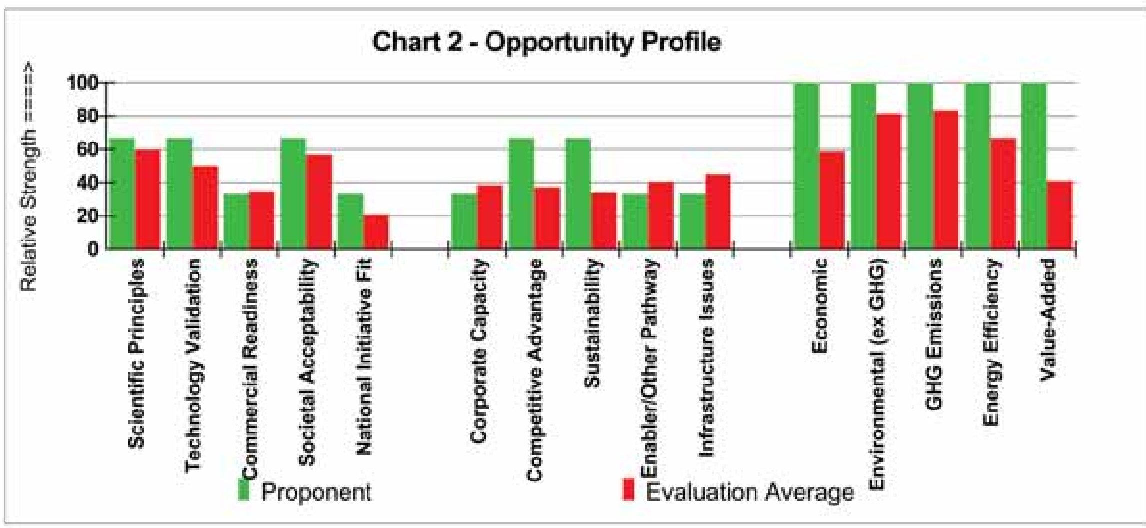


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 18	Proponent : Sadhankar, Oberth, Smith	Page : 1

Opportunity Title : Hydrogen Production Transportation and Use

Opportunity Summary:

The vision of the hydrogen economy is based on two expectations: (1) that hydrogen can be produced in a manner that is affordable and environmentally benign, and (2) that applications using hydrogen-fuel cell vehicles, for example-can gain market share in competition with the alternatives. To the extent that these expectations can be met, Canada, and indeed the world, would benefit from reduced vulnerability to energy disruptions and improved environmental quality, especially through lower carbon emissions. However, before this vision can become a reality, many technical, social, and policy challenges must be overcome. This pathway outlines the fundamental transformation that is required both on the supply side and the demand side.

The Opportunity was assessed by 7 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 4.2

Expected Impact = 5.5

R Value = 48%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

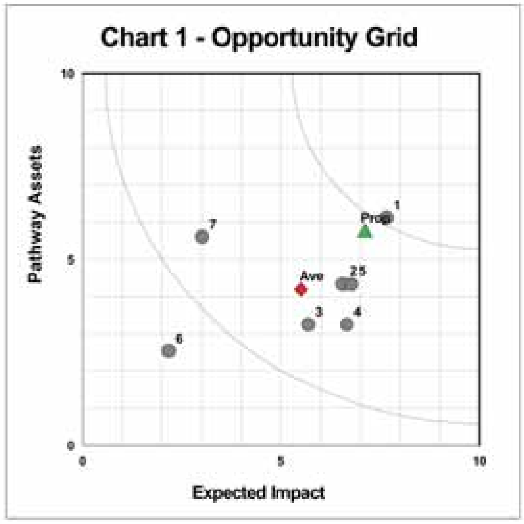
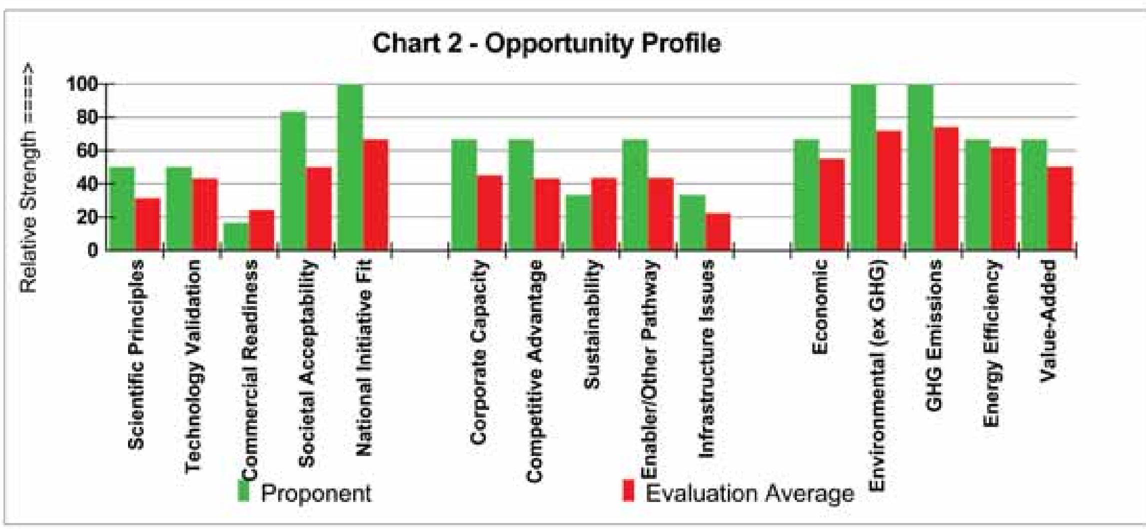


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 19a **Proponent : William Smith Greg Naterer**

Opportunity Title : Geothermal Borehole Thermal Energy Storage

Opportunity Summary:

A Geothermal Borehole Thermal Energy System (BTES) is an energy storage system that stores energy in an underground rock formation contiguous to targeted buildings. Waste heat energy produced from cooling in the summer is stored below ground and used in the winter for heating; in the winter, the waste cold energy produced for heating is stored for use in the following summer for cooling. A BTES is most economically attractive for larger scale installations (such as blocks of buildings), with installation in conjunction with original construction.

The Opportunity was assessed by 5 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 7.0

Expected Impact = 5.3

R Value = 60%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

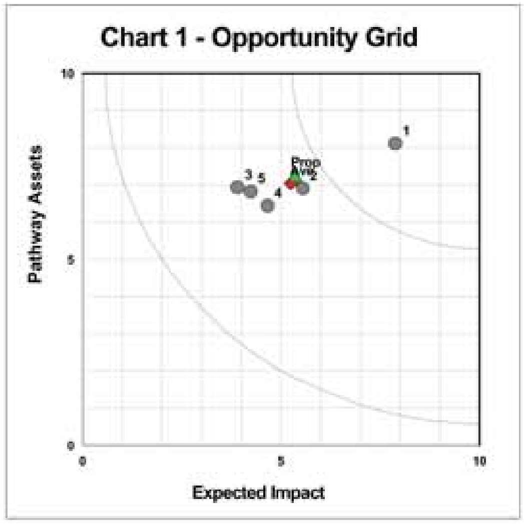
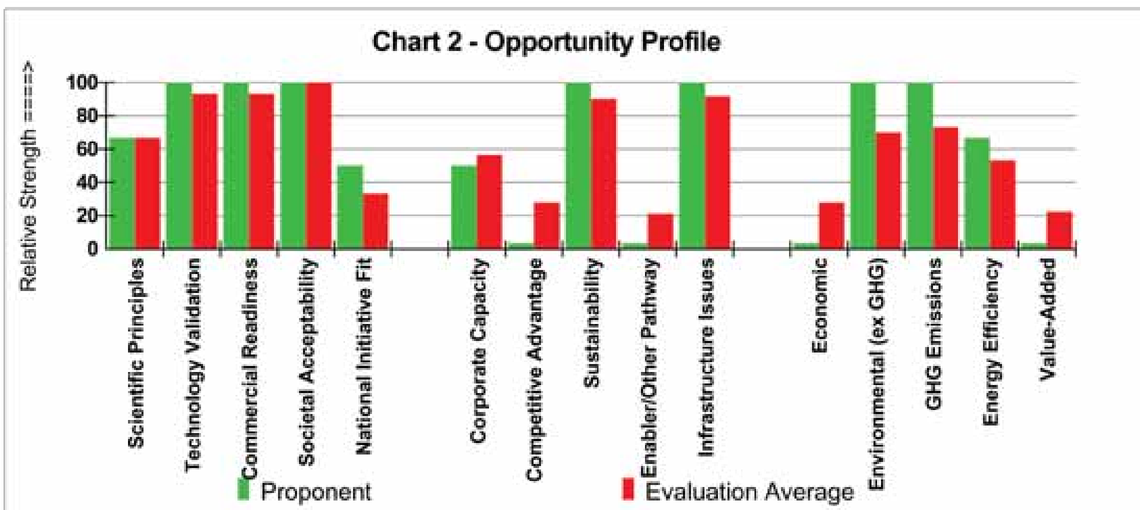


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 19b **Proponent : Doug James** **Page : 1**

Opportunity Title : Mid-depth and Deep Geothermal

Opportunity Summary:

Mid-depth (< 6000 M) and deep hot rock (> 6000 m) geothermal energy resources are potentially very significant sources of moderate temperature (40º C to 180º C) and higher temperature (>180º C) heat. This heat can be used directly for heating or commercial and industrial processing, including potentially oil sands processing and district heating, or for electrical power generation from facilities ranging in size from a few kilowatts to potentially hundreds of megawatts. New or existing reservoirs will be required for heating water (or potentially other carriers), transporting the hot fluid to the service, extracting the heat and recycling the spent fluid back to the reservoir.

The Opportunity was assessed by 6 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 4.8

Expected Impact = 5.7

R Value = 52%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

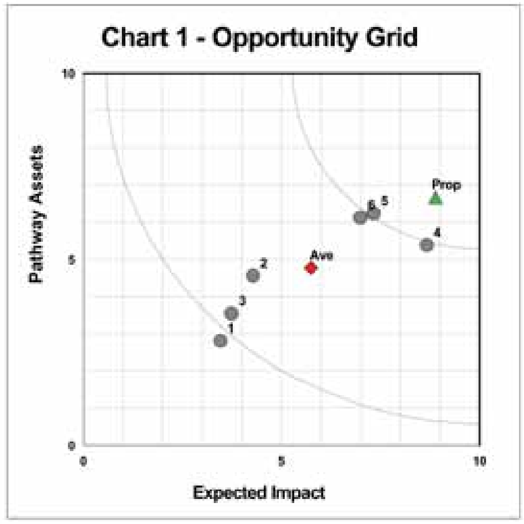
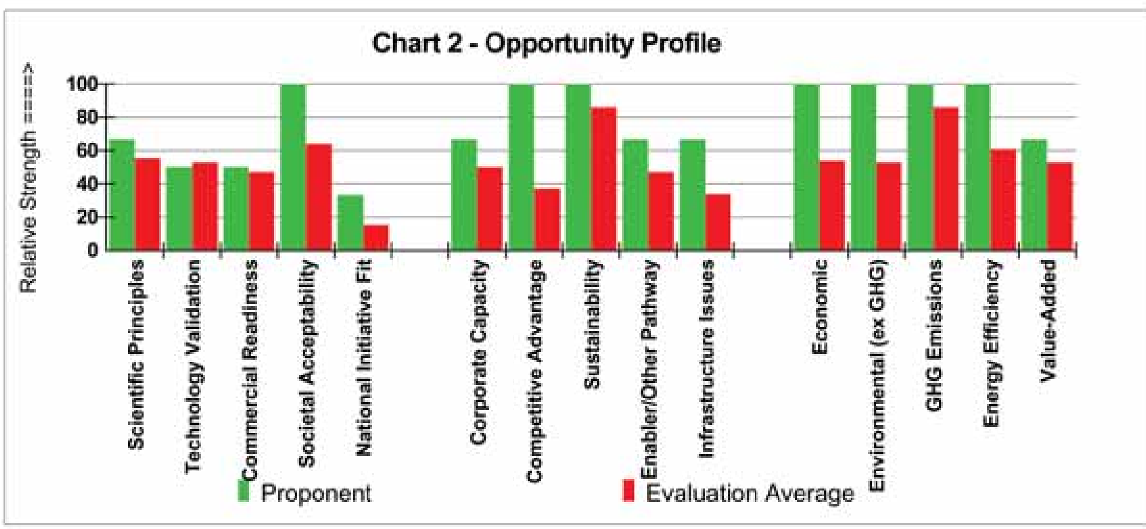


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 20 **Proponent : William Smith, Sandy Colvine, Bruce Peachey Page : 1**

Opportunity Title : Natural Gas Hydrates

Opportunity Summary:

Methane hydrates exist in large quantities below permafrost and in sub-sea sediments. Estimates of Canadian natural gas volumes in hydrate form range from 1,540 to 28,500 trillion cubic feet (45 to over 800 trillion m3). If methane can be efficiently extracted from this resource, it provides a vast new source of natural gas. Hydrate deposits which are found in Arctic gas formations in conjunction with free gas are likely to be developed first and are already in production in Russia simply by producing the free gas and depressuring the reservoirs so that the hydrate will dissociate.

The Opportunity was assessed by 5 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 2.3

Expected Impact = 4.2

R Value = 32%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

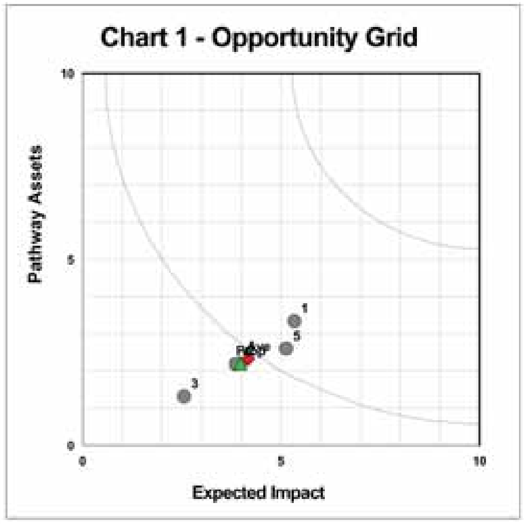
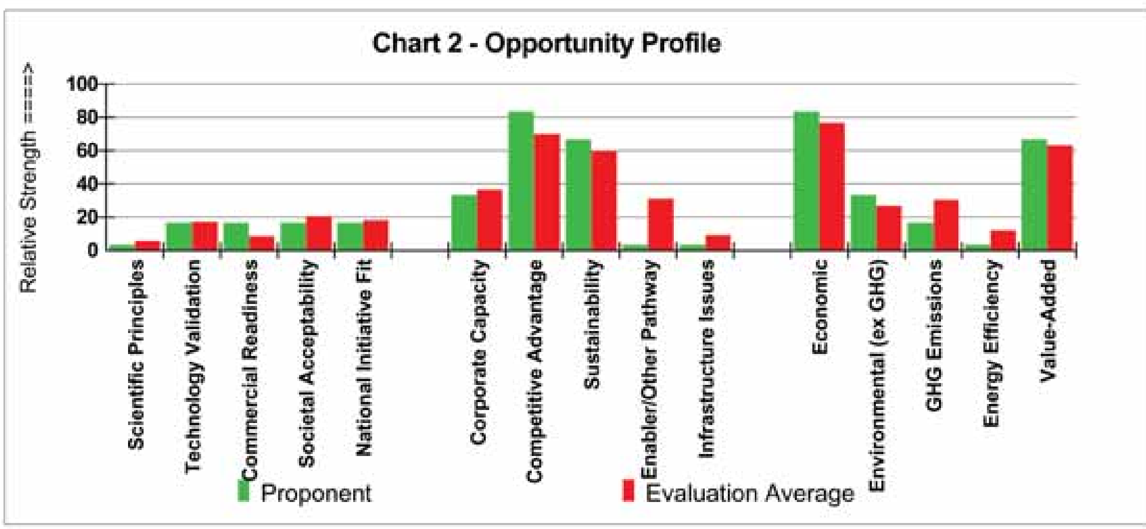


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 21 **Proponent : Bruce Peachey** **Page : 1**

Opportunity Title : Development of Coal Bed Methane

Opportunity Summary:

According to PTAC's Unconventional Gas Roadmap, Canada has over 1,500 trillion cubic feet (43 trillion m3) of coal bed methane in place, vs. about 370 Tcf (10.5 trillion m3) of remaining conventional natural gas potential. At a projected production rate of up to 7.5 Tcf/yr to meet on-going exports to the U.S., and increasing domestic demand for power generation and oilsands development, new sources such as CBM will be required to compensate for declining rates of conventional gas production. CBM production in the U.S. already provides almost 30% of the domestic gas production, is already underway in Alberta, and being considered in other provinces.

The Opportunity was assessed by 5 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 6.1

Expected Impact = 4.6

R Value = 53%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

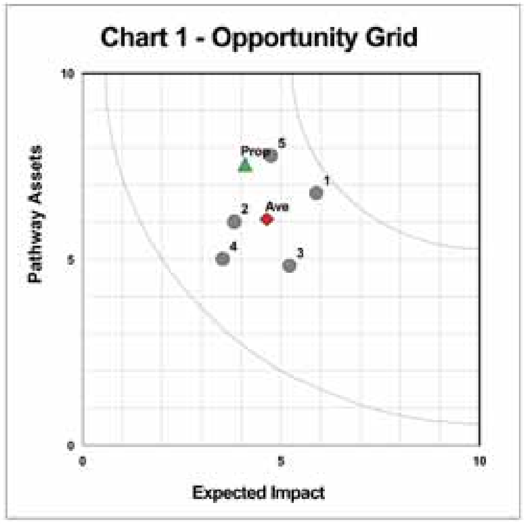
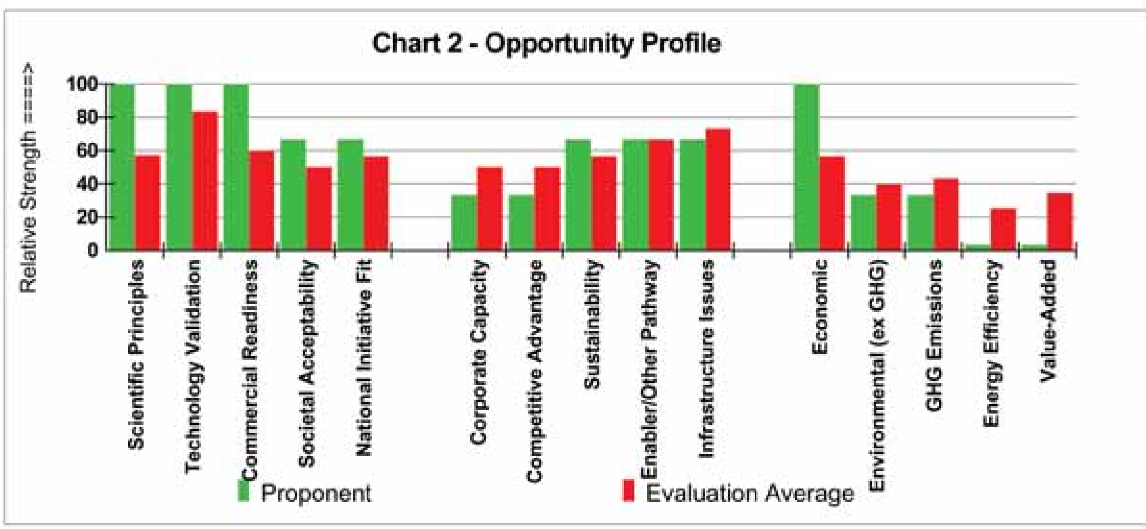


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 23 **Proponent : Dr. Chris Campbell** **Page : 1**

Opportunity Title : Tidal and Wave Energy for Electical Power

Opportunity Summary:

Canada has 40,000 MW of identified tidal stream energy, and countless irrigation channels, inflows, spillways (and instream river flow) opportunities for energy harvest. The east and west coast deepwater wave energy may exceed 200,000 MW with nearshore resources exceeding 30,000. A dozen Canadian technology companies are working with concept, prototype or pilot approaches. Ten leading international technology companies are actively looking to work in Canada because of resource availability. Canada has excellent research capacity and infrastructure to support the sector and its ocean technology, marine, and power industry capacity can readily deploy in this market. This is an emerging energy opportunity.

The Opportunity was assessed by 5 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 3.2

Expected Impact = 6.3

R Value = 45%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

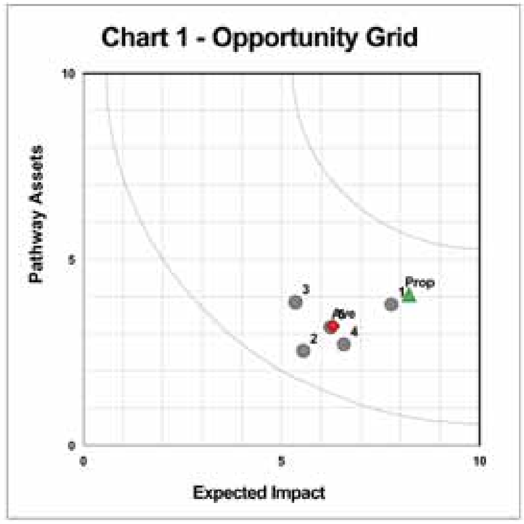
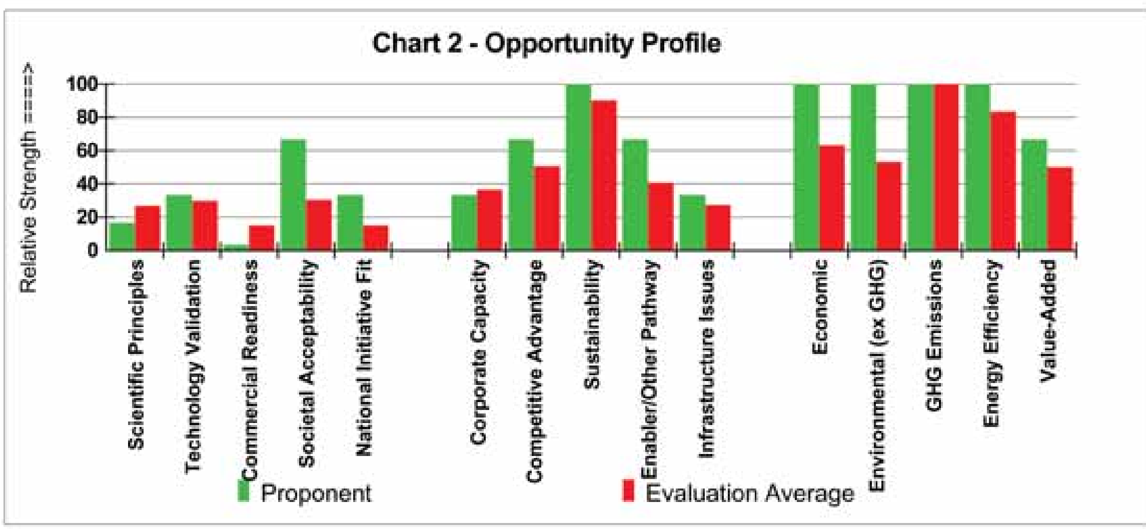


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 24 **Proponent : Dr. Surindar Singh** **Page : 1**

Opportunity Title : CO2 Capture, Transportation, Storage & Use

Opportunity Summary:

Canadian greenhouse gas (GHG) emissions to the atmosphere could be significantly reduced by extracting CO2 from gas streams in large industrial, oil sands and power plants, then compressing and transporting it to geological storage sites, such as depleted oil and gas reservoirs, deep coal seams and saline aquifers in the Western Canadian Sedimentary Basin. This is (perhaps the only) 'win-win' pathway that would minimize the impact on our economy and ensure the sustainability of our energy sector, while effectively addressing the climate change challenge.

The Opportunity was assessed by 10 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 5.3

Expected Impact = 6.7

R Value = 59%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

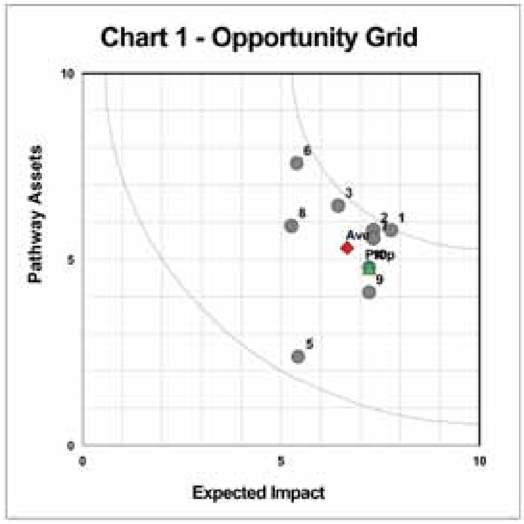
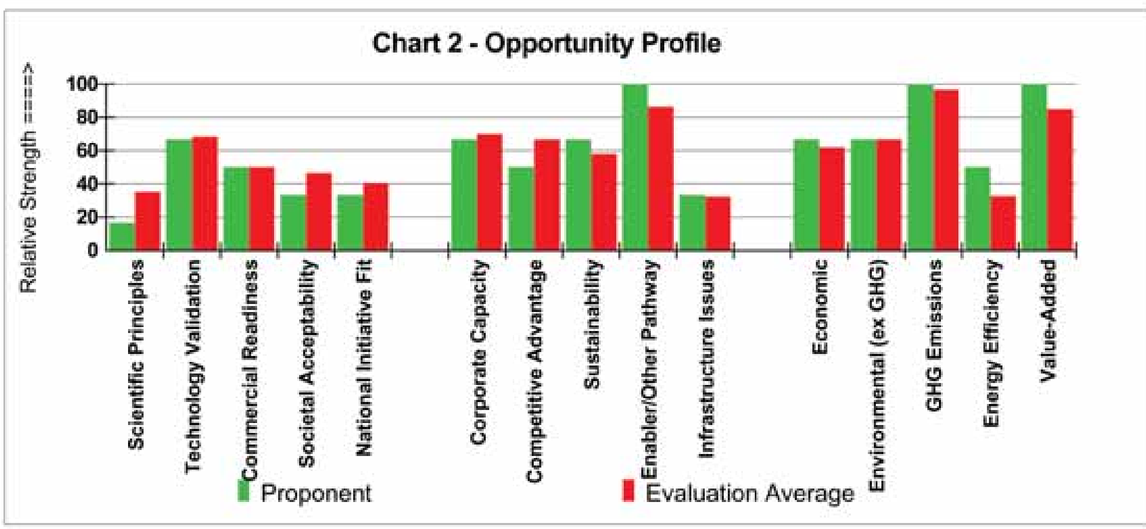


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 25 **Proponent : AECL & George Bereznai** **Page : 1**

Opportunity Title : Advanced Fission Reactors for Electical Power

Opportunity Summary:

Generation IV reactor systems are being developed with the aim of advancing fission reactors in the following areas: 1) Sustainability, 2) Safety, 3) Economics, and 4) Proliferation Resistance and Physical Protection. Six reactor systems are currently being developed under the GenIV initiative. Theses reactor systems differ in the degree of enhancement in the above four metrics and range from reactors that are highly economic for nearer term application (i.e., supercritical water cooled reactors) to reactors that would extend the Uranium supplies almost indefinitely (e.g., fast breeder reactors).

The Opportunity was assessed by 6 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 6.0

Expected Impact = 8.2

R Value = 69%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

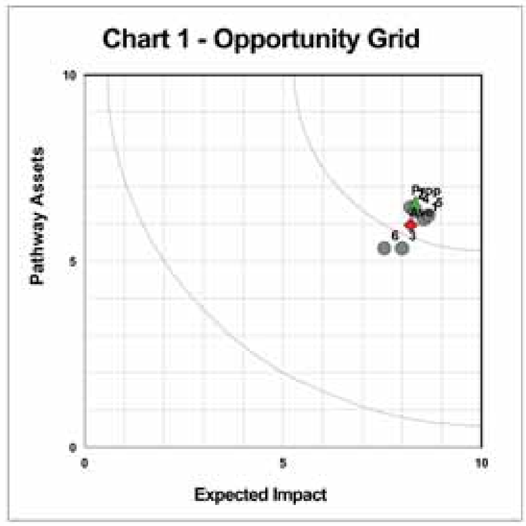
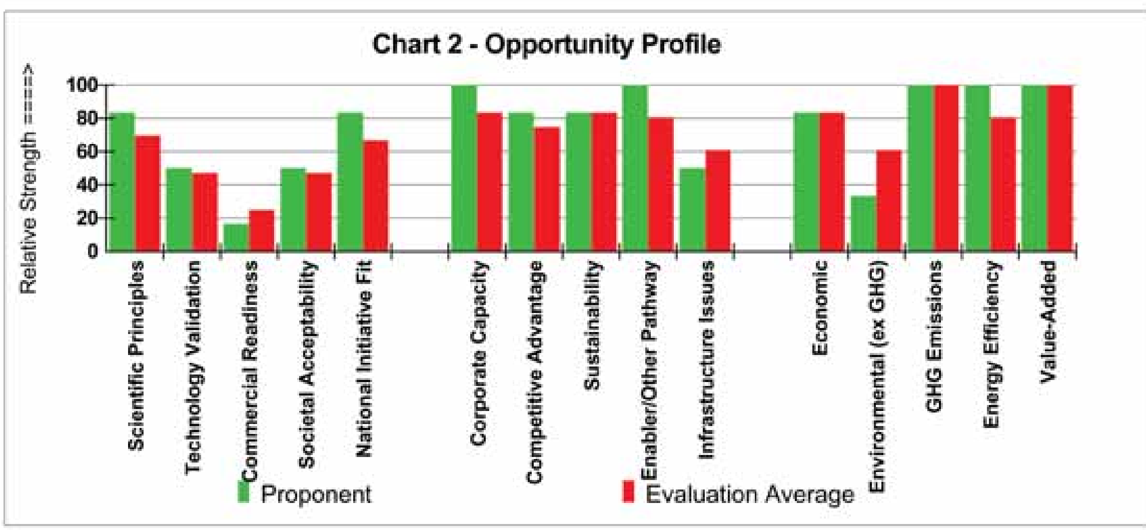


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 26 **Proponent : Dr. Rick Sydora** **Page : 1**

Opportunity Title : Magnetic Confinement Fusion for Electrical Power

Opportunity Summary:

A thermonuclear fusion power plant is based on high temperature magnetic confinement of hydrogen isotopes of deuterium and tritium. Fusion of one deuterium and one tritium atom produces one alpha particle (ionized helium atom) that carries 20% of the energy produced and one neutron that carries the remaining 80%. One gram of deuterium and tritium in equal numbers will produce an energy equivalent to almost 100,000 kwh. The alpha particles give up their energy to the plasma thereby maintaining its temperature. The neutrons, carrying most of the energy, are captured in a lithium 'blanket' surrounding the reactor vessel where they provoke further reactions with lithium to produce tritium and give up their energy to the coolant.

The Opportunity was assessed by 5 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 3.3

Expected Impact = 6.5

R Value = 47%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

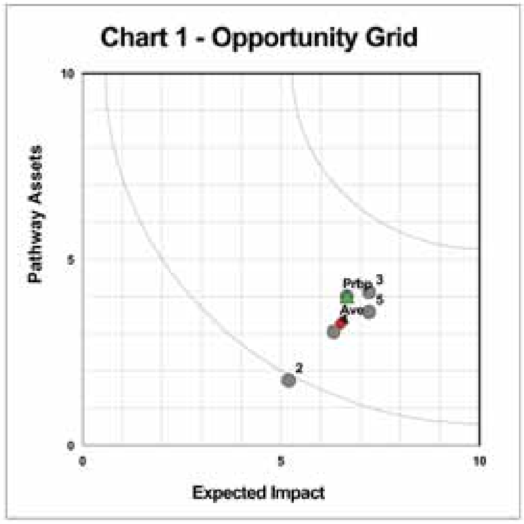
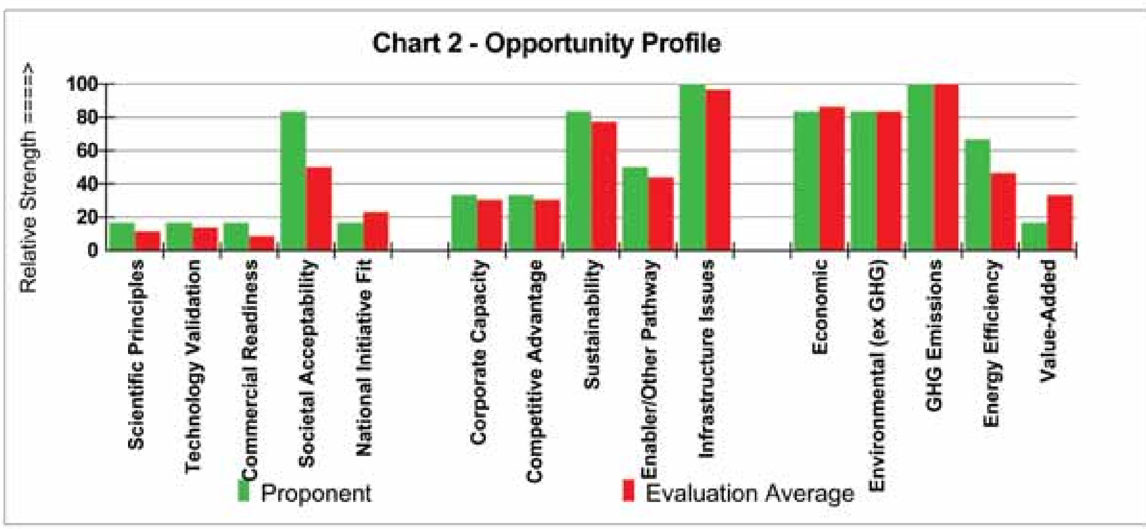


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity Title : Inertial Fusion Energy for Electricity

Opportunity Summary:

Fusion of isotopes of hydrogen (D, T) offers the potential of virtually unlimited, universally available, environmentally clean energy. Successful energy production, however, requires heating the fuel to 100 million degrees and confining it for sufficient time to provide net energy gain. The high density, short confinement time approach - inertial fusion energy (IFE) - is based on using laser (or ion) beams to compress and heat fuel pellets to ignition conditions. In a power reactor, the fusion reaction energy resulting from pellet burn (primarily in neutrons) would be captured in a circulating lithium blanket (used for both producing more tritium fuel and carrying heat to an external thermal-electric generation cycle).

The Opportunity was assessed by 10 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 5.1

Expected Impact = 8.4

R Value = 63%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

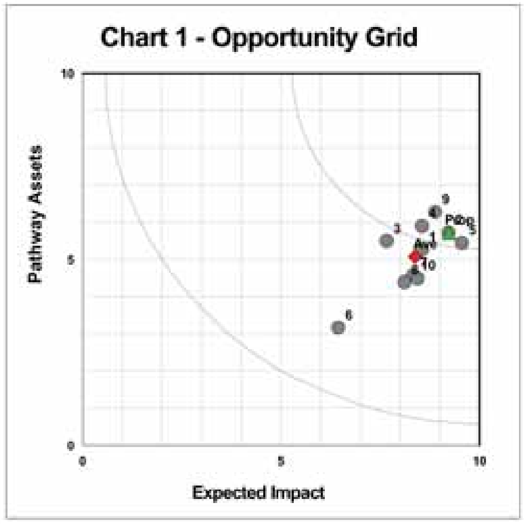
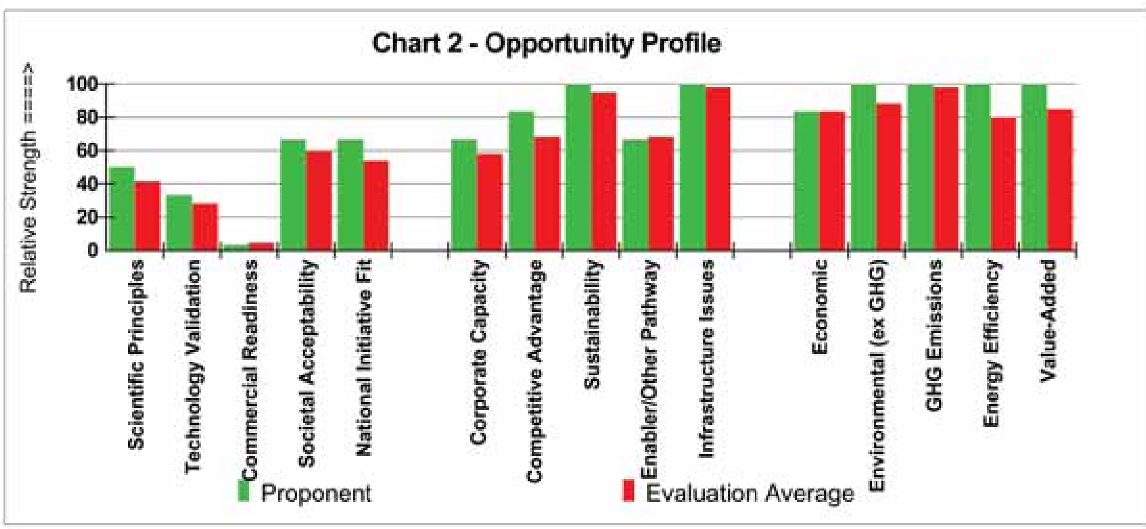


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 28 **Proponent : Ted Heidrick, Dzung Nguyen**

Opportunity Title : Recovery of Bitumen from Carbonate Deposits

Opportunity Summary:

While bitumen is generally associated with oil sands, 71.1 billion m3 or 26% of Alberta's bitumen resources are contained in carbonates rather than sand formations. The "Carbonate Triangle" deposits have been identified as being the most technically challenging. This is not a new realization, as carbonates were originally targeted for technology development by AOSTRA in the 1970's and 1980's, and did see the development of production pilots but with mixed success. However, the problems encountered 20 years ago during the pilot trials could be solvable today. The industry now has mining and drilling technologies such as continuous miner, horizontal wells and well completion technologies that would increase the likelihood of success.

The Opportunity was assessed by 7 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 4.7

Expected Impact = 6.4

R Value = 55%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

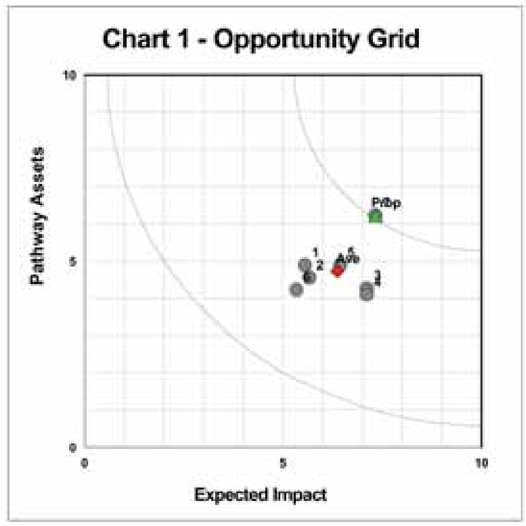
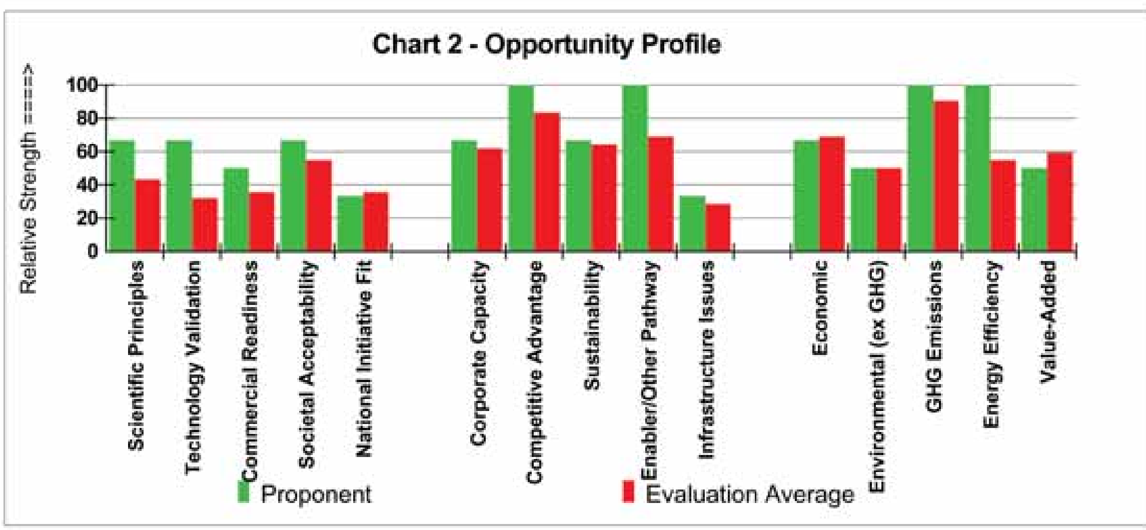


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 29 **Proponent : Bruce Peachey** **Page : 1**

Opportunity Title : Increased Conventional Oil Recovery

Opportunity Summary:

While Canadian conventional oil has been reported to be in decline, this is only from primary production from established and mature basins. Over 70% of the oil in those basins is known to be still in the reservoirs, and is awaiting enhanced oil recovery methods to be more extensively applied to increase recovery. A recent PTAC report "Ramping up Recovery" indicates that there is still over $1 trillion of conventional oil that might be produced with proven methods. At the same time additional new deposits will eventually come on-stream from the Arctic and offshore which will require unique production technologies to match the unique environments.

The Opportunity was assessed by 7 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 6.2

Expected Impact = 5.6

R Value = 59%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

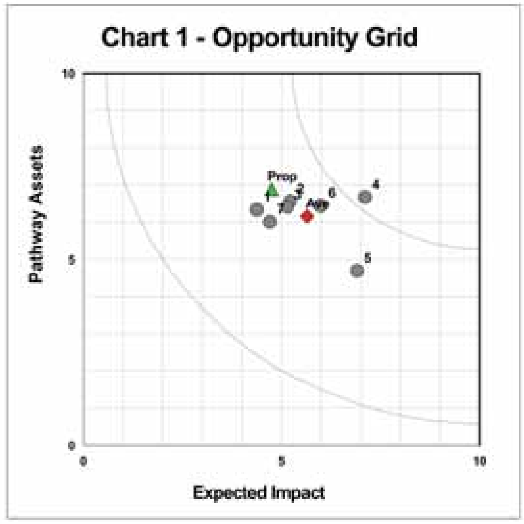
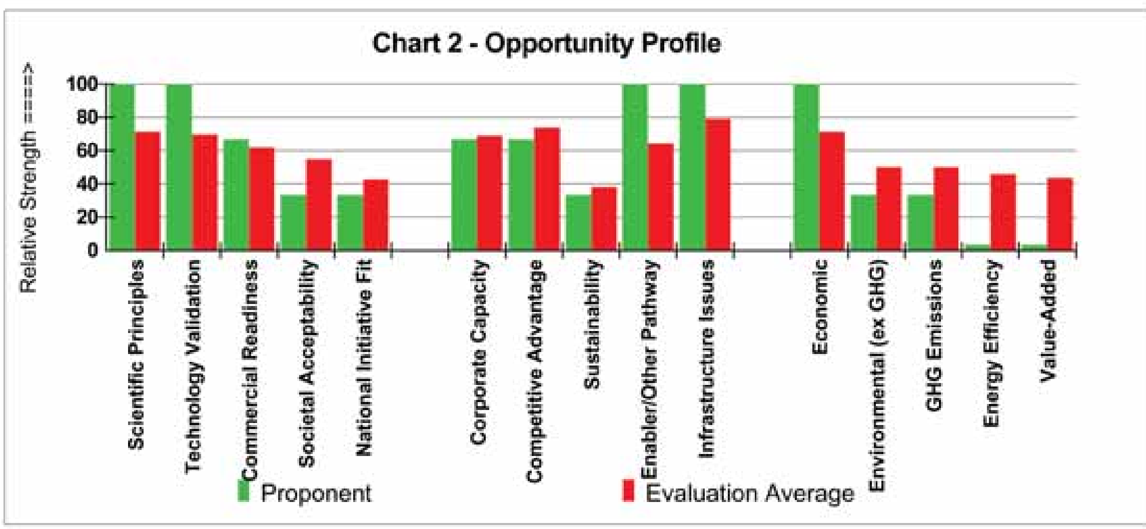


Chart 2 - Opportunity Profile.

Shows the ratings for each of the performance criteria, comparing the Proponent rating with the average rating of the Evaluators. This chart is useful in identifying strengths and weaknesses of the Opportunity and for tracking progress.



Opportunity No : 29b **Proponent : Dr. Norman Freitag** **Page : 1**

Opportunity Title : Enhanced Oil Recovery by Air Injection

Opportunity Summary:

Air injection technology could potentially be applied to several types of petroleum reservoirs ranging from deep light oils to heavy oils, with an increase of perhaps a few percent (2 to 10%?) in the recovery of conventional oil in Canada. The incremental oil would be refined, some of it after upgrading, into liquid fuels for ultimate use in engines within the agriculture, industrial and transportation sectors. Transportation would be conducted primarily by pipeline or tanker truck, depending on the volumes being transported along specific routes.

The Opportunity was assessed by 7 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 3.6

Expected Impact = 4.4

R Value = 40%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

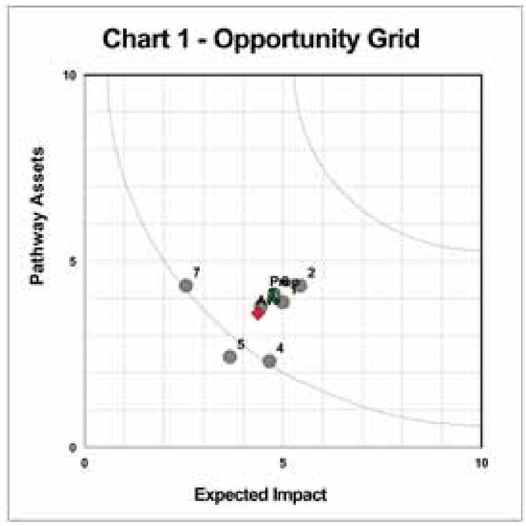


Chart 2 - Opportunity Profile.

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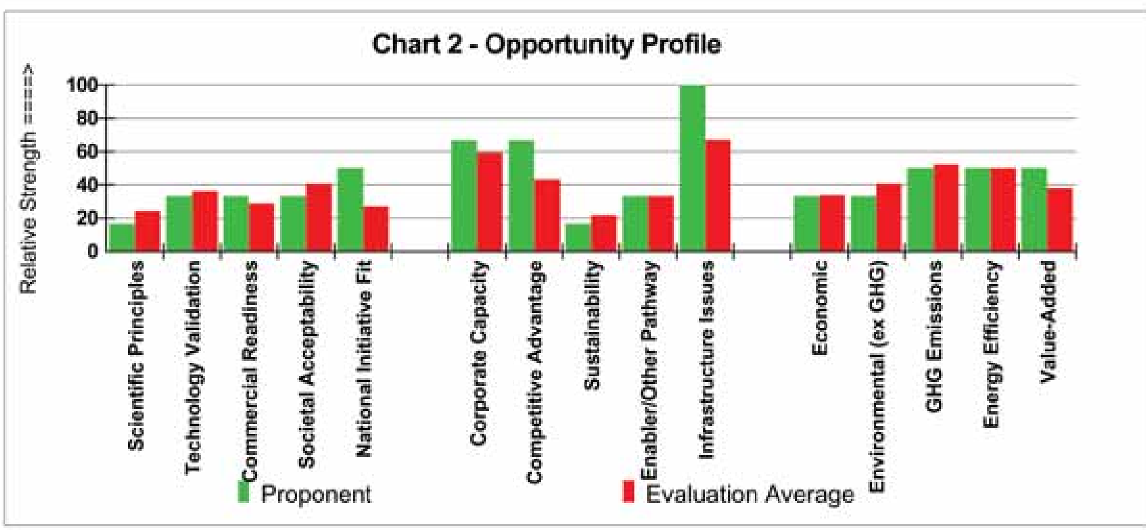

Opportunity No : 30 **Proponent : Bruce Peachey** **Page : 1**

Opportunity Title : Increased Natural Gas Recovery

Opportunity Summary:

Canadian natural gas from conventional mature basins is expected to begin a decline sometime in the next 5-10 years. Conventional gas recoveries are considered to be anywhere from 59-72% of the gas in place, depending on the pool, economics during production, etc. The recent PTAC report "Ramping up Recovery" estimated that besides the current reserves there is likely to be an additional 12-13 TCF of conventional gas, valued at over $400 billion dollars that could be recovered with better application of existing technology in Alberta and B.C. Frontier gas resources are still relatively unknown and unexploited, but would also benefit from technology advancements.

The Opportunity was assessed by 4 Evaluators.

Chart 1 - Opportunity Grid.

Shows the current grid position as determined by the Proponent, each Evaluator, the Evaluation Average, with respect to the Overarching Objectives: Expected Impact and Pathway Assets.

The Opportunity ratings have the following characteristics:

Pathway Assets = 7.3

Expected Impact = 4.6

R Value = 57%

(the R Value is a measure of the distance of the grid position for the proposed opportunity from the point X=10 and Y=10, with the point 10,10 representing 100% and the point 0,0 representing 0%)

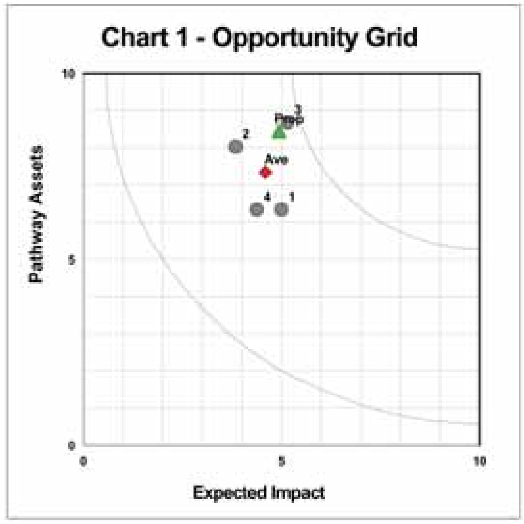

Chart 2 - Opportunity Profile.

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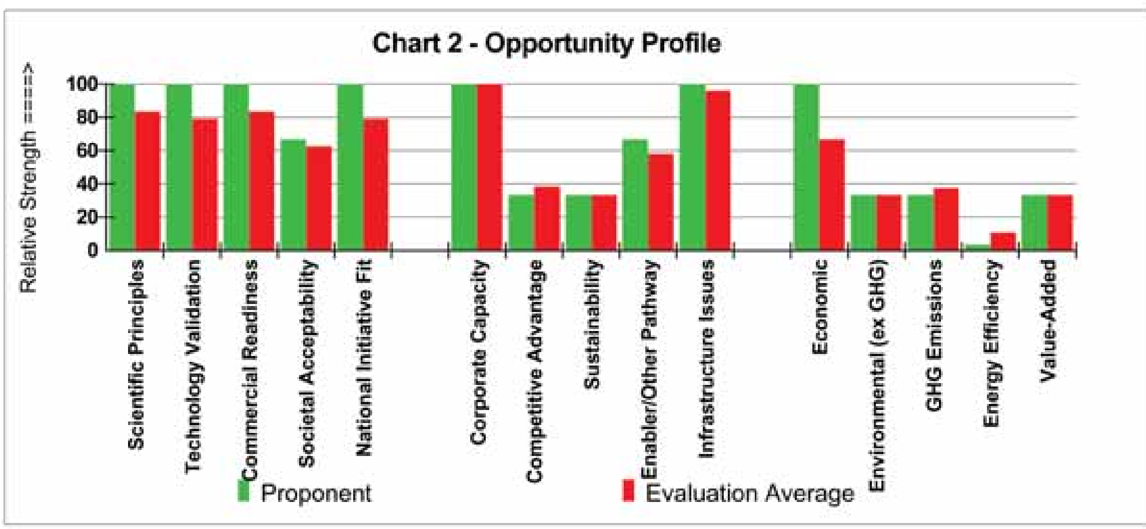

Pathway Summaries

No.	Pathway	Summary
1	Coal Gasification with CO_2 Capture	Canada has abundant coal resources; enough to meet the country's energy needs for hundreds of years. Gasification and the associated shift reaction convert coal in the presences of oxygen and steam into CO_2 and hydrogen. The hydrogen can be used for generating "clean" power, for refining oil, upgrading bitumen and for producing petrochemicals ("poly-generation") while the carbon dioxide can be captured and used in enhanced oil recovery and coal bed methane applications or sequestered in saline aquifers. Gasification economics depend on the quality of the coal and little is known about gasifying low rank (quality) Canadian coals. Canada's pathway consists of evaluating and improving known and emerging gasification technologies, and demonstrating commercial readiness for specific Canadian polygeneration applications.
2	Clean Coal Combustion	Canada has abundant coal resources. Clean coal combustion can make this resource a Canadian asset for future energy sources and remove the perception that coal is an environmental liability. Clean coal combustion will reduce emissions of NOx, SO_2, particulates and mercury to very low levels as well as capture most of the CO_2.
3	Energy Products from Agricultural & Forestry Feedstocks	On an annual basis, the renewable resource residues available from forestry, agriculture and related manufacturing industries are equivalent to approximately 25 percent of the energy Canada derives from fossil fuels. The pine beetle infestation in the forests of British Columbia, will add a substantial amount of forest bio-mass that will need to be disposed off during the next 10-20 years. Marginal agricultural land can be used to produce bio-energy crops in harmony with farming and ranching to maintain a sustainable source of biological energy feed-stocks. Proven technologies exist for converting these feed-stocks into a broad range of fuels such as wood pellets, fuel oils, bio-diesel, and ethanol from a wide variety of biological feed-stocks. Canada is well positioned to become a world leader in the production of bio-fuels.
4	Power from Agricultural Feedstocks (Straw)	Biomass is considered carbon neutral i.e. the amount of carbon released during its combustion is nearly the same as taken up by plant during its growth. This characteristic of biomass contributes enormously to the greenhouse gas mitigation. Power from straw is not economic today in western Canada, where power is generated from a large base of hydroelectric, gas fired, and coal fired plants. However, it is the "least negative cost" of any baseload large scale green power source available at large scale in Alberta. Cost of power from a large-scale straw fired power plant (more than 300 MW) is in the range of C$65- $75 per MWh. Field sourced biomass plants have a competition in cost elements between the transportation of fuel to the plant, which increases with increasing plant size, and the capital and operating cost of the plant per unit output (e.g. investment and operating cost per MWh), which decrease with increasing plant size due to economy of scale. Numerous studies, including a detailed study based on western Canada straw, confirm that the optimum size of a straw based power plant is 250 to 450 MW. Small scale power plants, e.g. 25 or 50 MW units, suffer from low thermal efficiency, due to higher heat losses, and from poor economy of scale. Straw is being used to produce heat and power in several plants in Europe on a commercial scale, and is also being cofired with coal. Technology is mature and can be implemented immediately.

No.	Pathway	Summary
5	Power and Heat from Municipal Solid Waste	In combination with an effective municipal waste recycling program, the remaining municipal solid waste (MSW) is largely a mixture of types of biomass that can be used as a fuel in combined heat and power plants to produce electricity and heat. In the past, incinerators were used in some locations to dispose of MSW. Such incinerators were often shown to operate with excessive emissions of pollutants (such as sulfur dioxide, nitrogen oxide, carbon dioxide, mercury and especially dioxins) and generally speaking have been closed. In contrast, modern waste-to-energy facilities are essentially power plants that use MSW as their source of energy. Current technology emissions control equipment allows waste-to-energy facilities to meet or exceed European and US emissions standards. There are over 400 waste-to-energy facilities operating in Europe and there are 89 operating in the US. More waste-to-energy facilities are under construction and planned in both locations. There are also a significant number of such facilities in Japan. Advances in technology that improve the economics are desirable but are likely to be incremental as opposed to being step changes. Waste-to-energy plants can provide an environmentally friendly and low foot print means of disposing of municipal solid waste relative to local or distant landfill options. This pathway can avoid the GHG emissions from methane gas escaping form landfills and reduce the GHG emissions from long distance transportation of wastes to available landfill sites while producing marketable energy products from an essentially renewable resource.
6	Wind Farms for Grid Supply	Wind farms consist of an array of factory built wind turbines and the balance of plant infrastructure to collect the electricity and feed it into the electrical grid. Wind turbines are driven by zero-cost, non-polluting fuel, the wind. Technology development in the last 20 years for the rotor, drive train and electrical power conditioning equipment, have made wind power economically competitive and desirable as a replacement for other forms of generation that are environmentally less benign. Wide spread public support has created a regulatory environment where wind farm development is favoured through a relatively rapid permitting and environmental assessment process.
9	Solar Energy for Electricity	The supply of power to homes, and the electrical grid, by generation of electricity from photovoltaic (PV) modules installed on the roofs or facades of buildings. There are two classifications: stand-alone systems that are independent of electrical supply grids but require an energy storage to ensure an uninterrupted supply; and grid-connected systems in which excess electricity from locally installed PV panels is fed through electrical interconnects to the electrical grid for distribution. In the latter case, when there is insufficient solar energy to meet the local load, power is drawn directly from the electrical grid rather than from a battery system.
11	Low Impact Surface Mineable Oil Sands	The Canadian Oil Sands have a total in place resource of over 2 trillion barrels, of which roughly 10% can be recovered by surface mining technology. Beginning with the pioneering work of the Alberta Research Council in the late 1920s and early 1930s, followed by the Alberta Government demonstration plant at Bitumount in the late 1940s, commercial production began with the Great Canadian Oil Sands Plant in the late 1960s and the Syncrude Canada plant in the 1970s. Many other companies

No.	Pathway	Summary
		are now involved and production of synthetic crude is expected to be about 2 million BPD of bitumen and synthetic crude in aggregate by 2012. The Oil Sands Technology Roadmap produced by the Alberta Chamber of Resources identified many of the internal and external challenges that the industry must address to achieve its long term goals.
12a	Solvent Vapor Extraction Process Heavy Oil	Solvent vapour extraction processes are less energy intensive, use less water, and are more suitable for thinner, partially-depleted reservoirs than are thermal recovery processes. In addition, these processes should reduce CO_2 emissions by 90% compared to steam injection. A major concerted effort between research organizations and industry will be required to make the solvent extraction process successful. A series of well defined laboratory studies, scaled and mechanistic physical modeling, and numerical simulations coordinated with ongoing field pilot operations will provide the technical and economical de-risking required for industry acceptance and wide-spread commercial application.
13	Alternative Hydrogen Supply for Oil Sands Development	Hydrogen is a key additive in the transformation of oil sands bitumen into synthetic crude oil (SCO). The current method of producing it is Steam-Methane Reforming (SMR), which consumes an increasingly expensive and scarce resource (natural gas) and co-produces substantial CO_2. Although other hydrogen production methods are potentially feasible (see Pathway 18 - Hydrogen Production by New Technologies, Transportation and Use), production by electrolysis is a mature technology. Hydrogen by electrolysis with the electricity produced by a nuclear reactor is now an economically attractive alternative, especially if it can be produced intermittently using off-peak electricity. It has the added benefit of long-term price stability.
14	Value-added Products from Oil Sands Development.	Alberta has very large recoverable reserves in the oil sands – more than those of Saudi Arabia. Current production levels of approximately 1 million barrels per day of bitumen and synthetic crude oil will more than triple by 2030, provided costs of recovery and upgrading can be continuously reduced through improved technology. An expanded mix of products and new markets must be developed, to avoid long term depressed netbacks on unprocessed bitumen. Canada's pathway to value-added products from oil sands bitumen will focus on improved bitumen characterization, new separation technologies, new catalysts, and integration of upgrading and refining processes, including gasification.
15	Nuclear Fission Energy for Oil Sands Development	The Athabasca region in northern Alberta includes the world's largest oil sands (crude bitumen) deposits and is the fastest growing source of crude oil in North America. Approximately 175 billion barrels of oil - comparable to the oil reserves in Saudi Arabia - are economically recoverable using surface mining and steam assisted gravity drainage (SAGD) technique for in-situ bitumen extraction. The Alberta oil sands region currently produces the equivalent of about 15% of Canadian primary energy usage and is expected to triple its output in the next ten years. The SAGD process injects medium pressure steam into an oil sand reservoir to reduce the viscosity of the bitumen in order to enable its extraction. SAGD operations currently represents only about 10% of total oil sands production but is expected to become the dominant recovery process due to large underground reserves, improving technology / recovery performance and generally lower environmental impact than surface mining. Once through steam generators (OTSG), occasionally backed up by combined-cycle gas turbines, are the most commonly used energy source to generate steam for the SAGD process. Increasing and volatile natural gas prices and

No.	Pathway	Summary
		supply uncertainties, coupled with concerns over CO_2 emissions, will limit the future use of natural gas as a prime energy source. This pathway outlines the potential to use of nuclear energy to generate injection steam at a competitive and stable price while reducing CO_2 emissions.
16	Alternative Energy Systems for Road Vehicles	This pathway would use electricity as the main energy carrier for light and medium duty road vehicles, by using " plug-in hybrid", or "grid-connected" hybrid vehicles. A vehicle range of up to 100 km would be obtained using the energy stored in a battery which has been charged from the electricity grid. A small, efficient, engine would be used to extend the range when required, and to provide power "assist" on steep hills, for example. The primary energy could then be obtained from any zero greenhouse gas source, including renewable energy and nuclear power.
18	Hydrogen Production, Transportation and Use	The vision of the hydrogen economy is based on two expectations: (1) that hydrogen can be produced in a manner that is affordable and environmentally benign, and (2) that applications using hydrogen—fuel cell vehicles, for example—can gain market share in competition with the alternatives. To the extent that these expectations can be met, Canada, and indeed the world, would benefit from reduced vulnerability to energy disruptions and improved environmental quality, especially through lower carbon emissions. However, before this vision can become a reality, many technical, social, and policy challenges must be overcome. This pathway outlines the fundamental transformation that is required both on the supply side (technologies and resources for hydrogen production) and the demand side (technologies and devices to convert hydrogen to energy) of the hydrogen economy.
19a	Geothermal Borehole Thermal Energy Storage (BTES) System	A Geothermal Borehole Thermal Energy System (BTES) is an energy storage system that stores energy in an underground rock formation contiguous to targeted buildings. Waste heat energy produced from cooling in the summer is stored below ground and used in the winter for heating; in the winter, the waste cold energy produced for heating is stored for use in the following summer for cooling. A BTES is most economically attractive for larger scale installations (such as blocks of buildings), with installation in conjunction with original construction.
19b	Mid-depth and Deep Geothermal Energy	This pathway will not consider shallow geothermal, as this is a well developed technology and is available commercially. Mid-depth (< 6000 M) and deep hot rock (> 6000 m) geothermal energy resources are potentially very significant sources of moderate temperature (40°C to 180°C) and higher temperature (>180°C) heat. This heat can be used directly for heating or commercial and industrial processing, including potentially oil sands processing and district heating, or for electrical power generation from facilities ranging in size from a few kilowatts to potentially hundreds of megawatts. The key features on non-hydrothermal (i.e. geyser) type sources of geothermal heat is that they will require the creation of new or utilization of existing reservoirs for heating water (or potentially other carriers), transporting the hot fluid to the service, extracting the heat and recycling the spent fluid back to the reservoir. The surface technologies are typical of power generation currently in use.
20	Natural Gas Hydrates	Methane hydrates exist in large quantities below permafrost and in sub-sea sediments. Estimates of Canadian natural gas volumes in hydrate form range from 1,540 to 28,500 trillion cubic feet (45 to over 800 trillion m^3). If methane can be efficiently extracted from this resource, it provides a vast new source of natural gas. Hydrate deposits which are found in Arctic gas formations in conjunction with free

No.	Pathway	Summary
		gas are likely to be developed first and are already in production in Russia simply by producing the free gas and depressuring the reservoirs so that the hydrate will dissociate.
21	Development of Coal Bed Methane	According to PTAC's Unconventional Gas Roadmap, Canada has over 1,500 trillion cubic feet (43 trillion m^3) of coal bed methane in place, vs. about 370 Tcf (10.5 trillion m^3) of remaining conventional natural gas potential. At a projected production rate of up to 7.5 Tcf/yr to meet on-going exports to the U.S., and increasing domestic demand for power generation and oil sands development, new sources such as CBM will be required to compensate for declining rates of conventional gas production. CBM production in the U.S. already provides almost 30% of the domestic gas production, is already underway in Alberta, and being considered in other provinces.
23	Tidal and Wave Energy for Electrical Power	Canada has 40,000 MW of identified tidal stream energy, and countless irrigation channels, inflows, spillways (and instream river flow) opportunities for energy harvest. The east and west coast deepwater wave energy may exceed 200,000 MW with nearshore resources exceeding 30,000. A dozen Canadian technology companies are working with concept, prototype or pilot approaches. Ten leading international technology companies are actively looking to work in Canada because of resource availability. Canada has excellent research capacity and infrastructure to support the sector and its ocean technology, marine, and power industry capacity can readily deploy in this market. This is an emerging energy opportunity.
24	Carbon Dioxide Capture, Transportation, Storage and Use	Canadian greenhouse gas (GHG) emissions to the atmosphere could be significantly reduced by extracting CO_2 from gas streams in large industrial, oil sands and power plants, then compressing and transporting it to geological storage sites, such as depleted oil and gas reservoirs, deep coal seams and saline aquifers in the Western Canadian Sedimentary Basin. This is (perhaps the only) 'win-win' pathway that would minimize the impact on our economy and ensure the sustainability of our energy sector, while effectively addressing the climate change challenge.
25	Advanced Fission Reactors for Electrical Power	Generation IV reactor systems are being developed with the aim of advancing fission reactors in the following areas: 1) Sustainability, 2) Safety, 3) Economics, and 4) Proliferation Resistance and Physical Protection. Six reactor systems are currently being developed under the GenIV initiative. Theses reactor systems differ in the degree of enhancement in the above four metrics and range from reactors that are highly economic for nearer term application (i.e., supercritical water cooled reactors) to reactors that would extend the Uranium supplies almost indefinitely (e.g., fast breeder reactors).
26	Magnetic Confinement Fusion for Electrical Power	A thermonuclear fusion power plant is based on high temperature magnetic confinement of hydrogen isotopes of deuterium and tritium. Fusion of one deuterium and one tritium atom produces one alpha particle (ionized helium atom) that carries 20% of the energy produced and one neutron that carries the remaining 80%. One gram of deuterium and tritium in equal numbers will produce an energy equivalent to almost 100,000 kwh. The alpha particles give up their energy to the plasma thereby maintaining its temperature. The neutrons, carrying most of the energy, are captured in a lithium 'blanket' surrounding the reactor vessel where they provoke further reactions with lithium to produce tritium and give up their energy to the coolant. The coolant in the closed coolant cycle in turn gives up its energy via a

No.	Pathway	Summary
		heat exchanger to the external coolant cycle, which drives conventional turbines and thus produces electricity.
27	Inertial Fusion Energy for Electricity	Fusion of isotopes of hydrogen (D, T) offers the potential of virtually unlimited, universally available, environmentally clean energy. Successful energy production, however, requires heating the fuel to 100 million degrees and confining it for sufficient time to provide net energy gain. The high density, short confinement time approach - inertial fusion energy (IFE) - is based on using laser (or ion) beams to compress and heat fuel pellets to ignition conditions. In a power reactor, the fusion reaction energy resulting from pellet burn (primarily in neutrons) would be captured in a circulating lithium blanket (used for both producing more tritium fuel and carrying heat to an external thermal-electric generation cycle). Attributes include: a) no greenhouse gas emissions, b) no long-term radioactive waste storage, c) no possibility of reactor runaway.
28	Recovery of Bitumen from Carbonate Deposits	While bitumen is generally associated with oil sands, 71.1 billion m^3 or 26% of Alberta's bitumen resources are contained in carbonates rather than sand formations. The "Carbonate Triangle" deposits have been identified as being the most technically challenging. This is not a new realization, as carbonates were originally targeted for technology development by AOSTRA in the 1970's and 1980's, and did see the development of production pilots but with mixed success. However, the problems encountered 20 years ago during the pilot trials could be solvable today. The industry now has mining and drilling technologies such as continuous miner, horizontal wells and well completion technologies that would increase the likelihood of successful recovery of bitumen from carbonates. (Peachy, B.; Heidrick, T.; et al., May 31, 2006)
29	Increased Conventional Oil Recovery	While Canadian conventional oil has been reported to be in decline, this is only from primary production from established and mature basins. Over 70% of the oil in those basins is known to be still in the reservoirs, and is awaiting enhanced oil recovery methods to be more extensively applied to increase recovery. A recent PTAC report "Ramping up Recovery" indicates that there is still over $1 trillion of conventional oil that might be produced with proven methods. At the same time additional new deposits will eventually come on-stream from the Arctic and offshore which will require unique production technologies to match the unique environments.
29b	Enhanced Oil Recovery by Air Injection Processes	Air injection technology could potentially be applied to several types of petroleum reservoirs ranging from deep light oils to heavy oils, with an increase of perhaps a few percent (2 to 10%?) in the recovery of conventional oil in Canada. The incremental oil would be refined, some of it after upgrading, into liquid fuels for ultimate use in engines within the agriculture, industrial and transportation sectors. Transportation would be conducted primarily by pipeline or tanker truck, depending on the volumes being transported along specific routes.
30	Increased Natural Gas Recovery	Canadian natural gas from conventional mature basins is expected to begin a decline sometime in the next 5-10 years. Conventional gas recoveries are considered to be anywhere from 59-72% of the gas in place, depending on the pool, economics during production, etc. The recent PTAC report "Ramping up Recovery" estimated that besides the current reserves there is likely to be an additional 12-13 TCF of conventional gas, valued at over $400 billion dollars that could be recovered with better application of existing technology in Alberta and B.C. Frontier gas resources are still relatively unknown and unexploited, but would also benefit from technology advancements.

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