

January, 2006



## 2006-11 Strategic Business Plan

*Mobilizing Advanced Technologies  
to Capture  
Alberta's Energy Potential*



Photo credit: Alberta Geological Survey

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# Executive Summary

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## Alberta's Clean Energy Challenges and AERI's Role

Alberta has over 70% of the world's oil sands resources. When combined with the province's coal and natural gas resources, we have one of the largest supplies of hydrocarbons in the world. Alberta's current prosperity is largely based on the past aggressive public and private investments in research and development and field trials which led to many new recovery and processing technologies and an array of enabling technologies such as horizontal drilling, instrumentation, automation, reservoir simulations and 3-D seismic surveys. While the potential for Alberta's energy economy has never been greater, the technological challenges facing the energy industry in Alberta have also never been greater

Production from conventional oil and gas resources has peaked and is declining; new technology is required to unlock the large remaining conventional energy reserves. Given the availability of the right technologies, bitumen, coal and coal bed methane have hundreds of years of production remaining, but production of those reserves depends on finding effective solutions and technologies that address the following challenges:

- The production costs which are affected by rising cost of natural gas.
- The increasing cost of hydrogen which is vital for the upgrading of bitumen to higher valued products.
- The limited availability of natural gas liquids which are used as feedstocks for the growing petrochemical sector.
- The limited market for bitumen and synthetic crude which with additional production coming on stream will result in lose of value for these products.
- The growing imperative to replace conventional coal burning plants for electricity generation by near-emission-free clean coal technology.
- The need to move from a relatively low to a much higher proportion of renewable and hydrogen energy options in the mix of energy production
- The need to address air emissions, land access, and water management issues which are critical to ensuring continued "access to resources".
- The growing gap of CO<sub>2</sub> emissions that need to be addressed in the context of climate change.

On behalf of the Government of Alberta (GOA), the AERI Board and staff have accepted the challenge to provide leadership to shape our energy future and promote sustained investments in energy research and innovation. AERI continues to work with industry on finding risk sharing mechanisms for high risk and costly demonstration and commercialization of technology to address the technical, economic, and environmental challenges faced by the energy industry.

## Providing Visionary Leadership to Shape Alberta’s Energy Future

In February 2004, the Alberta Energy Innovation Strategy become official government policy and was highlighted in the Speech from the Throne. In a powerful way, it serves as the innovation component of Alberta Government’s Climate Change Action Plan, the Integrated Energy Strategy and the Value Added Strategy. It is also well positioned to serve as the energy research component of the Water for Life Strategy.

The Alberta Energy Innovation Strategy is based on the following key principles:

- Secure maximum value for Albertans from all energy resources
- Stimulate economic development in Alberta
- Increase access and effectiveness of energy markets
- Increase development of clean energy and the “access to resources”
- Reduce the environmental impacts of energy development

The Alberta Energy Innovation Strategy was developed from recognition that solution to energy challenges emerge when the energy industry is seen as one interconnected system – integrated horizontally across the energy system and vertically along the value chain through technology platforms. Taking advantage of these points of leverage leads to significant new breakthrough opportunities while balancing economic gains with environmental responsibility.

## Taking a Systems Approach

When the energy industry is seen as one interconnected system, key issues such as hydrogen requirements for upgrading, water reuse, and greenhouse gas emissions are addressed through effective integration. Working with its stakeholders, AERI built its portfolio management system by applying **SMART Objectives** methodology resulting in key platform technologies.

Platform Technology	Strategic Areas					
	Clean Carbon/Coal	Upgrading	Improved Recovery	Renewable Energy	CO <sub>2</sub> Management	Water Management
CO <sub>2</sub> Storage	Major Impact	Major Impact	Major Impact	Minor Impact	Major Impact	Major Impact
Gasification	Major Impact	Major Impact	Major Impact	Major Impact	Major Impact	Minor Impact
Catalysis	Major Impact	Major Impact	Major Impact	Major Impact	Major Impact	Minor Impact
Separation	Major Impact	Major Impact	Major Impact	Major Impact	Major Impact	Minor Impact
In Situ Tech.	Minor Impact	Major Impact	Major Impact	Minor Impact	Major Impact	Major Impact
Hydrogen Tech.	Major Impact	Major Impact	Major Impact	Major Impact	Major Impact	Minor Impact
Water Treatment	Minor Impact	Minor Impact	Major Impact	Minor Impact	Minor Impact	Major Impact

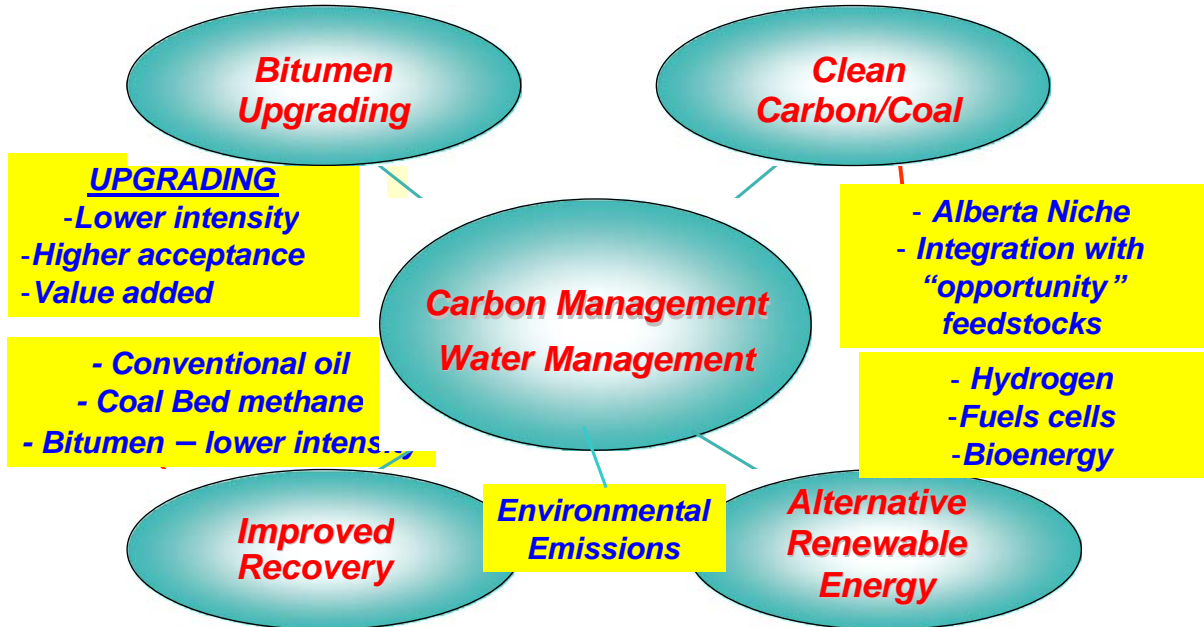
  

	Major Impact		Secondary Impact		Minor Impact
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**Figure 1: Summary of platform technologies and impact on Strategic Areas.**

## Providing Strategic Focus

In order to achieve its overall objectives, the Alberta Energy Innovation Strategy is focused on six innovation programs as illustrated below.



**Figure 2: Showing AERI strategic priority research and technology areas.**

The strategic focus provided by the AERI strategy has directly guided the energy research programs at the Alberta Research Council, Universities of Alberta and Calgary. All three organizations feature prominently AERI's strategic priority research and technology areas in their business plans. The focus areas have also influenced the Federal science and technology programs and directions.

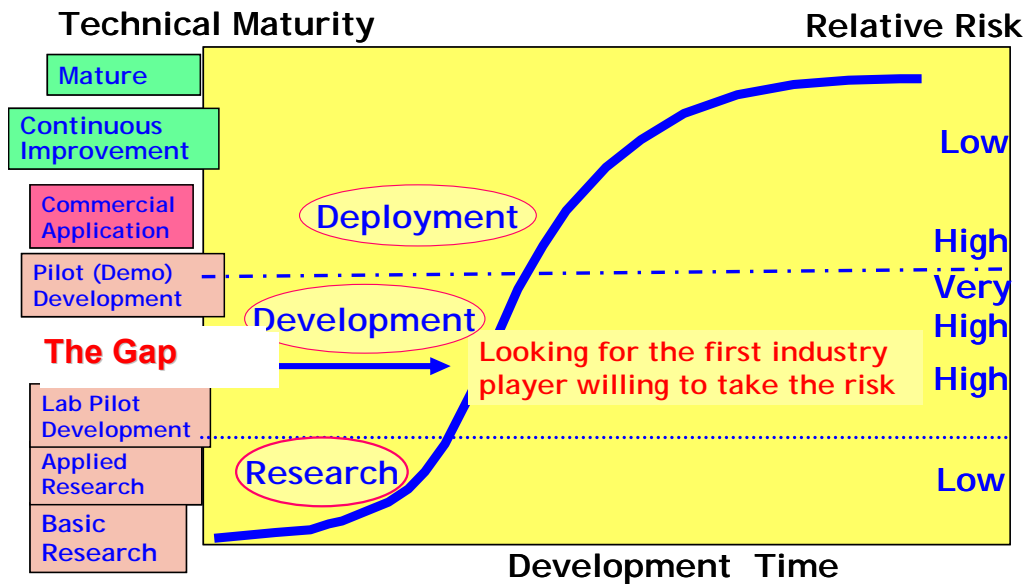
## Promoting Risk Sharing Mechanisms for Technology Development

Energy innovation is needed across the full technology development path, encompassing fundamental research, technology development, and continuous improvement of commercial experience. The oil sands experience has shown that governments, where it makes long term strategic and business sense, can be instrumental in providing leadership to address the innovation gap between research and the higher cost and risk inherent in costly demonstration and commercialization of advanced technology.

Consistent with this strategy of accelerating the pace of commercialization, AERI supports the DOVAP Pilot to test new technology that uses solvents in lieu of steam for bitumen recovery and has the potential of significantly reducing natural gas use and lowering GHG emissions. AERI's pro-active approach to feasibility

and business case analysis has also led to the development of the Innovative Energy Technology Program (IETP) by the Alberta Department of Energy. IETP is a \$200 Million royalty incentive program for industry to field test advanced *in situ* oil and gas recovery technology. AERI manages the project evaluations and the intellectual property including the dissemination of the learnings from IETP on behalf of the Department of Energy.

In the key technology platforms such as gasification AERI is focusing on filling the technology gaps and intends to participate in pilot testing of clean coal technology to produce hydrogen, electricity and heat and in conversion of domestic and industrial waste to electricity (see Major Priorities section below).



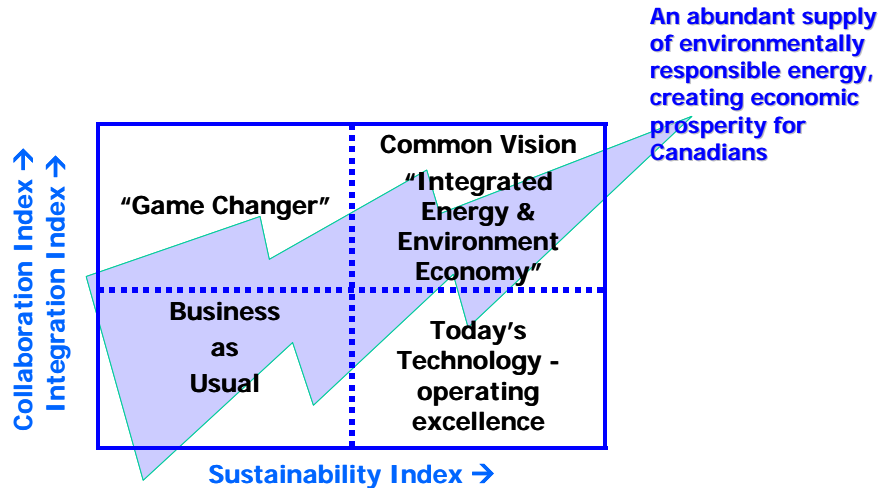
**Figure 3: Reducing risk to cross the innovation gap from research to commercialization (Adapted from Ken McCready and Judy Fairburn).**

### Proactive Strategy Implementation and EnergyINet

The Alberta Energy Innovation Strategy is being implemented through the direct involvement and guidance of industry and the innovative capacity of the research community. AERI is working closely with these partners to position Alberta for the future in energy.

AERI's main initiative has been the establishment of EnergyINet as a fully integrated and collaborative research network across Canada. Since its recent incorporation, the election of a new Board of Directors and the appointment of a new CEO, EnergyINet Inc. is in the process of strategically positioning itself to play a key role in developing Canada as an "energy superpower" by bringing together industry, governments and researchers to contribute to a pan-Canadian, integrated energy production and environmental innovation framework.

AERI created EnergyINet to be a vehicle for transformation – moving from the traditional approach of funding projects by single research providers to a higher level network approach that integrates across boundaries and achieves industry-federal-provincial goals to accelerate innovation for common problems faced by other jurisdictions.



**Figure 4: Schematic showing the power of collaboration and integration to “change the game” and the positioning of EnergyINet.**

### Major Priorities for the Next Five Years

Partnership and international collaboration will continue to guide AERI as expressed in the following statement:

*Public and private sector partners from across Canada will work together on research and technology to further oil sands technology, develop cleaner coal technology, reduce greenhouse gas emissions, manage water resources, improve conventional oil and gas recovery and explore alternative energy sources.*

The strategy can make huge contributions to the Alberta and Canadian economy, with beneficial social and environmental impacts over the next 20 or more years. The challenge is to continue the process of converting this strategy into action and to harness the innovative power of Alberta and Canadian engineers and scientists to generate the new technologies needed to achieve the objectives. For this reason, the focus will be on the following priorities:

- **EnergyINet:** Proactively participate with EnergyINet in developing scenario’s and modelling of Canada’s energy pathways, and business plans that will attract substantial new investments from industry and governments ensuring that Alberta’s interests are well represented.

- **Capacity Building:** Sustain investments in energy research and innovation through both strong university based programs and industrial training that will attract world-class researchers and support the development of the energy industry in Alberta.
- **Balanced Portfolio:** Maintain a balanced portfolio of energy research, development and demonstration projects, based on market intelligence and current, near-term and future Alberta resource development needs.
- **Technology Transfer:** Undertake analysis and technology evaluations focussed on investments being made by AERI and the Department of Energy (IETP) and ensure dissemination and effective transfer of technology.
- **Tools to Improve and Track Performance:** Continue to pioneer the use of an integrated set of comprehensive tools and processes designed to progress from the overarching strategy to full implementation of the strategy. The tools being adapted include:
  - **The Challenge Dialogue System** as a process of intensively engaging key stakeholders to clearly define measurable goals and achieve a common vision.
  - **The SMART Objectives System** to determine the impacts and achievability of the targets and develop technology platforms.
  - **Feasibility studies, business case studies and roadmaps** to validate and refine the goals and targets.
  - **The Operational Plan** including the **Global Intelligence System** to identify and exploit the best available technology.
  - The **ProGrid® methodology** to track the performance and progress towards achieving the overarching goals on an annual basis.
- **Initiate Major Projects:** Work with industry to capitalize on significant opportunities and ensure new Alberta funding for major projects that are currently being planned including:
  - **Clean Coal Gasification Pilot:** To develop reliable design criteria for the first full-scale commercial plants that will position Alberta as a world leader in adaptation of clean coal technology to produce clean fuel for different industrial applications.
  - **Energy from Municipal Waste:** To demonstrate the production of synthetic gas and electricity from municipal solid waste and other low grade fuels.
  - **Hydrocarbon Upgrading Demonstration and Training Facility:** To overcome the difficulty of demonstrating new upgrading technology, and the lack of trained personnel for the downstream oil and gas industry.
  - **Geothermal Energy for Oil Sands Process Heat:** To develop deep rock geothermal energy as a substitute for generating steam from natural gas for oil sands production.

# Vision & Mission

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*AERI's mission will be achieved by promoting collaborative research conducted by the private sector, government labs and universities. We will work closely with the Alberta Department of Energy, Alberta Environment and other provincial government departments to strengthen our energy sector. Our role is to take a long-term strategic view, ensuring that the knowledge required for maximizing the value of Alberta's resources continues to grow, by catalyzing and stimulating the research and development of new technology.*



## Vision:

***Alberta is the world leader in energy technology, recognized worldwide for developing leading-edge technology in all forms of environmentally sustainable energy production, transportation, and value added use.***

## Mission:

To ensure that the technology required to continuously improve the processes for the discovery, recovery, processing and transportation of Alberta's energy resources is in place and that these processes are environmentally sustainable.



# Promoting Alberta Goals

AERI under the Ministry of Alberta Innovation & Science (AI&S) is mandated to facilitate the implementation of the GOA's energy and environmental related innovation goals. The major clients, who include AERI's goal and targets in their business planning, are the Alberta Department of Energy (ADOE), Alberta Environment (AENV) and Alberta Economic Development (AED). AERI partners with industry, the federal government and AI&S research institutes and agencies to leverage resources. AERI invests in a number of organizations to achieve its goals and targets including EnergyINet, ARC, NRCan, universities and industry.

## Aligned with GOA Innovation Strategy & Departmental Goals

We actively support the “Unleashing Innovation” strategy in the GOA twenty-year strategic plan, *Today's Opportunities, Tomorrow's Promise*, which was released in 2004. “Unleashing innovation” focuses on Alberta becoming a world leader in innovation, research, development and commercialization of new ideas.

## Selected Examples of Support for GOA Goals

The following table shows how we support other GOA departmental goals.

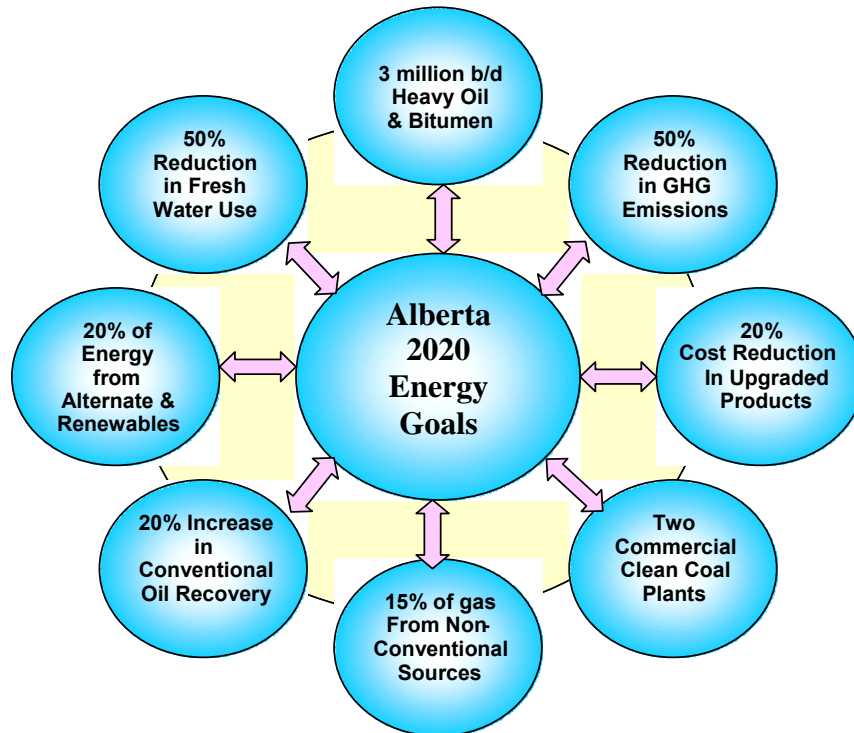
GOA Goals	Selected AERI Technology Initiatives
<b><i>Accelerate innovation in the energy sector (AI&amp;S)</i></b>	<ul style="list-style-type: none"> <li>• EnergyINet</li> <li>• Capacity Building Initiative</li> </ul>
<b><i>Value-Added Strategy (AED)</i></b>	<ul style="list-style-type: none"> <li>• Hydrocarbon Upgrading Demonstration &amp; Training Facility</li> <li>• National Center for Upgrading Technology</li> </ul>
<b><i>Climate Change Action Plan (AENV)</i></b>	<ul style="list-style-type: none"> <li>• Clean Coal Pilot for Western Canadian Feedstocks</li> <li>• Monitoring, Measurement &amp; Verification at the Penn West CO<sub>2</sub> Enhanced Oil Recovery Pilot</li> </ul>
<b><i>Integrated Energy Strategy (ADOE)</i></b>	<ul style="list-style-type: none"> <li>• Innovative Energy Technologies Program</li> <li>• DOVAP Vapex Field Pilot</li> <li>• AERI/ARC Core Industry Research Program in Heavy Oil Recovery</li> </ul>
<b><i>Water-For-Life</i></b>	<ul style="list-style-type: none"> <li>• Oil Sands Tailings Recycle &amp; Reuse</li> </ul>

## Strategic Program Areas

In order to implement these goals, AERI uses the following matrix to guide development in its six strategic program areas.

Inputs Strategies	Outputs Economic, Environmental and Social Impact
<b><i>Unleashing Innovation</i></b> <b><i>Integrated Energy Strategy</i></b> <b><i>Alberta Climate Change Action Plan</i></b> <b><i>Value Added Strategy</i></b> <b><i>Water-for-Life Strategy</i></b> <b><i>Accelerate Innovation in the Energy Sector</i></b> <b><i>Alberta Energy Innovation Strategy</i></b>	<b>Clean Carbon/Coal</b> Coal; Biomass; Heavy Liquids and Environment
	<b>Bitumen Upgrading</b> Efficiency; Diversified Products and Environment.
	<b>CO<sub>2</sub> Management</b> CO <sub>2</sub> Environment; CO <sub>2</sub> Use & Disposal
	<b>Recovery</b> Conventional Oil; Natural Gas and Oil Sands
	<b>Alternate &amp; Renewable Energy</b> Hydrogen/ Fuel Cells; Bio-energy Geothermal energy
	<b>Water Management</b> Cross-cutting Initiatives; Upgrading and Recovery

Based on roadmaps, evaluation studies and business case analysis the following eight goals /targets were developed for the 2020 timeframe.

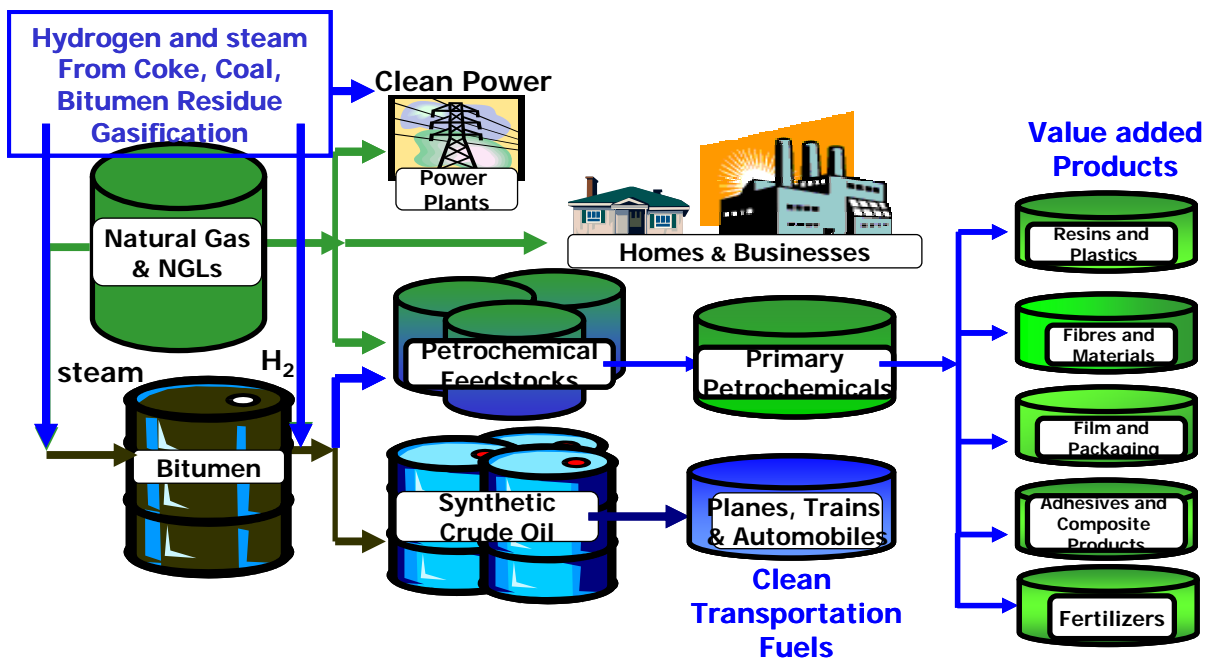


**Figure 5: Targets that guide AERI's technology investment portfolio.**

## Performance Measures & Monitoring

AERI evaluates its progress by using a 16 cell ProGrid® Evaluation Matrix. The premise of the evaluation methodology is that Alberta's energy goals over the next 15 years will only be realized if substantive new technologies and innovations are put into place. The plan identifies two desired future states, one to be achieved by 2012 (Future 1) and the other to be achieved by 2020 (Future 2). Attainment of these future states will have huge economic, environmental and social benefits. Having overarching goals and targets, such as those defined in Figure 5 and based on business case analysis and roadmaps, puts the emphasis on the goals/targets and the necessity for making progress toward those goals/targets.

With this commitment to achieve the 2020 goals, AERI is pioneering the application of a process to quantify progress on an annual basis, which will involve the active engagement of key clients and partners.



**Figure 6: Illustrating that progress to 2020 goals can lead to an integrated energy industry future, diversified and high value products serving broad markets.**

# Major Initiatives

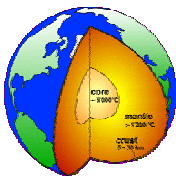
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To achieve its strategic priorities, AERI requires significant new funding. This will enable the launch of several important new initiatives, including the following (ranked in order of priority):

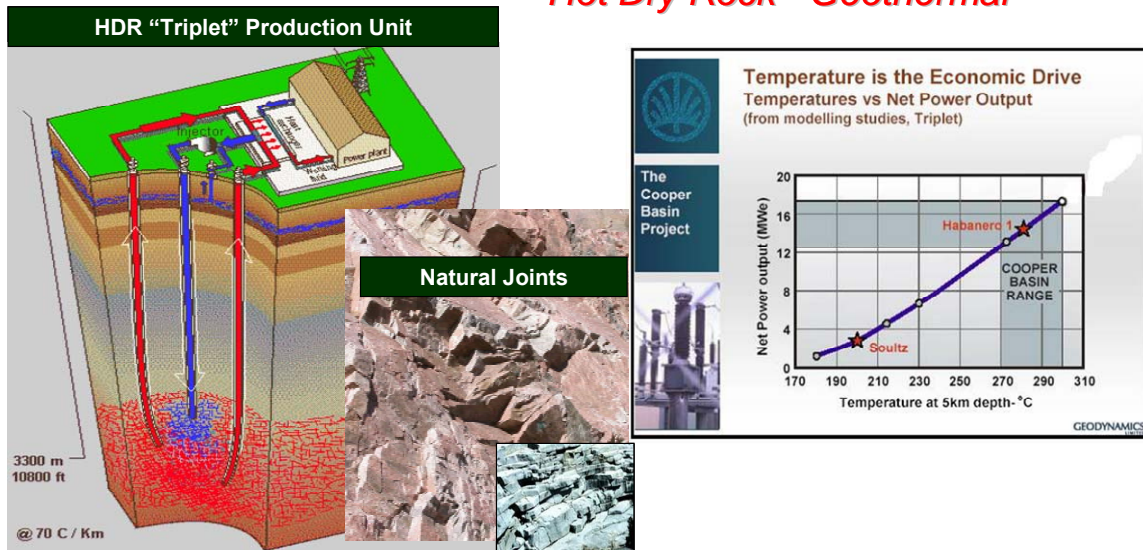
- **Gasification Pilot - To build and operate a pilot plant producing hydrogen from coal and mixed feeds such as coal/coke mixtures:** The these projects are developing technologies for transforming coal into a cost-effective clean fuel for different industrial applications. The main focus is on developing a competitive alternative to the use of natural gas as a source of hydrogen for the upgrading and refining of bitumen, and for the chemical industry in Alberta. Building and operating a pilot plant at an existing industrial site in Fort Saskatchewan is a key part of their strategy to improve the technology, and to develop reliable design criteria for the first full-scale commercial plants. Such a facility will be a major step towards achieving the vision of Alberta being a world leader in the adaptation and integration of clean coal technologies with minimal environmental impact.
- **Demonstration Plant for the Production of Synthetic Gas and Electricity from Municipal Solid Waste (MSW) and other low grade fuels:** Work completed to date confirms that feed preparation and the fluid-bed air-blown gasification technologies selected for this process are technically and economically viable. The project is now moving into the process optimization stage, which will be followed by detailed design and costing, construction and commissioning of a demonstration facility. The success of this project could have tremendous impact for municipalities in Alberta in their efforts to reduce waste going to landfills. Municipalities are facing increasing pressures, as numerous landfills are nearing their capacity and economic and social issues make the building of new sites more difficult. This project will also contribute to both the Region and municipalities in reaching their waste management and GHG reduction targets. The demonstration plant will also provide an air-blown fluid bed gasification test facility for evaluating biomass and other solid feeds available Alberta.
- **Hydrocarbon Upgrading Demonstration and Training Facility (HUDTF):** This project addresses two of the key needs identified in the February 2005 HUTF workshops: the difficulty of demonstrating new upgrading technology, and the lack of trained personnel for the downstream oil and gas industry. The final outcome of this three-phase project will be a commercial plant for demonstrating new upgrading technologies, designed with the flexibility to easily incorporate alternate processes and integration options. An integral part of the project will be a hands-on training program for research and technical personnel, including engineers and operators. A further outcome will be the development of a strong process simulation capability, which will help

AERI and industry to select other upgrading technologies and process schemes with the best breakthrough potential, and integrate them into configurations with the best potential for achieving the desired overall performance targets.

- Geothermal Energy for Oil Sands Process Heat:** The objective in Alberta is to use the produced hot geothermal fluids directly in the reservoirs of such hydrocarbons as oil sands, heavy oil and carbonates to improve the oil recovery and reduce production costs. Typically, this geothermal energy will back off the need for natural gas used to generate steam for in-situ oil recovery. The research and development challenges facing the consortium include: deep drilling into granite to depths of up to 12 kilometers, fracturing the hot granite, heating the water injected from the surface and producing hot fluids for injection directly into the oil reservoir nearer the surface. The water produced with the oil is treated and recycled into the hot granite for re-use.



### Hot Dry Rock - Geothermal

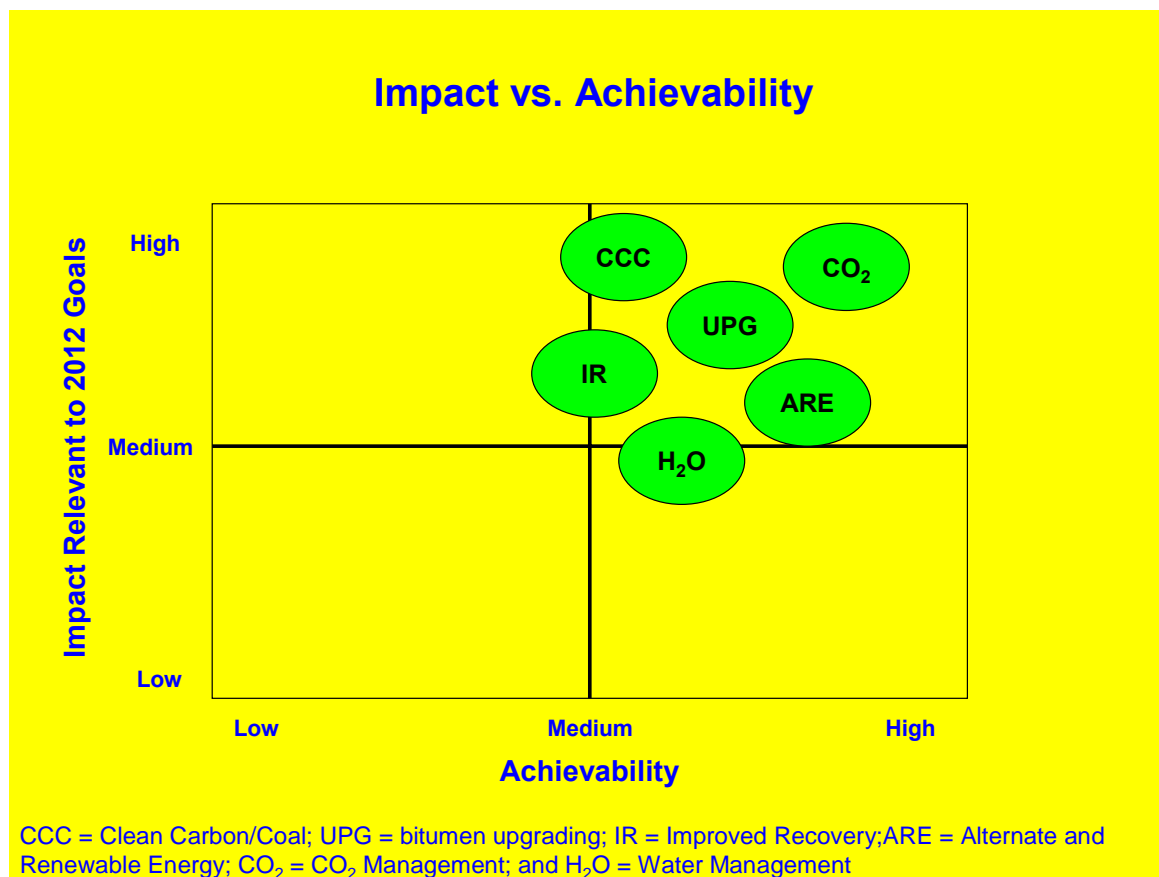


**TEMPERATURE** is the **ECONOMICS DRIVER** ■ **THERMAL GRADIENT** is the **DEPTH DRIVER**

**Figure 8: Schematic of hot dry technology adapted to produce steam for oil sands production.**

# Program Impact & Benefits

The “Impact versus Achievability” of the key initiatives is provided in the Appendices for the individual strategic program areas. The figure below represents the aggregate on a program basis for the six strategic programs, assuming all major initiatives and associated investments are realized. Additional initiatives will be required over the next few years to ensure that all program areas meet or exceed their performance goals.

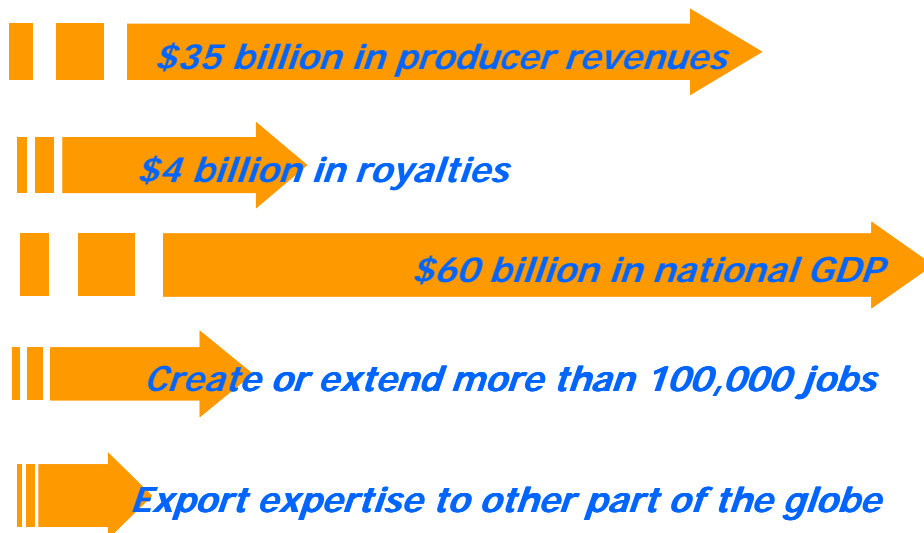


If all the program goals are met, the incremental economic benefits to Alberta would be \$53.5 billion per year in 2012. This estimate is based upon the following assumptions:

- **Bitumen-derived Production:** Currently around 1 million barrels/day – Additional 1 million barrels/day by 2012. At \$40 per barrel = \$14.6 Billion/year by 2012.
- **Upgraded Bitumen:** Upgraded bitumen currently around 0.5 million barrels/day – Additional 1 million/day by 2012. Assuming that the value-

added (price difference between synthetic crude and bitumen) is \$20 per barrel = \$7.3 Billion/year by 2012.

- **Conventional Oil Recovery:** Current production approximately 1 million barrels per day. By 2012 additional 100 thousand barrels per day at \$50 per barrel is around \$6 Billion by 2012. This is a small portion of the economic impact that will result from reserve growth due to new enhanced oil recovery technology (see Figure 7 below).
- **Natural Gas:** Current natural gas production approximately 6 trillion cubic feet (TCF) per year. Incremental goal of approximately 1 TCF/year of conventional and non-conventional gas by 2012, at \$10/MMSCF = \$10 Billion/year.
- **Green Hydrogen:** Turning a waste product such as municipal solid wastes or petroleum coke into saleable products such as hydrogen, natural gas and electricity would result in incremental revenues of \$1.5 billion annually.
- **Fuel Cells:** It is estimated that by 2012, the revenues generated from fuel cells will be in the \$2.5 billion/year range.
- **Bioenergy:** The potential revenues generated by converting agricultural and forestry residues are estimated to be around \$1.6 billion/year.
- **Geothermal:** The replacement of natural gas by geothermal and the zero greenhouse gas emissions from this source are estimated to be worth \$10 billion/year.



**Figure 7: Economic impact due addition of incremental reserves from enhanced oil recovery based on the estimates provided in the Spudding Innovation Report, 2003 (available from [www.ptac.org](http://www.ptac.org)).**

# Appendices

# Clean Carbon/Coal

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Alberta has an abundance of coal, coke, oil sands and refinery residues and biomass that could be converted to higher value products through new and improved gasification technologies. Alberta's coal contains more than twice the energy of all the province's other non-renewable energy resources including oil sands, conventional oil and natural gas. The goal of this program is to demonstrate that it is technologically feasible and potentially commercially viable to:

- Produce electricity from coal and other low-value carbons with minimal harm to the environment;
- Create a variety of new products from coal ("polygeneration"), including synthesis gas which can be converted into high-value hydrogen, chemicals, fertilizers and ultra-clean fuels. These products are currently produced from natural gas, thus clean/carbon technologies provide an alternative sustainable source of feedstock for this industry

## **PROGRAM VISION:**

*Alberta will become a leader in adapting and integrating technology and knowledge for the effective utilization of coal and other low-value carbon fuels as an energy source for the production of electricity, heat and chemical feedstocks with near zero or minimal environmental impacts on land, air and water.*

## **2012 GOAL**

Alberta is supporting the development and demonstration of the key technologies that will be incorporated in one or more clean carbon/coal demonstration plants converting low value fuels into electricity, hydrogen, heat and chemicals with minimum adverse impact on the environment and have the capability of capturing CO<sub>2</sub>.

## **2012 STRATEGIES**

- **Coal** - Alberta has one or more demonstration plants in operation converting sub-bituminous coal into electricity, hydrogen, heat and chemicals (poly-generation) a
- **Carbon** - Alberta has one or more demonstration plants in operation converting biomass and other low-value carbons feedstocks into electricity, hydrogen, heat and chemicals (poly-generation)
- **Environment** - Innovative processes are developed that will reduce the environmental impact and have the capability of capturing CO<sub>2</sub>.

## **KEY BENEFITS**

Clean Carbon/Coal Technologies (CCTs) can increase the economic value of coal and other low-value feeds such as coke by providing sustainable low cost feedstocks not only for clean electrical power production (including CO<sub>2</sub> capture), but also for generating high-value products such as hydrogen, petrochemicals, chemicals, and fertilizers (poly-generation) currently produced from costly natural gas. About 50% of Alberta's electric power is also generated from natural gas. Competitive CCT's can support future 'clean' electric power production as well as provide hydrogen for the growing upgrading, refining and chemicals industries.

Summary of key benefits:

- Provide a competitive and sustainable alternative to natural gas for clean power production, oil sands extraction (SAGD), upgrading and refining of bitumen and for the chemical and petrochemical industries.
- Alberta's 2004 gross revenues from all hydrocarbon sources were \$63.8 billion, with natural gas accounting for half the total. (<http://www.alberta-canada.com/economy/naturalAdvantages/energy.cfm>). Supplementing or replacing a small percentage of Alberta's natural gas production with competitive CCTs can translate into billions of dollars per year of sustainable revenues.
- Stimulate new investments in Alberta's coal, electricity, upgrading, refining, chemical and petrochemical industries
- Develop Alberta's vast coal resources to become a vital component of the province's total energy resources
- Economic utilization of oil sands coke currently being stockpiled
- Reduced environmental impact including capture of CO<sub>2</sub>, which can be used for enhanced recovery of conventional oil and coal bed methane.

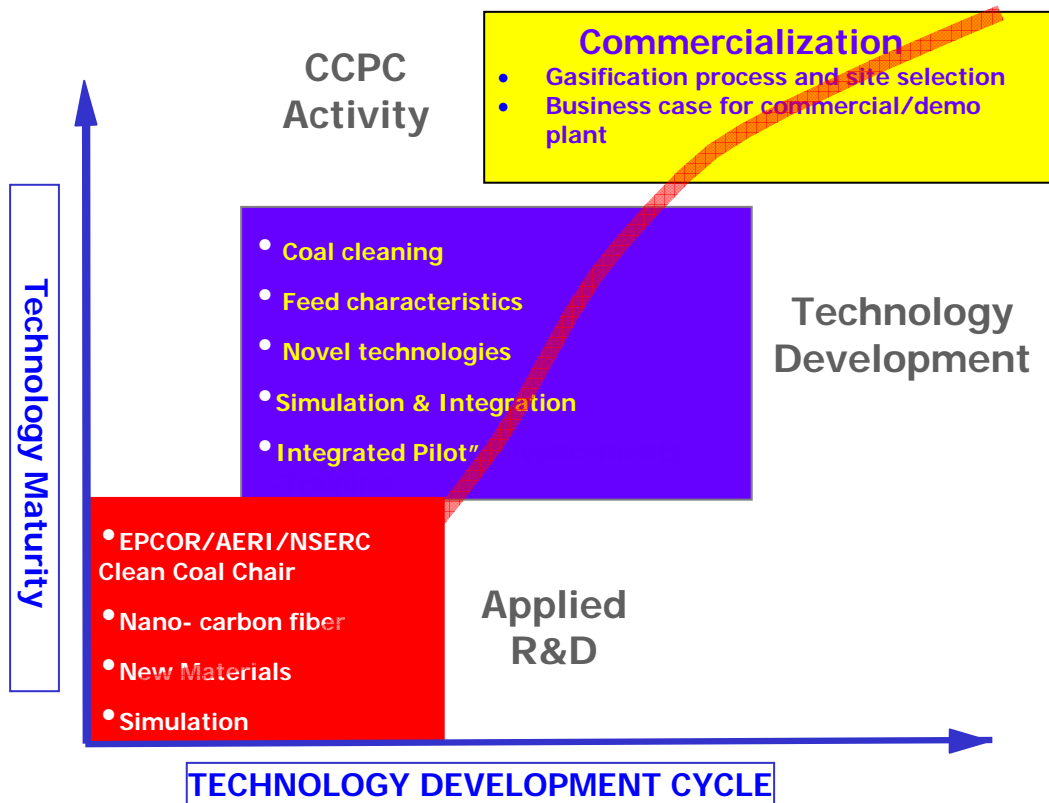
## **KEY INITIATIVES**

The key milestones and benefits expected from existing and new AERI-funded projects (in the base budget) are summarized in the following table.

<b>Key Initiative</b>	<b>Major Milestones</b>	<b>Expected Outcomes</b>
<b>University of Alberta Combustion Chair</b>	<ul style="list-style-type: none"> <li>○ An inventory of mercury content of different coal deposits</li> <li>○ Identify conditions for the pre-combustion removal of mercury</li> <li>○ Identify means of reducing minerals from sub bituminous coals</li> </ul>	<ul style="list-style-type: none"> <li>○ Knowledge of the variations in mercury emissions from different coal seams</li> <li>○ Identify best methods for the pre-combustion removal of mercury from sub-bituminous coals</li> <li>○ Increasing the value of Alberta's low rank coals and their suitability for combustion and gasification.</li> </ul>
<b>Canadian Clean Power Coalition -Phases 2 &amp; 3</b>	<ul style="list-style-type: none"> <li>○ Identify technologies best suited to gasify Alberta's low rank coals and for the removal CO<sub>2</sub> form the produced gas</li> </ul>	<ul style="list-style-type: none"> <li>○ Selection of the most suitable gasifier design to be demonstrated in Alberta. Identification of oil fields suitable for enhanced CO<sub>2</sub> oil recovery</li> <li>○ Identify sites best suited to demonstrate</li> </ul>

Key Initiative	Major Milestones	Expected Outcomes
	<ul style="list-style-type: none"> <li>○ Determine the cost of generating clean power from coal including CO<sub>2</sub> capture</li> </ul>	<ul style="list-style-type: none"> <li>gasification and polygeneration technologies</li> <li>○ Facilitate the commercialization of clean coal technologies by individual industry members of CCPC</li> <li>○ Establish CCPC as an integral part of EnergyNet's Clean Coal program which represents 90% of Canada's coal and electric power companies and has international participation.</li> </ul>
<b>Coal Cleaning</b>	<ul style="list-style-type: none"> <li>○ Evaluate leading coal cleaning technologies with different Alberta coals</li> </ul>	<ul style="list-style-type: none"> <li>○ Identification of new processes for reducing the mineral and water contents of coals to improve their gasification characteristics</li> </ul>
<b>Gasification Characteristics of Alberta Feedstocks</b>	<ul style="list-style-type: none"> <li>○ Identify laboratories capable of conducting pilot plant runs with large coal samples</li> <li>○ Conduct test with Alberta coals at selected centers</li> <li>○ Gasification test results with Alberta feeds</li> </ul>	<ul style="list-style-type: none"> <li>○ Sample bank of representative feedstocks</li> <li>○ Potential to reduce capital and operating costs of gasifying Alberta low grade feedstocks</li> </ul>
<b>Gasification Pilot Plant for Producing Hydrogen from Western Canadian Feedstocks</b>	<ul style="list-style-type: none"> <li>○ Select technologies for an integrated coal cleaning/gasification pilot plant for producing hydrogen</li> <li>○ Design and build a pilot plant to produce hydrogen for an existing commercial plant in Fort Saskatchewan</li> <li>○ Operate the pilot plant to demonstrate the commercial readiness of the new technology</li> </ul>	<ul style="list-style-type: none"> <li>○ Establishing the first gasification pilot/demonstration facility in Alberta</li> <li>○ Fills identified gaps in gasification technology for Alberta coal and coal/coke mixtures</li> <li>○ Unique facility available for use by other operating companies and technology developers:</li> <li>○ Provides an alternative to the use of natural gas as a source of hydrogen for upgrading and refining bitumen and for petrochemical production in Alberta.</li> <li>○ Training of skilled personnel</li> </ul>
<b>Evaluate new feedstocks and blends</b>	<ul style="list-style-type: none"> <li>○ Test new low rank coals and coal/coke blends</li> <li>○ Determine optimum blend compositions</li> </ul>	<ul style="list-style-type: none"> <li>○ Performance data with different feeds</li> <li>○ Optimized gasification performance</li> </ul>
<b>Novel Gasification Technologies</b>	<ul style="list-style-type: none"> <li>○ Evaluate novel gasifier designs and ancillary components for generating power and hydrogen</li> </ul>	<ul style="list-style-type: none"> <li>○ Comparison of performance with existing technologies</li> <li>○ Simulate optimize &amp; Integrate new advances</li> </ul>
<b>Collaborative programs e.g. Alberta China Coal MOU</b>	<ul style="list-style-type: none"> <li>○ Develop program with China</li> <li>○ Develop programs with other countries and organizations</li> </ul>	<ul style="list-style-type: none"> <li>○ Transfer of knowledge and relevant technologies</li> </ul>

## TECHNOLOGY S-CURVE



## INDUSTRY PARTNERS

- Western Canadian Power Producers, including ATCO, EPCOR, SaskPower and TransAlta.
- Western Canadian chemical/mineral producers including Sherritt, and in the future upgrading and refining companies and other chemical producers.
- Western Canadian Coal Producers, including Luscar.

## ENVIRONMENTAL & POLICY DRIVERS

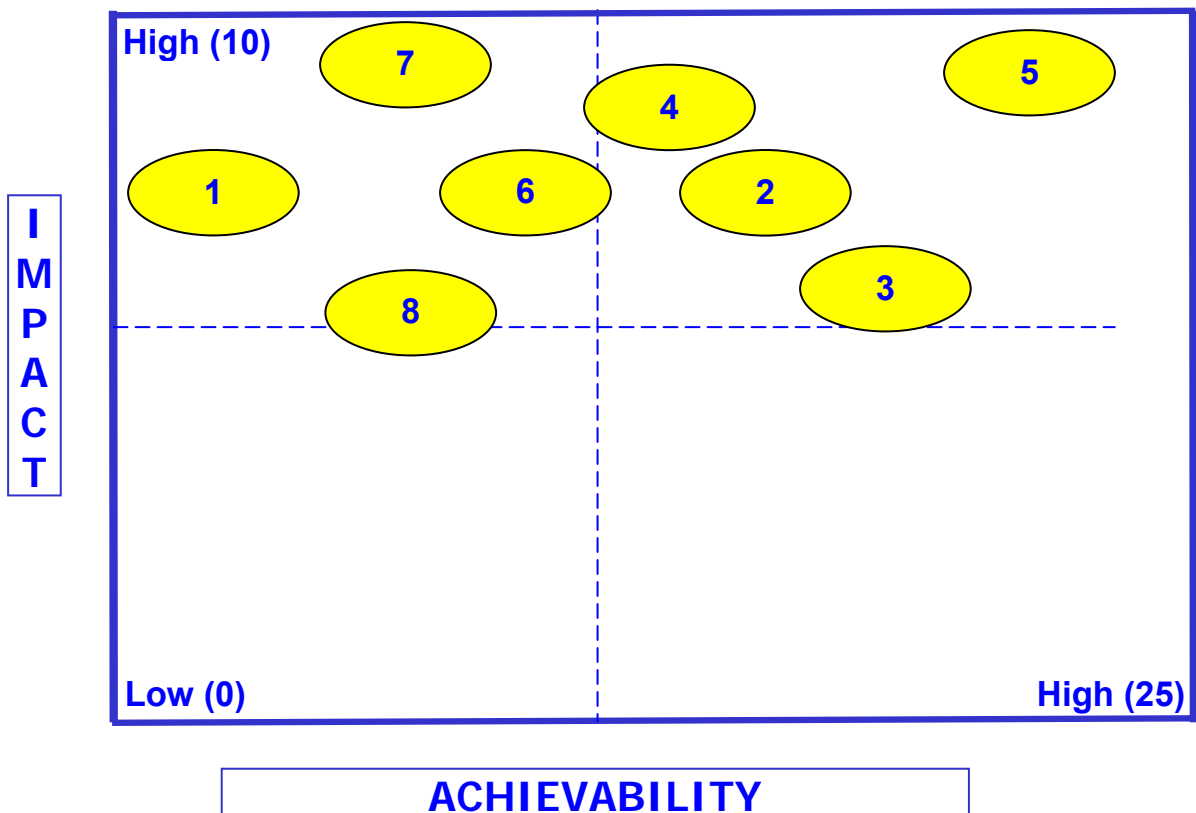
- Late in 2001, Alberta established a policy that new coal-fired power generation must effectively reduce the greenhouse gas (GHG) emission intensity to the same level as a natural gas combined cycle plant. Existing coal-fired generation facilities are not required to meet this criterion.
- In July 2005, Alberta Environment asked for public input with respect to mercury emissions in the electricity sector.
- Most large power generation facilities will be classified as Large Final Emitters and be subject to a GHG emissions penalty, which has yet to be finalized by the federal government.

# Clean Carbon/Coal Program

## Impact vs Achievability of key Initiatives relevant to 2012 Goals

The key initiatives are described in the tables on Major Milestones and Expected Outcomes and include:

1. University of Alberta Combustion Chair
2. Canadian Clean Power Coalition -Phases 2 & 3
3. Coal Cleaning
4. Gasification Characteristics of Alberta Feedstocks
5. Gasification Pilot Plant for Producing Hydrogen from Western Canadian Feedstocks
6. Evaluate new feedstocks and blends
7. Novel Gasification Technologies and ancillary components. Simulation & optimization
8. Collaborative programs e.g. Alberta China Coal MOU



# Upgrading

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Alberta bitumen is either upgraded to a synthetic crude oil (SCO) or pipelined in an unprocessed state, blended with either diluent or SCO. Upgrading is preferred, since it adds value within the province. Upgrading requires either carbon rejection (“coking”) or hydrogen addition. In Alberta, coking results in significant amounts of waste coke, which currently has no value, and is difficult to store. The liquid product requires the addition of hydrogen to reduce sulfur and nitrogen content and has high requirements for natural gas and water. In addition, upgraders have high capital costs and energy requirements, therefore smaller producers have no option other than to dilute their bitumen to get it to market. However, there are already some diluent shortages, and the situation is projected to become increasingly critical as bitumen production triples in the next decade.

Novel upgrading processes are urgently needed that will contribute to increasing the market share of bitumen-derived products by improving product quality and identifying diversification opportunities, while reducing environmental impact. At the same time, profitability could be increased through reduced energy input, lower capital cost, and a diversified mix of fuels and other higher-valued products.

## **PROGRAM VISION**

*Alberta has achieved a competitive hydrocarbon industry that expands the market for Alberta’s bitumen resource and produces higher value products in Alberta.*

## **2012 GOAL**

AERI is supporting projects that will contribute to increasing the market share of bitumen-derived products by improving product quality and identifying diversification opportunities while reducing environmental impact, increasing profitability through reduced energy input, lower capital cost and a diversified mix of fuels and other higher valued products

## **2012 STRATEGIES**

- **Improved Efficiency** – Innovative and efficient processes are developed which will reduce capital costs and operating costs by 10%
- **Diversified Products** – Innovative products are developed that will shift the product mix from the 1.5 MBPD bitumen produced to >25% of higher-valued products other than synthetic crude oil

- **Environment** – Innovative processes are developed that will reduce the environmental impact per unit of product for carbon dioxide and SO<sub>2</sub> emissions, waste coke and sulphur, and reduce fresh water use by 10%

## **KEY BENEFITS**

This program targets four core technology platforms:

- Separation technologies,
- Catalysis (primarily ring-opening catalysts),
- Utilization of bitumen fractions, and
- Process integration.

These technology platforms are designed to achieve product diversification, full resource utilization, reduction in natural gas requirements and lower greenhouse gas emissions. Other key benefits include lower capital costs and reduced diluent requirements.

## **KEY INITIATIVES**

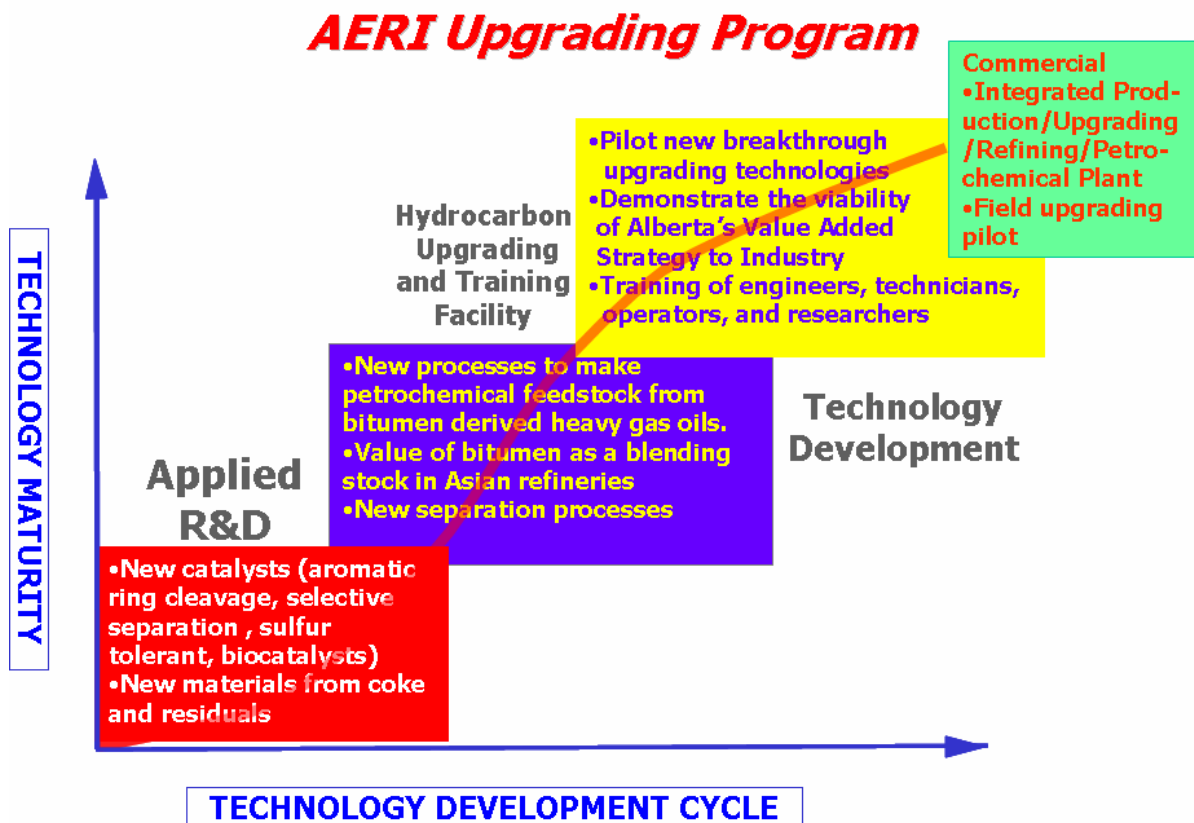
The key milestones and benefits expected are summarized in the following table.

<b>Key Initiative</b>	<b>Major Milestones</b>	<b>Expected Outcomes</b>
Develop Petrochemical Feedstocks from Heavy Gas Oils, Phase III, 2006, Phase IV, 2007-09	<ul style="list-style-type: none"> <li>○ Two patent applications granted from Phase - II</li> <li>○ Phase III - Demonstrate application of new catalysts and processes developed under Phase II at small pilot scale.</li> <li>○ Phase IV – Demonstration of this new technology in the HUDTF.</li> </ul>	<ul style="list-style-type: none"> <li>○ Develop a new family of catalysts, and new technologies to achieve higher yield of olefins for petrochemical feedstock. This has the potential to provide a major breakthrough in the upgrading Alberta bitumen into higher value products</li> <li>○ Develop new aromatic ring saturation catalysts to increase yield of olefins from feed resulting from first process</li> </ul>
Hydrocarbon Upgrading Task Force (HUTF) , Ongoing	<ul style="list-style-type: none"> <li>○ Ongoing cross-ministry initiative. Participate with Alberta Economic Development (AED), ADOE and industry to further Alberta's Value-Added Strategy.</li> </ul>	<ul style="list-style-type: none"> <li>○ The identification of necessary technology advancements to achieve Vision 2020</li> <li>○ Develop the business case to achieve Vision 2020.</li> </ul>
Naphthenic Acid Corrosivity of Alberta Oil Sands Crudes (2006-08)	<ul style="list-style-type: none"> <li>○ Confirm the existence of two different types of naphthenic acids, to show that Alberta bitumen is not as corrosive as is commonly believed.</li> <li>○ Develop a new test for total acid number (TAN), specifically designed for heavy feedstocks such as</li> </ul>	<ul style="list-style-type: none"> <li>○ Increase the value of Alberta bitumen and heavy oil in Canadian and U.S. refineries, with a consequent increase in revenue to the Alberta Government.</li> </ul>

Key Initiative	Major Milestones	Expected Outcomes
	Alberta bitumen and heavy oil.	
Hydrocarbon Upgrading Demonstration and Training Facility (HUDTF) Phase I, 2005-06, Phase II, 2006-07, Phase III, 2008+	<ul style="list-style-type: none"> <li>o Complete a feasibility study to determine the optimum combination of breakthrough upgrading technologies to be included in the HUDTF.</li> <li>o Design, engineering, and site selection for the HUDTF in Alberta.</li> <li>o Operation of the HUDTF as a commercial demonstration and training facility.</li> </ul>	<ul style="list-style-type: none"> <li>o Breakthrough upgrading technologies can be demonstrated to industry, thus changing the current status in the province of using 60 year old technology to upgrade bitumen.</li> <li>o Training of a new generation of engineers, technicians, operators, and researchers in an area where there are critical manpower shortages.</li> </ul>
Comparison of Solvent Deasphalting Technologies for Use in Field Upgrading	<ul style="list-style-type: none"> <li>o Compare the economics of various solvent deasphalting technologies when used as a field upgrader.</li> </ul>	<ul style="list-style-type: none"> <li>o Potential to reduce the need for diluent, and provide asphaltenes for on-site generation of steam and hydrogen to reduce the need for natural gas.</li> </ul>
Development of Dispersed Catalyst for Aromatic Ring Opening	<ul style="list-style-type: none"> <li>o Develop a novel low cost dispersed catalyst that could be used either above ground or in situ to reduce the aromaticity of Alberta crudes.</li> </ul>	<ul style="list-style-type: none"> <li>o Development of a low cost non-shape selective dispersed catalyst for the opening of aromatic rings could lower operating costs and reduce energy requirements in the upgrading process.</li> </ul>
Field Pilot of Field Upgrading Technology	<ul style="list-style-type: none"> <li>o Demonstrate the Ensyn upgrading process on Alberta bitumen in a field pilot.</li> </ul>	<ul style="list-style-type: none"> <li>o Low cost integrated field upgrading process could provide steam/power for production and hydrogen for hydropolishing, while eliminating the need for diluent.</li> </ul>
Selective Separation of Asphaltenes	<ul style="list-style-type: none"> <li>o Completion of Phase I.</li> </ul>	<ul style="list-style-type: none"> <li>o A new technology for the upgrading of heavy oil and a new feedstock for hydrogen production</li> </ul>
Catalysts for Upgrading and Hydrogen Production from Converted Asphaltenes	<ul style="list-style-type: none"> <li>o Completion of Phase I.</li> </ul>	<ul style="list-style-type: none"> <li>o A catalyst matrix that can be used in the steam reforming process to generate hydrogen from low-value feedstocks such as asphaltenes</li> </ul>
Noble Metal Sulfur Tolerant Catalysts for Hydroprocessing Heavy Gas Oils	<ul style="list-style-type: none"> <li>o Completion of Phase I.</li> </ul>	<ul style="list-style-type: none"> <li>o Develop a noble-metal containing catalyst that is both active for opening the aromatic rings of heavy oil, and is sulfur resistant</li> </ul>
Processability of Athabasca Bitumen Products in Chinese Refineries	<ul style="list-style-type: none"> <li>o Phase II completion.</li> </ul>	<ul style="list-style-type: none"> <li>o Projected Benefits are increased marketability of Alberta crude oils to Asian markets, increased technology transfer between Alberta and China, and fostering long-term relationships between Alberta producers and Chinese refineries</li> </ul>

Key Initiative	Major Milestones	Expected Outcomes
Producing Activated Carbon from High-Sulfur Oil Sands Coke for Mercury Capture from Coal-fired Power Plant Waste Stacks	<ul style="list-style-type: none"> <li>Develop processes to simultaneously activate waste coke and remove sulfur from the coke.</li> </ul>	<ul style="list-style-type: none"> <li>Outcome could be an inexpensive means of capturing mercury from power plant flue gases using a waste product from the upgrading process. Potential large-scale positive effect on the environment, both via reducing coke stockpiles, and emissions scrubbing.</li> </ul>
Four COURSE Upgrading Projects	<ul style="list-style-type: none"> <li>All projects should be completed by 2006.</li> </ul>	<ul style="list-style-type: none"> <li>Training of Highly Qualified Personnel. Potential incremental advances to existing technology, and potential further development of bio-treatment for corrosion reduction during upgrading</li> </ul>

## TECHNOLOGY S-CURVE

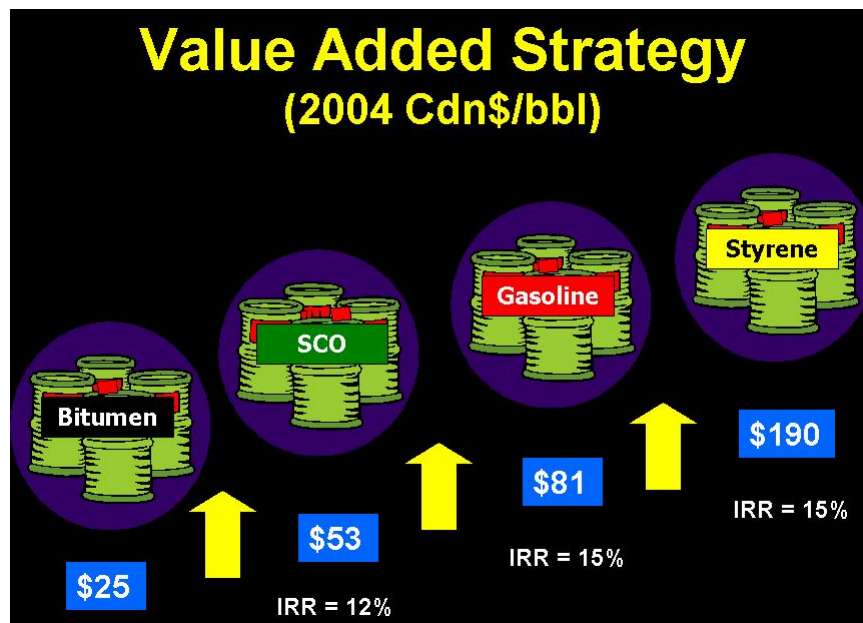


## **INDUSTRY PARTNERS**

- Existing oil sands producers, including Shell, Suncor and Syncrude
- Emerging oilsands producers, including Canadian Natural Resources Ltd., and Synenco
- Steam-Assisted Gravity Drainage producers are looking for a feasible field upgrading process.
- Any country with heavy oil or the capacity to refine heavy oil, including China, Russian, Venezuela and the United States, would be interested in the technologies developed within this program.

## **ENVIRONMENTAL & POLICY DRIVERS**

- Most upgrading facilities will be classified as Large Final Emitters and be subject to a GHG emissions penalty, which has yet to be finalized by the federal government.



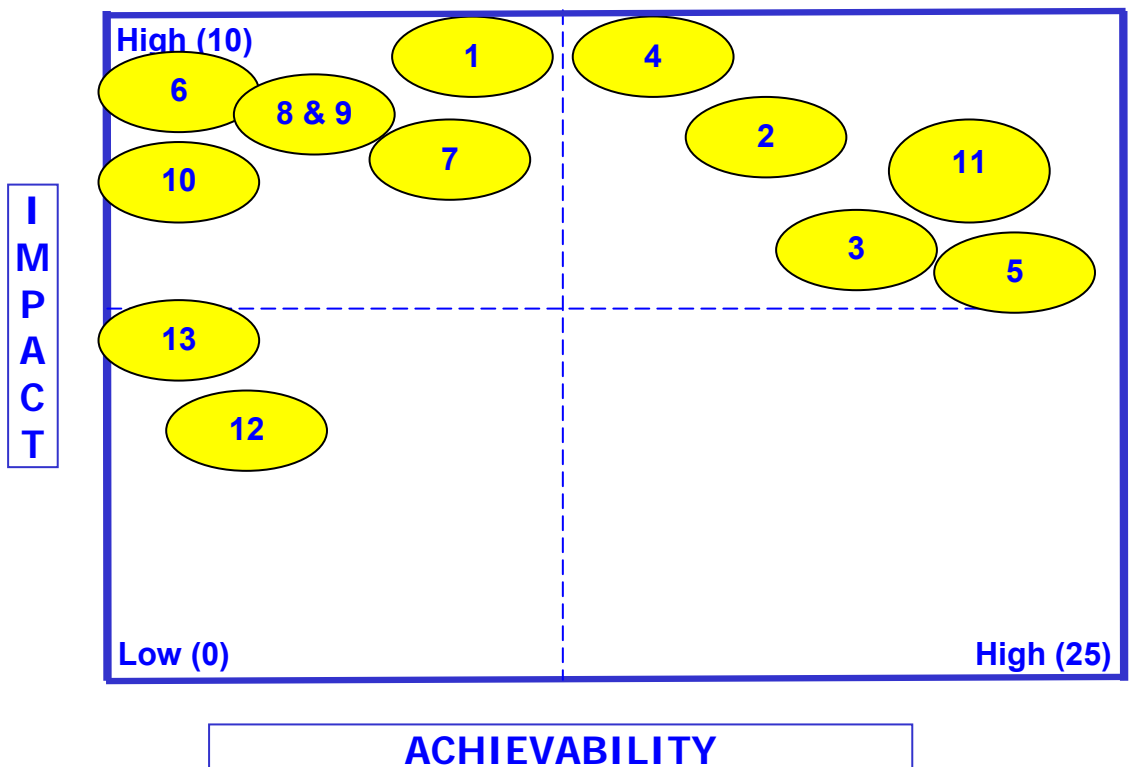
**Figure 9: Illustrating the potential return on investment through upgrading.**

# Upgrading Program

## Impact vs Achievability of key Initiatives relevant to 2012 Goals

The key initiatives are described in the tables on Major Milestones and Expected Outcomes and include:

1. Develop Petrochemical Feedstocks from Heavy Gas Oils
2. Hydrocarbon Upgrading Task Force (HUTF) ongoing
3. Naphthenic Acid Corrosivity of Alberta Oil Sands Crudes
4. Hydrocarbon Upgrading Demonstration and Training Facility (HUDTF) Phase I, 2005-06, Phase II, 2006-07, Phase III, 2008+
5. Comparison of Solvent Deasphalting Technologies for Use in Field Upgrading
6. Development of Dispersed Catalyst for Aromatic Ring Opening
7. Field Pilot of Field Upgrading Technology
8. Selective Separation of Asphaltenes
9. Catalysts for Upgrading and Hydrogen Production from Converted Asphaltenes
10. Noble Metal Sulfur Tolerant Catalysts for Hydroprocessing Heavy Gas Oils
11. Processability of Athabasca Bitumen Products in Chinese Refineries
12. Producing Activated Carbon from High-Sulfur Oil Sands Coke for Mercury Capture from Coal-fired Power Plant Waste Stacks
13. Four COURSE Upgrading Projects



# Improved Recovery

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Canada has one of the largest supplies of hydrocarbon reserves in the world. Conventional light oil production in the Western Canadian Sedimentary Basin (WCSB) peaked in 1973 and by 2001 had declined by some 60%. The shortfall has been filled by increased production of conventional heavy oil using new extraction techniques (16% of total oil production in 2001, up from 4% in 1973) and the extraction of bitumen from the oil sands (43% of total production in 2001, up from 4% in 1973). Current trends show that conventional natural gas production has peaked and will start to decline. Non-conventional gas sources, such as coal bed methane, will need to be developed.

In 2003, AERI commissioned a study to identify the research and technology innovation required in order to extend the recoverability of oil and gas in the WCSB. The study estimated that:

- Only 27% of conventional oil from known sources is being recovered in the WCSB the remaining 73% will remain in the ground, as current technology is not available to extract the balance due to technological, environmental, social and economic barriers. With the next generation of technology it is anticipated that this recovery factor could be increased to an average of 41%.
- The recovery factor for conventional natural gas could be raised from 59% to an average of 72%.

In 2005, AERI commissioned another study to identify technologies that could recover an additional 5 billion barrels of oil reserves and an additional 25 trillion cubic feet of natural gas in the WCSB. The study provided interesting insights and developed an effective tool to aid in the preliminary matching of current technology and identification of technology gaps to specific reservoirs.

## **PROGRAM VISION**

*The focus of the Recovery program is aimed at improved recovery from conventional and non-conventional resources while reducing energy intensity.*

## **2012 GOAL**

Key recovery technologies have been developed that will allow industry to achieve 2012 production and reserves targets of conventional and unconventional hydrocarbon resources.

## **2012 STRATEGIES**

- **Gas-Over-Bitumen:** Support the development of key technologies that will enable a solution to allow the recovery of resources from pressure depleted gas overlain bitumen reservoirs. Solutions developed as part of this goal,

particularly alternative operating parameters, alternate lift systems, and newly configured systems may be applicable to unaffected reservoirs.

- **Bitumen-derived Production Technologies** (i.e. In Situ Solvent Recovery & Combustion): Support the development of key technologies that will contribute to the growth of production levels to two million barrels per day of heavy oil and bitumen while reducing energy intensity and water consumption by 30% of requirements for current day technology.
- **Conventional Oil and Gas:** Support the development of key technologies that will lead to a 20% increase in oil recovery and 15% of total gas production coming from enhanced recovery methods.
- **Unconventional Gas:** Support the development of key technologies that will lead to 15% of natural gas production coming from enhanced gas recovery techniques and from non-conventional resources.

**KEY BENEFITS**

The key benefits include: the simultaneous recovery of natural gas and bitumen from gas-over-bitumen reservoirs; incremental conventional oil and gas recovery; the development of new technologies for the recovery of non-conventional oil and gas and significant increases in revenues and royalties.

**KEY INITIATIVES**

Key initiatives are listed in the table below. They include: the evaluations of enhanced recovery of field pilots approved under the Alberta Department of Energy’s CO<sub>2</sub> Royalty Credit Program and the Innovative Energy Technologies Program (IETP); and continued participation in the Gas-Over-Bitumen (GOB) technical solution committees. Several research and demonstration projects are currently underway in search of a technical solution for concurrent gas and bitumen production in bitumen reservoirs having overlying gas reservoirs. In addition, AERI has supported other strategic field pilots and demonstration projects.

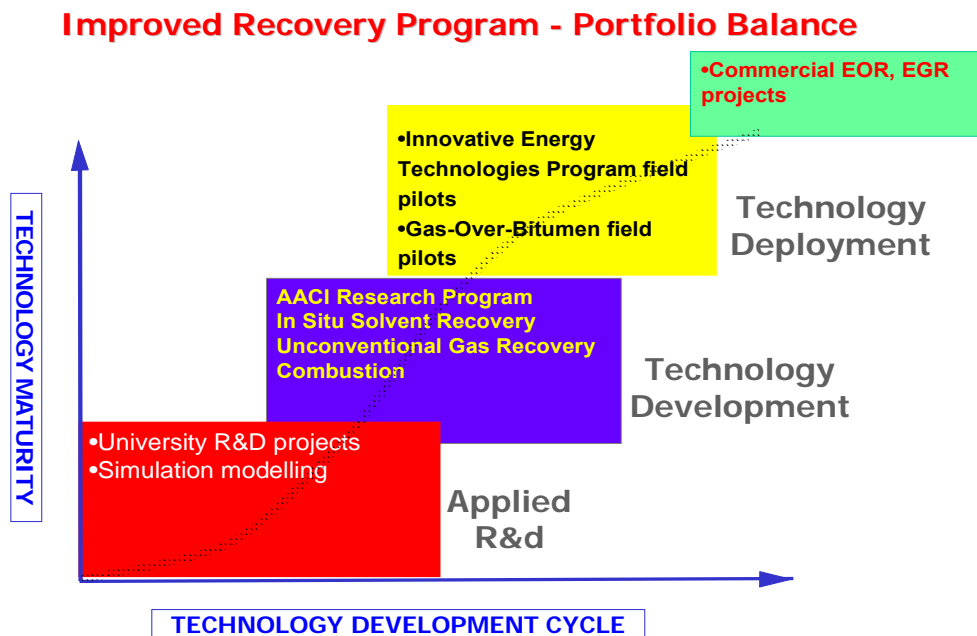
AERI continues to participate in the AERI/ARC Core Industry (AACI) Program that provides fundamental research, process development, and technology transfer for oil sands and heavy oil processes including thermal, solvent, thermal and solvent hybrid, and heavy oil techniques, and participates in strategic field demonstration projects.

Key Initiative	Major Milestones	Expected Outcomes
<b>Gas Over Bitumen</b>	<ul style="list-style-type: none"> <li>○ Development of Gas over Bitumen Committee supported experimental work and piloting.</li> <li>○ Identification and support of Gas over Bitumen experimental programs and piloting in conjunction with Alberta</li> </ul>	<ul style="list-style-type: none"> <li>○ Hybrid SAGD, low-pressure SAGD, high-pressure/high temperature artificial lift systems design and testing, reservoir pressure maintenance, synergies with solvent work, field</li> </ul>

Key Initiative	Major Milestones	Expected Outcomes
	<p>Government investment under the IETP identify potential pilots and monitor approved projects.</p> <ul style="list-style-type: none"> <li>○ Testing and identification of an artificial lift system capable of operating at high temperature and pressures conducive for reduced-pressure Steam-Assisted Gravity Drainage (SAGD).</li> <li>○ Piloting and development of a reduced energy intensive and economical process for bitumen production.</li> </ul>	<p>demonstration pilots.</p> <ul style="list-style-type: none"> <li>○ Reduction of energy and water requirements for SAGD production.</li> <li>○ Increased recovery from gas over bitumen and development of bitumen marginal reservoirs.</li> </ul>
<b>In Situ Solvent Recovery</b>	<ul style="list-style-type: none"> <li>○ Operation and optimization of non-thermal and thermally assisted solvent processes.</li> <li>○ Identification and demonstration of artificial lift technology for solvent recovery processes.</li> <li>○ Development of novel in situ electrical heating recovery pilot for bitumen.</li> <li>○ Support the development of the \$200 million ADOE IETP, identify potential pilots and monitor approved projects.</li> </ul>	<ul style="list-style-type: none"> <li>○ Optimized capacity and production rates of various solvent injection/recovery techniques for in situ bitumen and conventional heavy oil.</li> <li>○ Solvent recovery mechanism support in order to reduce energy intensity, water usage, and greenhouse gas emissions.</li> <li>○ Electrical heating pilot demonstration to reduce energy requirements, water use and increase recovery accessibility of shallow, thin, and marginal oilsands resources.</li> </ul>
<b>Conventional Oil and Gas</b>	<ul style="list-style-type: none"> <li>○ Support the development of the \$200 million ADOE IETP Energy Technologies Program, identify potential pilots and monitor approved projects.</li> <li>○ Completion of a business case study for the entire WCSB that includes reservoir management and technology adaptation activities.</li> </ul>	<ul style="list-style-type: none"> <li>○ Innovative technology and techniques capable of adding significant recoverable reserves.</li> <li>○ Creation of a “Super Database” of oil and gas reservoirs with imbedded enhanced recovery technology screening tools for implementation of enhanced recovery techniques.</li> <li>○ Initiation of novel demonstration pilots to develop enhanced recovery technology.</li> </ul>
<b>Combustion</b>	<ul style="list-style-type: none"> <li>○ Initiation of a strategic research area within the AACI Program.</li> <li>○ Identification, support, development, and monitoring of pilots through the IETP.</li> </ul>	<ul style="list-style-type: none"> <li>○ In situ combustion techniques developed for bitumen and heavy oil, including post primary production.</li> <li>○ Support and development of combustion recovery pilot.</li> </ul>

Key Initiative	Major Milestones	Expected Outcomes
<b>Unconventional Gas</b>	<ul style="list-style-type: none"> <li>○ Support the development of the \$200 million ADOE IETP, identify potential pilots and monitor approved projects.</li> <li>○ Conduct additional water quality studies to enhance the CBM water quality database for Alberta.</li> <li>○ Initiation and completion of an unconventional gas technology roadmap to increase production and reserves.</li> <li>○ Commencement of an enhanced CBM pilot project.</li> </ul>	<ul style="list-style-type: none"> <li>○ CO<sub>2</sub> and acid gas production enhancement, fracture technology, water handling, water quality and gas component tests and studies.</li> <li>○ Development of an Industry supported roadmap identifying unconventional gas and technology opportunities.</li> <li>○ Demonstration of novel unconventional gas drilling and completion techniques.</li> </ul>
<b>Simulation modeling</b>	<ul style="list-style-type: none"> <li>○ Development of enhanced simulation capabilities for CO<sub>2</sub> enhanced oil recovery, enhanced gas recovery, enhanced coal bed methane recovery, and for CO<sub>2</sub> storage predictions.</li> <li>○ Verification of simulators with field data and history match.</li> </ul>	<ul style="list-style-type: none"> <li>○ Development of more sophisticated computerized models</li> </ul>

## TECHNOLOGY S-CURVE

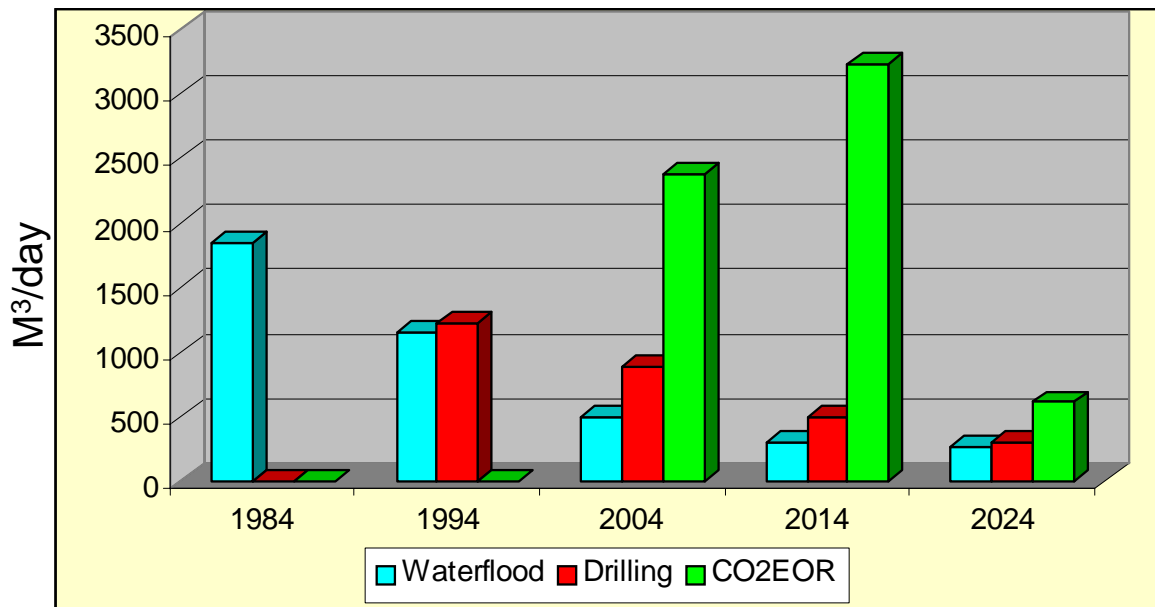


## **INDUSTRY PARTNERS**

- AERI/ARC Core Industry Program: Alberta Research Council, BP Exploration Inc. , Canadian Natural Resources Ltd., Chevron Corp., Computer Modelling Group, ConocoPhillips, Husky Energy Inc., Imperial Oil Resources Ltd., Japan Canada Oil Sands, Nexen Canada Ltd., Petrobras, Petro-Canada, Shell International, Statoil, Suncor Inc. and Total
- DOVAP Consortium: Petro-Canada, Devon, Chevron, Imperial Oil, Total, Suncor, Canadian Natural Resources Ltd., Nexen, Japex, ConocoPhillips, Shell
- Innovative Energy Technologies Program: CDX Canada, MGV Energy Inc., Precision Energy Services, Petro Canada, Deer Creek Energy Ltd., Paramount Resources, Suncor Energy, Petrobank Energy and Resources Ltd., EnCana Corporation, ConocoPhillips, Penn West, Husky Energy
- Technologies developed within this program would have worldwide application.

## **ENVIRONMENTAL & POLICY DRIVERS**

- Climate Change challenges.
- Regulations required for the development of coal bed methane reservoirs.



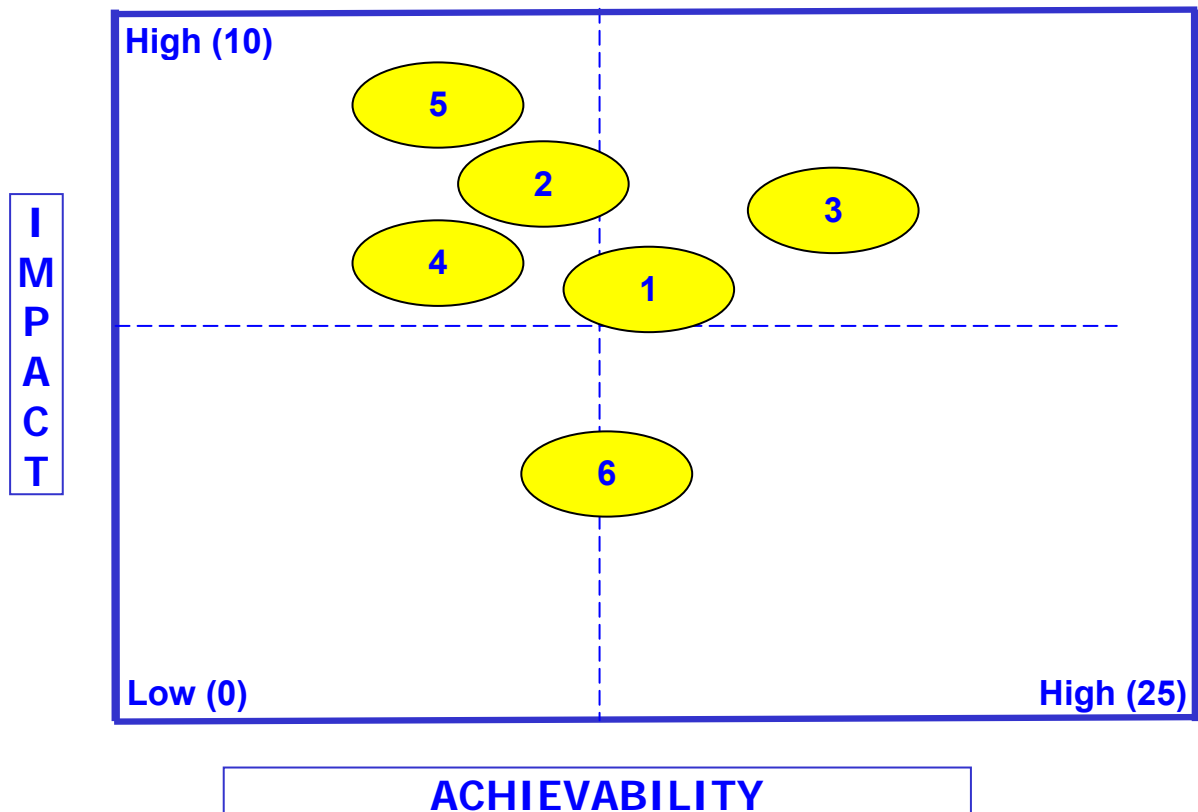
**Figure 10: Actual and projected production in the Weyburn Field showing the impact of CO<sub>2</sub> enhanced oil recovery (green bars).**

# Improved Recovery Program

## Impact vs Achievability of key Initiatives relevant to 2012 Goals

The key initiatives are described in the tables on Major Milestones and Expected Outcomes and include:

1. Gas over Bitumen
2. In situ Solvent Recovery
3. Conventional Oil & Gas'
4. Combustion
5. Unconventional Gas
6. Simulation Modelling



# Alternate & Renewable Energy

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Alberta has significant renewable energy resources that have yet to be commercially exploited. It produces and uses more hydrogen than any other province in Canada, and indeed it is one of the world's centres of hydrogen production, making it the most likely jurisdiction in Canada in which to initiate the implementation of a "Hydrogen Economy". Fuel cells are the most efficient electricity producing machines known. Fuel cells are expected to operate as distributed energy sources, reducing the need to increase the capacity of the existing electrical grid. Alberta's "clustered" agriculture and forest industries are well positioned to take advantage of the current "adoption" of bioenergy and biofuel technologies. Finally, the strong emphasis on gasification of low-value hydrocarbons positions Alberta well to take advantage of technologies which can produce hydrogen gas with a corresponding net reduction of GHG gases such as CO<sub>2</sub> (green hydrogen).

## **PROGRAM VISION**

The aim of this program is to develop, improve and adapt alternate and renewable energy technologies, such as green hydrogen, fuel cells, geothermal and bioenergy.

## **2012 GOAL**

To advance alternative and renewable energy technologies (including fuel cells) to the point that they produce 15% of Alberta's electrical energy needs by the year 2012, as compared to the current 10% level.

## **2012 STRATEGIES**

- **Fuel Cells** – Develop a prototype fuel cell that can run directly on hydrocarbon fuels and can be readily adapted to both residential and small commercial settings for combined heat and power needs. This will set the stage for commercial deployment by 2015 and the opportunity to provide up to 2.5% of Alberta's residential and small commercial heat and power needs
- **Bioenergy** – Development and demonstration of emerging technologies in bioenergy combined heat and power as well as biofuels, such as ethanol and biodiesel. This should position the agricultural and forestry industries to be able to produce 3% of Alberta's energy demand from bio-energy sources.
- **Other Renewables** – Development of key technologies and protocols that will allow industry to increase Alberta's energy production from geothermal, solar, wind and hydro energy sources up to 10% of total electrical energy demand in

the province. Deepwell geothermal will be examined through engineering assessment and pilot well programs.

**KEY BENEFITS**

- Decreased emissions from hydrocarbon fuels through the production of green hydrogen. The total value of green hydrogen byproducts from coke gasification is about \$1.5 billion annually.
- Growth of environmentally sustainable distributed generation of electricity through the introduction of fuel cells in residential and small commercial settings. The total value of 5% Combined-Heat-Power (CHP) from fuel cells is about \$2.5 billion per year.
- Enhanced viability of the Agriculture and Forestry sectors through the introduction of bioenergy. The total value of 3% CHP from biomass is about \$1.6 billion per year.
- The potential to achieve zero emissions heat and power production in industrial and urban settings through the use of deepwell geothermal heat. The total value of zero emissions CHP from geothermal heat is about \$20 billion per year.

**KEY INITIATIVES:**

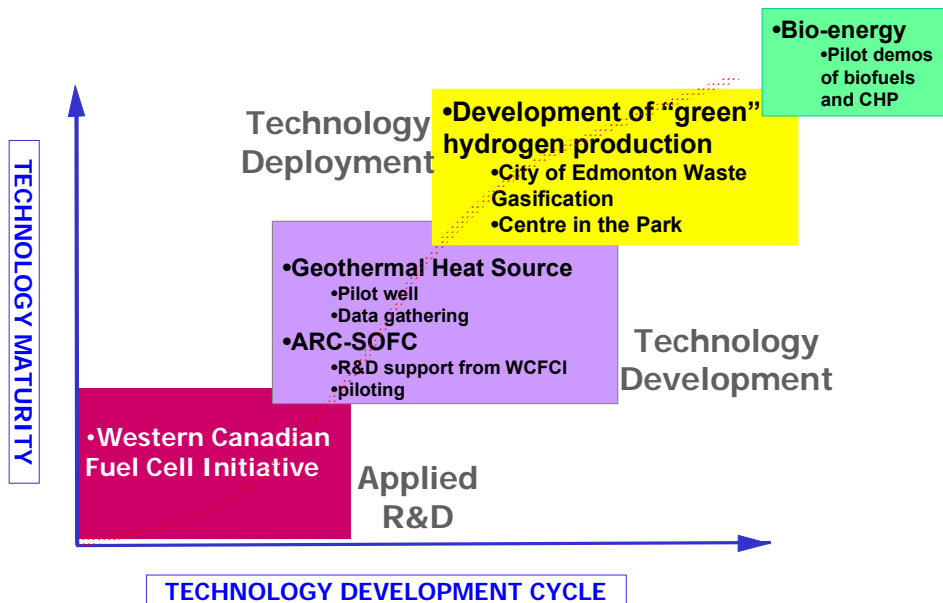
The key milestones and outcomes expected from existing and new AERI-funded projects are summarized in the following table.

Key Initiative	Major Milestones	Expected Outcomes
Fuel Cell Initiative	<ul style="list-style-type: none"> <li>○ Accomplishments of the Western Canadian Fuel Cell Initiative:               <ul style="list-style-type: none"> <li>• Industry led consortium funding</li> <li>• Direct hydrocarbon anode and cathode supported catalysts</li> </ul> </li> <li>○ National level Solid Oxide Fuel Cell network via EnergyNet.</li> <li>○ Development and piloting of a direct hydrocarbon cathode supported SOFC system</li> </ul>	<ul style="list-style-type: none"> <li>○ Development of core technologies for high-temperature fuel cells</li> <li>○ Develop fuel cells suitable for the “impure hydrogen” sources available in Western Canada</li> <li>○ ~0.5% of Alberta’s energy demand is coming from fuel-cell sources by 2015</li> <li>○ Residential and small commercial scale Distributed Generation.</li> </ul>
Geothermal Heat Source for Oil Sands Extraction	<ul style="list-style-type: none"> <li>○ Engineering technical and economic viability study completed</li> <li>○ Pilot well drilled and tested.</li> </ul>	<ul style="list-style-type: none"> <li>○ Demonstration of the viability of geothermal sources for oil recovery from oil sands, with potential benefit of significantly reduced CO<sub>2</sub> emissions from SAGD and other processes</li> </ul>

Key Initiative	Major Milestones	Expected Outcomes
		<ul style="list-style-type: none"> <li>10% of Alberta's energy demand is coming from geothermal, small hydro, solar and wind technologies</li> <li>Potential for zero emission heat and power in urban centres</li> </ul>
Bio-energy	<ul style="list-style-type: none"> <li>Crossfield CHP demo</li> <li>Bioenergy challenge dialogue through BIOCAP</li> <li>Participation in various test pilots on biomass gasification and biofuels utilization</li> </ul>	<ul style="list-style-type: none"> <li>Demonstration of novel technologies for use of biomass in energy production</li> <li>A national strategic plan for coordination and funding of Bioenergy research and commercialization</li> <li>Enhanced viability of Alberta's Agriculture and Forestry sectors</li> <li>3% of Alberta's energy demand is coming from bio-energy sources by 2015</li> </ul>
Hydrogen	<ul style="list-style-type: none"> <li>Formation of a Hydrogen working group via EnergyNet</li> <li>Development and piloting of "green" hydrogen projects for electrical and thermal energy needs (CHP) in an urban and/or industrial setting.</li> </ul>	<ul style="list-style-type: none"> <li>Development of optimized hydrogen production technologies that produce less CO<sub>2</sub> through improved process and integration with sequestration.</li> <li>Integrated with existing hydrogen infrastructure</li> <li>2% of Alberta's energy demand is coming from "green" hydrogen by 2015</li> </ul>

## TECHNOLOGY S-CURVE

### Alternative & Renewable Energy - Portfolio Balance

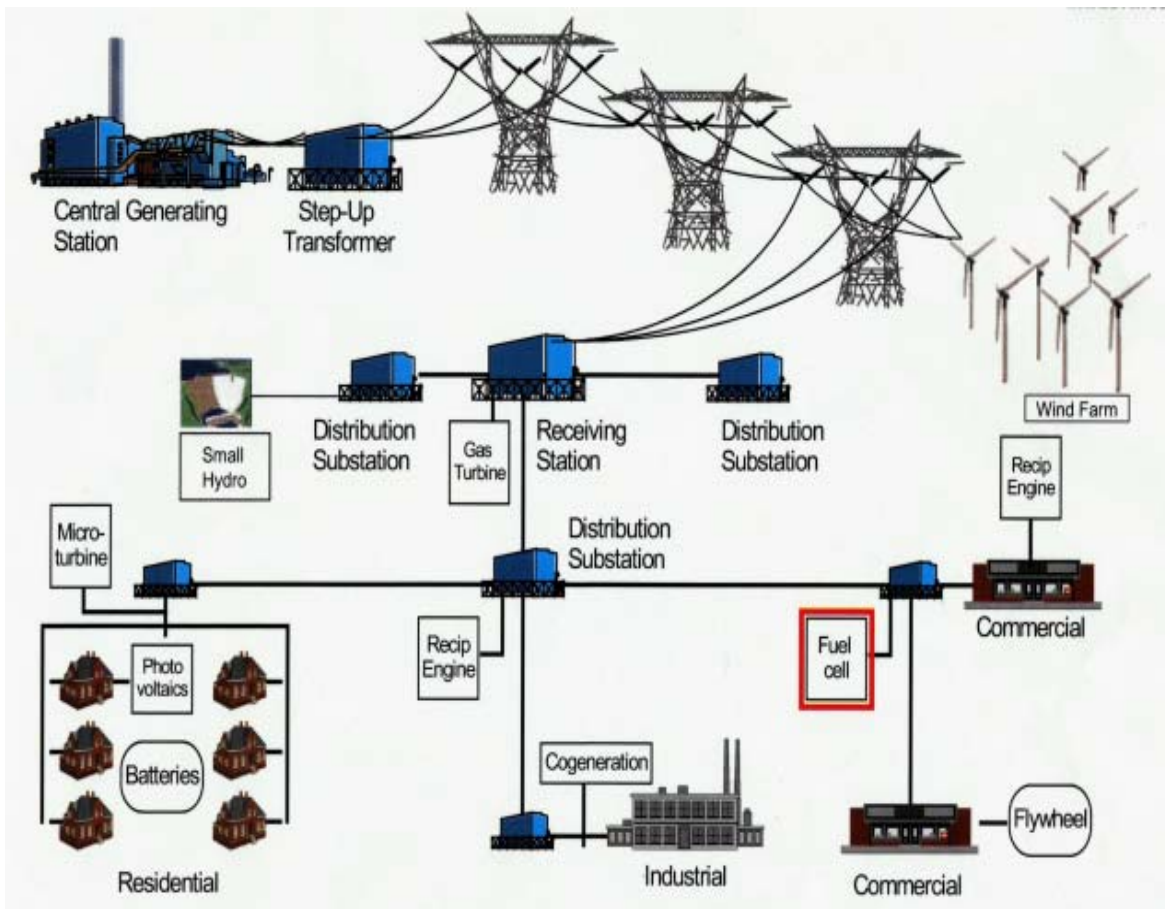


## **INDUSTRY PARTNERS**

- Western Canadian Power Producers, including ATCO Gas
- Alberta-based fuel cell manufacturers, including Global Thermoelectric
- Geothermal consortium (still at a formative stage) : Nexen, Petro-Canada, ConocoPhillips, EnCana and Suncor
- Small and medium companies interested in ‘Green Energy’

## **ENVIRONMENTAL & POLICY DRIVERS**

- Lack of adequate incentives and regulations in ‘Green Energy’.



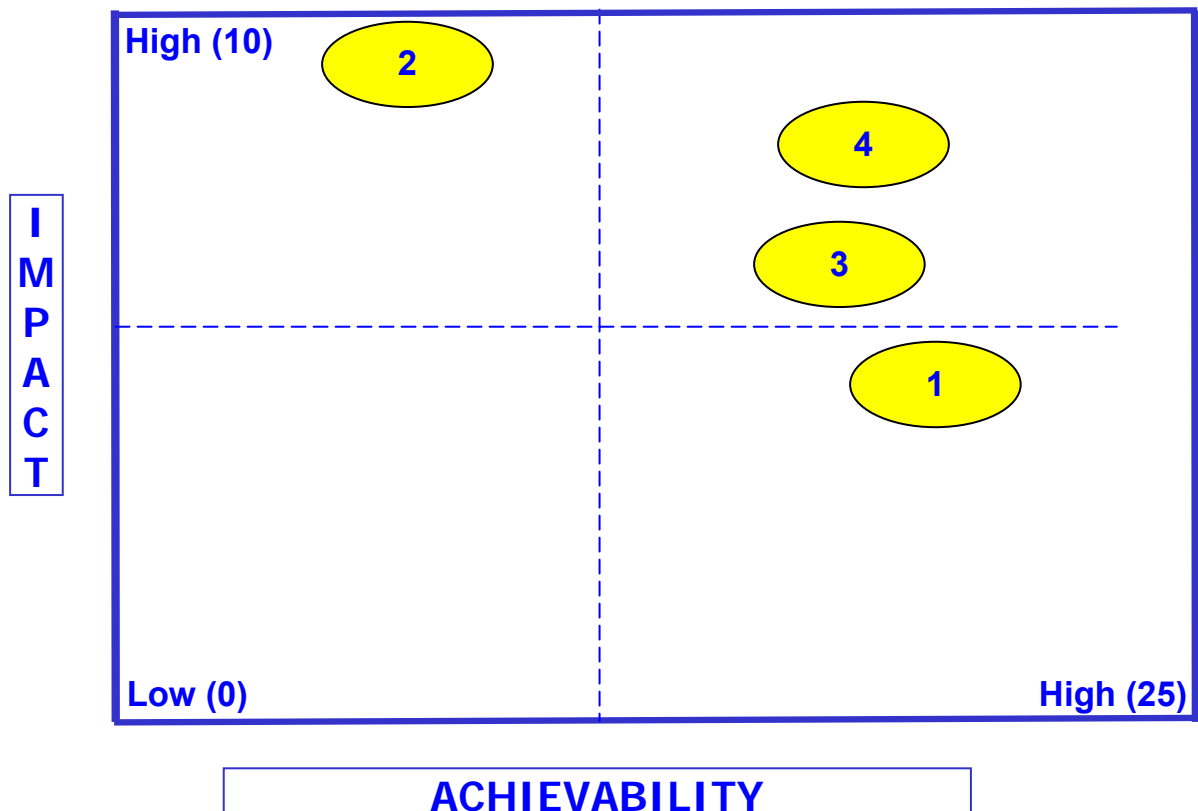
***Figure 11: Illustration of the emerging energy supply providing opportunity for distributed generation, fuel cell and “green” power.***

# Alternate & Renewable Energy Program

## Impact vs Achievability of key Initiatives relevant to 2012 Goals

The key initiatives are described in the tables on Major Milestones and Expected Outcomes and include:

1. Fuel Cell Initiative
2. Geothermal Heat Source for Oil Sands Extraction
3. Bio-energy
4. Hydrogen



# Carbon Dioxide Management

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The goal of the climate change challenge is to reduce the amount of anthropogenic greenhouse gases (GHG) that are emitted into the atmosphere. There are three major options to pursue: (a) increased efficiency of energy use, (b) switching to less carbon intensive fuels, and (c) carbon management. Carbon management involves capturing CO<sub>2</sub> and storing it in geological formations, biomass, and the oceans. Although all three can be utilized in the proper setting, only geological storage provides long-term storage in excess of thousands of years. Therefore, CO<sub>2</sub> capture and geological storage (CCS) is a particularly attractive technology option to reduce Canada's GHG emissions and allow the continued use of fossil fuels, and provide the time required for the transition to lower-carbon energy intensive technologies. This technology involves capturing CO<sub>2</sub> from large point sources, transporting it and either using it to enhance the recovery of oil and coal bed-methane or storing it underground geological formations.

Canada is a world-leader in many areas of carbon capture and storage technology. In addition Canada has excellent regions for geological storage in the depleted or underutilized pore space of the mature WCSB which has a CO<sub>2</sub> storage capacity exceeding 20 giga-tonnes of CO<sub>2</sub>. Alberta is unique, in the sense that it not only requires geological storage to reduce CO<sub>2</sub> emissions, but it requires hydrogen to process its large bitumen resource where CO<sub>2</sub> is a major byproduct. The synergies between hydrogen production, CO<sub>2</sub> capture, storage and utilization in enhanced oil and gas recovery, has the potential to lead to Canada being a world leader in the transition to zero emission fuels.

## **PROGRAM VISION**

*The aim of this program is to reduce greenhouse gases by developing technologies to capture, transport and store carbon dioxide – and use it to increase oil and gas recovery.*

**The intent** is to make a concerted and coordinated effort to push suites of CO<sub>2</sub> capture, transport and storage technologies and strategies needed for evolving fossil energy systems and infrastructure over the top from “developing” through “commercially available” to “commercially attractive” in Canada within the next 10 to 20 years.

## **2012 GOAL**

To support the development of key technologies that will enable a 25% reduction in greenhouse gas emissions per unit of energy produced. Technologies will be developed to use the captured carbon dioxide to increase oil and gas recovery.

## **2012 STRATEGIES**

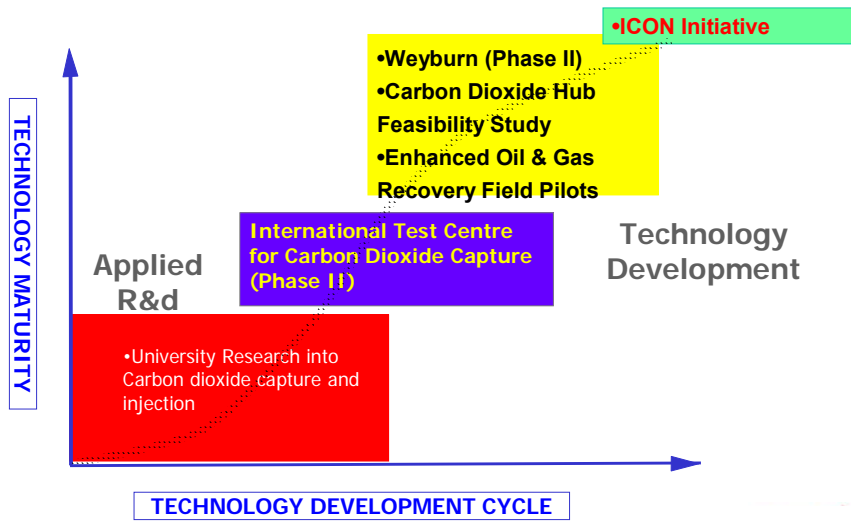
- **CO<sub>2</sub> Capture** – Key technologies adapted to enable industry to reduce the cost of CO<sub>2</sub> capture by 50% of 2005 costs.
- **CO<sub>2</sub> Transportation** - A CO<sub>2</sub> Trunk Line completed from Fort McMurray to Fort Saskatchewan.
- **CO<sub>2</sub> Storage and Use** - Key technologies developed that will enable industry to use 20% of its CO<sub>2</sub> emissions in energy production and CO<sub>2</sub> storage.

## **KEY INITIATIVES:**

The key milestones and benefits expected from existing and new AERI-funded projects are summarized in the following table.

Key Initiative	Major Milestones	Expected Outcomes
Weyburn CO <sub>2</sub> Monitoring	<ul style="list-style-type: none"> <li>○ Phase II completion</li> </ul>	<ul style="list-style-type: none"> <li>○ Development of CO<sub>2</sub> storage technologies and protocols</li> </ul>
Computer Modelling Group Reservoir Model	<ul style="list-style-type: none"> <li>○ The CMG reservoir model for the simulation of CO<sub>2</sub> storage</li> </ul>	<ul style="list-style-type: none"> <li>○ Reservoir modelling would facilitate the development of CO<sub>2</sub> storage field pilots</li> </ul>
PennWest Field Pilot	<ul style="list-style-type: none"> <li>○ A set of nine separate monitoring, measurement and verification projects</li> </ul>	<ul style="list-style-type: none"> <li>○ Technology development and the verification of long-term CO<sub>2</sub> storage potential.</li> </ul>
CO <sub>2</sub> Enhanced Oil Recovery (EOR)	<ul style="list-style-type: none"> <li>○ Completion of a CO<sub>2</sub> business case study</li> <li>○ Monitor active CO<sub>2</sub> pilots funded under the CO<sub>2</sub> Royalty Credit Program</li> </ul>	<ul style="list-style-type: none"> <li>○ Identification of candidate locations and available point sources and infrastructure</li> </ul>
Enhanced Gas Recovery	<ul style="list-style-type: none"> <li>○ Field demonstration of CO<sub>2</sub> or Flue gas enhanced gas recovery.</li> <li>○ Completion of laboratory studies supporting performance optimization.</li> <li>○ Coordination of AERI activities with the IETP.</li> </ul>	<ul style="list-style-type: none"> <li>○ Flue and CO<sub>2</sub> capture and injection, lab and simulation verification, and simulation technology development</li> </ul>
Integrated CO <sub>2</sub> Network (ICON)	<ul style="list-style-type: none"> <li>○ Support industry initiatives to develop a CO<sub>2</sub> backbone linking oil sands sources and industrial sources of CO<sub>2</sub> to enhanced oil and gas recovery plays in Alberta.</li> </ul>	<ul style="list-style-type: none"> <li>○ Development of CO<sub>2</sub> backbone stretching linking Fort McMurray and Fort Saskatchewan with oil and gas and CBM fields.</li> </ul>

## Carbon Dioxide Management Program - Portfolio Balance

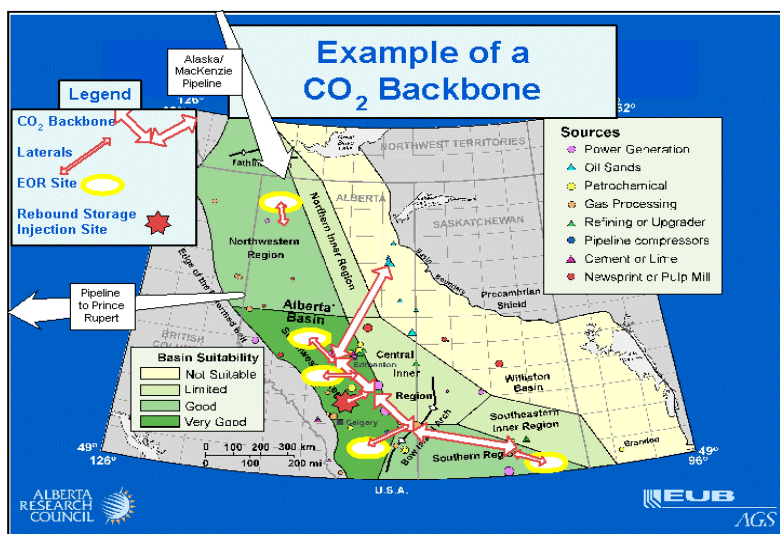


### INDUSTRY PARTNERS

- Western Canadian conventional and non-conventional oil and gas producers
- Alberta-based Large Final Emitters, who require CO<sub>2</sub> storage options.

### ENVIRONMENTAL & POLICY DRIVERS

- The development of a CO<sub>2</sub> backbone and the negotiations between the federal government and the Large Final Emitters of carbon dioxide will determine how much carbon dioxide is captured and stored.



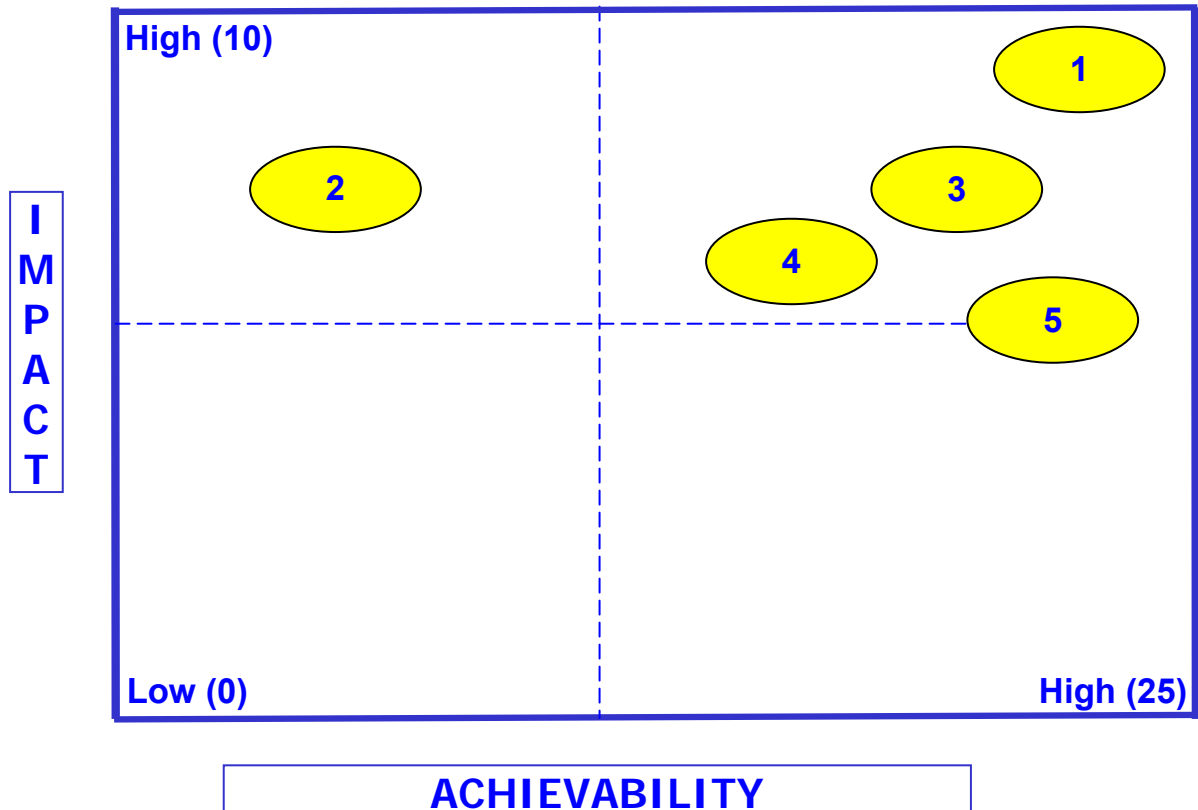
**Figure 12: Schematic of a backbone linking hubs in the Western Canada.**

# CO<sub>2</sub> Management Program

## Impact vs Achievability of key Initiatives relevant to 2012 Goals

The key initiatives are described in the tables on Major Milestones and Expected Outcomes and include:

1. Weyburn CO<sub>2</sub> Monitoring
2. Computer Modelling Group Reservoir Model
3. PennWest Field Pilot
4. CO<sub>2</sub> Enhanced Oil Recovery (EOR)
5. Enhanced Gas Recovery



# Water Management Program

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Water and energy are closely linked. Water is co-produced with oil and gas. It is needed to produce heavy oil, hydrogen and to cool power reactors. Energy is required for water treatment and desalination.

With around 0.5 percent of the global population, Canada has 20 percent of the world's freshwater supplies. Surface water is well delineated but groundwater is not. Canadians have the cheapest drinking water prices and are among the highest per capita consumers of water in the world. Regional water shortages have been caused by drought and generally been of short duration. Other issues of concern include the safety of drinking water supplies, the availability of water for recreational, livestock and agricultural purposes and the protection of our ecosystems.

## **PROGRAM VISION**

*The aim of the program is to recognize the dependence of the energy industry on water, by developing technologies that would reduce the use of fresh water and implement cost-effective water re-use and recycle systems.*

## **2012 GOAL**

AERI is supporting the development of the key technologies that will allow the energy sector to reduce its fresh water usage by 25% per unit of production.

## **2012 STRATEGIES**

Goal is the development of key technologies that will allow the energy industry to reduce its freshwater usage by 25% per unit of production.

- **Produced Water Treatment & Recycle** – Novel technologies developed that will contribute to the target of 25% reduction in fresh water usage.
- **Oilsands Fine Tailings Treatment** – Novel technologies and protocols have been developed that will contribute to a target of 25% reduction in the total mature fine tails (MFT) inventory and a 25% reduction in the MFT per barrel of bitumen produced.
- **Geological Assessment of Groundwater in support of CBM development** – Enable coal bed methane production to increase to 5% of total natural gas produced in Alberta.
- **Reduce cooling water needs** – Key technologies developed that will allow the thermal power industry to reduce fresh water consumption by 10% per unit of product.

## **KEY BENEFITS**

- The cost of oil and gas produced water handling, disposal and recycling can be approximated at about \$5 per barrel of oil. The reduction of water usage by the industry by 25% would translate into a saving of \$1.25 per barrel of oil. However, this value is complicated by the need of the industry for water and the fact that reduction in freshwater would likely be substituted by other liquids (such as saline water) or gases (such as CO<sub>2</sub>) – hence cost reduction may not be realized and in fact could increase.
- The cost of oil sands tailings handling, storage and reclamation can be approximated at about \$2 per barrel of oil. A 25% reduction of tailings volume would translate into a saving of \$0.50 per barrel of oil.
- The volume of natural gas produced in Alberta in 2012 can be assumed to be 4.5 trillion cubic feet. 5% of this would be 225 billion cubic feet, or about 225 million GJ (at \$10 per GJ).
- The volume of freshwater used for cooling at thermal power facilities in Alberta is about 15,000m<sup>3</sup> per Mica. With 7400 MW Cap from coal in 2012 – this would equate to an annual cooling water need of about 110 million m<sup>3</sup> per year. Assuming a cooling water handling cost of about \$1 per m<sup>3</sup> – this translates to \$15,000 per MW capacity

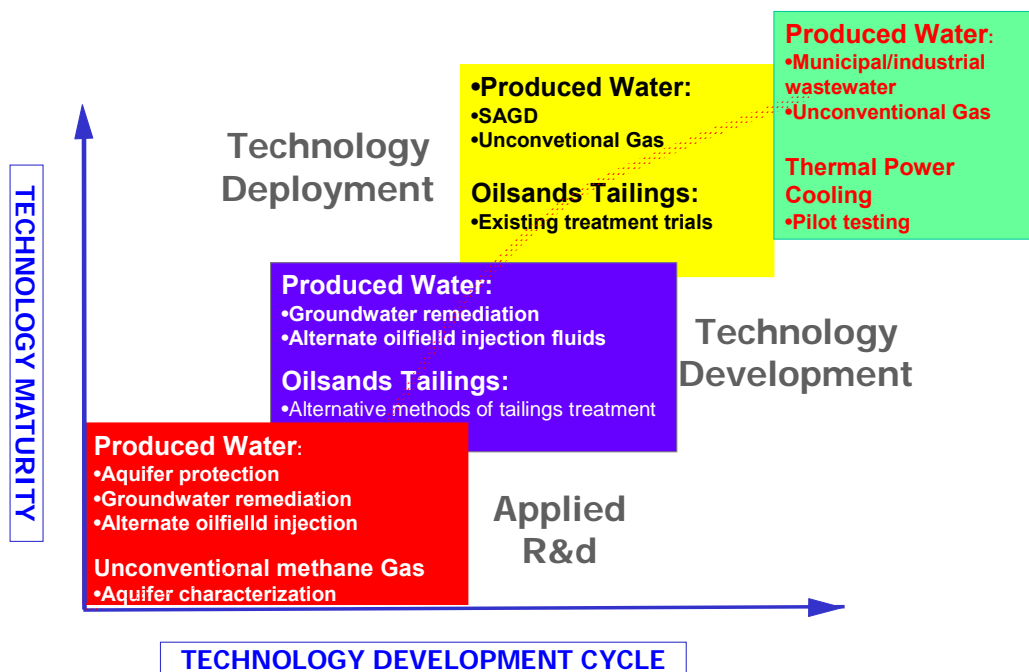
## **KEY INITIATIVES:**

Water Management is a crosscutting initiative; AERI-funded projects in other strategic focus areas have reduced water consumption as one of their primary objectives. The key milestones and outcomes expected from existing and new AERI-funded projects are summarized in the following table.

<b>Key Initiative</b>	<b>Major Milestones</b>	<b>Expected Outcomes</b>
Produced Water Treatment & Recycle	<ul style="list-style-type: none"> <li>○ Participate in select feasibility and test pilots on:               <ul style="list-style-type: none"> <li>- Produced water treatment</li> <li>- alternative uses</li> <li>- Unconventional Gas development</li> <li>- Water use in SAGD</li> <li>- Aquifer protection</li> <li>- Groundwater remediation</li> <li>- Oilfield injection</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>○ Development of novel prototype technologies and testing of alternatives for de-oiling and secondary treatment of produced and process affected waters</li> <li>○ 25% reduction in the use of freshwater by the oil &amp; gas sector by 2015</li> </ul>
Oil sands tailings treatment	<ul style="list-style-type: none"> <li>○ Formation of a cross ministry tailings working group</li> <li>○ Feasibility, university based R&amp;D</li> </ul>	<ul style="list-style-type: none"> <li>○ Optimization of commercial practices on existing consolidated tailings &amp; Paste technologies</li> <li>○ Verification protocols on commercial practice</li> </ul>
Unconventional Gas production	Geological Assessment of Groundwater : <ul style="list-style-type: none"> <li>○ Scoping and preliminary site</li> </ul>	<ul style="list-style-type: none"> <li>○ Summarization of groundwater and disposal horizon availability in key areas of the province</li> </ul>

Key Initiative	Major Milestones	Expected Outcomes
	<ul style="list-style-type: none"> <li>○ selections</li> <li>○ Drilling and characterization program</li> </ul>	
Thermal power cooling water	<ul style="list-style-type: none"> <li>○ Scoping and feasibility studies</li> <li>○ Participation in specific technology developments</li> </ul>	<ul style="list-style-type: none"> <li>○ Detailed examination and summarization of R&amp;D technology needs for further participation</li> <li>○ Development of novel prototype technologies</li> </ul>

## Water Management Program - Portfolio Balance



### INDUSTRY PARTNERS

- All Western Canadian oil and gas producers and power generators.
- Technologies developed within this program will have worldwide applicability.

### ENVIRONMENTAL & POLICY DRIVERS

- Policy based incentives to significantly increase the amount of treated and recycled water used in the energy industry.

# Water Management Program

## Impact vs Achievability of key Initiatives relevant to 2012 Goals

The key initiatives are described in the tables on Major Milestones and Expected Outcomes and include:

1. Produced Water Treatment & Recycle
2. Oil sands tailings treatment
3. Unconventional Gas production
4. Thermal power cooling water

