The ecoENERGY Innovation Initiative
Canada-Israel Energy S&T Fund (CIESTF Fund)



PUBLIC FINAL REPORT

Presented by Canada-Israel Industrial R&D Foundation

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Executive Summary

In 2013, Canada-Israel Industrial R&D Foundation (CIIRDF) undertook the challenge of launching the Canada-Israel Energy S&T (CIEST) Fund to facilitate the bilateral development and commercialization of innovative energy technologies and processes. The Fund had a strong focus on innovations that enable the responsible development of unconventional oil and gas resources.

It was a challenge because CIIRDF had to ensure that the Fund was committed to high quality collaborative R&D projects that could be sourced, assessed, evaluated and completed within a 36-month period. Moreover, the Israeli and Canadian energy R&D communities had almost no history of cooperation, or knowledge of each other's capabilities.

Selected by Natural Resources Canada (NRCan) to deliver the CIEST Fund, CIIRDF established an ambitious set of strategic goals to overcome these challenges. Within three years of receiving this mandate, CIIRDF delivered seven high calibre Canada-Israel energy projects with a collective value of more than $23 million. The following table illustrates the summary of achievements:

Strategic Goals	Achievements to Date
To connect Israeli innovation capabilities with Canada's energy R&D needs	• Identified 680 Israeli solutions that are relevant to Canada's oil sands industry • Generated 30 new Canada-Israel energy collaborations • Developed 7 projects bringing Israel's key technological expertise in water treatment and analytics
To specifically focus on unconventional oil and gas with particular attention to oil sands	• 6 out of 7 CIEST Fund projects addressed challenges faced by unconventional oil and gas industry • Submitted 34 technological 'offers' from Israel to address key environmental challenges of Canada's oil sands industry
To establish bi-lateral partnering platforms to 'institutionalize' the Canada-Israel links	• CIIRDF's activities as a Canada's Oil Sands Innovation Alliance (COSIA) Associate Member created a sustainable platform
To apply this through ecoEII program in a leveraged approach	• Leveraged NRCan funds by 5-to-1. • Leveraged networks and expertise of strategic partners: Israel Innovation Authority, NRCan, COSIA, Alberta Innovates, PTAC, etc.

These results provide evidence that the objectives have been met and even surpassed. Achieving the strategic goals of the CIEST Fund by CIIRDF is a reflection of the substantial potential for continued Canada-Israel cooperation on energy technologies and provides compelling proof of the economic value to both countries of this cooperation.

Importantly, the CIEST Fund has established a base for sustainable and systematic connectivity of Israeli 'enabling technologies' applicable across the energy sector, beginning with the environmental/innovation priorities of Canada's oil sands sector.

Through the explanation of the specific targets within each of the supported projects, this report describes specifics on the expected economic and other benefits that will be derived from this program. These are the tangible benefits of the CIEST Fund. The additional benefits, through extended outreach, are also presented and should not be seen as being merely 'intangible'. In the case of the COSIA example, the oil sands companies themselves have expressed clear indication of their financial value. All point to exceptional returns from the CIEST Fund to the Canadian taxpayer as well as to the contribution of the CIEST Fund to overall Canada Israel bilateral relations.

The results presented in this report show that when we set the bar high, much can be achieved. Much more will be achieved by building on the strong base established through the delivery of the CIEST Fund by extending this program in the coming years.

Background

In December 2012, NRCan selected CIIRDF to deliver and manage the new Canada-Israel Energy Science and Technology (CIEST) Fund. The CIEST Fund aimed to facilitate the bilateral development and commercialization of innovative energy technologies and processes. With a strong focus on key challenges in the unconventional oil and gas sector, the CIEST Fund was designed to support industry-led R&D partnerships between Canada and Israel. These collaborations aimed to spur the development of innovative energy technologies and processes that enable the responsible development of unconventional oil and gas resources, including applications to address environmental challenges. The Fund specifically promoted innovation that would reduce environmental impact associated with energy exploration, extraction, processing and production. It also encouraged initiatives on other critical energy sources, such as renewable energy, of interest to both countries. The emerging bilateral partnerships are expected to yield ground-breaking new technologies that enable Canadian and Israeli innovators to capitalize on the evolving global unconventional oil and gas market.

The Government of Canada committed up to $5 million to the CIEST Fund over four years (2013 to 2016), with matching funds to be allocated by the Israel Innovation Authority (IIA) on a project-by-project basis. Leveraging investment from both countries, the fund was expected to generate up to $20-40 million in collaborative R&D.

Opportunity and Objective

The CIEST Fund was established to help Canada tap and capitalize on Israel's world class technological know-how, R&D and commercialization capabilities, and jointly develop new innovations with application in Canada's energy sector. The fund capitalizes on many synergies between the two nations. Israel is home to hundreds of technology-based SMEs with internationally recognized expertise in materials, intelligent systems, water technologies, robotics and unmanned systems, sensors, imaging and other 'enabling' technologies. The nation is also expected to become a gas exporter by the end of the decade. Its Leviathan field features 17 trillion

cubic feet of gas, while its Tamar field boasts almost 10 trillion cubic feet of gas. Canada has the third largest crude oil reserves in the world with 97 percent based in Alberta oil sands, and the country is expected to become the fourth-largest oil producer in the world by 2035. With a national energy industry and extensive technological know-how in unconventional oil and gas, Canada is well positioned as an ideal technology partner.

By combining the strengths of Canadian and Israeli firms, the CIEST Fund propelled the development and commercialization of new solutions that address key challenges in Canada's energy sector. This included new applications in unconventional oil and gas, bioenergy and energy efficient communities, industry and transportation. Canadian firms gained new technological know-how that enables them to develop new products and become more competitive in global markets. Downstream, the emerging innovations will benefit the Canadian economy, creating enhanced efficiencies and reducing negative environmental impact.

Project Evolution

Connecting Two Communities

Canada's unconventional oil and gas industry was not largely known to the Israeli scientific and technological communities. To help facilitate bilateral partnership development and CIEST Fund R&D project applications, CIIRDF established excellent working relations with NRCan and the energy group in Israel Innovation Authority (IIA). As well, CIIRDF partnered with key organizations in Canada's oil and gas industry; e.g., PTAC (Petroleum Technology Alliance of Canada), COSIA (Canada's Oil Sands Innovation Alliance) and Alberta Innovates. Creating linkages between Canada's oil sands industry (including its associated supply chain) and Israeli innovators was essential to the success of this program.

To help identify strategic technological synergies, CIIRDF commissioned Signals Analytics to produce a set of Israeli Technological Capabilities Ecosystem Map (Israeli Innovation for Oil Sands). These interactive e-maps identified 680 Israeli solutions that are relevant to Canada's oil sands industry and provided a comprehensive overview of technological capabilities in Israel that could help to address key environmental and other challenges in Canada's unconventional oil and gas sector. This was instrumental in helping Canadian companies to identify prospective Israeli R&D partners for CIEST Fund R&D projects.

Figure 1: Israeli Innovation for Oil Sands Map

During the first Partnership Exploration phase of the CIEST Fund, CIIRDF:

- Generated more than 60 linkages between Canadian and Israeli energy technology firms;

- Hosted three partnership development activities with Canadian and Israeli companies, researchers and other innovators in Tel Aviv, Israel; Calgary, Alberta; and Toronto, Ontario. This included three bilateral workshops that assembled more than 250 participants; and
- Established a new bilateral platform with Canada's Oil Sands Innovation Alliance (COSIA) to enable the development and application of novel technologies that promote the responsible development of Canada's oil sands.

R&D Activities performed

The CIEST Fund achieved its major objective by committing all allocated funds from NRCan to seven Canada-Israel energy R&D projects. Two calls for proposals resulted in seven collaborative technology projects between Canadian and Israel companies. With a total value of $23 million, these initiatives leveraged CIEST funding by a factor of 5-to-1.

The resultant knowhow and technologies are expected to fulfil the objectives of the fund: facilitate development of technologies that enhance Canada's ability to develop important resources (e.g., oil sands and shale-derived hydrocarbons) responsibly, improve the efficiency of key energy sources, and reduce environmental impact. The following section provides the summary of progress and achievements reported by project lead companies.

Project 1: Enhanced Oil Sands Produced Water Evaporators
Canada Lead: Clean Harbors Energy & Industrial Services Corp., the Canadian subsidiary of Clean Harbors, North America's leading provider of environmental, energy and industrial services
Israel Lead: IDE Technologies, an Israeli pioneer and world leader in water technologies

The water treatment process employed to extract crude oil and bitumen from oil sands is costly and challenging. Mechanical Vapor Compression (MVC) Evaporators are a critical part of this practice. Comprised of a complex network of pipes that process heavy oil and sludge, these systems demand frequent chemical cleaning given scaling and the accumulation of unwanted materials. They also demand hundreds of thousands of gallons of water that cannot be recycled and reused. Moreover, processing plants must be shut down for days to cleanse the evaporator, impeding oil production.

This Canada-Israel R&D project aimed to improve the operation, service and maintenance capabilities of MVC evaporators by integrating IDE's unique horizontal evaporator design with Clean Harbors' chemical expertise. The solution minimizes the evaporator downtime, improves the safety and reliability of the water treatment process, and ultimately boosts the productivity and profitability of crude oil processors. The evaporator includes a removable tube bundle that is easily accessed and cleaned by operators. Clean Harbors developed customized chemical blends and cleaning procedures to optimize the maintenance of the system.

The companies conducted a bench-scale pilot program at an Alberta Innovates Technology Futures' facility in Edmonton, achieving excellent efficiency. Although it typically requires one week to cleanse an evaporator, the CIEST Fund-supported technology achieved this objective within 24 hours. It also eliminated waste, and reduced water consumption by 97 percent, enabling recycled water to be used for steam generation. The pilot served as an excellent demonstration for prospective clients.

Importantly, the companies gained a generalized understanding of the nature of scale and deposits present in the desalination systems used in SAGD production. From this information and working with samples generated in this project and other related systems, Clean Harbors succeeded in developing new and different method that should result in commercial success.

Project 2: Produced Water - Enhanced Reuse & Hyper-saline Desalination
Canada Lead: KmX Corporation, a Canadian firm that converts spent solvent and wastewater streams into valuable reusable products
Israel Lead: RWL Water (Nirosoft), an Israeli company that specializes in advanced quality water treatment solutions and wastewater treatment systems

Two water treatment expert companies collaborated on the development of an innovative water treatment and desalination system. The resulting technology will enable the recovery and re-use of high salinity water generated during unconventional oil and gas production. It will address some of the key challenges associated with traditional hydraulic fracturing (or fracking) techniques employed in the extraction of shale oil and gas.

The fracking process uses high pressure water combined with chemicals to fracture the shale rock and enable the release of shale oil and gas. With the hydraulic fracking market valued at $37 billion in 2012, this approach is increasingly used around the world despite the many challenges of high salinity water disposal. This Canada-Israel team aimed to develop, qualify and integrate innovative water technologies into a full treatment process that addresses key issues with fracking-produced water. For example, it removes high levels of dissolved contaminants such as metals, oils, chemicals, solids, bacteria to enable safe water re-use. This cost-effective system features a Vacuum Membrane Distillation (VMD) that acts as a selective barrier allowing water vapor to transfer through the surface, leaving behind highly concentrated salt along with these undesirable elements.

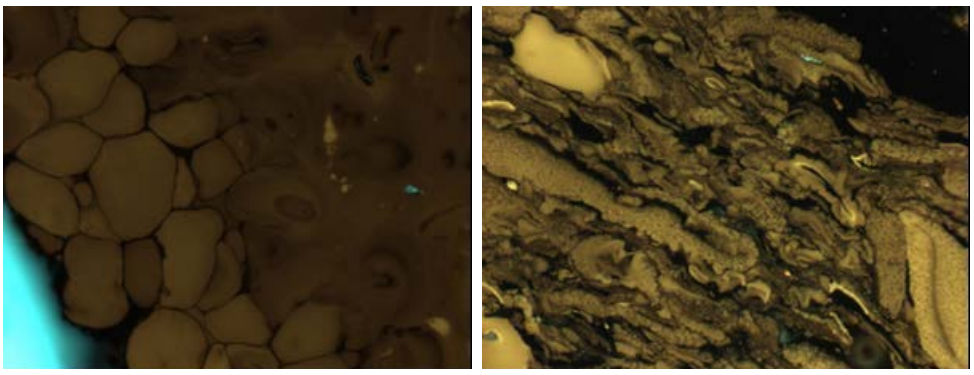
Project 3: Assessment of Oil Shales from Israel and Canada
Canada: FG & Partners, a Canadian SME that specializes in the exploration of natural resources such as hydrocarbon and coal, **University of Calgary** and **Geological Survey of Canada**
Israel: Israel Energy Initiatives Ltd., an Israeli company and world leader in in-situ oil shale development and **Ben Gurion University**

This Canada-Israel team developed a new technology that enables the rapid and accurate assessment of Canadian and Israeli oil shale deposits. Israel and Canada possess vast shale

deposits; however, little is known about which shale basins are most suitable for recovery. This novel tool will assess the potential to recover shale oil and gas from source rocks in these regions, and the potential value of these unconventional resources. As part of this project, collaborative between the Canadian and the Israeli team resulted in the following:

- Development of fast techniques to assess the hydrocarbon potential of oil shale deposits, accurately and in a timely manner, which is very useful for determination of source rock and therefore very useful for oil/gas exploration;
- Determination of the hydrocarbon potential of Canadian oil shales and delineation of deposits, which are of academic interest with interesting story, and low hydrocarbon yield due to geological configuration from those with good-moderate yield (25-60L/tonne) and economic potential;
- Selection the deposit(s) that have potential for *ex situ* and *in situ* extraction. Most Canadian oil shales have potential for Ex-situ extraction, except the oil shale form Emma Fiord, Arctic Canada;
- Discovery that Israeli oil shales were buried in a shallow depth therefore thermally immature and their organic matter composition is unique; and
- The Israeli oil shales are an excellent source for the generation of hydrocarbons and in geologically more mature areas will provide Israel with onshore oil/gas resources.

Figure 2: The petrology of Cannel and Canneloid from Melville Islands, Arctic Canada consists mostly of resinite (left), Micro and mega sporinites (right).



Project 4: Integration of Fe-based Fischer-Tropsch (FT) conversion with a bitumen upgrader

Canada Lead: Nexen Energy ULC, a Canadian subsidiary of CNOOC Ltd. that is developing energy resources responsibly and **University of Alberta**

Israel Lead: Merchav Engineering Ltd, an Israeli firm that specializes in process engineering and development and **Ben Gurion University**

This Canada-Israel industry-academic team collaborated on the development of a new process that, if successful, would increase the production of value-added products from the Alberta oil sands. Oil sands are a naturally occurring mixture of sand, clay or other minerals, water and bitumen. To process the bitumen into oil, it must first be separated from the water and sand. It is then upgraded and refined to produce transportation fuels such as gasoline and jet fuels as well

as chemical feedstock and other products. It is estimated there are 100-200 million barrels of oil in Canada's oil sands. Asphaltenes are extremely heavy and dense materials that are solvent separated during the bitumen upgrading process. Asphaltenes are typically disposed of in landfills, increasing the volume of non-biodegradable waste in these areas, or utilized as gasification feed to be converted into syngas, as is the case at Nexen's Long Lake facility.

To achieve the R&D objective, the team focused on the FT process which converts syngas into liquid hydrocarbons. These hydrocarbons could be transformed into a variety of commercial products, including waxes, chemical compounds, gasoline, naphtha and diesel. The innovators demonstrated key aspects of the FT process for an unconventionally CO-rich syngas composition, and its integration possibilities into the Nexen's Long Lake facility, which is designed to upgrade 72,000 bpd of bitumen into premium synthetic crude oil in Alberta, Canada. Although the FT process is well known for converting syngas to liquids, this project focused on directly converting CO-rich syngas to liquids, and integrating the liquids with bitumen upgrading.

The first objective was to develop a suitable catalyst for converting CO-rich ratio syngas to liquids. The best performing catalyst in this study was developed at the Ben-Gurion University's Blechner Center for Industrial Catalysis and Process Development. This catalyst met all specified performance targets with the required activity, required stability and good heavy product selectivity. The study was extended to include investigations on parameters such as the operating range, and effects of water quality, temperature and pressure on catalyst performance.

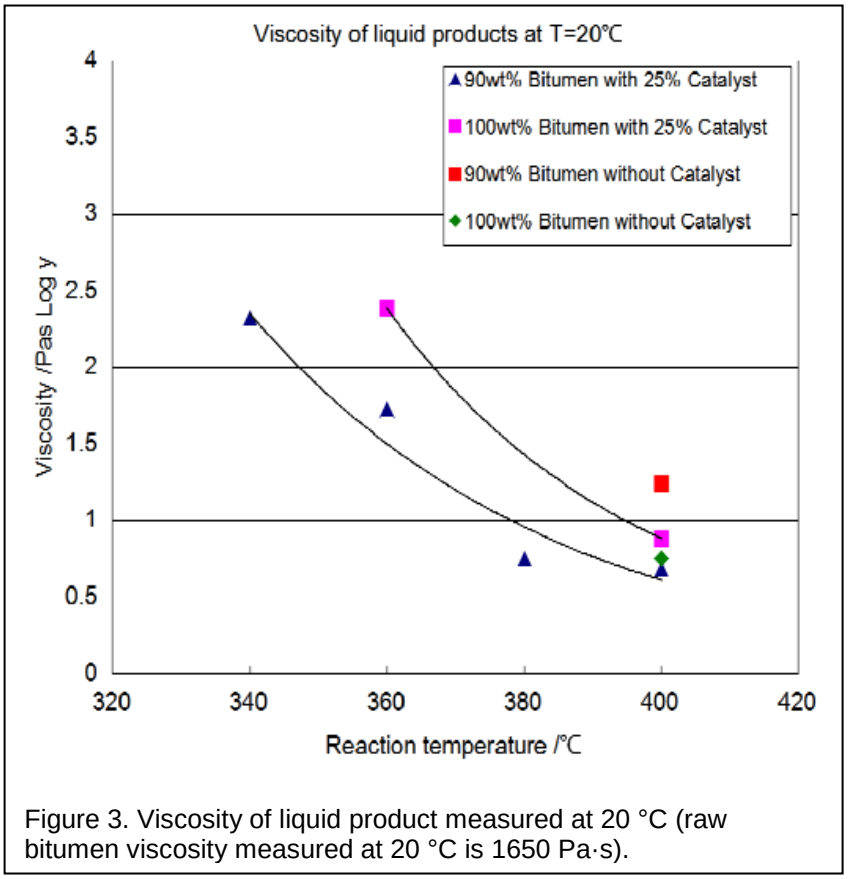


Figure 3. Viscosity of liquid product measured at 20 °C (raw bitumen viscosity measured at 20 °C is 1650 Pa·s).

A range of hydrocarbons can be produced from the FT process. The main product cuts are the FT tail gas, the FT oil and the FT wax. The researchers at the University of Alberta have demonstrated the liquids product from the overall FT process could potentially be increased by converting a percentage of the olefins in the FT tail gas to liquids using an oligomerization process without prior separation of the unconverted syngas. The University of Alberta also determined the preferred

integration pathway for the co-processing of FT wax with bitumen derived oil. It was found that co-processing in a hydrocracker leads to competitive adsorption resulting in a decrease of overall conversion but that co-processing in a visbreaker was technically viable.

A preliminary process flow diagram for a modular design of the FT process was completed in this study. Commercial gas purification technology could potentially be used to remove the impurities in the syngas therefore minimizing additional technical risk to the project. By potentially incorporating this process into upgrader facilities, liquid yield could be increased while reducing CO_2 intensity per barrel of upgraded product.

This study demonstrated the possibility of applying a FT type technology to a bitumen upgrader facility by investigating each portion of the process independently. A potential next step would involve production of a large commercial catalyst batch using commercially acceptable procedures and larger scale demonstration with the catalyst identified in this study. More detailed reactor design can be completed with data from a pilot demonstration, while further work on integration possibilities can add value to the overall process.

Project 5: Online Boiler Feed Water Quality Analyser

Canada: Luxmux Technology, a Canadian SME developing unique turnkey solutions and optical components designed for the next generation of sensing systems, **Agar Canada Corp, University of British Columbia** and **University of Calgary**
Israel: NDT Ultrasonics and **Hebrew University-Institute of Medical Research**

Canada has 174 billion barrels of oil, 169 billion of which are located in the oil sands. This makes “Canada the third largest oil reserves in the world” with 97% of these reserves located in Alberta. For In-situ operations commonly referred to as thermally enhanced heavy oil recovery, steam is produced and injected into the ground to reduce the viscosity of oil so that it can be extracted. In-situ oil production in Canada is currently producing 1.2 million barrels of oil per day (BPD) with large amounts of water needed for the steam generation and approximating 4.8 millions of barrels per day. It is expected that in-situ production in Canada will double in the next ten years.

The Alberta Energy Regulator (AER) specifically Directive 81 regulates the amount of fresh, typically brackish water in which producers are allowed to dispose, requiring producers to typically re-use over 85% of the water which is injected and returned with the oil being produced. Water quality is an important factor in the efficiency of oil extraction in thermally enhanced heavy oil recovery. With increased regulatory constraints producers are required to recycle more of the produced water, i.e. clean and treat the water that returns with the oil, and are limited on the amount of makeup water allowed. Higher quality water ensures higher quality steam which equates to increased oil production. When water quality is poor deposits form on the tubes, hot spots are generated and the tubes rupture leading to expensive down time creating a need for better management of water quality measurement systems. In order to ensure water quality and properly treat water, producers need to identify and measure contaminants. The parameters of interest in which they require an online analyser and do not have an available/reliable online solution consists of Oil and Silica measurements.

The project team aimed to address the lack of an online water quality analyzer system that has been costing oil sands producers millions of dollars every day. This CIEST Fund supported project

developed an online boiler feed water quality analyzer to provide water analysis online and in real time. Currently, heavy oil producers for thermally enhanced heavy oil recovery are performing water quality assessments and measurements on as a needed be basis through the use of sampling and lab analysis for lack of a better online and immediate solution.

Combining the world-class expertise of project participants, the Canadian company, Luxmux Technologies forecasts the total revenue of over $10 million by the year 5 of the product launch.

Project 6: Integrated Energy Management and Monitoring System (IEMS)
Canada: EllisDon, a world-leading construction services company with more than 60 years of experience, **Magna, Guelph Hydro, University of Waterloo, University of Guelph,** and **Sheridan College**
Israel: **Rafael Advanced Defense Systems,** a world leader defense command and control, computing and communications system

This ground-breaking Canada-Israel R&D project is adapting technologies developed for civilian defense applications and develop a next-generation smart grid management system that improves energy efficiency and conservation, reduces waste, and lowers costs for utilities, operators and customers.

Integrated Energy Management and Monitoring System (IEMS) is a foundation system designed with an open architecture to integrate with disparate controllers, SCADA systems and Historians used for aggregating data. The solution is intended to be a disruptive technology that will add economic decision making and efficiency to SCADA and building management systems. A key differentiation of the IEMS from other SCADA systems allows for operational models to be independent of plant engineer and operator capabilities, experience and knowledge. The initial product requires a manual thermal and technical/economic model construction via a consulting service provided by the engineering teams of EllisDon and Rafael. The purpose of the model is to create a simulation of the target systems. Once defined, the IEMS will create a desired state based on baseline inputs and variable inputs such as weather, production schedules, commodity pricing to name a few. Collection of data in real-time will allow the IEMS to determine the optimal performance schedule of the CHP (Combined Heat and Power[1]) and optimize production of a Grid connected load displacement generator or Distributed Energy Resources. As the software develops the IEMS will develop the model via the collection and importing of data. Included in the project was the development of a management interface for collection information from a number of locations with generators and systems for the purpose of determining performance, costs, savings, aggregating alerts and alarms and overall command and control of the assets.

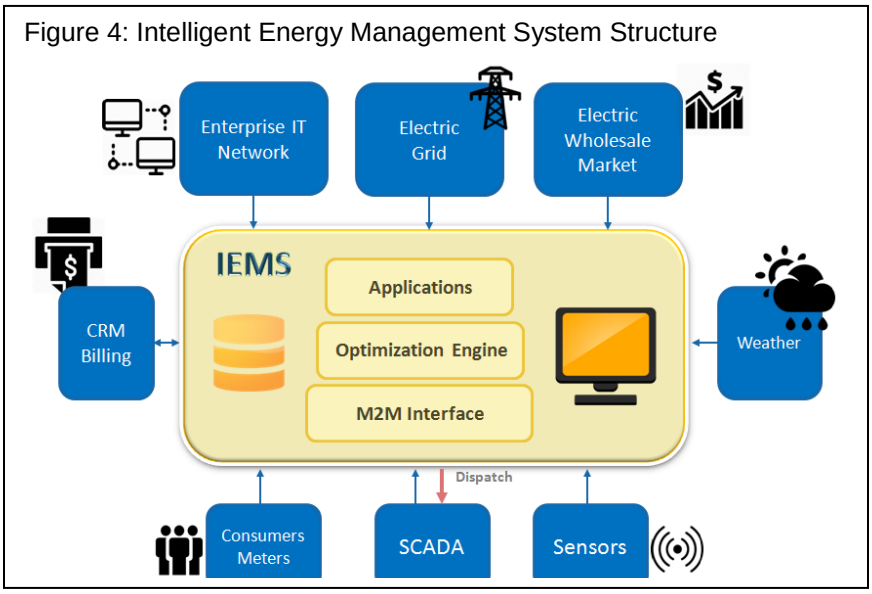
As a powerful centralized energy management system, capable of autonomously controlling single or multiple facilities, the IEMS reduces operational expenses by cutting fuel consumption, maintenance and labor costs. While managing CHP-distributed generation, the IEMS can

[1] Combined heat and power (CHP) integrates the production of usable heat and power (electricity), in on single, highly efficient process. (The Association for Decentralized Energy, http://www.theade.co.uk/what-is-combined-heat-and-power_15.html)

calculate runtime functions either by comparing runtime costs versus grid supplied electricity at spot rates or impacts related to rate schedules.

This autonomous decision-making system encompasses advanced algorithms and forecast analysis to enable real-time situational intelligence and optimized economical thermal-electrical generation dispatch. Multiple sources of real-time data, such as load consumption, energy flow, weather conditions and market rates, are analyzed together with other physical, economic and regulatory constraints to realize immediate and long-term measurable operational and ownership cost savings.

Figure 4: Intelligent Energy Management System Structure



Project 7: Oil Sands Evaporator Blowdown Produced Water
Canada: Saltworks Technologies Inc, a Canadian SME that delivers solutions for desalination and wastewater treatment
Israel Lead: IDE Technologies, an Israeli pioneer and world leader in water technologies

Alberta's Oil Sands Steam Assisted Gravity Drainage (SAGD) Produced water treatment is highly challenging due to the quality of the water, the requirement for recycling more than 90% of the water for re-use, and the limited disposal options on-site. Developing a more reliable, sustainable and cost effective water treatment process is one of the key market goals.

MVC evaporators are a critical step in the SAGD water treatment process, recovering ~95% of the water and providing boiler feed water quality. Currently, the options for volume reduction and solidification of the evaporator blowdown (waste) stream are limited and not reliable. Many SAGD sites cannot dispose of the evaporator waste on-site, and have to pay millions of dollars per year to "truck" (transport) the waste stream to a dedicated disposal well.

This R&D project aimed to develop and validate a cost-effective combined evaporation-evaporation waste treatment process that will increase the overall water recovery and decrease the disposal volumes in SAGD production. The joint development focused on optimizing a zero liquid discharge (ZLD) process, treating produced water all the way to solids, while achieving maximal availability and reliability of each step and insuring minimal downtime.

Challenges encountered

The downturn in the oil and gas industry that started in 2014 has been the single and largest

source of impact on the projects supported under CIEST Fund as six out of seven CIEST Fund projects addressed challenges and innovation needs of the unconventional oil and gas sector. The following projects have experienced impacts of this downturn and modified the projects or predictions accordingly.

Project 2: Produced Water - Enhanced Reuse & Hyper-saline Desalination

Because of the downturn in the oil and gas industry in 2015, the initial host site partner for the pilot trials had to withdraw, forcing KmX to find alternate. This process impacted the project schedule by 6 months as well as increasing the overall cost. In future, it would be beneficial to find ways to incent upstream and downstream beneficiaries of new technology to participate in the development process.

Project 3: Assessment of Oil Shales from Israel and Canada

When this project was submitted in 2013, the price of oil was $110 USD/bbl WTI; therefore, it was economical to explore unconventional sources such as oil shale, which are more expensive to develop compared to conventional hydrocarbon deposits. The subsequent collapse of oil prices (~$40USD/bbl WTI) at present constrains the market's ability to finance the exploration and development of unconventional resources. This constraint affects the economic feasibility (at least for a short-term) of the new assessment techniques resulting from the project.

Project 7: Oil Sands Evaporator Blowdown Produced Water

The economic downturn in the oil and gas industry proved difficult to identify a pilot project site for an integrated IDE evaporator-SaltMaker system; hence the project did not proceed to the Phase 3, Design integration of IDE evaporator with SaltMaker.

Results

R&D Project Results

The CIEST Fund projects have generated significant results ranging from new (to be patented) evaporator cleaning techniques, a new enhanced membrane-based hyper-saline desalination technique for oil sands and fracking industry, a number of publications and conference presentations, identification of the content of hazardous elements in key oil shale deposit, a new fast assessment methodology for determination of hydrocarbon source rock, expanded opportunities and strategic partnerships for all the participating Canadian companies.

Sustainable Platform to Source Solutions for Canada's Energy Needs

The CIEST Fund provided a platform where CIIRDF developed a Canada-Israel collaboration model addressing challenges of oil sands industry that can sustain beyond the terms of the program. In 2014, CIIRDF became an Associate Member of the Canada Oil Sands Innovation Alliance (COSIA). CIIRDF joins a group of multinationals, institutes and organizations whose associate membership is predicated on their potential to provide technological solutions to the innovation challenges of Canada's 13 oil sands producers. Specifically, these challenges relate to the ability of COSIA members to address environmental challenges in the following four Environmental Priority Areas (EPAs): land, water, air and greenhouse gases.

Working closely with the Israel Innovation Authority, Israel had become one of the largest single sources of new technological 'offers' for consideration by COSIA members. By June 2016, 34 new technologies were submitted to COSIA and have been reviewed. The joint opinion piece by CIIRDF President Henri Rothschild and COSIA's CEO, Dan Wicklum published by Research Money (Appendix 1) provides a good glimpse into benefits of this model. Dr. Wicklum made clear that he had sign off for this article from all 13 COSIA members:

> *"The resulting "research harvest" exposes Canada to technologies that would have cost hundreds of millions of dollars to develop on its own. And because oil sands companies are collaborating with other sectors like forestry and mining, technologies sourced in Israel can find their way into many sectors..."*

Because of the success already realized through the CIIRDF Associate Membership in COSIA, this approach will now be applied to strategically connect Israel's world leading technological capacity in cybersecurity with sectors of the Canadian economy with interest in this strategic and 'disruptive' technology. This will begin in the energy sector, including oil and gas and electrical grid management. Indeed, CIIRDF has been mandated by the Israeli National Cyber Bureau to apply the COSIA model by sourcing Canadian industry gaps and priorities with the cyber capabilities in the Israeli industrial and academic communities. Included in this activity will be the connection of leading university researchers from both countries. The expected "research harvest" referred to in the Rothschild/Wicklum opinion piece has the potential to be even more substantial that already experienced by the oil sands producers.

Benefits

The CIEST Fund supported R&D projects have realized and continue to realize a diverse range of economic and environmental benefits, including improved knowledge translation between academic institutions and industry. The following section summarizes the benefits reported by the lead R&D performing companies.

Project 1: Enhanced Oil Sands Produced Water Evaporators

As a result of this collaborative project, Clean Harbors gained:

- A better understanding of Scale forming species and deposit composition
- Improved methods to clean SAGD systems
- Increased efficiency in water desalination process
- Reduced chemical cost in cleaning processes
- Determination of ultrasonic methods in a field application

This project has been a tremendous success for Clean Harbors as not only did they develop a new chemistry that will be patented, they are also working to patent the cleaning process that will be game changing to the industry as a whole. No one is cleaning exchangers this way, and the benefits of reduced water, reduced downtime, and a safer cleaning technique will give Clean Harbors the ability to continue to grow their market share, not only in Canada, but abroad as well.

Project 2: Produced Water - Enhanced Reuse & Hyper-saline Desalination

The project proved that Vacuum Membrane Distillation (VMD) is an effective and low cost solution for the recovery of "hypersaline" O&G produced waters. With the growth in unconventional Oil and Gas production, this technology will have a significant environmental benefit in reducing

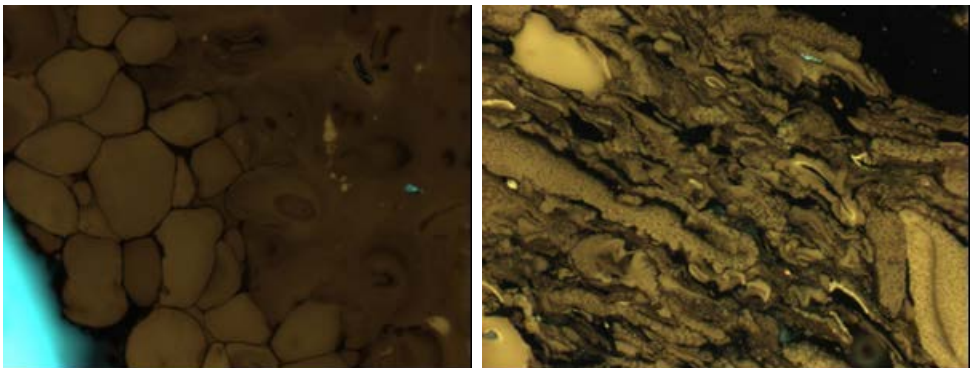
"fresh" water usage and in deep well/tailing pond storage requirements. It will also have a major economic benefit in the reduction of water related disposal and energy costs for the industry. By developing this project in Canada, the country has the potential to become a technology leader in the field of membrane distillation as it applies to unconventional oil and gas, mining and industrial wastewater recovery. Over time, an entire infrastructure can be built to provide membrane system manufacturing, field services, and new application development for both Canada and abroad.

Project 3: Assessment of Oil Shales from Israel and Canada

This project realized a several layers of benefits.

- Environmental: Most hazardous elements in Canadian oil shales (such as Arsenic, Molybdenum, Selenium and Sulfur) are associated with pyrite and increase with the pyrite content of oil shales. Since pyrite does not dissociate at temperatures below 600^{o}C the hazardous elements are not thermally mobilized at the temperatures required for *ex situ* operations (a maximum temperature of 500^{o}C).
- Efficiency: The importance of the fast techniques developed in this study is twofold, first: the techniques accurately assess the hydrocarbon potential of oil sand deposits and, second: data is collected in a matter of days as compared to an *in vitro* assessment, which takes 6 months to complete. Furthermore, the fast technique for the assessment of hydrocarbon potential can be used to determine the hydrocarbon source rock and therefore very useful for oil/gas exploration.
- Energy Security: Based on data obtained on Israeli oil shale, which are immature source rock and have excellent source potential for generation of hydrocarbon and their exploration in geologically more mature area will provide Israel with their onshore oil/gas resources. Importantly, energy self-sufficiency as well as export will establish and maintain closer ties with regional neighbours (e.g. Turkey, Jordan).
- Applicability*:* The fast assessment technique developed by Canadian team is proved very useful and will be used for assessment of hydrocarbon potential by FG&P in their hydrocarbon exploration studies world wide.

Figure 5: The petrology of Cannel and Canneloid from Melville Islands, Arctic Canada consists mostly of resinite(a), Micro and mega sporinites(b).



Project 4: Integration of Fe-based Fischer-Tropsch (FT) conversion with a bitumen upgrader

There is a potential for economic benefit to Nexen related to the production from an integrated FT process at the Nexen Long Lake facility. The steam assisted gravity drainage (SAGD) operation requires injection of high pressure steam into the reservoir to decrease the viscosity of the bitumen. The bitumen water emulsion is pumped from the ground and the bitumen is separated. SAGD is a carbon intensive process due to the fuel required for steam production. In this existing Nexen Long Lake facility, the current main fuel gas source is CO-rich syngas. The levels of carbon emission could potentially be reduced if syngas is to be replaced with natural gas, which has lower carbon emission for the same heating value.

- Economic benefit: If an FT process is added to the current upgrader configuration it will lead to increased liquid product of a marketable product.
- Environmental Impact: The FT process would likely result in decrease in direct carbon emission from Nexen Long Lake facility. Replacing syngas with natural gas to generate steam would result in less carbon emission for the same heating value.
- Energy efficiency: The heat of reaction from the reactors could be used to generate stream for the bitumen extraction process.
- Knowledge development: Knowledge on FT with respect to catalyst development, FT process design and operating as well as FT integration will be developed.

Project 5: Online Boiler Feed Water Quality Analyser

The project consisted of development and testing of an online water analyser. The project was successful in proving the analyser for oil in water can be achieved for ppm measurements which are required by the heavy oil producers in order to reduce upsets and scaling during steam generation.

Currently the heavy oil producers do not have a device to measure oil in water online and in real time. This project enabled the feasibility of the technology to be proven. It is expected that, once the field trials are complete, there will be a wide adoption of the solution among most of the heavy oil industry. The environmental benefits and energy efficiencies will be proven once commercial roll out is complete by Agar.

Figure 6: The Luxmux BeST-SLED solution used to measure ppm oil in water

Project 6: Integrated Energy Management and Monitoring System (IEMS)

Although customer economic benefits will vary and in some cases savings may not be realized the economic value provided by the IEMS and the deployment across Ontario and throughout North America could be significant. A 10 % savings for each customer would result in significant savings for operating plants and optimizing runtime, including the provision of capacity at lower

operating costs. The IEMS will require additional resources to support the ongoing development, maintenance and product management in North America and possibly worldwide as deployments reach other markets and customers. A detailed business plan is being developed to support the growth of the IEMS in North America is likely to create the following job opportunities within Ontario.

Focus on the environment is a key message for the IEMS. Optimization and efficiency improvements will ideally improve the overall performance of CHPs, the use of thermal and the ability to offset peak periods of grid supplied power. As more Utilities move from a centralized to distributed generation model the ability to provide, promote and fund projects through government incentives will encourage the growth of distributed CHP systems. Although the systems in theory can provide a 30% to 40% efficiency gain from centralized power supply, no 2 distributed systems will be the same. The IEMS is focused on driving additional efficiency of 5% to 10% and allow operators to focus on maintenance and not operations.

Project 7: Oil Sands Evaporator Blowdown Produced Water

The SaltMaker provides the benefits of water recycling, reduced energy requirements and GHG emissions, and lower costs. The oil and gas downturn resulted in early termination of the original project, limiting the direct benefits for Canada. However, the learnings from the project have lead to new developments and patents for SaltMaker applications to landfill leachate, shale gas, and mining. Further, through this project, Saltworks has built a relationship with IDE for future collaborations. The project provided each company a good understanding of each other's technology and applications for future projects.

Saltworks' growth and early commercialization success, described above, directly benefits the energy industry in Canada and abroad. Saltworks' success is leading to reduced environmental impact, reduced costs, increased competitiveness, and job growth in the Canadian and worldwide energy industry.

Conclusion

The CIEST Fund project results provide evidence of expected economic and technological benefits to be derived from the R&D cooperation supported by the Fund. All of these projects address the key innovation challenges faced by the Canadian unconventional oil and gas sector. These challenges include Canada's ability to develop important new sources of energy production and reduce the environmental footprint of the industry. The economic benefits to be derived will be realized both directly by the Canadian and Israeli companies involved in the project and by Canada's energy sector as a whole. In the latter case, this is because CIIRDF has established closer and ongoing relationships between numerous companies from both countries that did not choose to apply for the CIEST Fund financial support but have nevertheless created a force multiplier basis for strong Canada Israel cooperation on energy technologies.

The particular case of the CIIRDF Associate Membership in COSIA stands out as a significant and strategic outcome of the CIEST Fund. This will produce a steady stream of technological cooperation in the years to come as well as establishing a new paradigm for Canada Israel technological cooperation across numerous technological disciplines and key sectors of the

Canadian economy, including other sub-sectors of energy. At the Israeli end, both the Innovation Authority and the National Cyber Bureau have mandated CIIRDF to build on the COSIA model in the critical area of cybersecurity, with a priority application to be considered in the electricity grid management area.

These are not trivial results. The successful delivery of the CIEST Fund points to the value that will be derived by its extension and, perhaps, to its expansion in terms of the energy/ technology areas covered under the next generation of the CIEST Fund. CIIRDF strongly recommends that the CIEST Fund be evaluated on that basis and stands willing and eager to meet the challenges of continued the CIEST Fund management with the same resolve and creativity demonstrated this far.

Appendix 1: Research Money Volume 30 Number 11

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Canada's resource industries & the knowledge-based economy: Proven global innovation

By Henri Rothschild and Dan Wicklum

Ever since science policy moved from the periphery to the centre of Canadian economic policy, conventional wisdom has it that we need to transform from a resource economy to a knowledge-based economy. Now science policy is termed innovation policy, and growing evidence on true innovation suggests that it is not a transition that is required, but rather, a need to build on our comparative global advantage in resource industries to create a true innovation-based economy.

For example, in the oil sands sector, a dramatic development, in the form of Canada's Oil Sands Innovation Alliance (COSIA) is providing such compelling evidence. New made-in–Canada models of collaboration are defining the global standard on how innovation works best, resulting in a growing awareness that resource development is not the opposite of, or even an impediment to, the knowledge economy. Quite the contrary. Natural resources development provides a country like Canada with a critical stimulus necessary for true innovation and an important underpinning to knowledge-based economic growth across all sectors.

About four years ago, stemming from a desire to accelerate their pace of environmental improvement, oil sands producers established a collaborative consortium designed to leverage technical resources and expertise in key environmental areas. They also agreed that through this consortium, they would share the risk of investing in the research and testing aimed at developing leading edge environmental technology capabilities.

Thus, COSIA came into being in 2012. Although some oil sands producers had been cooperating since the late 1970s, the creative approach that COSIA took to acquire the needed technologies and transform the sector into a component of the knowledge economy is what is truly innovative.
One COSIA innovative element is its Associate Membership Program, whereby organizations (e.g., large multinationals like General Electric, universities, government agencies like Natural Resources Canada or Alberta Innovates, or technological ‘hubs', such as British Columbia Innovation Council or Climate Change and Emissions Management Corporation, among others) would sign on to source technological capabilities within their networks that align with the oil sands producers' priority technical gaps and challenges.

These gaps are themselves associated with key areas of leading-edge technologies developed for purposes other than oil sands development. High-tech sensors, nanomaterials, sophisticated algorithms and other forms of advanced intelligence systems are finding their way at a faster pace into this key Canadian industrial sector in a flurry of ‘technological diffusion' that has little precedence in Canadian corporate history.

SOURCING ISRAELI TECHNOLOGIES

One example of this creative approach is the sourcing of advanced technologies from Israel, renowned internationally as a country consistently at the crest of the wave of every generation of new transformative, or ‘disruptive' technologies.

In June 2014, COSIA unanimously accepted a new Associate Member, the Canada Israel Industrial Research and Development Foundation. CIIRDF is itself an innovative structure, with a mandate to support Canada-Israel cooperation in technological development.

As a COSIA Associate Member, the mission of CIIRDF was to evaluate the dozens of technological gaps of the COSIA members across four environmental priority areas (water, land, greenhouse gases and tailings) and identify Israeli capabilities specifically suited for further co-development with COSIA member companies.

In February 2015, CIIRDF arranged for a site visit to Israel by COSIA engineers in which over 100 Israeli scientists, engineers and entrepreneurs were involved in evaluating the applicability of Israeli technologies to the gaps. Since Israel has no oil industry and only a nascent, and offshore, natural gas sector, all of these technologies emanated from other sectors, including defence, security, bio-medical and cleantech.

By the Fall of 2015, Israel had become one of the largest single sources of new technological 'offers' for consideration by COSIA members, with over 25 new technologies under review.

This approach is being repeated this year with the promise of similar results. The resulting "research harvest" exposes Canada to technologies that would have cost hundreds of millions of dollars to develop on its own. And because oil sands companies are collaborating with other sectors like forestry and mining, technologies sourced in Israel can find their way into many sectors.

For Israel, the CIIRDF membership in COSIA provides innovative and direct access to the oil sands value chain and eventual market, thus extending the economic return on its breakthrough technologies developed in other sectors.

For Canada, this global sourcing of oil sands priority technology needs provides technological capabilities in advanced multi-disciplines. And, the COSIA members and their value chain are now interconnected with a global leader in technological innovation and through this, becoming one of the most knowledge-driven sectors of the Canadian economy. It's clear evidence that Canada's oil sands industry is truly resourceful and provides valuable learnings for innovation policy and practise.

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