REVIEW ON ALBERTA BITUMEN LINK (ABL) PROJECT ENTITLED:

"SUPPLYING JAPAN AND PACIFIC RIM COUNTRIES WITH SYNTHETIC CRUDE OIL AND OTHER UPGRADED FUELS GENERATED IN ALBERTA, CANADA, FROM INDIGENOUS ATHABASCA BITUMEN AND LOW RANK COALS"

PREPARED BY

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The subject review is based on information that I was provided with, on my background in fossil fuels science and technology and on the following two documents:

- Alberta Government document dated February 12, 2009, titled "Responsible Action— A plan for Alberta Oil Sands"
- INTERIM REPORT on Alberta Bitumen Link (ABL) Project: Supplying Japan and Pacific Rim Countries with Transportation Fuels Generated by Integrated Processing of Alberta Bitumen and Low-rank Indigenous Coals

1. INTRODUCTION

A. Preamble

Fig. 1 outlines the distribution of world oil reserves; this distribution is the key factor that determines the geopolitics of oil. Presently Japan and Pacific Rim countries are supplied with Middle East crude oil. Any disruption in oil supply resulting from volatile political situation in the Middle East would place the Pacific Rim countries, including our country, in a very difficult position.

Japan and Pacific Rim countries have alternative source of crude oil supply. Fig. 2 and 3 show that importing crude oil from Canada would shorten the ocean transportation distance by over 2,000 nautical miles. After Saudi Arabia, Canada has the largest reserves of recoverable oil. In terms of ultimate, in-place reserves of petroleum that cannot be economically recovered using existing, inefficient technologies, Canada's reserves are actually about seven (7) times larger compared to those of Saudi Arabia.

The ABL technology which is the subject of this review promises to unlock the huge reserves of Canadian non-conventional petroleum and that can be done under conditions that are technically advanced, economically sound and environmentally friendly. Japan shall not miss the opportunity to become a major player in this endeavour.

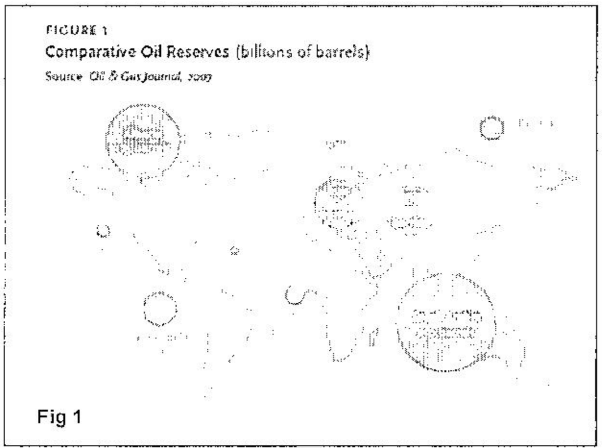


FIGURE 1

Comparative Oil Reserves (billions of barrels)

Source Oil & Gas Journal, 2009

Fig 1

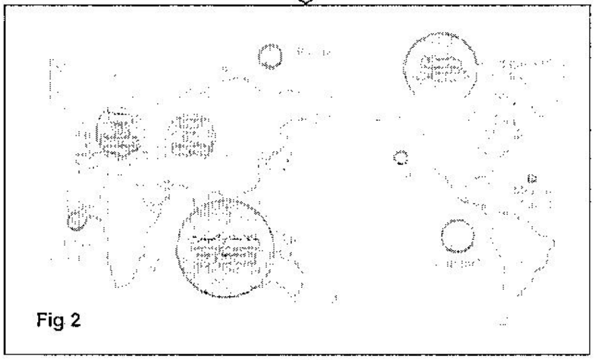


Fig 2

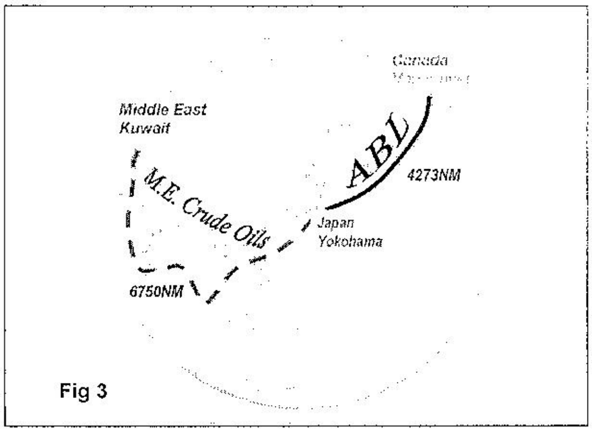


Fig 3

B. Alberta Government Long Range Plan

This plan was formally announced on February 12, 2009, and its key elements are presented in Fig 4. Fig 4 does not provide the information on the technology; it outlines the objectives of the Alberta Government Energy Strategy for the Future. Fig. 6, which presents in most general form the principle of the ABL technology, shows how the objectives of the Alberta Government could be met.

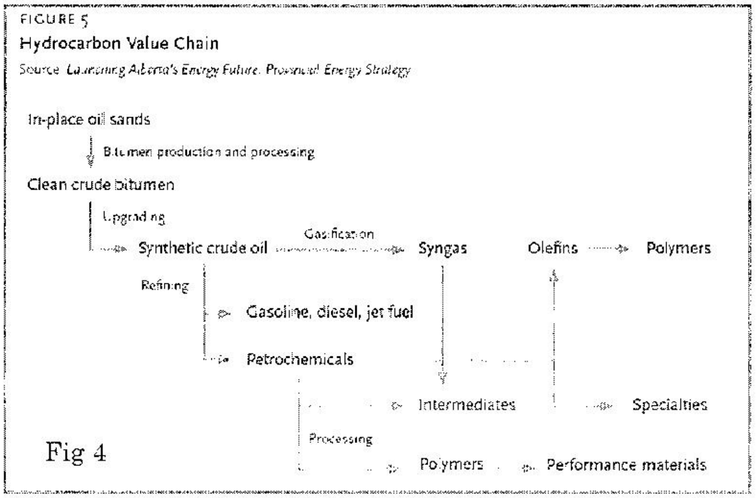


Fig 4

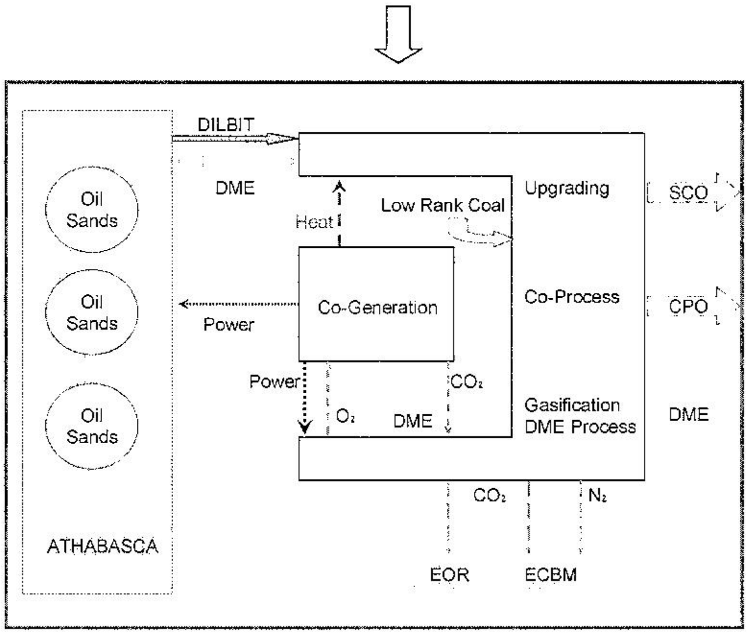


Fig. 5 ABL Technology Principles

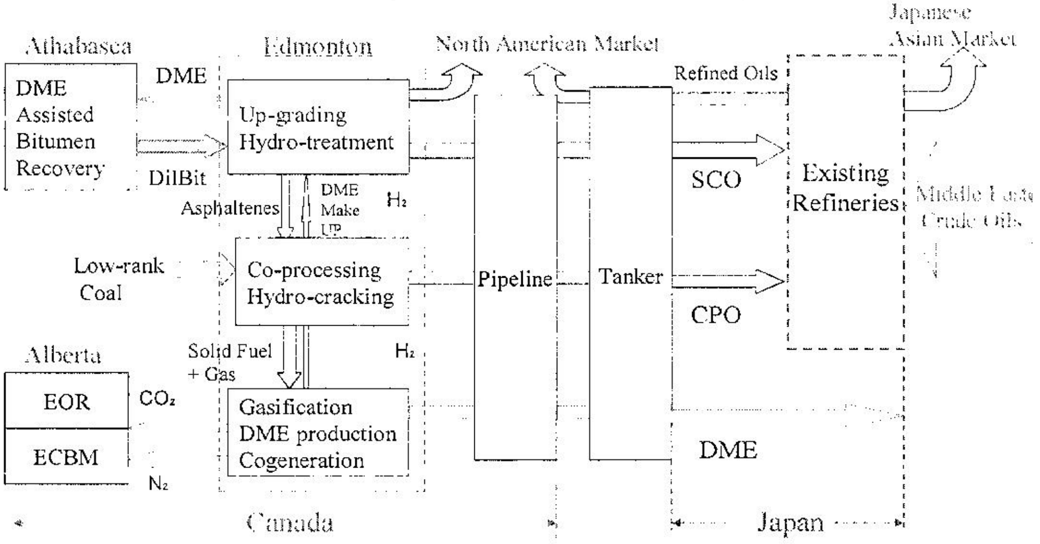
2. RATIONALES FOR THE GOVERNMENTS OF JAPAN AND ALBERTA TO COOPERATE ON ABL TECHNOLOGY DEVELOPMENT.

The rapid increases in fossil fuel prices in 2007 and the first half of 2008 were followed by equally dramatic reductions by the end of 2008. The price reductions were caused not by flooding the markets with fossil fuels but by unprecedented, since the great depression, crash of the global financial system resulting in collapse of world economic structure and rapid decrease in demand for raw materials and energy. It may take years for the global economy to recover. However, any recovery will be accompanied by increased demand for energy and, especially petroleum and natural gas and will spark a new wave of fossil fuels price increases. Japan is lacking indigenous energy resources and, therefore, compelled to import all required petroleum, natural gas and solid fuels. Security of fossil fuels supply is of considerable concern to Japan and requires that more emphasis be placed on diversification of fossil fuels supply. Canada, with its stable social and political structures and enormous reserves of fossil fuels shall be the primary target of our diversification drive. Recently Japan has taken steps to develop a commercial venture aimed at importing Canadian LPG to our country. A few years ago we became actively involved, via JACOS, into Athabasca oil sands with emphasis on improving in-situ bitumen recovery technologies. Mitsui & Co has been long active in evaluating the business opportunities associated with utilization of the huge Western Canadian deposits of thermal and coking coals by Japanese private sector.

I believe that of all Canadian energy resources the Alberta reserves of bitumen and heavy oil shall become the focus of our country attention. Alberta proven and recoverable, using existing technologies, reserves of bitumen and heavy oil match those of Saudi Arabia. The ultimate, in-place reserves are estimated at about 1,700 billion barrels, approximately seven (7) times the reserves of Saudi Arabia. At today's depreciated oil prices Alberta bitumen/heavy oil industry, that continues to employ out-dated, inefficient and environmentally unfriendly recovery and upgrading technologies, is struggling to survive. Alberta and Canadian Federal governments are subjected to considerable pressure coming from within as well as outside of Canada and the United Stated in particular, to either curtail the production of "dirty crude" from bitumen or develop efficient, environmentally friendly technologies for bitumen recovery and upgrading. Both, Alberta and Federal governments allocated billions of dollars for development of new technologies and, specifically, for CO2 capture and sequestration. The Alberta Government Energy Strategy document, published on February 12, 2009, shows strong commitment of the Province of Alberta to supporting development of novel bitumen recovery and conversion technologies. It is increasingly obvious that in order to survive, the oil sands industry has little choice but to embrace the directives of the Energy Strategy document. Innovative technology train concepts are being developed and evaluated and, in my opinion, the ABL concept summarized below appears to have more potential for successful commercialization compared to others that I have had the opportunity to get acquainted with.

3. EXTENDED ABL TECHNOLOGY/BUSINESS CONCEPT

Fig. 6 Pacific Rim Alberta Bitumen Link
ABL Project Business Concept



SCO: Synthetic Crude Oil *CPO: Co-Processed Crude Oil* *DME: Di-Methyl Ether*

EOR: Enhanced Oil Recovery *ECBM: Enhanced Coal Bed Methane*

Of the processes to be employed in ABL technology train (Fig. 6) all but two are fully commercialized. The not fully commercialized processes are: application of di-methyl ether (DME) as a solvent for recovery of bitumen/heavy oil and diluent for pipelining the recovered bitumen/heavy oil and application of ABL co-processing for conversion of the asphaltenic fraction of bitumen/heavy oil, into distillable oils. In addition the ABL technology generates C_1-C_3 hydrocarbon rich gas and high calorific value solid fuel. The solid fuel, when used as gasification feed, improves thermal efficiency of the process and significantly reduces the size of gasification and oxygen generation plants.

A. Advantages of DME

Thorough evaluation of the physical, rheological and chemical properties of DME indicates that DME should be very effective as solvent and diluent for bitumen. The effectiveness of DME for this purpose has to be ultimately confirmed through field testing. JACOS is in the process of developing the capabilities for field testing of promising solvents for in-situ bitumen recovery and these capabilities should be utilized for DME testing. The properties of DME are summarized below and compared to properties of other most promising solvents for bitumen recovery.

DME production is fully commercialized – DME can be most economically produced by gasification of coals (huge deposits of low-cost surface mined coals are available in Alberta) and reacting the generated synthesis gas in a catalytic ebullated bed to form the DME. Apart from its potential application as solvent and diluent, DME has been demonstrated to outperform conventional Diesel fuel in two-stroke Diesel engines. DME production cost is approximately 60% of that of conventional Diesel fuel. It is expected that during the next ten years China and European Union will replace significant portion of conventional Diesel fuel with DME for Diesel engines firing.

DME has the capability to dissolve water and is expected to be a better solvent for polar compounds compared to low boiling hydrocarbons; that should enhance the mobilization of bitumen during in-situ recovery. DME has significant advantage over propane, considered to be so far the most promising hydrocarbon for bitumen recovery. At the same pressure, DME allows to raise the temperature of the gravity drainage chamber of the reservoir by about 20°C higher, compared to propane. That will reduce the viscosity of the binary (bitumen/DME) liquid in the chamber significantly more compared to what can be accomplish using propane. When the operating temperature/pressure in the chamber reaches 97C/4.25 MPa, the heat of propane condensation cannot be transferred to the chamber. By contrast, due to its higher critical temperature, DME can effectively transfer the heat of condensation at temperatures/pressure up to127C/5.37 MPa. DME application for in-situ bitumen recovery can be safely practiced over wide range of depths (50 – 700 m) and, therefore, allows extracting the bitumen from the deepest (700 m) reservoirs using relatively mild pressures approaching 5 MPa. Neither propane no butane can compete, in this respect, with DME. The viscosity of the binary (bitumen/DME) liquid recovered from the reservoir will depend primarily on its temperature and the content of DME in the liquid. The binary liquid containing 15-20 wt% DME and having temperature in the range of 10-50°C will have kinematic viscosities ranging from 11 cSt at 50°C to 200 cST at 10°C; this is significantly below the 250 cSt or less required for pipelining the bitumen/condensate mixtures.

DME is expected to be effective for both bitumen recovery and pipelining. This will eliminate the demand for heat to produce steam and significantly reduce the consumption of power and heat for bitumen recovery and pipelining. Application of DME fired O_2/CO_2 drive two-stroke Diesel co-generation engine with DME re-burning O_2/CO_2 drive boiler and cryogenic CO_2 capture system contributes greatly to reducing power and heat consumption. Thermal efficiency of the two-stroke Diesel engine operated as outlined above is about 90%. The heat required to raise the temperature of DME prior to its injection into the gravity drainage chamber would be provided by application of the Skin Electric Current Tracing technology. Consequently, the bitumen recovery plant(s) located in Athabasca area would be supplied with DME (by pipeline) and electric power (by transmission lines) only. The DME based in-situ recovery plant(s) would pipeline the binary liquids, freed of particulates directly to integrated facility located in Edmonton area for separation, processing of recovered bitumen and pipelining the recovered plus make-up DME back to the in-situ bitumen recovery plant. The integrated facility would include coal surface mining/upgrading facility, co-processing plant, oxygen based gasification plant, bitumen separation and upgrading plant and electric power generation/co-generation facilities. The ABL project business and technology concept is expected to simplify the operation and reduce the capital and operating costs of the bitumen recovery plant(s) and the integrated facility located at a mine site near Edmonton. The bitumen recovery plant(s) would not emit any CO_2 and/or volatile organic hydrocarbons (VOC's); it would not require natural gas, natural gas pipeline, condensate, condensate gas pipeline, oxygen plant or oxygen pipeline, CO_2 pipeline, water clean-up plant and the auxiliary equipment associated with natural gas combustion, generation of heat and steam, separation and disposal of CO_2.

B. Advantages of Co-Processing

In addition to DME application, the second innovative component of the ABL technology train is co-processing. ABL co-processing is capable of converting the mixtures of asphaltenic fractions (separated from bitumen or heavy oil) and low rank subbituminous coals into distillable crude oil, hydrocarbon rich gas and high calorific value aggregated solid fuel. Compared to other co-processing technologies developed since the 1940's, the ABL co-processing is remarkable in this respect that it does not require hydrogen, operates at atmospheric pressures, utilizes marginal value asphaltenic fractions and low rank coals and generates value added marketable products. Other advantages of co-processing are presented in Fig.7.

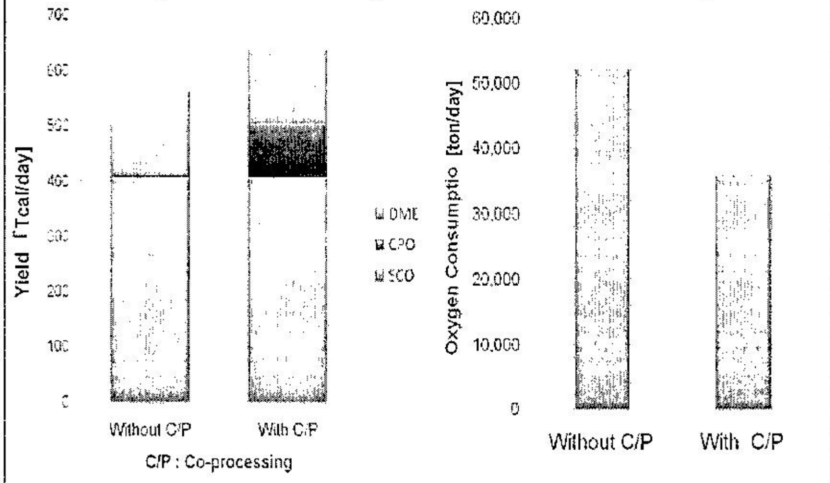


Fig. 7 Advantages of Co-Processing

It is most desirable to demonstrate the ABL co-processing and, if the demonstration results confirm the potential of this technology, steps should be taken to commercialize the co-processing as an integral part of the ABL technology train.

During the 1940's the heat treatment of a mixture of coal and coal derived diluents (BP 200-300C) was researched in Japan to produce ash-free coal. The solvolysis was carried out at about 400C, in presence of hydrogen and final reaction pressure of about 30 Kg/cm2. The ash-free coal was recovered from the solvent and the solvent was recycled in the process. Therefore, no product oil was generated in the process.

In 1970th co-processing technology was researched to produce SRC (Solvent Refined Coal) I and II. The SRC co-processing was based on reacting the mixture of coal-derived heavy oil and coal and generated light fuel oil and upgraded coal. The SRC was also capable of producing binders for cokes, high calorific value steam coal and liquid fuel. The hydrogen pressures employed were in the range of 100-150 Kg/cm2 and that resulted in significant increase in capital and operating plant costs. The ABL co-processing, as already stated, does not require hydrogen and operates at atmospheric pressure.

In the 1970th the co-processing under ambient pressure was researched by Kyusyu Research Institute of METI in Japan. The developed process known as SOLVOLYSIS was one of the "Sunshine Project" undertakings. The process was carried out by heating a mixture of coal and asphalt at about 400C. Its objective was to generate a solution of coal in heavy oil as an alternative to heavy fuel oil. It did not produce distillable oils.

Comparing the ABL co-processing with other processes listed above leads to the conclusion that the capability of the ABL co-processing to generate distillable oils at very mild processing conditions, from coal/asphaltenic fraction mixtures, containing low concentrations of asphaltenic fractions (16.7 – 33.3%, by mass) is most likely associated with favourable selection of mixture components and their ratio, chemical structure of selected components of the feed and catalytic properties of the coal/asphaltenic fraction matrix.

In terms of selection of feed mixture components and their ratio there is a basic difference between ABL co-processing and all other liquefaction/co-processing/ solvolysis processes of which the most important were referred to, above. The liquefaction/co-processing/solvolysis feedstock was typically composed of about 2/3 of the solvent (coal derived hydrogenated oils or bitumen/heavy oil) and 1/3 of coal. In the ABL co-processing the feedstock is composed predominantly of coal (2/3 or more) and the asphaltenic fraction (not the bitumen/heavy oil) accounts for a maximum 1/3 of the feed. The reason for this significant difference in feedstock components ratio is that whilst the objective of the liquefaction/ co-processing/ solvolysis/ processes was to transfer hydrogen from the solvent to hydrogen deficient coal to increase its solubility, the objective of the ABL co-processing is to supply hydrogen from coal to hydrogen-rich radicals generated from thermal decomposition of asphaltenes.

A lot of work has been done on the chemical structure of coal and solvents used in liquefaction/co-processing/solvolysis processes. Fundamental work on coal carried out during the last fifty years provided evidence that coal contains hydroaromatic structures of which some have hydrogen donating capacities exceeding those typical of the best hydrogen donors (e.g. tetralin). However, coal is relatively deficient in hydrogen (H content 4-6 wt %) and the concentration of hydrogen donating sites on its surface is relatively small. On the other hand the solvents used in liquefaction/co-processing/solvolysis processes have relatively high hydrogen content (7-10.5%) and high concentrations of hydrogen donating sites. However these sites do not match, as a rule, the hydrogen donating capacities of coal.

Commercial processes for bitumen/heavy oil upgrading convert the asphaltenic fraction mainly into coke and gases. The ABL co-processing postulates, as a first processing step, separation of the bitumen into asphaltenic fraction and maltenes. The maltenes can be processed as conventional petroleum and the asphaltenic fraction is co-processed with coal at about 430C, in inert atmosphere and ambient pressure. Under optimum reaction conditions the yield of distillable oils from co-processing is essentially equivalent to the mass of the asphaltenic fraction taken for co-processing. ABL co-processing takes advantage of the superior hydrogen donating capabilities of coal. The key requirements are that the components of the feed (coal and asphaltenic fraction) have to be well blended and that there is sufficient mass of coal (availability of transferable hydrogen) in the blended feed so that most of the radicals generated by thermal decomposition of the asphaltenic fraction (at ~ 340^{0}C) will be converted into distillable oil rather than coke and gases.

Ultimate analyses and mass balances carried out for ABL co-processing substrates and products confirm that hydrogen transfer from coal is the key mechanism driving the co-processing reactions. Under reaction conditions when the contents of asphaltenic fractions in coal/asphaltenic fraction mixtures were 16.7 wt % in one series of tests and 33.3 wt % in another series of tests, the distillable oil yields decreased from about 96-97 wt % to 75-76 wt % (on asphaltenic fraction mass), respectively. That demonstrates that sufficient quantities of transferable hydrogen must be supplied by coal to generate high yields (96-97 wt %) of distillable oils.

The distillable oils generated from ABL co-processing of a blend containing 16.7 wt % of asphaltenic fraction (the asphaltenic fraction accounted for 19.5 wt % of the bitumen) contained: significantly more hydrogen (0.85-0.95 wt %), significantly less sulfur (5.5-6.5 wt %), less nitrogen (0.2-0.3 wt %) and less oxygen (0.10-0.14 wt %) compared to asphaltenic fraction. The asphaltenic fraction contains most of vanadium and nickel present in the bitumen. The distillable oils generated from the asphaltenic fraction by ABL co-processing are essentially metals free. Over 70 wt % of oils generated by co-processing distills below 430C. Whilst the asphaltenic fraction is solid until it reaches the decomposition temperature (~340°C), over 45 wt% of oils generated by co-processing of asphaltenic fraction distills below 340C. The values for absolute and kinematic viscosities (at 50C) for the generated oils are about 5-6 times lower, compared to values obtained for the deasphalted (asphaltenic fraction free) bitumen.

The feed coals used in co-processing contained: significantly more hydrogen (0.90-0.95 wt %), less sulfur (0.75-0.85 wt %), less nitrogen (0.75-0.85 wt %) and significantly more oxygen (12.0-13.0 wt %) compared to the solid fuels generated from the feed coals. The generated solid fuels had calorific values 30-40 % higher compared to the feed coals.

When the asphaltenic fraction is processed without coal it generates mainly high sulfur content coke and gases. Apart from generating high yields of distillable oils, the ABL co-processing generates high calorific value aggregated solid fuel and volatile hydrocarbons ($C_1 - C_3$) rich gas.

The role of mineral matter present in asphaltenes and coal in particular has not been fully explored. However, it was demonstrated that significant increase in clay content in the feed for ABL co-processing had a deleterious effect on products properties.

It is my opinion that demonstration of both namely, application of DME as solvent for bitumen recovery an diluent for pipelining of recovered bitumen and co-processing as a means of increasing the distillable oils yield and improving the gasification process are vital steps in evaluating the effectiveness of the ABL technology train. Results of preliminary testing of DME effectiveness as solvent and the results of batch testing of co-processing indicate that incorporating these two processes into the proposed ABL technology train has the potential to make the ABL bitumen recovery and upgrading technology competitive with the recovery of conventional petroleum from sea water flooded reservoirs of Saudi Arabia while, at the same time, making the technology environmentally friendly.

3. COOPERATION BETWEEN JAPAN AND CANADA

Fig. 8 outlines the division of business activities between Canada and Japan.

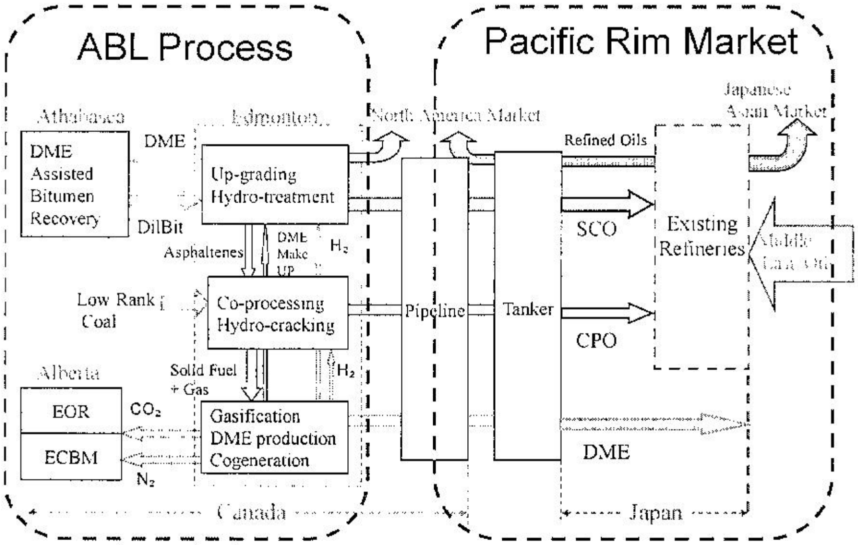


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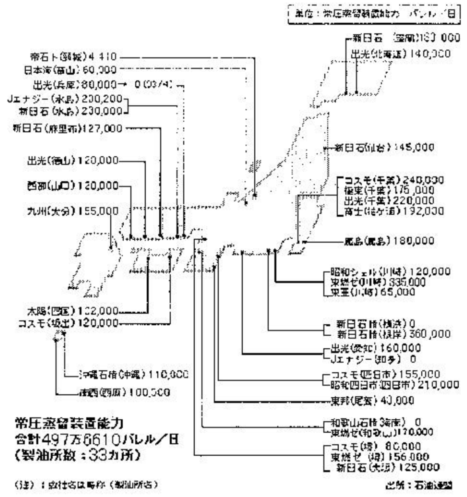
Fig. 8 Business Activities in Canada versus Japan

A. Role of Existing Japanese Refineries

Fig. 9 Location of Existing Japanese Refineries



The capacity of existing state-of-the-art Japanese refineries is about 5 MM bpd. Significant percentage of this capacity is presently not fully utilized. Utilization of the refining potential of Japanese refineries to produce transportation fuels to be sold within the Pacific Rim market is an important component of business activities to be carried out by Japanese companies.

B. Involvement of AIST into Comprehensive Information Centre (CIC)

CIC requires comprehensive scientific and engineering capabilities. AIST (3,200 employs) has the capability to cover almost all R&D fields, including hydrocarbon (oil, coal, and gas), DME production, utilization and health effects, environmental and climate change problems (air, water, and soil) and so on. AIST maintains close relationship with the R&D departments of most of Japanese large private companies. The involvement of AIST into CIC would provide most effective means of technology transfer to ABL technology development and commercialization.

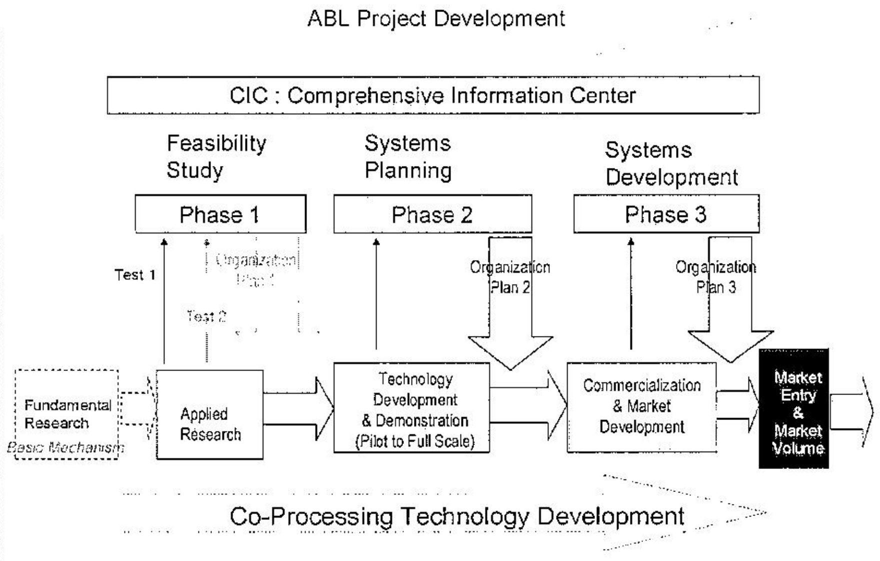
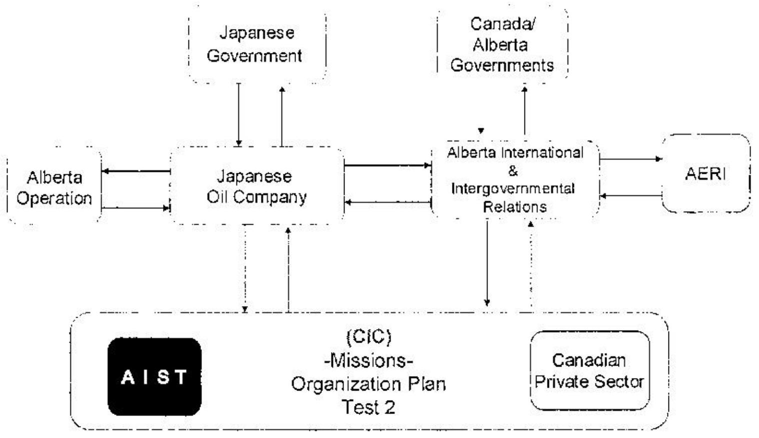
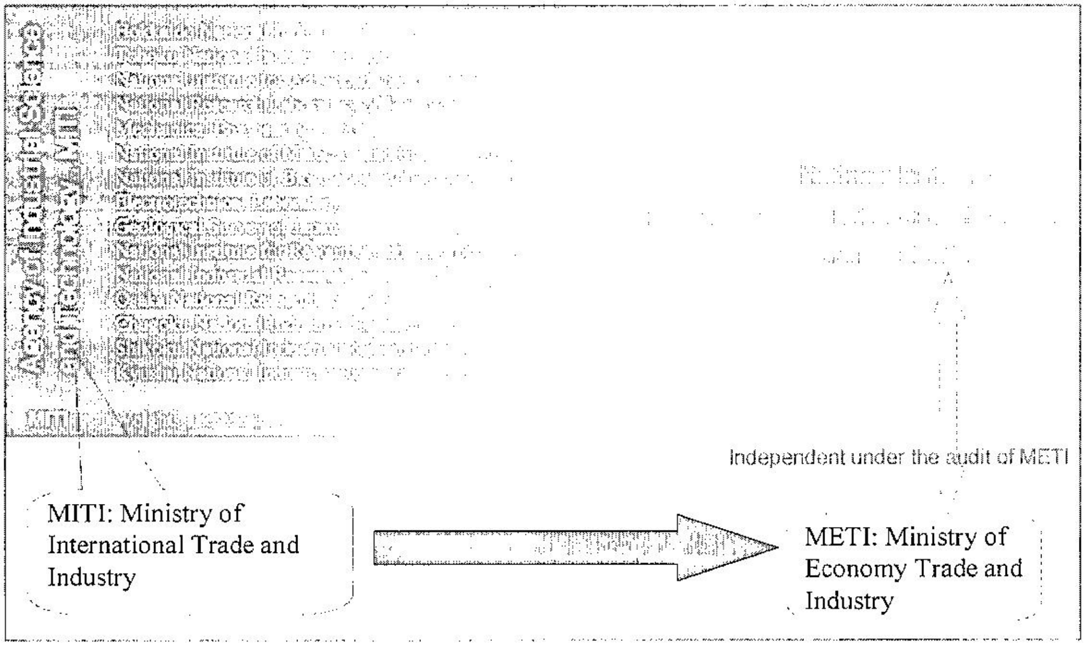


Fig. 10 ABL Project Development Scheme

Fig 11 Organizational Plan – Pre-Demonstration Program



The National Institute of Advanced Industrial Science and Technology (the new AIST) was formed on April 1, 2001. Formation of AIST resulted from amalgamation of 15 research institutes previously existing within the Agency of Industrial Science and Technology in the Ministry of International Trade and Industry and the Weights and Measures Training Institute. The new AIST is Japan's largest public research organization with many research facilities and around 3,200 employees including scientists, engineers and supporting staff. AIST has direct contact with most of the R&D Departments of the large Japanese companies.



Close cooperation between Japan and Canada is required to demonstrate the DME and co-processing and successfully commercialize the ABL technology train. I believe that there is a very good chance that the ABL technology will provide long term, significant benefits to Canada, Japan and Pacific Rim countries.

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Sapporo, Japan, March 18, 2009

Dr. Yousuke Maekawa
Summary of Curriculum Vitae

- 1968 – Ph.D. Engineering, Hokkaido University, Thesis: Coal Liquefaction Mechanism
- 1965 – 1995, Research Officer, Section Chief, Department Head, Hokkaido Research Institute, Agency of Industrial Science and Technology (AIST), MITI, Japan
- 1975 – 1977, Post-Doctoral Research Fellow at the Alberta Research Council, Edmonton, Canada
- 1983, Award for Scientific Excellence
- 1984, MITI Award for Promotion of Coal Liquefaction
- 1995, Appointed as Senior Technical Advisor, Energy Section, Department for Development, Support and Management Services of the United Nations
- 1996 -1999, Appointed as JICA (Japan International Energy Agency) Energy Expert for Indonesia
- 2004, Award from Japanese Government for Outstanding Scientific/Technical Achievements
- Books, Publications, Patents: Co-author of four (4) books, one hundred forty two (142) papers, twenty seven (27) reviews, fifteen (15) patents in the area of coal chemistry, coal liquefaction, coal gasification, heat pumps system, bio-gas generation and so on