Environmental Fossil Fuels Sciences & Technology Group

In cooperation with Envirotech Consulting Inc.

Challenges and Opportunities for Alberta's Bitumen Industry

Alberta's huge bitumen reserves could ensure long lasting benefits to this Province and Country provided SAGD is replaced with an economically sound and environmentally friendly bitumen recovery technology.

Nearly three decades ago the Alberta government made a decision to develop the in-situ steam-based SAGD technology. The SAGD technology has been embraced by the industry and continues to be employed for bitumen recovery.

Prior to 2009, crude oil prices oscillated near US$ 100 per barrel and the environmental problems, including CO_2 emissions and potable water consumption were of little concern. Since 2014 the environmental and economic shortcomings of SAGD began attracting increased criticism in Canada and abroad. That could have been prevented had the industry and the consecutive governments of Alberta paid attention to early warning signs.

In 2007/8 the Japanese government (METI) proposed to the Alberta government, in cooperation with ECI, to replace SAGD with a jointly demonstrated DME (Dimethyl Ether) technology. The technology has been patented in Canada and is privately owned. Despite the favorable recommendations of two world renowned energy experts (Doc. 2 & 3), the proposal was rejected in 2009 by the Alberta government on recommendation of Alberta Innovates (AIs) energy advisors (Doc.1).

The multinational petroleum companies have lost interest in SAGD's unsatisfactory performance and abandoned the oil sands business. During the 2014-20 period, reportedly 330,000 direct and indirect jobs in the oil and gas industry have been lost. According to Bloomberg (JWN, August 7, 2020) *"if any place in North America should have been prepared for the crush in oil prices, it's petroleum-rich Alberta. Alberta could have had C$ 575 billion ($ 433 billion) wealth fund to cushion the blows of COVID-19. Instead the Alberta Heritage Trust Fund is down to just C$ 16.3 billion after losing C$ 1.9 billion because of the pandemic and wrong-way bet against the market volatility. That's not enough to provide much help in province suffering from Canada's second higher unemployment rate at 15.5%, a falling credit rating and a dark period ahead for its most important industry."*

On September 15, 2020 JWN reported that, according to Bloomberg….*"the most expensive and polluting oil fields such as tar sands in Canada may never be developed."*

Since 2014 the interest in DME for bitumen and extra heavy crudes recovery attracted a lot of attention in and outside of Canada. In 2015-17 the AIs' scientists and engineers confirmed experimentally the superb performance of DME (2017 Report "Study on Solvent-Assisted In Situ Bitumen Recovery") for bitumen recovery thus contradicting the Alberta's governmental advisors' evaluation issued in 2009 (Doc. 1). Regrettably, several proposals submitted by the private sector companies, regarding the DME technology applications have been rejected by AIs management. To stop the collapse of the Alberta bitumen industry the Alberta and federal governments have to review and acknowledge the potential of DME technologies in rejuvenating the economy of this Province and Country. Recovery and utilization of bitumen for applications not limited to production of transportation fuels only shall be also evaluated. It is essential that the simplest version of the technology, the “DME-assisted SAGD” is field demonstrated as soon as possible. Especially that the bitumen industry has recently, after nearly three decades of commercial application, acknowledged the need for replacing the SAGD technology.

The advanced “DME-based extraction” technology, as compared to SAGD, eliminates potable water and steam usage, natural gas combustion, process water treatment and reduces (by 84- 98%) GHG emissions. The technology is expected to recover 80-90%, instead of 50%, of reservoir’s bitumen at recovery rates 3-4 times higher as compared to SAGD. DME, as compared to SAGD will reduce the demand for energy by around 10 times. The mass flow of SAGD’s injected steam/water fluids exceeds that of DME flow by around 31 times. The effectiveness and simplicity of the “DME-based extraction” plant (see Website: Fig. 1 and 2) is reflected in reducing its capital cost by up to 5 times, as compared to an equivalent SAGD plant.

The most advanced “Integrated DME-based extraction” technology will have the capacity to convert its by-products into value-added products; that includes converting the residual CO_2 into DME. The breakeven cost of the “Integrated DME-based extraction” will be reduced to a level comparable to the least expensive crude oils (US$ 3-12 per barrel) produced by Saudi Arabia and Russia.

The SAGD’s breakeven cost is today approximately US$ 40 per barrel of bitumen. This cost is the key factor undermining the competitiveness of Alberta’s bitumen in world’s petroleum markets. By recycling and utilizing the by-products generated by the Integrated Central Facility (ICF) and oxy-combustion of a small fraction (about 15%) of the produced DME in a low speed 2-stroke Diesel engine, the producers will benefit significantly (B, chapter 1.4). The “Integrated DME-based extraction” will provide the technology license holders with the tools required to dominate bitumen and DME production.

Whilst petroleum price volatility is unpredictable the experts agree that over a long run the lowest cost producers will succeed in maintaining the old and developing new markets. The demonstration of the “DME-assisted SAGD” is essentially risk and cost (except for the cost of DME) free. Successful demonstration of “DME-assisted SAGD” will convince the bitumen producers of the benefits of “DME-based extraction” technology. Both technologies could be readily implemented in the next several years thus bringing by 2030 the bitumen production, if required, to nearly 4 million barrels per day. Because of very high rates of bitumen recovery using the “DME-based extraction” (3-4 times faster compared to SAGD) about 33% only of the existing SAGD plants would have to be converted to “DME-based extraction” mode.

To bring the bitumen recovery breakeven cost to a level of less than US$ 7-8/barrel, additional confirmatory testing would have to be carried out on how to optimally recycle and convert the by-products of the ICF into value-added products. Catalytic photosynthesis of CO_2/H_2O blends into methanol and oxygen has been demonstrated. Dehydration of methanol generated from CO_2 into DME will transform the bitumen recovery industry from being traditionally a CO_2 emitter to an industrial scale acceptor and effective utilizer of CO_2. By pursuing this line of business the ICF would be capable of supplying the “DME-based extraction” plants with DME and electric power at a rock-bottom production cost thus resulting in converting the bitumen industry into sustainable, highly profitable and immune to petroleum price volatility industry.

2. The Impact of DME technology on Reducing CO_2 Emissions of In-Situ Bitumen Recovery

The "DME-based extraction" plant shall reduce the CO_2 emissions of an equivalent SAGD plant by 84%. The assumptions made for both plants are presented in Table 1. The CO_2 emissions estimates, based on Table 1 assumptions, are presented in Table 2. Depending on specific operation mode of "DME-based extraction" plant (e.g. DME is recycling for bitumen recovery) the emissions will be reduced by more than 84% (see "GHG Emission Sources", item 2.). "Integrated DME-based extraction" plant will eliminate CO_2 emissions.

TABLE 1. Assumptions for GHG Reductions Estimate*

SAGD – Baseline Assumptions		**DME – Project assumptions**	
CO_2 sources : 2 (A & B	Value	CO_2 sources : (A & B)	Value
Facility annual output	109.5mln bb/y 17.41 Mm^3/y	Facility annual output	109.5mln bb/y 17.41 Mm^3/y
A:Consumption of electric energy generated by natural gas combustion	295 TJ/d	**A: Electric energy for fluids pumping** **$56x\ 10^{12}\ J/d / 47{,}700\ m^3/d$ = 1174**	56 TJ/d
1/S. Thermal efficiency of NG fired power plant:	42%	**1/D**. Thermal efficiency (for DME-fired co-generation Diesel plant)	48%
2/S. Electrical energy consumption per barrel of bitumen produced (published data) 45 kWh/bbit	1,019 MJ/m^3_{bit}	**2/D**. El. energy used per barrel of bitumen produced- 8.5 kWh (from numerical analysis equal 19% of SAGD process)	193 MJ/m^3_{bit}
3/S. CO_2 emission factor from NG: (US EPA, 2008) 0.000263 $kgCO_2/kcal$ Other data Nat gas C02 emissions 0.052.8 kgCO2/MJ Other 0.0503 kgCO2/MJ	0.000263 $kgCO_2/kcal$ 0.063 $kgCO_2/MJ$	**3/D**. CO_2 emission factor for DME: 1.913 kg CO_2/6900 kcal (0.0002775 $kgCO_2/kcal$) = 0.0663 $kgCO_2/MJ$ (3,607 kcal/ kg_{CO2}) 1/0.0663 $kgCO_2/MJ$=15.09 MJ/kg_{CO2}	0.0663 $kgCO_2/MJ$ 15.09 MJ/kg_{CO2}
B: CO_2 emissions from NG combustion to provide heat for steam generation		**B: Electric energy for reservoir heating**	38 TJ/D
4/S. CO_2 originates from boilers only		**4/D**.100% electric energy conversion to heat (SECT technology)	100%
5/S. Saturated wet steam	20 wt.%	**5/D**. Reservoir composition: 12 wt.% bitumen, 12 wt.% water, 76 wt.% minerals (silica & clay)	Composition 12%+12%+76%
6/S. NG heat value ** 8,211 $kcal/m^3$= 34.45 MJ/m^3	34,355 kJ/m^3	**6/D**. Temperature increase: (10°C - 70°C)	70°C
Boiler efficiency:	80%	Thermal efficiency of Diesel engine	48%

7/S. Steam injection pressure	2.5 MPa		
SOR:	3.5		
8/S. CO_2 emission factor for NG:	1.891 kg_{CO2}/m^3		
Bitumen reservoir temp	80-100°C	**Bitumen reservoir temp**	50-70°C
Bitumen recovery from reservoir	50%	Bitumen recovery	80-90%
Bitumen recovery rates	1 (47.7 Km^3/d)	Bitumen drainage capacity	3-4 times faster
Condensate content in pipeline	~30%	**DME content in pipeline**	15-17%
Breakeven cost	US$ 40	**Breakeven cost**	US$ 7-8

*Carried out for 300,000 bpd plant; 100% availability;

**Other gas: Methane - 35.95 MJ/Nm^3 or 49 MJ/kg

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Table 2. Technologies Operational Parameters

SAGD Technology Baseline Conditions		**DME Technology Operational Conditions**	
Parameter	*Value*	*Parameter*	*Value*
3S. Bitumen production	47.7 Kt/d	3S. Bitumen production	47,7 Km^3/d
8S. Thermal energy in steam delivered to bitumen reservoir	338.4 TJ/d	8D. Electrical energy delivered to bitumen reservoir for heating	38 TJ/d
10S.Natural gas used by boiler for steam generation (boiler efficiency 80%)	17.19 Mm^3_{NG}/d	DME used by local electrical energy generator (diesel engine eff. 48%)	6.75 Kt/d (3.29 Mm^3/d)
11S. CO_2 emissions related to boiler operation	32,500 t/d	CO_2 emissions related to local electrical energy generator used for reservoir heating (eff. 48%)	*not emitted but recycled*
1S.Consumption of electric energy by water pump (from grid)	295 TJ/d	1D. Consumption of electric energy by fluid pumps (from local diesel engine generator)	56.05 TJ/d
		Total electrical energy used by plant (pumping and heating) (diesel engine eff. 48%)	94 TJ/d
4S. Daily CO_2 emission related to pumps fed from a grid (effi.42%)	7,238 t/d	4D. Daily CO_2 emission from local electrical generator (eff. 48%) not emitted but recycled	6.52 kt/d *recycled*
6S Process water demand (2.5 b /bb bit)	120 Km^3/d	6S Process water demand	No water used
12S.Total CO_2 emissions (ref. pump+boiler)	39.78 kt/d (14.5 Mt/y)	12D.Total CO_2 emissions (ref. pump+heater) *(not emitted but predicted to be recycled to plant)*	6.52 kt/d (2.38 Mt/y)

Amount of condensate needed (30% blend)	20,700 t/d	Amount of DME used (15% blend)	8,528 t/d

Steam reforming of DME, as compared to natural gas, generates large volumes of hydrogen and proceeds under very mild conditions (see “DME’s Potential for the Hydrogen Economy”). DME handling, including storage, pipelining and shipping does not present problems; the infrastructure developed for LPG can be employed for DME. DME can be reformed to hydrogen via catalytic photosynthesis (CPS) of CO_2/H_2O blend. Successful scale-up of (CPS) shall result in drastic reduction of the DME production cost. That would further reduce the cost of bitumen production and bring Alberta a step closer to hydrogen economy implementation.

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