NOVEMBER 23, 2015: THE LATEST DIMETHYL ETHER INSIGHT FROM CHEMBIOPOWER

Leadership, Finally! Alberta Sets a Carbon Tax

Following an opinion gathering process lead by a group of business leaders, academics and policy makers, the Province of Alberta, Canada announced on November 20, 2015 an economy wide carbon dioxide tax beginning in 2017 and ramping up in 2018. Rachel Notley, Alberta's NDP Premier made the announcement with the support of oil industry executives and the Treaty 6 First Nations. Along with environmentalist and other government supporters, most opinion leaders welcome the new toll and CO2 limits. Highlights of the plan include:

- In 2017, a 20 $/tonnes carbon dioxide (CO2) tax will be levied on all sources.
- In 2018, a 30 $/tonnes carbon dioxide (CO2) tax will be levied on all sources.
- In 2019, the tax will increase from the 30 $/tonnes base by 2% plus the rate of inflation every year.
- All oil sand activities will be capped at 100 megatonnes, where current emissions are about 80 megatonnes.
- A ban on new coal generation, with all coal generation eliminated by 2030.
- Drop all methane emissions by 45%, eliminating fugitive piping emissions and natural gas venting.

This policy will drive carbon dioxide emissions lower using an incremental approach, achieving the greatest CO2 reduction with the least cost and disruption. The policy will lower all provincial greenhouse gas emissions without destroying the oil and gas industry or the greater economy. Consumers in British Columbia (BC) have been paying a less comprehensive levy on transportation fuels and it appears to be having the intended effect in that province. Unlike BC, Alberta has tremendous gas deposits, which can be used to for chemical production and low carbon fuels. Alberta also has the finest wind assets in North America, located along the eastern slope of the Rockies.

Policy Momentum Favors Carbon Fees

Over the past decade, governments have discussed limiting carbon emissions. Some market advocates support a cap and trade system similar to previous air pollution control initiatives targeting acid rain. Other economists support a carbon fee (or tax) that penalizes all CO2 emissions equally across the economy. Tax jurisdictions aim to make these taxes "revenue neutral" by reducing general revenue taxes (i.e. property tax, sales tax, income tax). These types of taxes are designed to modify behavior, and subsequently economic decisions, are called Pigovian taxes.

"Pigovian taxes are named after economist Arthur Pigou who also developed the concept of economic externalities. The tax is intended to correct an inefficient market outcome, and does so by being set equal to the social cost of the negative externalities William Baumol was instrumental in framing Pigou's work in modern economics."

Currently other jurisdictions are proceeding with legislation to implement similar taxes. Carbon Washington, sponsor of a statewide ballot initiative for a revenue-neutral tax, wants to charge emitters $15/ton of carbon dioxide emitted in the first year of implementation, $25/ton of carbon dioxide in the second, and up to $100 /ton in the following years. Similar initiatives exist in Oregon, Vermont and Massachusetts

Steven Chu, a physics professor at Stanford University and a former U.S. energy secretary. Taxing greenhouse gases "gives much more certainty to industry, to businesses, so they can plan"

Welcome to the Methanol and Dimethyl Ether Economy

These policies will swing the liquid fuel industry to the methanol economy (methanol, dimethyl ether [DME], dimethyl carbonate [DMC]), etc.) The economy can grow with reduced emissions and create value for export. Unlike diesel, these products can be safely transported with little risk of environmental consequences, eliminating the historical animosity to pipelines. Importantly, the carbon tax will favor DME for remote power generation. In Table 1 (see below), the clear winners and losers become evident in a carbon neutral world. For motive power, compression engines will prevail, with DME and BioDiesel as the leading fuels. In the case of spark ignition engines, compressed natural gas (CNG) will be the leading candidate for fleets operating in "hub and spoke" systems. This will depend on the distribution of CNG charging station. The cleanest technology for small-scale power sources utilizes hydrogen for fuel cell powered sources. Ultimately, over the next 10 years, fuels that can be formed using hydrolysis on a global scale and capture carbon will ultimately be declared sustainable. These include hydrogen (H2), methanol (MeOH) and dimethyl ether (DME).

Liquid Fuels	*Energy*	*Density*	*Energy*	*CO2*	*C*	*Penalty*	*Penalty*	*Eff.*	*Penalty*
Units	MJ/kg	kg/liter	MJ/liter	kg/GJ	kg/GJ	$/GJ	$/liter	%	$/MW-hr
Crude oil	42.69	0.847	36.14	73.3	20.0	$2.20	$0.079	26%	$30.45
Conventional gasoline	43.45	0.745	32.36	69.3	18.9	$2.08	$0.067	26%	$28.79
U.S. conventional diesel	42.79	0.837	35.80	74.1	20.2	$2.22	$0.080	39%	$20.52
Low-sulfur diesel	42.61	0.847	36.09	74.1	20.2	$2.22	$0.080	39%	$20.52
Petroleum naphtha	44.94	0.725	32.59	74.1	20.2	$2.22	$0.072	26%	$30.78
Methanol	20.09	0.794	15.96	68.4	18.7	$2.05	$0.033	26%	$28.42
Ethanol	26.95	0.789	21.27	71.6	19.5	$2.15	$0.046	26%	$29.74
NG Liquids (LPG)	46.61	0.508	23.68	64.8	17.7	$1.94	$0.046	26%	$26.21
Liquid Natural Gas (LNG)	48.63	0.428	20.83	56.1	15.3	$1.68	$0.035	26%	$23.30
Dimethyl Ether (DME)	**28.88**	**0.665**	**19.21**	**66.2**	**18.1**	**$1.99**	**$0.038**	**39%**	**$18.34**
DME-Ammonia 80% 20%	26.46	0.670	19.01	61.5	16.8	**$1.85**	$0.033	39%	**$17.65**
Methyl Ester (BioDiesel)	37.53	0.888	33.32	75.3	20.5	$2.26	$0.075	39%	$20.85
Butane	45.28	0.585	26.47	67.0	18.3	$2.01	$0.053	26%	$26.21
Propane	46.30	0.507	23.48	63.1	17.2	$1.87	$0.045	26%	$23.30
Hydrogen (NG & Fuel Cell)	120.21			61.0	16.6	$1.83		40%	$16.47
Coal Plant (Reference)	29.30			125.1	34.1	**$3.75**		36%	**$37.54**

TABLE 1: FUELS IN ALBERTA IN 2018 UNDER A 30 $/TONNE CO2 TAX (DATA FROM IEA AND BIOMASS ENERGY CTR)

Why Not Liquefied Natural Gas?

A recent study projects that annual methane emissions from the Canadian oil and gas industry will remain stable until 2020 at 60.2 Mt equivalent of carbon dioxide (CO2). The legislation has correctly identified methane as potent greenhouse gas, over 20 times more damaging over a 100-year period than carbon dioxide. The legislation recognizes that methane is often vented, in particular in LNG systems where "boil off" gases cannot be recompressed. LNG truck fleets require regular maintenance and can sit idle over 5 days. Any LNG powered truck remaining idle for 4 days will vent methane to prevent a LNG tank rupture. Compressed natural gas (CNG), as opposed to liquid natural gas (LNG), does not require tank venting while idle.

Dimethyl Ether – Keep the Engine, Change the Fuel

The diesel compression engine is the least expensive, most efficient power source produced on a global basis. No other power source has a global supply chain or an application space as large as the compression engine. Diesel engines provide power from 1 kW to 20 MW. Moreover, compression engines do not rely on exotic materials and are completely recyclable. Compression engines can operate easily for over 50,000 hours before overhaul.

The challenge is to find a fuel for compression engines that is environmentally friendly, stores easily and transported simply. DME or DME-NH3 combinations can be used in a traditional diesel engine by modifying the fuel system and the injectors. DME can be readily synthesized from Alberta's abundant natural gas and biomass feedstock using a number of well-established chemical processes.

Clearly, the carbon tax favors dimethyl ether, DME-NH3 mixes and methanol over diesel and gasoline. Moreover, since DME has a cetane number of 55 versus 46 for regular diesel, the compression ratio for a DME engine can be up to 22:1, creating a large efficiency gain over regular engines working at 16:1 compression ratios. DME is benign, evaporates after a spill, burns smoke free with no sulfur, minimizes nitrous oxide and generates 1 to 2 liters of water for each liter of fuel produced. Most importantly, producing DME and methanol (along with hydrogen), solves the "fuel to tidewater" issue since these fuels pose no threat by being spilled or leaked during transportation.