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Reference: Best practice recommendations for including the value of avoided GHG emissions into economic evaluations of solution gas conservation and conversion schemes in Alberta.

This letter provides guidance for integrating the value of avoided greenhouse gas (GHG) emissions into economic evaluations required by the Alberta Energy Regulator (AER) Directive 060 (D060) when considering solution gas conservation and combustion options. This alternative to the current D060 requirement (i.e., burn solution gas if volumes are sufficient to sustain stable combustion) is proposed because GHG abatement costs increase dramatically as flows approach zero and GHG mitigation investments should be directed to more cost effective options (e.g., installing instrument air instead of natural gas to drive pneumatic devices).

Background

Natural gas conservation and conversion options are evaluated at oil batteries where gas production exceeds site energy demands but is not sufficient to motivate gas gathering infrastructure. These stranded gas flows are often released directly to the atmosphere as a reliable and low cost means of disposal. When observed at isolated batteries, venting excess sweet natural gas is a safe practice that doesn't cause offsite odours, exceed ground level ambient air quality objectives, increase lease sizes or incur landowner objections to aesthetically displeasing flare stacks. However, when aggregated together oil and bitumen battery venting is a noteworthy greenhouse gas (GHG) emission source with 8.95 megatonnes carbon dioxide (CO_2) equivalent (E) released in 2011 (approximately 9 percent of direct GHG from the Canadian upstream oil and gas industry as published in Environment Canada, 2014).

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The proposed approach adopts D060 economic evaluation criteria with the following GHG quantification tasks for subject batteries:

1. Determine initial solution gas flow, production forecast and composition.
2. Determine site natural gas energy demands (i.e., engine and heater fuel consumption).
3. Calculate GHG reductions as the difference between baseline and project emissions achieved by the technology scenario under consideration.
4. Calculate NPV considering the value of avoided GHG emissions (defined by the jurisdiction regulator).

Guidance for determining average abatement cost is also provided below.

<u>Determining gas flows, composition and production forecasts</u>

Solution gas flow rates are determined according to Sections 4 and 12 of AER Directive 017 Measurement Requirements for Oil and Gas Operations (D017). To minimize inconsistencies in gas-to-oil (GOR) results, producers should also follow the standard approach to measurement practices developed by New Paradigm Engineering Ltd. (2004). Gas compositions are determined according to Section 8.2.3 of D017.

Production forecasts should consider planned drilling and pressure maintenance programs in addition to well decline rates. Forecasts are driven by commodity price, drilling and completion program success, technology advancements and operational factors rather than physical reservoir pressure and production declines.

<u>Determining site energy demands</u>

Estimating site energy demands is required to quantify baseline GHG emissions that occur from purchased fuel combustion. For example, well sites typically feature reciprocating engines that drive production pumps and tank heaters that aid the separation of oil and water in production tanks. Guidance on estimating natural gas fuel volumes is available in Section 3.1 of CAPP, 2005.

<u>Calculating net GHG reduction</u>

The net GHG emission reduction is the difference between baseline and project emissions that occur each year over the project life. Baseline contributions include combustion emissions from purchased fuel (typically constant over time) plus solution gas venting (declining over time according to the production forecast) that occurs onsite. Project emission contributions are those that occur onsite after GHG mitigating technologies are installed. They should include all onsite combustion (i.e., solution gas that is flared, incinerated or used as fuel plus purchased fuel) and any solution gas not captured by the mitigating technology that continues to be vented.

GHG emissions are accounted on a CO_2 Equivalent (e) basis using Global Warming Potentials (GWP) of 1 for Carbon Dioxide, 25 for Methane and 298 for Nitrous Oxide from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (IPCC, 2012). Solution gas combustion CO_2 emissions are determined by mass balance and conversion efficiency of 1.0 while emission factors for CH_4 (49.58 g/GJ) and N_2O (1.305 g/GJ) are adopted from WCI Table 20-4 (WCI, 2013). Venting CO_2 and CH_4 emissions are determined by mass balance while propane combustion factors are adopted from WCI Table 20-2 (60.96 kg CO_2E/GJ). Fugitive emissions are excluded for simplicity and because the difference between baseline and project fugitives is small.

For example, baseline emissions for a two-well Cold Heavy Oil Production with Sand (CHOPS) battery that purchases propane fuel to meet site energy demands and vents all casing gas are presented in Table 1 (column A). If a vapour combustor is installed to dispose up to 1,500 m^3/day of casing gas, GHG emissions decrease and resulting project case emissions are presented in column E. Project emissions are calculated by summing casing gas combustion (column B volume multiplied by combustion factors); casing gas venting (excess volume not combusted in column C multiplied by methane and carbon dioxide mole fractions); and propane fuel combustion (column D energy demand multiplied by combustion factor). Annual avoided GHG emissions (column F) equal column A minus column E. Over the eight year project life, total avoided GHG emissions equal 59,819 t CO_2E.

Table 1: Avoided GHG emissions when disposing excess casing gas in a vapour combustor.

Year	Baseline	Project Case				Avoided GHG Emissions
	GHG Emissions	Casing Gas Combusted	Casing Gas Vented	Propane Combusted	GHG Emissions	
	(t CO_2E/yr)	($10^3 m^3$/yr)		(GJ/yr)	(t CO_2E/yr)	(t CO_2E/yr)
	(A)	(B)	(C)	(D)	(E)	(F)
2016	12,749	548	183	9,931	4,718	8,031
2017	11,816	548	126	9,931	3,785	8,031
2018	10,954	548	75	9,931	2,923	8,031
2019	10,158	548	27	9,931	2,127	8,031
2020	9,424	530	0	9,931	1,648	7,775
2021	8,746	489	0	9,931	1,568	7,178
2022	8,120	452	0	9,931	1,494	6,626
2023	7,542	417	0	9,931	1,426	6,116
Total	79,509	4,078	410	79,449	19,690	59,819

Further emission reductions could be achieved by using excess casing gas to meet site energy demands. Moreover, decisions regarding gas conservation should not be delayed until consistent GOR measurement results are observed over a period of time. Given the finite period of stable flow, delaying installation of gas conservation or conversion equipment until after stabilized flow is observed will jeopardize project economic feasibility.

Calculating NPV

The NPV of a conservation or conversion project is the algebraic sum of the present value of projected incremental benefits less the present value of projected incremental costs over the project's useful life. It is calculated by multiplying the positive projected incremental benefits (i.e., where relevant, revenue from sales, avoided fuel purchases, and the salvage value of project infrastructure) and negative incremental costs (i.e., investment expenditures and recurring operating costs, net of any baseline cost savings) incurred each year, by the appropriate discount factor, and summing all the resulting discounted values over the useful life of the project.[1] Project NPVs are calculated on a *before-tax* basis and exclude contingency and overhead costs.

If methane venting emissions are monetized, the present value of avoided GHG emissions would then be included in the sum of incremental benefits. The value applied per tonne of CO_2E avoided and NPV threshold trigger should be specified by the regulator having jurisdiction over the subject facility.

When calculating NPV in Alberta, economic criteria to be used are specified in Section 2.9.1 of D060. Further clarification are provided for the following criteria.

Discount Rate

The nominal annual discount rate is based on the most recent prime lending rate of ATB Financial on loans payable in Canadian dollars plus 3% per year. The discount factor determines the weight assigned to future economic costs/benefits in the NPV calculations. This factor (and weight) declines exponentially with time. Also, the higher the annual discount rate, the lower the weight assigned to future costs/benefits in the determination of a project's NPV. All future economic costs/benefit flows are discounted at the nominal annual discount rate in the NPV calculations (i.e., converted to present day equivalents). The value of future GHG reductions are already accounted in the global warming potential (GWP) term and therefore not subject to further discounting.

Price Forecasts

Natural gas and purchased fuel price forecast are from GLJ Petroleum Consultants Limited (GLJ) using the Alberta Natural Gas Reference Price (ARP) which is an average field price for all Alberta gas sales, as determined by the Alberta Department of Energy through a survey of actual sales transactions. The full (current dollar) time series provided by GLJ over the project period should be applied.

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[1] The discount factor constitutes the weight applied to dollars received in future years. It is used to convert future dollar flows into present day equivalents: discount factor = $(1 + r)^{-t}$. Where r is the nominal annual discount rate and t is the year in which a cost or benefit is incurred. The discount rate is constant over the life of the project.

The electricity price should consider the most recent 12-month rolling average of the pool monthly summary price published by the Alberta Electric System Operator (AESO). This power price is then escalated at the long-term annual rate of general price inflation.

Inflation Rate

This should be the long-term annual rate of general price inflation based on the average year-on-year (all-item) Consumer Price Index (CPI) observed in Alberta over an extended period (i.e., 10 to 20 years). The CPI for Alberta is generated by Statistics Canada and published monthly in "Economic Trends" by the Government of Alberta, Treasury Board and Finance, Economy and Statistics.

The long-term annual rate of general price inflation rate is used to escalate net annual costs and estimated salvage values (where relevant), in addition to electricity prices. This is necessary to ensure consistent treatment of all cost and benefit streams in the NPV calculations, which is performed in current (or nominal) dollars.

Carbon Pricing

Ultimately, the carbon value used in NPV calculations is specified by the jurisdiction regulator. This value may be equivalent to an existing provincial carbon levy or based on the social cost of carbon.

The social cost of carbon—or SCC as it is known—is used in the U.S. to evaluate the climate change benefits of proposed new rules or changes to existing rules (EPA, 2015a). The US EPA defines the SCC as "an estimate of the economic damages associated with a small increase in CO_2 emissions, conventionally one metric ton, in a given year." It measures the full global damage costs of an incremental unit of carbon (or equivalent amount of other greenhouse gases) emitted at a particular point in time, summing the full global cost of the damage that unit imposes over its lifetime in the atmosphere. Damage costs include a wide range of anticipated climate-related impacts, including *inter alia* net changes in agricultural productivity, adverse human health outcomes, property and infrastructure damage from flooding, and changes in energy system costs associated with changes in cooling and heating demand. It is thus a measure of social costs.

Calculating the SCC requires quantification of the whole process linking anthropogenic emissions of GHGs with impacts on social welfare at a global scale; this task is performed by integrated assessment models (IAMs). Three IAMs from the peer-reviewed literature were used to generate values of the SCC for rulemaking in the U.S (EPA, 2015b); values for the SCC are shown in current Canadian dollars in Table 2. Many climate-related impacts associated with an incremental unit of carbon emitted today are expected to occur for many decades and even centuries. The present value of those damages is thus highly sensitive to the chosen discount rate; this is evident from the values in Table 2, which are provided for three different discount rates typical of climate policy analysis. Moreover, since the amount of damage done by each incremental unit of carbon in the atmosphere depends on the concentration of atmospheric carbon today and in the future to which the increment is added, the SCC associated with emissions in 2020, 2025, 2030 rises as global emissions and concentrations of GHGs in the atmosphere increase. The SCC also increases over time as more people, assets and wealth are affected, and as natural and socio-economic systems become increasingly stressed in response to greater levels of climatic change (reducing their coping capacity).

The SCC is important because it signals what society should, in theory, be willing to pay now to avoid future damages caused by incremental carbon emissions. Policy-makers should be willing, in the interests of society, to make rules that result in emissions savings which cost up to and no more than the damage they expect the emissions to cause, because to do so would make society better off. This is how the SCC values are applied in the U.S., i.e., to value the benefits (and justify the implementation) of GHG emission reductions in rules like the proposed New Source Performance Standards (NSPS) for the oil and natural gas industry (EPA, 2015a).

Table 2: Estimates of the Social Cost of Carbon (Average across all three IAMs, in current Canadian dollars).

Year	**Base-case (3% discount rate)**	**Lower Bound (5% discount rate)**	**Upper Bound (2.5% discount rate)**
	($ / t CO_2E)	**($ / t CO_2E)**	**($ / t CO_2E)**
2016	54	16	84
2017	57	17	88
2018	61	17	91
2019	64	18	95
2020	67	19	99
2021	70	20	103
2022	73	21	107
2023	75	22	112
2024	78	23	116
2025	81	24	120

Average GHG abatement cost

Some jurisdictions may use an average (net) GHG abatement cost (in current $ per t CO_2E avoided) threshold to determine whether gas is combusted or vented. In these cases, average abatement cost equals the total cost, *net* of revenue from sales or avoided fuel purchases, incurred by the operator to avoid the release of one tonne of CO_2E to the atmosphere.

$$Average\ Abatement\ Cost = \frac{PVC - PVB}{GHG}$$

Where:

PVC	=	Present Value Costs
	=	$\sum_{t=0}^{N} \frac{C_t}{(1+r)^t}$
PVB	=	Present Value Benefits
	=	$\sum_{t=0}^{N} \frac{B_t}{(1+r)^t}$
GHG	=	Avoided GHG Emissions
	=	$\sum_{t=0}^{N} E_t$
t	=	year (with year $t = 0$ being the year in which the investment is made)
N	=	useful life of project (in years)
r	=	nominal annual discount rate
C_t	=	project's costs in year t
B_t	=	project's benefits in year t (excluding the monetization of CO_2E savings)
E_t	=	project's CO_2E savings in year t *determined with global warming potentials defined by the regulator*

If PVC >PVB, then the average abatement cost is positive. This implies the operator incurs a cost for each tonne of CO_2E saved. In contrast, if PVC < PVB, the average abatement cost is negative, and the operator accrues a resource saving for each tonne of CO_2E saved.

The average abatement cost has several useful interpretations. In the current context, it provides a yardstick for determining whether or not a conservation project (at different casing gas flow rates) is economic relative to different valuations of the CO_2E savings. In general:

- If the average abatement cost of a conservation project is negative, then that project is economic even without the monetization of CO_2E savings;
- If the average abatement cost of a conservation project is positive, but is *less than* the prevailing carbon price, then that project is economic if CO_2E savings are monetized and included in the benefits stream; and

- If the average abatement cost of a conservation project is positive, but is *greater than* the prevailing carbon price, then that project is uneconomic even if CO_2E savings are monetized and included in the benefits stream.

We trust these recommendations will be helpful to operators when incorporating the value of avoided GHG emissions into economic evaluations for solution gas conservation and conversion projects.

Yours truly,
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