COSIA CHALLENGE

Mobilizing the world's minds and resources to improve environmental performance.

Post Combustion CO_2 Capture from Natural Gas Combustion Flue Gas

SOLUTION DESCRIPTION:

Looking for new transformative technology to capture CO_2 from flue gas streams from natural gas combustion in a once through steam generator (OTSG) or potentially a gas turbine.

CREATED: October 1st, 2016

All projects are evaluated and actioned as they are received.

CHALLENGE SPONSOR:

COSIA's **GHG EPA** is sponsoring this challenge.

Our aspiration is to **produce our oil with lower greenhouse gas emissions than other sources of oil.**

COSIA has four Environmental Priority Areas (EPAs): Water, Land, Tailings, and Greenhouse Gases (GHGs).

For more information on this COSIA Challenge please visit **www.cosia.ca**

Canada's Oil Sands Innovation Alliance (COSIA) accelerates the pace of environmental performance improvement in Canada's oil sands through collaborative action and innovation. COSIA Members represent more than 90 per cent of oil sands production. We bring together innovators and leading thinkers from industry, government, academia and the wider public to identify and advance new transformative technologies. Challenges are one way we articulate an actionable innovation need, bringing global innovation capacity to bear on global environmental challenges.

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WHAT TO SUBMIT TO COSIA

COSIA requires sufficient non-confidential, non-proprietary information to properly evaluate the technology.

Some items that will be especially important to present in your submission are:

- Concept and basic unit operations
- Technical justification for the approach (e.g. laboratory batch or continuous experiments; pilot or demo plants; process modeling; literature precedent)
- Describe quantities and qualities of utilities and consumables that are required
- Energy inputs – quantity and type(s)
- Capital and operating cost estimates if available based on described capacity targets
- 3rd party verified comparison of your proposed technology against an MEA baseline. 3rd party verifiers should be reputable, independent engineering companies if possible
- Basis of cost estimation, including estimation scope, contingency, etc.
- IP status of your proposed technology
- What operating environment restrictions might your technology face:
  - Explosive atmospheres
  - Severe weather
  - Power fluctuations

FUNDING, FINANCIALS, AND INTELLECTUAL PROPERTY

COSIA Members are committed to identifying emerging technologies and funding the development of the technologies to the point of commercialization, while protecting the Intellectual Property (IP) rights of the owner of the technology.

COSIA Members have funded over 400 projects to date, totaling over $1 billion.

Successful proposals can receive funding from COSIA members to develop and demonstrate the technology in an oil sands application. Multiple technologies may be funded, at the discretion of the Members.

HOW TO SUBMIT TO COSIA

Submit a summary of your solution using COSIA's Environmental Technology Assessment Portal (E-TAP) Process, available at: **http://www.cosia.ca/initiatives/etap/idea-submission-form**

Please note: ETAP is a staged submission process. The initial submission requires only a brief description and limited technical information. Upon review by COSIA, additional information may be requested. Instructions for submission are provided on the ETAP site.

All information provided is non-confidential. COSIA will respond to all submissions.

DETAILED SOLUTION DESCRIPTION

The successful technology will:

- Perform >50% (preferably > 75%) better than benchmark amines (30% monoethanolamine (MEA)) based post-combustion capture technologies on an energy and cost basis i.e. >50% reduction in capital expenses, operating expenses, capture energy requirements and CO_2 avoided cost *. CO_2 avoided costs must account for both direct and indirect** CO_2 reductions.
- Achieve high level of CO_2 purity (e.g ~>95vol % CO_2), although somewhat lower levels will be acceptable, depending on the end use of the CO_2 and if there are significant CAPEX/OPEX savings.
- Capture > 90% of CO_2, although lower capture levels will also be considered if there are significant CAPEX/OPEX savings.
- Have a minimal land-based footprint
- Have no adverse environmental or safety impacts (e.g. increased NOx emissions, toxic chemical release)
- Have minimal impact on or beneficial integration opportunities with existing operations.

Technologies at all stages of technical maturity are of interest.

BACKGROUND

Oil sands operations consume large quantities of natural gas to produce steam for in situ bitumen extraction. A typical 33,000 BPD in situ facility would operate six once through steam generators (OTSGs) requiring 1600 GJ/h (LHV) of combined energy input and emitting ~2,200 tonnes CO_2 per day. Conventional air supply (containing 21% O_2) for combustion of pipeline specification natural gas in OTSGs produces flue gas with a low CO_2 content (~7-8% by volume) at atmospheric pressure. OTSG flue gas contains 10 to 15% (volume) water, has a temperature ~185 ^{o}C, and can have 25 – 30ppm SO_2 resulting from burning produced gas from the bitumen reservoir. OTSGs are also used for steam generation in oil sands mining and extraction operations.

Gas turbines, with heat recovery steam generators, are also applied in some oil sands in situ or mining operations in place of one or more OTSGs. While gas turbine flue gas is a candidate for CO_2 capture, CO_2 concentration in the flue gas is much lower (4% by volume).

COSIA is ideally seeking transformative CO_2 capture technologies that significantly outperform today's state-of-the art advanced amines. The ultimate fate of the CO_2 could be geological storage or conversion to useful products, for which purity, contaminants, and required delivery pressure may vary. Innovative combinations of post-combustion capture technologies will also be considered (e.g. "hybrid" approach of using a membrane for initial concentration of CO_2 prior to capture).

Modularization and offsite fabrication is preferable given the remote location of Canada's Athabasca oil sands.

Material and energy flow diagrams for a standard 33,000 BPD Steam Assisted Gravity Drainage (SAGD) facility are provided below.

APPROACHES NOT OF INTEREST

The following approaches are not of interest for this specific Challenge Statement:

- Incremental improvements to advanced (next generation) amine based capture systems – targeting significantly better performance as detailed in the "Request for Proposal Description" section;
- Pre-combustion technologies;
- Oxy-combustion technologies;
- CO_2 conversion technologies; and
- Fuel cell technologies.

ADDITIONAL INFORMATION

* CO_2 Avoided Cost

The CO_2 Avoided Cost is the overall cost measure most commonly reported in CCS studies. It compares a plant with CO_2 Capture (CC) to a "reference plant" without CC, and quantifies the average cost of avoiding a unit (typically in tonnes) of atmospheric CO_2 emissions while still producing the same quantity of useful product. The CO_2 avoidance cost can be directly compared with market carbon price or regulatory carbon compliance cost. The Cost of CO_2 Avoided (\$/tonnes CO_2) is calculated as follows.

$$\text{Cost of CO}_2\text{ Avoided} =$$

$$\frac{\text{Cost of Plant with CC} - \text{Cost of Reference Plant (no capture)}}{\text{CO}_2\text{ emissions from Reference Plant} - \text{CO}_2\text{ emissions from Plant with CC}}$$

Capturing carbon dioxide requires energy which is generally produced by the combustion of a fuel. Therefore, CO_2 is created to facilitate the capture process. This additional CO_2 produced is not included in the avoided cost calculation because it is additional emissions to the reference case with no CO_2 capture. The Avoided CO_2 emissions from Plant with CC is the difference between the amount of CO_2 captured and the CO_2 emitted by the operation of the CO_2 Capture Plant (including both direct and indirect** CO_2 emissions).

The avoided cost of your technology must be compared to a reference case of post combustion CO_2 capture at a SAGD facility using 30% MEA. As COSIA members must compare capture costs on an equal and consistent basis, use the avoided cost calculations found in the *Alberta Innovates – Energy and Environment Solutions report "*ECM Evaluation Study " (Case 1B). This report can also inform your key assumptions and avoided cost calculation methodology.

Case 1B provides you the cost build up and avoided cost calculation methodology for the 30% MEA case as applied to OTSG flue gas CO_2 capture. To evaluate your technology on a comparable basis, please provide the following in your submission:

Base Case: Your estimate for the avoided cost for the base 30% MEA capture case (Case 1B). If your assessment of the Base Case is different from Case 1B above, please provide supporting documentation to support your claims.

New Capture Technology Case: provide an assessment of your proposed capture technology using the same methodology as used to assess the Base Case. A comparison of the avoided cost and operating performance against the Base Case will be required. The CO_2 will be delivered at the facility battery limits at the same operating and purity specifications as Case 1B.

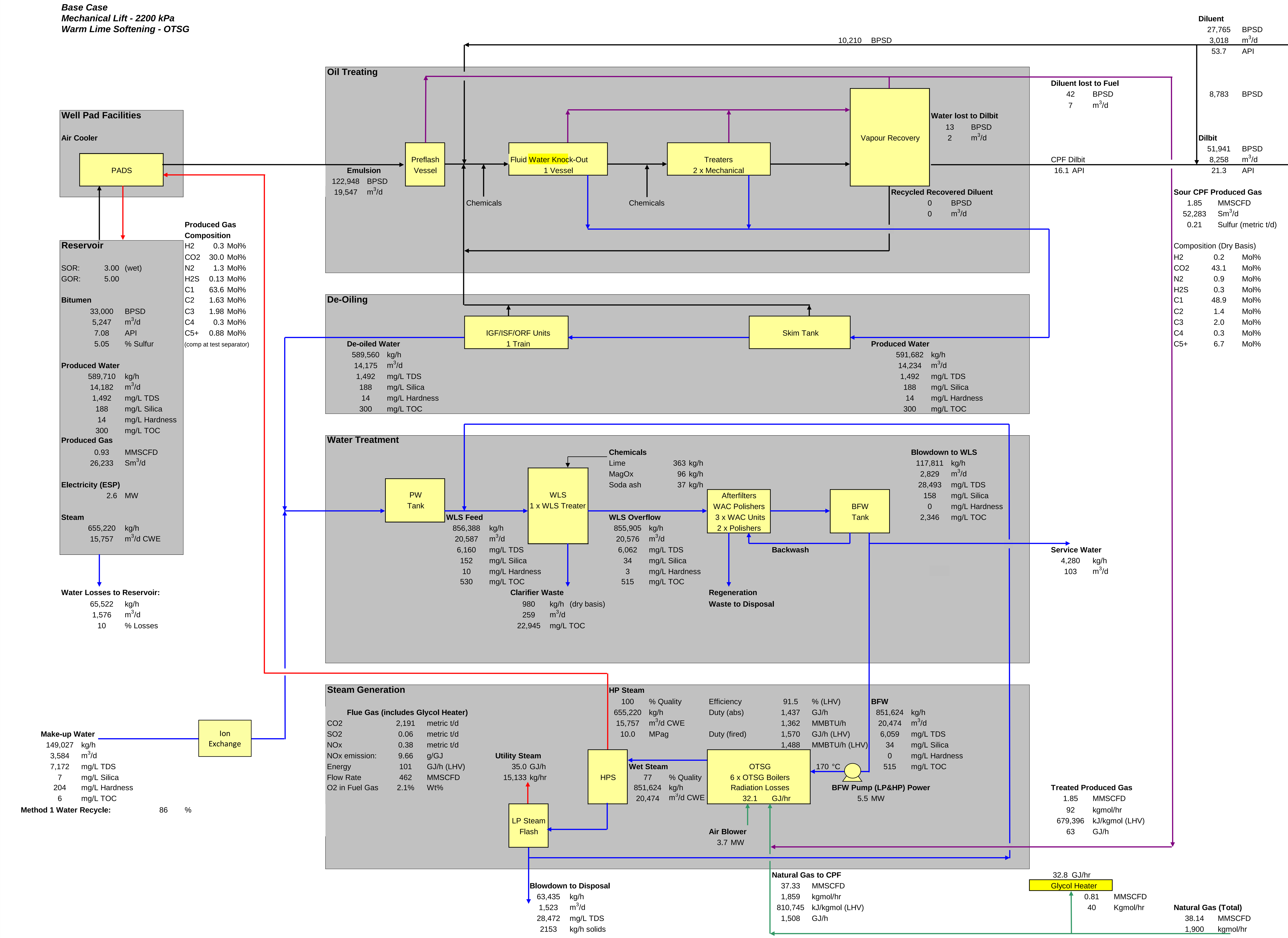
Ensure to provide COSIA with a breakdown of the cost calculations and assumptions for your technology. Submissions that do not include an assessment of both the Base Case and New Capture Technology Case using the referenced methodology described above will be rejected.

** Indirect Emissions

For any power consumption within the capture process, an electricity grid GHG intensity factor of 0.64 t CO_2e/MWh can be assumed, as per the Alberta Government's "Carbon Offset Emission Factors Handbook, 2015, No.1."

COSIA SAGD TEMPLATE

Base Case
Mechanical Lift - 2200 kPa
Warm Lime Softening - OTSG



Summary Table	
MU TDS (ppm)	7,172
PW TDS (ppm)	1,492
PW TOC (ppm)	300
LP Flash BD (%)	8%
BD Recycle (%)	60%
TDS to Boiler (ppm)	6,059
Boiler TOC (ppm)	515
MU Flowrate (kg/h)	149,027
WLS Sludge (kg/d)	23,530
Disposal Type (L,S)	L
Disposal Rate (kg/h)	63,435
Disposal Solids (kg/d)	51,662

Water Balance

Stream	Flow kg/h	Flow m^3/d	TDS ppm	Silica ppm	Hardness ppm
Steam to reservoir	655,220	15,757	-	-	-
Losses to reservoir	65,522	1,576	-	-	-
Produced Water	591,682	14,234	1,492	188	14
Losses to production	85	2	-	-	-
De-oiled Water	589,560	14,175	1,492	188	14
Make-up Water	149,027	3,584	7,172	7	204
Supernatant					
WLS Feed	856,388	20,587	6,160	152	10
WLS Overflow	855,905	20,576	6,062	34	3
Clarifier Waste to Land	980	259			
Blowdown to Disposal	63,435	1,523	28,472	158	0
LP Steam to WT	0	0	0	0	0
LP Steam to Header	15,133	363,198	0	0	0
Service Water	4,280	103	6,059	34	0
BFW	851,624	20,474	6,059	34	0

Emissions Summary

Source	SO2 metric t/d	S metric t/d	CO2 metric t/d	NOx metric t/d
OTSG Flue Gas	0.06	0.03	2191	0.38
Recovered Sulfur	-	0.00	-	-

ENERGY FLOW DIAGRAM
Base Case: WLS - OTSG

Exchangers	Duty GJ/h
Emulsion / BFW	136.9
Produced Water Glycol Cooler	13.4
PW / BFW Exchanger	84.5
Produced Gas Air Cooler (s)	3.5
Diluent Glcyol Heater	4.4
Sales Oil Coolers	43.9
Make-up Water Glycol Heater	21.8
PW / MU water exchanger	18.1
Blowdown Glycol Cooler	79.3
BFW Preheaters	86.7
OTSG Air Glycol Heaters (two services)	22.7
OTSG Air Preheater (Flue Gas)	N/A
Utility Coolers	11.4
Glycol Air Cooler	124.7

Electrical Loads	Power MW	Equivalent Heat GJ/h
HP BFW Pump	4.8	31.1
LP BFW Pump	0.8	5.2
Downhole Pumps	2.6	17.0
Pad Auxiliaries	1.3	8.5
Forced Draft Fan	3.7	24.0
Misc Users	1.9	12.2
VRU Compressors	2.1	13.7
WLS/Evaporator	0.5	3.1
Glycol System	0.4	2.5
Total	17.9	117.3
Direct CO2 Generation	2,191 MT/day	417.6 kg/m3 Bitumen
Indirect CO2 Generation	328 MT/day	62.5 kg/m3 Bitumen
Total CO2 Emissions	2,519 MT/day	480.1 kg/m3 Bitumen

Assumes electricity grid CO2 emissivity of 763 kg CO2eq / MW-hr
Direct Emissions from Combustion only

Inputs	Energy GJ/h
Natural Gas	1538
Electrical Power	117.3
Total	1655