COSIA ARCTIC Waste Heat Challenge – Request for Responses from Innovators

Response Due Date: November 28, 2015

Opportunity and Financials: $610,000 for 2 to 5 Challenge "Sprints"

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***Only non-confidential information should be included in the response ***

COSIA

Canada's Oil Sands Innovation Alliance (COSIA) is an alliance of oil sands producers focused on accelerating the pace of improvement in environmental performance in Canada's oil sands through collaborative action and innovation. COSIA brings together leading thinkers from industry, government, academia and the wider public to improve measurement, accountability and environmental performance in the oil sands in four priority areas. These four Environmental Priority Areas (EPAs) are tailings, water, land, and greenhouse gases (GHG).

COSIA's GHG EPA is looking for innovative and sustainable solutions to significantly reduce GHGs at oil sands mining and in situ (in place) operations without environmental burden shifting (causing negative environmental impacts in other areas). Its aspiration is to "Produce our oil with lower GHG emissions than other sources of oil."

Foresight ARCTIC

Foresight is a catalyst and connector, providing Canadian and international innovators with access to resources, expertise, talent and partners to mature and implement innovative solutions quickly. Advanced Resource Clean Technology Innovation Centre (ARCTIC) is a Foresight program designed to fulfill the need for a demand-pull approach while identifying both specific environmental, operational and environmental challenges in the resource sector and potential sources of innovation from across Canada and connecting them to drive performance improvements and accelerate the commercialization of new technologies. The ARCTIC program is funded with support from BC Innovation Council (BCIC), Western Economic Diversification (WD) and Canada's National Research Council's Industrial Research Assistance Program (NRC/IRAP). In this Challenge, the ARCTIC program is working with COSIA to search for environmental technologies that target one of the oil sands challenges – waste heat recovery.

Challenge Overview

Steam assisted gravity drainage (SAGD) and cyclic steam stimulation (CSS) are processes employed for in situ production of bitumen from oil sands reservoirs. The more common recovery process (by existing and planned total production capacity) is SAGD, and many environmental technologies applicable to SAGD would likely also be applicable to CSS facilities. In the SAGD process, steam is generated in boilers at a Central Processing Facility (CPF) by combusting large quantities of natural gas. The combustion process results in heat lost through boiler stacks as high temperature (around 200°C) flue gas, which contains CO_2, NOx, SOx (if combusting produced gas), water vapour, and various other minor constituents. The boiler flue gas is considered **high-grade waste heat**.

From the CPF, steam is transported to well pads, and injected below ground into a horizontal well bore within the reservoir. The heat supplied by the steam warms the heavy oil in the reservoir allowing it to flow via gravity drainage into a second underlying wellbore that captures the oil/water mixture and produces it to the surface.

Once at the surface, the mixture of oil and water is cooled from around 200°C down to around 130°C prior to separation through a 'process-to-process' boiler feedwater heat exchanger. The cooled mixture is sent to an oil/water separator. A flue gas economizer heats the boiler feedwater. Produced water is treated and recycled for steam generation. The bitumen is further treated to remove all water, and delivered into a pipeline for shipping.

Heat transfer equipment used in a SAGD facility consists primarily of shell and tube heat exchangers, with some spiral and plate and frame exchangers. There are multiple heat transfer services, which include cooling and heating: bitumen emulsion, diluted bitumen, produced water, boiler feed water, make-up water (fresh or brackish), diluent, sales oil, natural gas, and air. These heat transfer services are performed through process-to-process contact as well as through a glycol loop network.

The glycol loop is a continuous circulation of a glycol/water mixture, and through a series of heat exchangers, absorbs excess heat from streams that need to be cooled, and redistributes heat to streams that need to be heated. Without exception, more heat is absorbed then redistributed, and this excess heat is released to the atmosphere as 60-80°C warm air. This is considered **low-grade waste heat** which is rejected to the atmosphere via air coolers. Importantly, the amount of heat dispensed during hotter summer months will be greater than during the winter.

The Challenge Statements

High Grade Waste Heat:

COSIA is seeking technologies that reduce GHG emissions by capturing approximately 200°C waste heat from flue gas and transforming it into higher value uses. In particular, COSIA is searching for higher value uses in the following areas:

- Preheating combustion air
- Preheating makeup water
- Space heating
- Electricity production
- Water treatment

See Appendix 1 for technical specifications.

Low Grade Waste Heat

COSIA is seeking technologies that reduce GHG emissions by capturing 60°C to 80°C waste heat from the glycol loop and transforming it into higher value uses.
In particular, COSIA is searching for higher value uses in the following areas:

- Preheating combustion air
- Preheating makeup water
- Space heating
- Electricity production
- Water treatment

See Appendix 1 for more information.

Key Performance Indicators

In addition to the operating parameters noted above, COSIA is interested in information that relates to the following key performance indicators, where possible, for each technology proposed. These are included in the Response template, Appendix 2:

- % of waste heat recovered on a high-level energy balance basis
- Lower cost of operations in $ value
- GHG emissions reductions in tonnes/year

- Total Cost of Ownership (TCO) $ value
- Installation downtime in days per year
- Land required/footprint
- Resilience (long life)
- Regulatory compliance hurdles
- Scalability
- (Bonus) recycle water

Opportunity and Financials

The ARCTIC Program

ARCTIC is designed to model a new approach for industry and innovator collaboration. There are four critical phases of activity designed to produce relevant field trials that will validate solutions to resource sector defined challenges.

Phase 1: Challenge Definition (3 months) - Completed

In conjunction with resource sector partners/ARCTIC participants, Foresight will define challenges in order to focus innovators on the most promising market opportunities.

Outcomes:

- Resource sector consultation events delivered in conjunction with communications or industry partners.
- Definition of resource sector challenges to focus innovators.
- Development of a broad community of industry and cleantech innovators.

Phase 2: Innovator Selection

Foresight and COSIA will launch this Waste Heat Recovery Challenge and invite potential solution providers to respond by filling out the attached Response Template (Appendix 2). A panel of industry, investors, and selected experts will select 2 to 5 solutions from the pool of innovators that responded to the Challenge for a six to nine month development sprint.

Phase 3: Challenge Sprint (6 to 9 months)

This Challenge Sprint will be sponsored by resource sector industry partners and will leverage the Foresight Accelerator and its mentorship program to:

- Further advance the development of the proposed solutions through performing a feasibility study of the technology, including integration with an oil sands in situ facility. Latter stage technologies are preferred, but earlier stage will be considered given sufficient operating data; (and)/or

- Further advance the development of proposed solutions through testing in a laboratory or other environment. Latter stage technologies are preferred, but earlier stage will be considered given sufficient operating data
- Move the companies to a point where they can seek first funding
- Deliver a focused stream of companies to operate within Foresight/ARCTIC's facilities. The ARCTIC program has access to specialized facilities in Alberta, BC and Saskatchewan that can respond to the needs of the selected innovators and solutions, if required. Alternatively, selected solution providers can use their own facilities for the Sprint.

Expected Outcomes:

- 2 to 5 promising solutions identified and evaluated.
- 1 technology/solution selected for field trial.
- 1 industry showcase event delivered with a marketing partner.

Phase 4: Field Trial Preparation (12 months)
Following the Challenge Sprint, one solution could be selected for field-testing, or for the next appropriate level of development.

The field trial phase will focus on getting the technology field trial-ready, including equipment specification requirements. Foresight will co-ordinate with the industrial partner(s) existing stage-gating process to determine the test parameters the technology must meet to achieve field trial readiness. The process will include quarterly progress reviews with the industry partner to ensure the development remains on track.

The Size of the Opportunity (for Innovators)

The total funding available for projects supported through this call for proposals is up to **$610,000** Canadian Dollars (CAD), subject to the discretion of Foresight Cleantech Accelerator Centre/ARCTIC and COSIA, and the availability of funds.

The range of funding available per Sprint project is **$87,000 to $305,000**, with a requirement for proponents to commit a minimum of **$50,000** per project as an in kind contribution. The per project costs can go up or down based on the final number of projects in the sprint. The maximum contribution includes provision for lab space and overheads, marketing, a lab manager, equipment, materials, accelerator mentoring and cash.

The winner(s) of the sprint will be invited to undertake the next step in the development of the innovation/field trial (or equivalent). This phase will have a maximum contribution from ARCTIC and COSIA at **$175,000**, with a requirement for proponents to commit **$100,000** as an in kind contribution. The maximum contribution from ARCTIC and COSIA to this phase includes support for a test site, test support, equipment, materials and cash.

Market Applications
Alberta currently has 55 thermal in situ oil sands facilities, with production varying from pilot scale (<10,000 barrels per day [bpd]) to 118,000 bpd[1]. Average facility production is approximately 35,000 bpd. It is estimated that by 2024, 33 additional thermal in situ oil sands facilities will be operating.[2] Similar applications for waste heat recovery exists in other industrial sectors, such as electricity generation, refineries, forest products etc. Proponents should note if waste heat recovery solutions can be applied to existing facilities and/or only built into new facilities.

SME Resources
In kind resources, such as time for a technical person, as well as potentially senior management, are a necessary contribution to participation in ARCTIC.

Schedule
The following table outlines the anticipated timeline for the Innovator Selection phase. Please refer to the ARCTIC website for updated information.

Table 1 – Innovator Selection Schedule

Action	By Whom	Dates
Innovation partners (e.g. SDTC etc) program briefing webinar	ARCTIC	November 2, 2015
Potential applicants/innovators program briefing webinar	ARCTIC	November 9, 2015
Proposal Submitted	Proponents	November 28, 2015
Shortlisted proponents contacted for presentations	ARCTIC Review Team	December 11, 2015
Final Sprint Decisions and Start Sprint (prototype or test, or equivalent)	Proponents and ARCTIC/COSIA	January 2016
Wrap up Sprint, choose Field trial winner	Proponents and ARCTIC/COSIA	July- September 2016

Leveraging Other Opportunities
The ARCTIC program and COSIA do not have restrictions on leveraging other sources of external funding, provided this works with the timelines of the Challenge Sprint. Other financing opportunities could include Export Development Canada, Sustainable Development Technology Canada, or others. The ARCTIC program

[1] *June Warren-Nickle's Energy Group, Active Oil sands Projects, June 2015* http://navigator.oilsandsreview.com/
[2] *CAPP Crude Oil Forecasts, markets and transportation, June 2015* and *June Warren-Nickle's Energy Group, Active Oil sands Projects, June 2015*

evaluation process could be leveraged to support accessing other investment[3].

ARCTIC/COSIA Non-Financial Support

COSIA technical experts will be involved in the evaluation process and will be available to the Sprint winners for technical support. Foresight will also provide access to executives in residence on business and commercial support, and exposure to financing experts.

[3] Western Economic Development, a funder of the ARCTIC program, might have conditions with regards to other federal funding applied to this program. It is the responsibility of the applicant to understand and abide by those restrictions

Appendix 1 – Technical Specifications

Waste Energy Source Characteristics: Flue Gas (High-Grade Heat)

A typical 33,000 barrel per day (BPD) facility operating at a steam to oil ratio (SOR) of 3 would operate six Once Through Steam Generators (OTSGs) requiring 1,600 GJ/h LHV (lower heat value) of natural gas to produce the steam injected into the reservoir. Combustion flue gas contains 7-8% CO_2, and the equivalent of 900 m^3/d of liquid water. It is important to note that condensed water from flue gas may be corrosive to carbon steel.

Typical flue gas characteristics for a 33,000 BPD production facility are:

- 200°C stack temperature
- 100 GJ/h (LHV)
- 460 MMSCFD flow rate
- 2,200 t-CO_2/d
- 0.06 t-SO_2/d
- 0.38 t-NOx/d

Combustion air is preheated to 55°C and boiler feed water is preheated to 170°C. A representative OTSG Flue Gas composition listed in Table 1.

Table 2 - Flue gas characteristics and composition

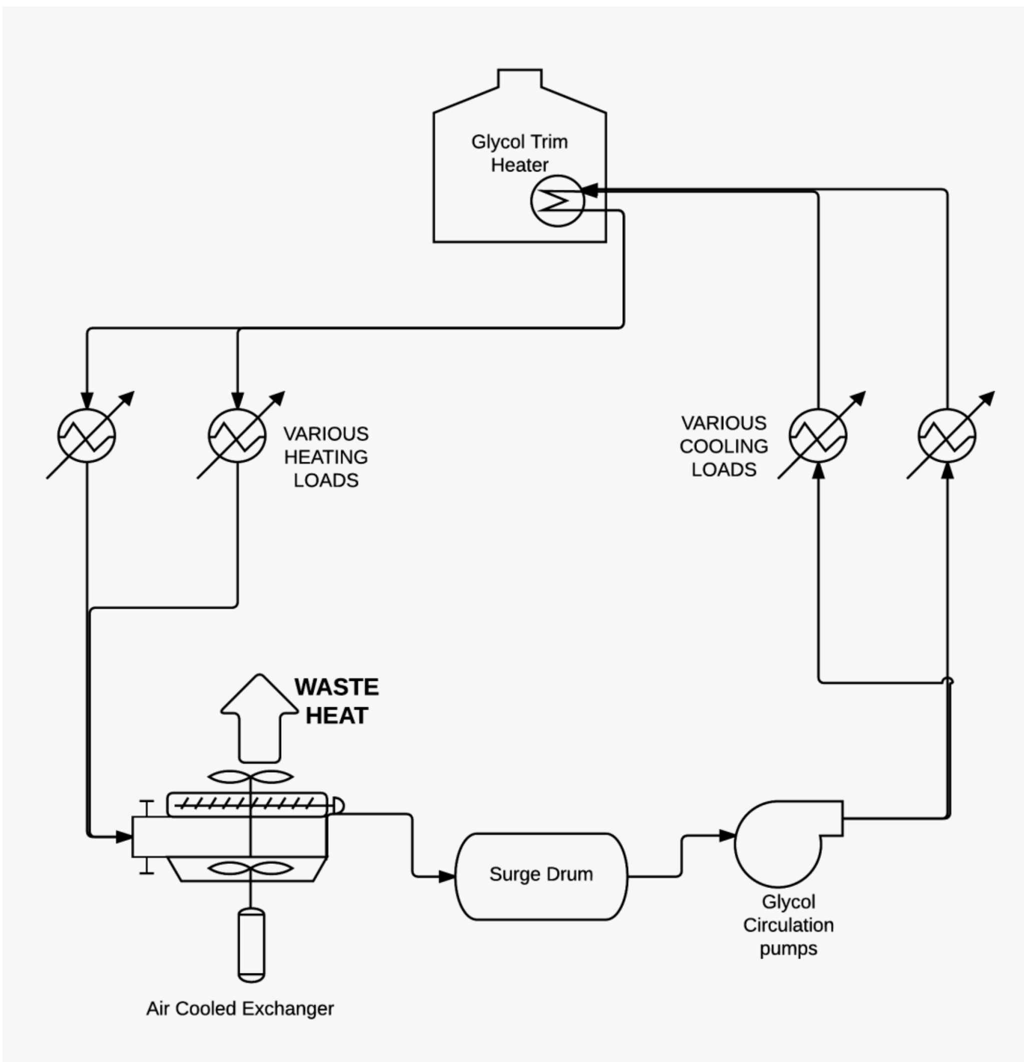
Parameter	Value	Unit
Flow per one OTSG	114,000	kg/h
Inlet Temperature	182	°C
Inlet Pressure	0.0 to +0.4	kPag
Composition:		
N_2	71.613	mole %
Ar	0.871	mole %
O_2	2.595	mole %
CO_2	8.616	mole %
H_2O	16.298	mole %
SO_2	24	ppmv
SO_3	<2	ppmv
NO	57	ppmv wet basis as NO_2
NO_2	3	ppmv wet basis
Particulates	<10	mg/Nm^3

Technologies should be capable of operating reliably in variable process conditions. The technologies should not risk negative impacts to critical equipment or have the potential to cause production interruptions. All waste streams should also be considered and quantified based on the composition referenced above, and the creation of new waste streams is discouraged. The potential solutions should also have a net energy balance. The waste heat should be designated for a specified higher value use, such as the areas listed on page 3.

Waste Energy Source Characteristics: Glycol Loop (Low-Grade Heat)

Glycol loops are used in SAGD heat integration schemes to transfer heat between various heating and cooling loads to improve energy efficiency. The circulating glycol picks up heat while servicing a number of cooling loads, and transfers heat to various heating loads. The overall heat balance of the CPF typically requires that additional heat be rejected via air coolers, as shown in Figure 1 below. This results in releasing 130 GJ/h low-grade waste heat at 60-80°C, which is 40°C after air cooling.

Figure 1: Glycol Loop



The location in the CPF of the two sources of waste heat and energy are shown in Figure 2 below. A material and energy balance of a SAGD facility is provided below.

Appendix 2: Response Template

ONLY NON-CONFIDENTIAL INFORMATION SHOULD BE INCLUDED IN THIS RESPONSE

This response template has two main sections: one that focuses on your technology and the other on your business.

1. Candidate Info

Name:
Company:
Address 1:
City/Town:
Province:
Postal Code:
Email Address:
Phone Number:
Website:

2. Technology Requirements:

2.1. Overview of technology, including process/flow diagrams

2.2. If proposing only a component of an entire solution, indicate remaining requirements in order to fully address the challenge

2.3. Mass and energy balances calculations

2.4. Information on capital and operating costs and all associated assumptions. The program is interested in technologies with a simple payout (undiscounted revenue = costs) in 4 years from startup.

2.5. Clear articulation of benefits (Economic, GHG, other environmental, safety, reliability, etc)

2.6. Levels 4 through 7 are of interest in this Challenge. Technology Readiness Level, and next steps required to advance the technology to the subsequent level

2.7. Potential challenges to implementation at commercial scale

2.8. Site and infrastructure considerations – including footprint, availability of critical input materials/chemicals, technical facility integration challenges, scalability, retrofittability

2.9. Any information on independent technical reviews

2.10. IP status

2.11. Experience of management team

2.12. Key performance indicators:

2.12.1. % of waste heat recovered on a high-level energy balance basis

2.12.2. Lower cost of operations in $ value
2.12.3. GHG emissions reductions in tonnes/year
2.12.4. Total Cost of Ownership (TCO) $ value
2.12.5. Installation downtime in days per year
2.12.6. Land required/footprint
2.12.7. Resilience (long life)
2.12.8. Regulatory compliance hurdles
2.12.9. Scalability
2.12.10. (Bonus) recycle water

Business Description

Please answer the following questions, for your business in general, as applicable:

3. Technology Offering (if there are non-technical aspects of your technology offering not covered in the above technical questions that you would like to share)

4. Technology is... (Check all that apply)
   - Strategic
   - Scalable
   - Ability to create jobs
   - Generate revenue through sales
   - Attract investment
   - Benefit society
   - Make a profit

5. Market Description: (who is your target market, how big is it, etc.)

6. Do you have current customers?
   - Yes, paying
   - Yes, no revenue
   - Commitments to purchase
   - None

7. Will your business create new jobs?
   - Unknown
   - Low Paying
   - High Paying

8. Business Model Description: (pricing strategy, sales strategy, etc.)

9. Is your business incorporated?
   - Yes - Incorporation Date:
   - No

10. List 2 or 3 specific goals for the next 12 months:

11. Current annual revenue

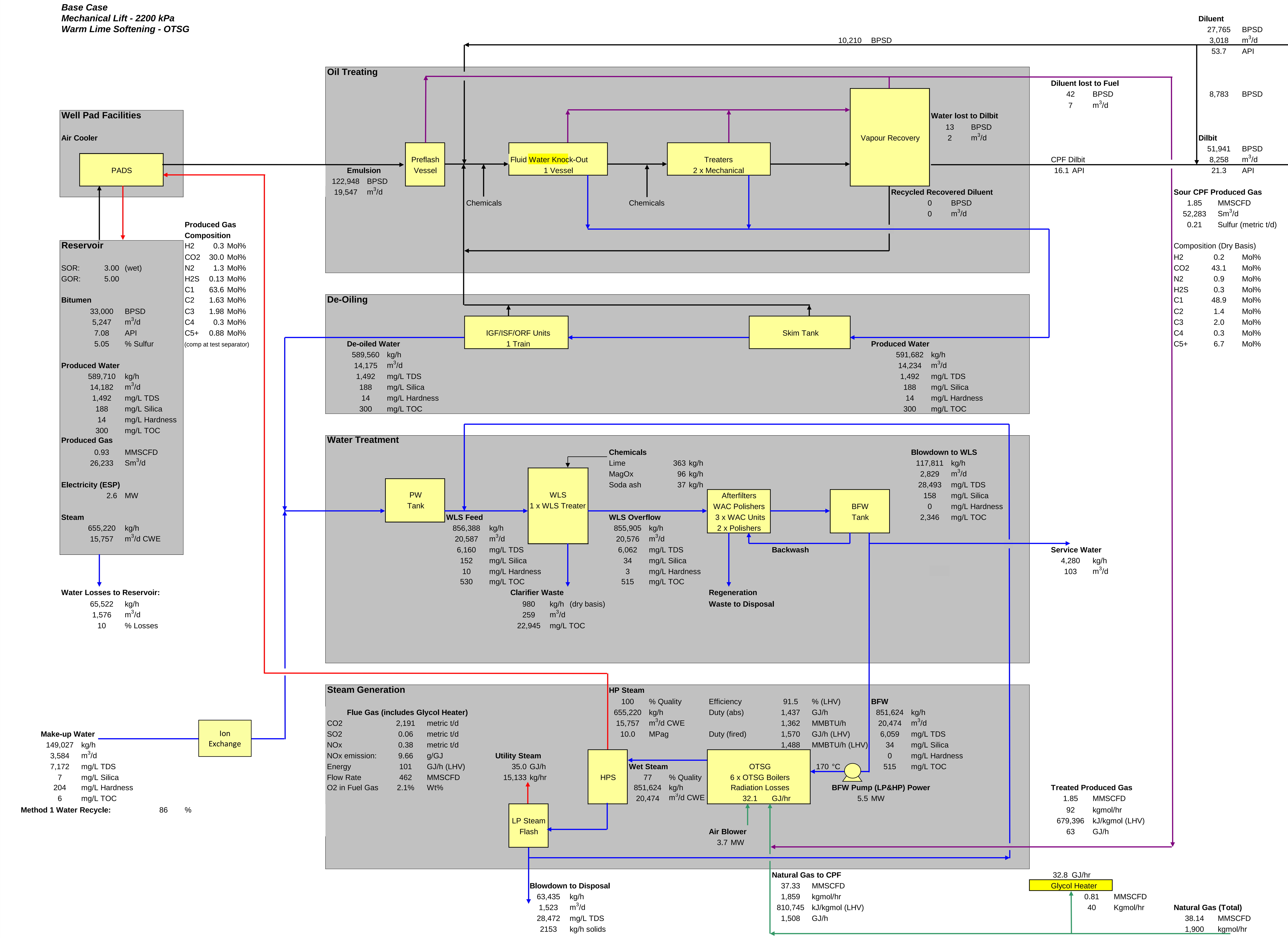
12. Has your company received IRAP funding?
    - Yes
    - No

13. How much money is invested in your company currently?

14. Who has invested in your company?

COSIA SAGD TEMPLATE

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



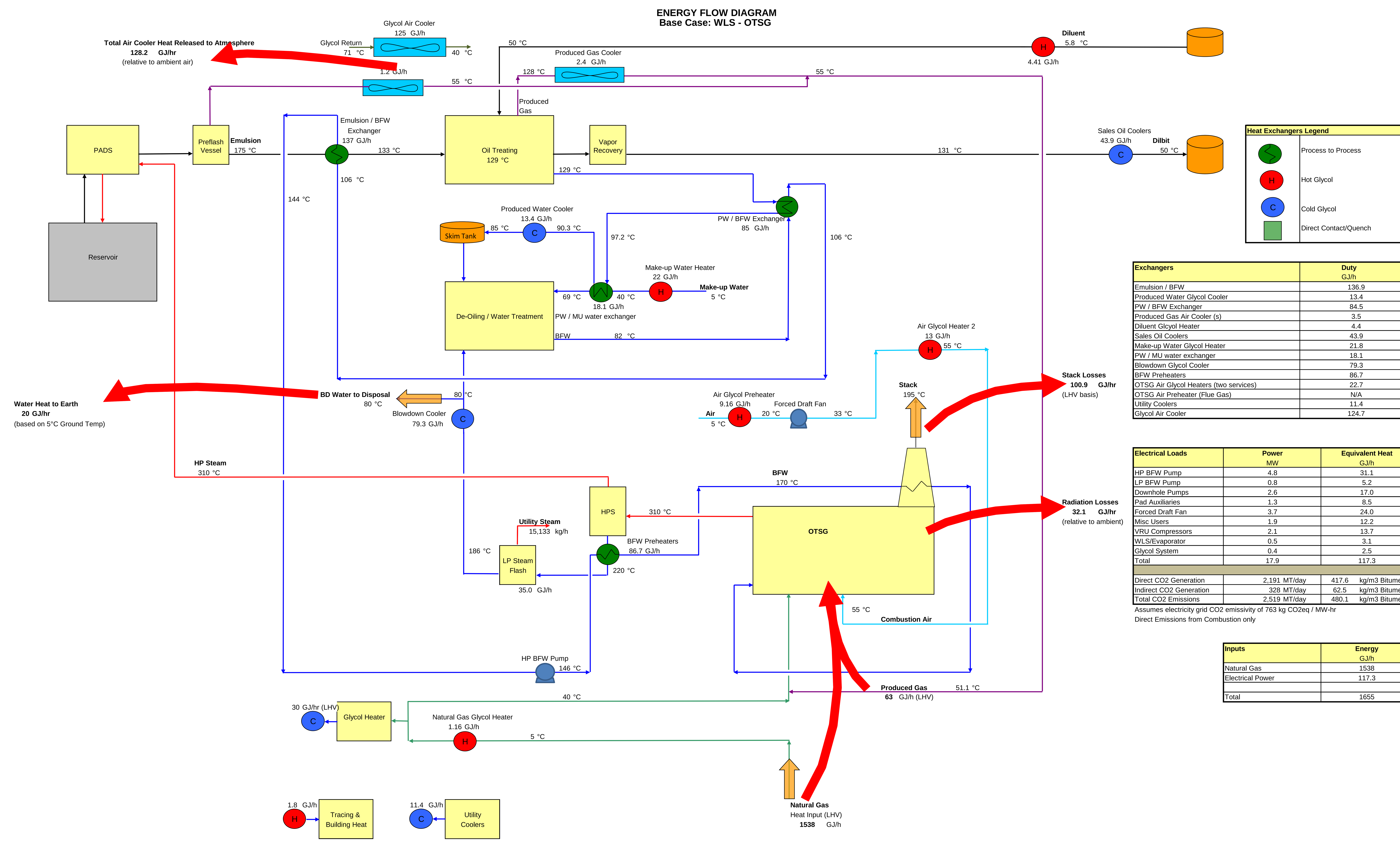
Summary Table	
MU TDS (ppm)	7,172
PW TDS (ppm)	1,492
PW TOC (ppm)	300
LP Flash BD (%)	8%
BD Recycle (%)	60%
TDS to Boiler (ppm)	6,059
Boiler TOC (ppm)	515
MU Flowrate (kg/h)	149,027
WLS Sludge (kg/d)	23,530
Disposal Type (L,S)	L
Disposal Rate (kg/h)	63,435
Disposal Solids (kg/d)	51,662

Water Balance

Stream	Flow	Flow	TDS	Silica	Hardness
	kg/h	m^3/d	ppm	ppm	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	S	CO2	NOx
	metric t/d	metric t/d	metric t/d	metric t/d
OTSG Flue Gas	0.06	0.03	2191	0.38
Recovered Sulfur	-	0.00	-	-



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