

COSIA CHALLENGE

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



Water and Energy Recovery from Flue Gas

<p>SOLUTION DESCRIPTION:</p> <p>The technology will provide valuable high grade heat to be integrated into the processing facility and produce clean water as condensate that can be used for steam production.</p>	<p>CHALLENGE SPONSOR:</p> <p>COSIA's GHG EPA is sponsoring this challenge.</p> <p>Our aspiration is to produce our oil with lower greenhouse gas emissions than other sources of oil.</p> <p><i>COSIA has four Environmental Priority Areas (EPAs): Water, Land, Tailings, and Greenhouse Gases (GHGs).</i></p>
<p>CREATED: October 8, 2014</p> <p>All projects are evaluated and actioned as they are received.</p>	
<p>For more information on this COSIA Challenge please visit www.cosia.ca</p>	

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.

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 (ETAP) 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.



#0009: Water and Energy Recovery from Flue Gas

DETAILED SOLUTION DESCRIPTION

The COSIA GHG Environmental Priority Area Steering Committee is seeking leading edge technologies that capture water vapour and waste heat from flue gas from natural gas combustion.

The successful technology will provide valuable high grade heat to be integrated into the processing facility and produce clean water as condensate that can be used for steam production. Ideally the technology could be retrofitted to existing combustion equipment.

Typical flue gas characteristics are:

- 200 °C stack temperature
- 100 GJ/h (LHV)
- 460 MMSCFD flow rate
- 2,200 t CO₂/d
- 0.06 t SO₂/d
- 0.38 t NO_x/d
- 2.1% by weight O₂ in flue gas

Combustion air is pre-heated to 55 degC and boiler feed water is pre-heated to 170 degC.

BACKGROUND

A common bitumen production process involves the injection of steam into the bitumen reservoir. The steam heats the bitumen 'in situ', meaning in place, reducing the viscosity of the bitumen such that it can be pumped to surface facilities for further processing.

In situ Oil Sands operations consume large quantities of natural gas to produce steam. A typical 33,000 BPD facility would operate six steam boilers requiring 1600 GJ/h (LHV) of natural gas. Combustion flue gas contains 7-8% CO₂, and the equivalent of 900 M³/d of liquid water. It is important to note that condensed water from flue gas may be corrosive to carbon steel.

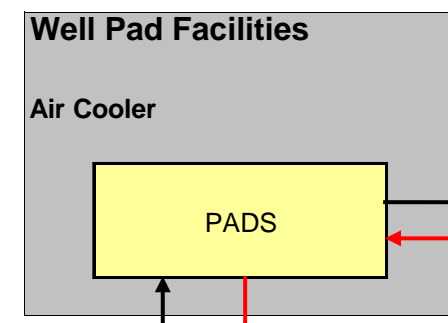
Material and energy flow diagrams for a standard 33,000 BPD in situ facility are provided below.

APPROACHES NOT OF INTEREST

ADDITIONAL INFORMATION

COSIA SAGD TEMPLATE

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



Reservoir

SOR: 3.00 (wet)
GOR: 5.00

Bitumen

33,000 BPSD
5,247 m³/d
7.08 API
5.05 % Sulfur

Produced Water

589,710 kg/h
14,182 m³/d
1,492 mg/L TDS
188 mg/L Silica
14 mg/L Hardness
300 mg/L TOC

Produced Gas

0.93 MMSCFD
26,233 Sm³/d

Electricity (ESP)

2.6 MW

Steam

655,220 kg/h
15,757 m³/d CWE

Water Losses to Reservoir:

65,522 kg/h
1,576 m³/d
10 % Losses

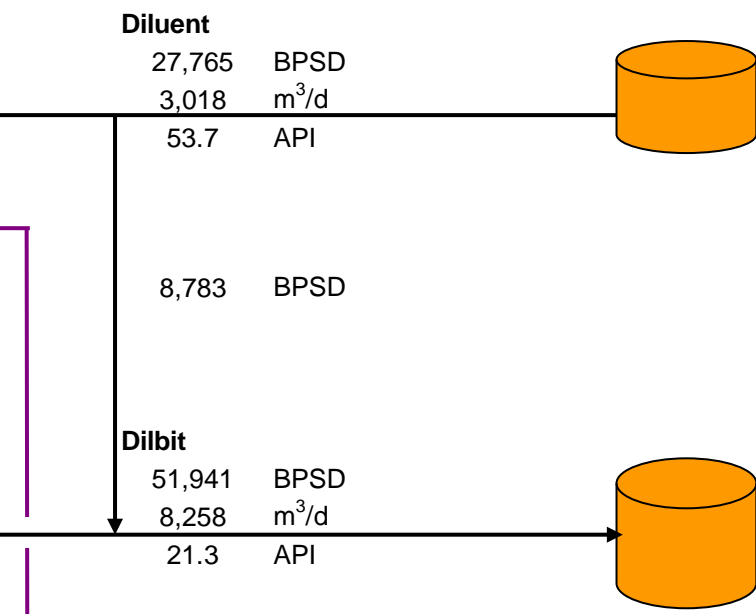
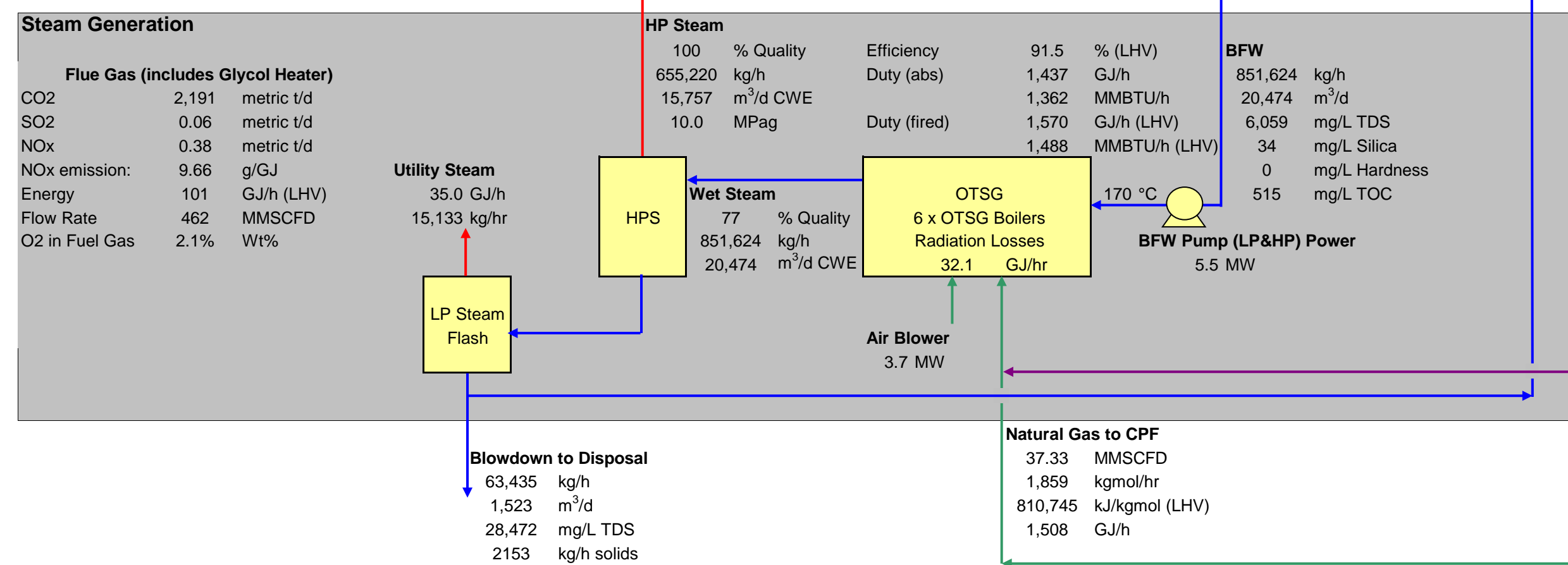
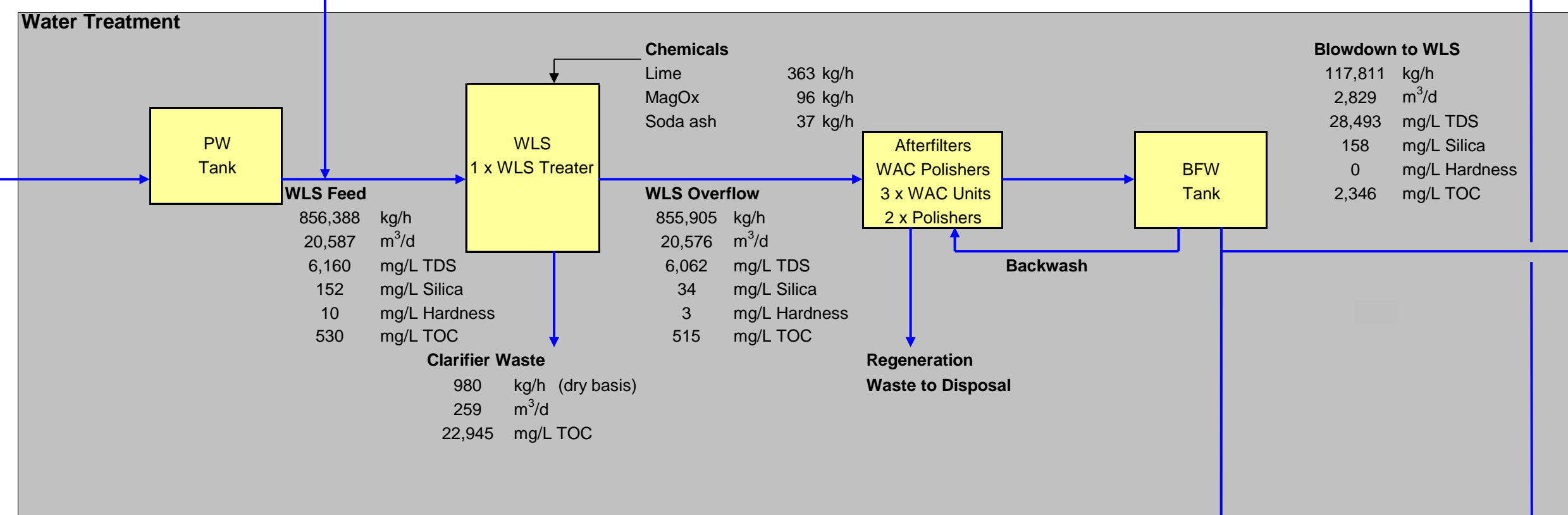
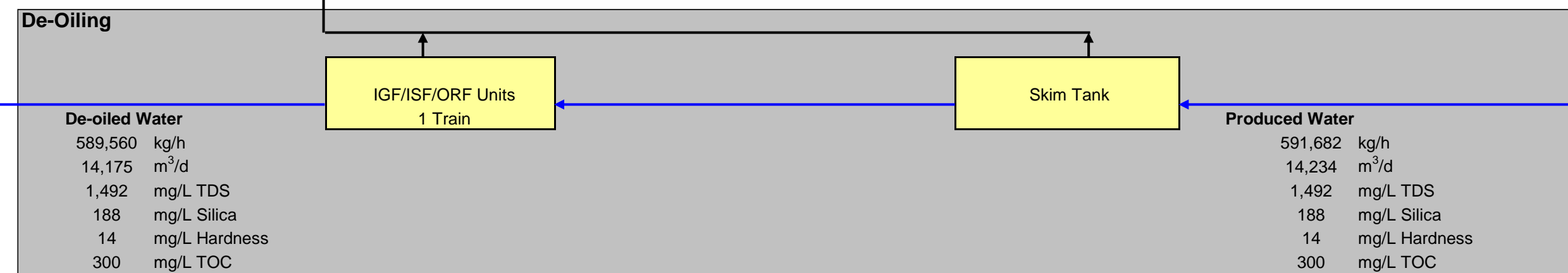
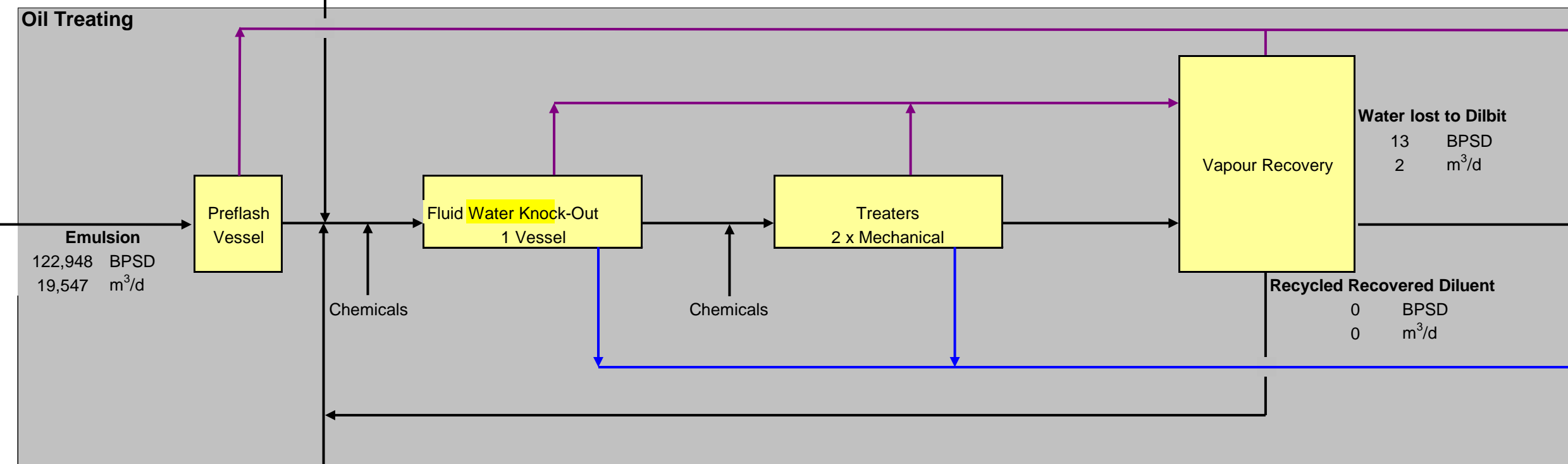
Make-up Water

149,027 kg/h
3,584 m³/d
7,172 mg/L TDS
7 mg/L Silica
204 mg/L Hardness
6 mg/L TOC

Method 1 Water Recycle: 86 %

Produced Gas Composition

H2 0.3 Mol%
CO2 30.0 Mol%
N2 1.3 Mol%
H2S 0.13 Mol%
C1 63.6 Mol%
C2 1.63 Mol%
C3 1.98 Mol%
C4 0.3 Mol%
C5+ 0.88 Mol%
(comp at test separator)



Sour CPF Produced Gas

1.85 MMSCFD
52,283 Sm³/d
0.21 Sulfur (metric t/d)

Composition (Dry Basis)

H2 0.2 Mol%
CO2 43.1 Mol%
N2 0.9 Mol%
H2S 0.3 Mol%
C1 48.9 Mol%
C2 1.4 Mol%
C3 2.0 Mol%
C4 0.3 Mol%
C5+ 6.7 Mol%

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/d)	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

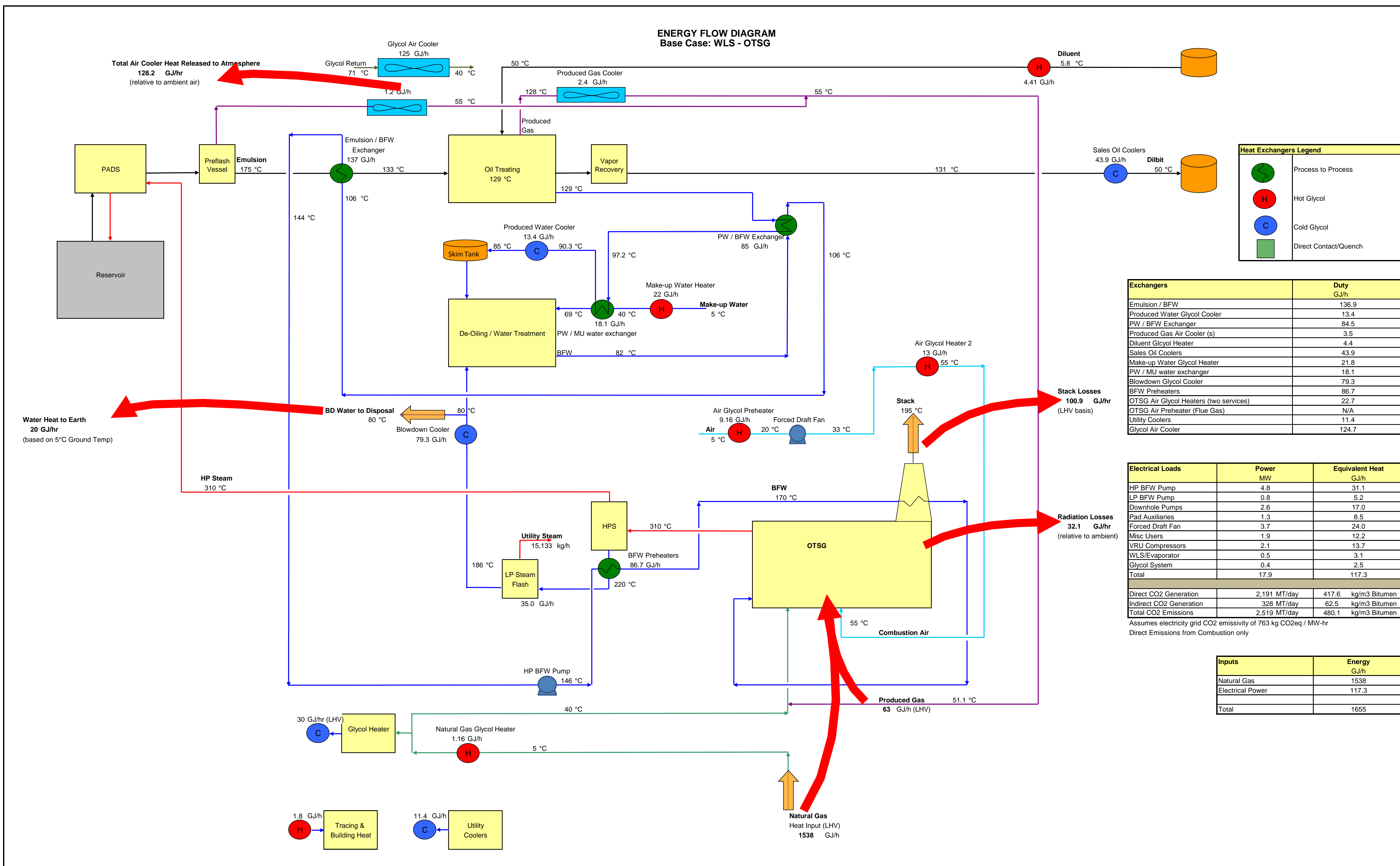
Water Balance

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



Heat Exchangers Legend

- Process to Process
- Hot Glycol
- Cold Glycol
- Direct Contact/Quench

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 Glycol 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

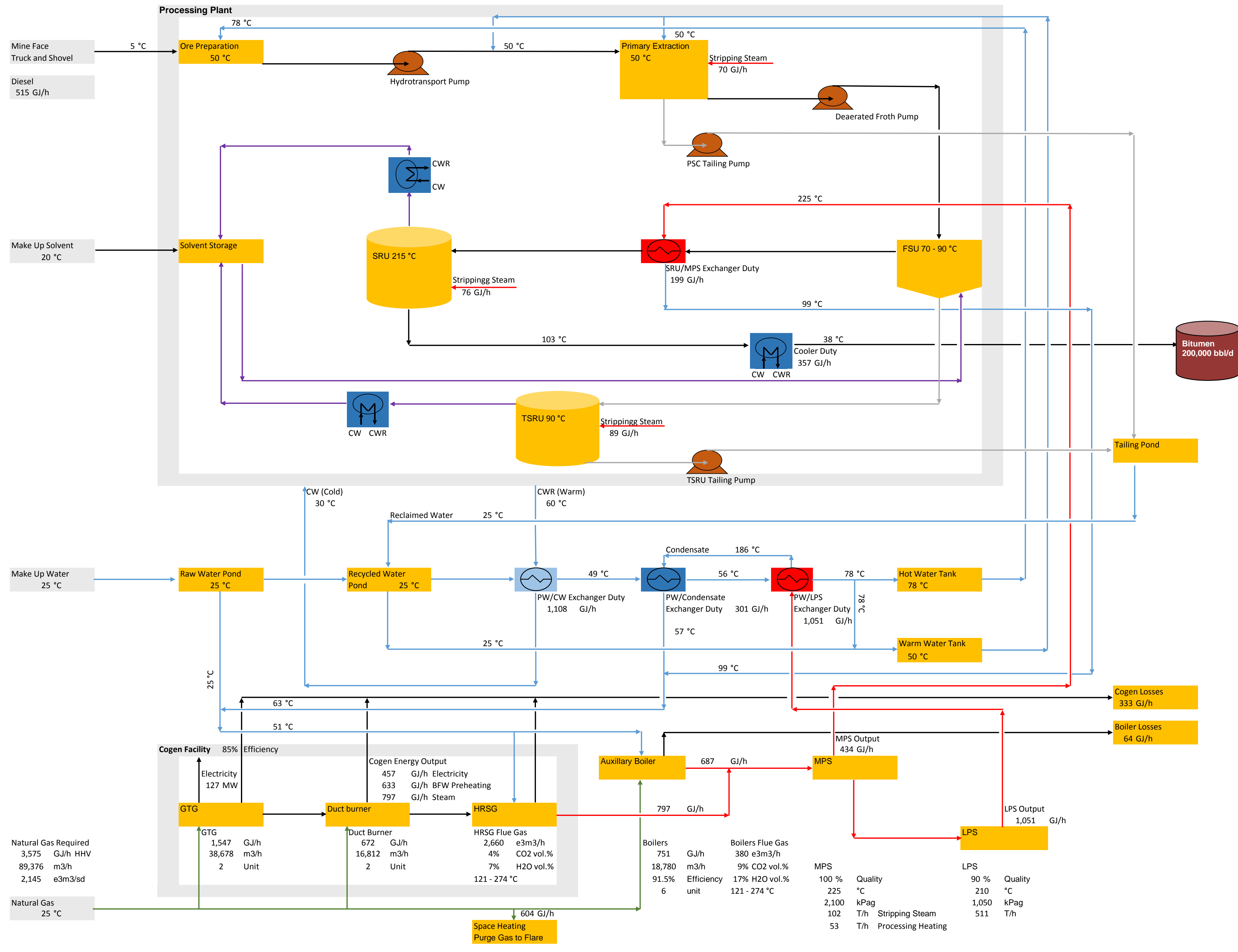
Direct CO2 Generation	2,191 MT/day	417.6 kg/m3 Bitumen
Indirect CO2 Generation	328 MT/day	62.5 kg/m3 Bitumen
Total CO2 Emissions	2,519 MT/day	480.1 kg/m3 Bitumen

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

COSIA Mining & Extraction: High Grade - Paraffinic Froth Treatment - Energy Flow

Ore Grade 12 wt%
 Fine Contents 11.9 wt%
 Waste to Ore 4.3 wt%



Legend	
Bitumen	
Water	
Steam	
Fuel gas	
Solvent	
Tailing	

Abbreviations	
BFW	Boiler Feed Water
CW	Cooling Water
CWR	Cooling Water Return
FSU	Froth Settling Unit
GTG	Gas Turbine Generator
HHV	High Heating Value
HRSG	Heat Recovery Steam Generator
LPS	Low Pressure Steam
MPS	Medium Pressure Steam
PSC	Primary Separation Cell
PW	Process Water
SRU	Solvent Recovery Unit
TSRU	Tailing Solvent Recovery Unit

Energy Output Summary				
	Input (GJ/h)	Output (GJ/h)		
Cogen	GTG	1,547	Electricity	457
	HRSG	672	BFW Preheating	633
			Steam	797
			Cogen Losses	333
Subtotal - Cogen	2,220		2,220	
Boilers			Steam	687
			Boiler Losses	64
Subtotal - Boilers	751		751	
Total	2,971		2,971	

Flue Gas - Based on Stoichiometric Combustion			
Natural Gas HHV	40	MJ/m³	
Excess air @ 13% O2	179	%	
Excess O2	13	%	
Cogen Flue Gas	2,660	e3m³/h	
CO2 in Flue Gas from Cogen	4%	vol.%	
H2O in Flue Gas from Cogen	7%	vol.%	
Boiler Flue Gas	380	e3m³/h	
CO2 in Flue Gas from Boilers	9%	vol.%	
H2O in Flue Gas from Boilers	17%	vol.%	
Flue Gas Temperature - Acid Dew Point Limit	121	°C	
Flue Gas - Max. without Economizer	274	°C	

Exchanger & Cooler		Duty (GJ/h)
Process Water / Cooling Water		1,108
Process Water / Condensate		301
Process Water / LPS		1,051
SRU Feed / MPS		199
Cooler		357

Energy Consumption Summary			
	GJ/h	e3m³/d	
Natural Gas	GTG	1,547	928
	HRSG	672	403
	Building Heating and Flare	751	363
	Boilers	604	451
Diesel	515	0.3	
Energy Intensity (GJ per bbl of bitumen produced)	0.49	GJ/bbl	
Electricity Generated	3,044	MWH/d	
Electricity Consumed	3,142	MWH/d	

GHG Emissions Summary			
Stationary Combustion & Flaring	4,137	t CO2e/d	
Mobile Equipment	892	t CO2e/d	
Fugitive Mine	0.0001 - 0.0150	kg CO2e/m²/d	
Fugitive Pond	0.0007 - 0.0201	kg CO2e/m²/d	
Total Cogen Emissions (Gt)	2,569	t CO2e/d	
Deemed emissions from Heat by Cogen (D _h)	2,069	t CO2e/d	
Deemed emissions from electricity by Cogen (D _e)	500	t CO2e/d	

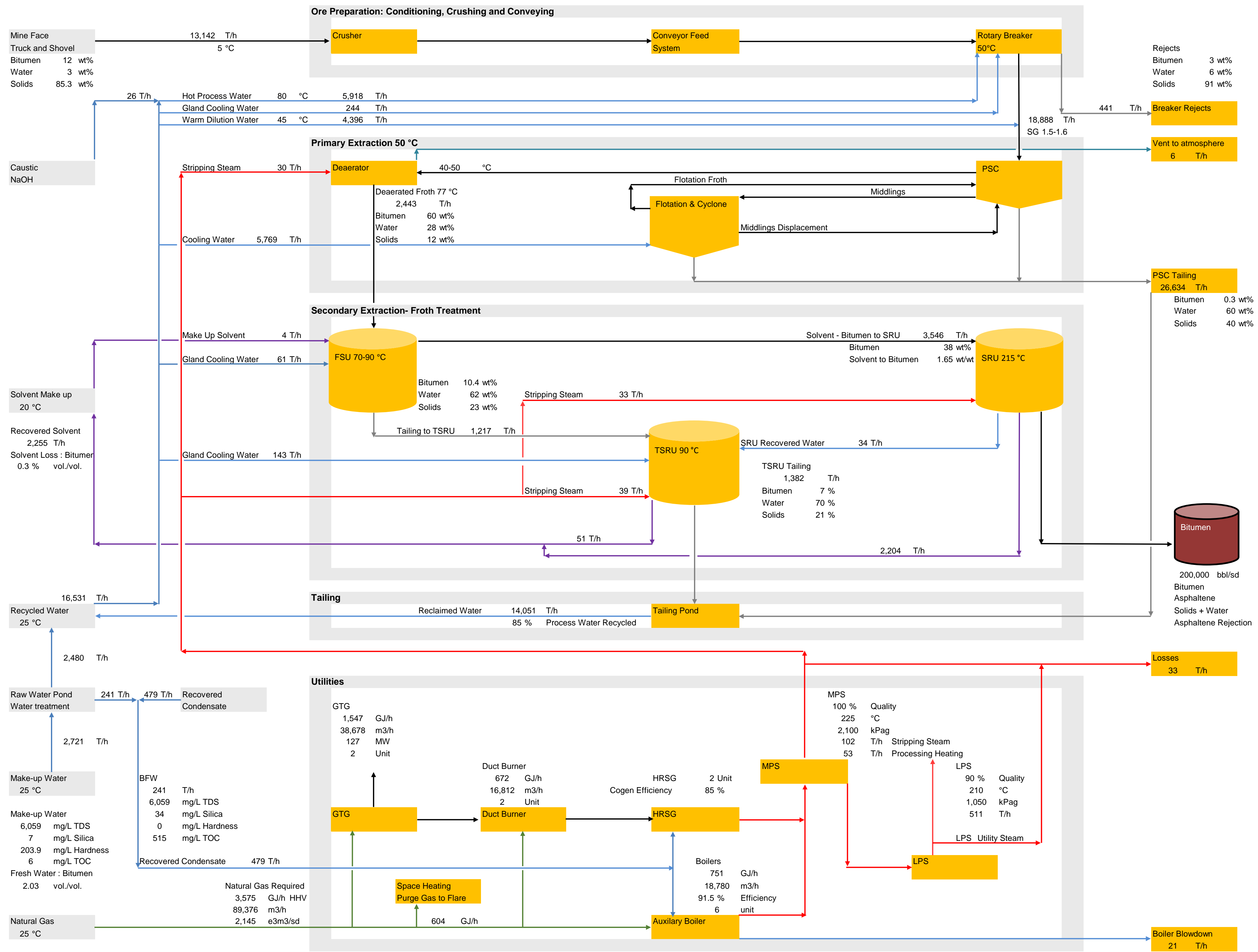
Project:	Static Oil Sands Mine and Extraction Reference Facility		
Case:	Paraffinic - High Grade	Revision:	v 2.3.9
Owner:	COSIA		
Date:	04-Oct-15		
Energy / Heat Flow	High Temperature Extraction, High Grade, Summer Condition		

This is a generic and hypothetical mine and extraction facility developed by COSIA. While representative, it is not based on any one facility. Recovery and solvent loss is based on Alberta Energy Regulator requirements.



COSIA Mining & Extraction High Grade - Paraffinic Froth Treatment - Material Flow

Ore Grade 12 wt%
 Fine Contents 11.9 wt%
 Waste to Ore 4.3 wt%



Legend	
Bitumen	
Water	
Steam	
Fuel gas	
Solvent	
Tailing	

Abbreviations	
BFW	Boiler Feed Water
FSU	Froth Settling Unit
GTG	Gas Turbine Generator
HHV	Higher Heating Value
HRSG	Heat Recovery Steam Generator
LPS	Low Pressure Steam
MPS	Medium Pressure Steam
Bitumen	99.9 %
Asphaltene	12.0 %
Solids + Water	0.1 %
Asphaltene Rejection	7.6 %
TSRU	Tailing Solvent Recovery Unit

Bitumen Recovery Summary	
Ore Preparation	99.0%
Primary Extraction	94.6%
Froth Treatment (without rejected asphaltenes)	98.4%
Total Bitumen Recovery	92.2%
Asphaltenes Rejection	7.6%
Total Bitumen Recovery (with rejected asphaltenes)	85.1%

Water Summary (T/h)	
Process Water	6,217
Cooling Water	6,217
Heated Water	10,314
Reclaimed Water	14,051
Raw Water	2,480
BFW	241
Boiler Blowdown	21
Make-Up Water	2,721
Condensate Return	479

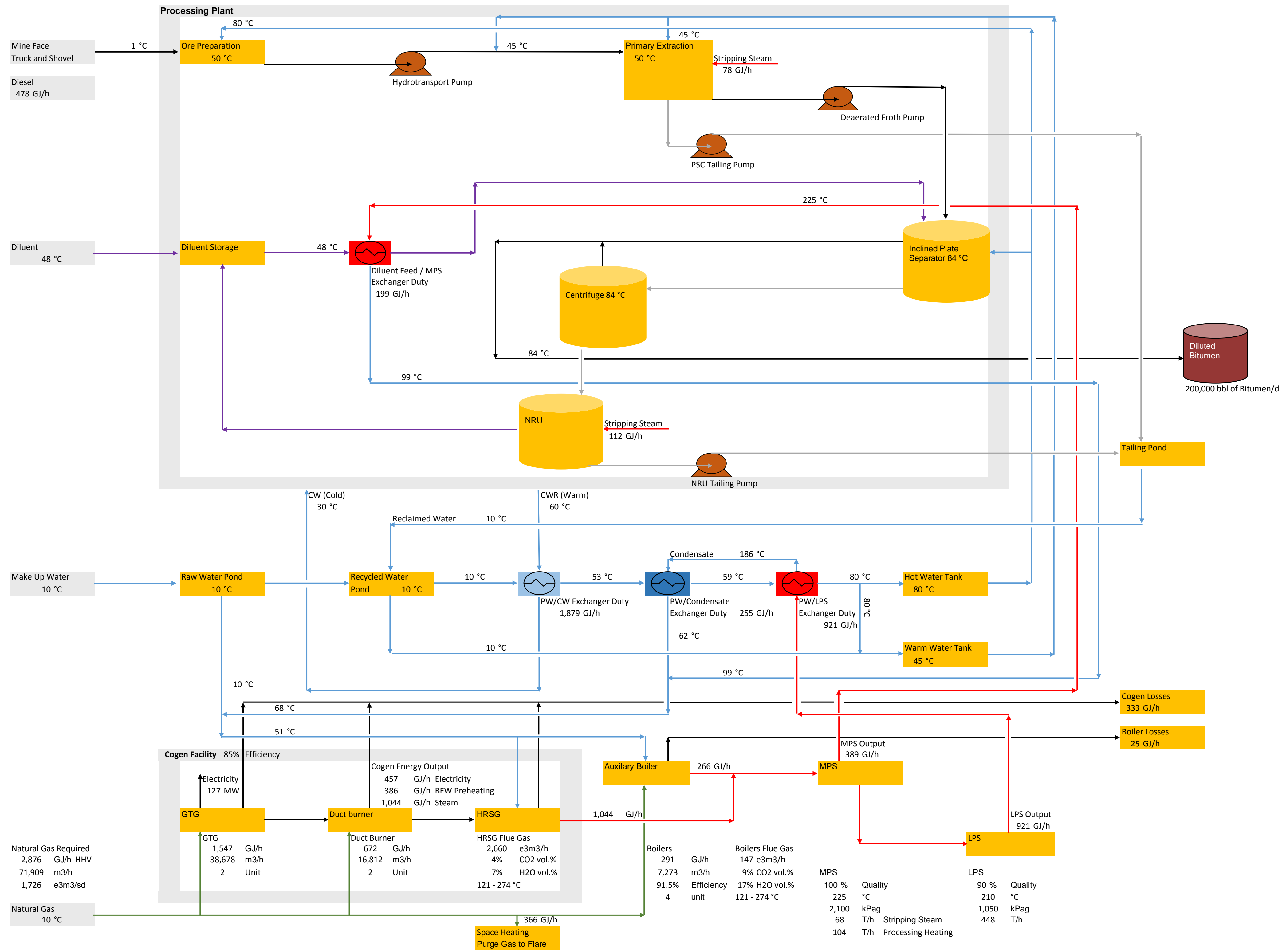
Project: A Static Oil Sands Mine and Extraction Reference Facility
 Case: Paraffinic - High Grade | Revision: V 2.7.7
 Owner: COSIA
 Date: 04-Oct-15
 Material Flow
 High Temperature Extraction, High Grade, Summer Condition

This is a generic and hypothetical mine and extraction facility developed by COSIA. While representative, it is not based on any one facility. Recovery and solvent loss is based on Alberta Energy Regulator requirements.



COSIA Mining & Extraction: High Grade - Naphthenic Froth Treatment - Energy Flow

Ore Grade 12 wt%
 Fine Contents 11.7 wt%
 Waste to Ore 4.3 wt%



Legend	
Bitumen	
Water	
Steam	
Fuel gas	
Diluent	
Tailing	

Abbreviations	
BFW	Boiler Feed Water
CW	Cooling Water
CWR	Cooling Water Return
GTG	Gas Turbine Generator
HHV	High Heating Value
HRSG	Heat Recovery Steam Generator
LPS	Low Pressure Steam
MPS	Medium Pressure Steam
NRU	Naphtha Recovery Unit
PSC	Primary Separation Cell
PW	Process Water

Energy Output Summary		
	Input (GJ/h)	Output (GJ/h)
Cogen	GTG 1,547	Electricity 457
	HRSG 672	BFW Preheating 386
		Steam 1,044
		Cogen Losses 333
Subtotal - Cogen	2,220	2,220
Boilers		Steam 266
		Boiler Losses 25
Subtotal - Boilers	291	291
Total	2,511	2,511

Flue Gas		
Natural Gas HHV	40	MJ/m ³
Excess air @ 13% O ₂ in Cogen	179%	%
Excess O ₂	13%	%
Cogen Flue Gas	2,660	e3m ³ /h
CO ₂ in Flue Gas from Cogen	4%	vol.%
H ₂ O in Flue Gas from Cogen	7%	vol.%
Boiler Flue Gas	147	e3m ³ /h
CO ₂ in Flue Gas from Boilers	9%	vol.%
H ₂ O in Flue Gas from Boilers	17%	vol.%
Flue Gas Temperature - Acid Dew Point Limit	121	°C
Flue Gas - Max. without Economizer	274	°C

Exchanger	
	Duty (GJ/h)
Process Water / Cooling Water	1,879
Process Water / Condensate	255
Process Water / LPS	921
Diluent Feed / MPS	199

Energy Consumption Summary		
	GJ/h	e3m ³ /d
Natural Gas	GTG 1,547	928
	HRSG 672	403
	Building Heating and Flare 366	220
	Boilers 291	175
Diesel	478	0.3
Energy Intensity (GJ / bbl bitumen produced)	0.40	GJ/bbl
Electricity Generated	3,044	MWH/d
Electricity Consumed	3,600	MWH/d

GHG Emissions Summary		
Stationary Combustion & Flaring	3,329	t CO ₂ e/d
Mobile Equipment	827	t CO ₂ e/d
Fugitive Mine	0.0001 - 0.0150	kg CO ₂ e/m ² /d
Fugitive Pond	0.0119 - 0.8054	kg CO ₂ e/m ² /d
Total Cogen Emissions (Gt)	2,569	t CO₂e/d
Deemed emissions from Heat by Cogen (D _h)	2,069	t CO ₂ e/d
Deemed emissions from electricity by Cogen (D _e)	500	t CO ₂ e/d

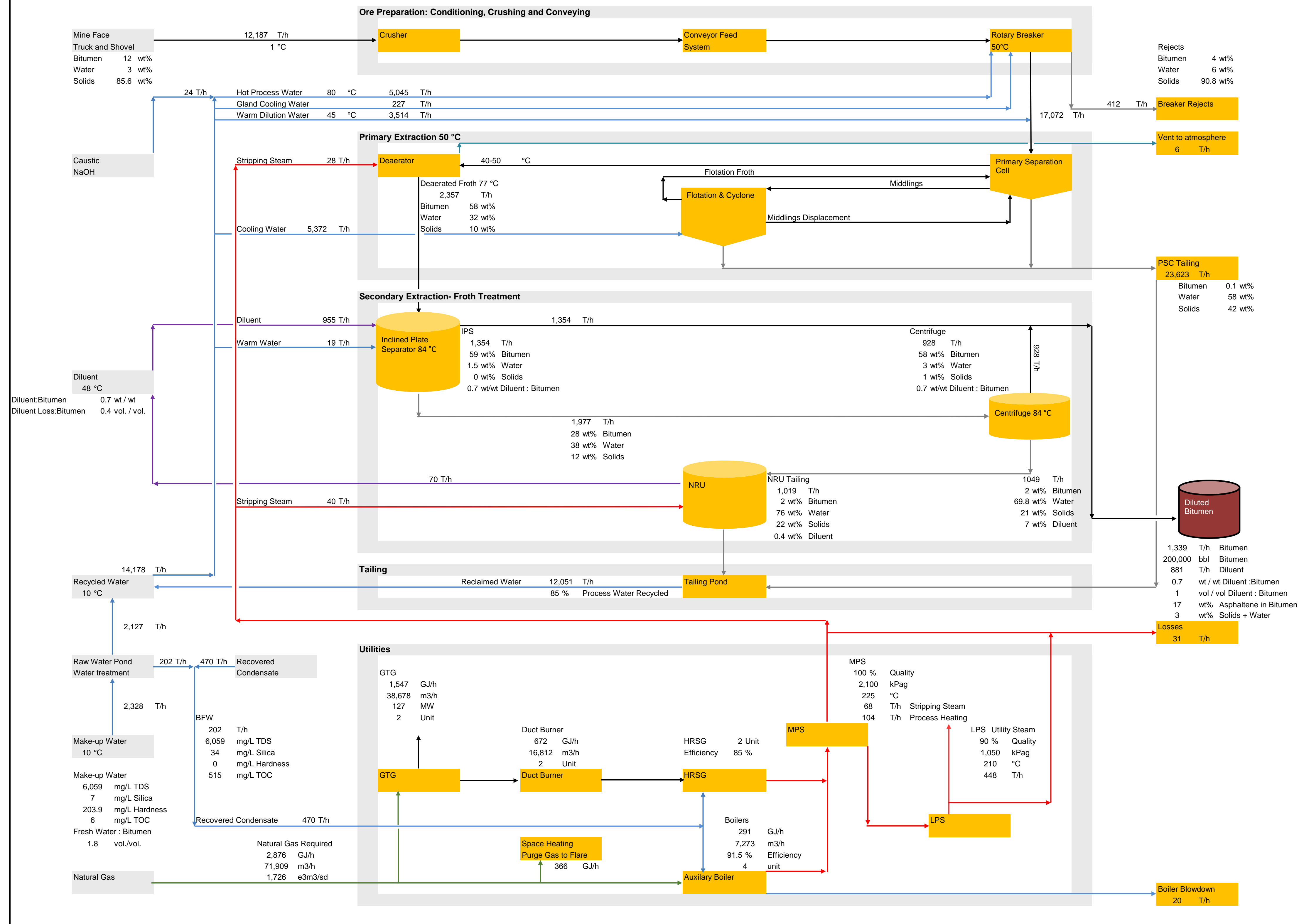
Project:	Static Reference Oil Sands Mine and Extraction Reference Facility	
Case:	Naphthenic - High Grade	Revision: v 1.6
Owner:	COSIA	
Date:	04-Oct-15	
Energy / Heat Flow	High Temperature Extraction, High Grade, Average Condition	

This is a generic and hypothetical mine and extraction facility developed by COSIA. While representative, it is not based on any one facility. Recovery and solvent loss is based on Alberta Energy Regulator requirements.



COSIA Mining & Extraction: High Grade - Naphthenic Froth Treatment - Material Flow

Ore Grade 12 wt%
 Fine Contents 11.7 wt%
 Waste to Ore 4.3 wt%



Legend	
Bitumen	(Yellow)
Water	(Blue)
Steam	(Red)
Fuel Gas	(Green)
Diluent	(Purple)
Tailing	(Grey)

Abbreviations	
BFW	Boiler Feed Water
GTG	Gas Turbine Generator
HHV	High Heating Value
HRSG	Heat Recovery Steam Generator
LPS	Low Pressure Steam
MPS	Medium Pressure Steam
NRU	Naphtha Recovery Unit
PSC	Primary Separation Cell

Bitumen Recovery Summary	
Ore Preparation	98.9%
Primary Extraction	98.0%
Froth Treatment (without rejected asphaltenes)	98.2%
Total Bitumen Recovery	95.2%
Asphaltenes Rejection	0.0%
Total Bitumen Recovery (with rejected asphaltenes)	95.2%

Water Summary (T/h)	
Process Water	5,599
Reclaimed Water	12,051
Raw Water	2,127
BFW	202
Boiler Blowdown	20
Make-Up Water	2,328
Condensate Return	470

Project:	Static Oil Sands Mine and Extraction Reference Facility	
Case:	Naphthenic - High Grade	Revision: 1.3
Owner:	COSIA	
Date:	27-Sep-15	
Material Flow	High Temperature Extraction, High Grade, Average Condition	

This is a generic and hypothetical mine and extraction facility developed by COSIA. While representative, it is not based on any one facility. Recovery and solvent loss is based on Alberta Energy Regulator requirements.

