LIFE CYCLE ASSESSMENT OF A NATURAL GAS PLANT

CASE STUDY: SARKHOON GAS TREATING PLANT IN IRAN

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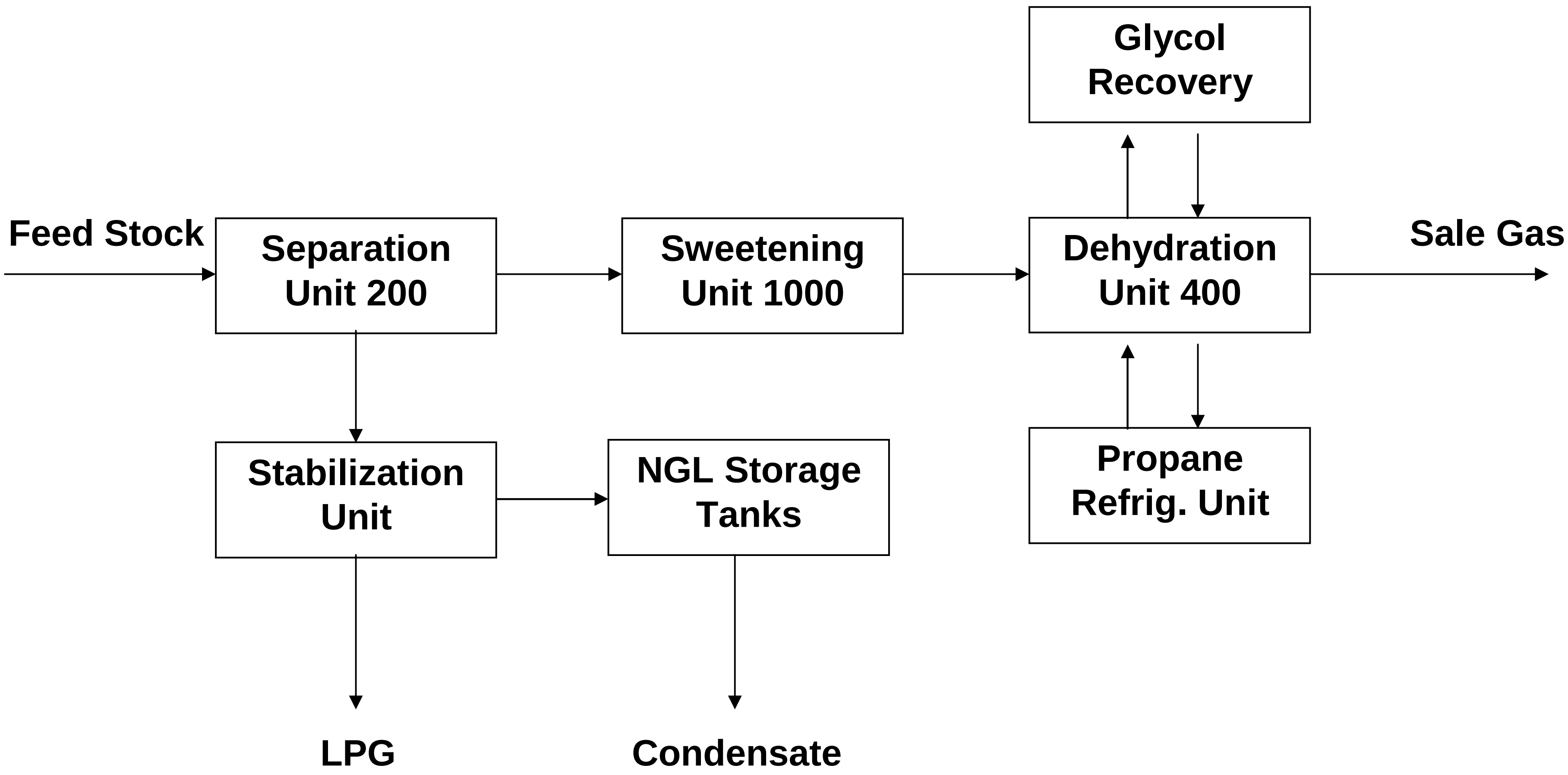
KEY ELEMENTS

- System description and major assumptions
- System boundaries
- Natural gas compositions
- Natural gas losses
- Emissions identification and monitoring
- Results
- Impact assessment
- Improvement opportunities

Sarkhoon Gas Treatment Plant Description and Assumptions

- This plant is located 25 kilometers to the north-east of Bandar Abbas the southern port of Iran. Whole project have been completed with daily production capacity of 14.4 million cubic meters of natural gas, 12000 barrels of stabilized condensate and 90 tons of LPG.
- The processing units of the plant , which have been designed and installed by acquiring the latest technology , sweetening , de-hydration , glycol recovery , refrigerating with propane , NGL stabilizing and LPG producing units .

Block Flow Diagram of the Natural Gas Plant

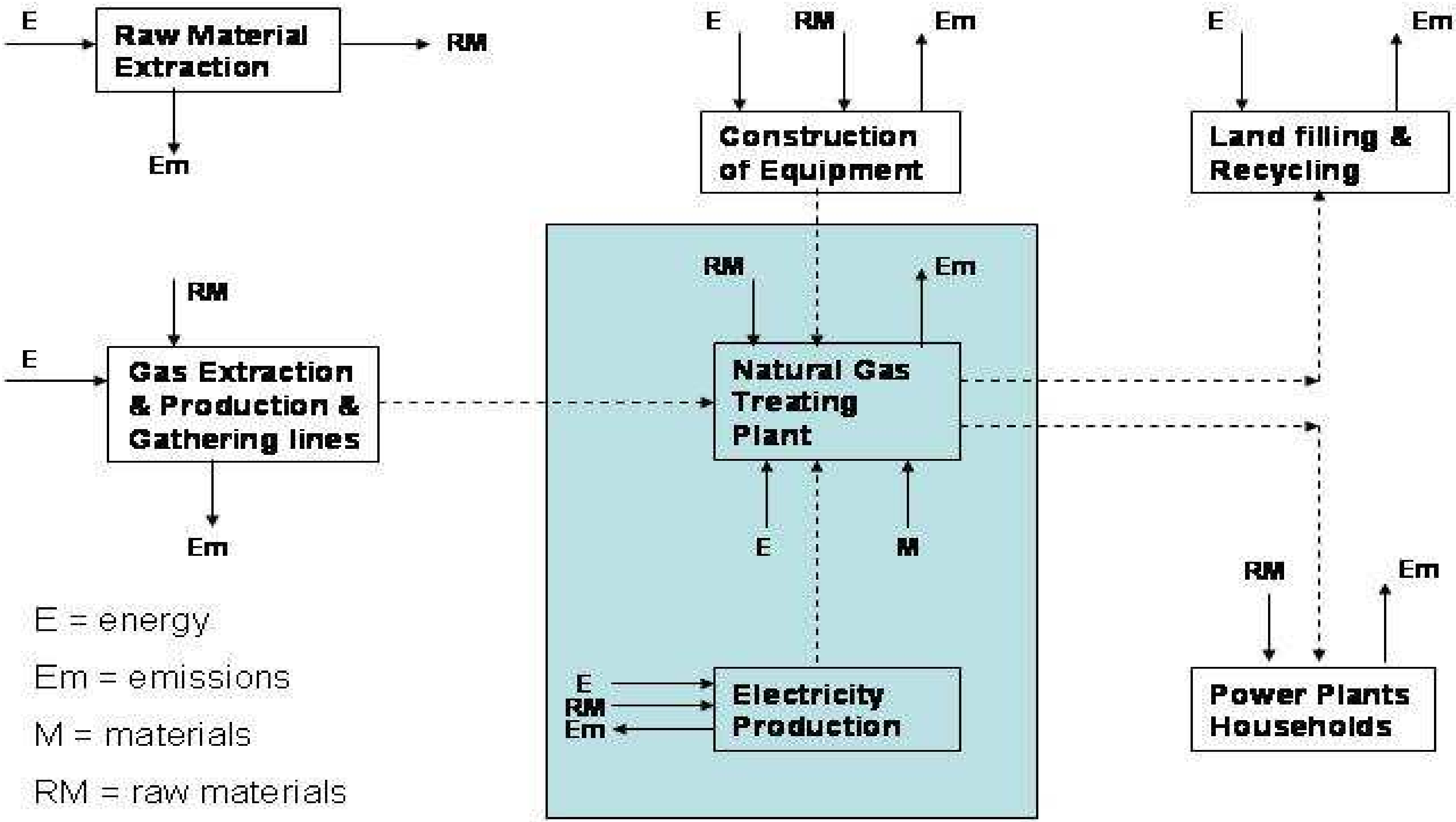


Design Parameter	Data
Plant size	14.4 mmscm/D Gas 12000 bbl/D NGL 90 tones LPG
Average Operating Capacity Factor	95%
Fuel Gas Consumption	100000 Cubic meter/D
Electricity Requirement	2.4 MWatt/D
Natural Gas Plant Energy Efficiency (Total energy produced/Total energy into plant	95%

System Boundaries and Major Assumptions

- The used methodology is governed by ISO 14040-14043 which describes the various steps of LCA.
- The software package used to track the material and energy flows between the process blocks in the system was HYSYS, TEAM, and plant DCS software.
- The stressors associated with natural gas production and distribution, as well as those for electricity generation, are taken from the TEAM and compared with collected through Plant data acquisition system.
- The emissions associated with each process step in the natural gas production, gathering, treatment, transportation and electricity production are through Ecobalance, Inc. and the fact data book of National Iranian Gas Co. (NIGC).
- The plant life was set at 20 years with 2 years of construction.

System Boundaries for Natural Gas Treating Plant



Natural Gas Composition and Losses

Component	Feedstock of Plant (mol%)	Sale Gas (mol%)
Methane	85.73	88.15
Ethane	3.54	3.27
i+n Butane	0.87	0.74
i+n Pentane	0.45	0.27
C6	1.36	0.17
Nitrogen	4.59	5.21
Carbon Dioxide	0.87	0.30
Hydrogen Sulfide (ppm)	0.01	0.17
Water	1.15	0.03
Net Heat Value Btu/Cubic Ft	1320	1000
Specific Gravity	0.710	0.6303

- In extracting, processing, transmitting, storing, and distributing natural gas, some is lost to atmosphere. Fugitive emissions are the largest source, accounting for about 38% of the total, and nearly 90% of fugitive emissions are a result of leaking well head and compressor components (Resch, 1995 and Harrison et al, 1997). The second largest source of methane emissions comes from pneumatic control devices, accounting for approximately 20% of the total losses (Resch, 1995). The majority of the pneumatic losses happen during the extraction step.
- According to the EPA, transmission and storage account for the largest portion of the total methane emissions at 37% followed by extraction at 27% distribution at 24% and processing contributing the least at 12% (that will determine again in this paper).Many publications are used in this paper such as; EPA/GRI/AGA and Perry handbook
- The base case of this LCA assumed that 1.4% of the natural gas that is produced for gas plant feed is lost to atmosphere due to fugitive emissions. The emissions of gas plant could be calculated accurately.

Results

1. Air Emissions

Air Emission	System Total g/kg of NG	% of total	% of total excluding CO2	% of total gas construction & decomm.	% of total gas production & transport	% of total from electric	% of total from NG plant operation
Benzene	1.4	<0.0%	1.3%	0.0%	110.9%	0.0%	0.0%
CO2	10620.6	99%	-	0.4%	14.8%	2.5%	83.7%
CO	5.7	0.1%	5.3	2.0	106.3	0.7	1.4
CH4	59.8	0.6%	55.7	<0.0	110.8	<0.0	0.0
NOx as No2	12.3	0.1%	11.0	1.8	90.3	9.5	7.3
NO2	0.04	<0.0%	<0.0%	7.3	37.6	58.7	0.0
NMHCs	16.8	0.2%	15.6	1.7	89.8	14.5	0.0
Particulates	2.0	<0.0%	1.8	64.5	25.2	11.6	1.1
Sox as SO2	9.5	0.1%	8.8	13.5	68.3	24.9	0.0

2. GHG and Global Warming Potential

	Emission amount (g/kg of H_2)	Percent of greenhouse gases in this table (%)	GWP relative to CO_2(100 year IPCC values)	GWP value (g CO_2 – equivalent/kg of H_2)	Percent contribution to GWP (%)
CO_2	10,621	99.4	1	10,621	89.3
CH_4	60	0.6	21	1,256	10.6
N_2O	0.04	0.0003	310	11	0.1
GWP	N/A	N/A	N/A	11,888	N/A

3. **Energy Consumption and System Energy Balance**

Energy consumption is an important part of LCA. The energy consumed within the system boundaries results in resource consumption, airman water emissions, and solid wastes

	System total energy consumption (MJ/kg gas)	%of total in this table	%of total from construction & decommissioning	%of total from natural gas production & gathering	%of total from electricity generation
Energy in the natural gas to gas plant	159.6	87.1%	N/A	1000.0%	N/A
Non-feedstock energy consumed by system	23.6	12.9%	2.4%	169.8%	17.0%
Total energy consumed by system	138.2	N/A	N/A	N/A	N/A

- Most of the energy consumed, about 87%, is that contained in the natural gas fed to the gas turbines. Following formulas contains four additional terms for evaluating the energy balance of the system and calculated data are shown below:

Life cycle efficiency % = (Eh2- Eu-Ef) / Ef = - 39.6%

External energy efficiency % = (Eh2-Eu) / Ef = 60.4 %

Net Energy Ratio = Eh2 / Eff = 0.66

External Energy ratio = Eh2 / (Eff – Ef) = 5.1

Where:

Eh2 = energy in the natural gas

Eu = energy consumed by all upstream processes required to operate the gas plant

Ef = energy contained in the natural gas fed to the gas plant

Eff = fossil fuel energy consumed within the system (e)

The energy in the natural gas is greater than the energy content of the gas produced. Therefore; the life cycle efficiency is negative. This reflects the fact because natural gas is non-renewable resource; more energy is consumed by the system than is produced.

4. **Resource Consumption**

- Fossil fuels, metals, and minerals are used in converting natural gas to sale gas. Excluding water, the major resource consumption requirements for the system are: as expected, natural gas at the highest rate, accounting for 94.5% of the total resources on a weight basis, followed by, iron (ore plus scrap) at 4.6%, limestone at 0.4%, and oil at 0.4%. The iron and limestone is used in the construction of the power plant and pipeline. The majority of the oil consumption (60.9%) comes from natural gas production and gathering while most of the gas is consumed to produce the electricity and refrigeration process which needed by the gas plant.

Total Water consumed	**19.8 Lt/Kg gas**
Percent of total Water consumed from construction & decommissioning	**3.6 %**
Percent of total Water consumed from gas production and transport:	**1.3%**
Percent of total Water consumed from electricity generation	**< 0.0 %**
Percent of total Water consumed from gas plant operation	**95.2 %**

5. Water Emissions

- The total amount of water pollutants for this study equals 0.19 g/kg of gas with the primary pollutant being oils (60%) followed by dissolved matter (29%). It is interesting to note that the water pollutants come primarily from the material manufacturing steps required for pipeline and plant construction.
- Similar to the findings of previously performed LCAs, the total amount of water pollutants was found to be small compared to other emissions

6. **Solid Waste**

- The waste produced from the system is miscellaneous non-hazardous waste; totaling 201.6 g/kg of gas produced .Following data contains a breakdown of the percentage of waste from each of the subsystems:

  Total Solid Waste: 201.6 Lt/Kg gas

  Percent of total Solid Waste from construction & decommissioning: 3.8 %

  Percent of total Solid Waste from gas production and transport: 72.3%

  Percent of total Solid Waste from electricity generation: 31.0 %

  Percent of total Solid Waste from gas plant operation: 7.1 %

- The majority (72.3%) comes from natural gas production and gathering. Breaking this down further, pipeline transport is responsible for 50% of the total system waste and natural gas extraction is the second largest waste source, accounting for 22% of the total.

Sensitivity Analysis

- A sensitivity analysis was conducted to examine the effects of the base case assumptions for several parameters. Each parameter was changed independently of all others so that the magnitude of its effect on the base case could be assessed. Therefore, no single sensitivity case represents the best or worst situation under which these systems might operate.

Variable	Sensitivity analysis cases	
Amount of materials required for plant construction	Decrease by 50%	Increase by 50%
Amount of materials required for pipeline construction	Decrease by 20%	Increase by 20%
Natural gas losses(% of gross production)	0.5%	4%
Operating capacity factor	0.80	0.95
Materials recycled versus materials land filled	50/50	
Natural gas boiler efficiency	64%	
Gas plant energy efficiency (HHV basis)	80%	

Impact Assessment

Stressor categories		Stressors	Major impact category H = human health E = ecological health	Area impacted L = local (county) R = regional (state) G = global
Major	Minor			
Ozone depletion compounds		NO	H,E	R,G
Climate change	Greenhouse gases	CO_2, CH_4, N_2O, CO and NO_x (indirectly), water vapor	H,E	R,G
	Particulates		H,E	L,R
Contributors to smog	Photochemical	NO_x, VOCs	H,E	L,R
Acidification precursors		SO_2, NO_x, CO_2	H,E	L,R
Contributors to corrosion		SO_2, H_2S, H_2O	E	L
Other stressors with toxic effects		NMHCs, benzene	H,E	L
Resource depletion		Fossil fuels, water, minerals, and ores	E	R,G
Solid waste		Catalysts, coal ash (indirectly), flue gas clean up waste (indirectly)	H,E	L,R

Improvement Opportunities

- Reduction of excess fuel gas
- Eco-mapping
- Energy Audit
- Gas turbine fuel system modifications
- Solar Dew waste water purification
- Co2 recovery from flue gases
- Smart emissions monitoring and control