Independent Study of CO2 Sales of Waste CO2 Stream from Freeport LNG Project 05-Jan-14

Convert to Solvent Based AGR, Compress and Dry CO2, Transport to Denbury for EOR Light Crude Oil Recovery

Proposed Pretreatment Facility

Freeport LNG Development, L.P.

CO2 Pipeline / Injection Well Assumptions

Pipeline Length	37
Pipeline Diameter 12 inches	
Number of Injection Wells 1	
Depth of Well 1,000 meters	
Electricity for Compression (DOE Study)	8,500
Electricity for Inlet Blower	0

CSS Cost Breakdown

Basis: Case 2-D2A from DOE Baseline Report
Compression Drying from Selexol Unit - same CO2 capacity as Freeport LNG
Source:
Cost and Performance of PC and IGCC Plants for a Range of Carbon Dioxide Capture
27-May-11 DOE/NETL-2011/1498
Key Assumptions:

1 CO2 Compr/Drying extracted from DOE capex
2 Costs for add'l utilities contols, electrical, etc scaled to CO2/TIC
3 Escalated per HIS CERA Downstream O/G Index 2006/7 to 2013
4 Overnight Cost 2013 no escalation for construction or operating periods
5 Estimating contingency of 15% added to total estimate
6 Use of Solvent based AGR deletes needfor inlet compression, surge tank, treatment/refrigeration
7 Added cost of Solvent over Amine is offset by savings in drying equipment, lower utilities
8 Use of Selexol or other Physical Solvent will require reconfiguring the PreTreatment Plant with dehydration upstream of AGR
9 The use of Selexol should reduce the cost of CCS. However, the net cost of reconfiguring the PT Plant has not been estimated.

Economics Method is from ATKINS 044167600 Report CO2 BACT Study

Cost Type	Units	Cost		
Pipeline Costs [1]				
Pipeline Materials	Scaled from similar CO2 lines	Private Sources	$15,000,000	
Pipeline Labor			$26,000,000	
Pipeline Miscellaneous, commissioning, frieght			$1,500,000	
Pipeline Right of Way, Surveys			$4,000,000	
Construction Management			$1,200,000	
Permits and Licenses			$700,000	
Total Pipeline Cost	per mile cost	$1,308,108	$48,400,000	per mile cost is consistent with FERC Reports
				compares to $37931,000 Atkins Estimate - omitted some cost elements?
Other Capital [2]				
Inlet Compression / Cooling		$0	$0	Not Needed
CO2 Compression and Drying Equipment		$26,000,000	$27,000,000	from scaled DOE Studies of similar equipment
Conversion Amine to Solvent bases AGR		$0	$0	Not estimated but believed to be similar when accounting for lower utillities
CO2 Surge Tank		$0	$0	Not Needed
Pipeline Control System		$340,000	$0	Included in estimate above
Total Capex			$75,400,000	37931
	per mile cost	$2,054,054	$76,000,000	Round Up
O&M - Pipeline [2]				
Fixed O&M		$8,632	$319,384	Use 37 mi to Hastings Denbury
O&M - Compress and Dry				
Fixed O&M	% of installed	2.5%	$675,000	Typical Compression FOM is 2-3%, including operating labor
Natural Gas for Amine Regeneration	$ p	$3.000	$0	Steam or fuel to operate Solvent AGR will be less than Amine System, not estimated, assume zero is safe
Electricity for Compression	$ p	$0.060	$4,467,600	
Electricity for Inlet Blower	$ p	$0.060		Solvent based AGR produces CO2 at elevated pressure, no blower is needed per DOE report
Amine Replacement		Engineering Estimate	$0	make up of solvent will be the same whether or not CO2 is compressed and sold to EOR
Credit for Shutting Down RTOs				No credit is taken for savings in fuel, power, O&M cost of RTOs
Annual O&M Costs (Compression, Drying, Pipeline)			$5,470,619	
Geologic Storage Costs [3] Capital				Not needed if CO2 is sold to Denbury at NG processing site or pipeline terminal
Site Screening and Evaluation		$0	$0	
Injection Wells	$ / i nie	$240,714 x e 0.0008 x well depth	$0	
Injection Equipment	$ / i nje	x # of injection wells)]0.5	$0	
Liability Bond		$5,000,000	$0	
Declining Capital Funds				
Pore Space Acquisition	$ / sh ort	0.334 / short ton CO2	$0	Not needed if CO2 is sold to Denbury at NG processing site or pipeline terminal
		Total Capital Cost	$76,000,000	
O&M - Geologic				Not needed if CO2 is sold to Denbury at NG processing site or pipeline terminal
Normal Daily Expenses (Fixed O&M)	$ / injection well	$11,566	$0	
Consumables (Variable O&M)	$ / yr / short ton	$2,995	$0	
Surface Maintenance (Fixed O&M)	see formula	x # of injection wells)]0.5	$0	
Subsurface Maintenance (Fixed O&M)	$ / f t-de	$7	$0	

Amortized CCS Cost

1.National Energy Technology Laboratory, "Carbon Dioxide Transport and Storage Costs in NETL Studies," DOE/NETL- 2013/1614, March 2013.

2.Costs are based on Revised Estimates based on Published DOE Studies

Total Capital Investment (TCI)	$76,000,000
Capital Recovery Factor (CRF) = i(1+i)n / ((1+i)n-1)	8.255%
I = interest rate	8.000%
n= equipment life, years	30
Amortized Installation Costs = CRF * TCI	$6,273,631
Annual O&M Costs	$5,470,619
Total CCS Annualized Cost	$11,744,250
Tons CO2 per Year Removed (AGRU \)	896,334
Average Annual Cost per Ton CO2 Removed	$13.10 per ton
(assume 100% of captured CO2 is compressed and sold to EOR operator)	

Independent Study of CO2 Sales of Waste CO2 Stream from Freeport LNG Project 04-Jan-14

Add CO2 purification, drying and compression to Existing Amine Based Design

Proposed Pretreatment Facility
Freeport LNG Development, L.P.

CO2 Pipeline / Injection Well Assumptions

Pipeline Length	37
Pipeline Diameter 12 inches	
Number of Injection Wells 1	
Depth of Well 1,000 meters	
Electricity for Compression (DOE Study)	8,500
Electricity for SulfaTreat, TEG Drying	1,500
Electricity for Inlet Blower	0
Total Power Requirements	10,000

CSS Cost Breakdown

Basis: Case 2-02A from DOE Baseline Report
Compression Drying from Selexol Unit - same CO2 capacity as Freeport LNG
Source:
Cost and Performance of PC and IGCC Plants for a Range of Carbon Dioxide Capture
27-May-11 DOE/NETL-2011/1498
Key Assumptions:

1 CO2 Compr/Drying extracted from DOE capex
2 Costs for add'l utilities contols, electrical, etc scaled to CO2/TIC
3 Escalated per HIS CERA Downstream O/G Index 2006/7 to 2013
4 Overnight Cost 2013 no escalation for construction or operating periods
5 Estimating contingency of 15% added to total estimate
6 Use of existing Amine Design requires adding SulfaTreat to reduce CO2 sulfur and integrating TEG dryer in the Compression System

Economics Method is from ATKINS 044167600 Report CO2 BACT Study

Compare to Akins 07202012 Response

		Cost Type	Units			
		Pipeline Costs [1]				
	9976724	Pipeline Materials	Scaled from similar CO2 lines	Private Sources	$15,000,000	
	22008464	Pipeline Labor			$26,000,000	
		Pipeine Miscellaneous, commissioning, frieght			$1,500,000	
	7483175	Pipeline Right of Way, Surveys			$4,000,000	
	??	Construction Management			$1,200,000	
	??	Permits and Licenses			$700,000	
$	39,468,363	Total Pipeline Cost	per mile cost	$1,308,108	$48,400,000	per mile cost is consistent with FERC Reports; compares to $37931,000 Atkins Estimate - omitted some cost elements?
		Other Capital [2]				
		Inlet Compression / Cooling		$0	$0	Not Needed
		CO2 Compression and Drying Equipment		$26,000,000	$27,000,000	from scaled DOE Studies of similar equipment
		Add SulfaTreat and TEG Dehydration		$0	$6,000,000	SulfaTreat estimate is $4mm, TEG adder is unknow, $2 mm is assumed
		CO2 Surge Tank		$0	$0	Not Needed
		Pipeline Control System		$340,000	$0	Included in estimate above
$	67,036,316	Total Compression / Drying Cost			$33,000,000	Atkins includes a 42% Contingency- this is excessive, we use 10-15% for estimate uncertainty
$	8,478,332	Engineering			included above	12.6% Atkins Eng'g is far above the industry norm of 8-10%
		Total Capex				
$	114,983,011		per mile cost	$2,200,000	$81,400,000	Round Up
		O&M - Pipeline [3]				
??		Fixed O&M		$8,632	$319,384	Use 37 mi to Hastings Denbury
		O&M - Compress and Dry				
$	1,629,741	Fixed O&M	% of installed	2.5%	$825,000	Typical Compression FOM is 2-3%, including operating labor
$	51,223	Natural Gas for Amine Regeneration		$3.000	$0	Steam or fuel to operate Solvent AGR will be less than Amine System, not estimated, assume zero is safe
$	7,787,928	Electricity for Compression		$0.060	$5,256,000	14,820 kw for Atkins. This is much higher than the DOE estimate +1500kw for intercooler TEG drying
$	34,433	Water Disposal			$34,400	should be easily handled in PT Plant system, include in our estimate to be consistent
$	-	Electricity for Inlet Blower		$0.060	$0	Solvent based AGR produces CO2 at elevated pressure, no blower is needed per DOE report
$	75,000	Amine Replacement		Engineering Estimate	$0	make up of solvent will be the same whether or not CO2 is compressed and sold to EOR
		Credit for Shutting Down RTOs				No credit is taken for savings in fuel, power, O&M cost of RTOs
$	9,578,325	Annual O&M Costs (Compression, Drying, Pipeline)			$6,443,419	
		Geologic Storage Costs [3] Capital				Not needed if CO2 is sold to Denbury at NG processing site or pipeline terminal
		Site Screening and Evaluation		$0	$0	
		Injection Wells	$ /	$240,714 x e^(0.0008 x well depth)	$0	
		Injection Equipment	$ /	[7389 / (280 x # of injection wells)]^0.5	$0	
		Liability Bond		$5,000,000	$0	
		Declining Capital Funds				
		Pore Space Acquisition	$ /	0.334 / short ton CO2	$0	Not needed if CO2 is sold to Denbury at NG processing site or pipeline terminal
				Total Capital Cost	$81,400,000	
		O&M - Geologic				Not needed if CO2 is sold to Denbury at NG processing site or pipeline terminal
		Normal Daily Expenses (Fixed O&M)	$ / injection well	$11,566	$0	
		Consumables (Variable O&M)	$ / yr / short ton	$2,995	$0	
		Surface Maintenance (Fixed O&M)	see formula	[7389 / (280 x # of injection wells)]^0.5	$0	
		Subsurface Maintenance (Fixed O&M)	$ /	$7	$0	

Amortized CCS Cost

1.National Energy Technology Laboratory, "Carbon Dioxide Transport and Storage Costs in NETL Studies," DOE/NETL- 2013/1614, March 2013.
2.Costs are based on Revised Estimates based on Published DOE Studies

$	114,983,011	**Total Capital Investment (TCI)**	$81,400,000	
		Capital Recovery Factor (CRF) = i(1+i)n / ((1+i)n-1)	8.255%	Akins reports 9% but formula says 8.26%
		I = interest rate	8.000%	
		n= equipment life, years	30	
$	9,491,591	**Amortized Installation Costs = CRF * TCI**	$6,719,389	
$	9,578,325	**Annual O&M Costs**	$6,443,419	
	$19,069,916	**Total CCS Annualized Cost**	$13,162,808	
	896,334	**Tons CO2 per Year Removed (AGRU)**	896,334	Use Atkins annual volumes
	21.28	**Average Annual Cost per Ton CO2 Removed** (assume 100% of captured CO2 is compressed and sold to EOR operator)	$14.69 r ton	