Fluor Solvent Evaluation and Testing (Project 70814)

August 15, 2018

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Disclaimer

This material is based upon work supported by the U.S. Department of Energy under Field Work Proposal FWP-70814.

Fluor's Gas Treating Solutions

- Fluor offers various gas processing solutions
- **Fluor Solvent℠** – Physical solvent to absorb H_2S and CO_2 at high pressure
- **Econamine℠** – Uses diglycolamine (DGA) for H_2S and CO_2 removal from natural gas streams
- **Econamine FG Plus℠** – Removal of CO_2 from low pressure, post-combustion flue gases
- Fluor has built over 425 gas processing facilities
  - Includes 30 Econamine FG+ plants built or licensed

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What is the Relevance of Water Lean Solvents?

- Carbon capture solvents typically contain 60 to 65% water by weight
- Fluor's target is a solvent with less than 40 to 50% water
- Water provides a medium for ionic reactions to take place
- But, water has several drawbacks
  - High heat of vaporization
  - High volatility
  - High specific heat
  - Low capacity for CO_2
- Replacement of a portion of the water with other solvents offers an opportunity for energy consumption reduction

Lean Solvent Formulation

- In 2016 Fluor discovered a water lean solvent opportunity with a promise for more energy efficient CO_2 capture
- Fluor worked with PNNL to measure the preliminary performance of the new solvent system
- Based on the results DOE was approached for a scale-up program that would involve demonstration testing at Technology Center, Mongstad

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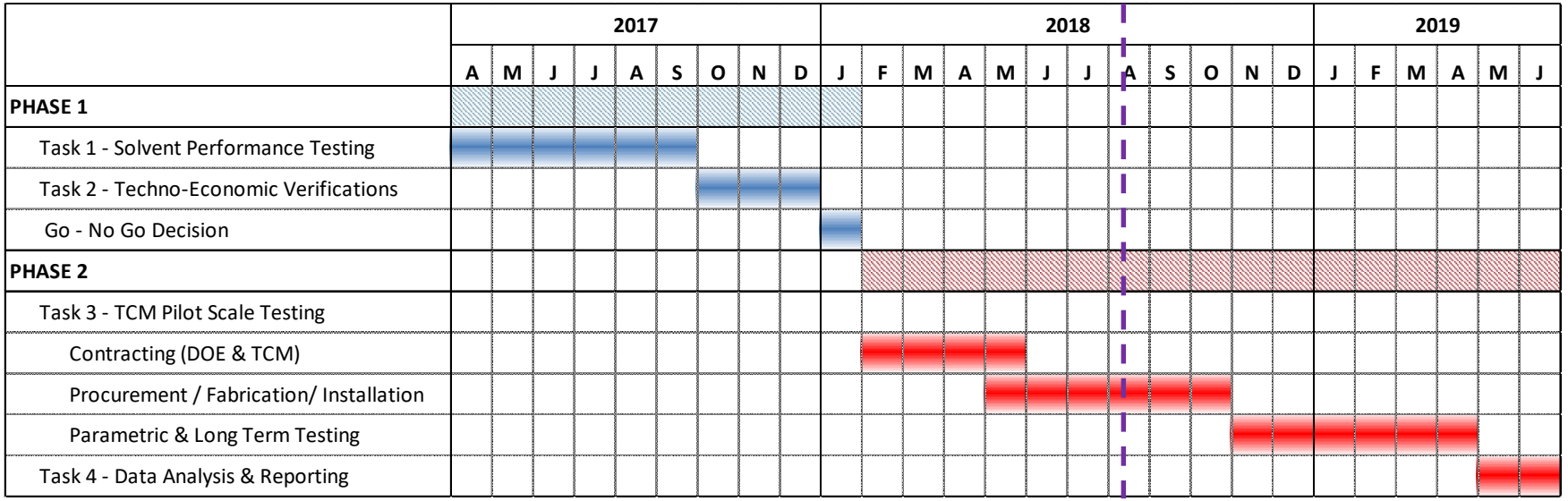
Project Schedule & Budget



DOE Funding:

Phase 1:	$284k
Phase 2:	$2,396k
Total:	$2,681k

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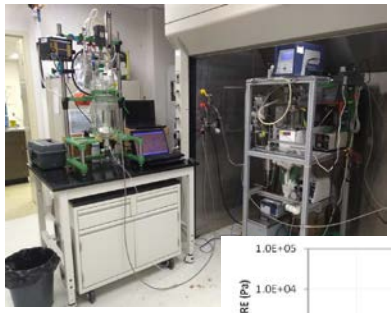
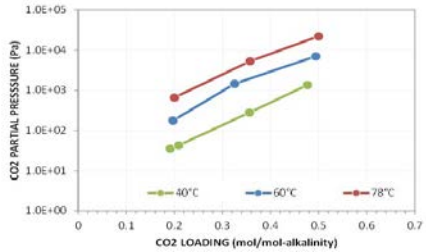
Results to Date:
Task 1 – Solvent Performance Testing

- VLE and kinetic data were measured for several different solvent mixtures
  - Thermodynamic and kinetic data developed
  - Solvent composition optimized



PNNL's Wetted Wall Column Capability



- Solvent degradation testing at SINTEF
  - 5-week testing with synthetic flue gas: 3.0 vol% CO2, 12% O2, and 10 ppmv NOx. Absorber/ desorber temps: 40C/ 117C.
  - One solvent component found to produce an undesirable degradation product – replaced with alternate material

SINTEF's Solvent Degradation Rig

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Results to Date:
Task 2 – Techno-Economic Verifications

	NETL Case 9	NETL Case 10	New Solvent
Case Description	Subcritical PC No Capture	Subcritical PC MEA	With EFG+ features
Solvent Parameters			
Solute	NA	MEA	Proprietary
Concentration (wt% - balance is water)	NA	30%	>50%
Overall Performance			
Net Plant Efficiency (%, HHV)	36.8%	26.2%	27.5%
Parasitic Load from Capture (%)	0.0%	28.9%	25.2%
Plant Energy for Capture (GJ/tonne CO2)	NA	3.14	2.74
Parasitic Energy Reduction Compared to MEA Baseline		0%	13%
Summary of Costs (¢/kWe-hr)	NETL Case 9	NETL Case 10	New Solvent
Fuel Cost	1.52	2.13	2.04
Capital Cost	3.12	6.03	5.63
Variable Cost	0.51	0.92	0.87
Fixed Operating Cost	0.78	1.31	1.25
Transp, Seques & Monitoring (TSM)	----	0.59	0.56
Total	5.94	10.97	10.36
Increase versus "No Capture"	----	84.7%	74.3%

- PNNL conducted an independent Techno-Economic Analysis (TEA)
- The TEA validated Fluor's analysis
- Attractive energy performance predicted (2.74 GJ/tonne CO2, versus 3.14 for NETL baseline case)
- Based on the results Phase 2 authorized

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Results to Date:
Task 3 - TCM Pilot Scale Testing

- Contracting (DOE & TCM)
  - Contracting completed
  - Fluor/PNNL will manage the DOE-funded portion of the project:
    - Proprietary equipment and solvent purchase
    - Installation of proprietary equipment and hook-ups
    - Solvent disposal
    - Deployment of personnel and travel costs
  - TCM will provide:
    - Use of the demonstration plant
    - All utilities
    - Operating staff
    - Analytical laboratory services
    - Office space and internet access
- Procurement / Fabrication / Installation
  - All major equipment ordered
- Parametric & Long Term Testing
  - Draft test plan complete
  - Testing will start in November/December

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Additional Detail & Comments

Solvent Selection Criteria

Evaluation Criteria	Desired Characteristic
Toxicology	Low toxicity
Oxidative degradation	Low – Minimizes solvent replacement costs and formation of byproducts
Thermal degradation	Low – Minimizes solvent replacement costs and formation of byproducts
Corrosivity	Low – Reduces operating and capital costs associated with high corrosivity
Vapor pressure	Low – Reduces solvent losses
Viscosity	Low – Faster mass transfer and ease of pumping
Specific heat	Low – Reduces the heat required to change the temperature or the solvent
Heat of absorption	Low to Moderate – Minimizes the regeneration energy required
Capacity for CO_2	High – Reduces the solvent circulation rate and equipment sizes
Cost	**Low**
Availability	**Widely available and widely deployed in various industries**

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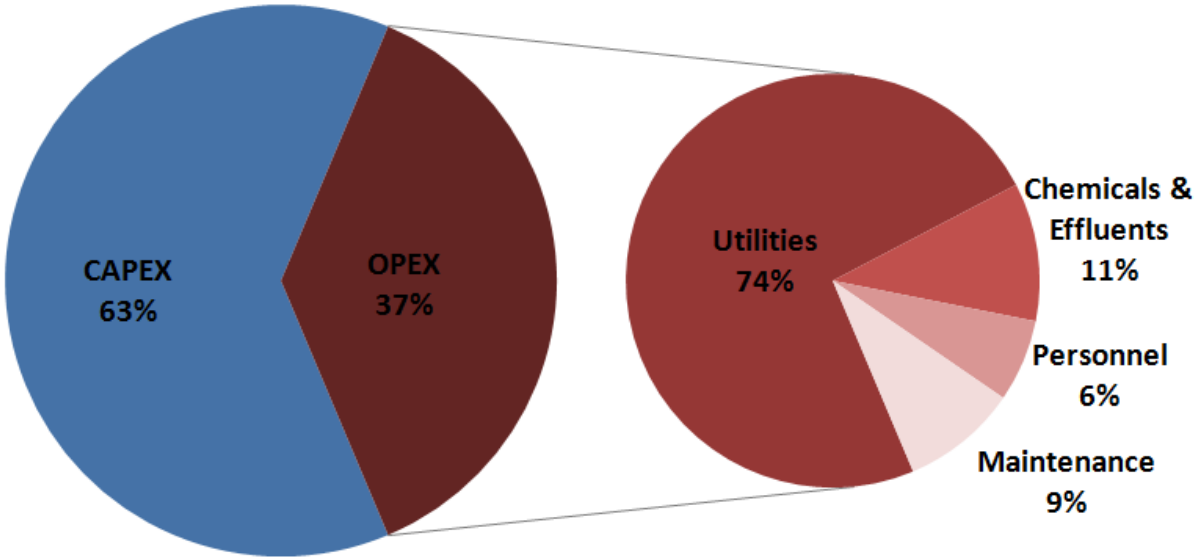
Breakdown: Cost of CO_2 from Flue Gas



Coal flue gas, includes CO_2 compression
30 yr. plant life
10% IRR
7,000 ton/day
Site specific costs for construction, labor, utilities

- Breakdown of cost of capture on a recent US project
- Most effort in CO_2 capture focuses on reducing process steam demand
- Too little focus is placed on reducing CAPEX
- The project targets both CAPEX and OPEX cost reductions

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Summary

- Fluor's new water-lean solvent formulation (>50 wt% Solvent) has promising energy and economic benefits for CO2 capture applications
- The project team is looking forward to a successful test campaign at Mongstad
- Fluor is well positioned to quickly bring new solvents to the commercial scale
  - Solvent is a possible drop in for Fluor's existing plants
- **Fluor's project is an great example of the US-Norway Collaboration on CCS**

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Acknowledgements

- Thanks to the Department of Energy's Office of Fossil Energy and the National Energy Technology Laboratory for their support and sponsorship
- Thanks to the Test Center Mongstad (TCM) team for their support, guidance and encouragement

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QUESTIONS