SUSTAINABLE ENERGY SOLUTIONS

Cryogenic Carbon Capture Development

2018 NETL CO_2 Capture Conference
August 13-17, 2018

Larry Baxter,[1,2] Kyler Stitt,[1] Chris Russell,[2] and Daisy Harmon[2]
[1]Sustainable Energy Solutions
[2]Brigham Young University

Outline

- Project Background
- Process, Energy, Economics Overview
- Field Test Summary
- Robust Unit Operations Review
- Next Steps

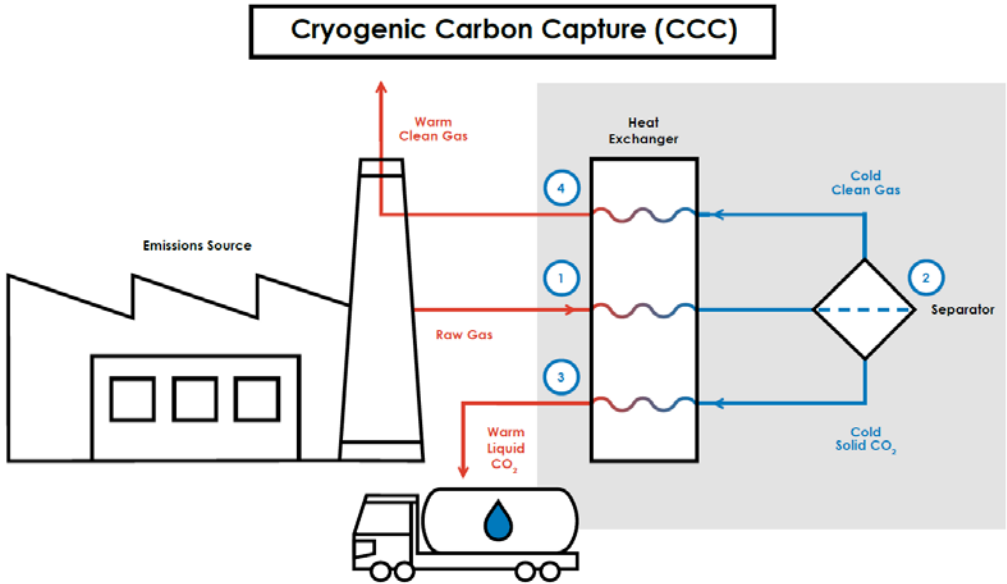
SES INNOVATION

Background

- SES developed the Cryogenic Carbon Capture™ process under separate funding to the stage of a 1 tonne/day skid-scale system that has been widely tested in house and in the field.
- DOE/NETL is funding the further development of unit operations in the existing skid to improve reliability and related issues that became apparent during the testing and updated TEA. (DE-FE0028697; $3.7M DOE/$4.7M total; 10/01/2016 – 03/31/2019)
- This presentation summarizes progress on the DOE-funded project.
- The culmination of this project is a 6-month field test (3 months under DOE funding) of the improved skid at a utility power plant, which starts 10/2018.

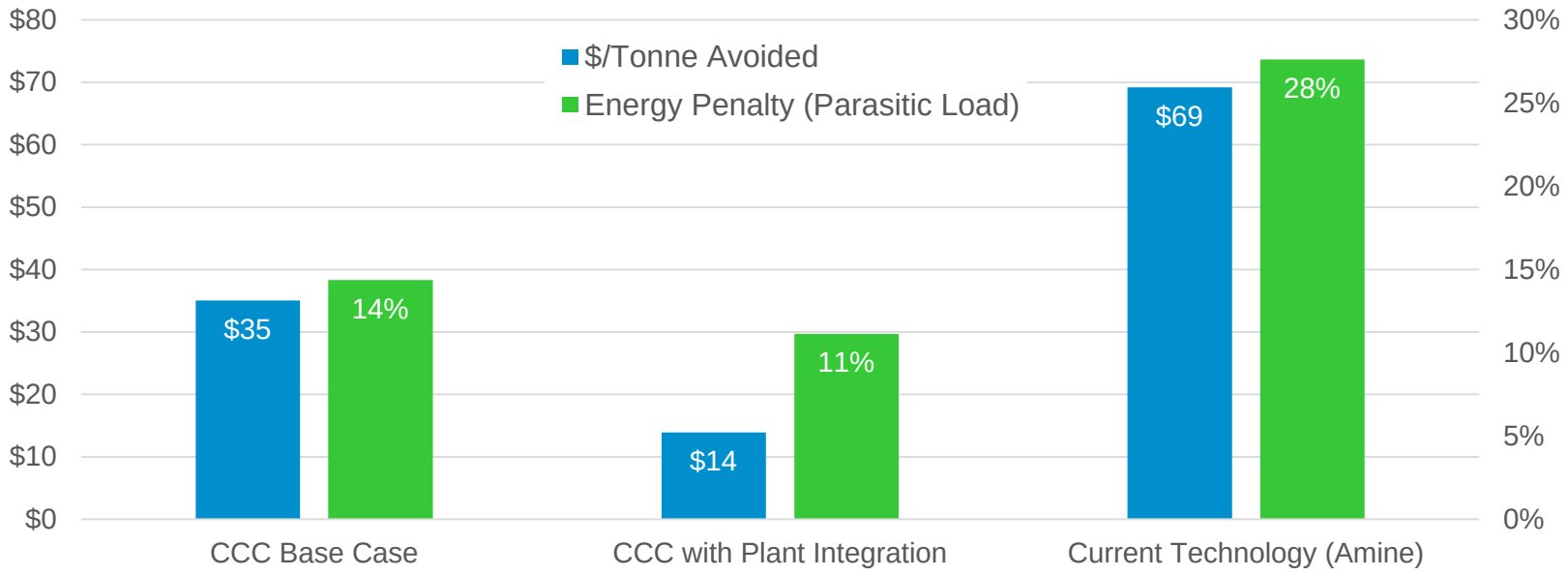
SES INNOVATION

CCC is a Simple Process



The CCC process (1) cools a dirty exhaust gas stream to the point that the CO_2 freezes using mostly heat recuperation, (2) separates solid CO_2 as it freezes from the clean gas, (3) melts the CO_2 through heat recuperation and pressurizes it to form a pure liquid, and (4) warms up the clean, harmless gas releasing it to the atmosphere. See appendix slides for more detailed flow diagrams.

Cryogenic Carbon Capture (CCC) Cuts Costs in Half



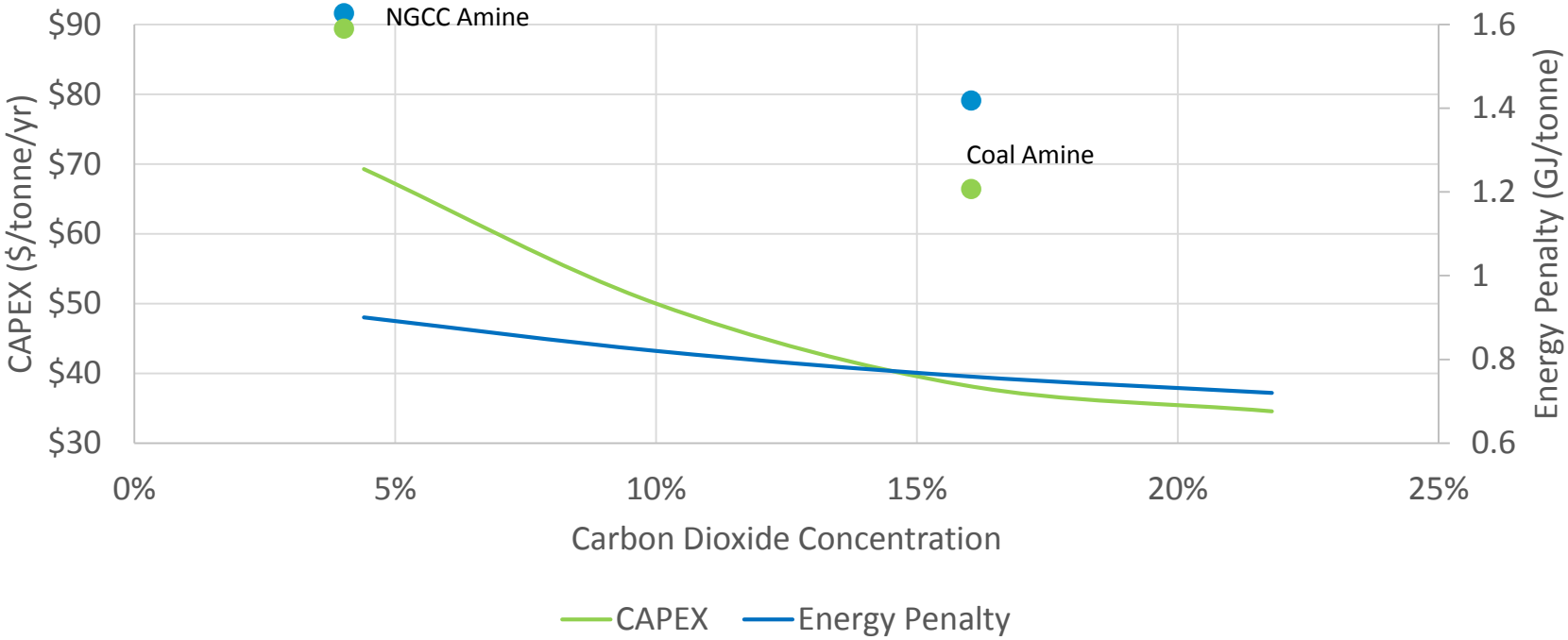
-Numbers based on NETL 2013 net 550 MW super critical pulverized coal plant

-Integration includes energy and cost savings from steam cycle improvements and offsetting cost and energy requirements for SO_X, NO_X, and Mercury controls.

-Additional value and revenues could be gained from CO_2 sales and energy storage.

SES INNOVATION

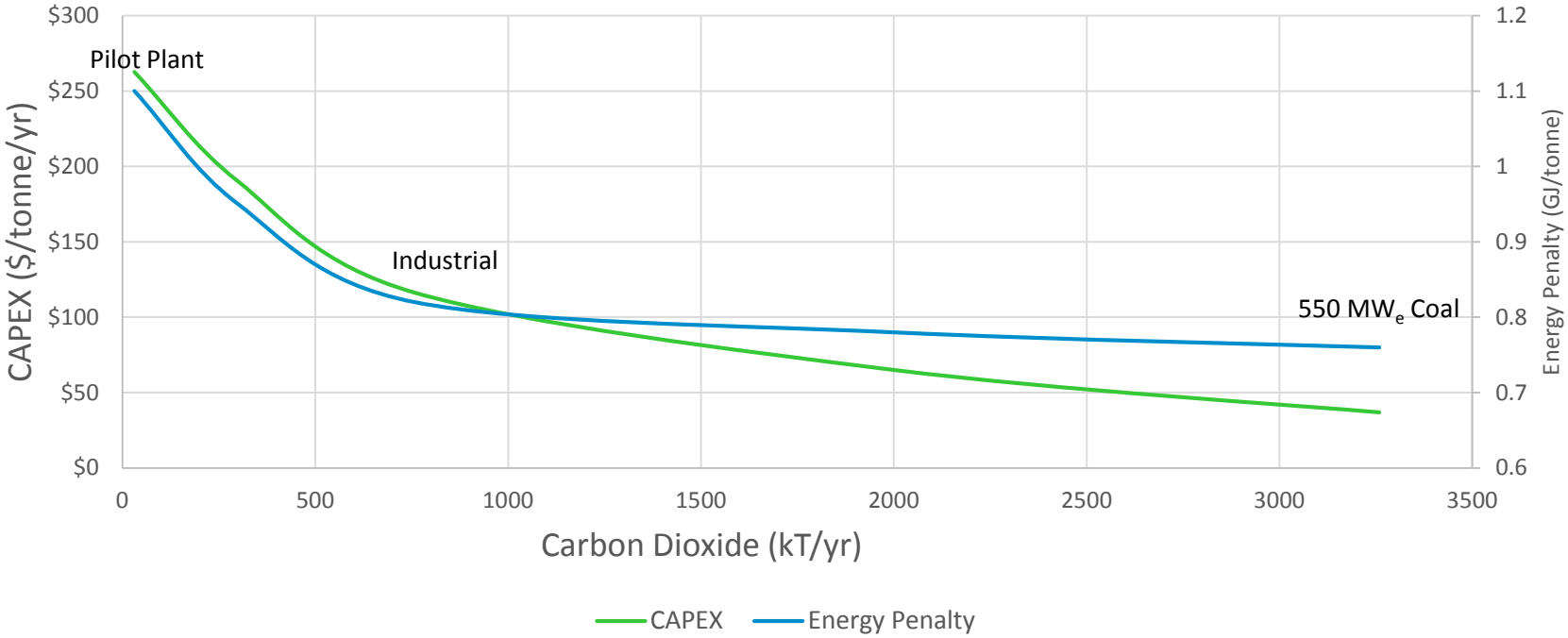
Cost and Energy with Composition



CAPEX numbers is the total equipment cost, not depreciated over any timeframe, and it does not include operating costs. These numbers assume large installations on the order of a power plant

SES INNOVATION

Cost and Energy with Plant Size



CAPEX numbers is the total equipment cost, not depreciated over any timeframe, and it does not include operating costs. These numbers assume a CO_2 composition of approximately 16% on a dry basis.

Additional CCC Benefits

- Bolt-on Retrofit
- Grid-level Energy Storage
- Multipollutant System
- Low Water Demand
- Highly Adaptable

SES INNOVATION

Previous CCC Demonstrations

- Fuels
  - Coal
  - Natural gas
  - Biomass
  - Municipal Waste
  - Shredded Tires
- Field Tests
  - Power Utilities
  - Heat Plants
  - Cement Kilns
  - Pilot Combustion Facilities

Thousands of cumulative hours of total testing.

SES INNOVATION

Demonstration Pictures

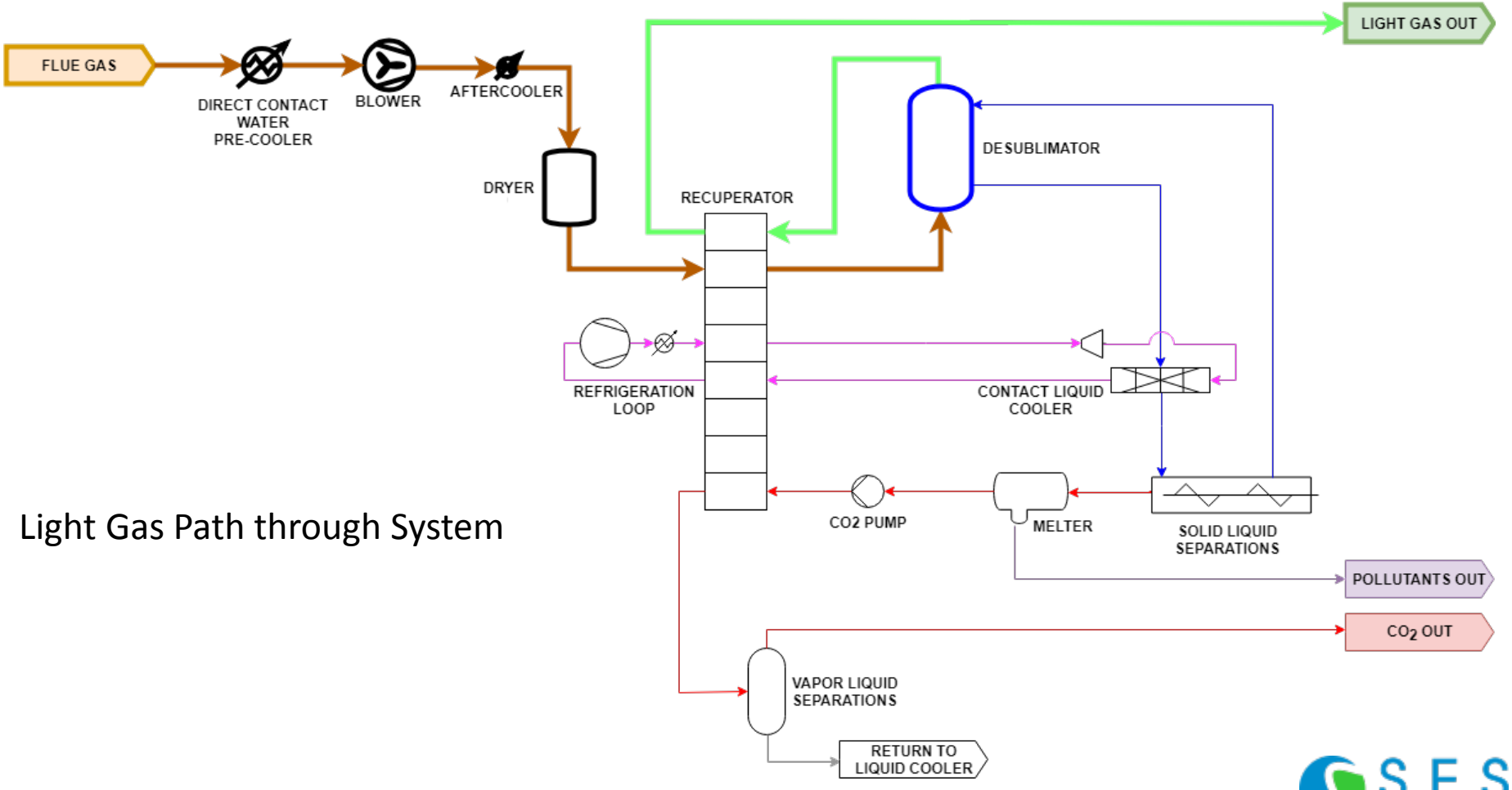
SES INNOVATION

CO_2 captured from cement

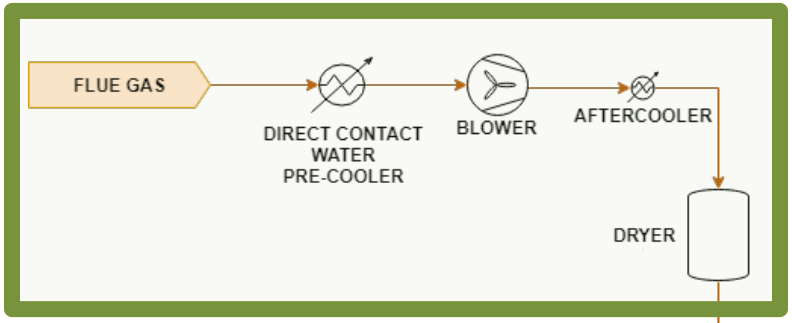
January 22, 2018

CO_2 used in concrete

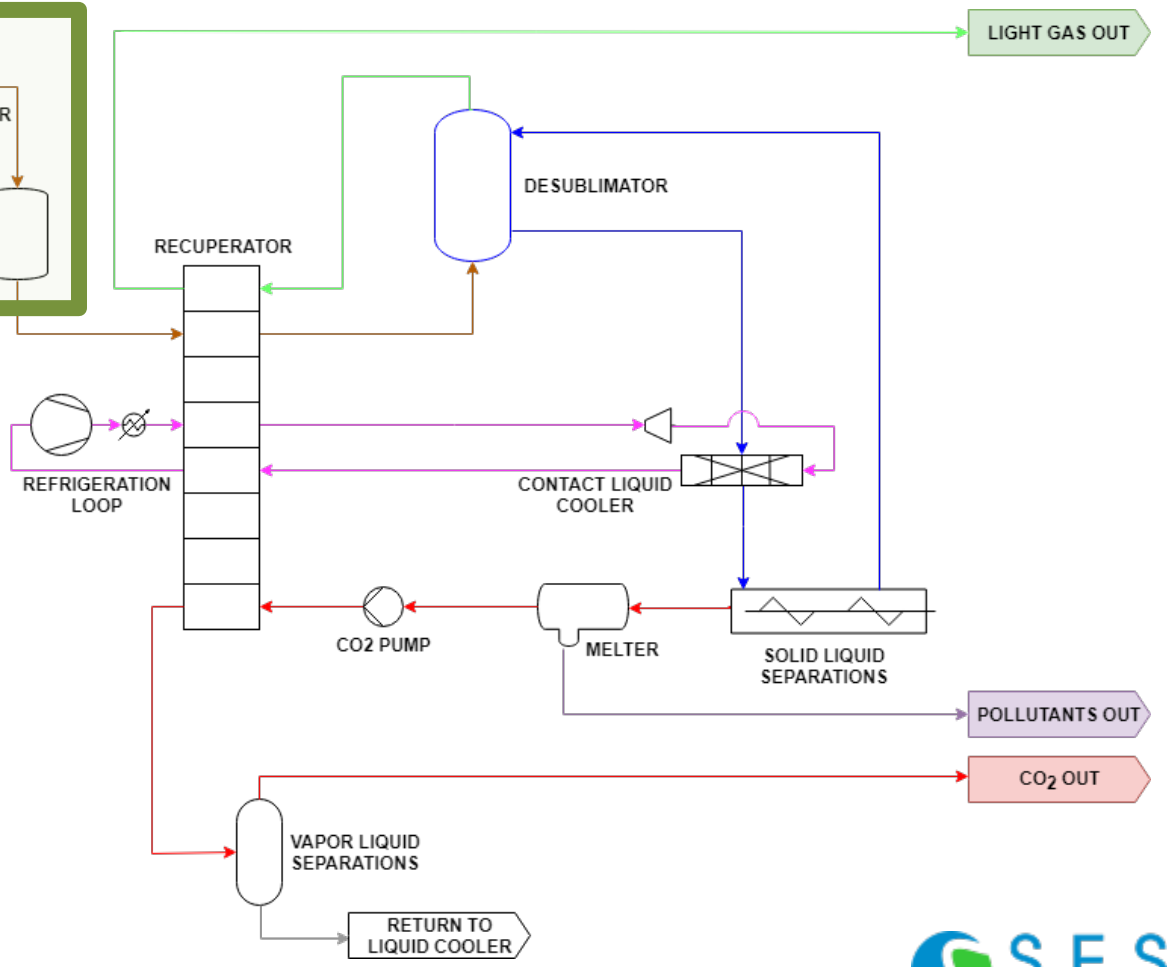
February 6, 2018



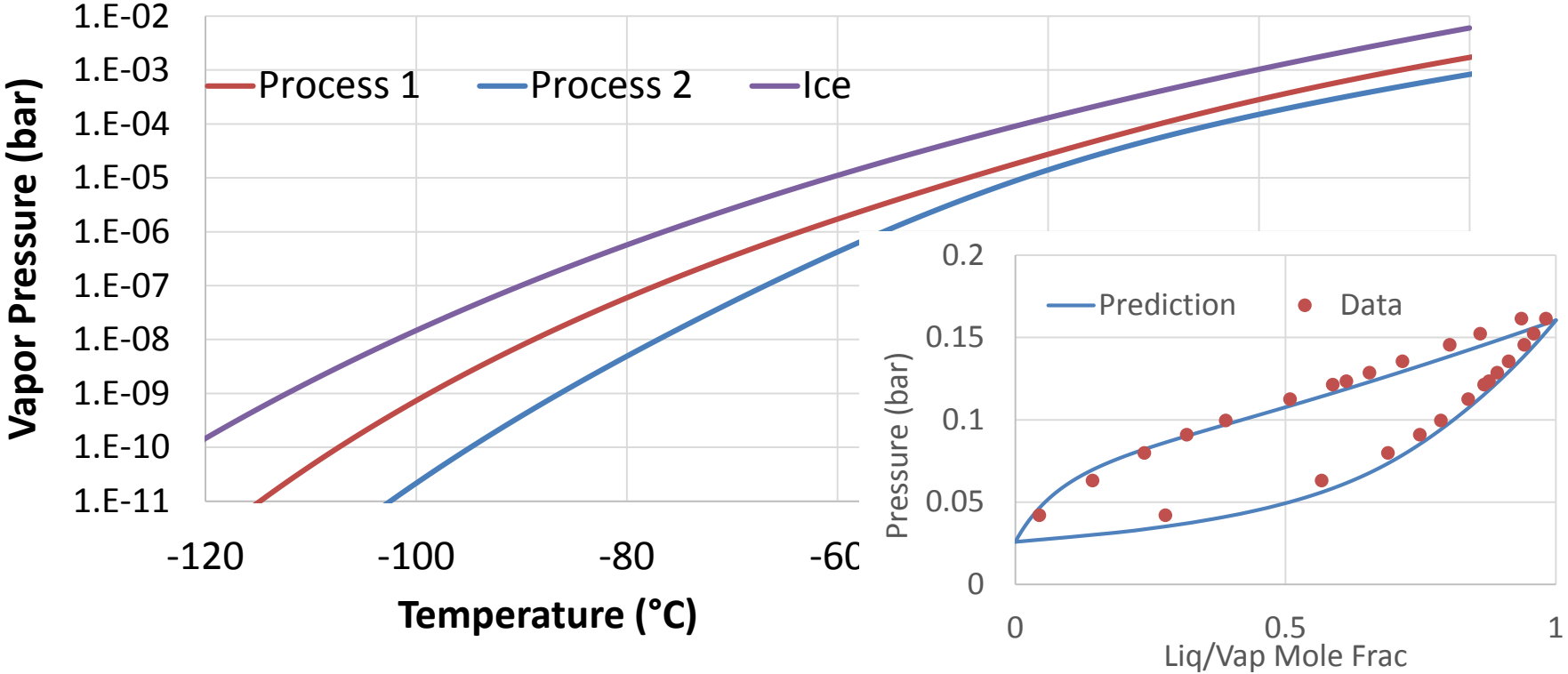
Light Gas Path through System



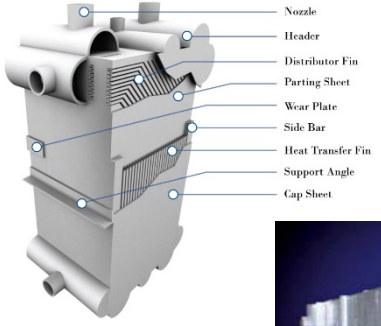
Front End and Dryer
- Commercially Available Technologies, with promising Dryer Modifications

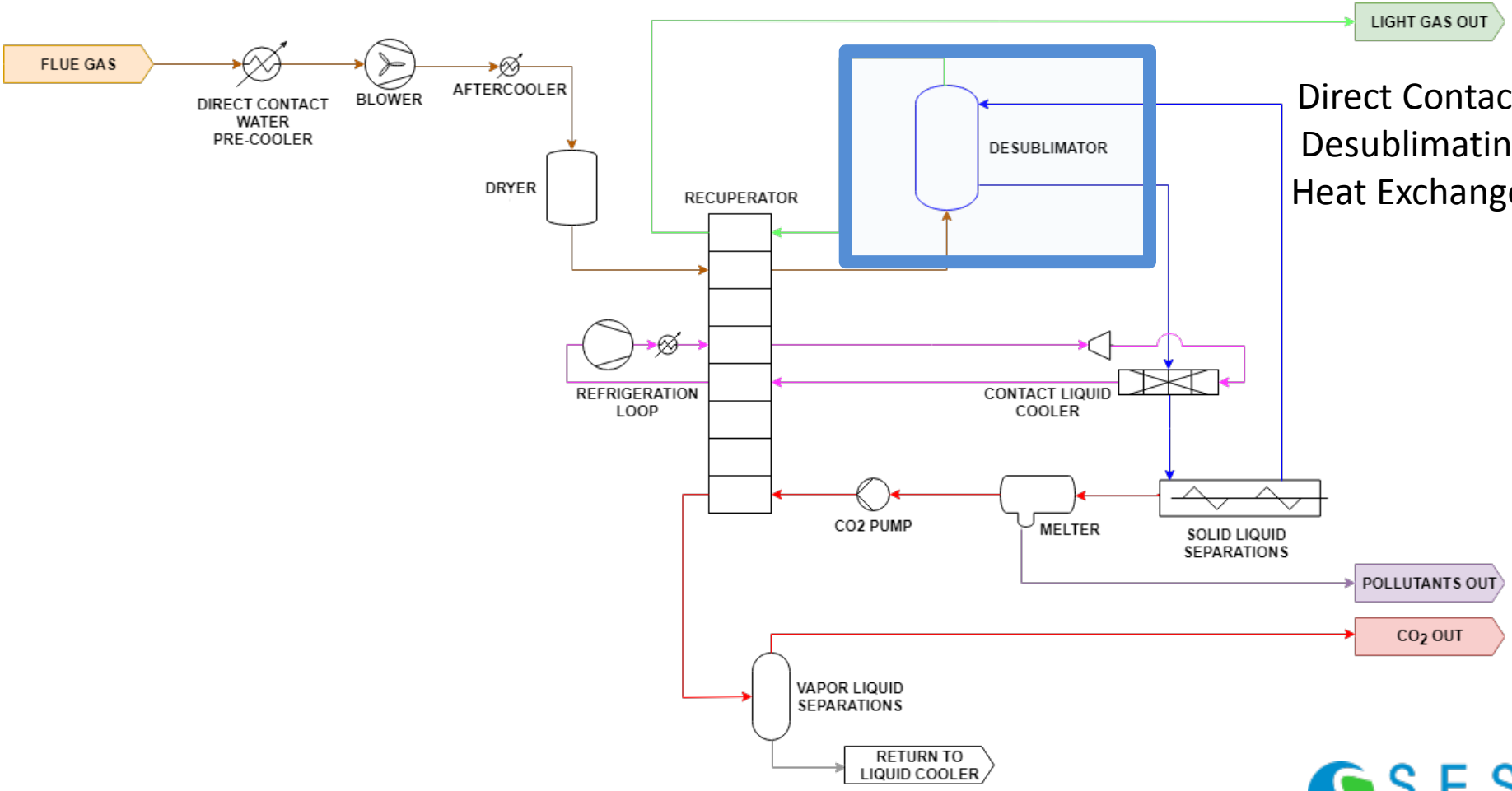


Water Vapor Pressure



Multi-Stream Heat Exchanger - Commercially Available In Partnership with Chart Industries





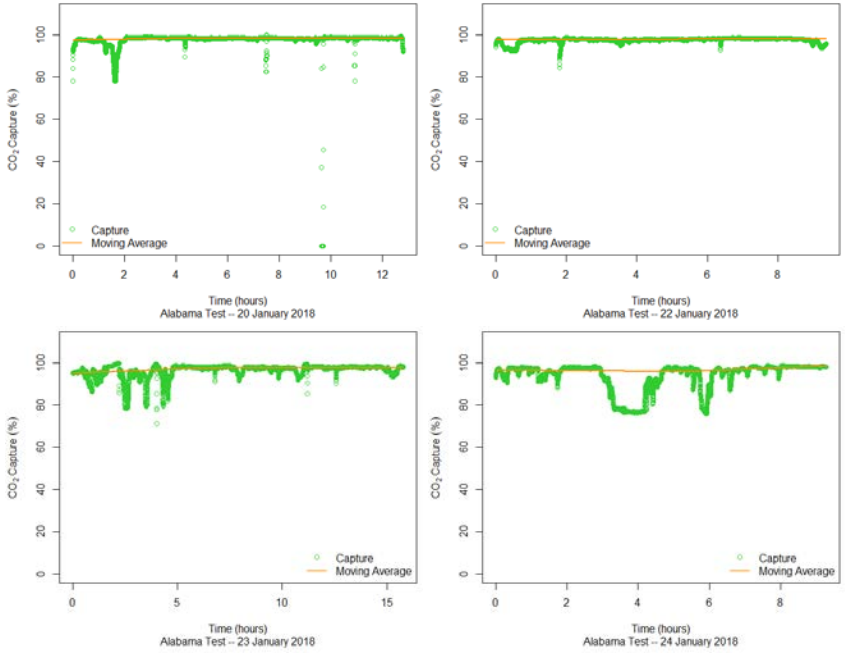
Direct Contact Desublimating Heat Exchanger

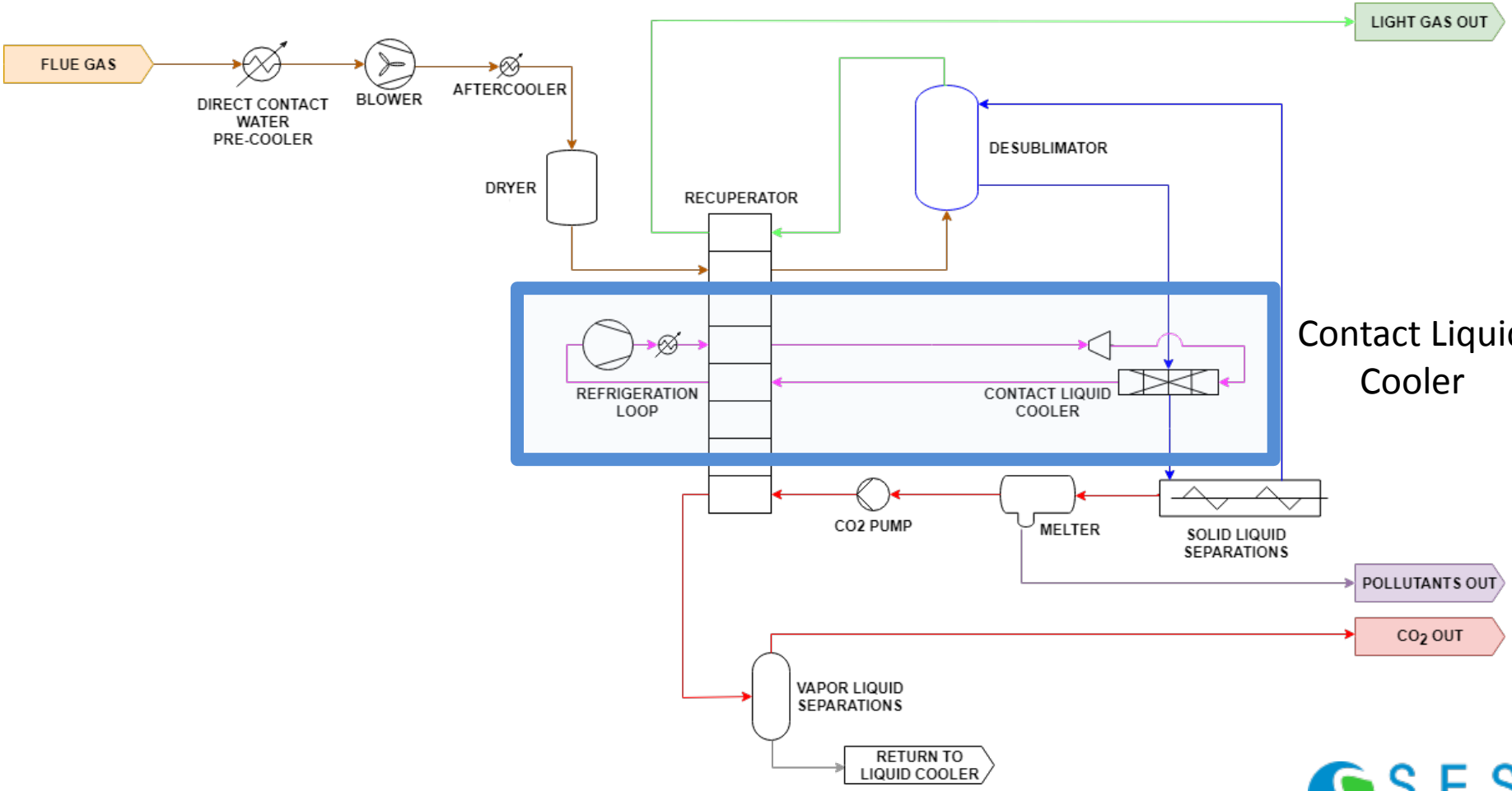
Spray Tower Selected as Main HX

- Easiest to scale
- Most similar to commercial processes
- Lowest pressure drop
- Most tested desublimating heat exchanger

Desublimating Heat Exchangers

- Spray tower has been proven, including on-site with real flue gas sources
- CO_2 capture above 90%, and can be increased up to 99% easily
- Average capture above 98% in tests at Alabama

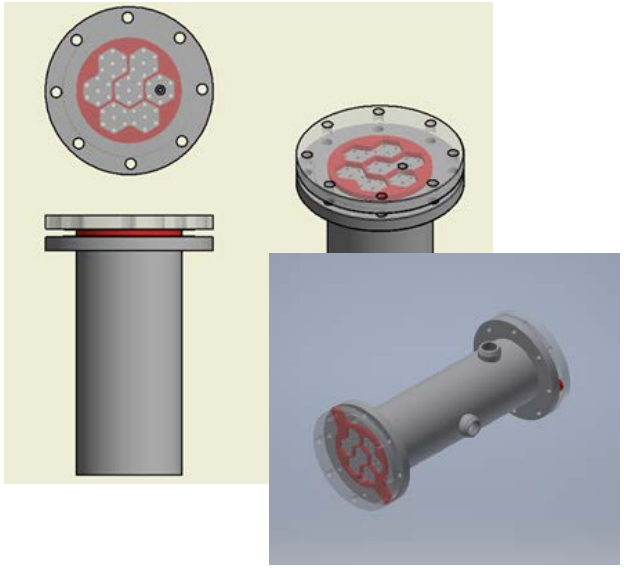




Contact Liquid Cooler

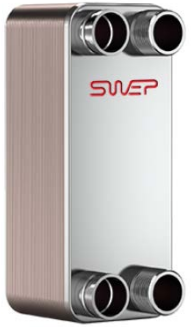
Contact Liquid Cooling Heat Exchangers

Used to cool the recirculating contact liquid without fouling



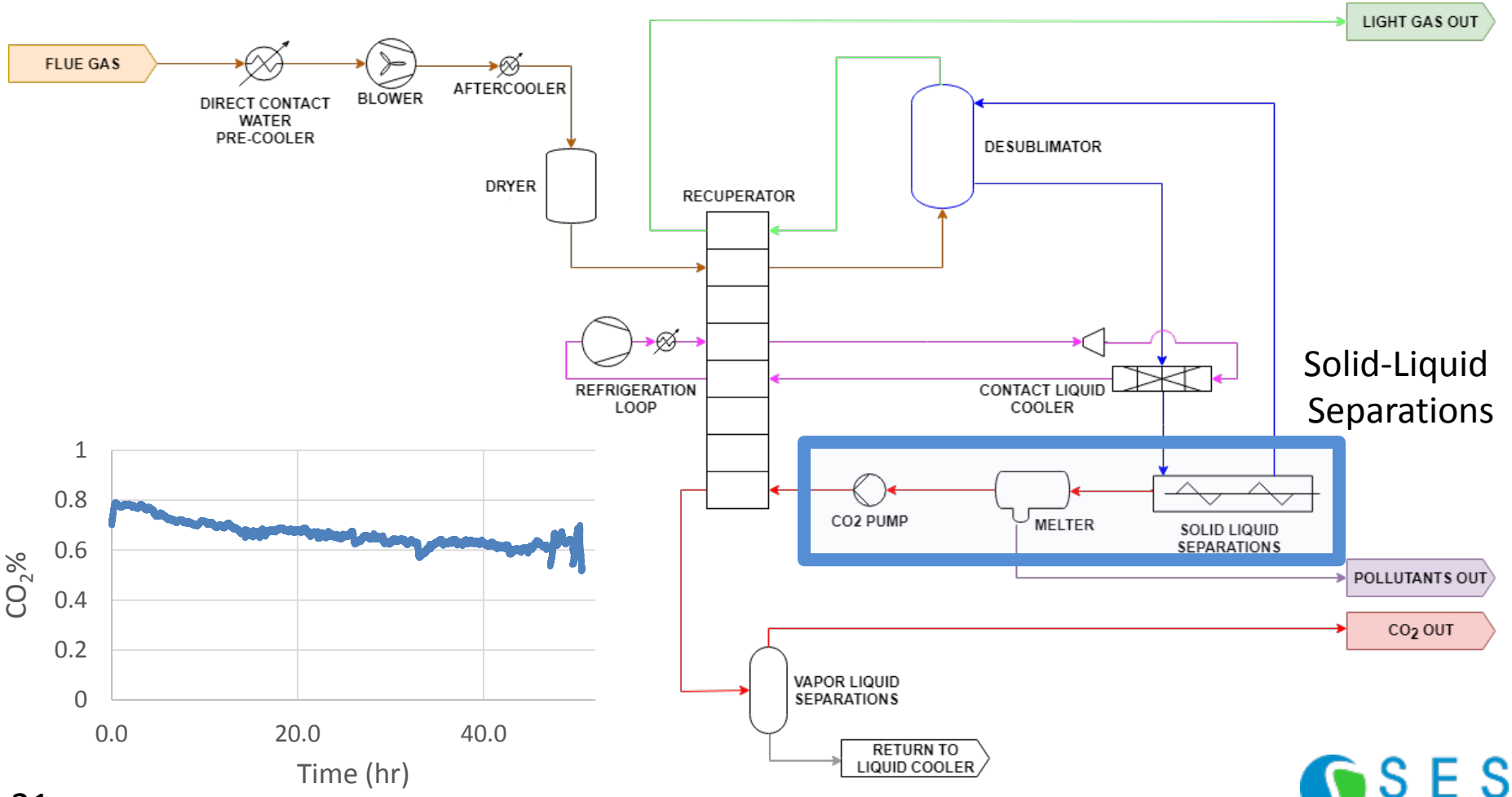
Self-cleaning Shell-and-tube

Particle Based Fluidized Bed



Custom Designed Brazed Plate HX
with Patented Clearing Mechanisms

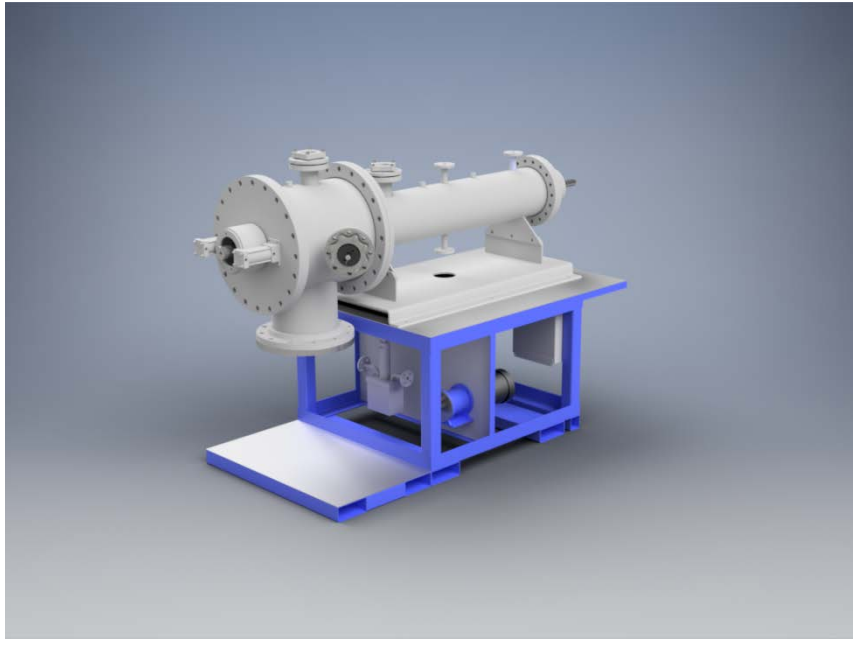
SES INNOVATION



Solid-Liquid Separations

Solid-Liquid Separations

- Increases the concentration of solid CO_2 before melting
- Current implementation is a screw press filtration system



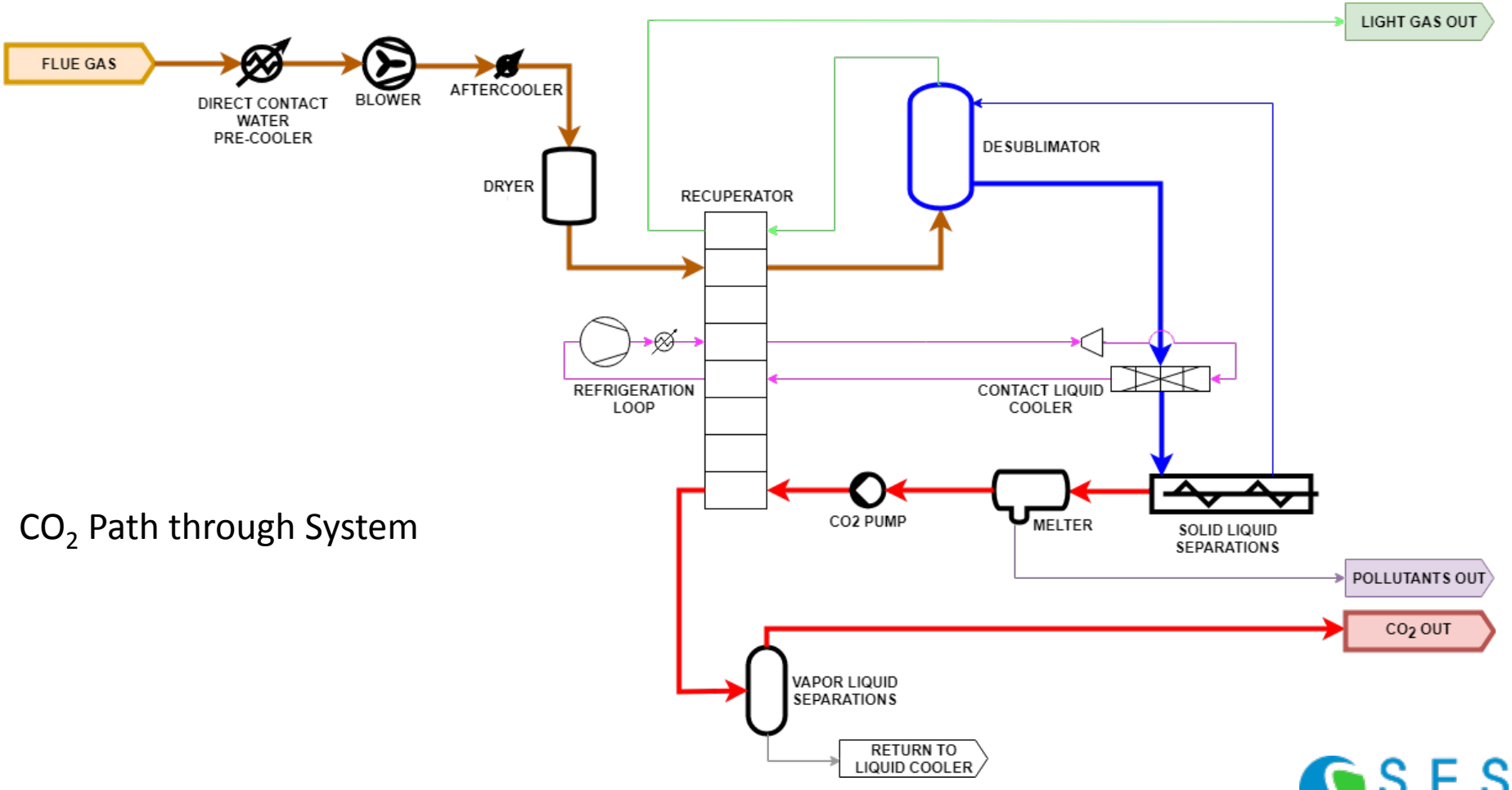
SES INNOVATION

Videos

Solid CO_2 separation:
https://youtu.be/9ZzIlBA3y9I

Solid CO_2 melting:
https://youtu.be/Qomy8H8cX00

SES INNOVATION

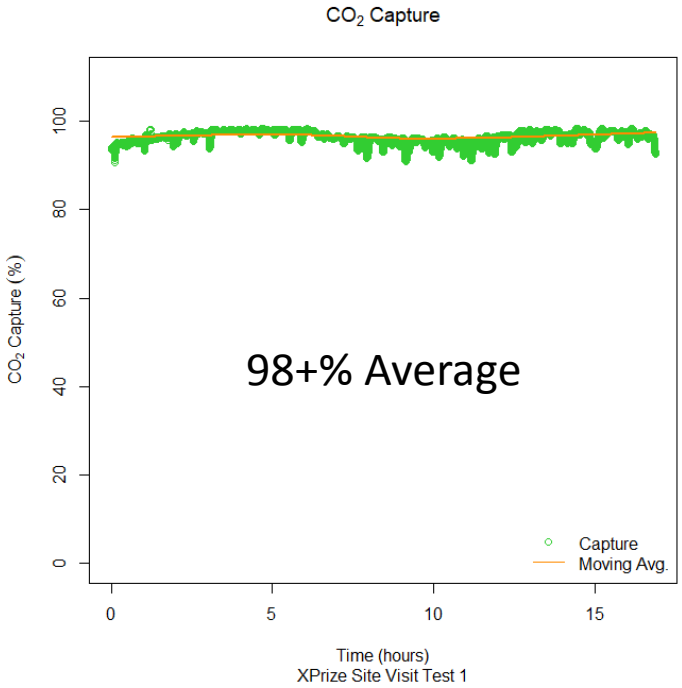


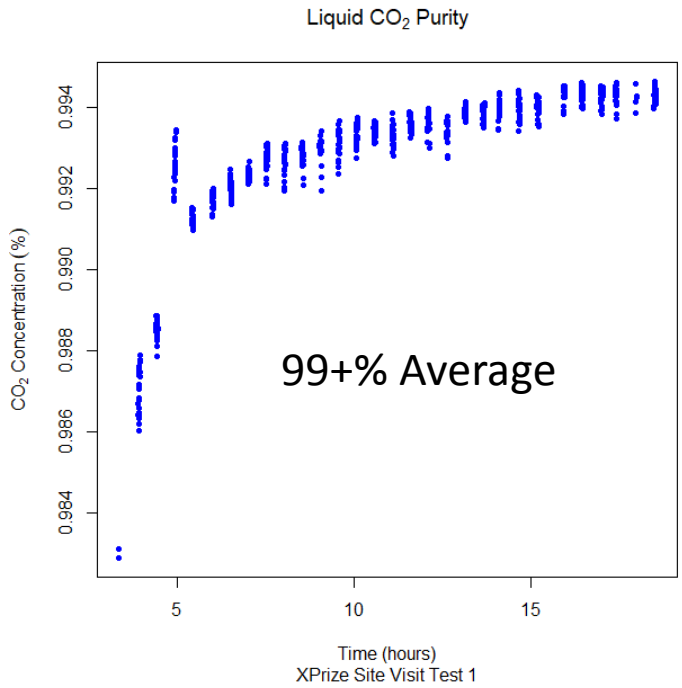
CO_2 Path through System

Final CO_2 Purification

- Commercially Available
- 99.99%+ CO_2 purity and high purity contact liquid

High Capture and Purity





Current Status

- Thousands of cumulative hours for the system and individual unit operations
- Consistently demonstrated high rate of capture
- Preliminary designs and quotes in place for larger pilot scale system
- Next step: six-month demonstration at Pacificorp power plant

SES INNOVATION

Next Step: $25M Pilot Project

Objective: Demonstrate industrial reliability and validate commercial-scale economics

First commercial-scale (100 TPD CO_2 liquid) demonstration

Design and engineering to begin first half of 2019

SES INNOVATION

Acknowledgements

- DOE/NETL Project No. DE-FE0028697
  - $3.7M DOE/$4.7M total
  - 10/01/2016 – 03/31/2019
- Lynn Brickett and David Lang of DOE
- SES Employees
- Partners – Pacificorp, EPRI

This material is based upon work supported by the Department of Energy under Award Number DE-FE0028697.

SES INNOVATION