T2C-ENERGY

Biogas to Diesel

Hinkley Center for Solid and Hazardous Waste Management

Funding 2011

CLEANTECH Intelligent Innovations

Funding 2016-Present

GlobalVenture Challenge™ 2010

Winner 2010

MegaWatt VENTURES

Winner 2012

CLEAN TECH OPEN SOUTHEAST

Winner 2013

U.S. DEPARTMENT OF ENERGY

Funding 2016-Present

FESC Florida Energy Systems Consortium

Universities Addressing Florida's Energy Needs

Funding 2008

tbtf Tampa Bay Technology Forum

Innovation of the Year 2013

Forbes

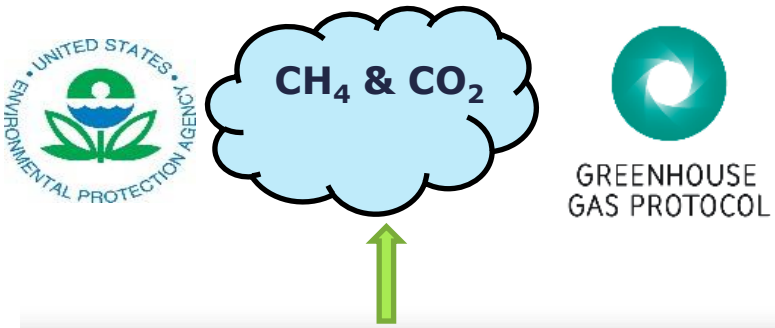
30 Under 30 2014

USF UNIVERSITY OF SOUTH FLORIDA

VENTUREWELL 20 years of idea to impact

Funding 2014

Problem/Opportunity



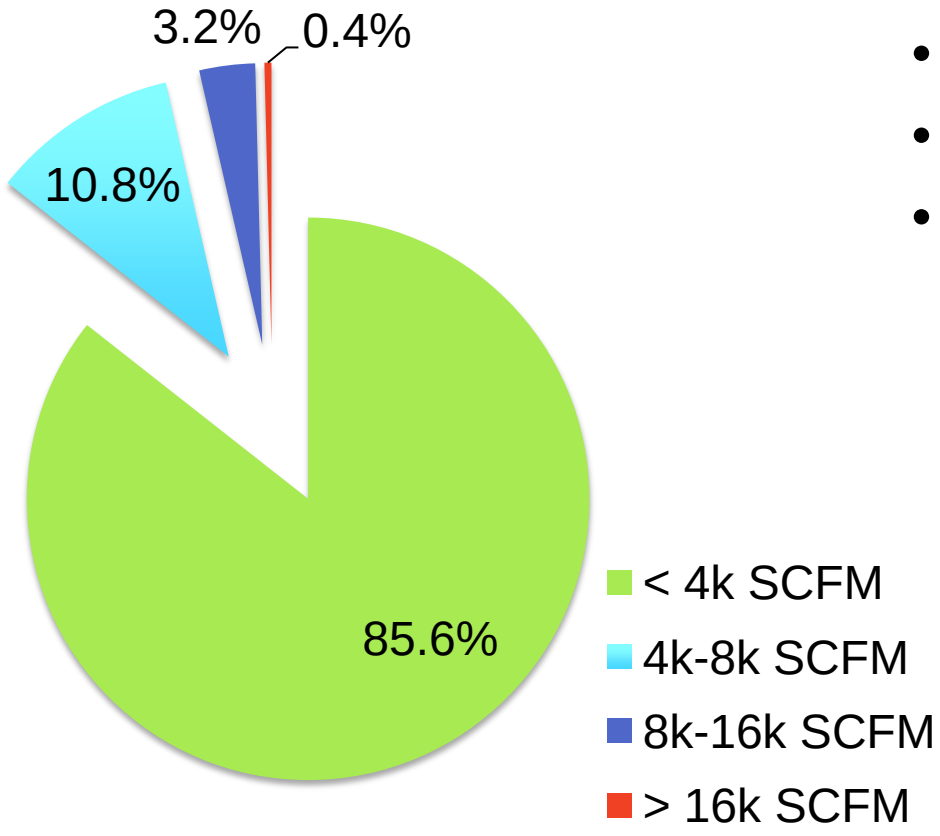
234 MM tons/year of Garbage

- 2,450 Landfills in US
- 20% of Human Source of Methane
- Requirement to Capture and Mitigate
- RFS Increase in RVO
- Waste Industry Consumes ~ 4% US Diesel consumption
- Ag Industry Consumes ~3% US Diesel Consumption
- AD Technology Advancements (~1,500 projects operating in US)

Current Issues

Total US Biogas Generation Rate ~ 800,000 SCFM

Landfill LFG Collection Rate



What's the best use of this energy resource?

- Electricity generation
- Biomethane
- Gas to Liquids

Key Factors

Economics

Infrastructure

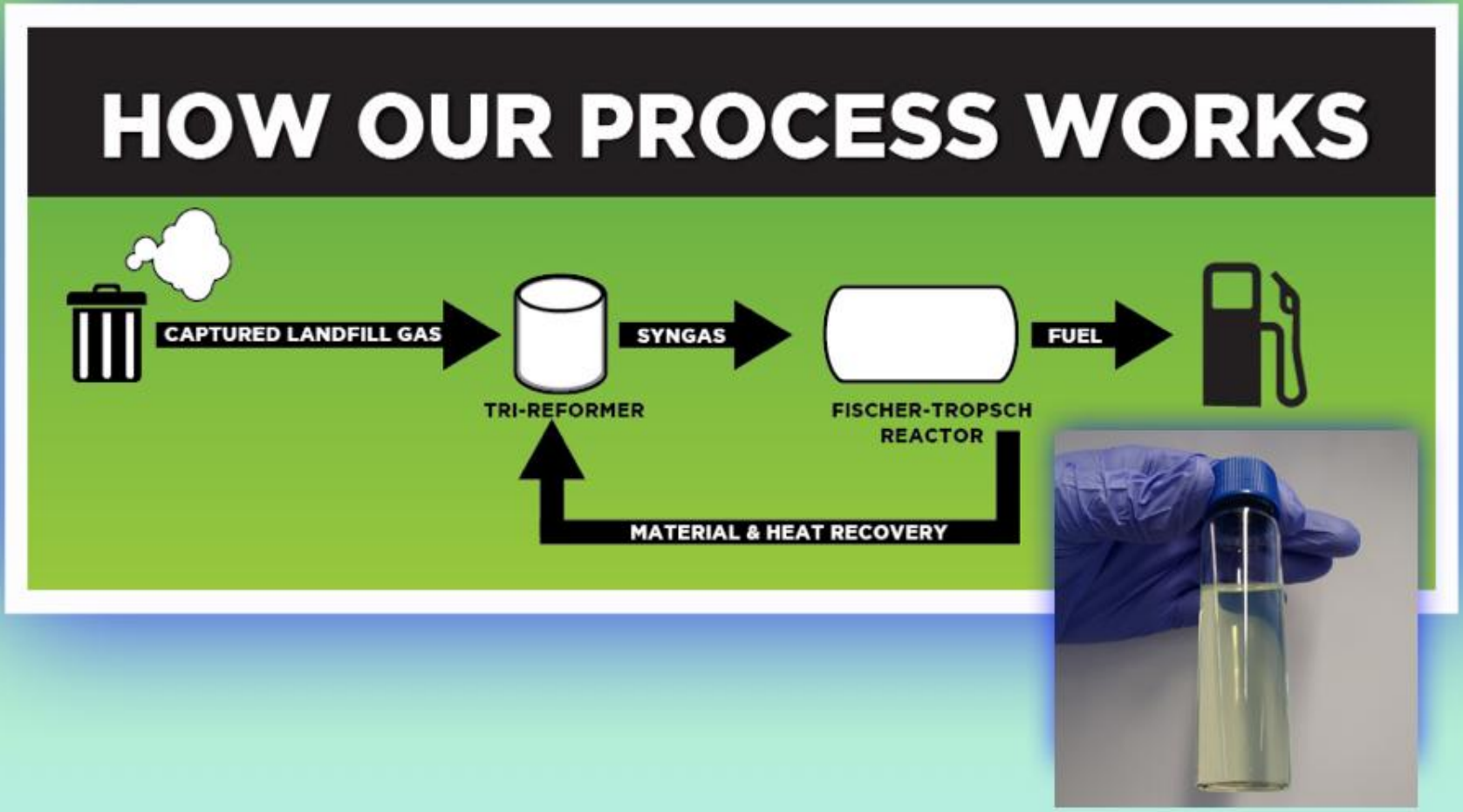
Location

Efficiency

Policy

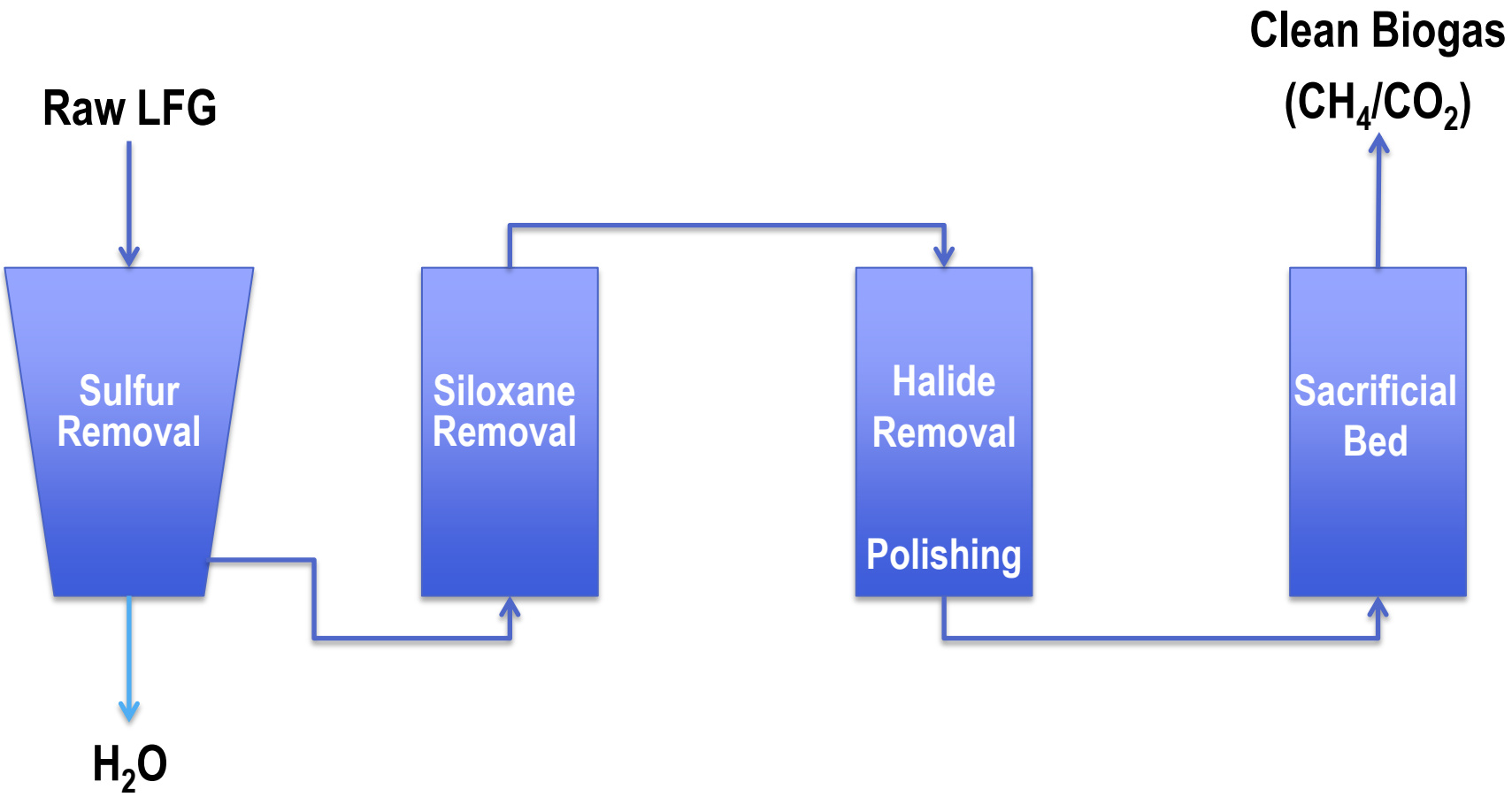
Focus and Technology

Demonstrate small scale GTL in economical and profitable manner



Project Overview

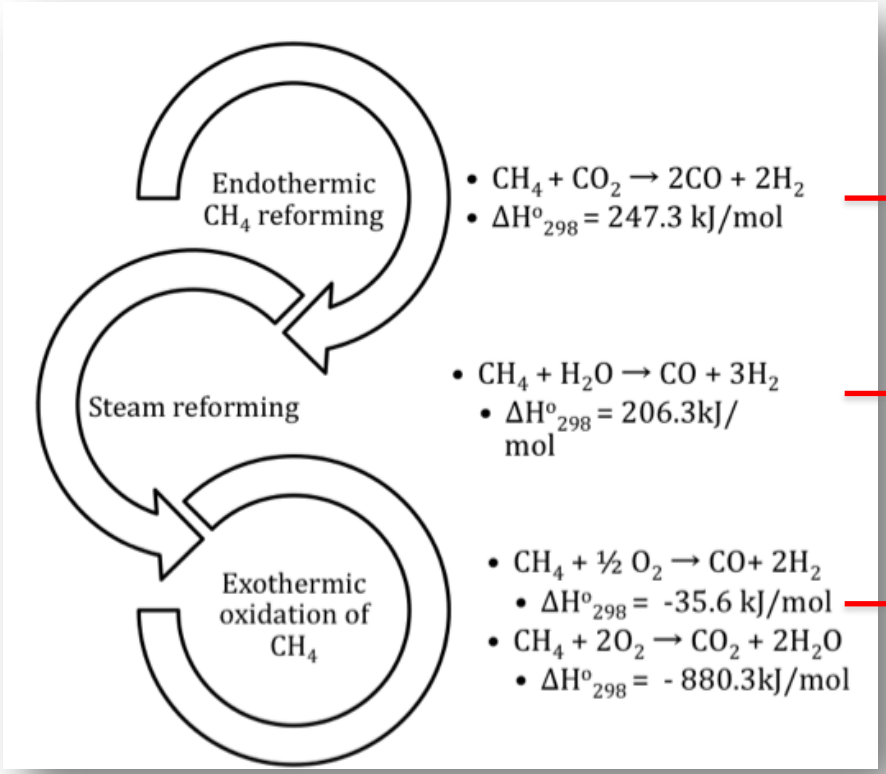
Trace Contaminant Pretreatment



Project Overview

Tri-reforming:

- Minimize cleanup and pretreatment process (No CO_2 removal)
- Less energy consumption
- Produce high quality syngas (H_2:CO ~ 2)



Utilize 100% of biogas as feedstock

Control H2 and CO selectivity

Generate heat in-situ

Project Overview

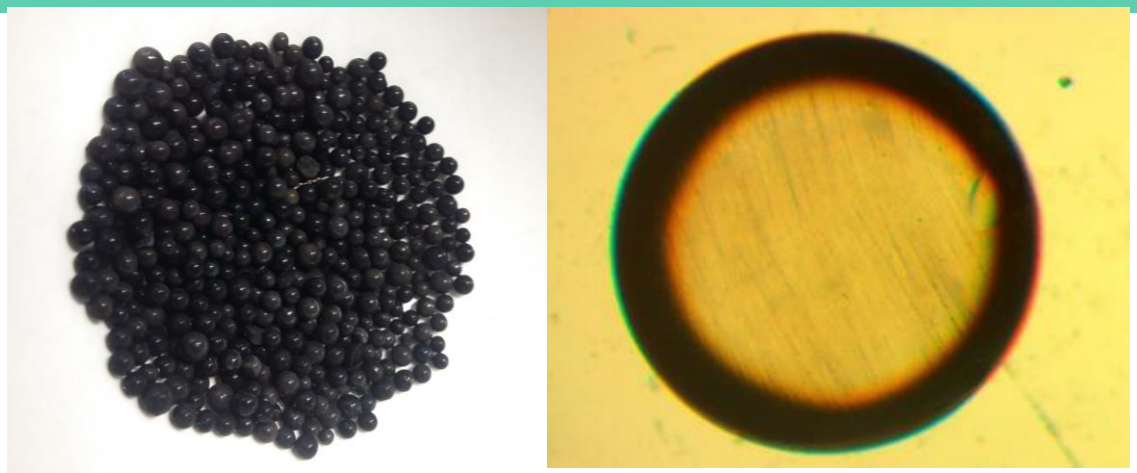
Tri-reforming of LFG

Catalyst Bed temp. (°C)	GHSV (h^{-1})	CH_4 conv. (%)	CO_2 conv. (%)	H_2:CO
770-810	30,000	92-99	52-72	1.70-2.23

Catalyst Optimization

Thermally Stable
High Surface Area
Coke Resistant
High OSC
Excellent Redox Properties
High Dispersion
Excellent Selectivity
High Activity
Economical
Low Pressure Drop

Project Overview



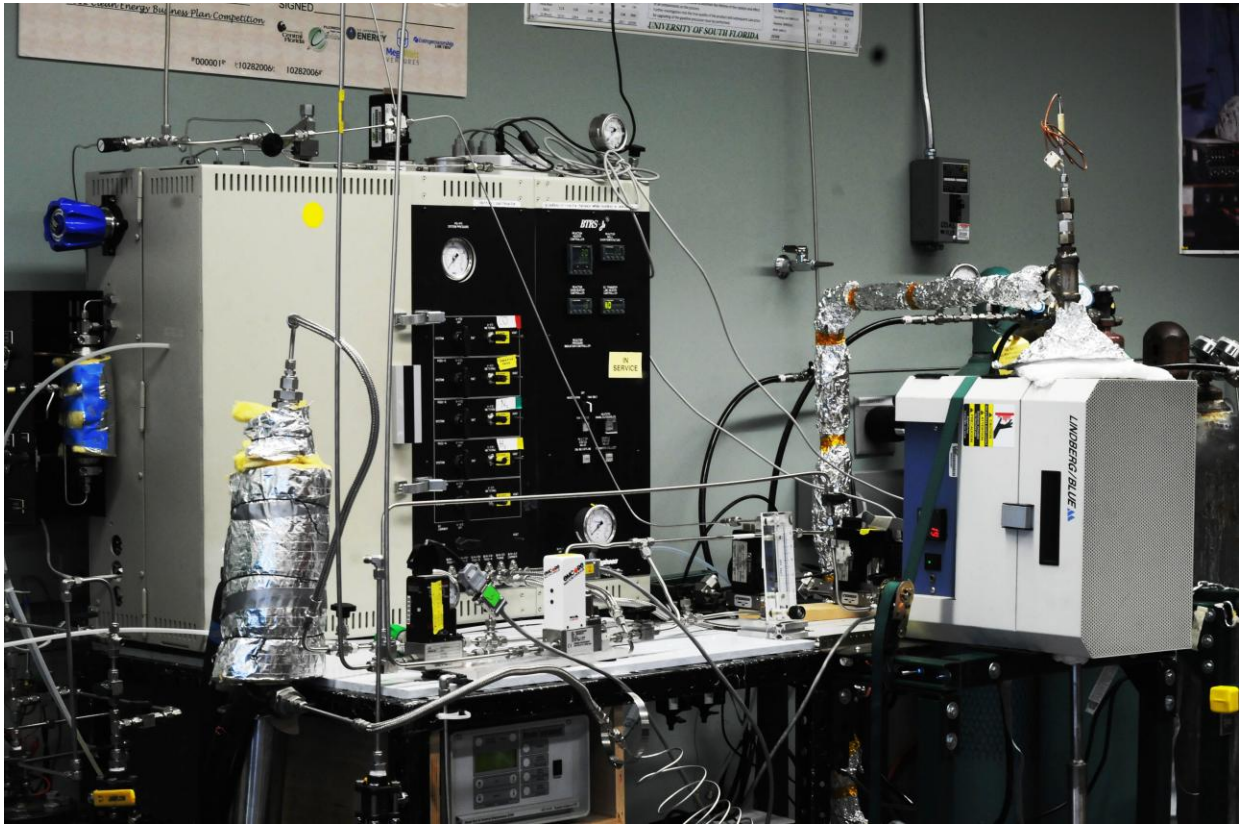
FTS Eggshell Catalyst

- Overcome mass and heat transfer limitations
- Selective product distribution in middle distillate region
- Avoid wax production

CO % Conv	LFG Energy Recovery In Liq Fuel (%)	Selectivity (%)		
		C_{1-4}	CO_2	C_{5+}
71	40	43.7	1.4	55.0

Project Overview

Benchscale TRIFTS Unit



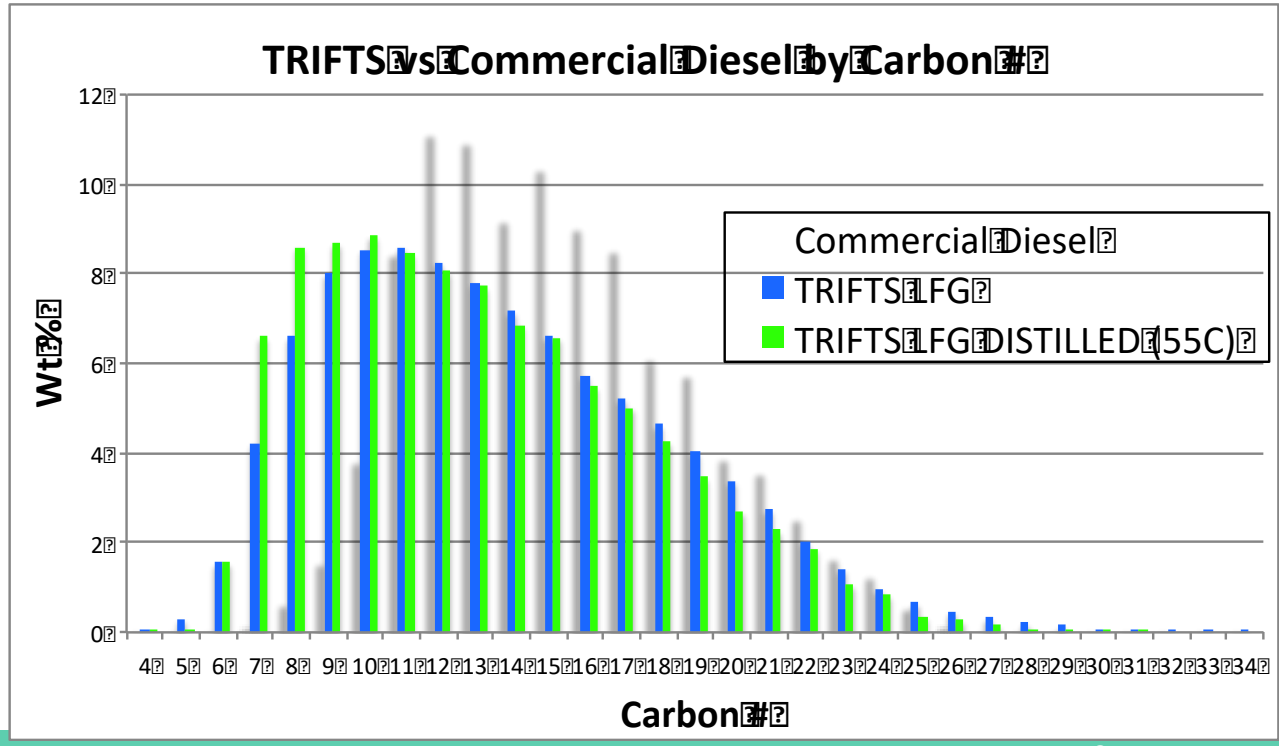
- **Optimize process conditions**
- **Facilitate Pilot/Demonstration Design**
- **Plug bench data into ASPEN**
- **Update full scale techno-economic analysis**

Project Overview

Fuel Analysis

- Low aromatics improve net heat of combustion and reduce soot
- Isomers improve cold temp properties
- Further reduce olefin content w/ addition of catalyst promoters
- Excellent middle distillate boiling point distribution
- Control phase separation temp to fractionate light ends
- Final boiling point aligns with commercial diesel

Hydrocarbon Family	T2C-E (H2:CO=1.7)	Commercial Diesel
Paraffins	67.164	19.95
Isomers	28.243	31.6
Olefins	4.323	0.92
Aromatics	0.02	39.48
Cyclics	0.25	8.05



Project Overview

ASTM D975 “Standard Specification for Diesel Fuel Oils”

Fuel Analysis Results

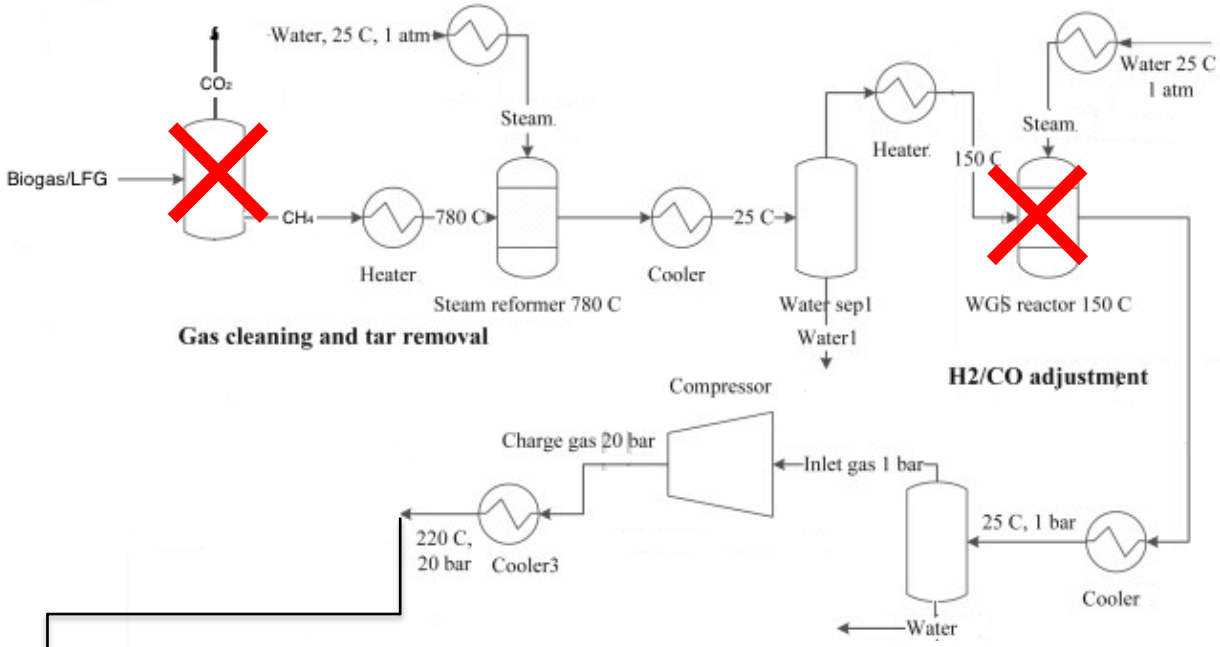
Fuel Analysis, ASTM Standard	Spec (No. 2 Diesel)	Commercial Diesel	TRIFTS LFG	TRIFTS LFG (Dist 55C)
Specific Gravity, ASTM D4052 (g/cc)		0.8215	0.7386	0.7489
Cetane Index, ASTM D976	≥ 40	57.6	84.5	72.7
Cetane Index, ASTM D4737	≥ 40	59.7	92.3	83.4
Flash Point, ASTM D93 (°C)	≥ 52	87	49	57
Cloud Point, ASTM D2500 (°C)		-6	-6	-3
Pour Point, ASTM D97 (°C)		-9	-9	-6
Distillation, ASTM D86 (°C)				
IBP: 0.5wt%		203	143	142
10%		220	164	154
50%		269	234	216
90%	282-338	329	327	314
FBP: 99.5%		378	388	378
Net Heat Comb., ASTM D3338 (MJ/kg)		43.164	44.520	44.355

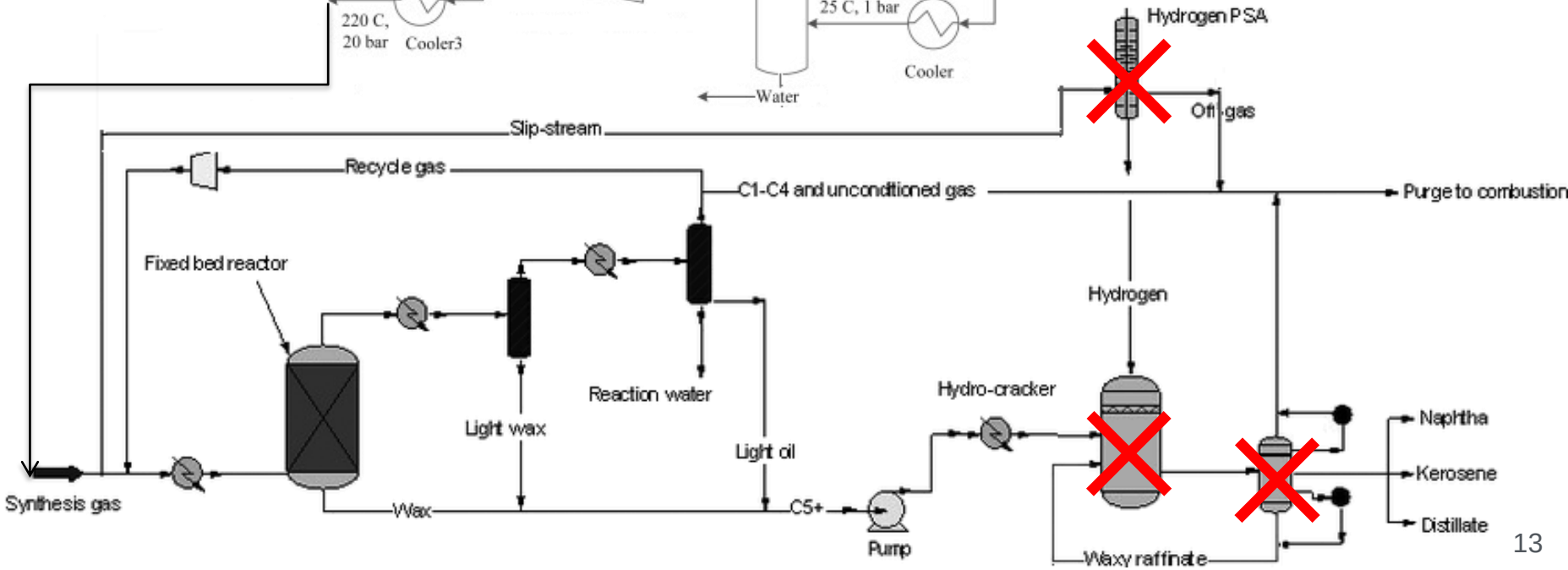
Pilot/Demonstration Scale Up

35 SCFM LFG Feed → **111 Gal/Day Diesel**

Example of skid mounted unit

Key Challenges and Approach





Key Challenges and Approach

- Reformer energy requirement met by FTS fuel gas
- Efficient heat integration
- Utility requirements provided by process itself
- Overall self sufficient process
- Minimize any outside fossil fuel derived energy inputs

Energy Requirements and Generation from 1500 scfm LFG Plant		
	BTU/hr Required	BTU/hr Produced
Reformer requires	4,472,000	
Fuel Gas Energy Content		2,488,465
Boiler	1,820,786	
LFG cooler	160,414	
Reformer HX		2,319,143
Syngas cooler	1,807,500	
FTS cooler	8,451,114	
FT reactor		9,761,143
Compressor 1	399,112	
Air Compressor	258,223	
Compressor 2	1,287,300	
Compressor 3	1,068,006	
TOTALS		
Equip/RXN Required	4,724,456	
Energy Produced		9,568,751
Net Energy Produced		4,844,295
Additional Electric Power Generation	0.86	MW

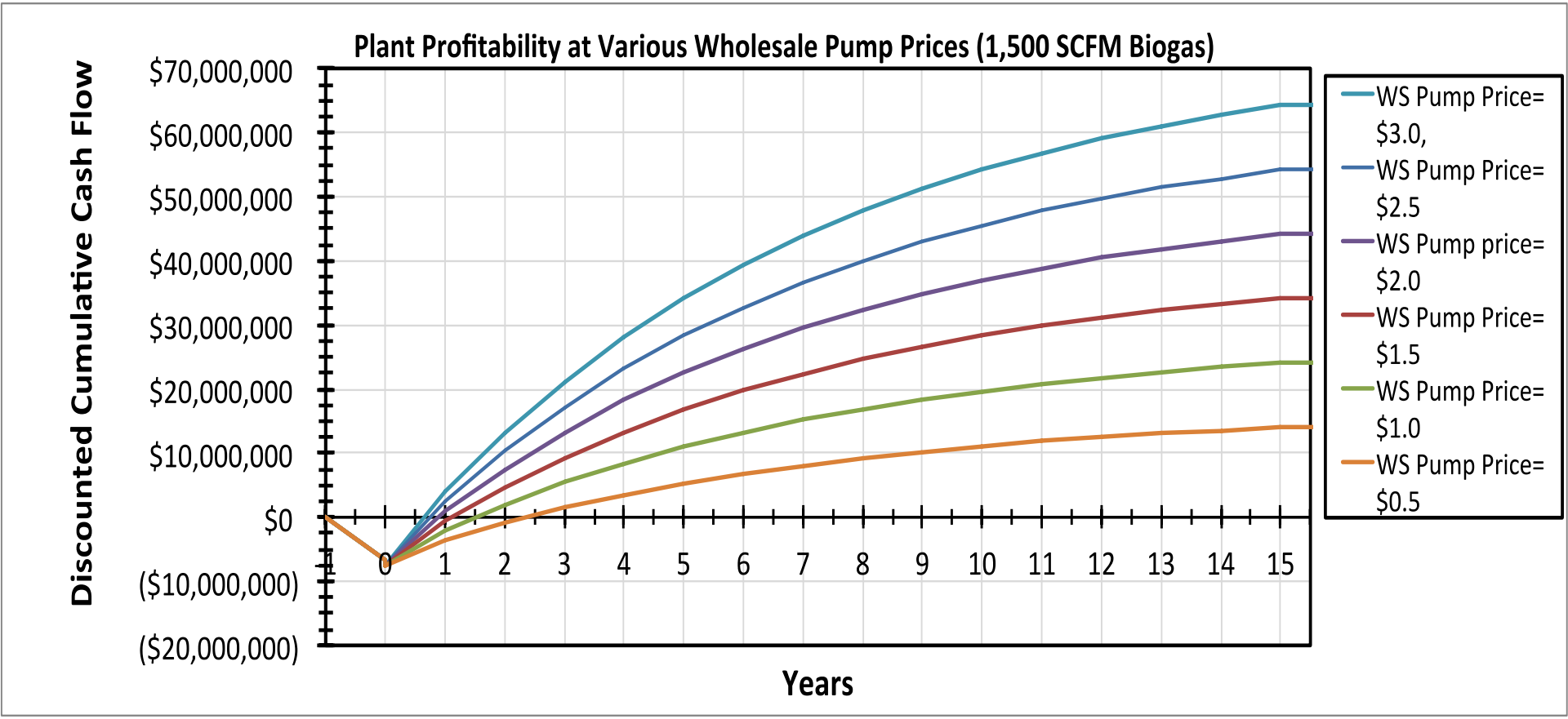
Financials

Scale (LFG Flowrate SCFM)	CAPEX	Annual OPEX	Annual Revenue	Annual Profit
500	$3.5 MM	$550 k	$3.5 MM	$2.1 MM
1000	$5.2 MM	$800 k	$7 MM	$4.5 MM
1500	$6.7 MM	$1 MM	$10.5 MM	$7.0 MM
2000	$7.9 MM	$1.2 MM	$14 MM	$9.5 MM
2500	$9.1 MM	$1.4 MM	$17.5 MM	$11 MM
3000	$10.1 MM	$1.6 MM	$21 MM	$14 MM
3500	$11 MM	$1.8 MM	$24.5 MM	$16.8 MM
4000	$11.9 MM	$2 MM	$28 MM	$19 MM

Assumptions

- 15% Interest Rate
- 35% Corporate Tax
- 5.5% FCI Maintenance Budget
- 7 Full Time Staff
- Wholesale Pump Price = $1.63
- RIN = $4.47/gal diesel (D3 ~ $2.63/RIN) EV=1.7

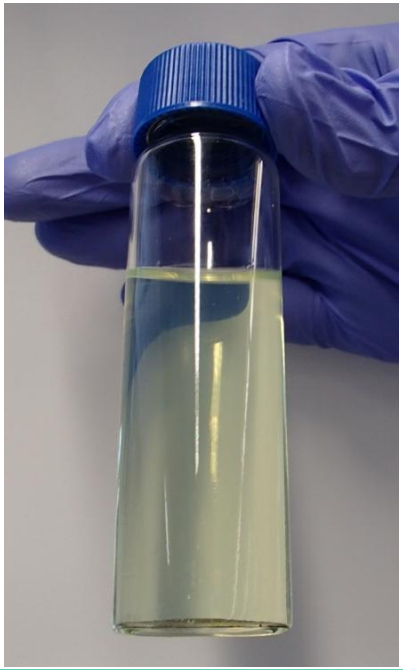
Financials (1,500 SCFM Biogas)
118 bpd (5k gal/day) Diesel Facility



- At current WS pump price of 1.63 NPV = $34MM
- RIN = $4.47/gal diesel (D3 ~ $2.63/RIN)
- Initial Construction Capital $6.7 MM
- Breakeven No RIN credit at 900 SCFM biogas production rate

Unique Aspect Summary

- **Utilize 100% of Biogas Feedstock (CO_2 Utilization)**
- **Significant Reduction of Unit Operations**
- **Compatible with Current Infrastructure**
- **High Quality Value Add Product (Drop-In Diesel)**
- **Self Sufficient Process**
- **Produce D3/D7 RIN**
- **Vastly Improved Economics and Profitablitliy**



Management Team

Devin Walker
CEO

Dr. John Kuhn
President

Dr. Babu Joseph
VP

Timothy Roberge
CFO

Dr. Ali Gardezi
CTO

- 40+ Years in Biofuel Industry
- Recognized Industry Leaders
- Proven Track Record in Technology Scale Up
- Partnered with USCleantech and Renovare Fuels as part of US and Global Business Strategy

Questions

Sustainable Solutions for The Waste To Energy Sector