Novel Sorbent to Clean Biogas for Fuel Cell Combined Heat & Power Systems

DE-EE0001184

TDA Research, Inc. & FuelCell Energy, Inc.

6/30/2010 – 9/30/2014

Dr. Gökhan O. Alptekin
TDA Research, Inc.
Wheat Ridge, CO

U.S. DOE Advanced Manufacturing Office Peer Review Meeting
Washington, D.C.
May 6-7, 2014

Project Objective

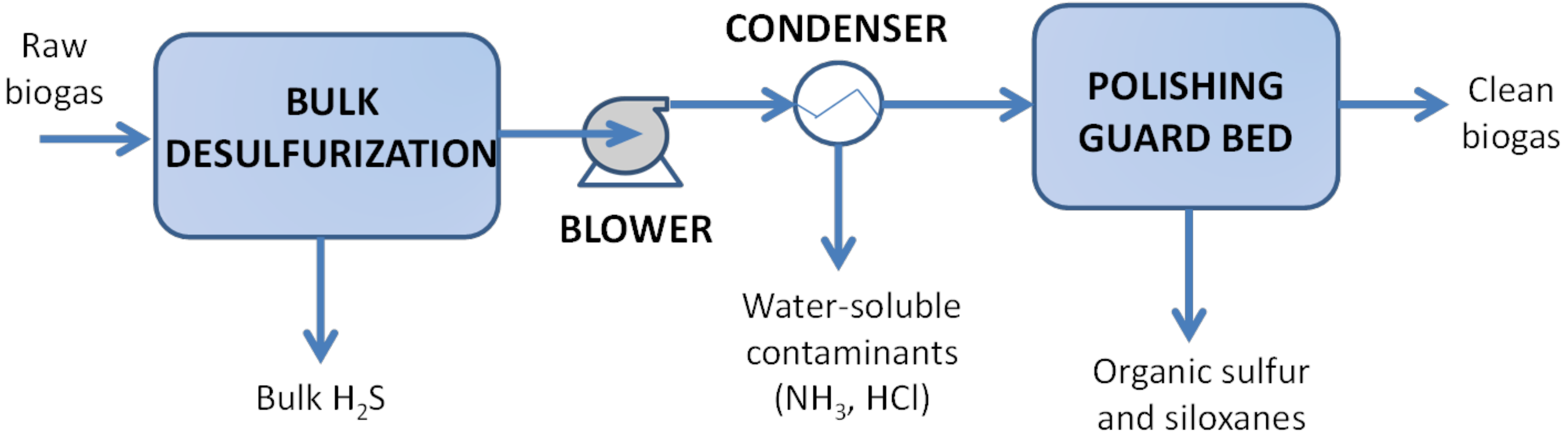
- The objective is to develop a low-cost, high-capacity expendable sorbent to remove both sulfur species in biogas to ppb levels, making its use possible in a fuel cell CHP unit
  - The high concentrations of sulfur species in the biogas (up to 1.5% vol.) poisons fuel cell electro-catalysts and corrodes fuel cell components
- Although most sulfur is present as hydrogen sulfide (H_2S), biogas also contains a variety of organic sulfur species, including dimethyl sulfide, dimethyl disulfide, methanethiol, carbon disulfide and carbonyl sulfide
- Existing processes are not effective for removing organic sulfur species
  - Biological/chemical scavengers or sorbents
- Siloxanes (organic compounds, containing silicon, oxygen and methyl groups) present in the biogas from the wastewater treatment plants also pose a threat

Silica deposits on engine cylinders used in CHP

Technical Approach

- TDA's approach is to use an ambient temperature gas clean-up system to remove all contaminants to ppbv levels
- The sorbent will be downstream of a bulk desulfurization system (biological, liquid redox or solid scavengers)
- No chillers will be needed (conventional siloxane cleanup systems require the use of chillers)

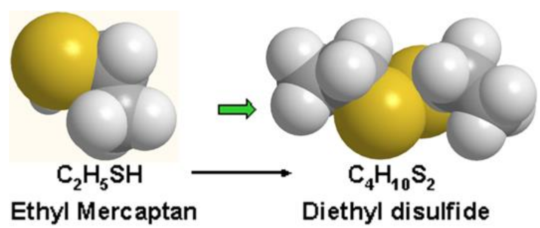
Expendable Sorbent-based Biogas Purification



Technical Approach

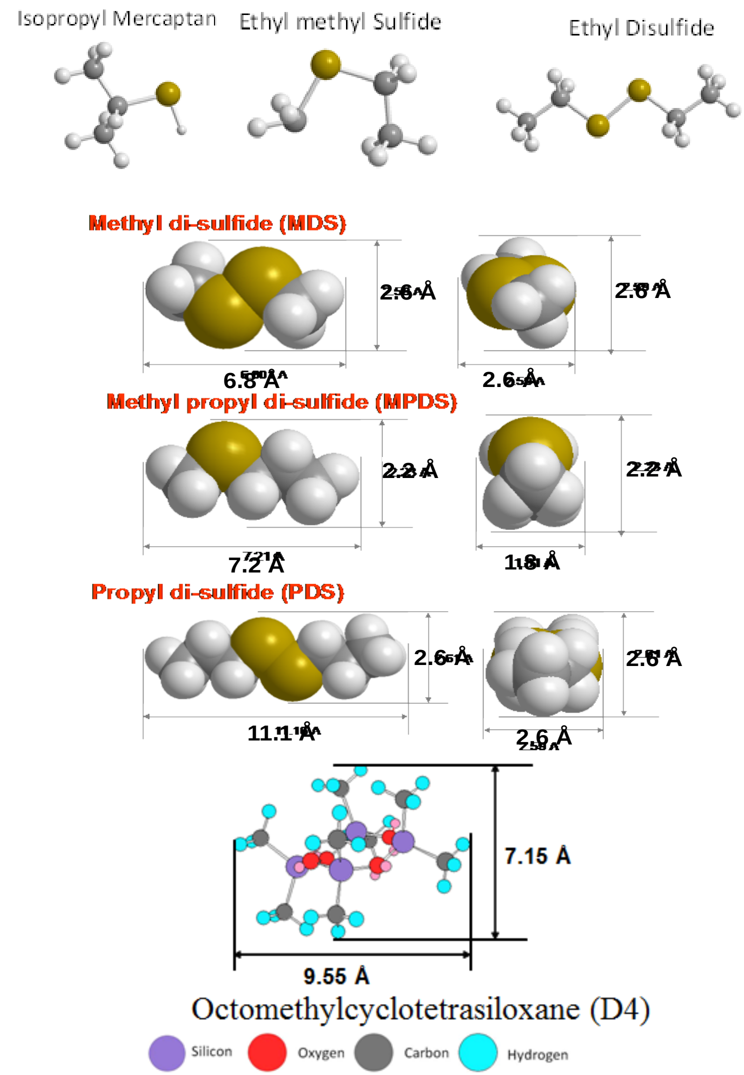
Bulk desulfurization sorbent

- High sulfur capacity (30+% wt. sulfur)
- Low cost <$3-3.25/lb
- No side reactions such as the dimerization reactions (shown below) promoted by Fe-based scavengers



Polishing desulfurization sorbent

- One-step solution to all contaminants
- Mesoporous structure to accommodate large sulfur molecules and siloxanes
- High sulfur capacity (3+% wt. sulfur) in presence of 4,000+ ppmv H2O
- Cost less than $12/lb



Species to be removed by the polishing sorbent

Transition and Deployment

Market/End-users

- The end user of this technology will be the fuel cell companies and their engineering service providers (e.g., site operators)
- Once the technology is fully proven in the field, they will directly purchase the sorbents
- Sorbent manufacturing capability is already in place

Business Strategy

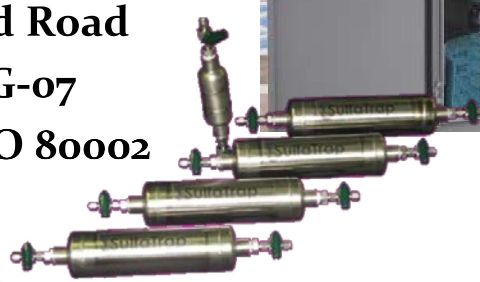
- With DOE funding TDA develops the technology and increases technological readiness by carrying out slipstream and full-scale field demonstrations
- Initial contacts will be established with technology users (fuel cell developers such as FuelCell Energy, ClearEdge, Bloom Energy)
- TDA will then license the technology to its spin-off SulfaTrap LLC

Transition and Deployment

- SulfaTrap LLC was established in 2012 and became fully operational in 2013 to manufacture, market and sell SulfaTrap™ desulfurization sorbents and turn-key desulfurization systems
- SulfaTrap currently supplies ~40% of the world's installed fuel cell capacity
  - 90 m^3 sorbent supplied in 2013 for natural gas and LPG desulfurization

SulfaTrap

5310 Ward Road
Suite G-07
Arvada, CO 80002



Measure of Success

- Removal of sulfur and siloxane species to ppb levels in high moisture gas (single digit ppbv levels at H2O content higher than 4,000 ppmv)
  - Extend the life of the fuel cell components
  - Reduce the maintenance cost such as stack replacement
  - Increase the availability of the fuel cell based power
  - Reduce capital cost (e.g., eliminate gas chillers)
- The operating cost (i.e., sorbent replacement) for sulfur/siloxane removal to be reduced below $0.65/MMBtu
- A detailed economic assessment of the technology is underway FuelCell Energy

Project Management & Budget

- **Project Duration:** 6/30/2010 – 9/30/2014
- **Project tasks and key Milestone schedule:**
  - Task 1. Project Management and Planning
  - Task 2. Sorbent Optimization and Scale-up
  - Task 3. Sorbent Screening
  - Task 4. Verification Testing – Completed on February 15, 2011
    - Develop ADG Sorbent specification – Completed on March 15, 2011
  - Task 5. Slipstream Testing on ADG – Completed on May 31, 2012
  - Task 6. Prototype Testing on ADG – Completion date September 30, 2014
  - Task 7. Cost Analysis and Final Report – Scheduled completion Sep. 30,2014
- **Project budget:**

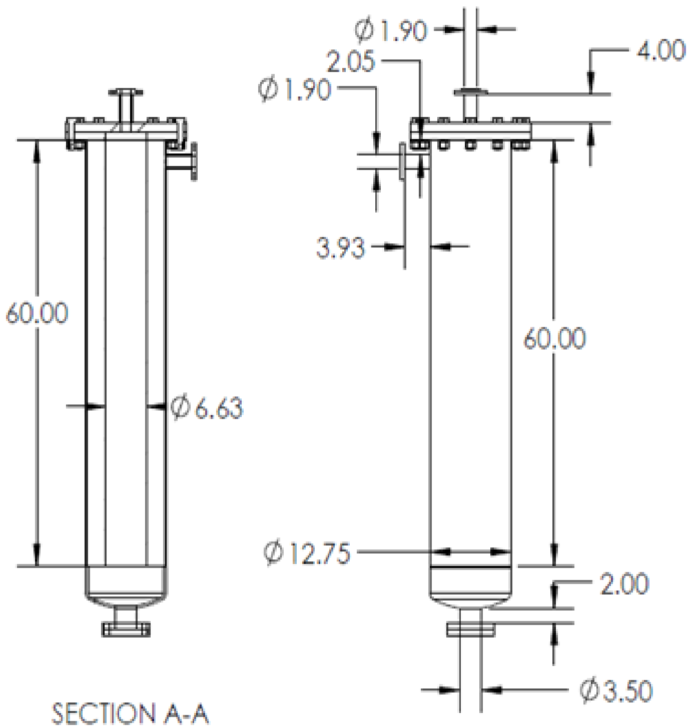
Total Project Budget	
DOE Investment	896,114
Cost Share	431,783
Project Total	1,327,897

Results and Accomplishments

- Scale-up of sorbent manufacturing was completed
- TDA previously completed successful slipstream demonstrations at two sites:
  - Eastern Municipality District Wastewater Plant, Moreno Valley (EMDWP), CA
  - City of Tulare Wastewater Treatment Plant, Tulare, CA
- In each of these 3-month long demonstrations we showed effective operation of both the bulk and polishing sorbents for removal of sulfur and siloxanes
- The design and fabrication of a full scale test unit was completed (will be shipped to Tulare site late May 2014)

Results and Accomplishments

- The highlights of the accomplishments for the current period are:
  - FCE completed shakedown testing of the full-scale lead-lag test system
  - FCE is finalizing site preparation activities for the demonstration in the summer of 2014



TDA provided the full design details

Full-scale Test Unit