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Contaminants Control for Fuel Cells – FCE Experience

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Ultra-Clean, Efficient, Reliable Power

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This presentation contains forward-looking statements, including statements regarding the Company's plans and expectations regarding the development and commercialization of fuel cell technology. All forward-looking statements are subject to risks and uncertainties that could cause actual results to differ materially from those projected. The forward-looking statements speak only as of the date of this presentation. The Company expressly disclaims any obligation or undertaking to release publicly any updates or revisions to any such statements to reflect any change in the Company's expectations or any change in events, conditions or circumstances on which any such statements are based. The Company may refer to non-GAAP (generally accepted accounting principles) financial measures in this presentation. The Company believes that this information is useful to understanding its operating results and the ongoing performance of its underlying business.

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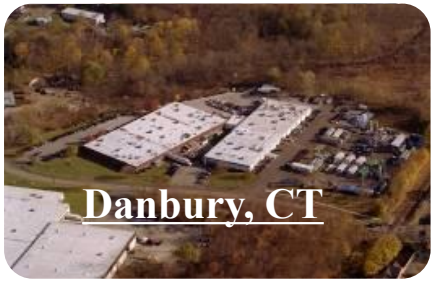
FuelCell Energy

- **Premier developer of stationary fuel cell technology**
- **More than 40 years of fuel cell development and commercialization experience**
- **Offers DFC products**
  - **100 MW capacity**
  - **Production rate of 70 MW/year**
- **Established commercial relationships with major partners and end users in the Americas, Europe, and Asia**



Global Technology and Manufacturing footprint

CO, USA/Calgary, Canada
SOFC Research

Ottobrun, Germany (*FCES*)
Capacity for European market

Pohang, South Korea (*POSCO Energy*)
Capacity being built for Asian market

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Integrated Fuel Cell Company

Design

Megawatt–class distributed power generation solutions

Manufacture

Global manufacturing footprint

- *North America*
- *Europe*
- *Asia via partner*

Sales

Direct & via Partners

Installations & orders in 9 countries

EPC*

Project Development and Project Finance, Engineering & Construction

Over 300 megawatts installed and in backlog

** Engineering, Procurement & Construction*

Services

Operate & maintain power plants

- *Over 100 DFC® plants operating at more than 50 sites globally*
- *Two billion kWh ultra-clean power produced*

Providing turn-key distributed power generation solutions that meet both economic and sustainability goals

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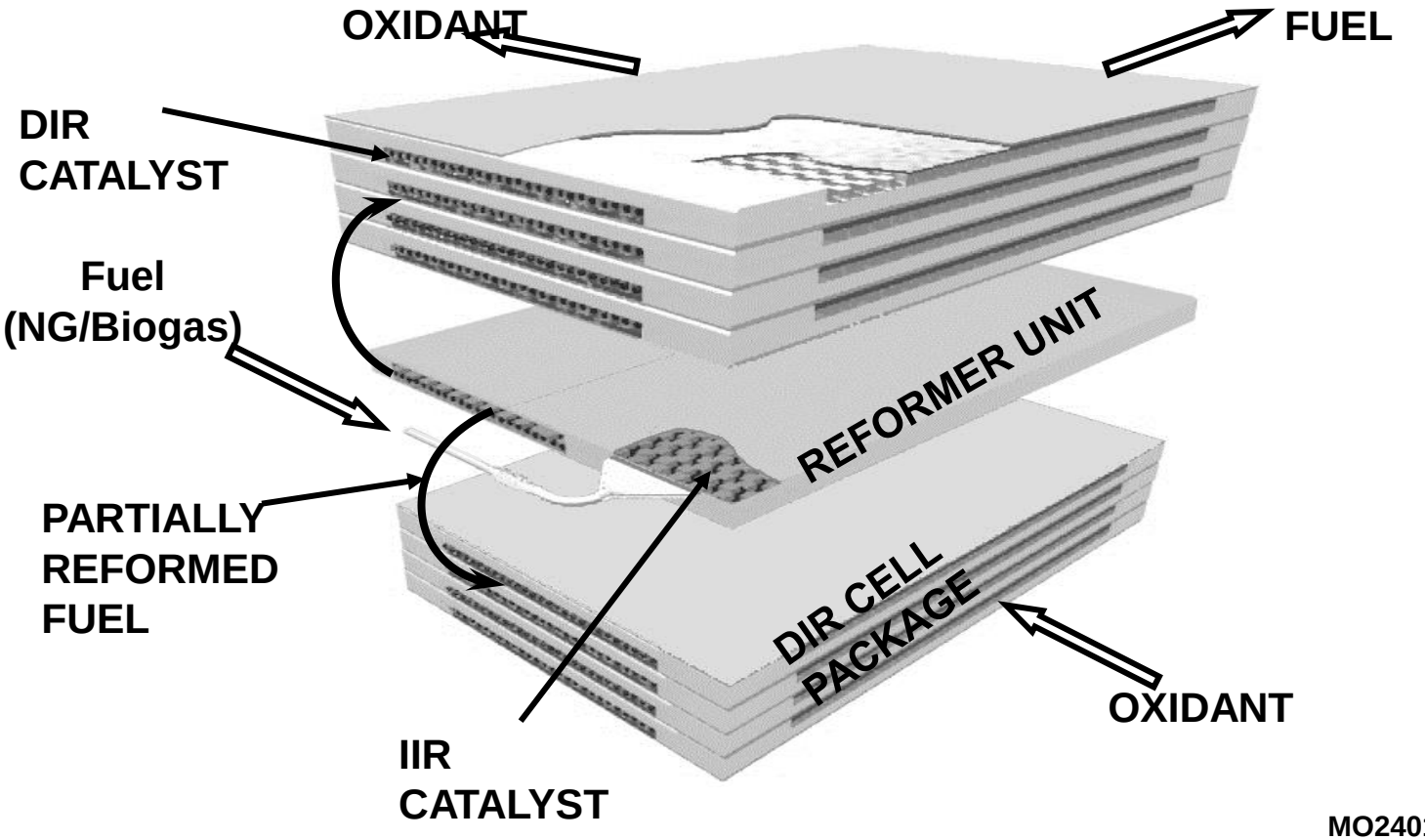
DFC Configuration



Integrates Indirect and Direct Reformers; has low sulfur tolerance

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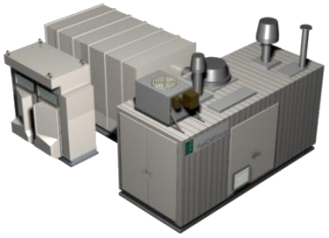
DFC Products

Cell Package and Stack

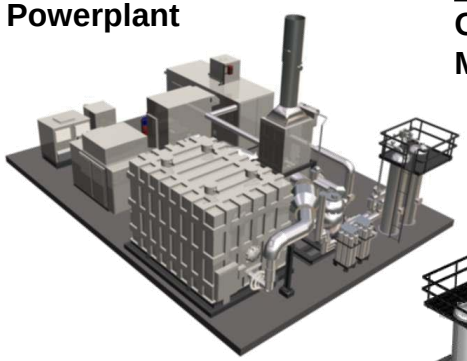
Single-Stack Module

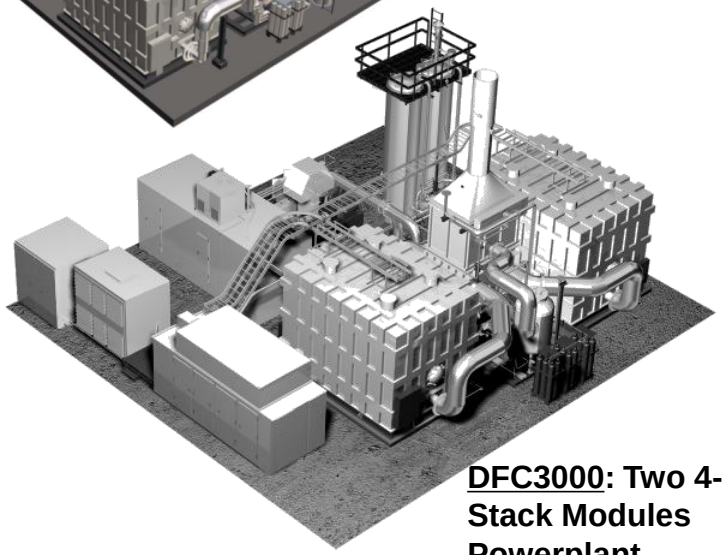
Four-Stack Module



DFC300
Single 1-Stack Module Powerplant

DFC1500B
One 4-Stack Module Powerplant





DFC3000: Two 4-Stack Modules Powerplant

Fuels Experience

DFC Fuels Experience

- Natural Gas
- Liquefied Natural Gas (LNG)
- Propane
- Biogas (by Anaerobic Digestion)
  - Brewery
  - Municipal Waste Water Treatment
  - Food Waste
  - Animal Waste
- Coal-bed methane

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Typical Fuels and Impurities

Impurities	Natural Gas		LNG		Biogases (wet)				
	Dry	wet	Cntry 1	Cntry 2	Brewery	Waste Water	Food Waste	Animal Waste	Landfill
%									
Oxygen (Vol)	<0.2	<0.2	0	<0.1	<0.5	<1	<1	<1	<2
Moisture	<154 ppm	0.2	<2ppm	<2ppm	>3	>3	>3	>3	>2
(ppm)									
H_2S	<0.1	<0.1	0	0	20-300	20-3000	80-10000	20-2000	10-2000
COS	**<0.3**	**<0.2**	0	<0.03	0	<0.1	<0.1	<0.1	<0.1
Mercaptans	<3	<3	<2	<2	0	<1	<3000	<30	<30
DMS	**<1**	**<1**	0	<2	0	**<0.2**	**<0.2**	**<0.2**	**<0.5**
THT	**<3**	**<3**	<2	0	0	0	0	0	0
Siloxanes	0	0	0	0	0	5-30	0	0-30	5-100
Halogens	<0.05	<0.05	0	<0.05	0	<0.2	<0.2	<0.2	**<100**

Sulfur Control Design Considerations

Sulfur clean-up system desired attributes

1. Low cost-of-electricity impact
    1) Low first time cost (capital)
    2) Low maintenance cost
2. Reliability (Simplicity)
3. Low parasitic power consumption

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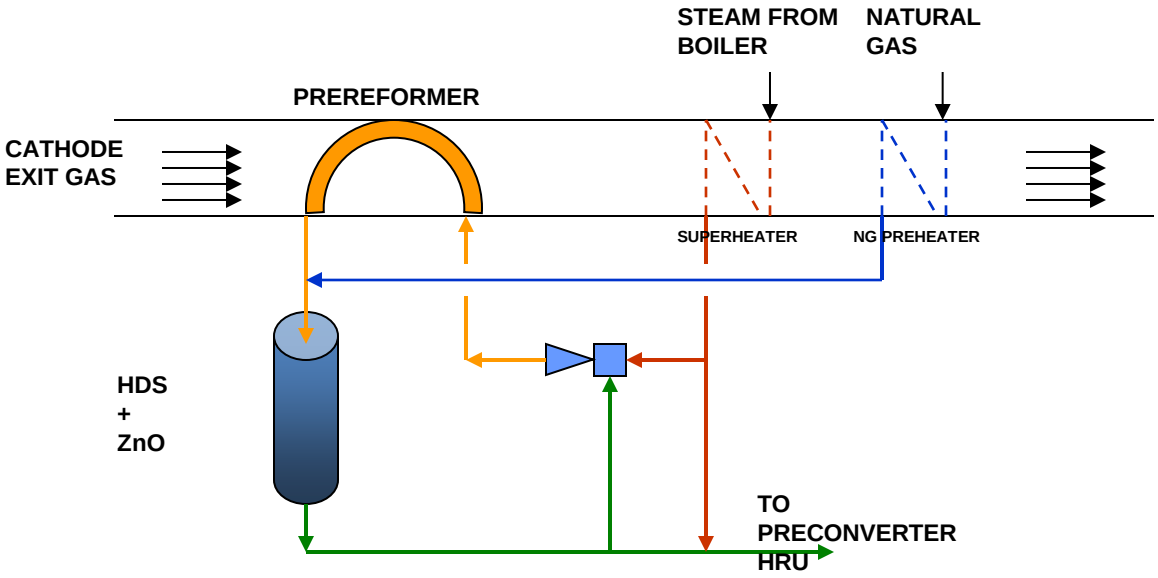
FCE Initial Experience-HDS System

- Santa Clara Demonstration (1995 – 1996)
  - 1.9 MW DFC Fuel Cell used HDS system
- Take-away from initial experience (HDS compared to cold cleanup)
  - More complex, higher risk to reliability
  - Higher initial cost for smaller systems
  - May be practical for large installations or fuels having certain contaminant challenges.



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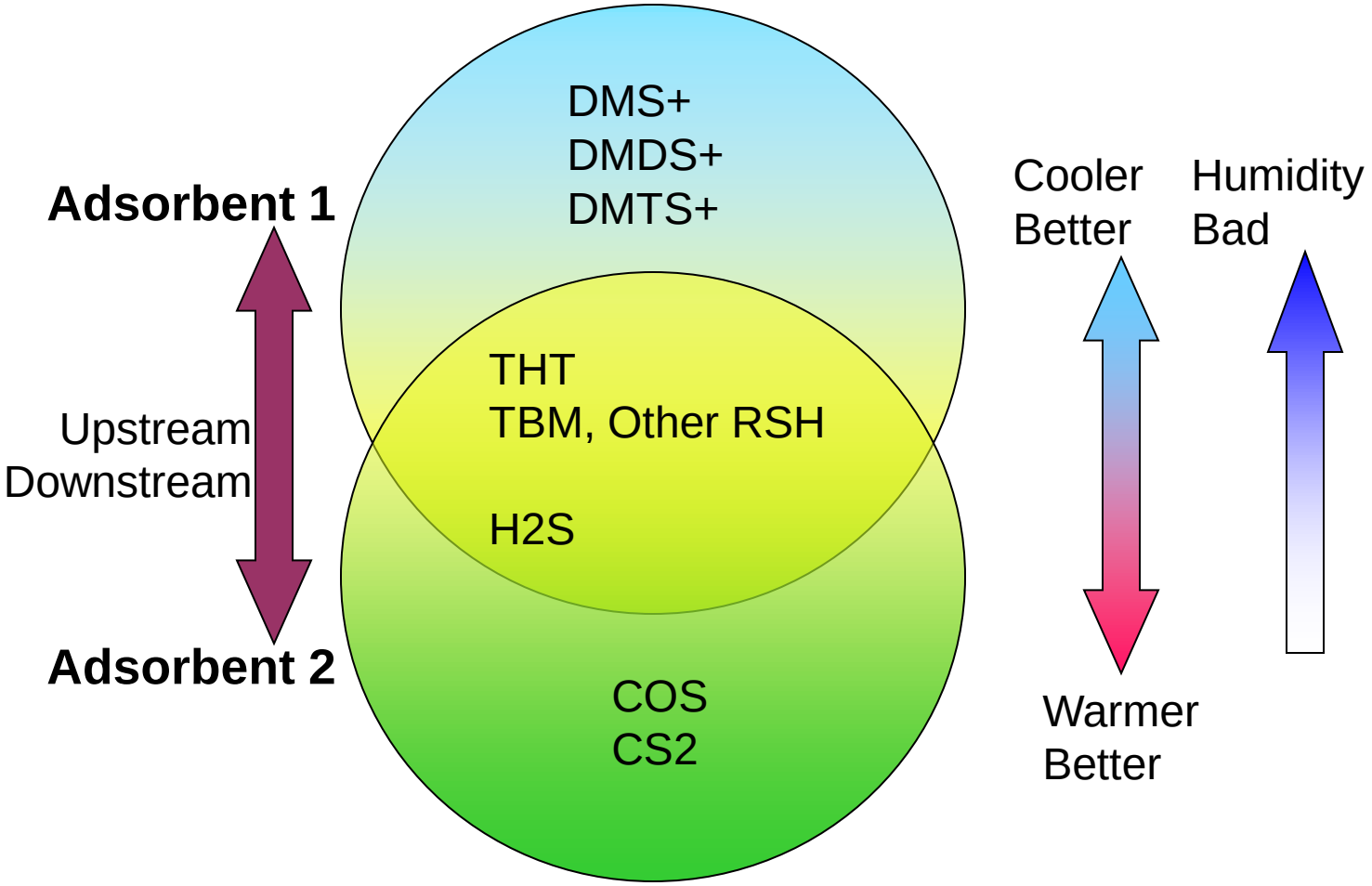
Two-Adsorbent System

Adsorbents Paired for Effective Control



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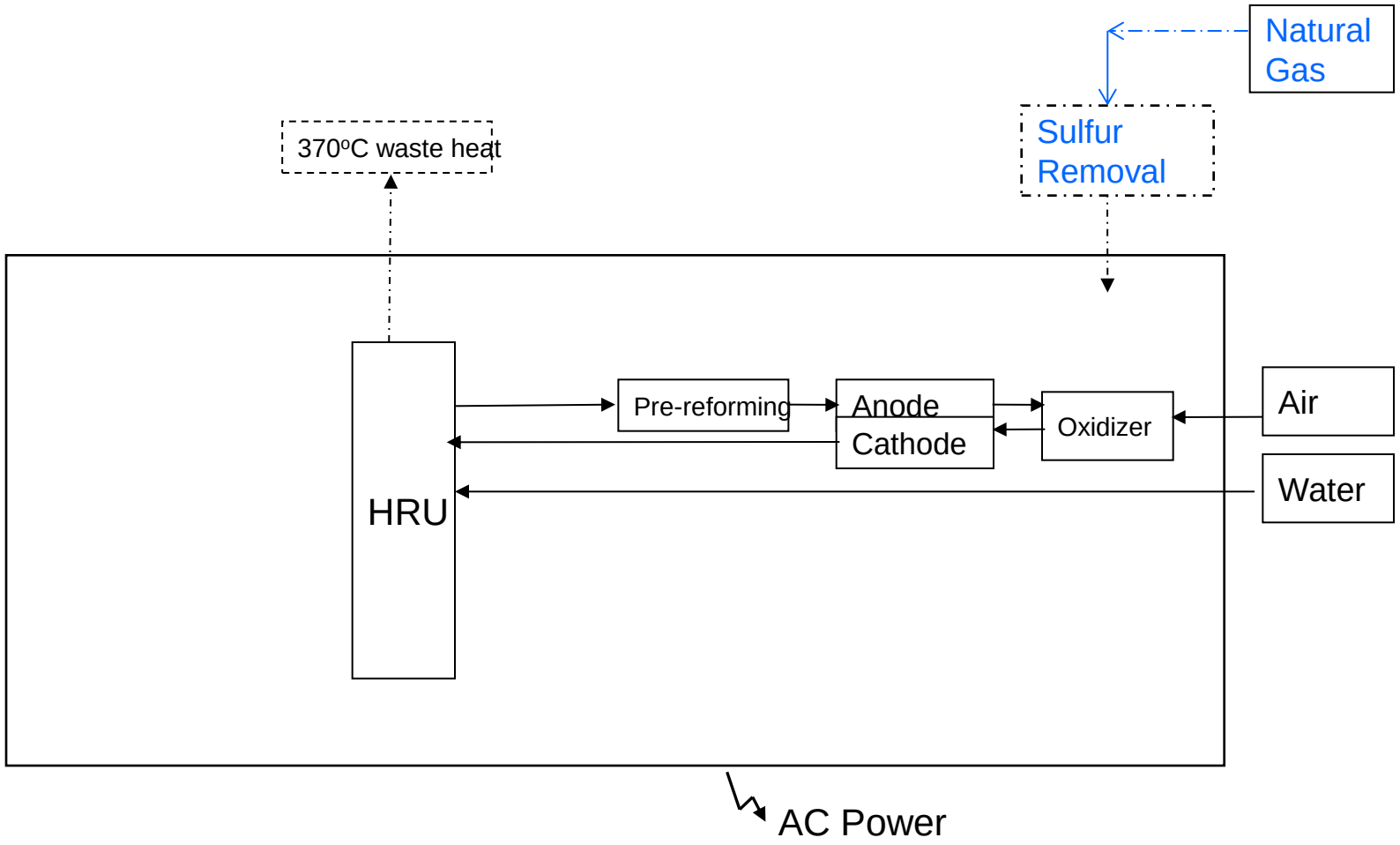
Natural Gas DFC with Sulfur Clean-up



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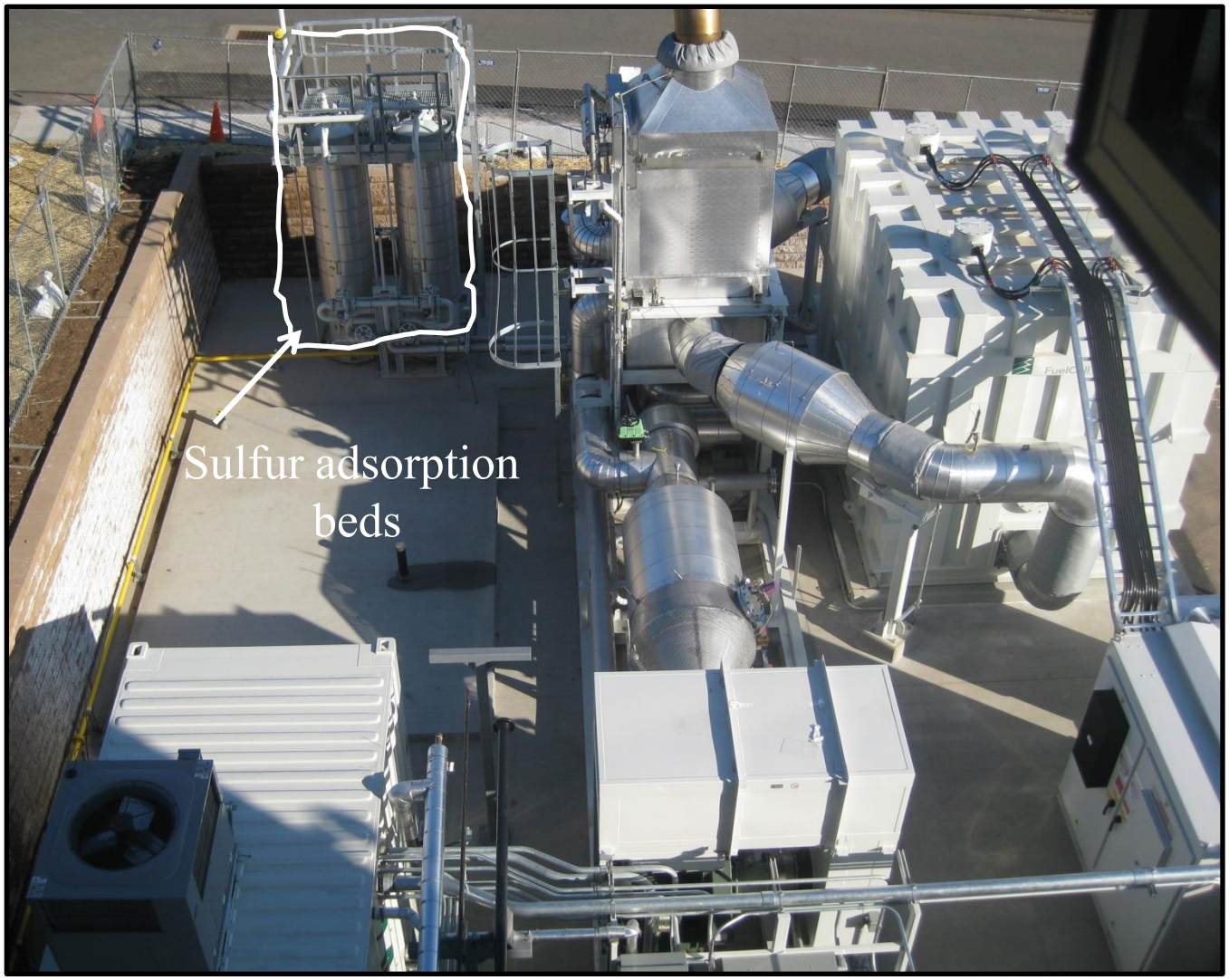
1.4 MW DFC Plant



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Consolidated Cleanup System

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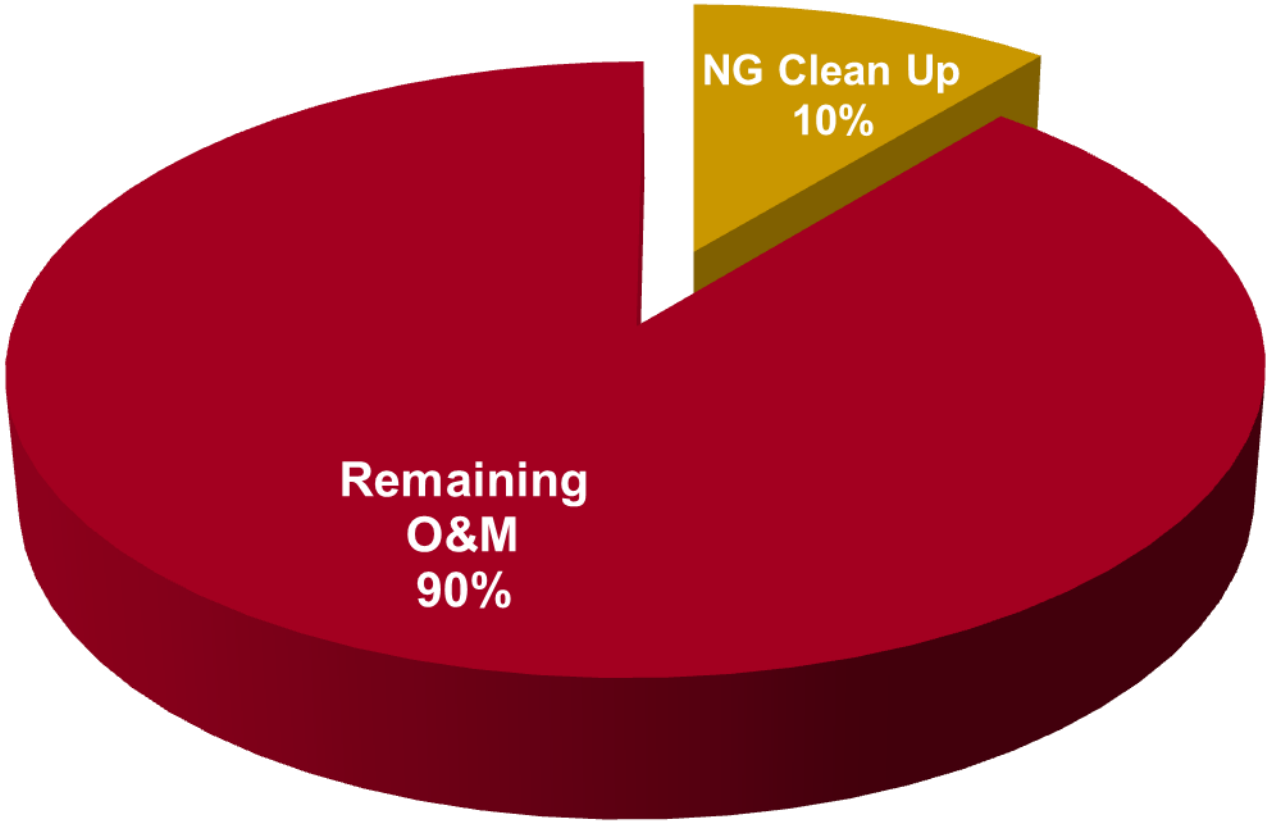
Natural Gas Units – BOP O&M Costs Breakdown



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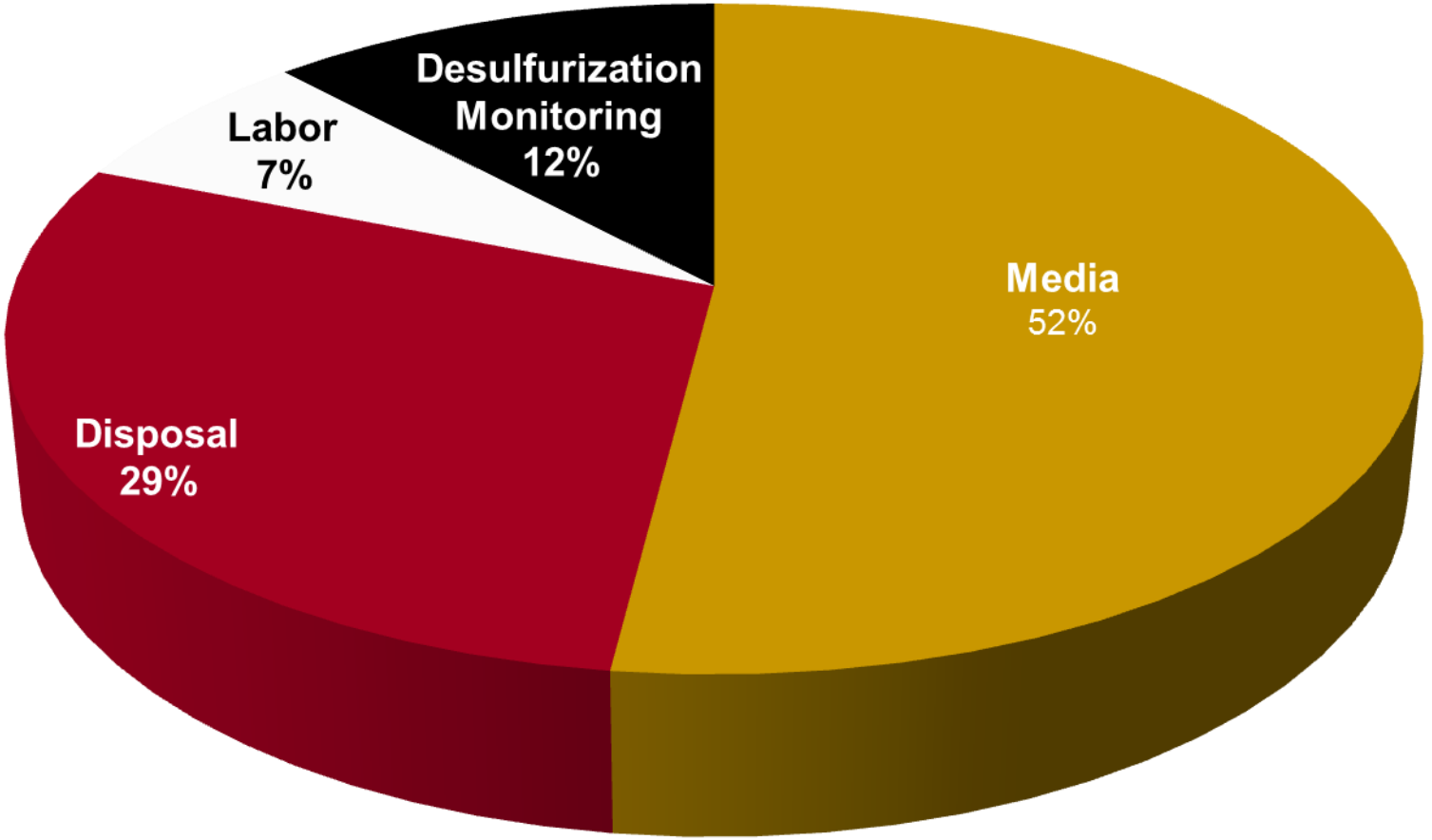
Natural Gas Clean-up – BOP O&M Costs Breakdown



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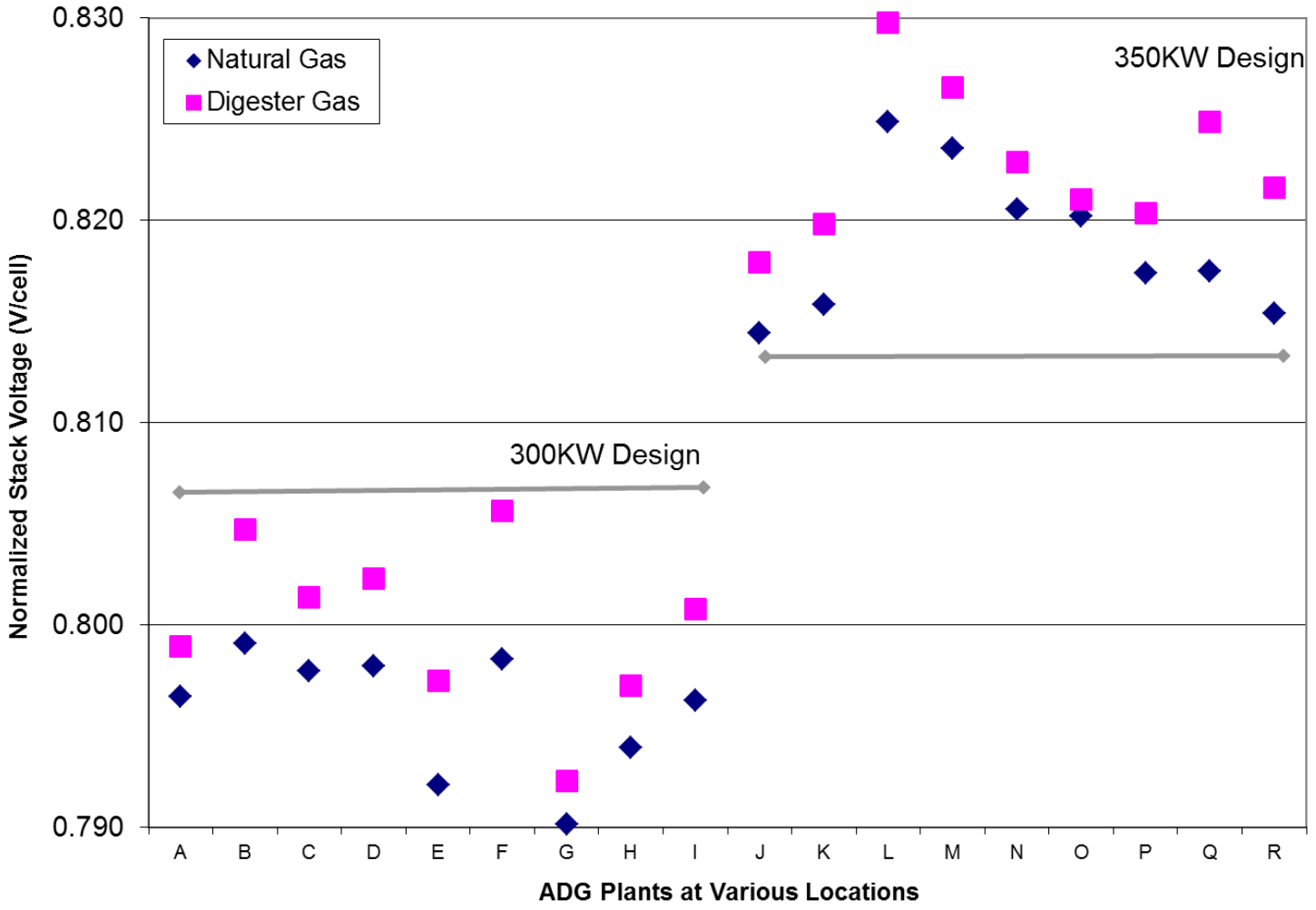
DFC Performance – ADG vs. NG

Consistently higher performance on ADG



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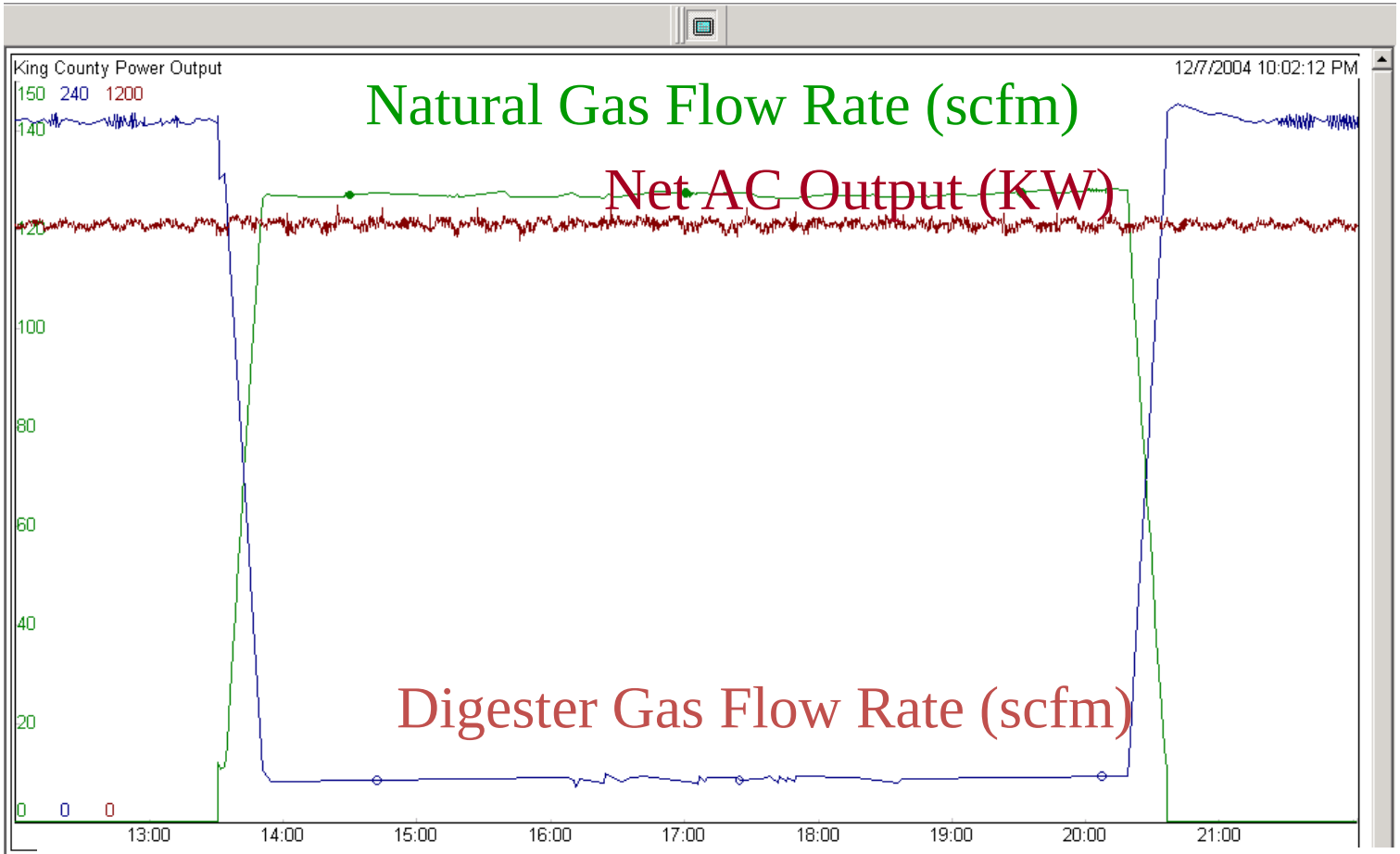
Example of Enhanced Reliability Operation on Biogas



Automatic fuel switch from DG to NG with minimum DG flow
Followed by another fuel switch back to DG, while maintaining output

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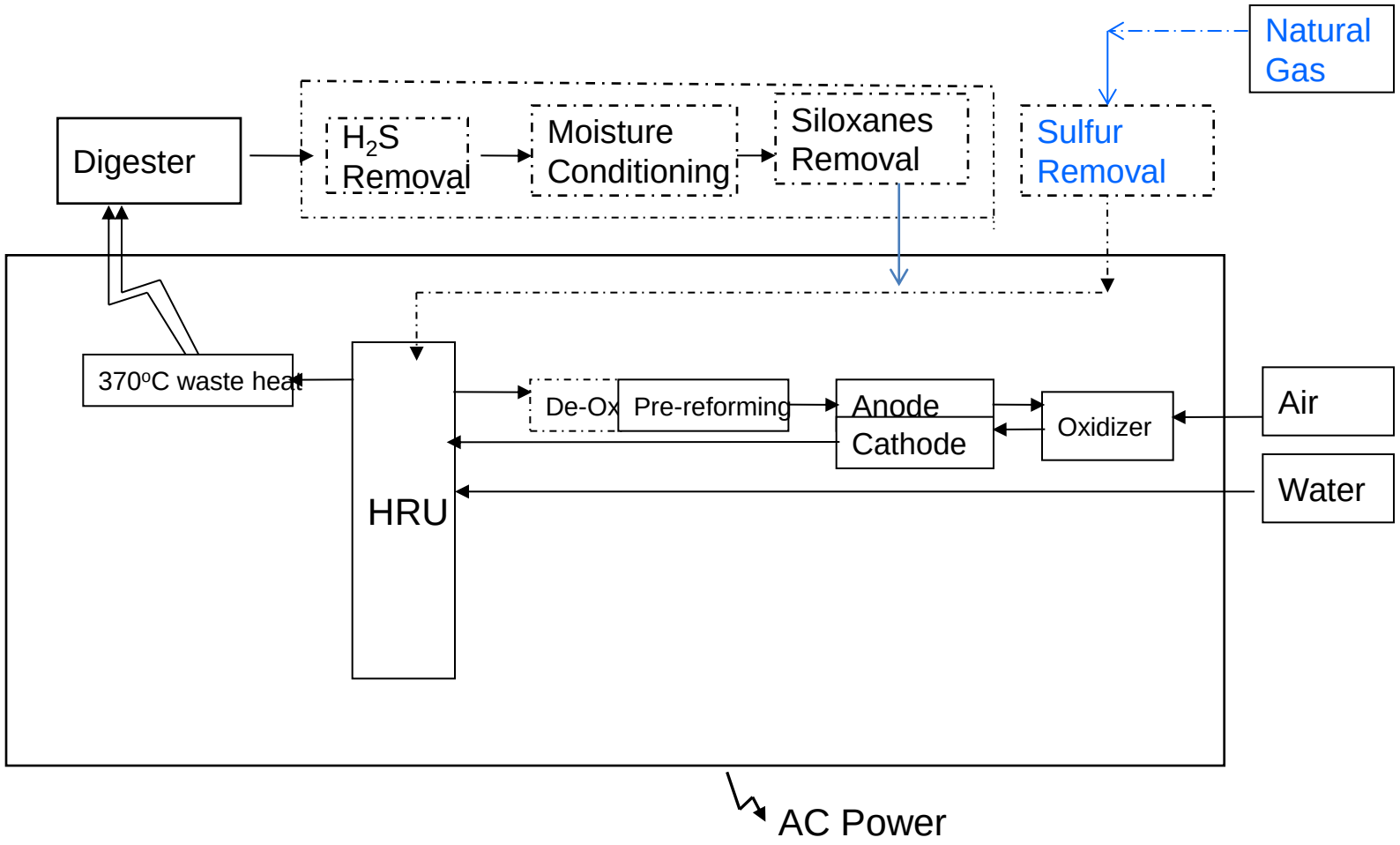
Schematic Showing Biogas to Natural Gas DFC



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1.4 MW DFC at Waste Water Treatment Facility

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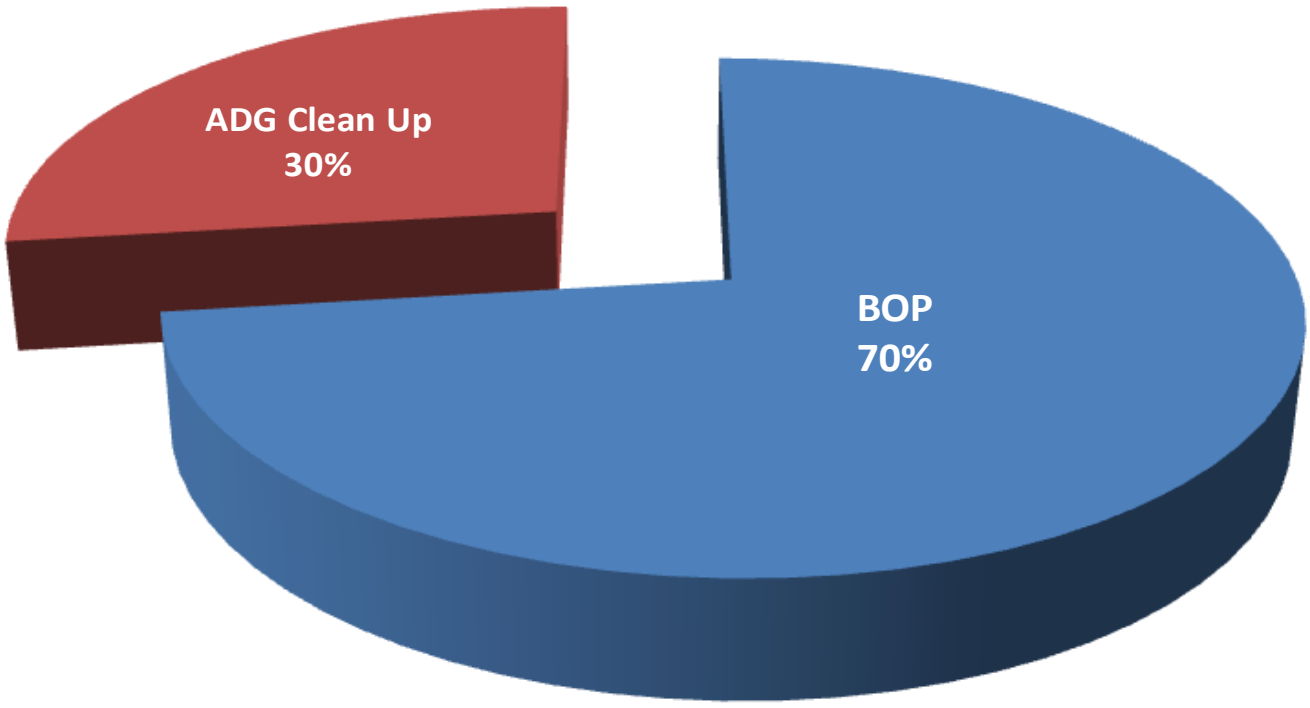
BOP O&M Cost – ADG Clean-up



(Based on three plants data)

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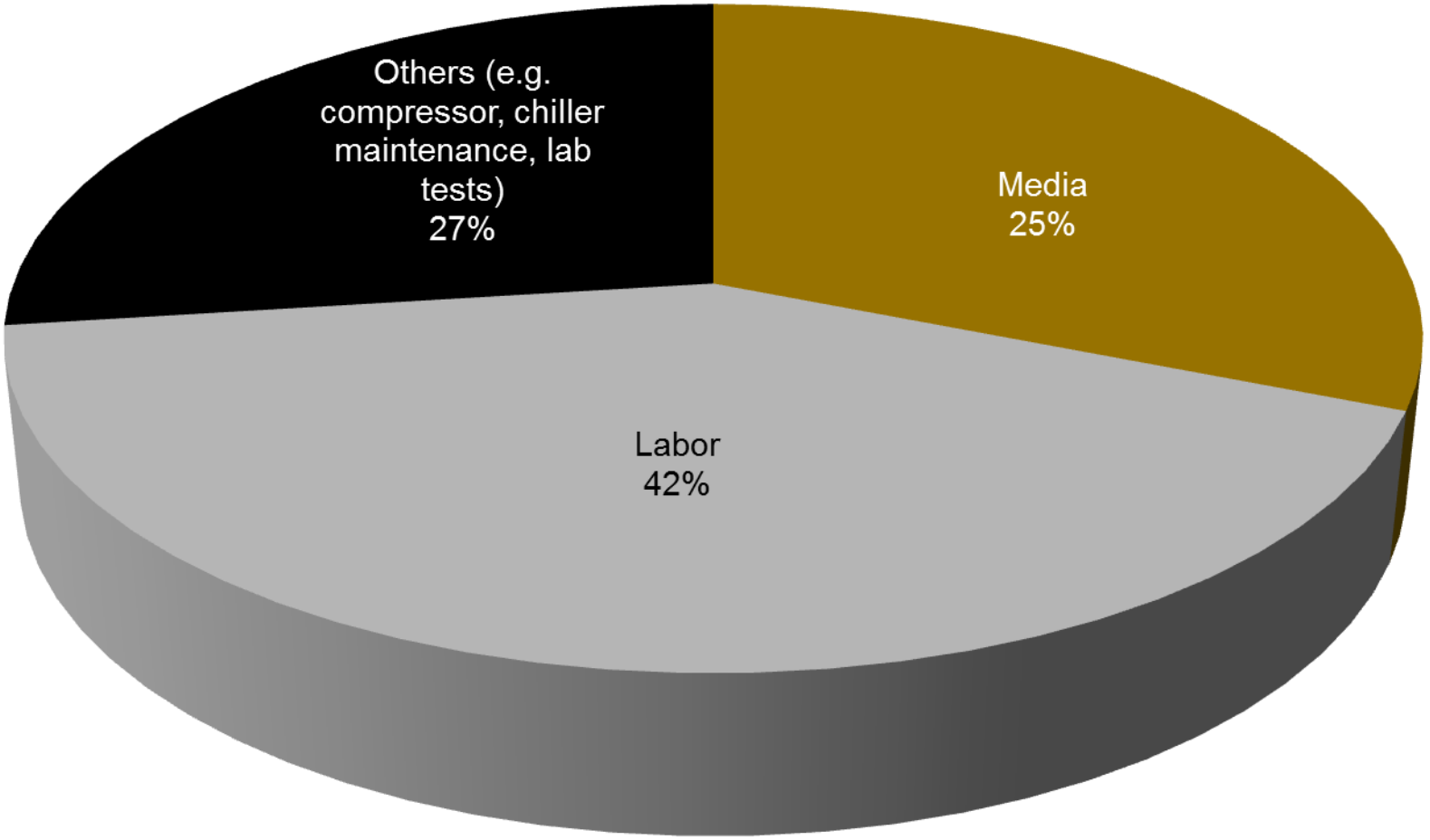
ADG Clean-up – O&M Costs Breakdown



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Bulk H_2S Removal Choices

1. **Iron Oxides or Iron hydroxides based materials (O_2 improves capacity)**
   - **SulfaTreat®**
   - **Iron Sponge**
   - **FerroSorp® S**
   - **NIDS**
2. **Carbon Based Materials (need moisture & O_2)**
   - **KI/C from Carbotech**
   - **RGM-3, Darko BGH from Norit**
   - **Sulfo 100 from Dopetac**

Comparative evaluation study will help to make an optimum selection

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Challenges of Biogas Applications

- Biogas supply is unreliable; NG backup is required to ensure high plant reliability
  - ➢ Results higher cleanup cost due to duplication (cold clean up needs independent NG and ADG systems)
    - ➢Consolidated design should result in cost reduction
- High moisture in biogas makes it difficult to clean trace non-H_2S sulfur and halogen compounds

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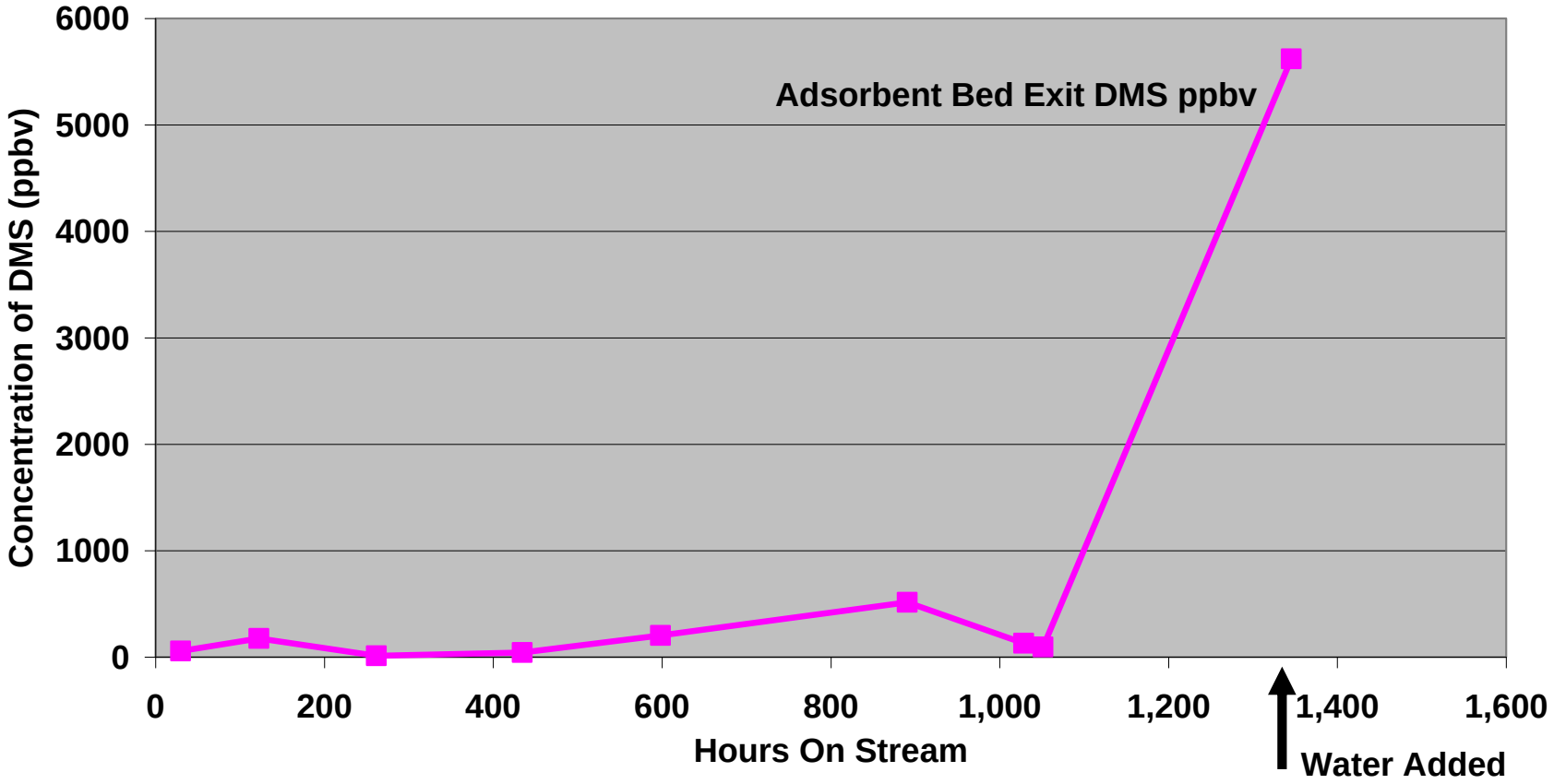
Concerns with Moisture in Fuel

- Water vapor competes with sulfur adsorption; can displace previously trapped sulfur.
- Controlled Experiment:
  - Adsorbent Bed was loaded with sulfur from natural gas contaiing DMS; natural gas spiked with water to increase concentration from 100 ppmv to 2000 ppmv H2O; large breakthrough of DMS.



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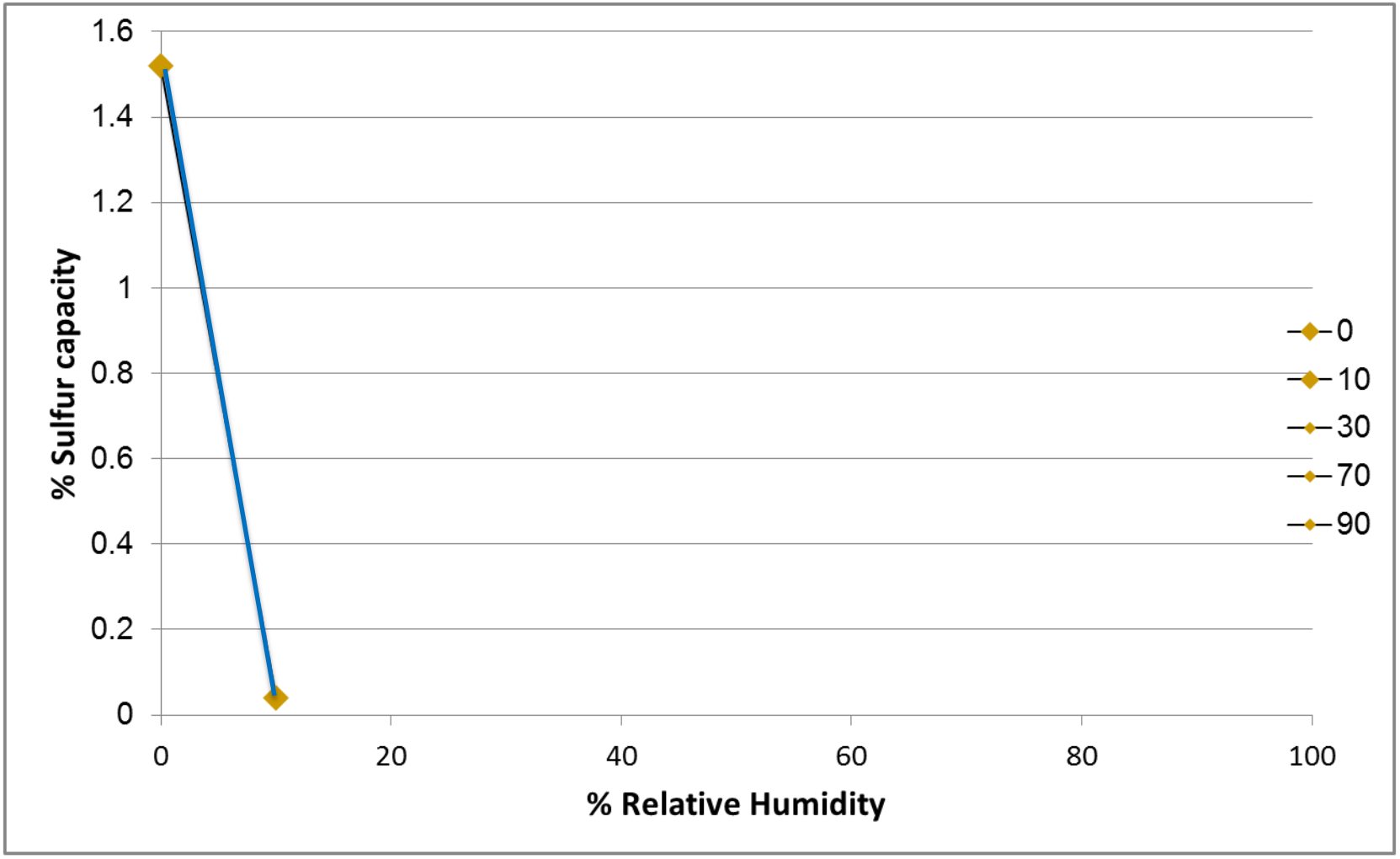
Impact of Fuel Humidity on DMS Removal Capacity



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On-line Sulfur Detector to Lower Cost of Sulfur Detection

- Function: Fuel gas on-line trace level sulfur detector (< 100 ppb).
- Capabilities Verified
  - Detects low level sulfur down to 30 ppbv
  - Detects all typical sulfur species (DMS, DMDS, COS, CS_2, H_2S, Mercaptans, etc.)
- Low Cost
- Status: Lab test completed; field verification continuing

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Improvement Opportunities

- Develop an efficient, low-cost media or system (mixed media) that can clean non-H_2S sulfurs, such as trace COS, CS_2, and organic sulfides.
  - The design is also desired to be fuel moisture tolerant so that it can be used for both natural gas and biogas.

- Introduce low-cost on-line sulfur detector to maximize use of sulfur adsorbents.

- Develop a modular clean-up system design which can be easily extended to accommodate different fuels and scaled up for different size power plants.

- Develop an efficient, low-cost media or system that can clean trace halogens, especially organic fluorides and chlorides (very important for landfill applications).