2010 DOE Hydrogen Program
The Effect of Airborne Contaminants on Fuel Cell Performance & Durability

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Project FC065

Overview

Timeline

- ✓ Start – Contract Pending
- ✓ Finish – May 2014*

Barriers

- ✓ Fuel Cells
  - A. Durability
  - C. Performance

Budget

- $4.5 million
  - $3.6 million - DOE
  - $0.9 million – Research Team
- Funding Received in FY10
  - $0

Partners

- University of Hawaii – Hawaii Natural Energy Institute (lead)
- University of Connecticut - Center for Clean Energy Engineering**
- Ballard Power Systems
- UTC Power

* Assumes original 4 year program period

** Formerly the Connecticut Global Fuel Cell Center at the University of Connecticut

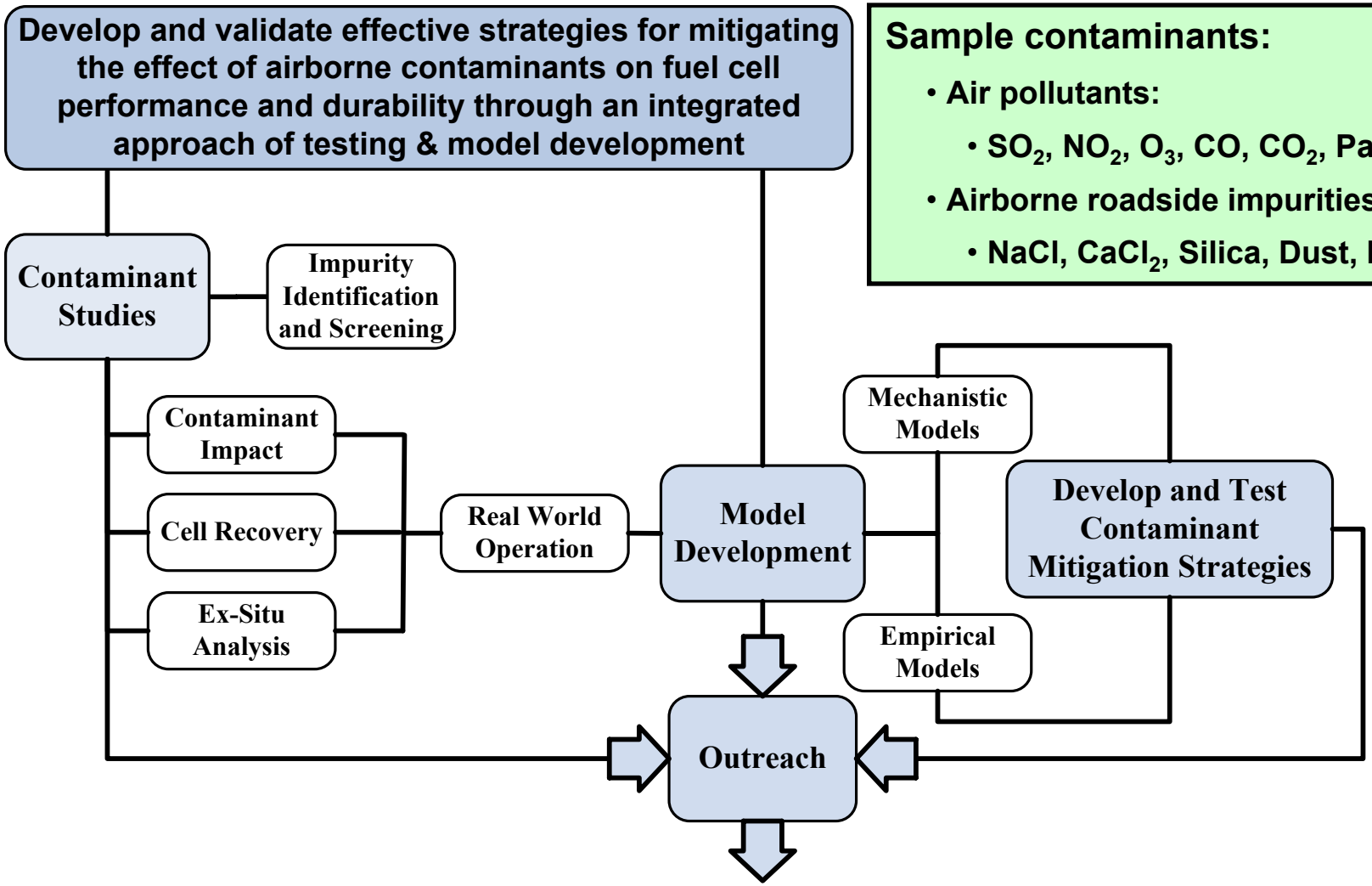
Technical Barriers/Targets-Relevance

- **Technical barriers to performance & durability:**
  - **Tolerance to air impurities not established**
  - **Need for mitigation strategies not established**
  - **Effects of air impurities on MEAs (e.g. ECA) are not known**
  - **Loss of performance with air impurities may present challenge to meeting performance targets at low catalyst loadings**
- **Technical targets for membranes & electro-catalysts:**
  - **Durability with cycling**
  - **Minimum ECA loss**
  - **Minimum catalyst support loss**
  - **Minimum mass and specific activity loss**

Objectives - Relevance

- **Characterize, analyze, and understand the effects of airborne contaminants that have the potential to reduce the performance or durability of PEMFC**
- **Develop empirical and mechanistic models to increase understanding of cell operation and kinetics in presence of contaminants**
- **Characterize *in situ* and *ex-situ* recovery techniques which will mitigate contaminant impacts**
- **Disseminate results to industry**

Approach


Develop and validate effective strategies for mitigating the effect of airborne contaminants on fuel cell performance and durability through an integrated approach of testing & model development
Sample contaminants:
• Air pollutants:
• SO_2, NO_2, O_3, CO, CO_2, Particulates
• Airborne roadside impurities:
• NaCl, $CaCl_2$, Silica, Dust, Particulates
Contaminant Studies
Impurity Identification and Screening
Contaminant Impact
Cell Recovery
Ex-Situ Analysis
Real World Operation
Model Development
Mechanistic Models
Empirical Models
Develop and Test Contaminant Mitigation Strategies
Outreach

Approach: Task Timeline & Milestones

Task	Year 1	Year 2	Year 3	Year 4
1. Contaminant Studies				
2. Real Life Operation & Mitigation Strategies				
3. Modeling of Contaminant Effects				
4. Outreach				
• End of Fiscal Year Milestones	• Prioritize, test, & report performance impact of relevant airborne contaminants	• Report effects of real life operation on performance & durability	• Report principle poisoning mechanisms and spatial modeling results	• Demonstrate successful mitigation of most significant airborne contaminants

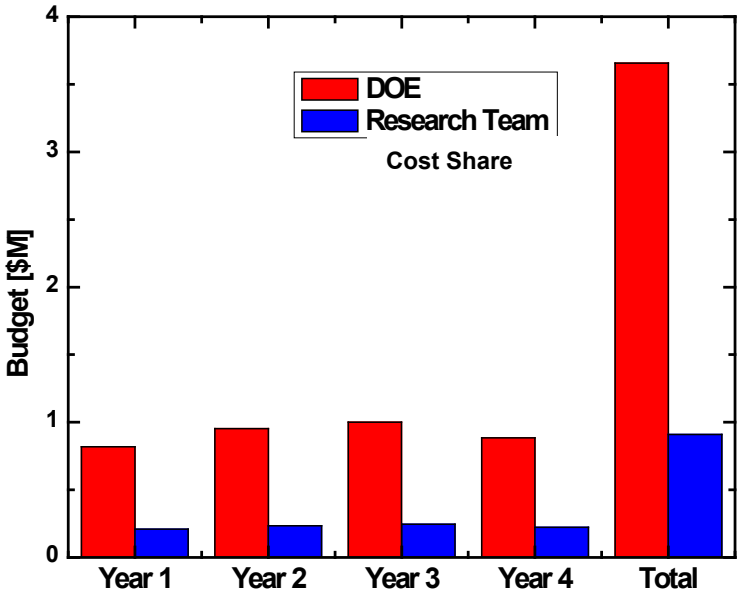
Approach: Partner Responsibilities

Task/Institution	HNEI	C2E2	Ballard	UTC
Impurity Screening	X	X	X	X
Testing	X	X		
Analysis	X	X	X	X
Empirical Modeling	X	X		
Mechanistic Modeling		X		
Mitigation Strategy Development	X	X	X	X
Mitigation Strategy Testing	X	X		
Outreach	X	X	X	X

Approach: Task Details

- **Task 1: Contaminant Studies**
  - Identify, survey, and prioritize contaminants)
  - Quantify impact under steady state & cyclic operation
  - Characterize self-recovery in neat air
  - Conduct *ex-situ* analysis of key components
- **Task 2: Real World Operation & Mitigation Strategies**
  - Characterize priority contaminants under transient & cyclic operation
  - Characterize effects of various purge and start-stop procedures
  - Explore mitigation strategies for contaminant removal or to enhance fuel cell tolerance
- **Task 3: Model Development & Application**
  - Develop empirical models to characterize spatial effects
  - Develop & use mechanistic models to increase understanding of electrochemical kinetics
- **Task 4: Outreach, Task 5: Project Management**

Approach: Yearly Budget & Annual Testing Hours



Additional inputs/needs:

- **DOE or lab lead coordination with goal of facilitating dissemination of information within program and communication of results for all air impurities' awards**

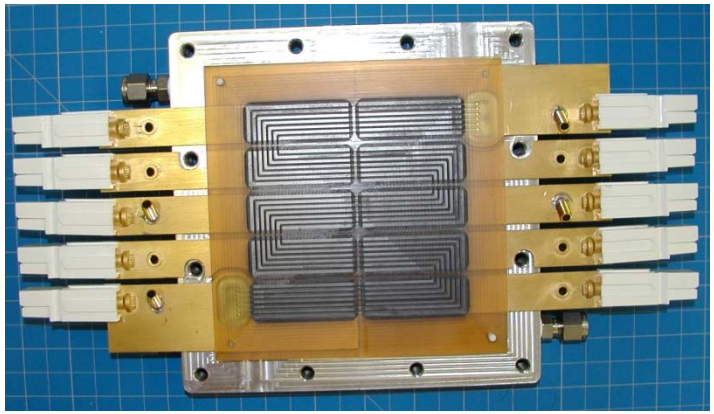
- **Estimated annual testing in hrs (assumes 2 dedicated test stations at each institution:**

Organization	Impurity Screening	Contaminant Impact/Recovery	Real World Operation & Mitigation Strategy Development	Total
HNEI	2000	12,500	2,500	17,000
CGFCC	2000	13,500	1,500	17,000

Go/No-Go Decisions After Year Two (All criteria must be satisfied)

No.	Success Criteria	YES	NO
1	Contaminant studies show significant impact on cell performance?	☐	☐
2	Modeling and experiments increase understanding of poisoning mechanisms and process?	☐	☐
3	Mitigations measures / techniques have been identified?	☐	☐

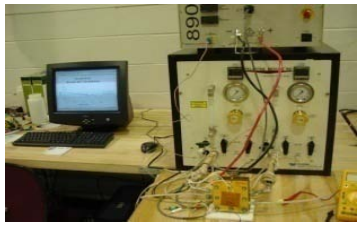
Capabilities – Hawaii Fuel Cell Test Facility

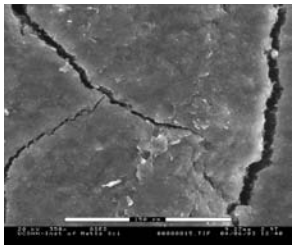


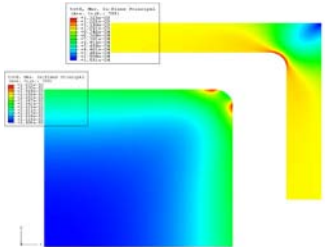
- Eleven test stations including single cell, stack, and HIL testing capabilities (up to 2kW)
- **High resolution on-line gas analysis with sub-ppm detection limits**
- Effluent water collection with ion selective electrode for measurement of S and Fl ions
- **Demonstrated closure of steady state molar flow balance for impurities to 1ppm level**
- **Multiple segmented cell testing systems with simultaneous electrochemical characterization of all segments over wide range of current density**
- Spatial gas sampling from flow channels under development
- Leverages ongoing work with NREL and ONR to characterize effect of fuel and air contaminants
- Laboratory for MEA and cell fabrication
- **Modelica modeling for analysis of spatial contaminant effects in cell**

Capabilities - Connecticut Center for Clean Energy Engineering

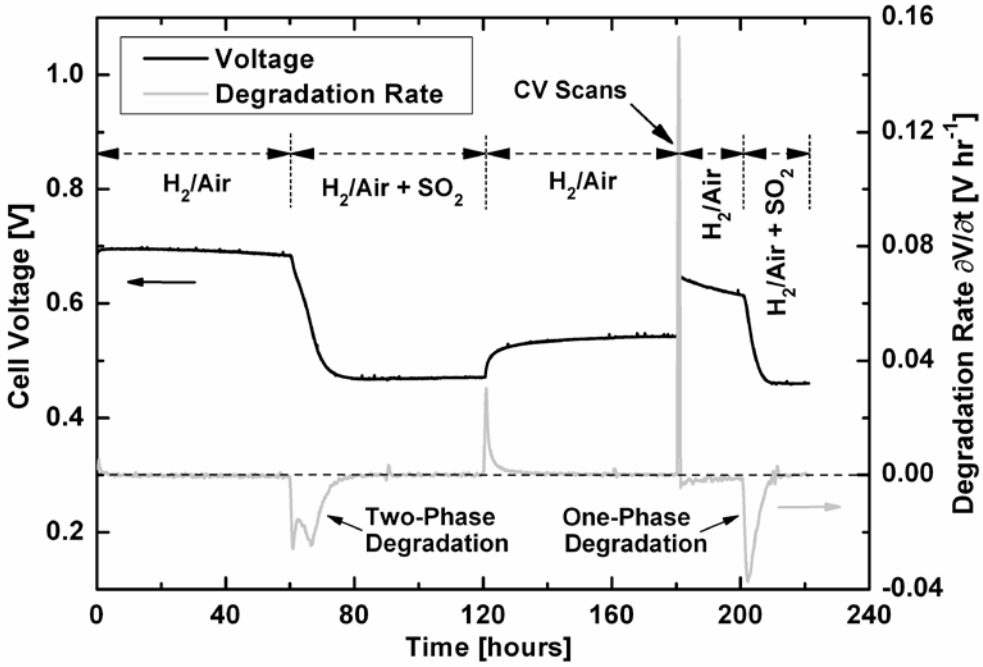
- 7 Fully-Automated Single Cell Fuel Cell Test Stations, Several Additional Systems in Place
- Multi-kW Test Capability for Full-Size Systems
- **Real-Time GC and MS Capability for Continuous Feedstock and Effluent Analysis**
- On-Site Scanning Electron Microscopy Facility and Access to UConn's Institute For Materials Science With Complete Materials Characterization Capability
- Prototype Component Fabrication Facility For Catalyst Formulation, Membrane Production, and MEA Fabrication
- **Facilities for Numerical Analysis and Multi-Physics Modeling**







Relevant Previous Work at HNEI (ONR funded) - Dual Poisoning Mechanism for SO_2



- SO_2 is an important air contaminant for both performance and durability effects

- Two performance degradation phases observed during initial poisoning
- Self-induced recovery in neat H_2 & scrubbed air is incomplete
- Initial performance can be restored with multiple CV scans
- Accelerated degradation in neat H_2 & scrubbed air upon subsequent poisoning
- Detailed analysis (e.g. cyclic voltammetry, segmented cells, gas chromatography & EIS) used to study poisoning processes
- Promising recovery techniques developed in collaboration with NRL/ONR
- Combined gas & effluent water analysis to close sulfur mass balance

Collaborations

Connecticut Center for Clean Energy Engineering

(PI: Trent Molter)

- **Conduct testing**
- **Analyze test results**
- **Develop mechanistic models**
- **Develop mitigation strategies**

Ballard Power Systems (*PI: Silvia Wessel*):

- **Assist in identification and prioritization of contaminants**
- **Assist in analysis of test results**

UTC Fuel Cells (*PI: Tom Madden*):

- **Assist in identification and prioritization of contaminants**
- **Assist in analysis of test results**

Others under development

Future Work: Year 1 Upon Award of Contract

Task 1 - Contaminant Studies

- **Subtask 1.1: Impurity Identification & Screening:**
  - Team will identify, survey, and prioritize airborne fuel cell contaminants most likely to negatively impact fuel cell performance
  - Available pubic and scientific information will be reviewed using industrial and professional expertise of team

- **Subtask 1.2 Contaminant Impact**
  - Test impact of priority contaminants on fuel cell performance and durability following USFCC 04-003 and 05-002 guidelines using properly calibrated test stands and accepted protocols
  - Utilize proven sophisticated tools in conjunction with empirical performance and mechanistic models to provide significant insight into cell response to contaminant exposure.
  - Utilize previously tested segmented fuel cell and high resolution on-line gas analysis systems.
  - Conduct spatial gas sampling along segmented flow fields.

Future Work: Year 1 Upon Award of Contract

- **Subtask 1.3: Cell Recovery:**
  - Investigate the ability of the fuel cell to self-recover from contaminant exposure when exposed to neat-air
  - Identify operating conditions that enhance cell recovery
  - Results expected to provide insights and potential approaches for development of practical mitigation strategies.

- **Subtask 1.3 Ex Situ Analysis**
  - Exposure to airborne contaminants may result in chemical and structural changes in fuel cell components causing irreversible changes to fuel cell performance.
  - Conduct ex-situ micro-analysis of MEAs and GDLs to characterize structural and compositional changes associated with irreversible impacts.
  - Micro-analytical methods may include SEM, TEM, XRD, IC, ICP-MS, XPSD, SAM, FTIR, EPMA with WDS, SIMS, XRF, BET and MIP.

Summary

- **Project has been on hold waiting for execution of contract**
- **Research team with proven record in characterization of impurities on PEMFC performance and durability has been assembled**
- **HNEI & C2E2 will conduct testing and develop models to identify impacts of airborne contaminants**
- **Ballard Power Systems and UTC Power will provide input and feedback on impurity selection & assist in the analysis of data**
- **Understanding of contaminant behavior from testing will be used to develop effective mitigation strategies wherever feasible.**