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Presentation noting some renewable gas RD&D topics of interest

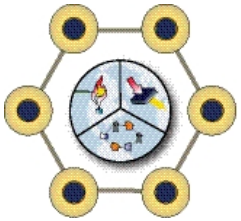
The attached presentation contains excerpts of a presentation on Power-to-Gas and renewable hydrogen. The most important slide is the second slide, which summarizes some topics that are important to consider as research, development and demonstration (RD&D) topics that deserve some attention. The following slides show some examples of RD&D accomplishments related to these topics.

Additional submitted attachment is included below.

Evaluation of Renewable Hydrogen Power-to-Gas (P2G) in California

Renewable Hydrogen Production Workshop

California Energy Commission – Sacramento



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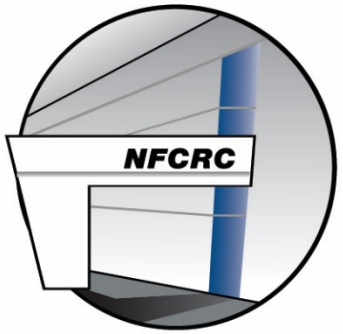

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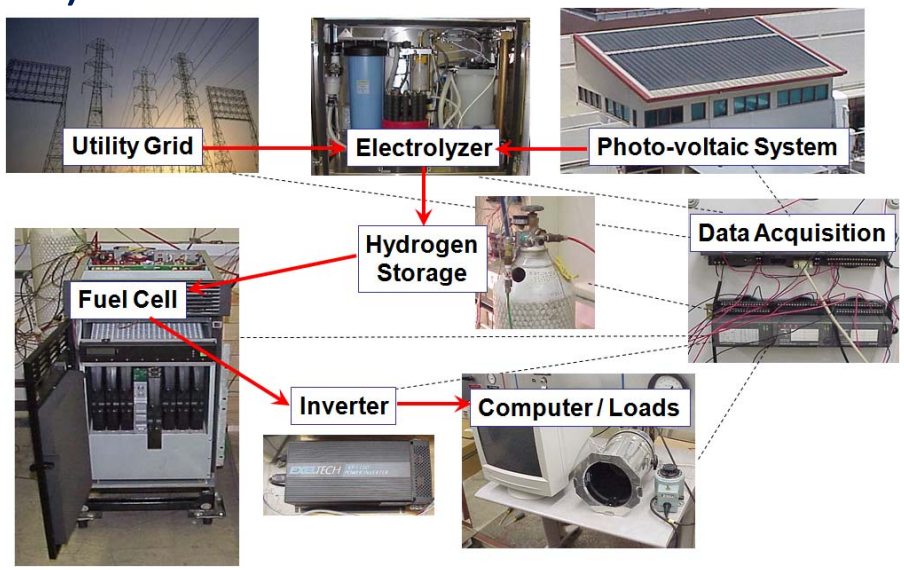
P2G RD&D Topics of Interest

Some P2G Research, Development and Demonstration Topics

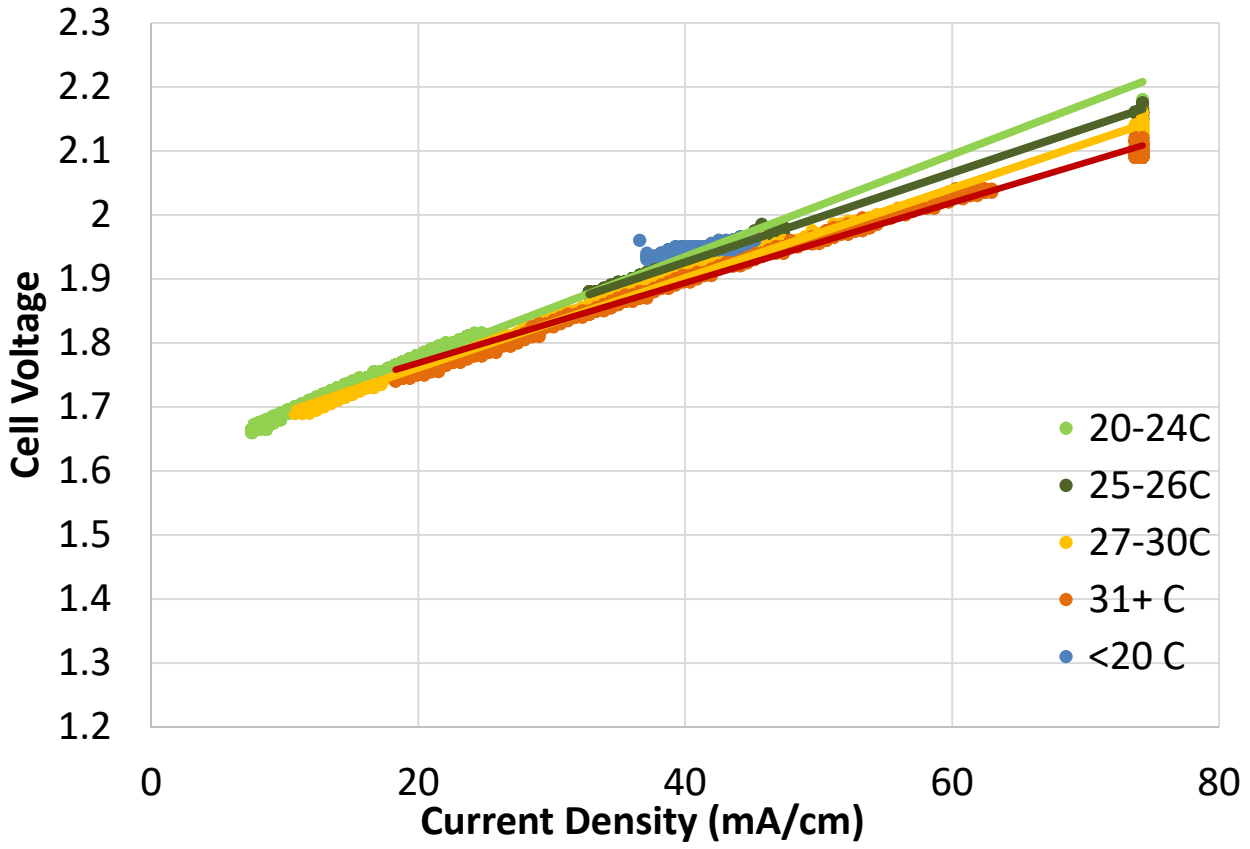
1. H_2 production dynamics by direct-DC connection to renewables
2. Hydrogen injection into existing natural gas distribution and/or transmission system infrastructure – assess leaks, mixing dynamics
3. Evaluation of leakage (both H2, NG, & H2/NG) mitigation strategies
4. Evaluate and advance novel new high efficiency electrolysis technologies (e.g., solid oxide, molten carbonate)
5. Simulation and experimental evaluation of pipeline materials impacts (e.g., embrittlement, fatigue)
6. Simulation of P2G impacts in the grid and microgrids
7. End-use conversion of P2G gases (H2, NG, & H2/NG blends)
8. Economic analyses



P2G Accomplishment: Lab-Scale Electrolyzer Dynamics

HOGEN-RE proton exchange membrane electrolyzer

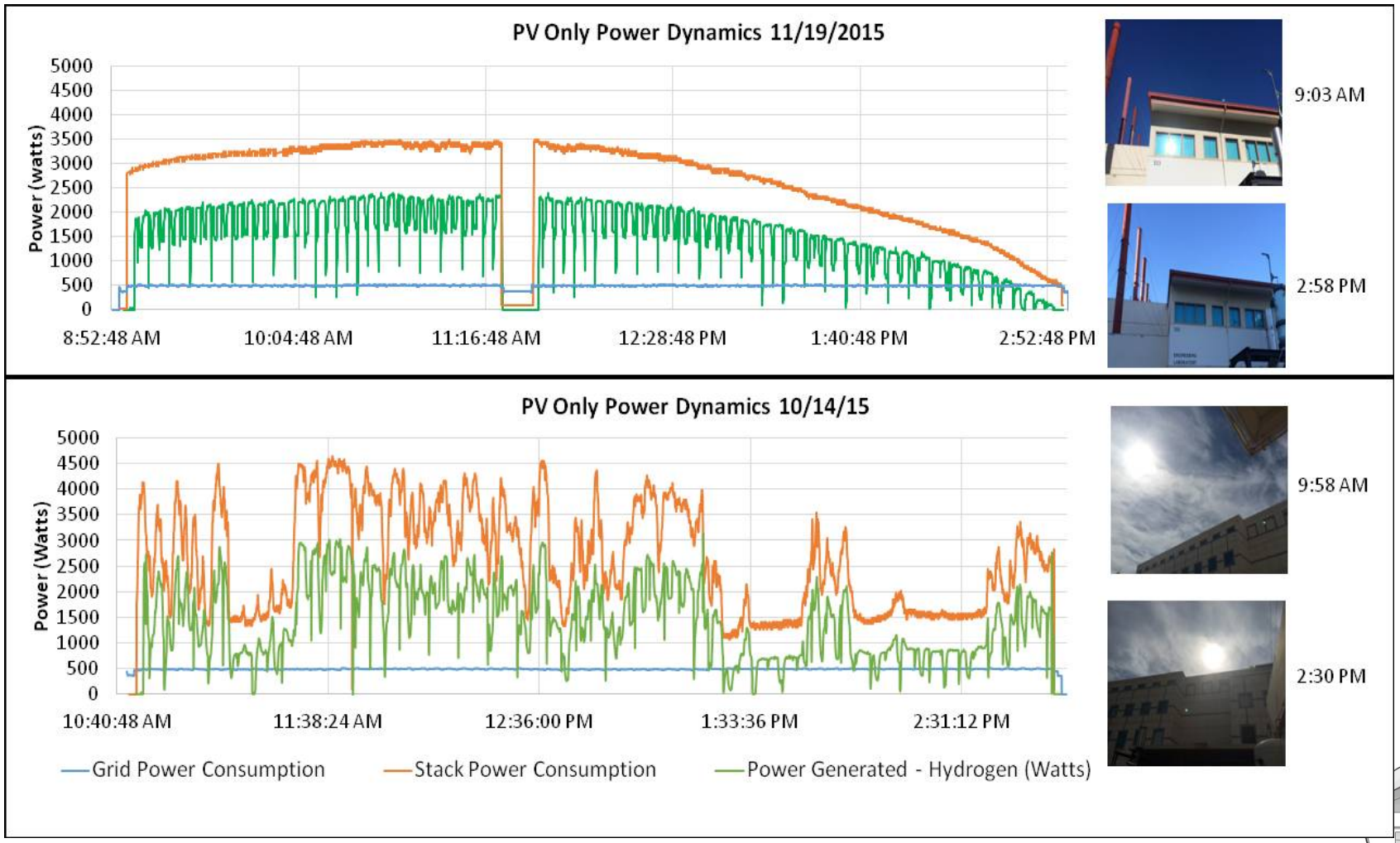
- Performs best when hot (summer vs. winter)



P2G Accomplishment: Lab-Scale Electrolyzer Dynamics

HOGEN-RE proton exchange membrane electrolyzer

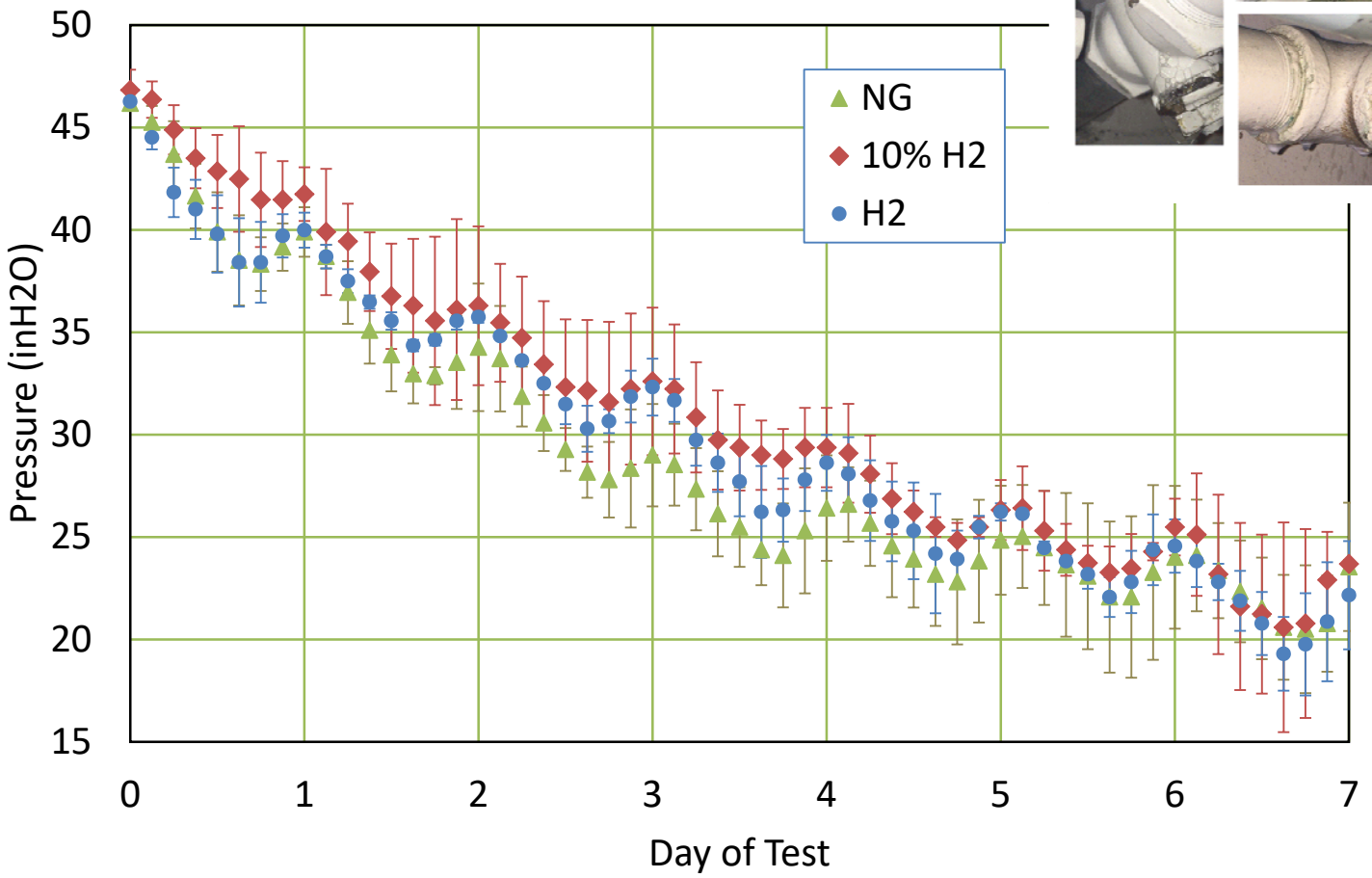
- Hydrogen production dynamics (with and without clouds)



P2G Accomplishment: Hydrogen Pipeline Injection

H2 injection into existing natural gas infrastructure (low pressure)

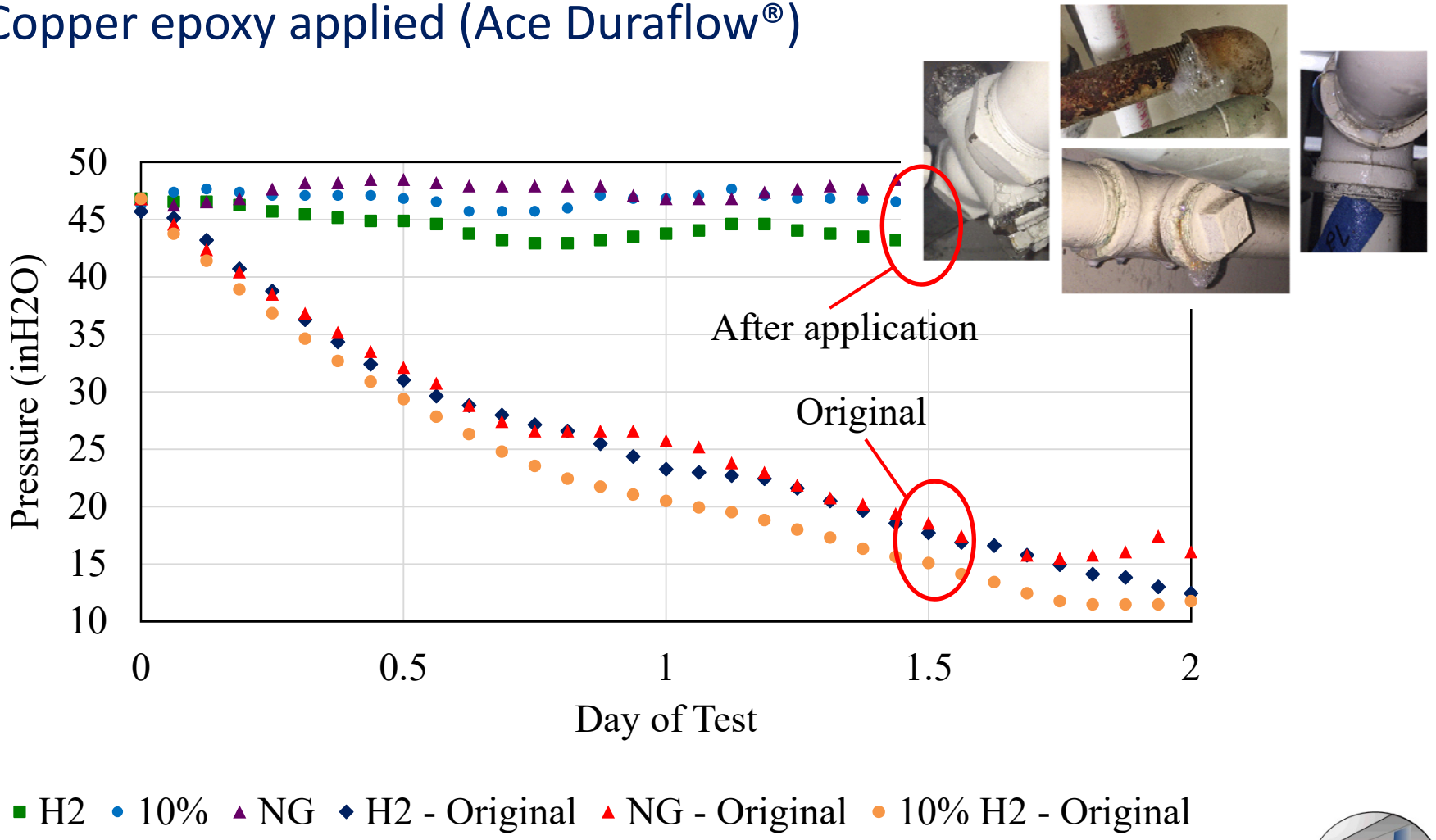
- NG, H2/NG mixtures, H2 leak at same rate



P2G Accomplishment: Leak Mitigation Evaluation

H2 injection into existing natural gas infrastructure (low pressure)

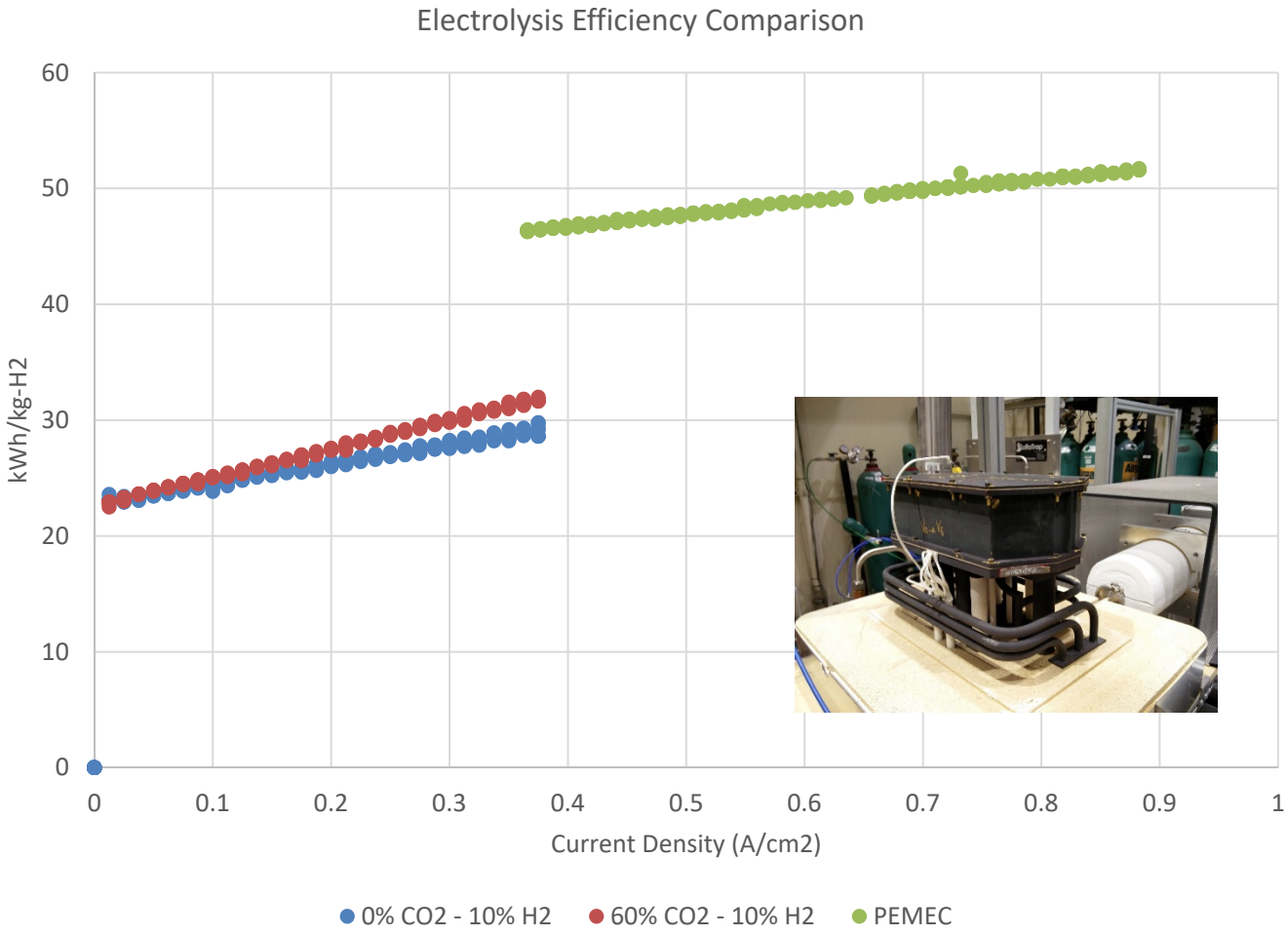
- Copper epoxy applied (Ace Duraflow®)



P2G Accomplishment: Electrolysis Alternatives

Solid Oxide Electrolysis and Co-Electrolysis

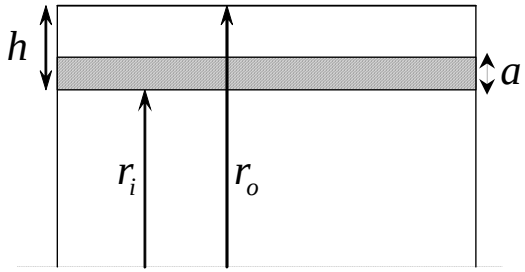
- Comparison to PEMFC (lower activation losses, higher ohmic losses)



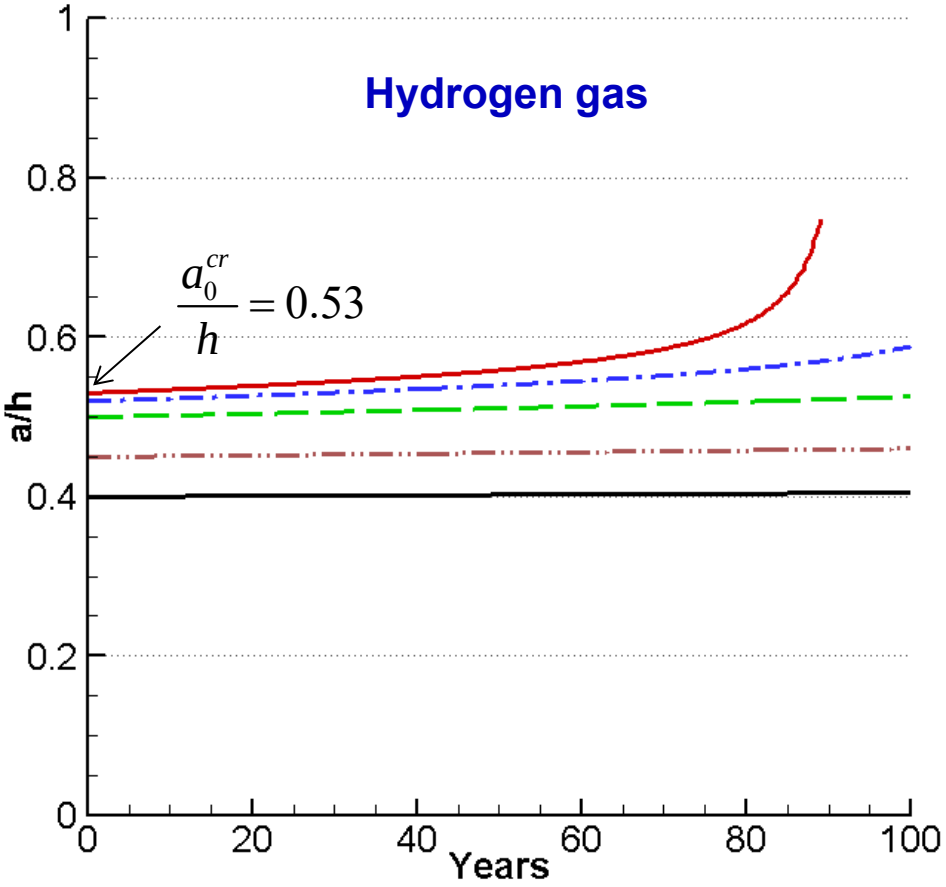
P2G Accomplishment: Pipeline Materials Impacts

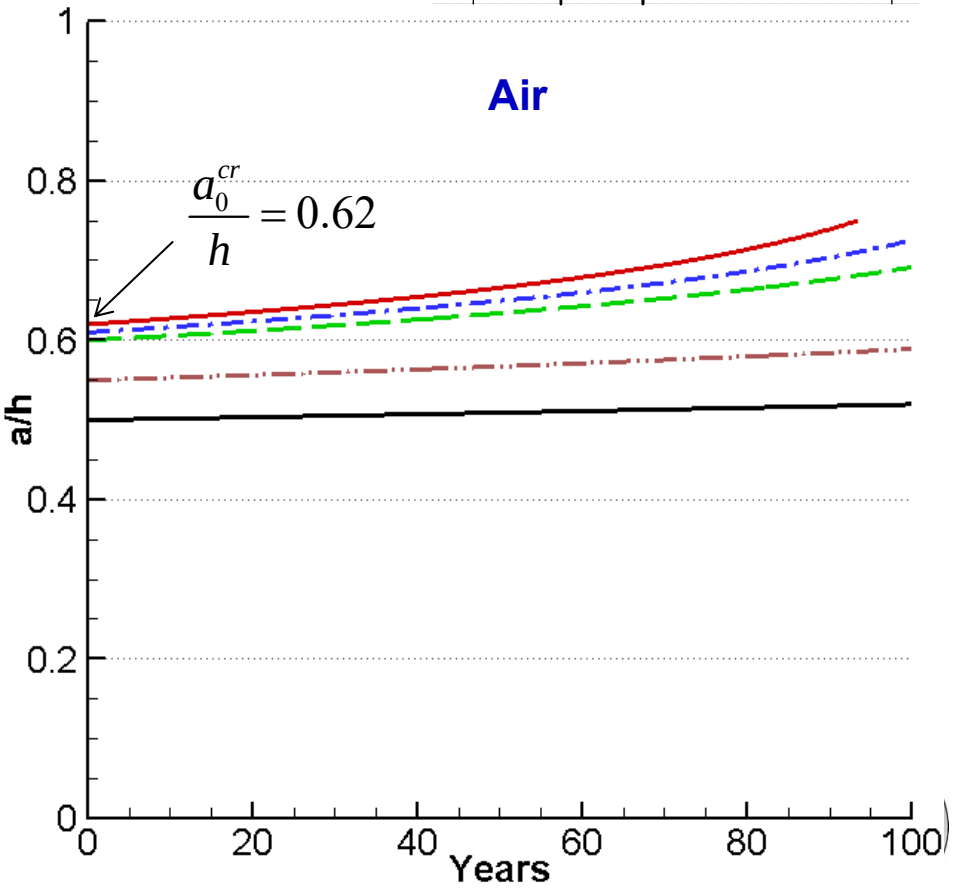
Simulation of H2 embrittlement and fatigue crack growth with UIUC

- Fatigue crack growth in 6” SoCalGas pipeline



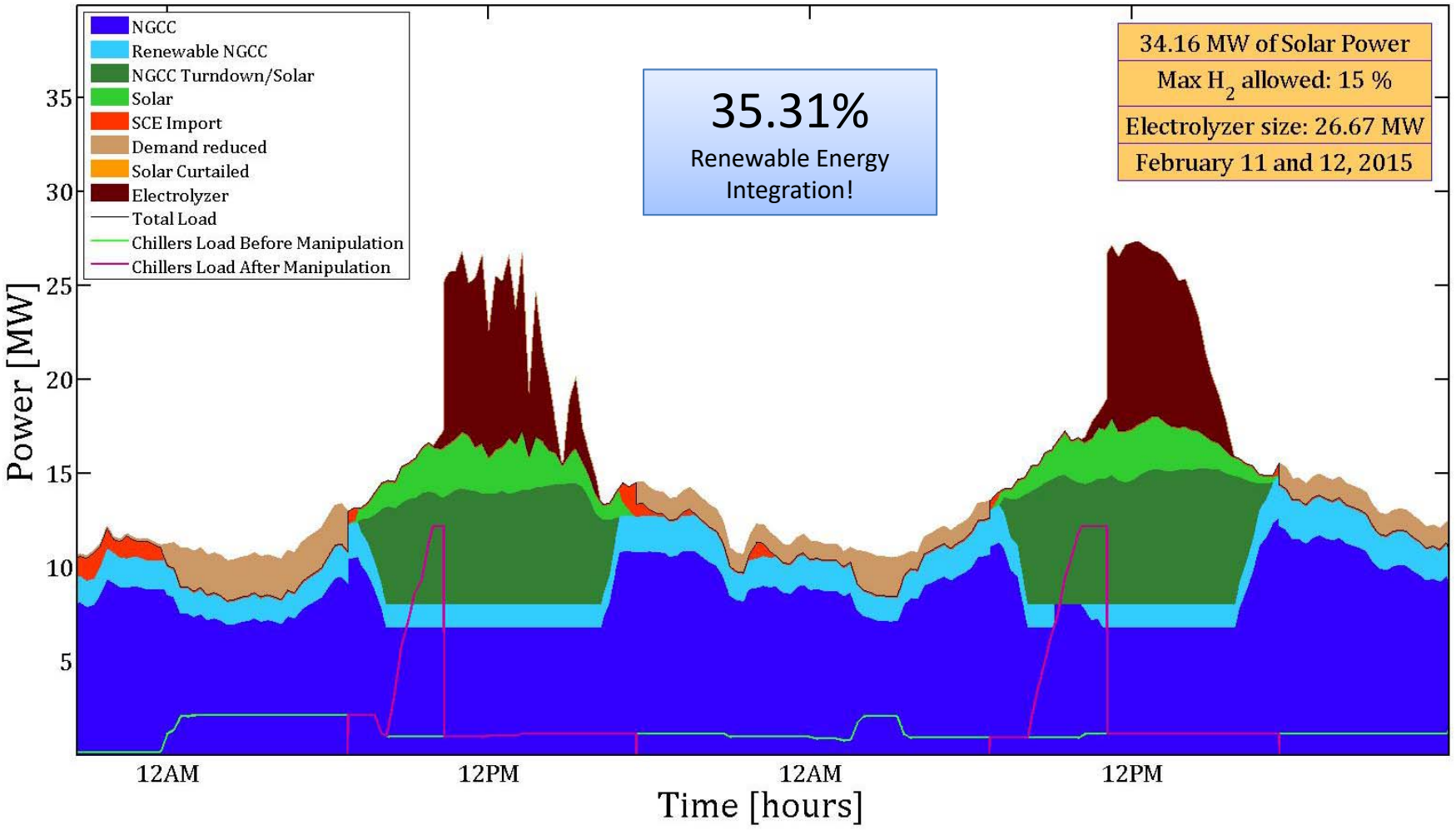
0.188” wall thickness: $(h = 0.188" = 4.8\ \text{mm})$





P2G Accomplishment: UCI Microgrid Simulation

- P2G could significantly increase renewable percentage at UCI



P2G Accomplishment: Large Electrolyzer Deployment

P2G Accomplishment: Large Scale Electrolyzer

Injection and combustion of H2/NG mixture in NGCC (400 psi line)

P2G Accomplishment: Large Scale Electrolyzer

Injection and combustion of H2/NG mixture in NGCC (400 psi line)

- ~0.24 volume % H2 in natural gas

P2G Accomplishment: Detailed Economic Analyses

Levelized Cost of Returned Energy (LCORE)

- Future Costs & Efficiencies
- 50% capacity factor for all equipment