Clean Hydrogen to US Energy Supply Chain -- A workshop sponsored by Shell Oil and Energy Biosciences Institute at UC Berkeley

May 13 - 14, 2020

SoCalGas
A Sempra Energy utility

SoCalGas

- **Largest natural gas distribution** utility in the US
- An active part of the community for more than **140 years**
- Serve **12 counties** and more than **21 million** people
- Employ more than **8,000 Californians**

Vision

SoCalGas' vision is to be the cleanest gas utility in North America, delivering affordable, reliable and increasingly renewable energy to our customers.

3

40 Million Ton Challenge

SoCalGas Climate Registry CO_2 Emissions.

- **Unverified 2018 Scope 1 emissions: 1,789,720 $MTCO_2e$**
- **Unverified Scope 2 (from purchased electricity): 21,647 $MTCO_{2e}$**
- **Verified Scope 3 (CARB Subpart NN combustion emissions for gas delivered to customers): 39,890,211 $MTCO_{2e}$**

Renewable Gas Goals

- **California Law:** GHG emissions 80 percent below 1990 levels by 2050

- **SoCalGas commitment:**
  - ≥ 5% Renewable Gas by 2022
  - ≥ 20% Renewable Gas by 2030

Scalable, affordable solutions

- **H2/NG Blending**
- **Electrolytic gas**
- **Advanced SMR with CCS**
- **Biomass gasification with CCUS**
- **Methane pyrolysis**
- **Solar water splitting**

H2 Blending

- UCI/UIUC Study
- Gas Operations Roadmap
- Hydrogen Blending System Design
- New Regulatory Proceeding

International Journal of Hydrogen Energy

Volume 44, Issue 21, 23 April 2019, Pages 10808-10822

Assessment of resistance to fatigue crack growth of natural gas line pipe steels carrying gas mixed with hydrogen

Mohsen Dadfarnia, Petros Sofronis, JackBrouwer, SiariSosa

- Analyzed hydrogen-induced fatigue crack growth in line pipe steels.
- Presented critical initial crack depths for line pipes under pressure fluctuation.
- Line pipes with initial flaw sizes less than 40% of the wall thickness are safe.

The results show that under typical pressure fluctuations in the natural gas network, cracks with depths less than 40% of the wall thickness will never reach depths equal to 75% of the wall thickness.

SoCalGas is Supporting the CPUC in Establishing a H2 Blending Standards

Joint Utility Engineering Work Group established

- Meeting once a month to share information, research, project ideas, etc.
  - SoCalGas, PG&E, and Southwest Gas
- Drafted a research action plan to study key areas
  - Results will inform a hydrogen injection standard
- Continuing conversations with industry stakeholders to share lessons learned

Common Variable System Elements

Issues that apply to most Utility Systems:

- **Long-Term System Integrity Impacts**
- **Industrial Customers, NGVs, and System Equipment**
- **End-Use Appliances (Residential and Commercial)**
- **Regulatory Rules and Tariffs**

Utility Systems have variability in pipeline and equipment characteristics and customer equipment profiles.

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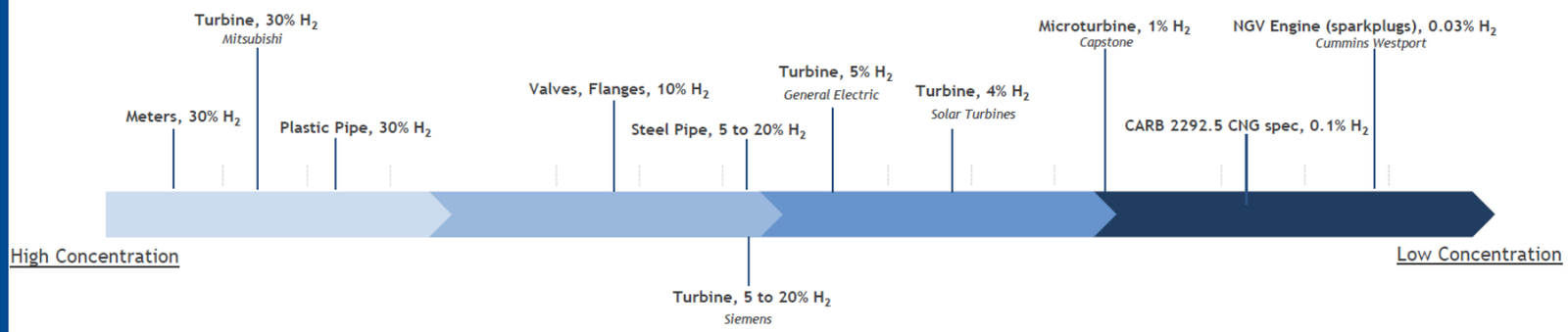
Areas of Study

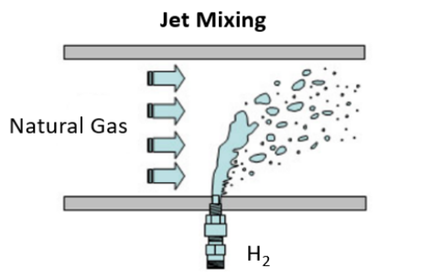
System Element	Research Topic
System Integrity	Potential embrittlement
	Crack growth
	Permeation
	Interaction with reservoir caprock
	Impact on sealant
End User	Performance
	Emissions
System and Industrial Equipment	Impact on engines
	Impact on equipment
	Measurement accuracy

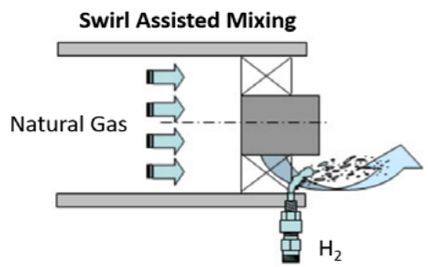
Current Limits of Knowledge

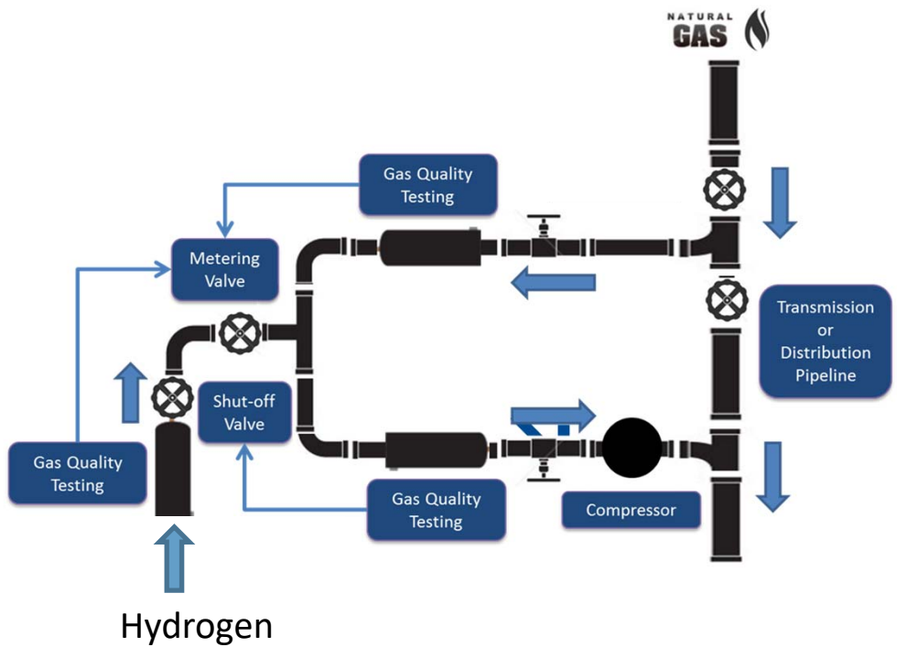


* Limits are determined by external parties through lab environment or new installation and therefore not conclusive for California utility systems. Warrants further studies distinctly profiled for the variability and dynamics of each utilities' natural gas system.

Gas Blending System – Illustrative Concepts







Regulatory Proceeding on Hydrogen Injection

- On 21 Nov 2019, California launched a new regulatory proceeding:

  1. To establish appropriate standards and interconnection protocols for injection of renewable hydrogen into the natural gas pipeline system to ensure safety and integrity of the gas delivery system and compatibility with end-uses.

  2. Initiate an independent technical study to address the potential impacts of increased hydrogen concentration in California's natural gas storage and delivery system

TECH DEV

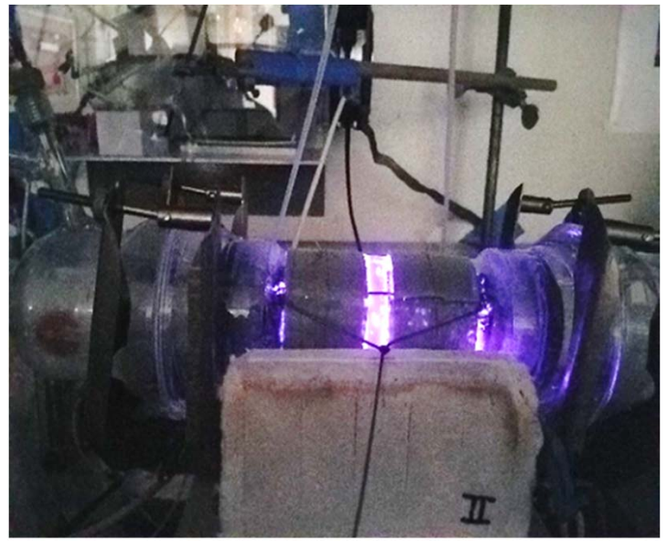
Distributed SMR

D3 Printed Induction Heated Microchannel Reactors

- The basic unit can produce 35 kg/day using 6 hours of sunlight
- Using renewable electricity to drive the endothermic reaction the system would produce 650 kg/d
- Cost target is $2/kg
- PNNL has spun-off STARS Technology Corporation to commercialize the technology.

Distributed SMR
Catalytic Non Thermal Plasma Reactor

- Dielectric barrier discharge (DBD) plasma enhances the catalyst performance and reduces the energy requirement for the SMR reaction.
  - Conversion energy efficiency: > 75%
  - Startup time: < 30 minutes; start-stop capability
  - Low-temperature operation
  - Subscale unit production capacity: ~ 1Kg H_2/day
  - Full-scale production capacity: 5kg/day
  - Production Cost: $ 2 - $4 /kg H_2

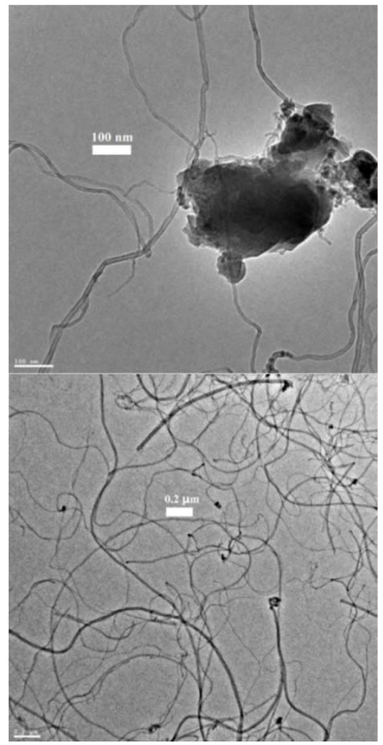


CNTP SMR Reactor

Methane Pyrolysis

» Microwave catalysis for process intensified modular production of carbon nanomaterials from natural gas
  - PI, Dr. Jianli Hu, Chair Professor and Director of WVU Shale Gas Center
  - Co-PI Robert Dagle, PNNL
  - Co-PI George Skoptsov, CEO, H-Quest Vanguard

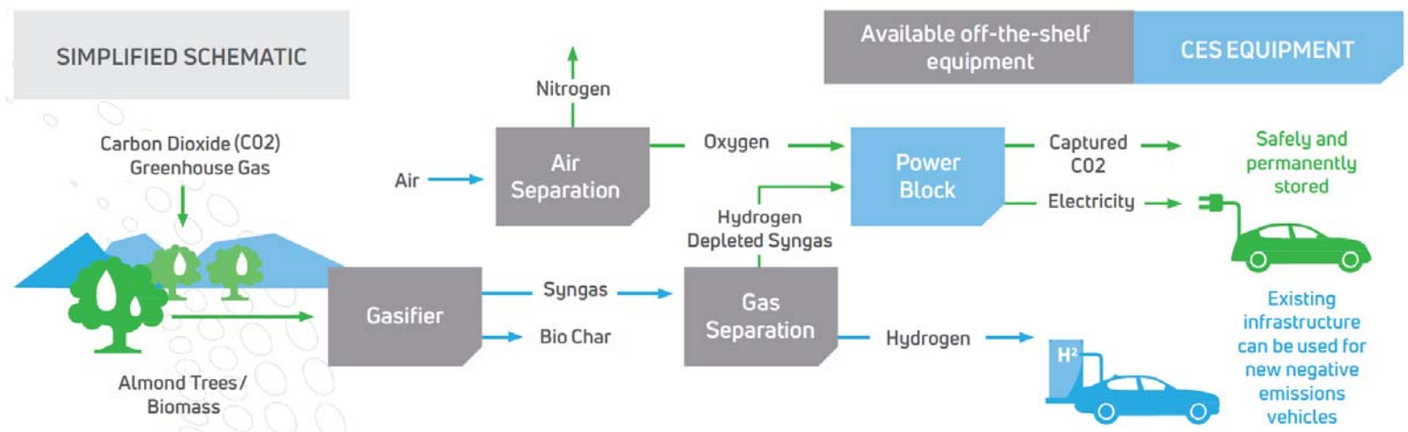
» Additional projects at Stanford and PARC

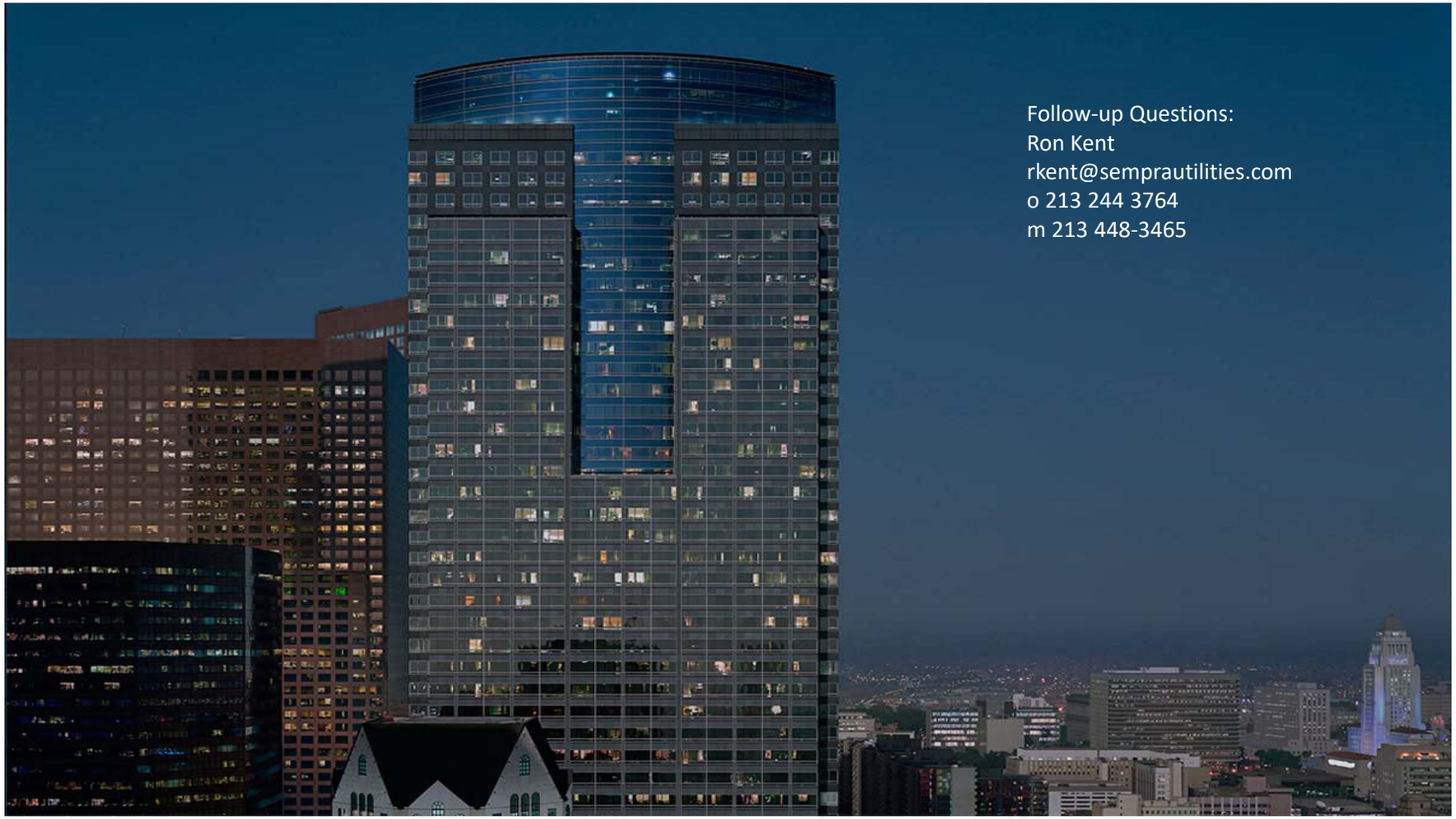


TEM image of CNTs produced from microwave catalytic decomposition of methane.

BECCS

- Carbon negative energy (CNE) plants use waste biomass fuels to produce syngas, from which hydrogen is separated for sale to the transportation sector.
- The remaining (hydrogen-depleted) fuel is passed through Clean Energy Systems technology to produce power, with full carbon capture to remove CO_2 from the atmosphere.





Follow-up Questions:
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