DOCKETED

Docket Number:	17-HYD-01
Project Title:	Renewable Hydrogen Transportation Fuel Production
TN #:	215722
Document Title:	CEC Pre-Solicitation Workshop
Description:	Powerpoint Presentation
Filer:	Tami Haas
Organization:	SoCal Gas
Submitter Role:	Public Agency
Submission Date:	2/1/2017 2:06:02 PM
Docketed Date:	2/1/2017

CEC Pre-Solicitation Workshop on Implementation Strategies for Production of Renewable Hydrogen in California

January 30, 2017

SoCalGas

A Sempra Energy utility

Glad to be of service.®

Discussion Points

- SoCalGas' RD&D Program – Low Carbon H_2 Projects
  - Power-to-gas
  - Solar Thermochemical SMR Hydrogen Production
  - Distributed, High-efficiency Hydrogen Production from Natural Gas
  - Co-Production of Power and H_2 with Sub Stoichiometric Oxy-fuel Combustion
  - Biomass gasification
  - Joint Center for Artificial Photosynthesis (JCAP)

- Utilities - An important Source of H_2 Infrastructure Resources
  - Biogas Conditioning/Upgrading Services Tariff
  - Compression Services Tariff
  - Other?

SoCalGas / UCI National Fuel Cell Research Center
P2G Project 1 - Demonstration and Modeling

Project

- Physical testing and characterization of H_2 production via electrolysis and blending in an “off-system” (inside the fence) gas/electric grid environment at UC Irvine leveraging the university’s microgrid and other H_2-related systems.
- Assessment of H_2 blending impacts on pipeline system materials

Objectives

- Design, build, install, test and demonstrate systems for PV electrolysis, microgrid integration & H_2 blending and pipeline injection
- Power-to-gas system testing for various operation modes such as PV only and grid only modes.
- Testing of electrolyzer stack efficiency, system efficiency, electrolyzer stack temperature dynamics, storage dynamics and threshold operation of the electrolyzer system are tested and characterized

Results

- The stack power demand profile was demonstrated to closely follow slightly variable photovoltaic inputs
- Evaluated the impact of H_2 blending and injection on pipeline durability – results indicate >80 year life expectancy.
- Achieved the first H_2 NG pipeline blending in US. The blended gas was delivered to a combined cycle power plant on the UCI campus.
- Demonstrated a 3x increase in campus renewable energy capacity
- Publishing results in peer reviewed journals

PEM Electrolyzer

Hydrogen Injection into UCI NGCC Power Plant

SoCalGas / UCI National Fuel Cell Research Center
(NFCRC) P2G Project 2 Technoeconomic Analysis

P2G Project 2 – Technoeconomic Analysis

- Conduct a techno economic assessment of power-to-gas compared to conventional energy storage technologies.
- Assess various hydrogen pathways involving use of the hydrogen or conversion to methane or electricity.

Objectives

- Determine the current lifecycle cost of returned energy (LCORE) of P2G and conventional energy storage systems such as batteries, pumped hydro, and compressed air.
- Conduct an LCORE assessment using projected efficiencies, capital costs and operating costs.

Results

- Results indicate that P2G is cost competitive with conventional storage technology under a variety of scenarios
- Publishing results in peer reviewed journals

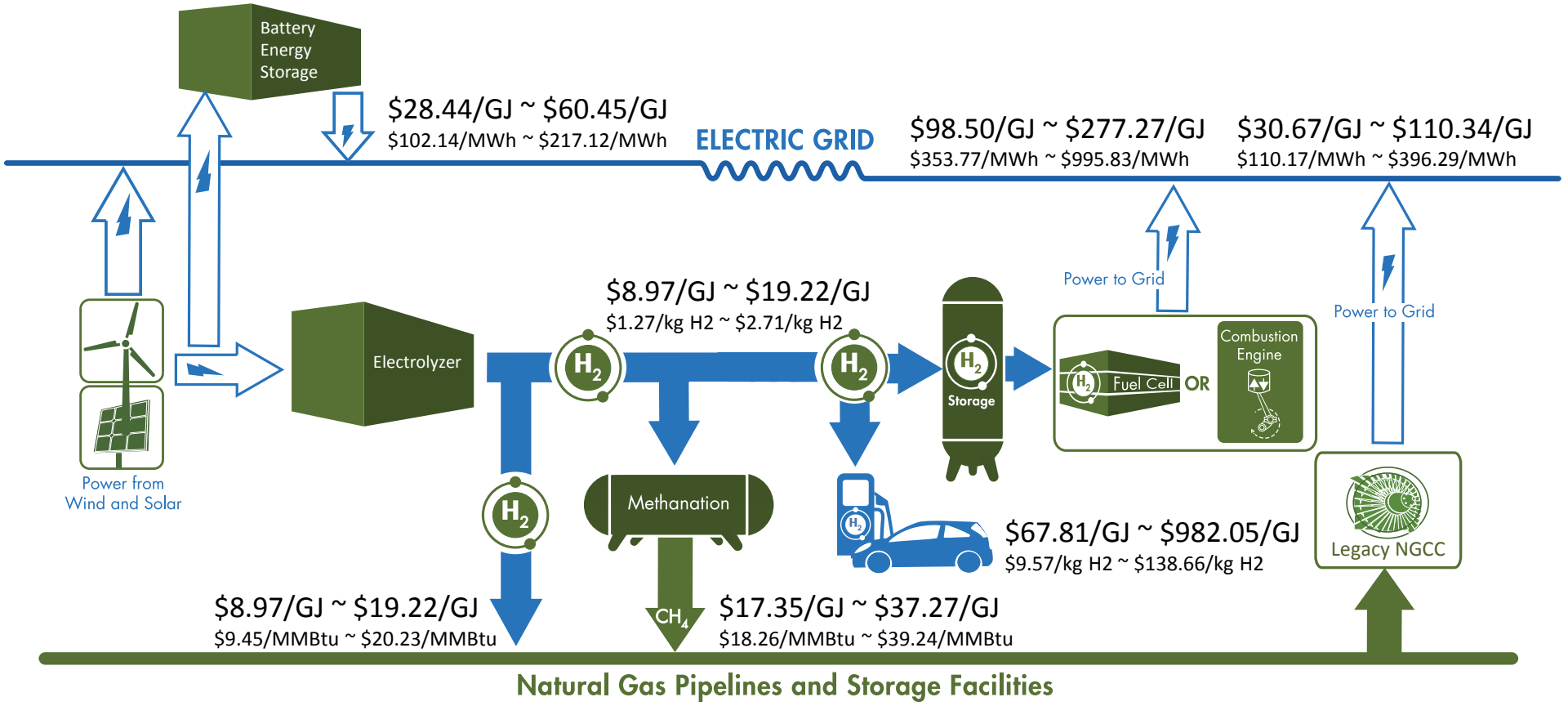
Attribution

- Lori Smith Schell, Empowered Energy, Durango, CO 81303-6440, USA
- Li Zhao, Advanced Power and Energy Program, University of California, Irvine, CA 92697-3550, USA
- Jacob Brouwer , Advanced Power and Energy Program, University of California, Irvine, CA 92697-3550, USA

LCORE Results

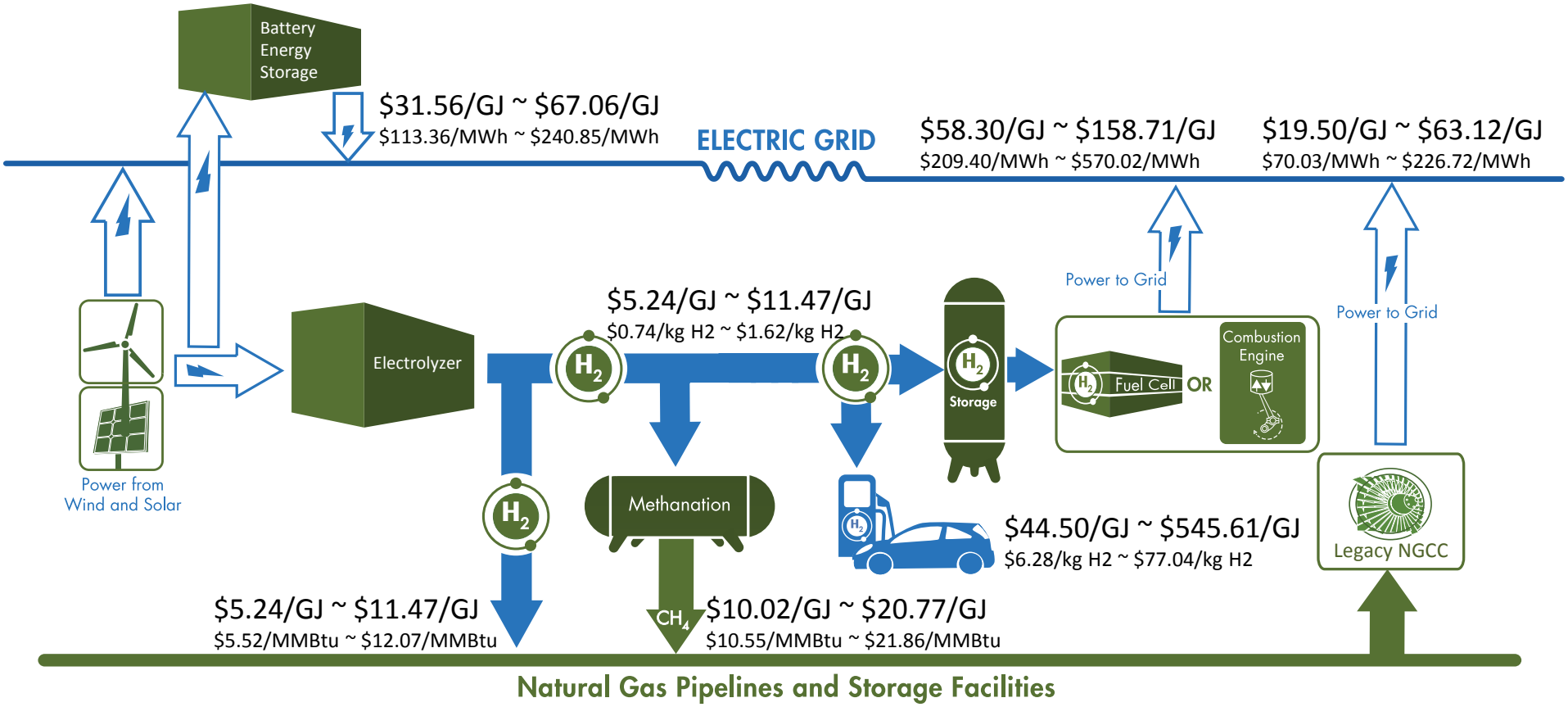
CURRENT COSTS & EFFICIENCES

50% Capacity Factor for All Equipment



LCORE Results

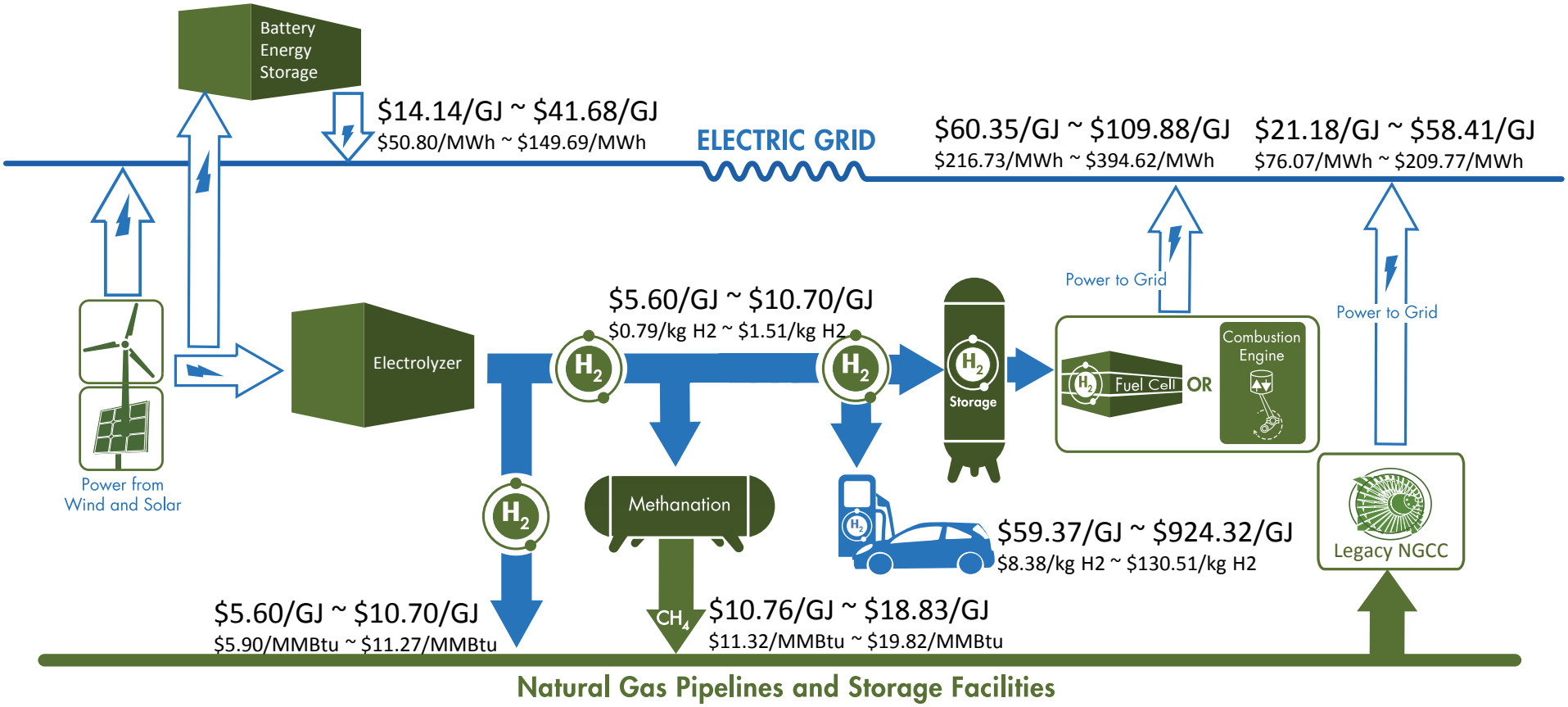
CURRENT COSTS & EFFICIENCES
45% Capacity Factor for Batteries;
90% Capacity Factor for All Other Equipment



LCORE Results

FUTURE COSTS & EFFICIENCES

50% Capacity Factor for All Equipment

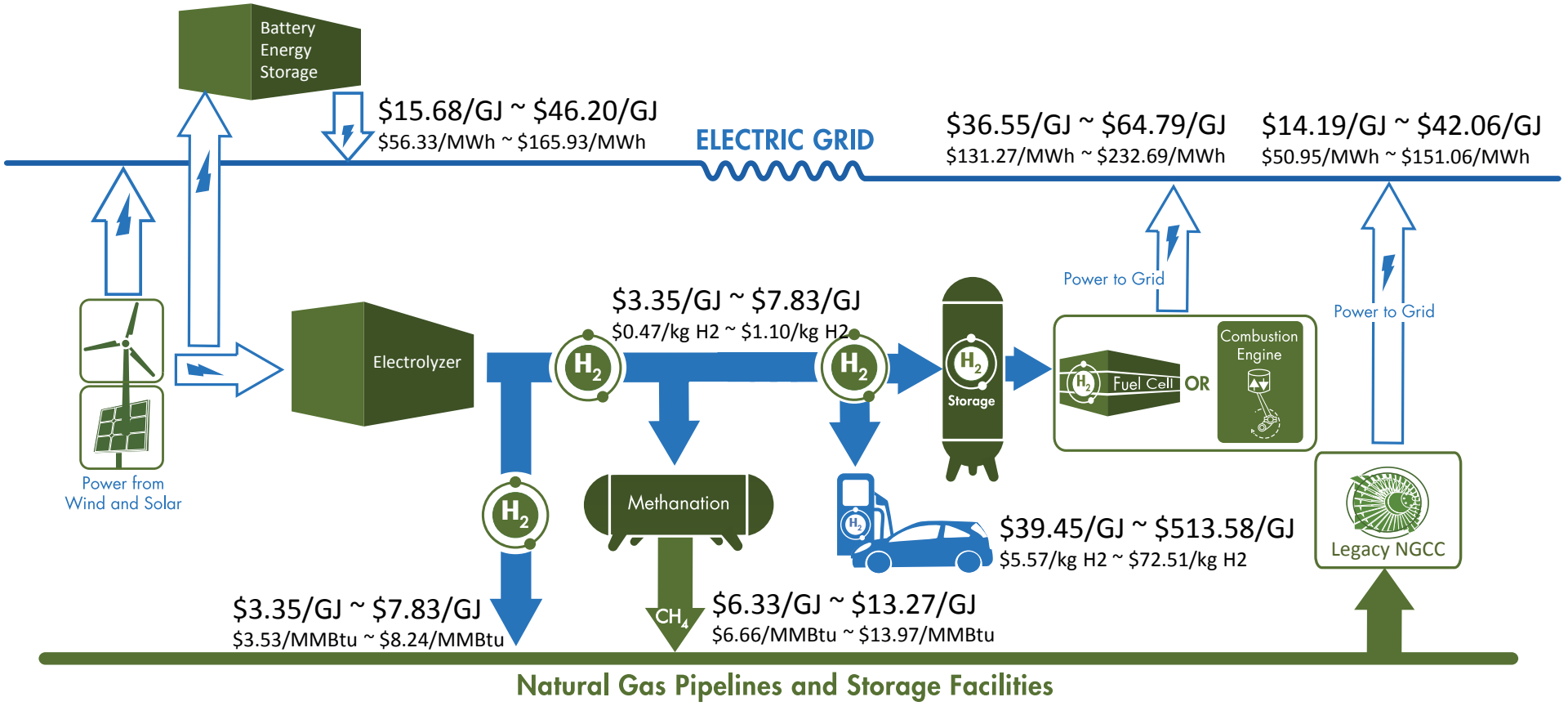


LCORE Results

FUTURE COSTS & EFFICIENCES

45% Capacity Factor for Batteries;

90% Capacity Factor for All Other Equipment



SCG/NREL Power-to-Gas
Biomethanation Demonstration

Project

» Conduct computer modeling, physical testing and characterization of power-to-gas round trip:

- PV (e-) → Water Electrolysis (H_2) → Biological Methanation
- (CH_4) → Steam Methane Reforming (H_2) → Fuel Cell (e-)

Objectives

» Demonstrate that very high levels of solar and wind can be achieved using the NG pipeline system for energy storage.

» Demonstrate the first biomethanation reactor in the U.S.

Accomplishments

» Completed initial modeling of energy storage using P2G using the natural gas pipeline system for energy storage.

» Completed design of the biomethanation reactor, including technical review by technology provider, Electrochaea (Munich, Germany).

» Launched fabrication of the first US biomethanation reactor.

» Working with PNNL, refurbished and commissioned an advanced microchannel steam methane reformer previously constructed and paid for by DOE.

Status

» Scheduled to complete biomethanation reactor fabrication in Q1 2017, with plant commissioning at NREL in Q2 2017.

Commercial Development

» 10 MW power-to-gas plant is being developed by the Hungarian utility MVM (Magyar Villamos Művek) and Munich-based startup Electrochaea GmbH. This is the worlkds first utility scale P2G system.

Archaea

Electrochaea's Pilot Biomethanation Reactor, Denmark

Solar Thermochemical SMR Hydrogen Production

Project

- Design, fabricate and test an advanced compact microchannel heat exchanger and catalysis reactor design to improve on the 69% chemical energy conversion efficiencies demonstrated by an earlier design.
- On-sun testing at SDSU Brawley

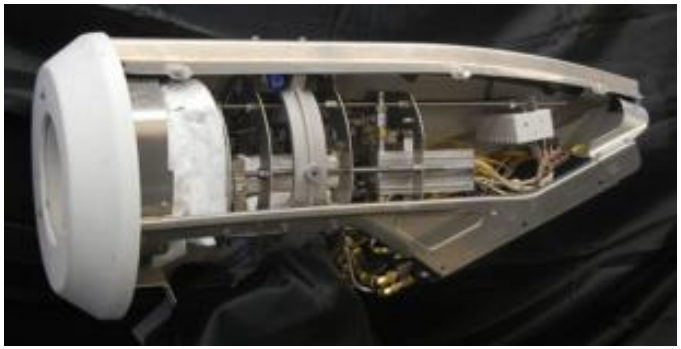
Objectives

- 20 percent incremental renewable energy attribute to hydrogen produced in a distributed solar steam-methane reforming reactor
- Solar-to-thermal energy conversion ~ 84%
- Solar-to-chemical energy conversion ~ 70%
- Overall energy conversion efficiency ~ 90+%

Results

- Objectives achieved
- Need fully optimized system integrated with water-gas shift and CO_2 separation step (membrane or PSA)

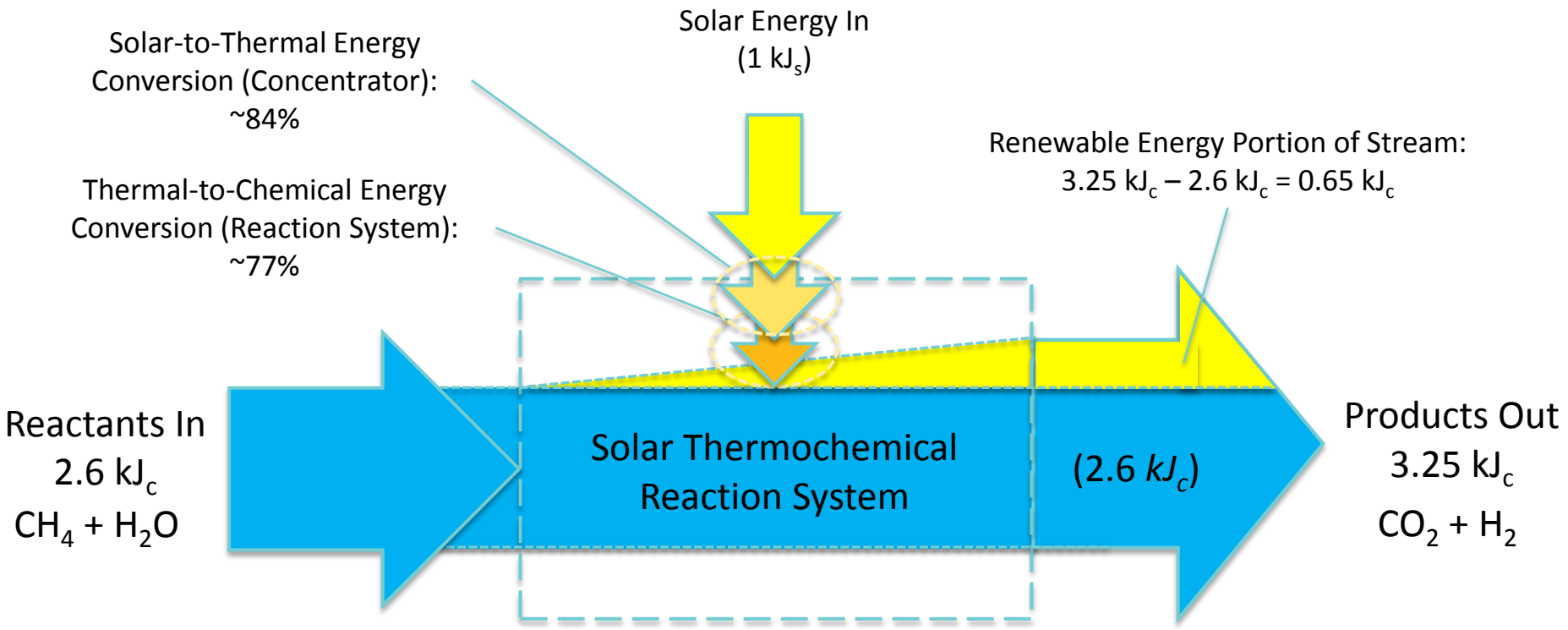
Solar Concentrator Test Stand



Microchannel SMR in Nacelle

Hydrogen Production

Solar Steam-Methane Reforming *with Water-gas Shift*



Net Idealized Reaction:
$CH_4 + 2H_2O \rightarrow CO2 + 4H_2$

Productivity Projections:

- 2015: ~ 42.9 lb H_2 per MMBTU Solar
- 2020: Up to 52.8 lb H_2 per MMBTU Solar

Net Solar-to-Chemical Energy Conversion Efficiency: ~65%

Net Overall Energy Conversion Efficiency: ~90%

Catalytic Nonthermal Plasma (CNTP) Technology
Distributed, High-efficiency Hydrogen Production from Natural Gas

Project

» Develop catalytic nonthermal plasma (CNTP) technology to efficiently produce hydrogen on an as-needed basis for distributed hydrogen generation from natural gas and water.

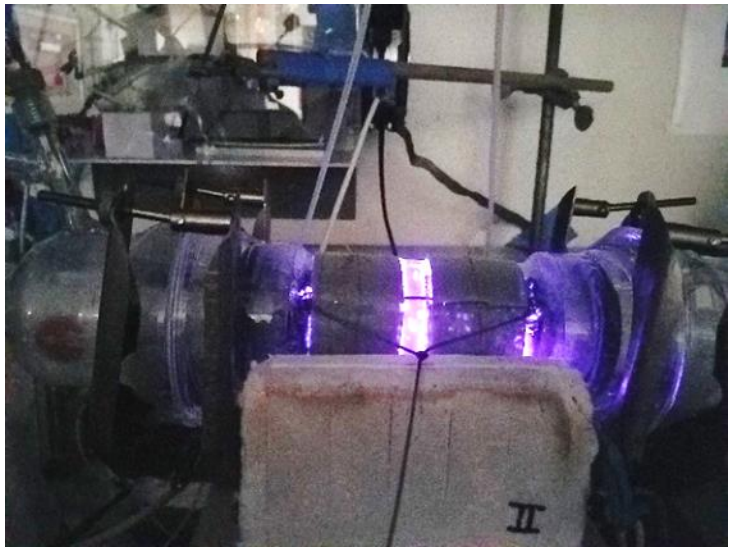
Objectives

» Conversion efficiency: > 75%

» Startup time: < 30 minutes

» Subscale unit production capacity: ~ 1Kg H2/day

» Production Cost: $ 2-4 gge H2



CNTP SMR Reactor

Results

» Designed, fabricated and operated scaled-up 2kg H2/day brassboard CNTP reactor. Tested steady-state and pulsed plasma.

» Demonstrated technical/engineering feasibility of CNTP H2 production
- CNTP Energy Efficiency, ηp 74%
- H2 Prod. Efficiency: 95%
- H2 Purity (H2/H2+CO) 97%
- CH4 Conversion 97.5%

Energy Efficiency, $\eta = \frac{\Delta H_{CO} + \Delta H_{H2}}{\Delta H_{CH4} + W}$

ΔH_{H2} = 285.8 kJ/mole
ΔH_{CO} = 283.0 kJ/mole
ΔH_{CH4} = 890.3 kJ/mole
W = external energy input

$CH_4 + H_2O \rightarrow CO + 3H_2$, ΔH = +206 kJ/mol
$CO + H_2O \rightarrow CO_2 + H_2$, ΔH = - 41 kJ/mol
$CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$, ΔH = 165 kJ/mol

Co-Production of Power and H_2
Sub Stoichiometric Oxy-Fuel Combustion

Project

» Design, fabricate and test an advanced oxy-fuel system that produces power and hydrogen with zero emissions.

Process

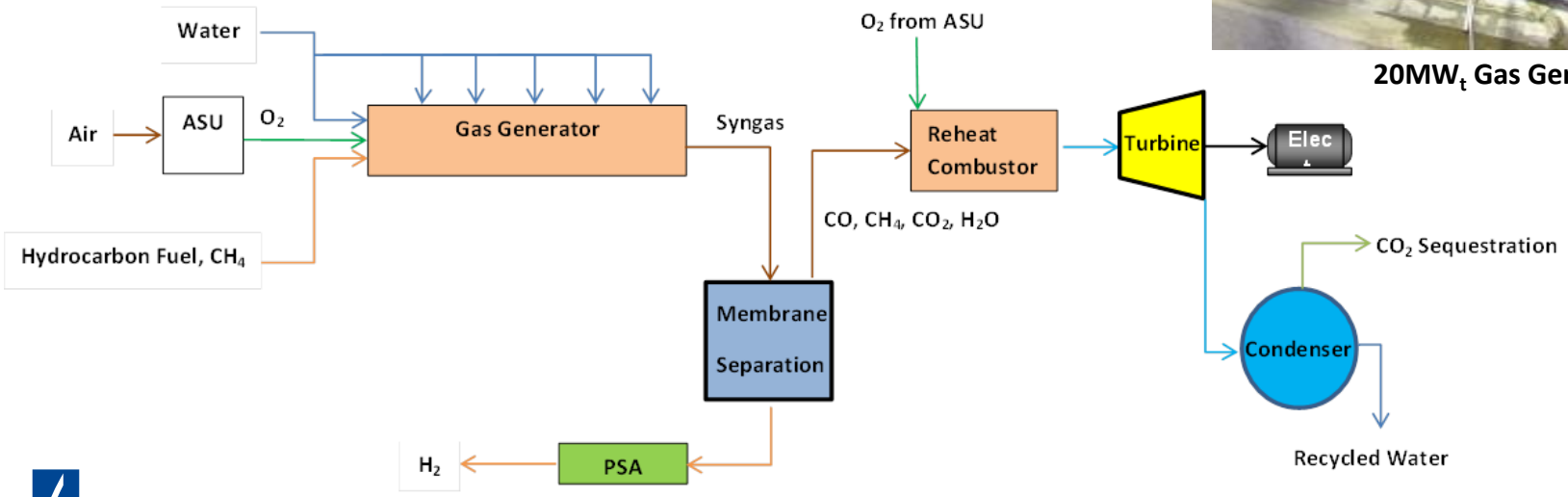
» Oxy-fuel combustion system operated in sub stoichiometric conditions produces H_2 and CO, plus smaller quantities of CO_2 and H_2O.

» H_2 is separated and delivered to an end-use application

» Low BTU syngas (primarily CO) is combusted in an oxy-fuel reheater

» CO_2 and H_2O pass through the system and are separated in the condenser

20MW$_t$ Gas Generator



SoCalGas A Sempra Energy utility

Glad to be of service.®

CEC / SoCalGas Solar Hydrothermal Processing
Dairy Waste to RNG

Project

» Dairy waste to renewable natural gas (RNG) by integrating concentrated solar power (CSP) with hydrothermal processing (HTP).

Objectives

» Design, install, and operate an innovative, small-scale waste-to-energy bioenergy system that:
  - Integrates CSP and HTP technologies
  - Converts dairy manure into low carbon intensity (CI), pipeline quality RNG for injection into the pipeline


Linear Fresnel CSP System

Accomplishments

» Optimized CSP receiver design to achieve 390º C

» Published paper and filed patent application covering receiver design optimization algorithm

» Updated HTP system design

» Hyperlight won an additional DOE award for work that will benefit this project.


Skid-mounted HTP system

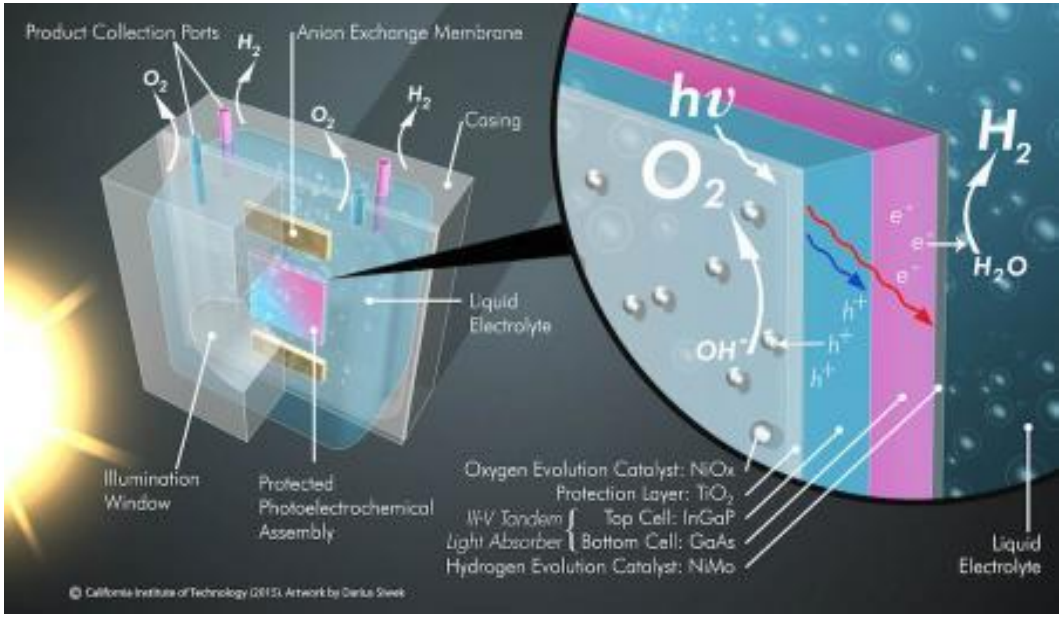
Joint Center for Artificial Photosynthesis (JCAP) Industry Partnership

Mission

» Support the Joint Center for Artificial Photosynthesis (JCAP) mission to create the scientific foundation for a scalable technology that converts carbon dioxide, water, and sunlight into renewable transportation fuels.

Objective

» Development of the foundation technology for renewable fuel plants.



SLAC BERKELEY LAB UCI Caltech U.S. DEPARTMENT OF ENERGY UC San Diego

Utilities - An important Source of Infrastructure Resources

- **Biogas Conditioning/Upgrading Services Tariff, G-BCUS**
  - An optional tariff service for customers that allows SoCalGas® to plan, design, procure, construct, own, operate and maintain biogas conditioning and upgrading equipment on customer premises.

- **Compression Services Tariff, GO-CMPR**
  - A non-residential, optional tariff service for customers that allows SoCalGas to plan, design, procure, construct, own, operate and maintain compression equipment on customer premises to meet pressure requirements as requested by the customer and agreed to by SoCalGas.
  - Examples of customer end-use applications that can be served by the Compression Services Tariff include compressed natural gas (CNG) vehicle refueling stations, combined heat and power (CHP) facilities and peaking power plants.

- **Other services could be considered**

Conclusions

- SoCalGas' RD&D Program includes several compelling low carbon H2 projects
  - Power-to-gas
  - Solar Thermochemical SMR Hydrogen Production
  - Distributed, High-efficiency Hydrogen Production from Natural Gas
  - Co-Production of Power and H_2 with Sub Stoichiometric Oxy-fuel Combustion
  - Biomass gasification
  - Joint Center for Artificial Photosynthesis (JCAP)

- Utilities represent an important source of H2 infrastructure resources
  - Biogas Conditioning/Upgrading Services Tariff
  - Compression Services Tariff
  - Other potential services

rkent@semprautilities.com

THANK YOU!