Experience with Long Term Energy Storage and Power-to-Gas

Electricity Advisory Committee Webinar

May 28, 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
- **>8,000 employees**
- **136 Bcf storage (= 13 to 19 TWh net)**

SoCalGas A Sempra Energy utility

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 $MTCO_{2e}$**

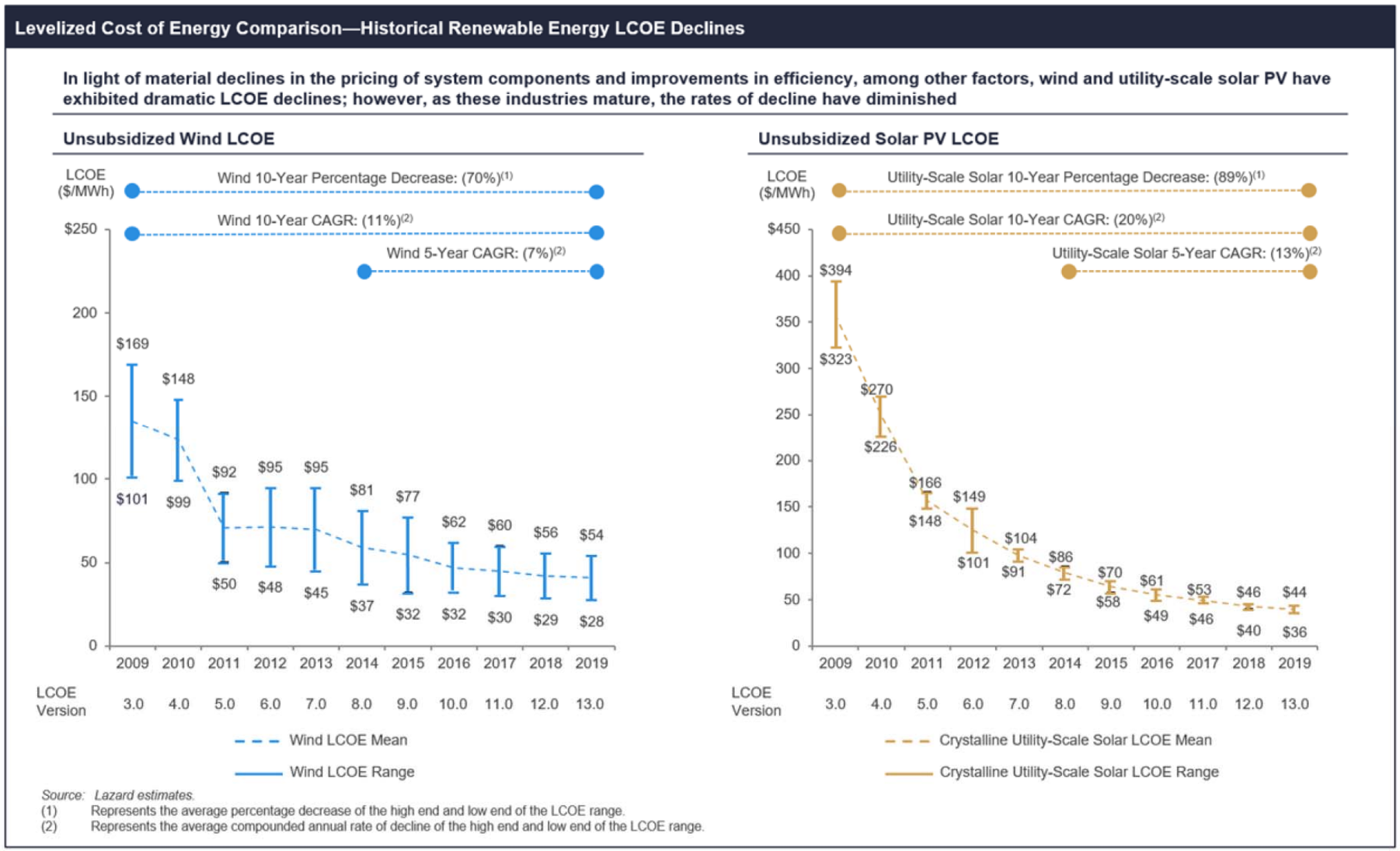
Renewable Gas Goals

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

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

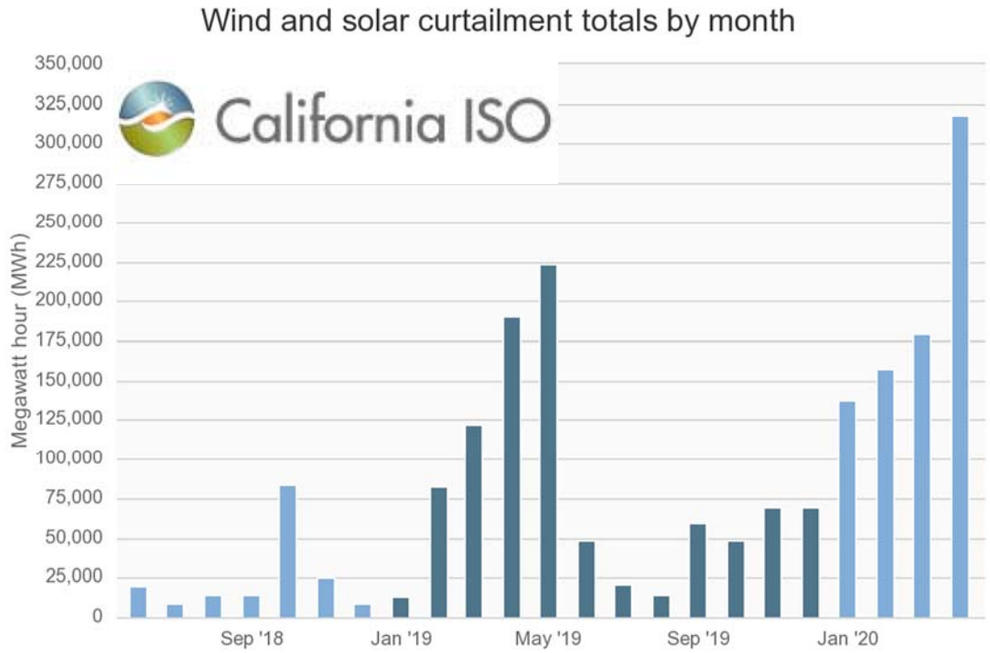
*Percent of core customer throughput

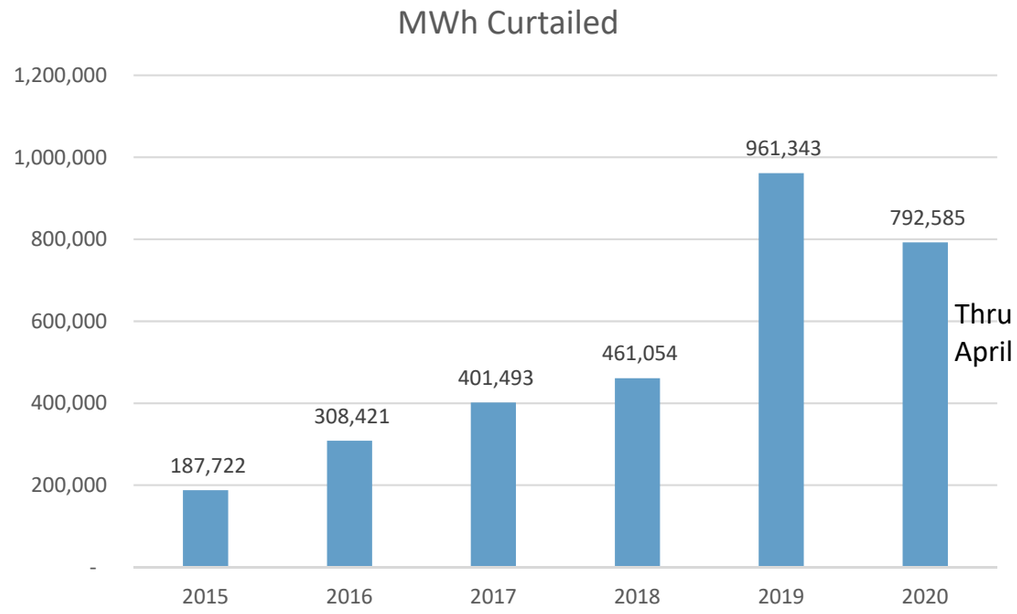
P2G Driver: Low Cost Renewables



https://www.lazard.com/perspective/lcoe2019

P2G Driver: Curtailment





Solar and wind curtailed by year

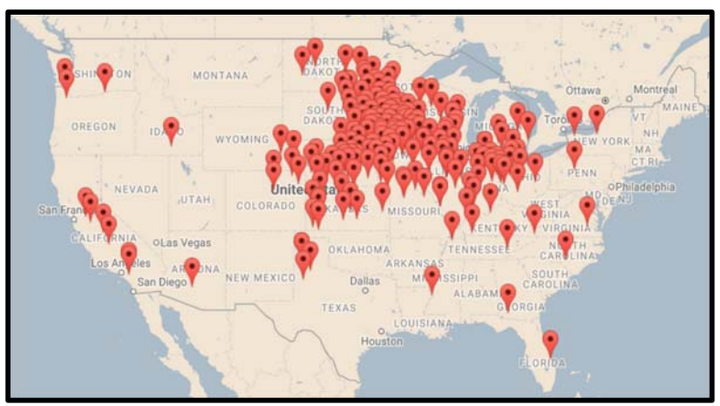
- Production only assume: 50 kWh/kg H_2
- 2020 curtailments are on track to exceed 2 TWh
- P2G could produce 40 MT Kg H_2 and recycle 200k MT CO_2

Year	MWh Curtailed	MT kg H2	MT CO2
2015	187,722	3,754	20,493
2016	308,421	6,168	33,670
2017	401,493	8,030	43,830
2018	461,054	9,221	50,332
2019	961,343	19,227	104,948
2020	792,585	15,852	86,525

Early Market CO_2 Sources – Plenty of Resource

- As of May 2018, the United States has over **200 operating refineries** producing **15.8 billion** gallons of ethanol per year (http://www.neo.ne.gov/statshtml/122.htm)
- Typical ethanol plant produces **50 million gallons of ethanol** per year and **150,000 metric tons of CO_2**
- Each **50 MW of electrolysis** (432 kg H_2/MW-day) feeding a bioreactor can recycle **37,000 metric tons of CO_2**
- Therefore, it would take **200 MW of electrolysis per typical ethanol** plant to recycle all of the CO_2 into CH_4

Source:
Kevin Harrison, Ph.D. NREL



http://www.ethanolrfa.org/resources/biorefinery-locations/

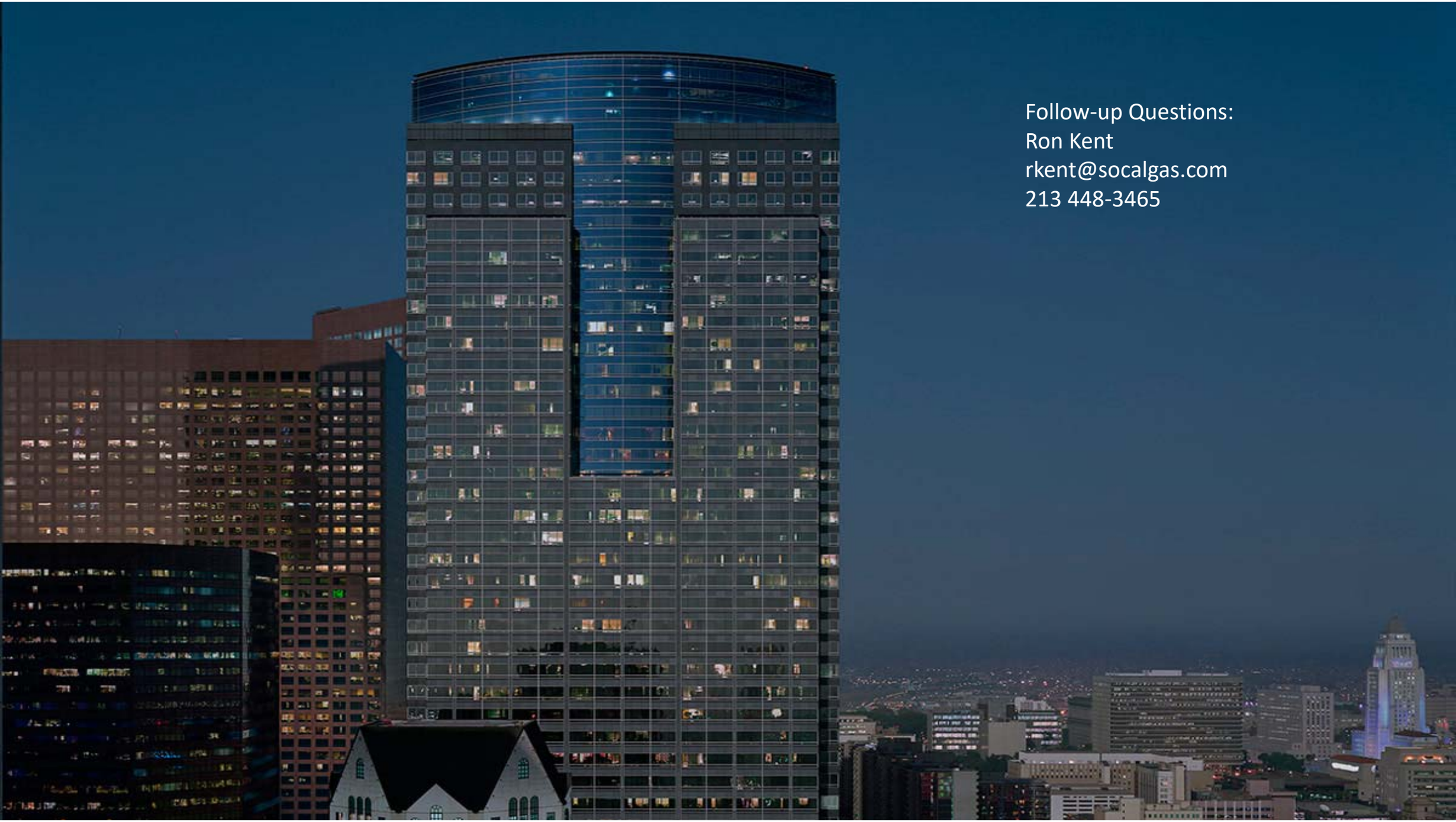
Last updated: April 30, 2018

What's Missing?

Viable Business Models

Hydrogen and Power-to-Gas Ecosystem

- Electric and gas grid integration
- Grid dispatch models
- Virtual storage "islands"
- Access to wholesale electric rates
- Financial trading and arbitrage instruments
- Enabling laws, regulations and tariffs



Follow-up Questions:
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Extra Slides

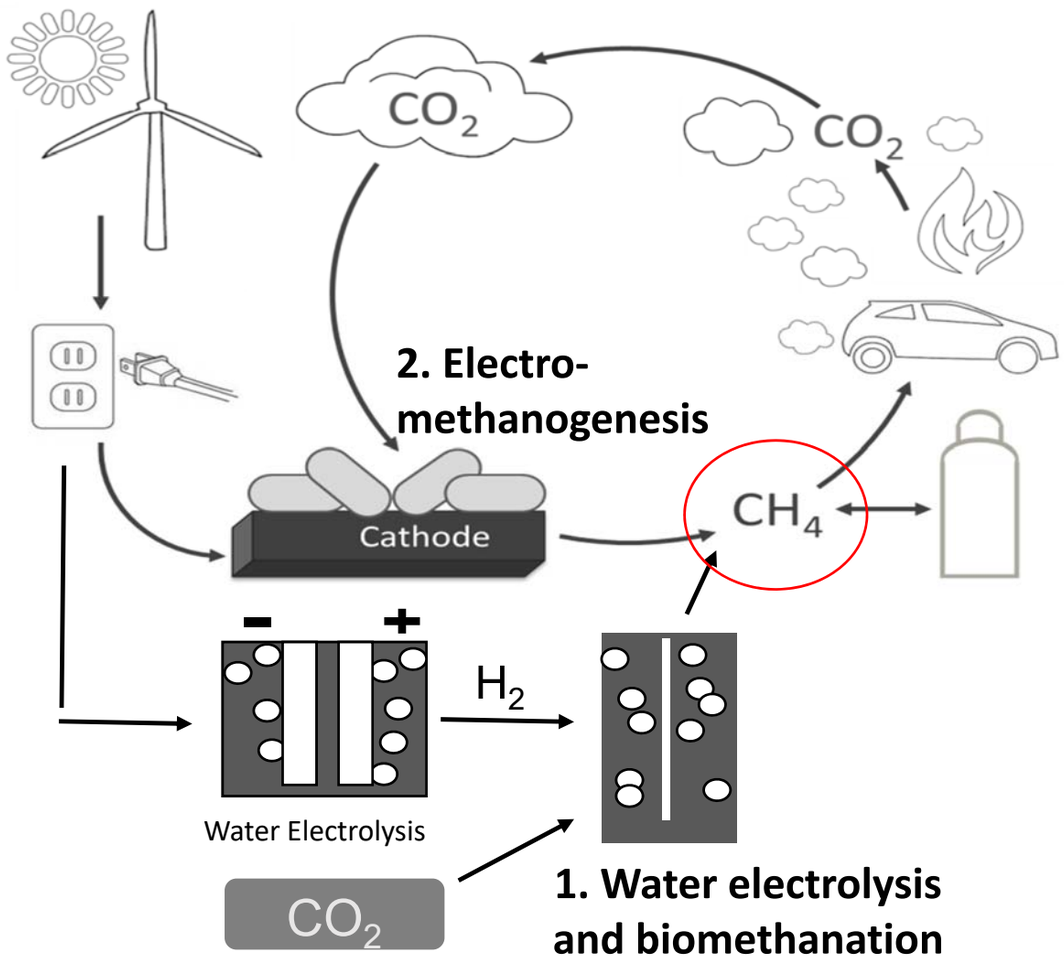
SOCALGAS POWER-TO-GAS RD&D

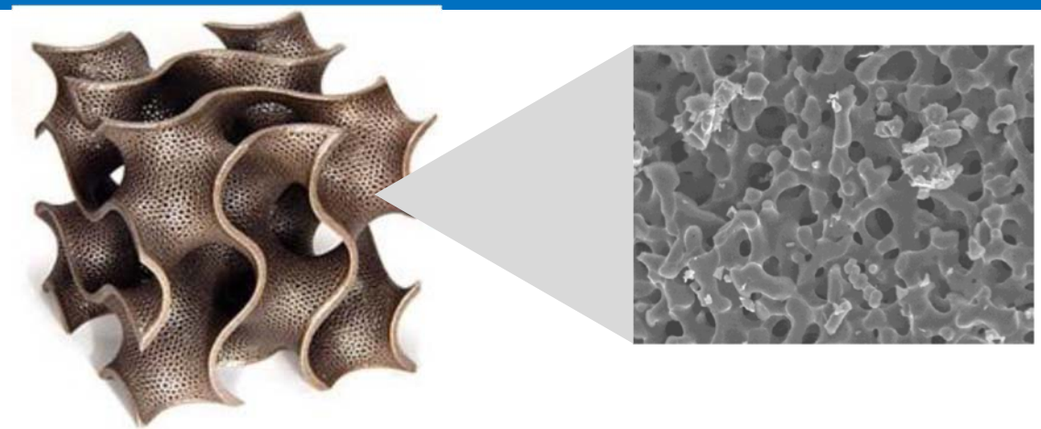
Scalable, affordable solutions

- **Electrolytic H_2 with methanation**
- **Direct Electromethanogenesis**
- **Electrochemical CO_2 reduction**
- **Distributed electric SMR with CCS**

Power-to-Gas with Biomethanation

Two Approaches





Electro-methanogenensis electrode with *mesopores* to increase surface area and *macropores* to ensure good fluid flow/mixing

Water Electrolysis & Biomethanation demonstration at NREL (Golden, CO), 700 liter vertical, stirred bioreactor.

Power-to-Gas: Water Electrolysis with Methanation

Using the renewable H_2 and CO2 in a downstream methanation process to produce renewable methane and water

$$4H_2 + CO_2 \xrightarrow{\text{Biocatalyst}} CH_4 + 2H_2O + \text{Heat}$$

Benefits of Renewable CH_4 via P2G

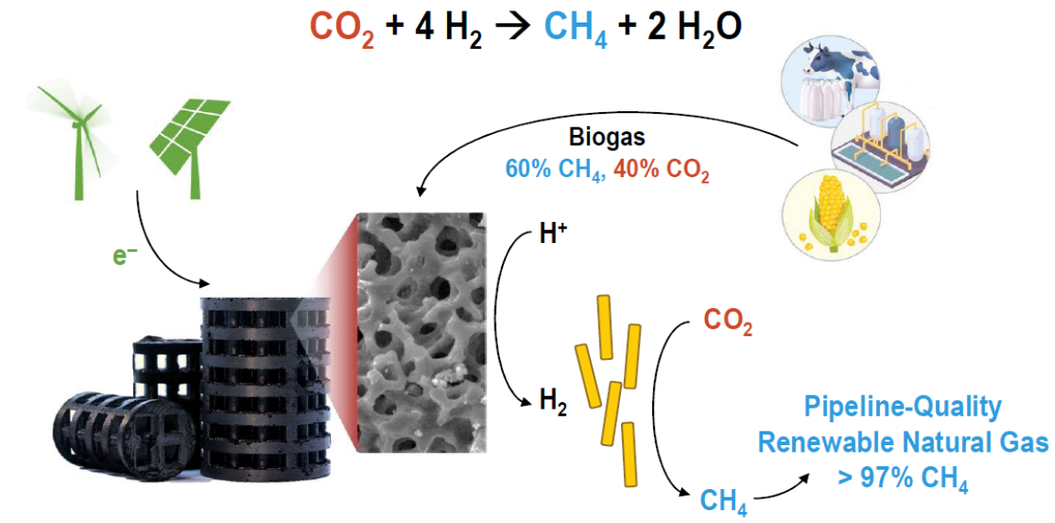
- Enables higher penetration of renewable electricity
- Recycles CO_2
- Meets pipeline quality standards
- Provides long-duration energy storage in the NG network
- Upgrades waste streams containing CO_2
  - Ethanol, dairies, wastewater, breweries
- Scale-able, non-toxic, self-replicating biocatalyst, low temperature systems

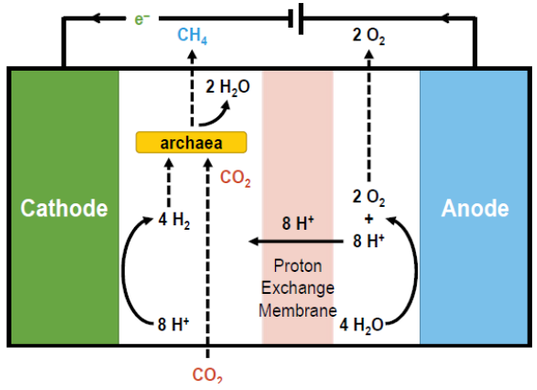
Rule of Thumb: 10MW_e of electrolysis feeding a bioreactor can recycle 7500 tons of CO_2 per year

Microbial Electromethanogenesis

In-Situ Microbial Electromethanogenesis

By producing hydrogen in the same reactor where the microbes utilize it to convert CO_2 into CH_4, we can overcome productivity limitations associated with poor solubility and mass transfer of hydrogen in water. By eliminating the need for a separate electrolyzer, the process can be made modular and the scale can be tuned to the size of the biogas source.

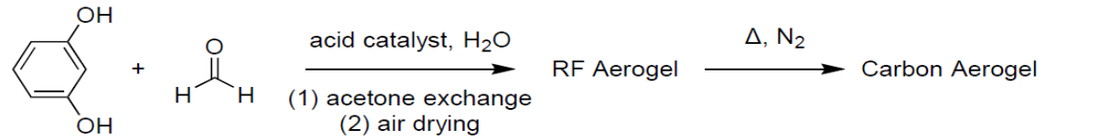


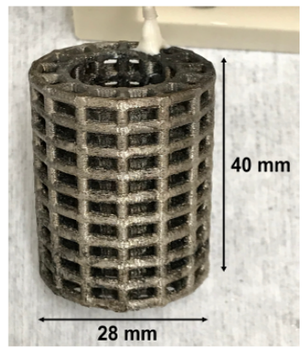


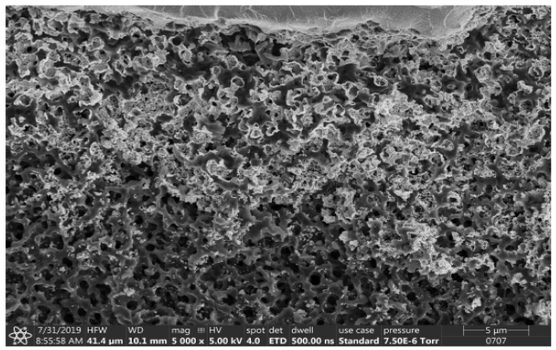
We are currently able to achieve 90% CH_4 in the outlet gas stream with constant current, gas flow, and microbial media recirculation, by matching the CO_2 flow rate and current to the rate of metabolism of the microbes.

Advanced Manufacturing of Electrodes

We can manufacture high surface area electrodes in any geometry for various applications. Cylindrical electrodes are electroplated with a NiMo catalyst for performing hydrogen evolution at neutral pH in a tubular bubble column flow reactor.







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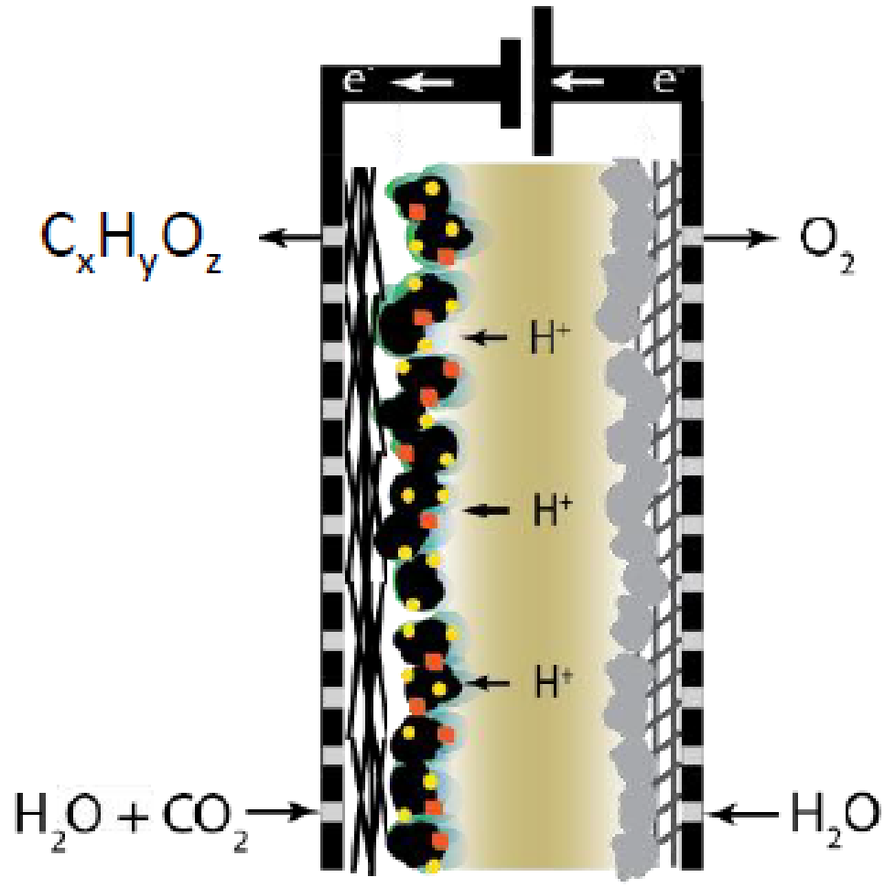
Opus 12 Electrochemical CO_2 Reduction

Purpose

- Demonstrate the viability of Opus 12's metal nanoparticle catalyst/polymer membrane combination to produce methane from CO_2, water, and electricity.

Objectives

- Test Opus 12's current catalyst formulation for the conversion of the CO_2 component of biogas to CH_4.
- Formulate and test a new catalyst structure that promises to provide improved selectivity for CO_2-to-CH_4 conversion.



Distributed Electric Steam Methane Reforming D3-Printed, Induction-Heated, Microchannel Reactors

- Using renewable electricity to drive the endothermic reaction results in a 20% renewable attribute.
- Efficiency: >70%
- Basic unit: 35 kg/day
- 20 compact reactors would produce 700 kg/d
- H2 cost target < $2/kg
- Commercialization channel:
  - STARS Technology Corporation”
  - PNNL spin-off

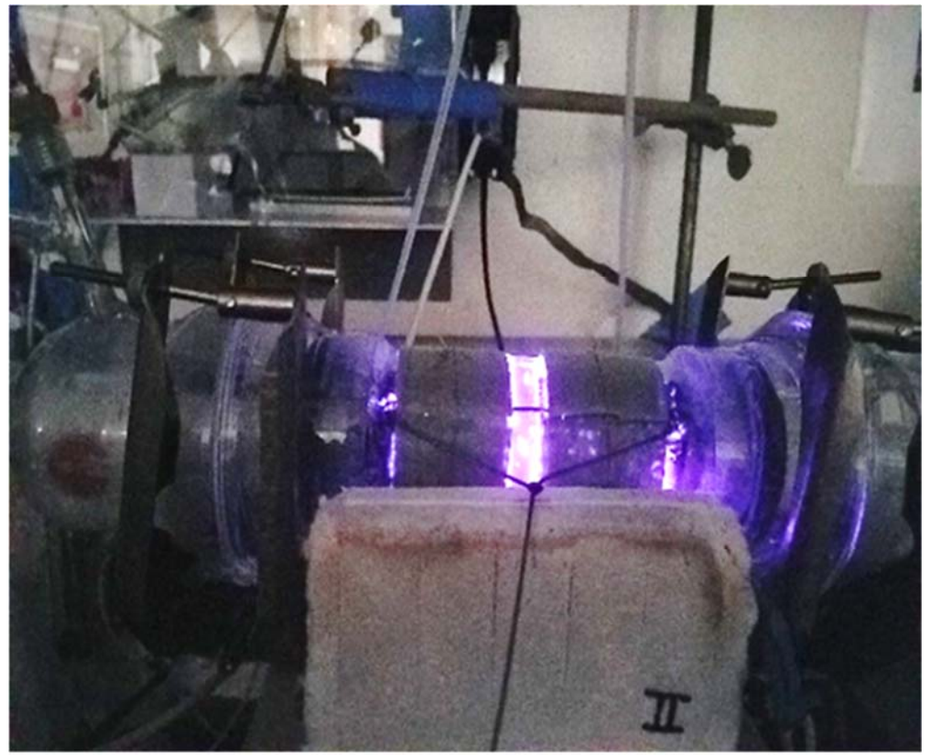

TRL 5


TRL 6


TRL 6

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;
  - Robust start-stop capability
  - Low-temperature operation (400° - 500°C)
  - Subscale unit production capacity: ~ 1Kg H_2/day
  - Full-scale production capacity: 5kg/day
    - numbering-up reaction tubes
  - Production Cost: $ 2 /kg H_2



CNTP SMR Reactor