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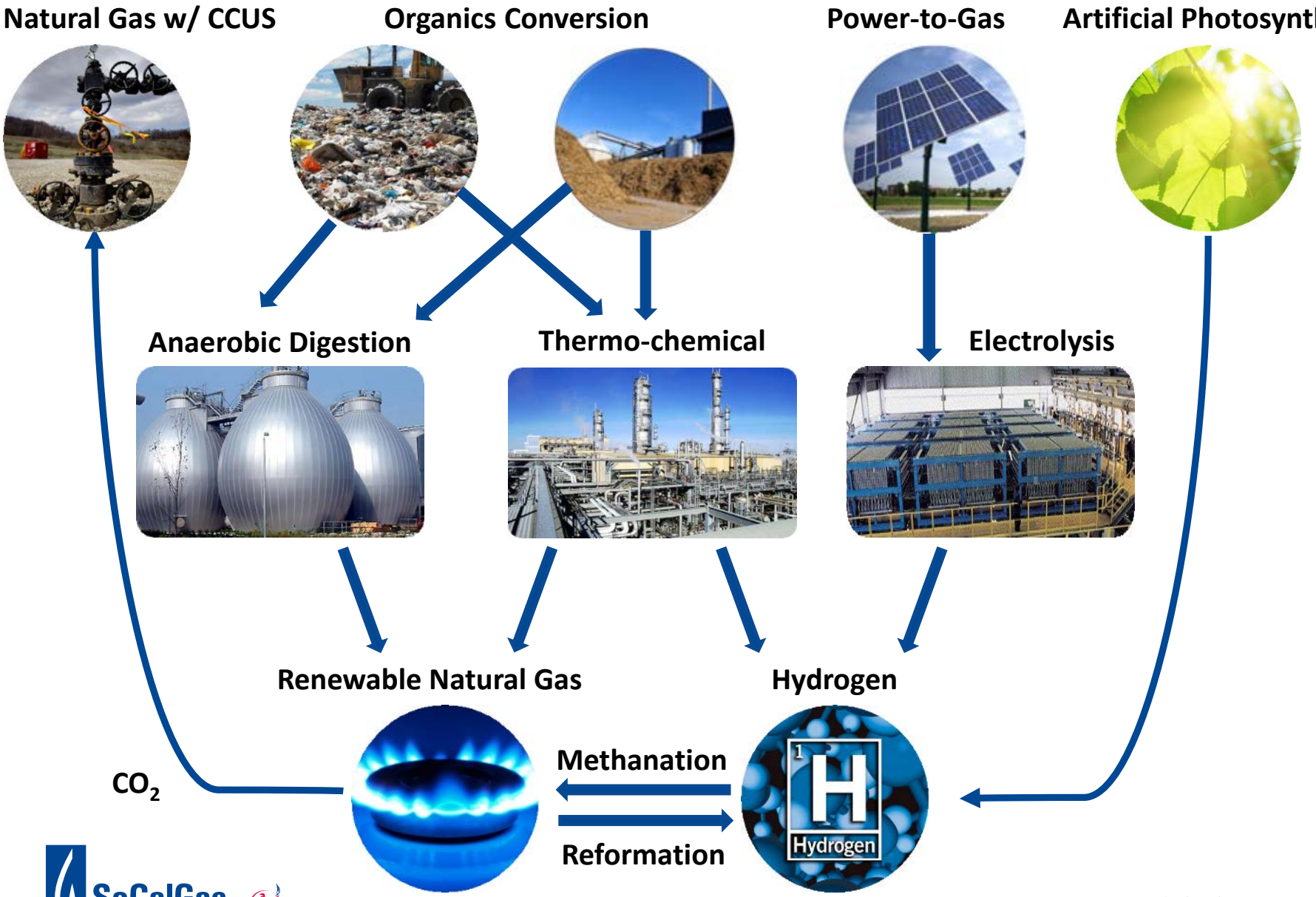
THE PROMISE OF POWER-TO-GAS
UC RIVERSIDE RNG CONFERENCE

May 17, 2017

Renewable and Zero-carbon Pathways



Renewable Energy Goals

CA Renewable Electricity Requirements:

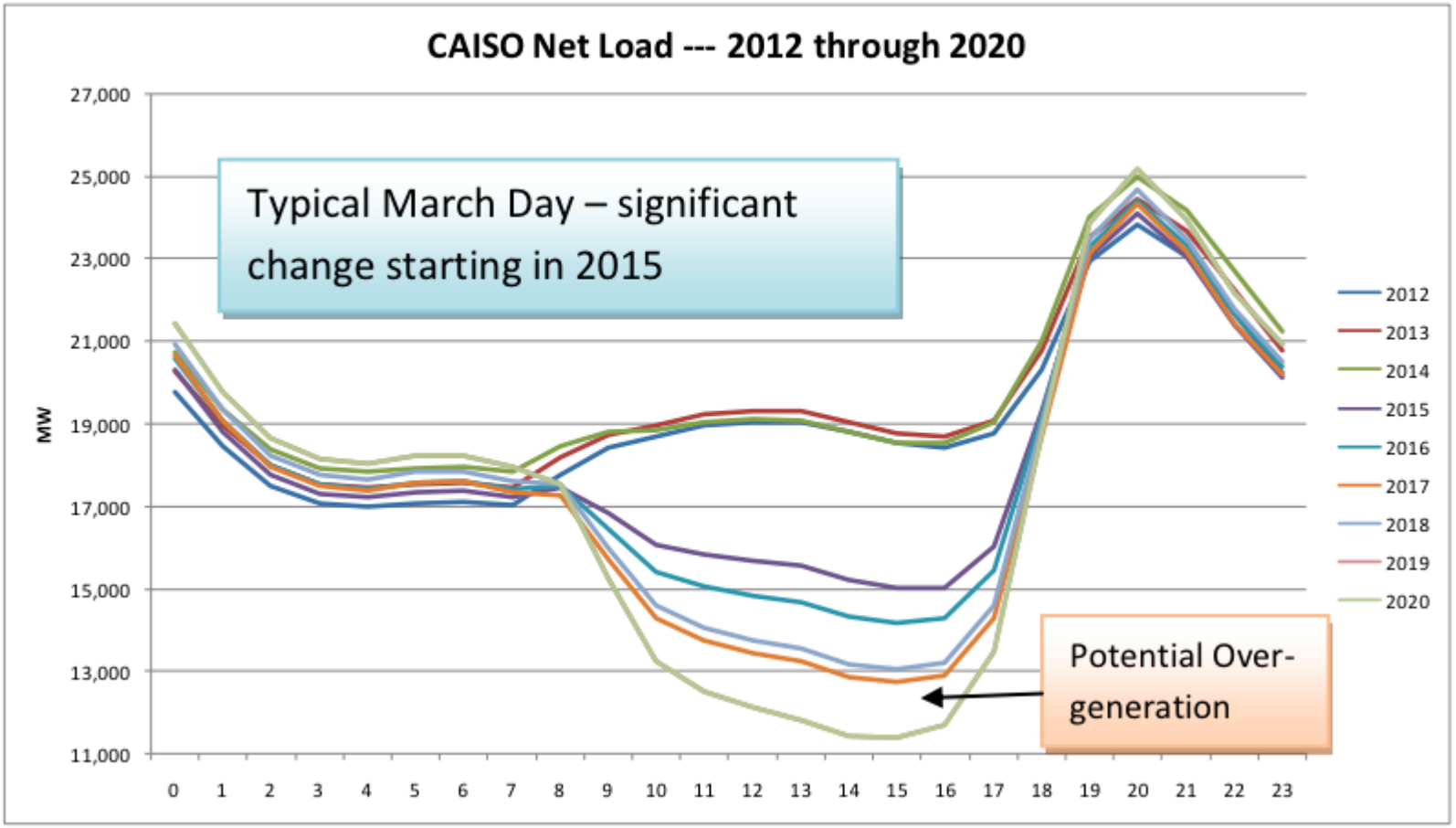
33% by 2020

50% by 2030

100% by 2045?

Supply/Demand Mismatch

The Famous California "Duck Curve"

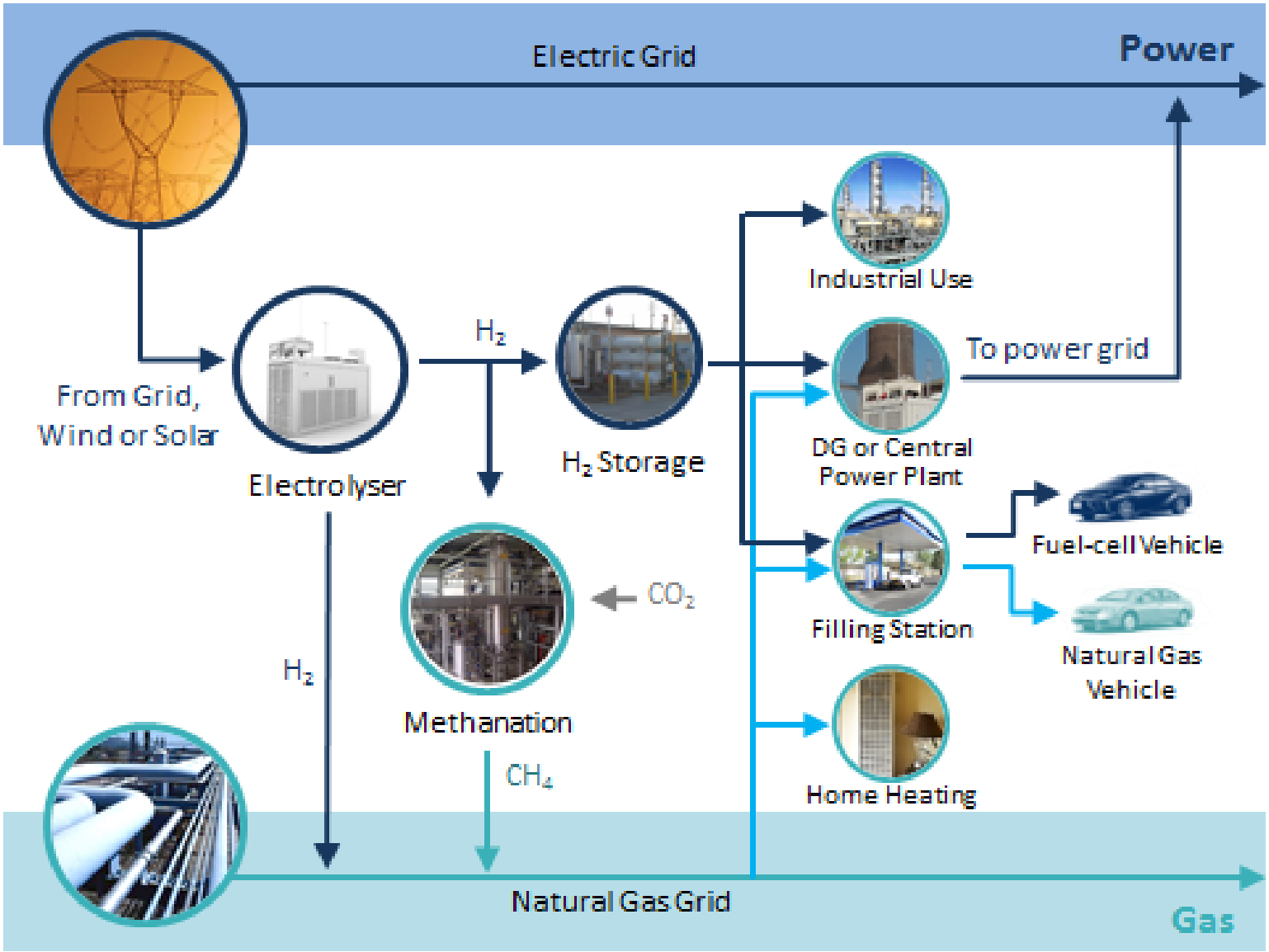


100% renewables requires massive supply shift mid day to evening and night… and summer to winter

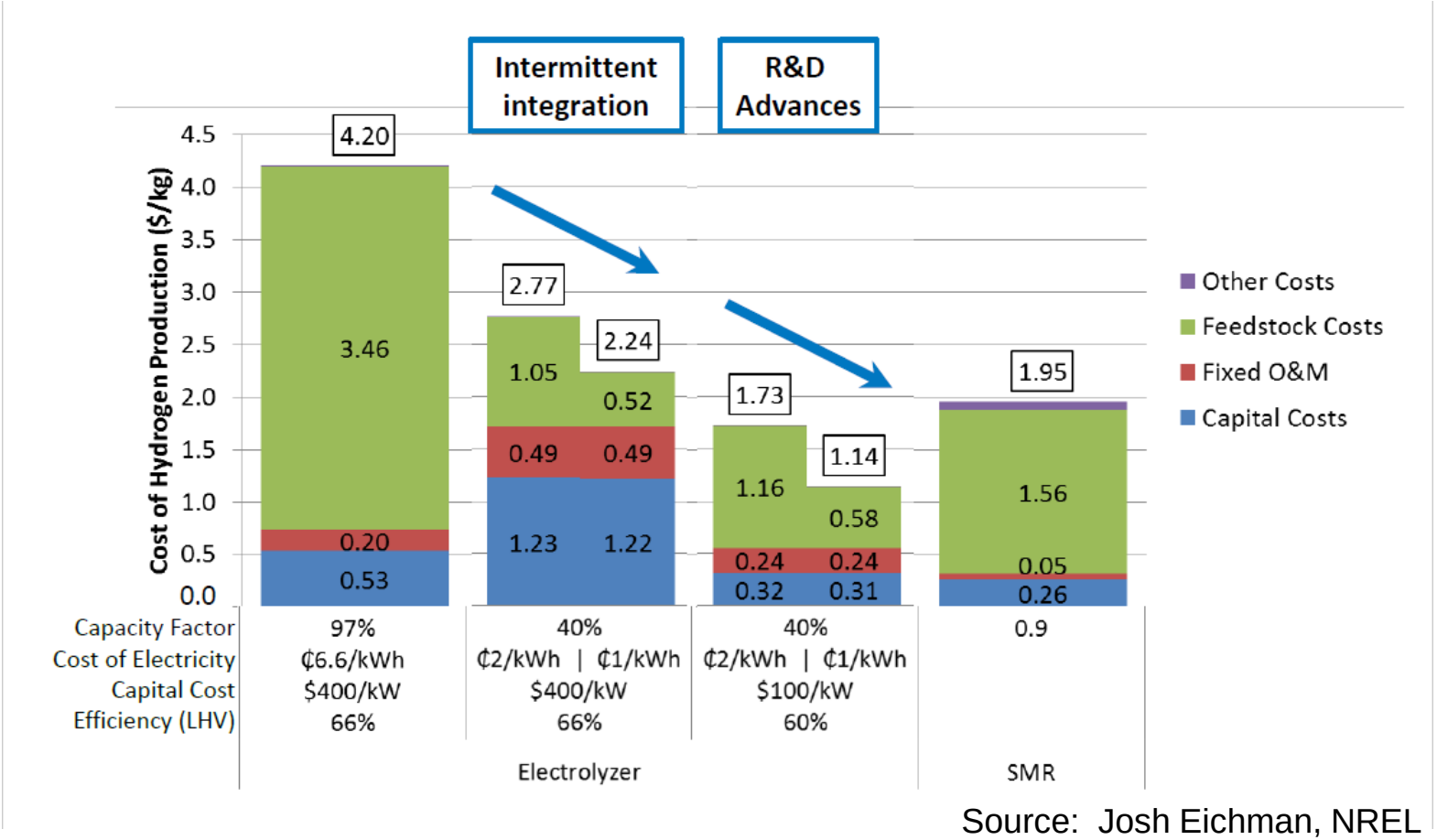
Supply/Demand Mismatch

- As ZNE requirements increase the deployment of rooftop solar, the duck curve will become even more extreme as empty homes export large amounts for solar to the grid during the middle of the day.
- The grid will need load shifting capacity of up to 12 hours and across days depending on weather patterns.
- Intermittency will require the grid to have very fast responding load resources.
- As time goes on and renewables go above 50%, seasonal variations in solar and wind will need to leveled as well.
- Power-to-Gas is a solution that addresses these challenges and, with advances in cost and performance, my do so less expensively than other resources such as batteries.

Power-to-Gas


Electric Grid
Power
From Grid,
Wind or Solar
Electrolyser
H_2
H_2 Storage
Industrial Use
To power grid
DG or Central
Power Plant
Fuel-cell Vehicle
Filling Station
Natural Gas
Vehicle
CO_2
Methanation
H_2
CH_4
Home Heating
Natural Gas Grid
Gas

Improving Economics of P2G



Source: Josh Eichman, NREL

Recent Bloomberg forecasts:

- New-build solar <$50/MWh
- Spot price for merchant solar $16/MWh in 2027

A vision of what's possible
GERMANY

GERMANY'S RENEWABLE ENERGY STORAGE

Potential for electrolysis is estimated at up to

170GW

which could power

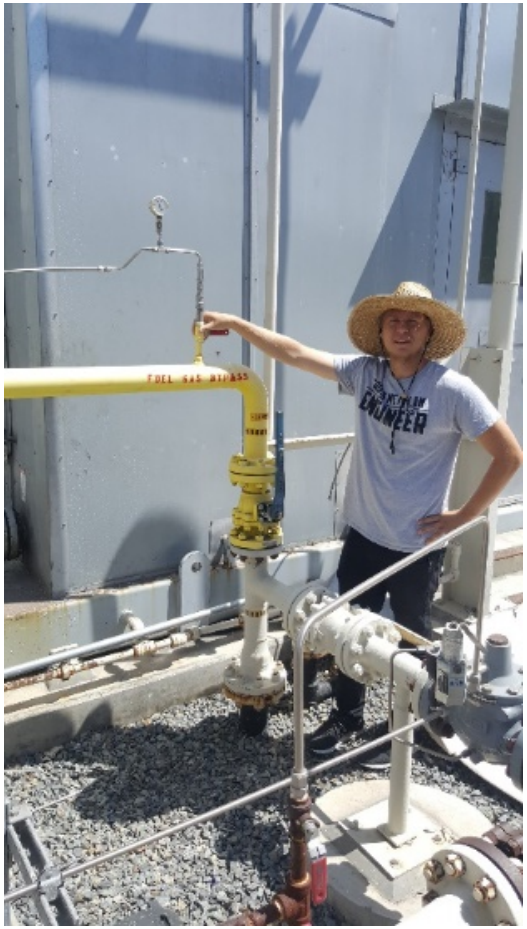
114 million

homes.

Source: Commercialization of Energy Storage in Europe, 2014

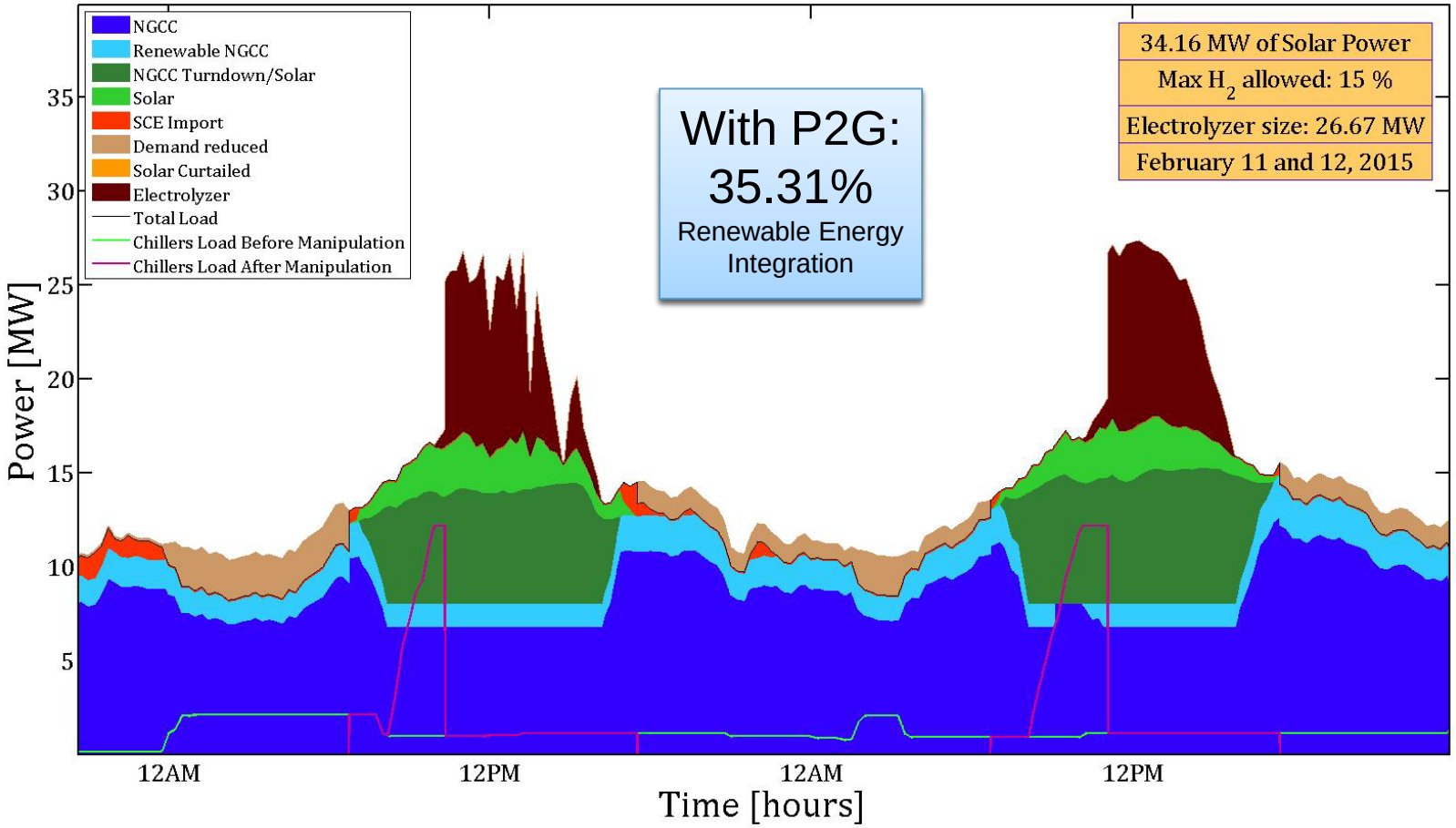
UC Irvine Electrolyzer Demo

- 60kW Proton OnSite Electrolyzer
- On-campus Pipeline Blending
- NGCC Power Production



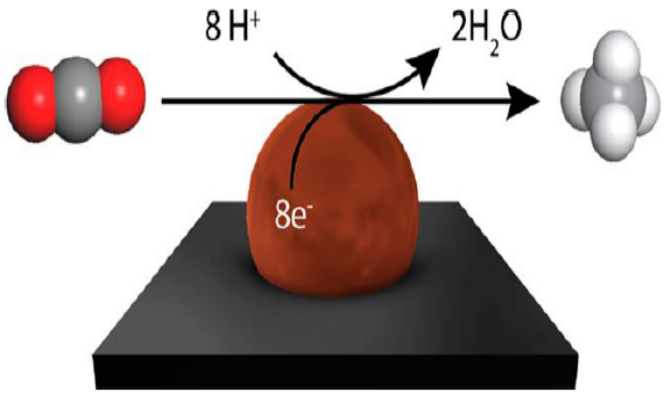
UC Irvine Microgrid P2G Project

» Simulation shows dramatic increase in solar utilization



Power to Methane

Electrochemical CO_2 Reduction



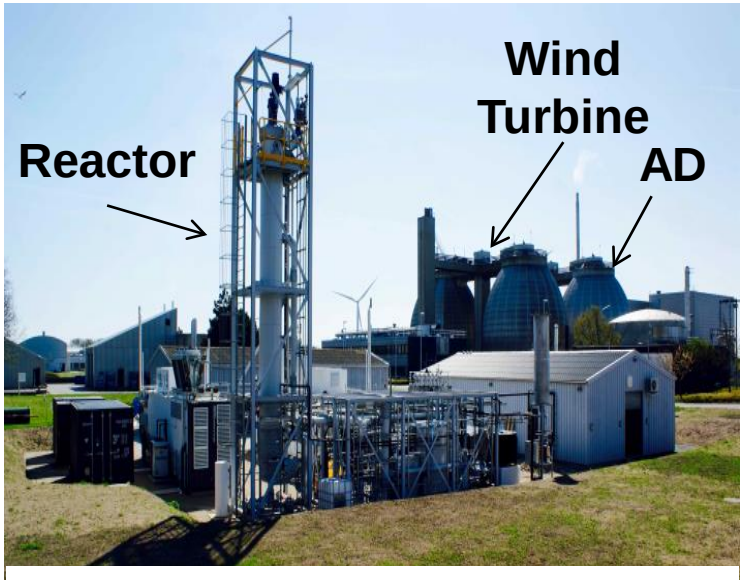
25 nm round copper particles have over 80% selectivity for methane

Combine water, CO_2, and electricity…

To produce methane

Biomethanation

Archaea



1 MW Pilot P2G / Biomethanation

Path Forward

- P2G supports California renewable goals:
  - Massive load shifting capability
  - Added resource diversity
  - Addresses “difficult to electrify” applications

- What’s Required:
  - Cost-based, real-time rates
  - Proper inclusion of power-to-gas in storage and grid services markets
  - Standards for tracking and trading renewable content
  - Fact-based dialogue

Panel Topics

- Challenges to widespread deployment of P2G in California.
- When will deployment begin to accelerate?
- How will it look? Roles of public and private entities? Distributed or central facilities? Role of existing infrastructure?
- Who are the stakeholders and what do they need to do?
- What role can a center like CRNG play in helping the cause?

THANK YOU

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