Role of Hydrogen in Energy Future

for: Sacramento Municipal Utility District

from: San Diego Union Tribune

Prof. Jack Brouwer, Ph.D., Director

Board Strategic Development Committee and Special SMUD Board of Directors Meeting

Public comment may be submitted via e-mail to PublicComment@smud.org.
Adopt More Solar & Wind

We must increasingly adopt energy conversion that is sustainable & naturally replenished quickly

Good News!

• Widely available around world
• Now typically cheapest form of primary energy

Directly Use More Renewable Electricity

• Electrify buildings, especially residential new construction – but not all built environment demand is amenable and some infrastructure upgrades are too costly
• Always use renewable electricity directly whenever possible (demand management)
• Store in electrochemical battery energy storage systems first (most efficient storage) – but some uses require rapid fueling, long range, heavy payload (fuel cells)
• Battery electric vehicles (BEV) & fuel cell electric vehicles (FCEV) are important
High Renewable Use is Challenging (Curtailment in CA)

June 7, 2022

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High Renewable Use is Challenging (Curtailment in CA)

Challenges of Dynamics already being realized – slowing pace of adoption
Renewable and Zero-carbon Gaseous Fuel Pathways

• “Green” in the traditional sense of environmentally sensitive and desirable

Organics Conversion

Power-to-Gas

Artificial Photosynthesis

Anaerobic Digestion

Thermo-chemical

Electrolysis

CO2

Renewable Methane

Renewable Hydrogen

Reformation

Methanation

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Renewable and Zero-carbon Gaseous Fuel Pathways

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- Anaerobic Digestion
- Thermo-chemical

- Power-to-Gas
- Electrolysis
- Artificial Photosynthesis

- CO2
- Renewable Methane
- Renewable Hydrogen

- Reformation
- Methanation

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Solar & Wind Power – most widely available resources

- Renewable future will be more equitable all around the world

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Dynamics of Renewable Future are Challenging

- Wind dominant case (37 GW solar capacity, 80 GW wind capacity)
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Deficit
Surplus

21 million EVs

Pumped Hydro

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Dynamics of Renewable Future are Challenging

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21 million EVs

Current Gas Storage converted to $H_2$

Pumped Hydro

Deficit

Surplus

Time (Jan to Dec)

Residual Load [GW]


June 7, 2022

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Dynamics of Renewable Future are Challenging

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Current Gas Storage converted to H₂
Seasonal

Pumped Hydro

Deficit
Surplus

21 million EVs
Dynamics of Renewable Future are Challenging

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Separate Power & Energy Scaling Needed for Massive Energy Storage

21 million EVs

Current Gas Storage converted to H2

Pumped Hydro

Deficit

Surplus

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Demonstrated Resilience of Fuel Cells and Gas System

- San Diego Blackout, 9/28/11
- Winter Storm Alfred, 10/29/11
- Hurricane Sandy, 10/29/12
- CA Earthquake, 8/24/14
- Hurricane Joaquin, 10/15/15
- Napa Fire, 10/9/17
- Hurricane Michael, 10/15/18
- Ridgecrest Earthquakes, 7/4-5/19
- Manhattan Blackout, 7/13/19

Why Hydrogen? Zero Emission Fuels Required

• Provide zero emissions fuel to difficult end-uses

Aircraft

Shipment

Fuel Cell Trains & Locomotives

Fuel Cell Buses

Toyota Fuel Cell:
Zero Emissions Big Rig

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Why Hydrogen? Zero Emission Fuels Required

- Provide zero emissions fuel to difficult end-uses

Anything that requires (1) rapid fueling, (2) long range, (3) large payload

Fuel Cell Buses

Aircraft

Shipping

Fuel Cell Trains & Locomotives

Toyota Fuel Cell: Zero Emissions Big Rig

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Why Hydrogen? Industry Requirements for Heat, Feedstock,

- Many examples of applications that cannot be electrified

Steel Manufacturing & Processing

Cement Production

Plastics

Ammonia & Fertilizer Production

Computer Chip Fabrication

Pharmaceuticals

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Infrastructure Limits Require both FCEV & BEV
Comparative Analysis of Infrastructures: H2 & FCEV vs. Grid & BEV

U.S. DOE “Hydrogen Energy Earthshot”

• Accelerate breakthroughs of more abundant, affordable, and reliable clean energy solutions within the decade - $9.5 billion in federal funding allocated

Office of Energy Efficiency & Renewable Energy » Hydrogen Shot

• Reduce RH₂ cost from ~$5/kg to $1/kg to unlock new markets for hydrogen, including steel manufacturing, ammonia, energy storage, and heavy-duty trucks

1 Dollar
1 Kilogram
1 Decade