# Do We Really Need Hydrogen?

## *H2@Scale Panel*

Long Beach, CA November 5, 2019

National Fuel Cell Research Center

UCIrvine | University of California

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Director

# Popular Thinking & Arguments


**Main Strategy:**

- 100% renewable (solar, wind, geothermal, …) power generation
- Electrify ~~all~~ some end-uses
- Use batteries to handle some intermittency on grid & for some end-uses

**Arguments against hydrogen & fuel cells:**

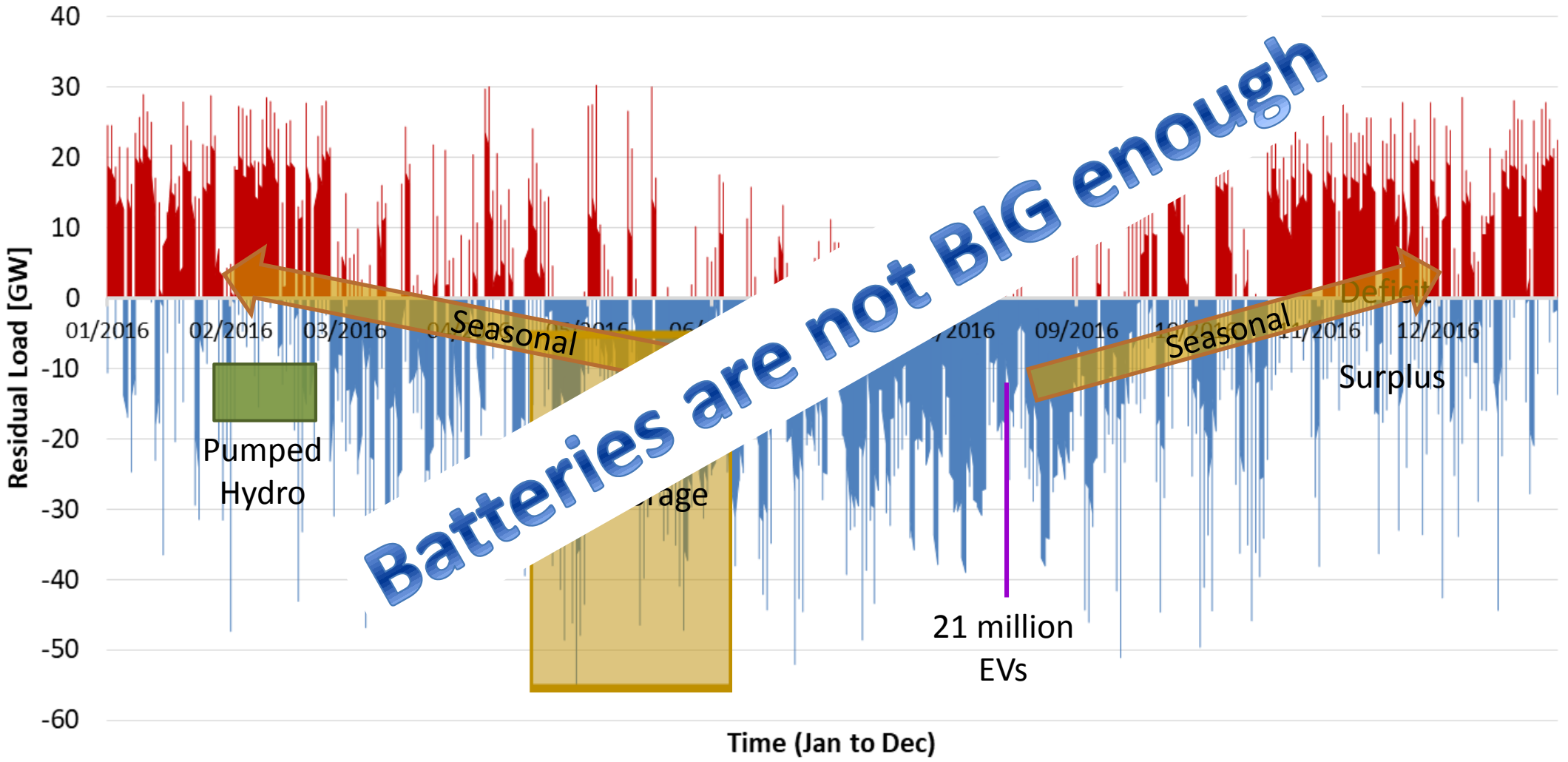
- Most hydrogen today is made from fossil fuels (natural gas)
- Making hydrogen from water & electricity is less efficient than charging a battery
- Making electricity from hydrogen in a fuel cell is less efficient than a battery (i.e., round-trip efficiency is lower than a battery except for long duration storage!)
- Hydrogen is difficult to store and move around in society

**I agree with most of this!**

**Subtly untruthful - Not the whole story**

# Amount of Storage Required

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



# Energy Storage Need

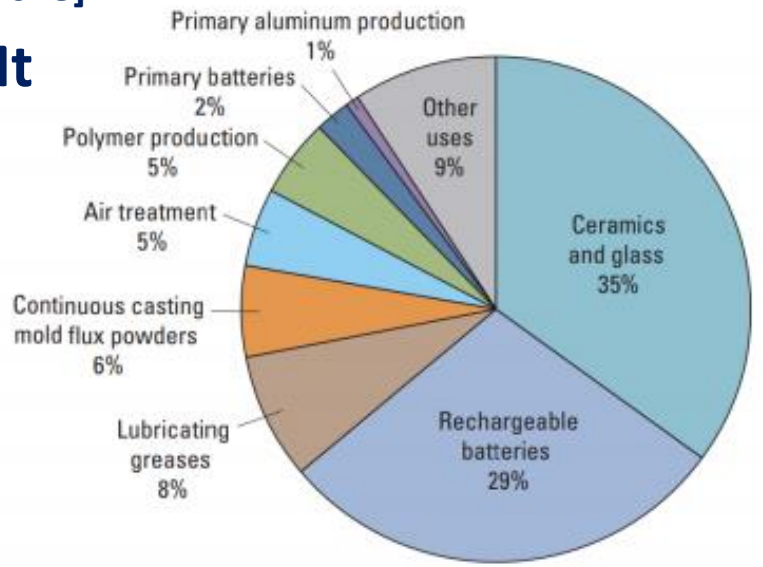
## Simulate meeting of TOTAL world electricity demand w/ Solar & Wind

| | Solar contribution | Wind contribution | Consumption and storage ratio | Consumption (TWh) | Storage (TWh) |
|---|---|---|---|---|---|
| Africa | 0.70 | 0.30 | 8.39 | 9 | 1,088 |
| America | 0.45 | 0.55 | 7.83 | | 4,919 |
| Asia | 0.50 | 0.50 | 7.95 | | 0,178 |
| Europe | 0.30 | 0.70 | 7.50 | | 3,592 |
| Oceania | 0.50 | 0.50 | | | 205 |
| TOTAL | | | | | 19,981 TWh |

There is not enough lithium or cobalt in the world

M.S. Thesis, 2018]

- To build one Li-ion batte Co: 25,815 Mt
- World Li resource
- World Co reso al), 120 Mt (ocean floor)
- 40% of Co come nocratic Republic of the Congo

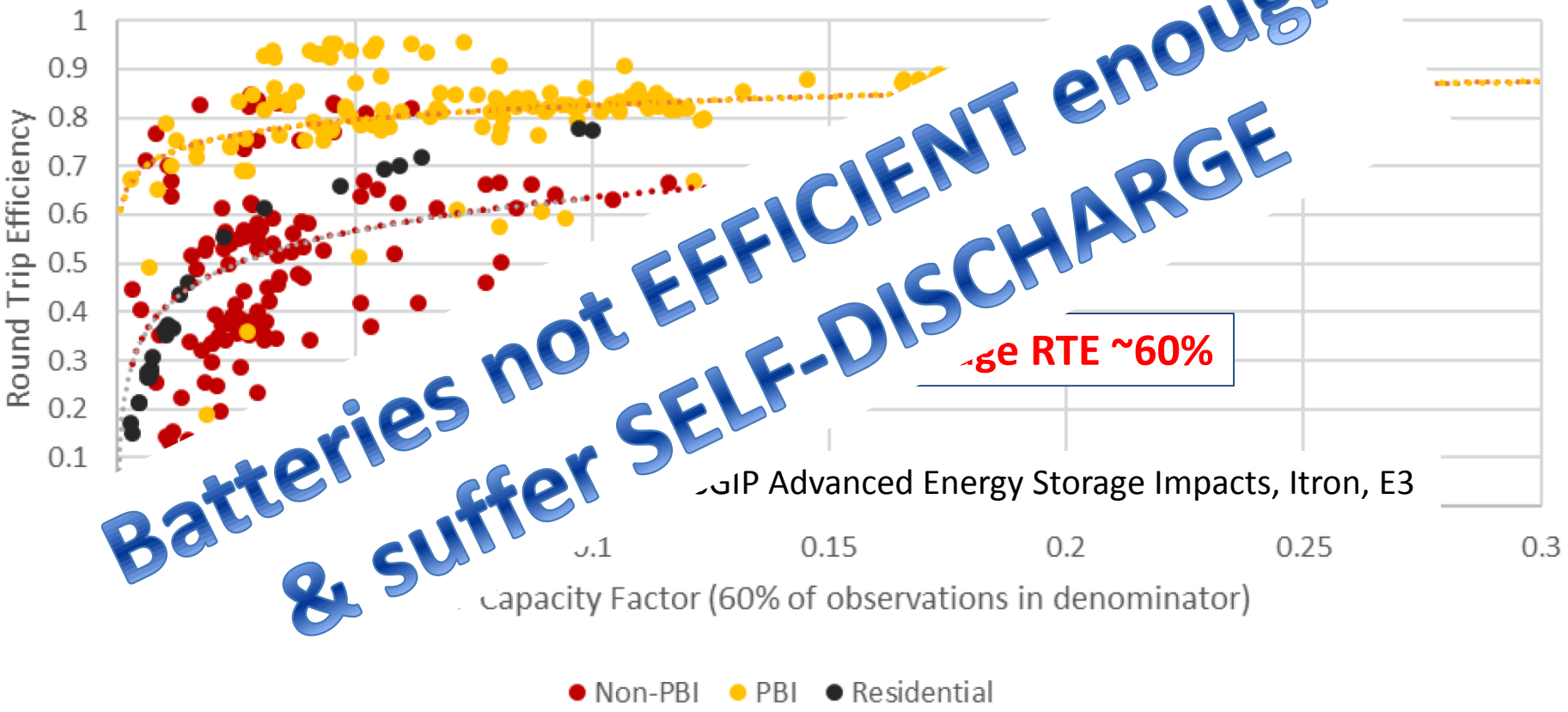



Source: U.S. Geological Survey, 2018

# Lithium-Ion Batteries

## Round-Trip Efficiency (>90% in Laboratory Testing)

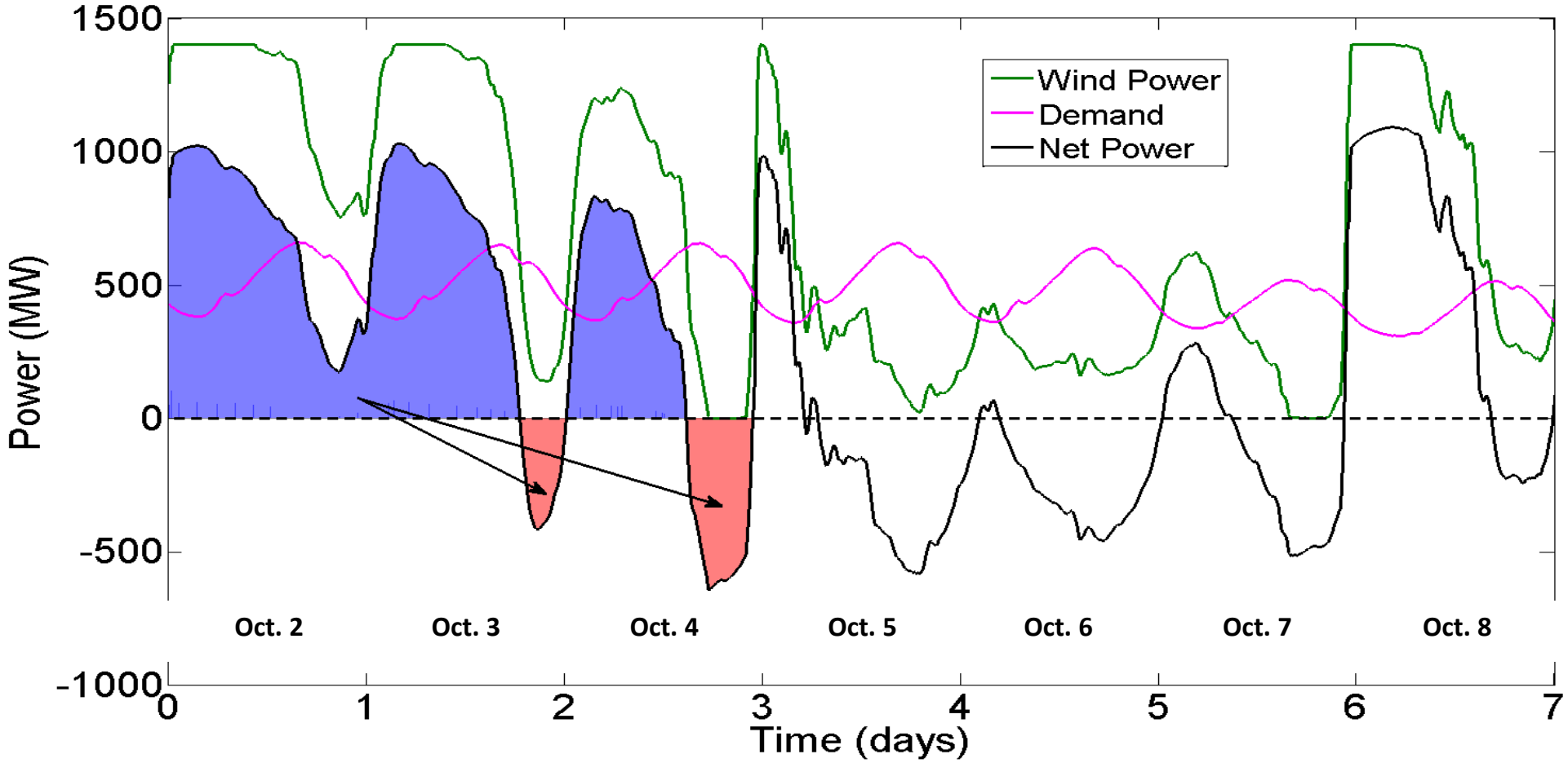
- **Measured battery system performance in Utility Applications**




- **Self-Discharge (the main culprit), plus cooling, transforming, inverting/converting, and other balance of plant**

# Hydrogen Energy Storage Dynamics

- **Compressed Hydrogen Storage complements Wind & Power Demand Dynamics in Texas**

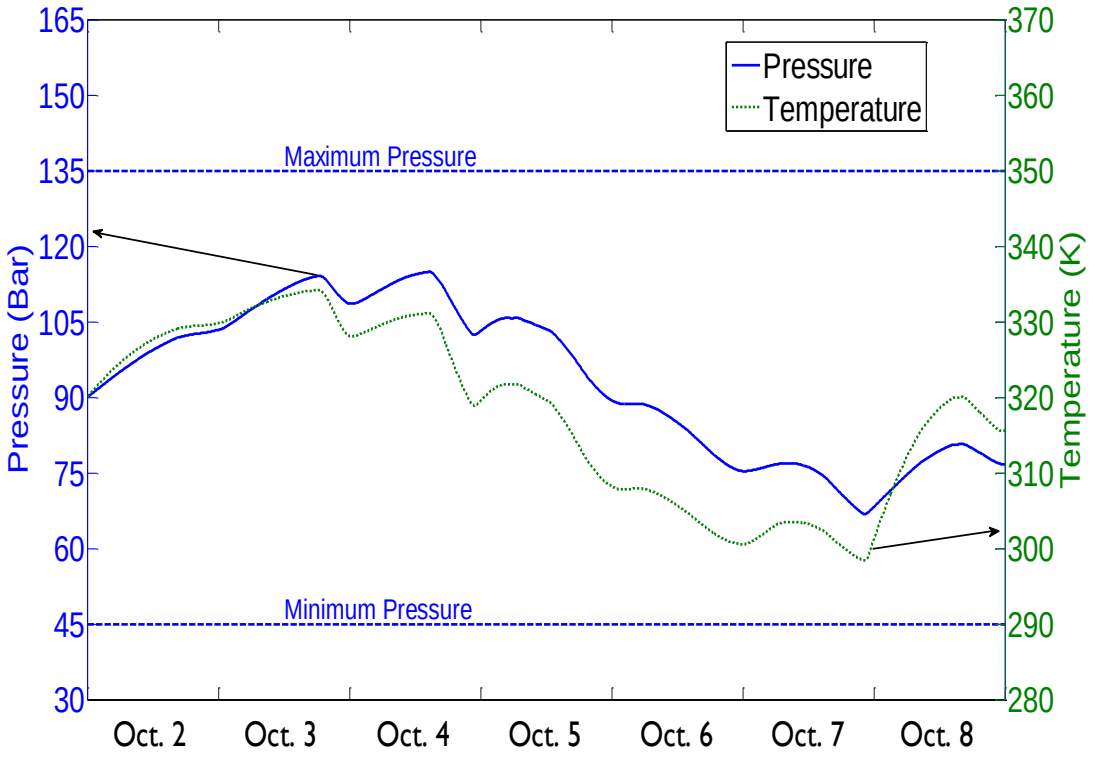



- **Load shifting from high wind days to low wind days**
- **Hydrogen stored in adjacent salt cavern**

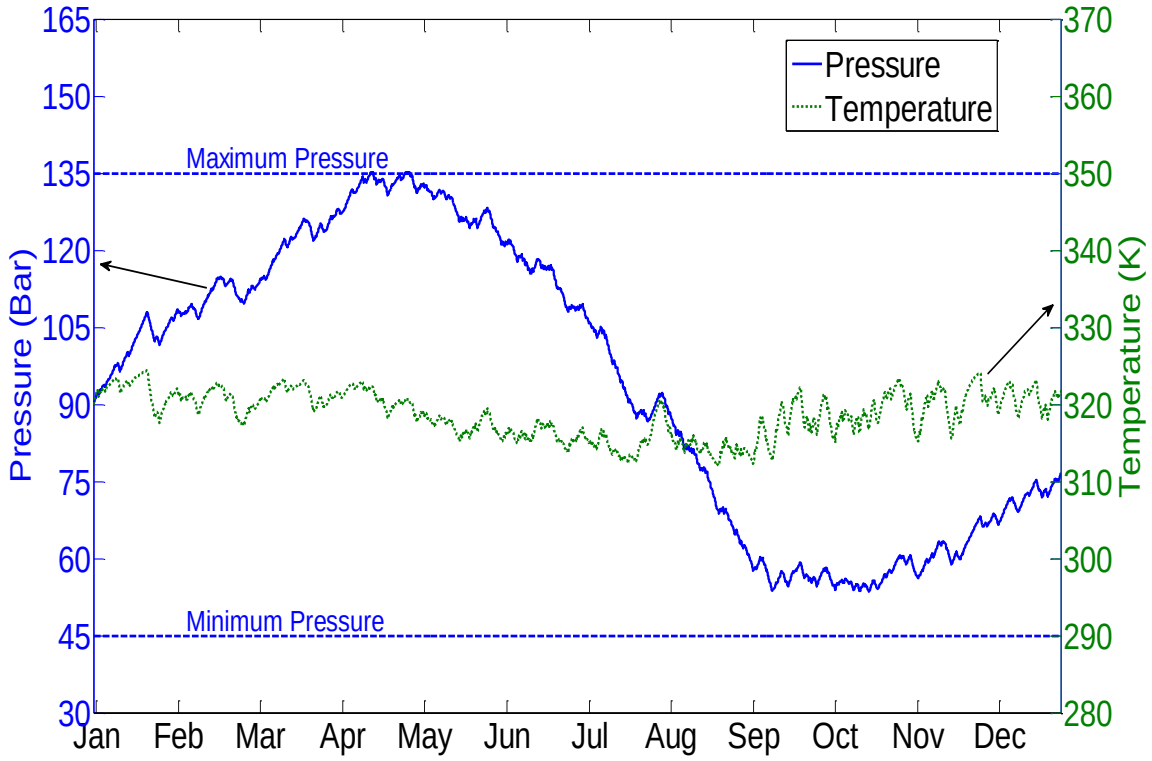
Maton, J.P., Zhao, L., Brouwer, J., Int'l Journal of Hydrogen Energy, Vol. 38, pp. 7867-7880, 2013

# Hydrogen Energy Storage Dynamics

- **Weekly storage and seasonal storage w/ H2, fuel cells, electrolyzers – all zero emissions!**
  - **Weekly**




**Seasonal**

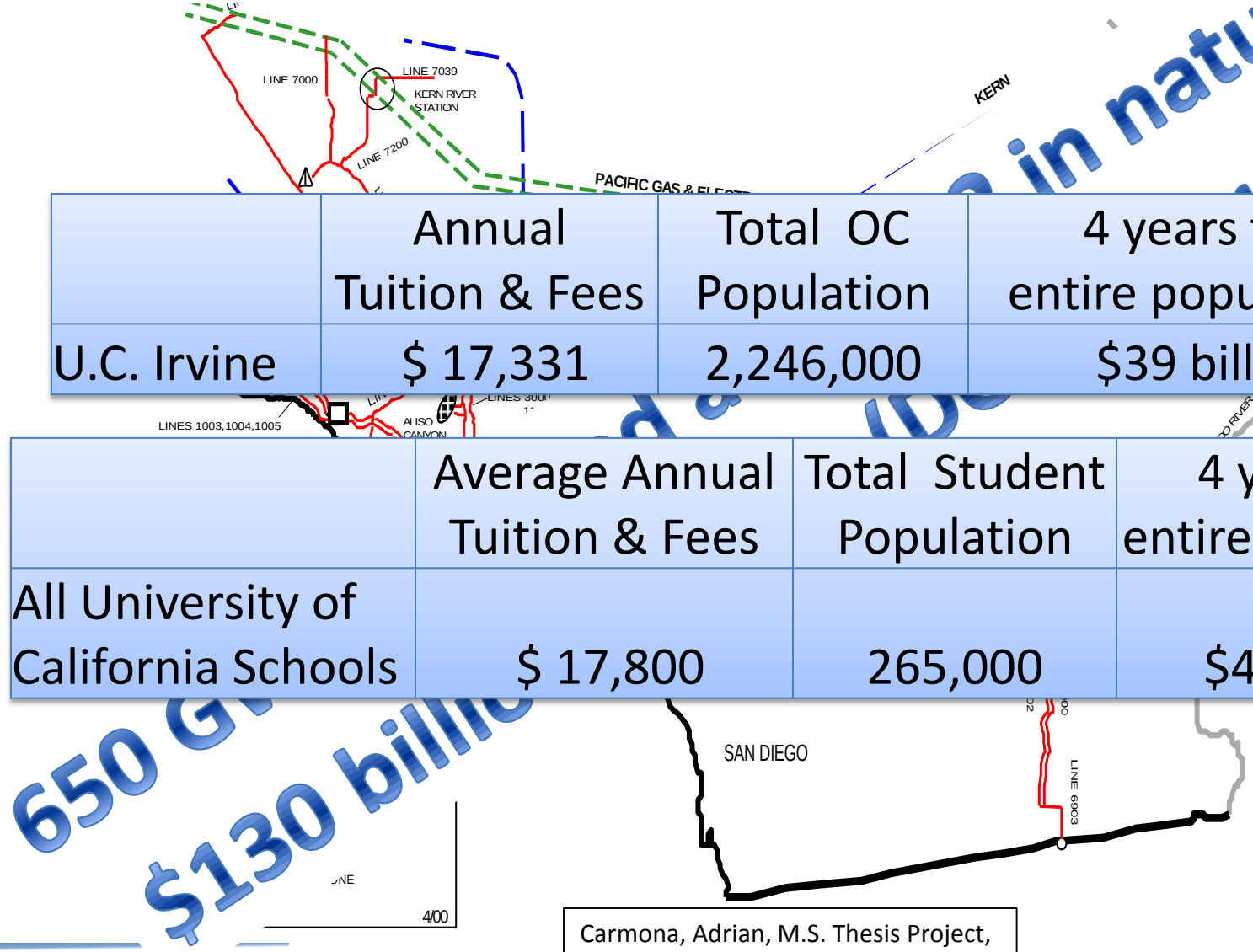



But what can we do if we don't have a salt cavern?

Maton, J.P., Zhao, L., Brouwer, J., Int'l Journal of Hydrogen Energy, Vol. 38, pp. 7867-7880, 2013

# "Natural" Storage & Transmission/Distribution Resource

- **Natural Gas Transmission, Distribution & Storage System**




| | Annual Tuition & Fees | Total OC Population | 4 years for entire population |
|---|---|---|---|
| U.C. Irvine | $ 17,331 | 2,246,000 | $39 billion |

| | Average Annual Tuition & Fees | Total Student Population | 4 years for entire population |
|---|---|---|---|
| All University of California Schools | $ 17,800 | 265,000 | $4.7 billion |

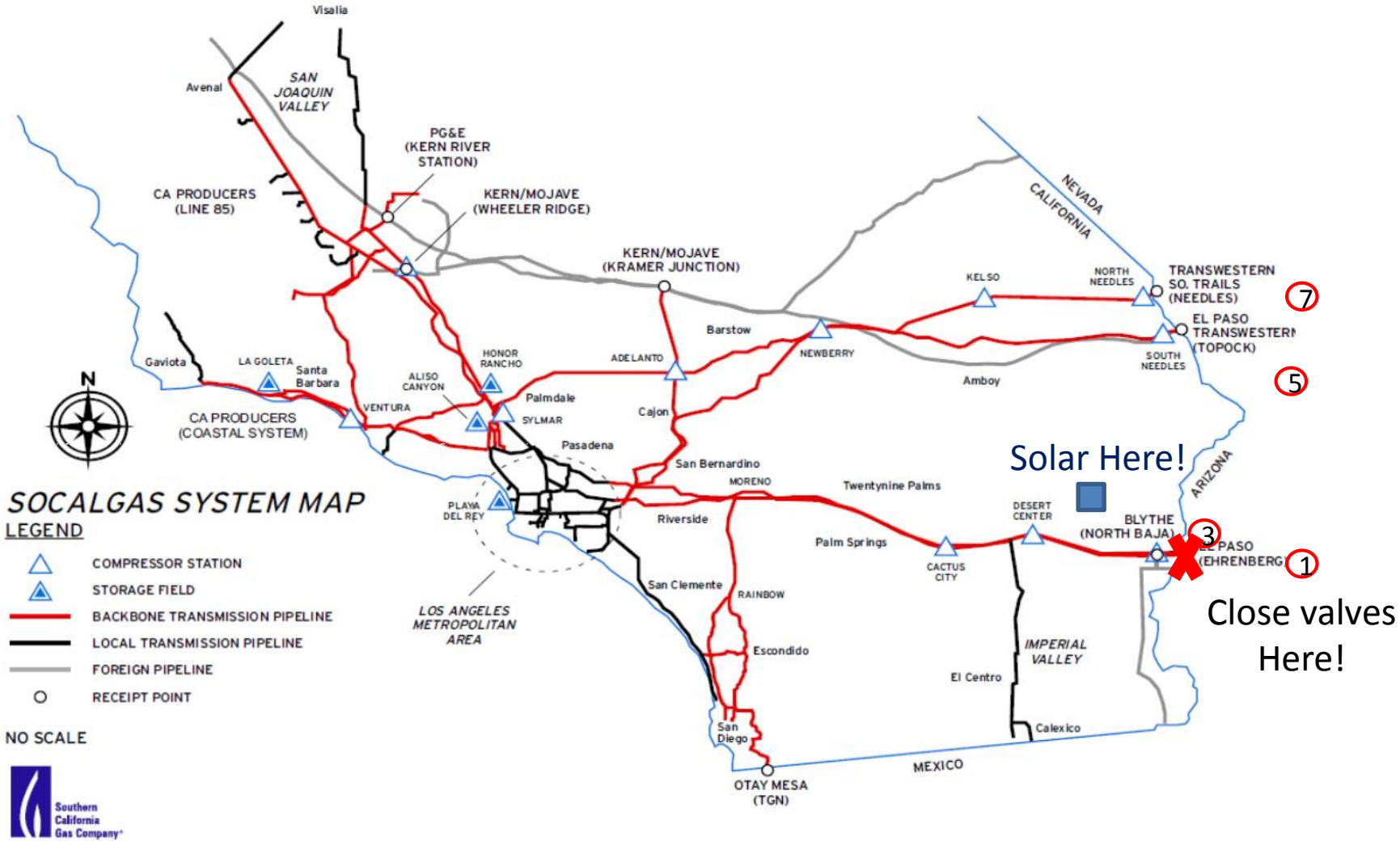
650 G… in natural gas

$130 billio… (D… cost)

Carmona, Adrian, M.S. Thesis Project, UC Irvine, J. Brouwer advisor, 2014.

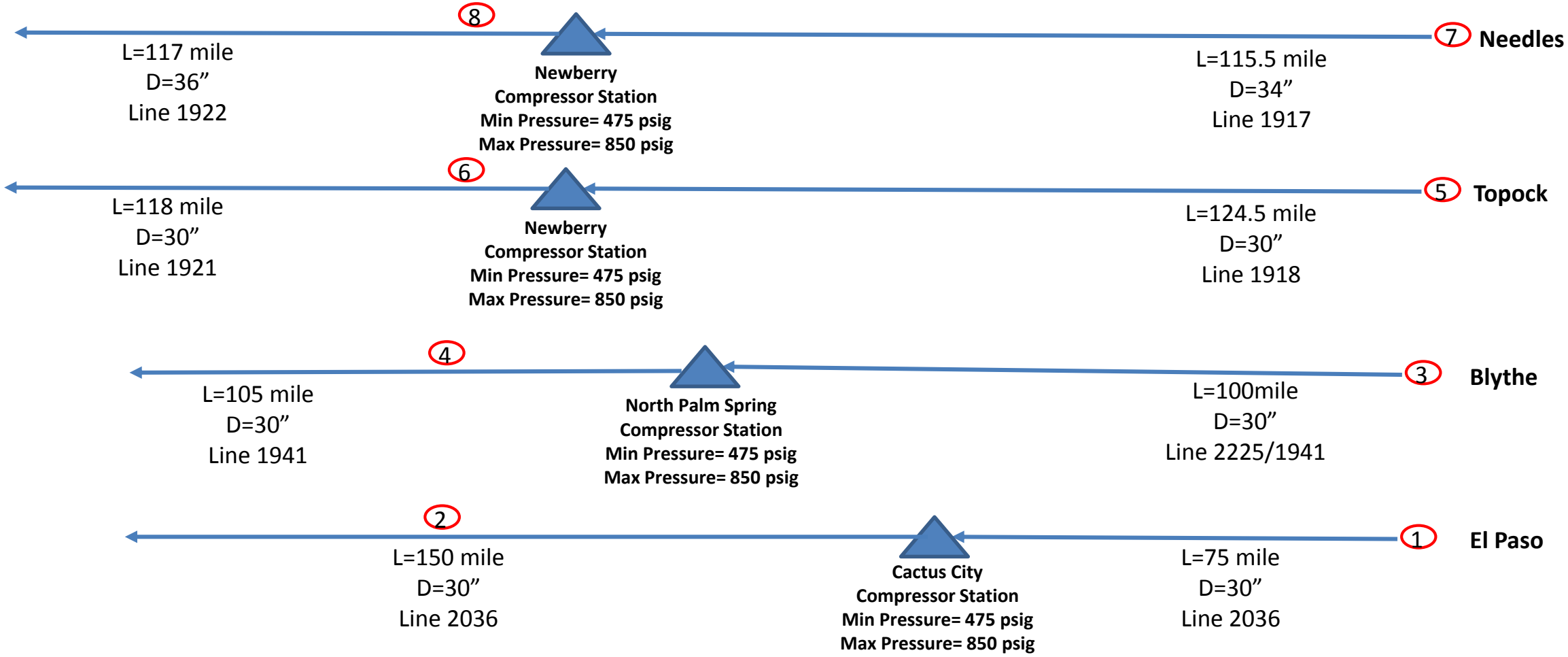
# Brief Gedanken experiment

- First mix up to X% – tremendous boon to grid renewables & transportation electrification
- Then piecewise conversion to pure hydrogen



# Pressure and Flow Dynamics

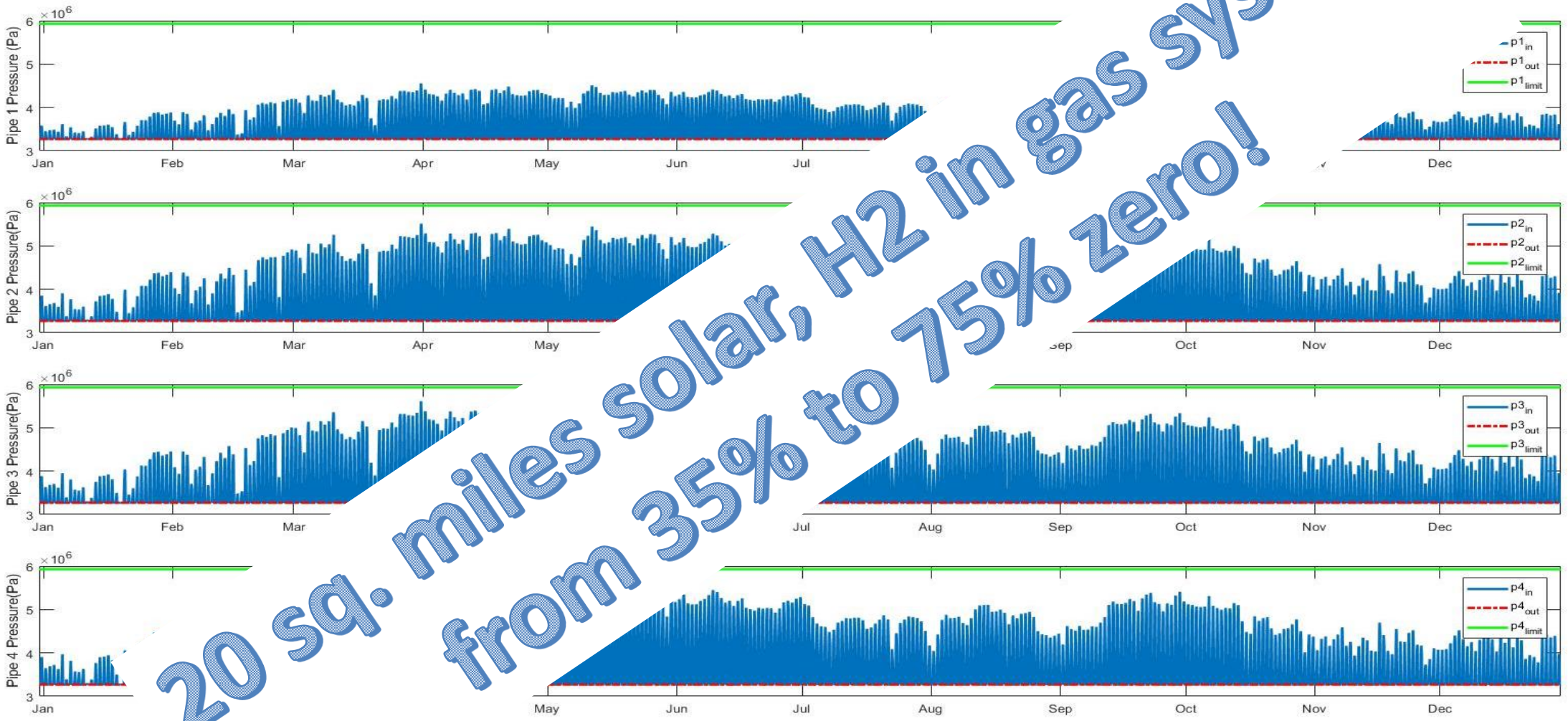
- **With renewable gas injection at border (in desert)**




Reference for pipe and compressor: stationhttps://www.arcgis.com/home/webmap/viewer.html?webmap=f8b54b821642463b8dc0becb2711093a

# Pressure and Flow Dynamics

- **40% of all electric demand – 20 sq. miles of solar, only gas system storage <u>AND</u> all T&D**




20 sq. miles solar, H2 in gas system from 35% to 75% zero!

# We Are Really Excited About Hydrogen!

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