# U.S. Shale Revolution Generates Opportunity for Low-cost, Large-scale Supply of Hydrogen

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Fuel Cell Technologies Office Webinar

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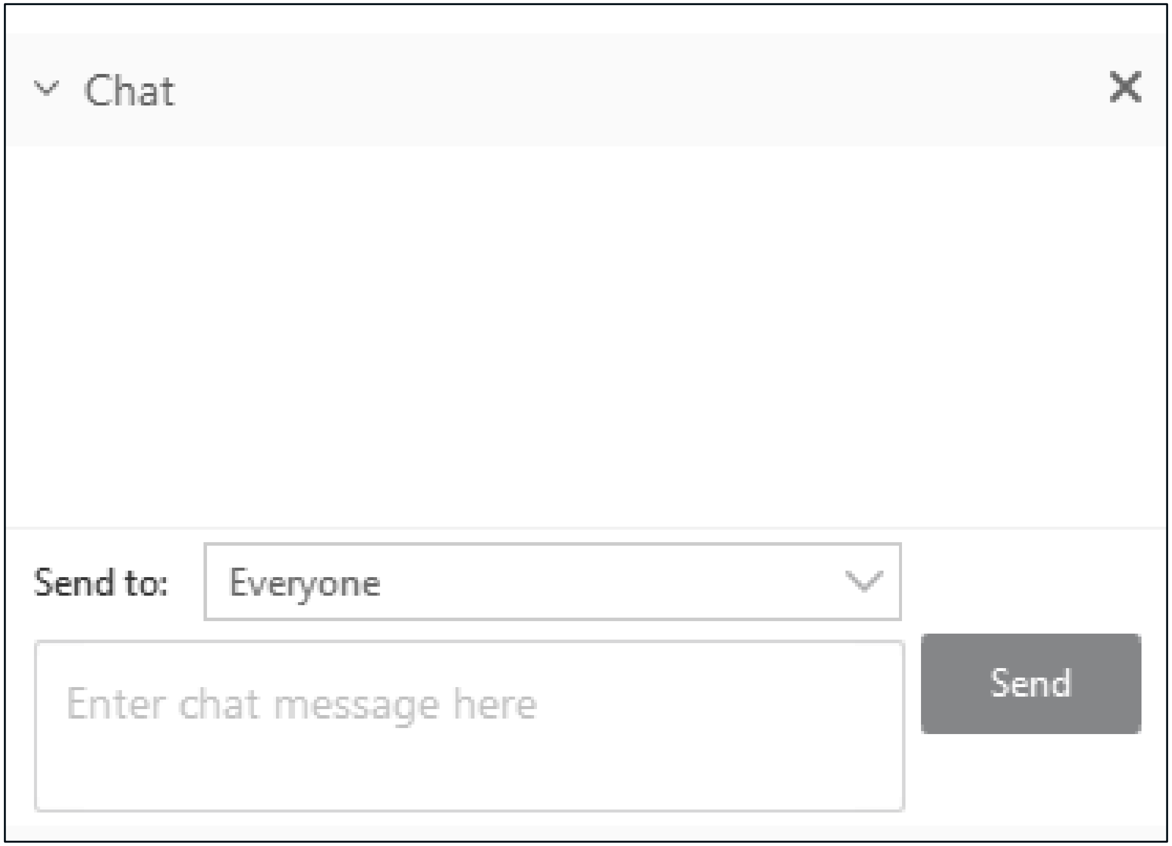
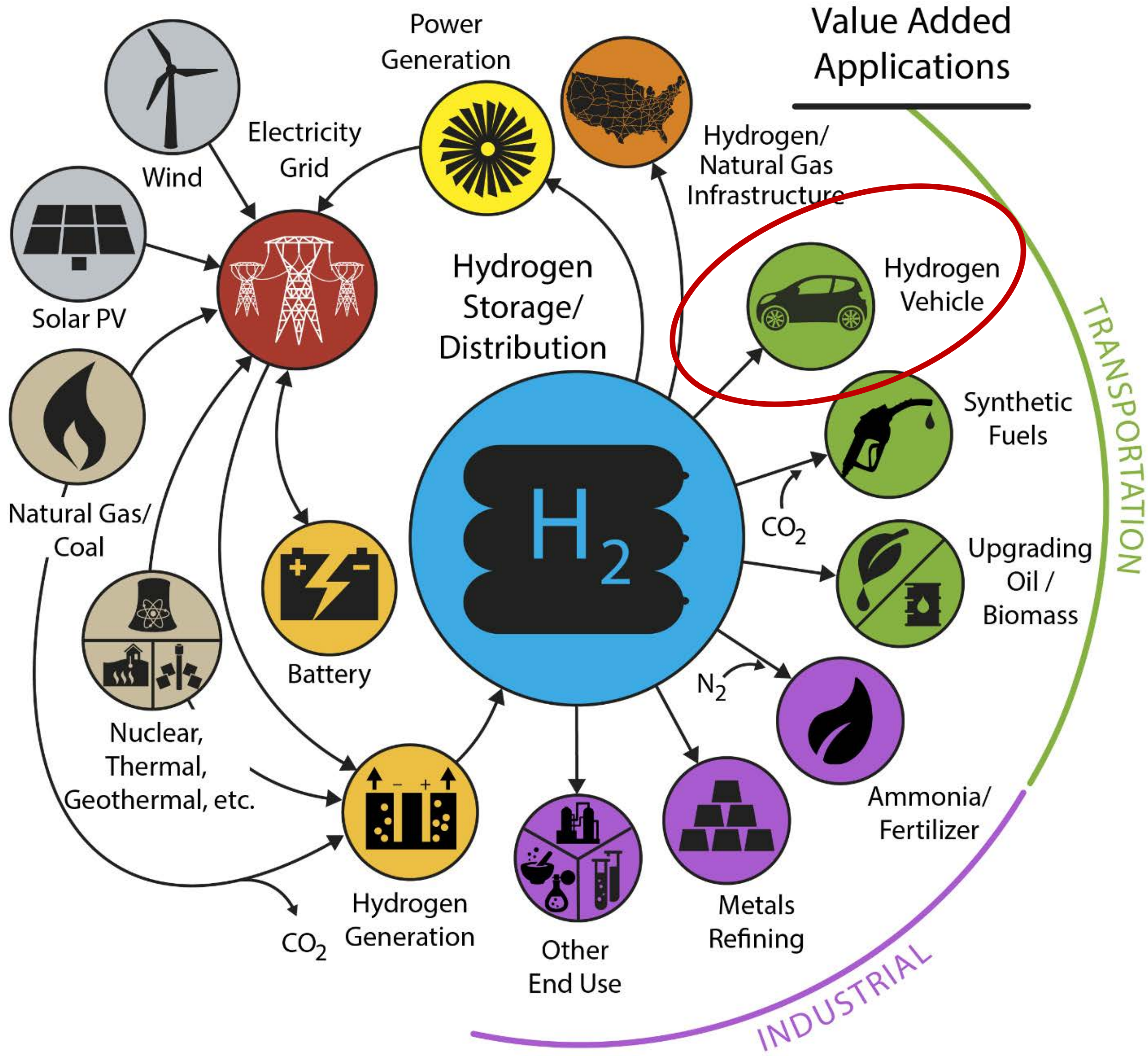
# Question and Answer

- Please type your questions to the chat box. **Send to: (HOST)**



# $H_2$ at Scale Energy System




*Illustrative example, not comprehensive

**The demand for hydrogen is expected to grow in the near-term with ramp up of FCEVs deployment**

**For more information on $H_2$@scale, please see:**
https://energy.gov/eere/fuelcells/h2-scale

# How much hydrogen does a FCEV need each day?

66 mi/kg_$H_2$

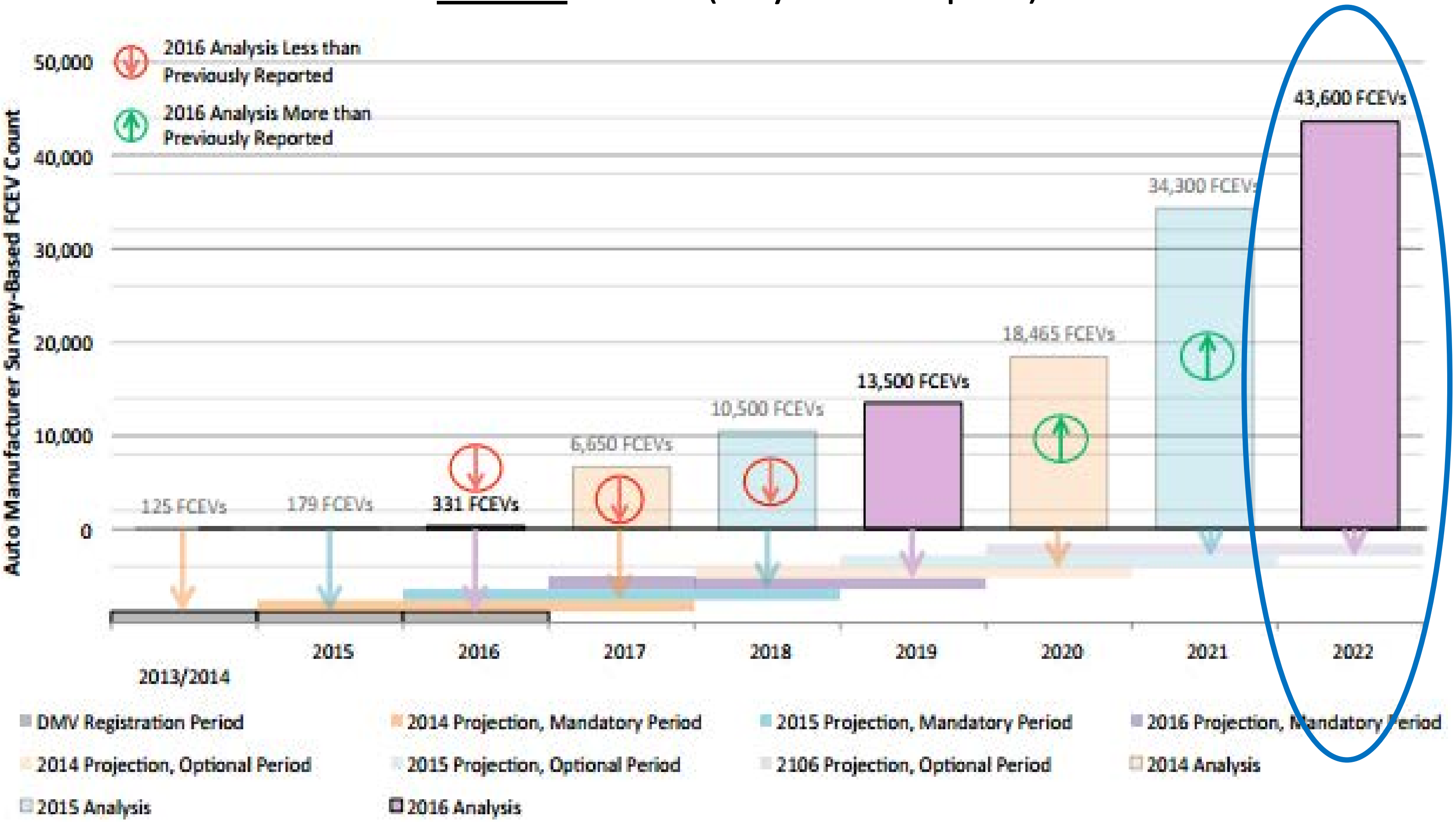

67 mi/kg_$H_2$

- **Average annual driving distance in the U.S. ~ 12,000 – 13,000 mi**
  - ✓ **~34 miles per day (DOT-FHWA)** Source: www.fueleconomy.gov

**Average FCEV needs ~0.5 kg of hydrogen per day**

# More than 40,000 fuel cell vehicles in CA within 5 years

Source: CARB (July 2016 report)




**Equivalent to more than 20 TPD of hydrogen in CA alone by 2022**

# Important questions that beg for answers

- **Where** will hydrogen come from in the near-term? (chicken and egg problem)
- How can we **bridge** today's production with future large scale hydrogen?
- Are there **opportunities** that can help the **transition** (incremental approach) as hydrogen demand grows over time?
- How can we enable **energy security** and US energy dominance with hydrogen?

# Requirements of new hydrogen production sources

- **Large scale** production, **high purity** (>80%)
- Low capital investment (low risk), **low-cost** molecules (market competitiveness)
- Properly **distributed** where demand exits (or is growing)
- Low **environmental impacts** (i.e., air quality, satisfies state low-carbon fuel standards and potentially qualifies for credits)

# Possible sources for hydrogen to satisfy growing demand in the near-term

1. Building **new** SMR hydrogen plants (central or on-site)

2. Utilizing **excess capacity** in existing **merchant** hydrogen plants

3. Exploring **byproduct hydrogen** from existing industrial operations

# Option 1(a): Building New Central SMR Hydrogen Plants

- Scale: 20-200 TPD
- Requires large capital investment (100s million$)
- Requires demand certainties and long-term contracts (low risk)
- Long lead time to operation (justification, permitting, engineering/design, construction, etc)

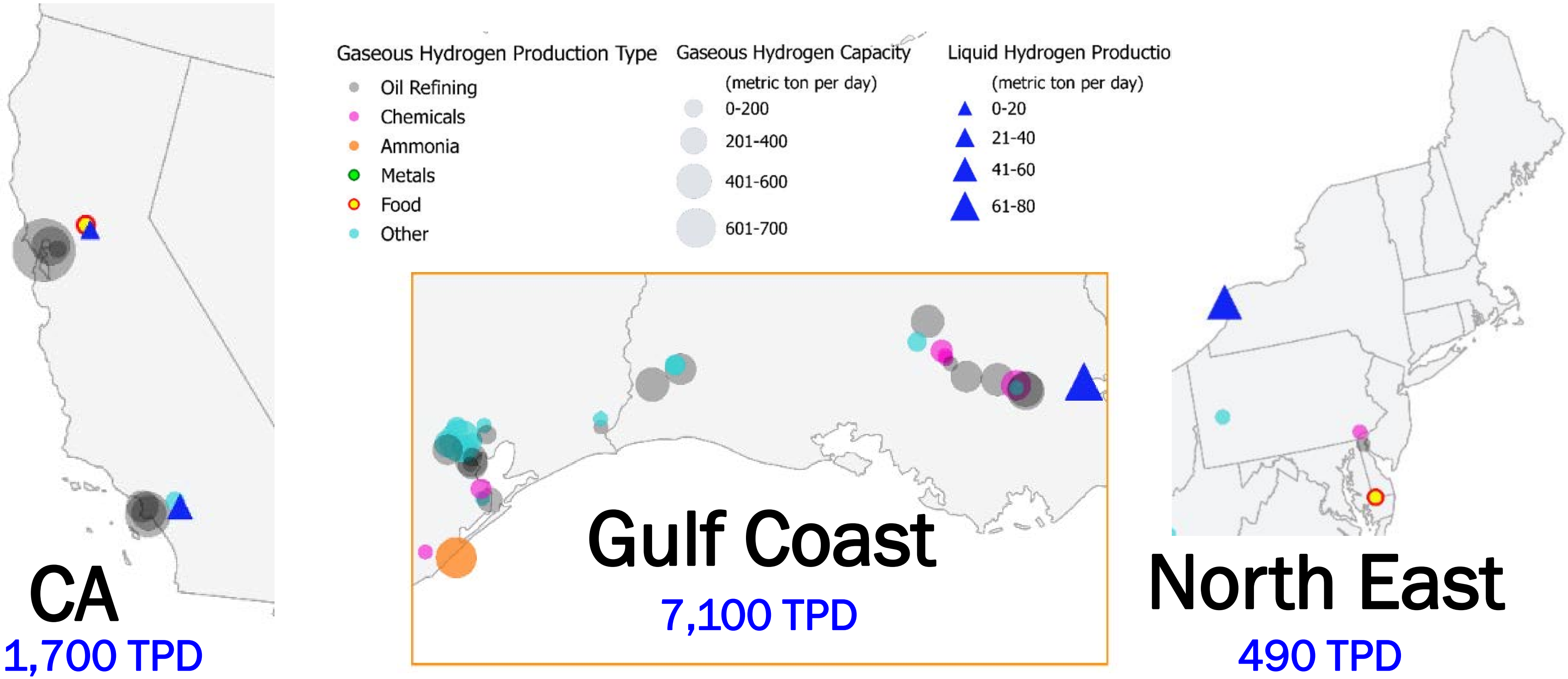
**Not viable in the near-term**

# Option 1(b): Building New Onsite Hydrogen Plants (at the hydrogen fueling station)

- Scale: 0.5-2 TPD
- Shifts the burden and risk to hydrogen station operator
- Requires high utilization of production capacity from day 1
- Challenges with footprint, purification, and other complexity not relevant to the hydrogen station business

**Not viable in the near-term**

# Option 2: Utilizing excess capacity in existing merchant hydrogen plants




- Total U.S. merchant $H_2$ capacity ~ 13,000 TPD; 260 TPD $LH_2$
- Only 26 TPD in CA and 40 TPD in NY for (non-refinery) customers
  - With 10% excess non-refinery capacity → ~6.6 TPD or just 13,000 FCEVs

**Limited potential in the near-term**

# Option 3: Exploring existing byproduct hydrogen from industrial operations

## a. Chlorine Plants:

→ ~1000 TPD of $H_2$

Process heat    vented

$$2\ NaCl + 2\ H_2O \xrightarrow{e} Cl_2 + H_2 + 2\ NaOH$$

High purity

## b. Cracker Plants:

→ more than 7,000 TPD of $H_2$

Process heat

$$C_2H_6 + heat \rightarrow C_2H_4 + H_2 + \text{other HC}$$

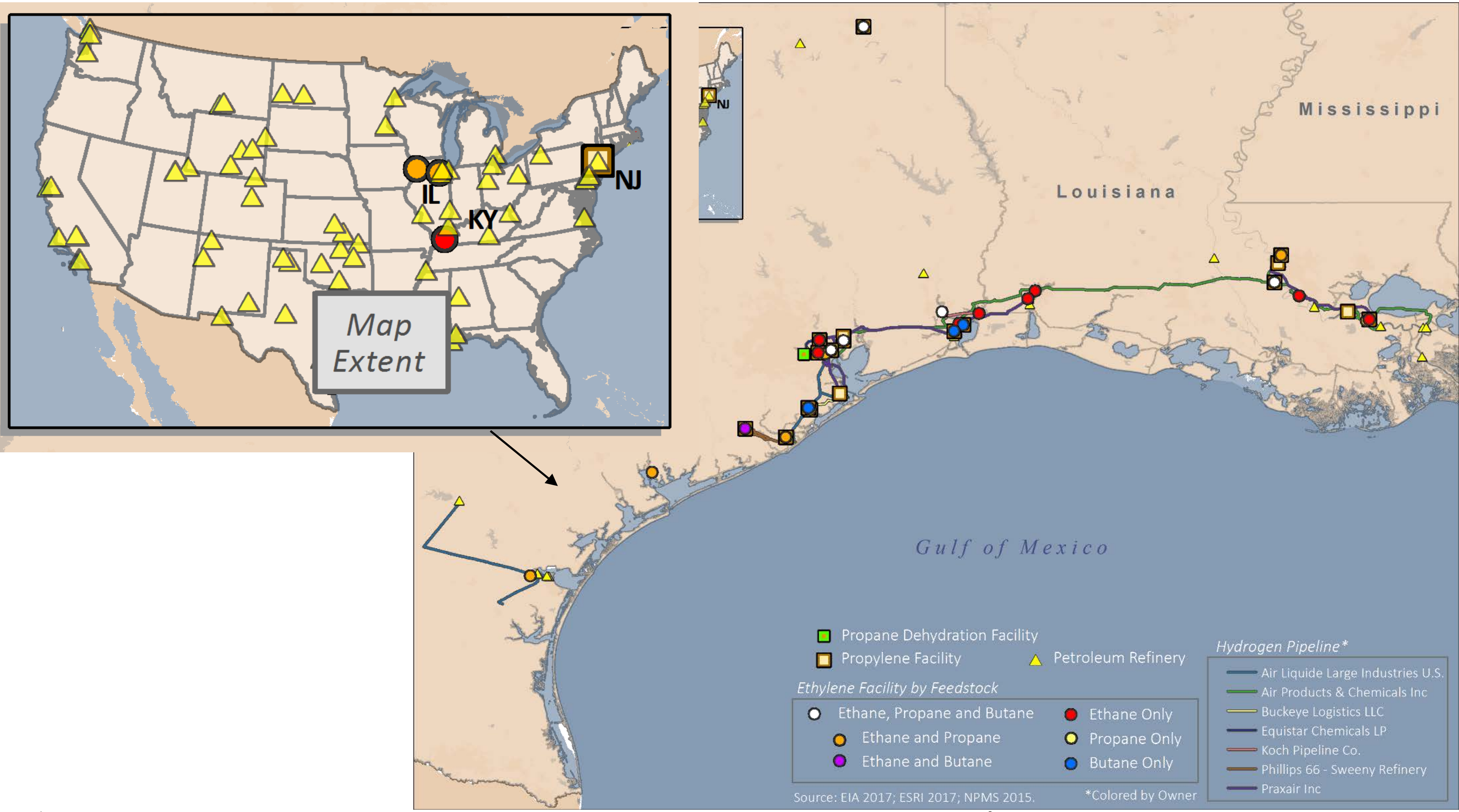
75-90% purity

NG

# Option 3: Exploring existing byproduct hydrogen from industrial operations (chlorine plants)

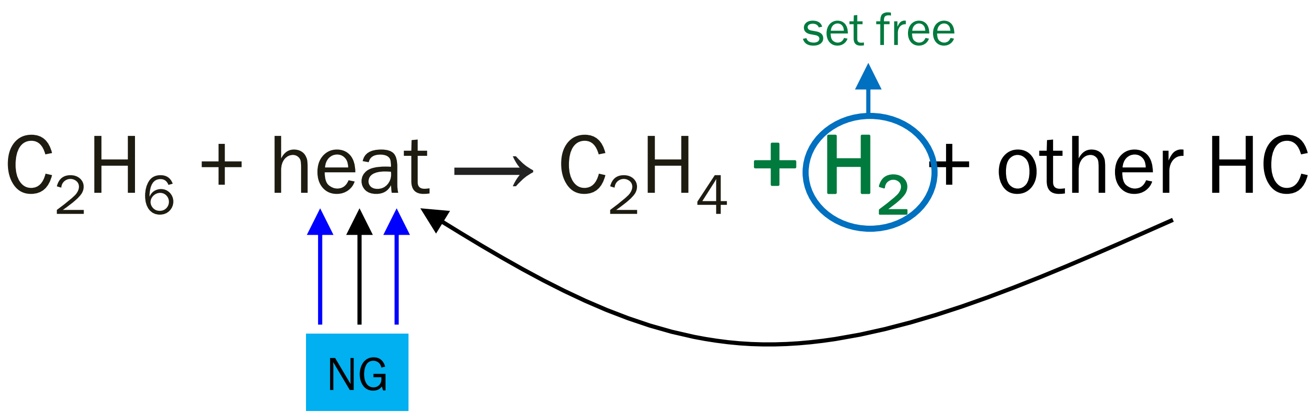

- 46 Chlorine production plants with ~13 million tonne/year chlorine capacity
  - ✓ 0.35 million tonne $H_2$/year (~1,000 TPD of $H_2$)

# Option 3: Exploring existing byproduct hydrogen from industrial operations (cracker plants)



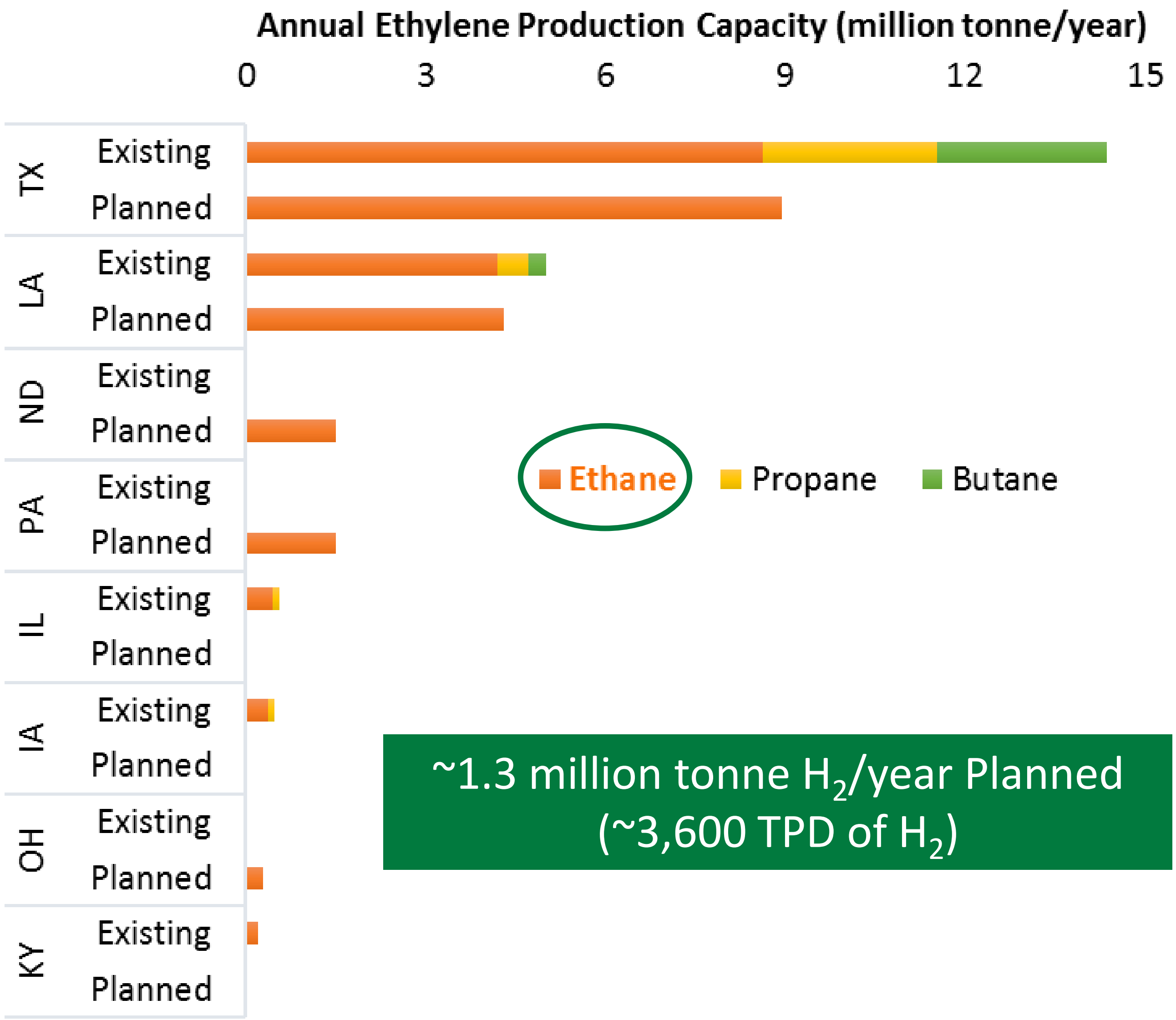

- 51 ethylene production plants with ~20 million tonne/year capacity
  - ✓ 1.3 million tonne $H_2$/year (> 3,600 TPD of $H_2$)

# Heating value of H2 in the fuel gas to satisfy process heat can be replaced with NG




- Hydrogen burned for its Btu value can be replaced with supplemental NG
- 1mmBtu of NG ~ $3-4
  - cost of displaced $H_2$ ~ \$0.3-\$0.4/$kg_{H2}$
- Cost of PSA purification is ~\$0.1-0.2/$kg_{H2}$
  - ✓ <u>Cost of purified hydrogen ~ \$0.5-\$0.6/$kg_{H2}$</u>
  - ✓ <u>Cost of $H_2$ compression is additional</u>

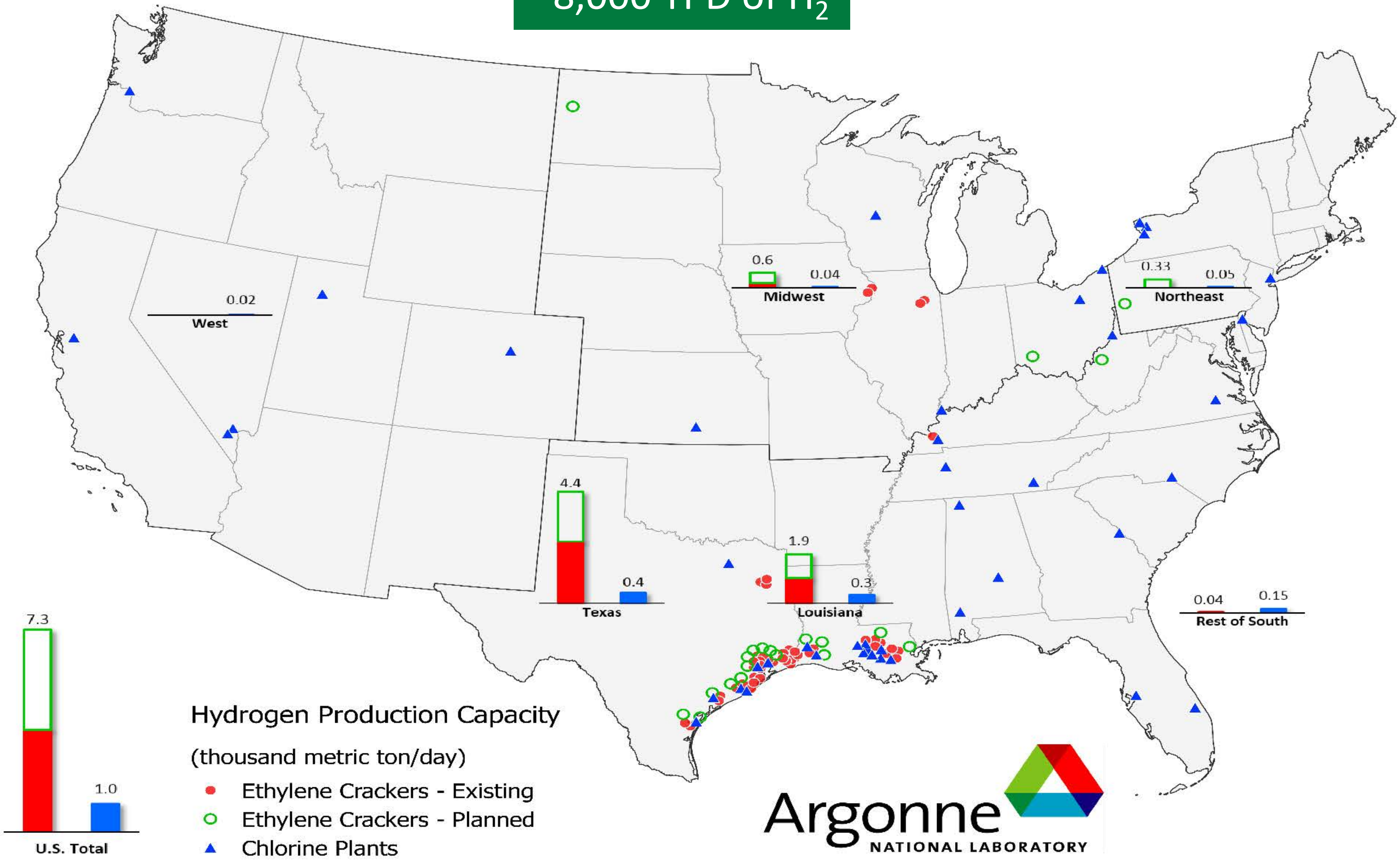
# Significant cracker capacity addition (>50%) is planned by 2020 (due to low cost NG)




~1.3 million tonne $H_2$/year Planned
(~3,600 TPD of $H_2$)

# Option 3: Potential byproduct hydrogen from industrial operations

~8,000 TPD of $H_2$

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**Can fuel 16M fuel cell electric vehicles**

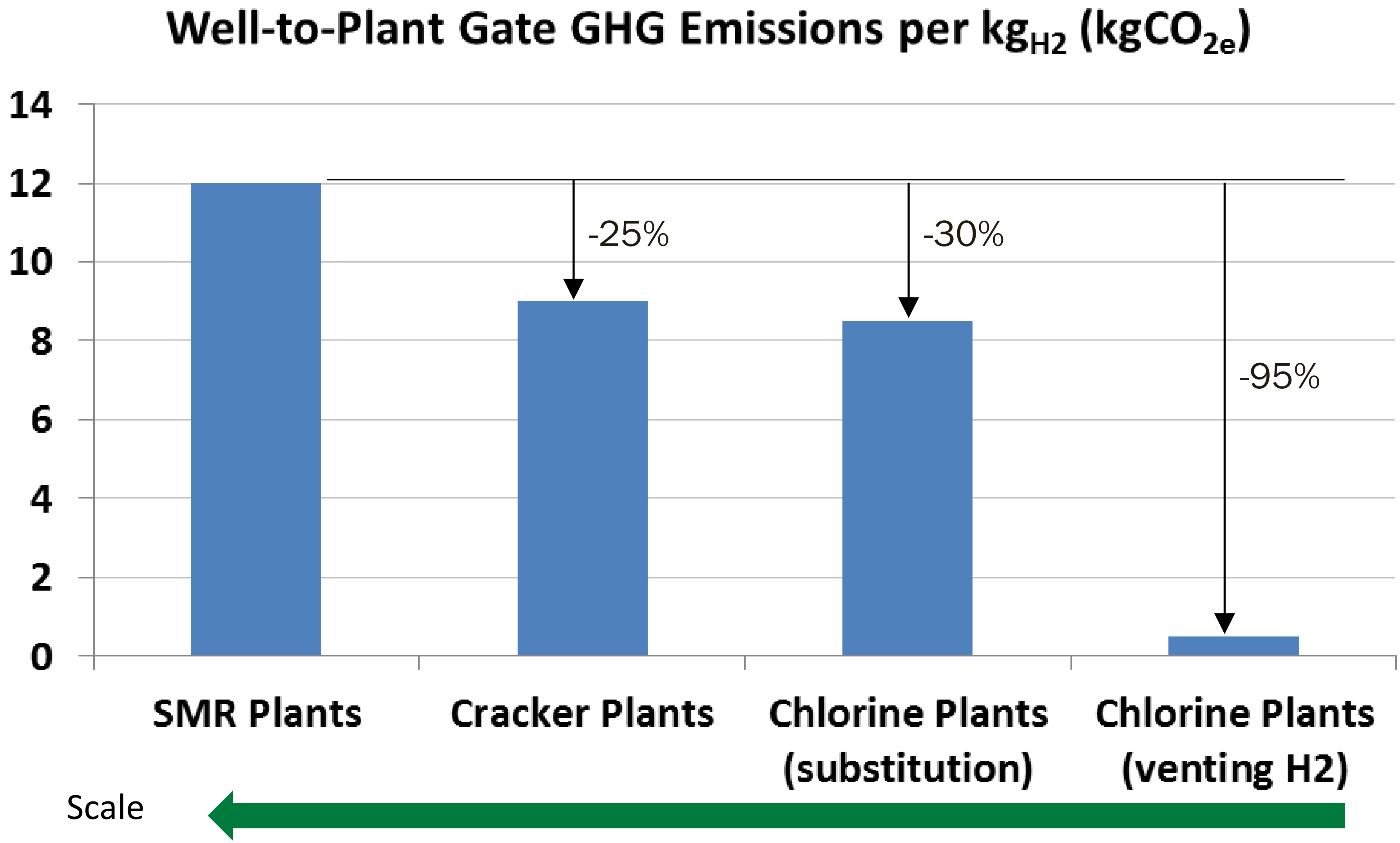
# Hydrogen Produced from Crackers is Low Carbon Fuel

SMR: 1.4-1.5 Btu NG → 1 Btu $H_2$

Crackers: 1 Btu NG → 1 Btu $H_2$

- Lower GHG emissions than $H_2$ from SMR
  - ~30% less GHG than SMR $H_2$
  - Other LCA methods result in lower GHG emissions

# Low GHG emissions of byproduct hydrogen



# Incentives in CA promote low-carbon hydrogen

| Time Period | Transfers [1] (number) | Total Volume[1] [2] (credits-MTs) | Avg. Price[1] [3] ($ per Credit) |
|---|---|---|---|
| CY 2016 | 929 | 5,343,000 | $101 |
| CY 2015 | 578 | 2,852,000 | $62 |
| CY 2014 | 304 | 1,667,000 | $31 |

Source: https://www.arb.ca.gov/fuels/lcfs/credit/20170509_aprcreditreport.pdf

**LCFS Credit Values for Selected Representative $H_2$ Pathways**

| | 100% Renewable Electrolysis [A] | 100% Dairy Biomethane SMR [B] | 100% Biomethane SMR [B] | 33% Biomethane SMR [A] | Natural Gas SMR (Gaseous H2) [A] | Natural Gas SMR (Liquified H2) [A] |
|---|---|---|---|---|---|---|
| CI Score (gCO2e/MJ) | 0 | -300 | 54 | 88 | 106 | 144 |
| FCEV EER-adjusted CI | 0 | -120 | 22 | 35 | 42 | 57 |
| Credit Value ($/kg) | $2.90 | $6.50 | $2.25 | $1.84 | $1.62 | $1.17 |

1 kg ≈ 1.04 GGE

[A] Certified LCFS Pathway

[B] Staff Estimate

Source: Sam Wade, CARB presentation at CHBC 2016

# Check points for byproduct $H_2$

- **Large scale** production, **high purity** (>80%)
  - Can motivate early-stage R&D to increase hydrogen use

- Low capital investment (low risk), **low cost** molecules (competitiveness)

- Properly **distributed** where demand exits or is growing

- Low adverse **environmental impacts**
  - ✓ Credits in CA may offset transportation cost from TX

# Analysis Team at Argonne National Laboratory

- D-Y Lee
- Leah Talaber
- Marianne Mintz
- Michael McLamore
- Stephens Folga

# Acknowledgments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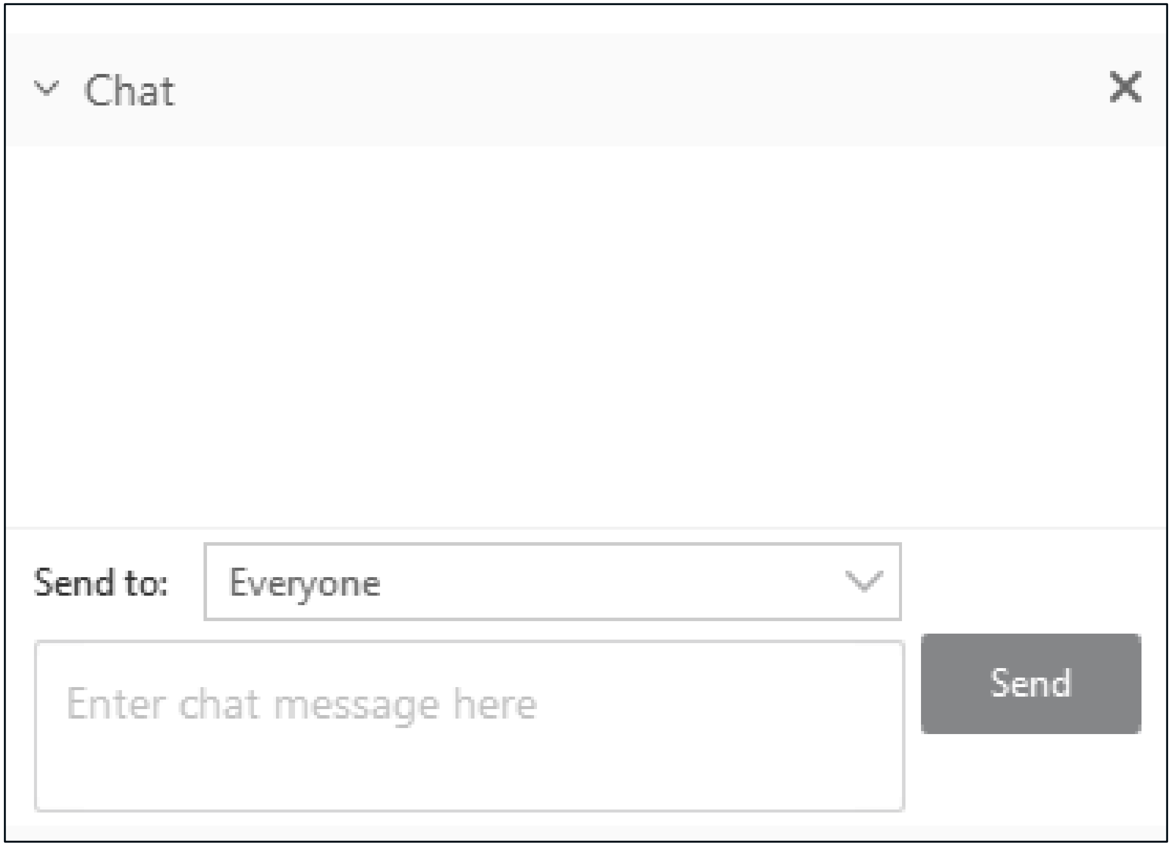


24

# Thank you

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