Hydrogen Infrastructure

Accelerating Electric Drive: The Next Generation of Hydrogen Fuel Cells

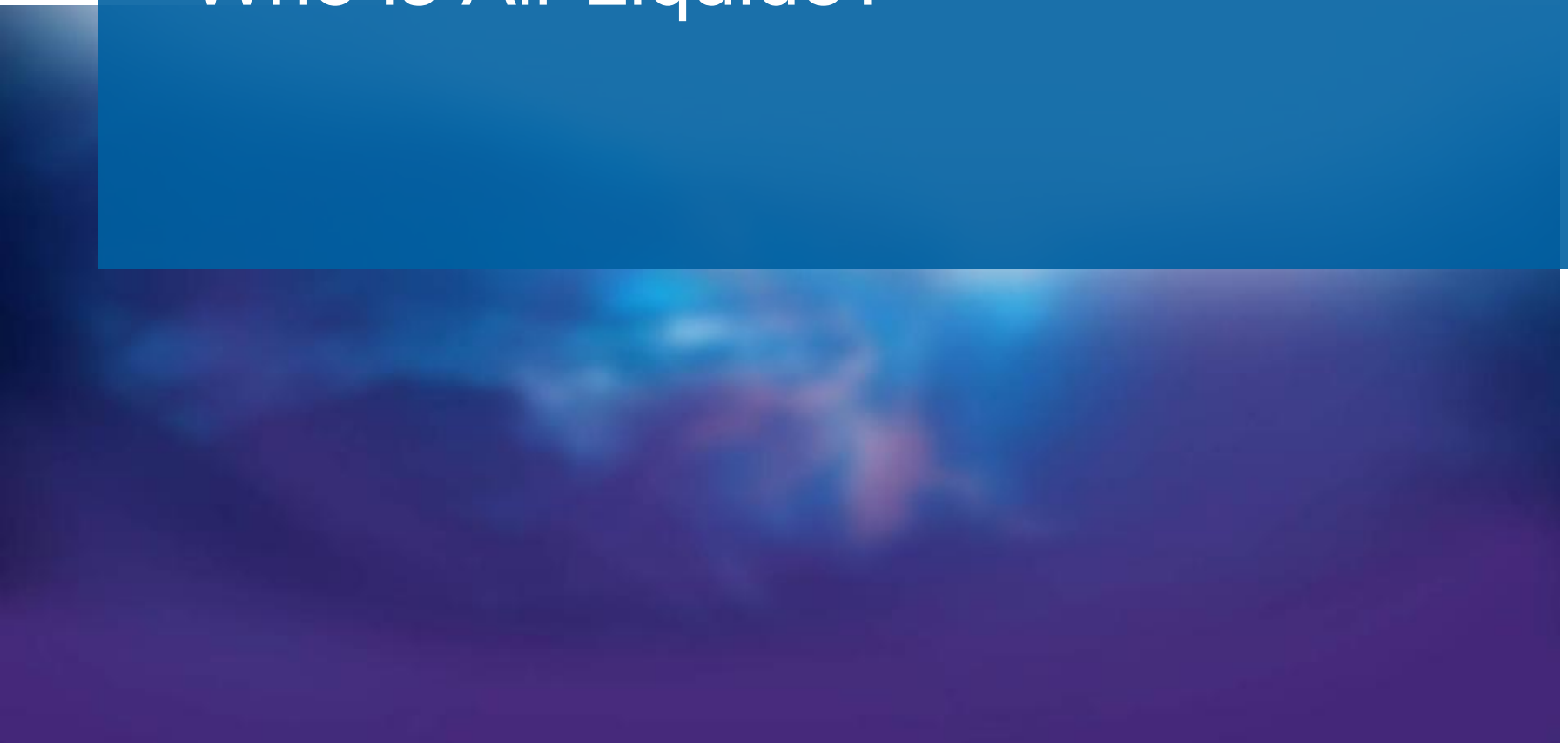
Dave Edwards, Air Liquide

DOE HTAC Meeting, October 27, 2015

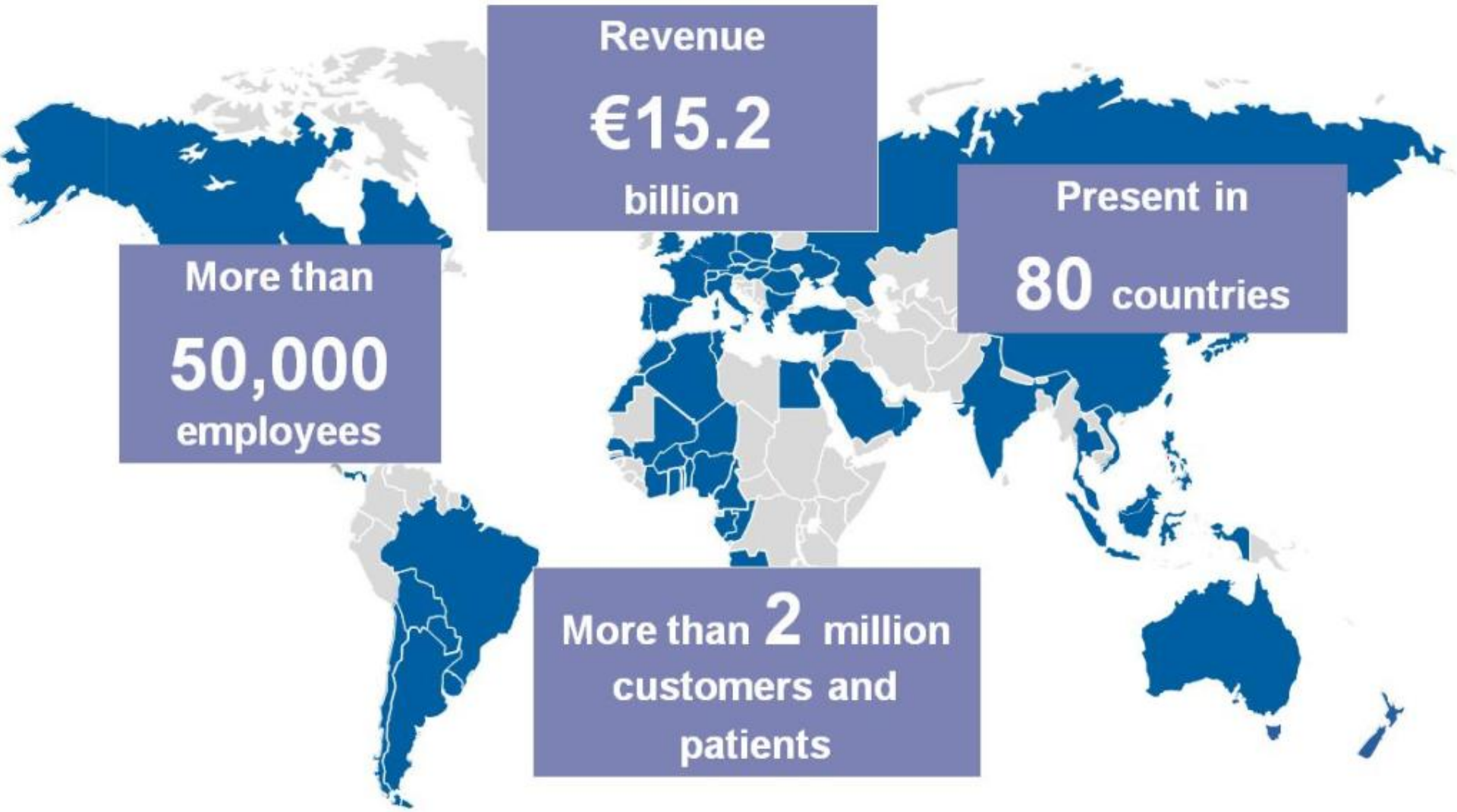
BLUE HYDROGEN
Clean energy solutions

AIR LIQUIDE™
ADVANCED BUSINESS & TECHNOLOGIES

Who is Air Liquide?



World leader in gases, technologies and services for Industry and Health



Megatrends driving our current and future business

Air Liquide - Hydrogen

Hydrogen: 40 years in industry

- $2.5B Revenue (refinery and chemicals)
- 1,800 km of pipelines
- 1,000 trucks
- 13 Billion Nm3/year
  (enough for 10M vehicle refills)

- 60 filling stations
- 300 fuel cell installations

Large H2 Plants and Pipelines

Air Liquide Hydrogen Mobility:

Light vehicle refueling
- GM/Shell demo stations- NY and CA
- Germany - H2 mobility
- California - 3 stations in development
- NE Fueling network

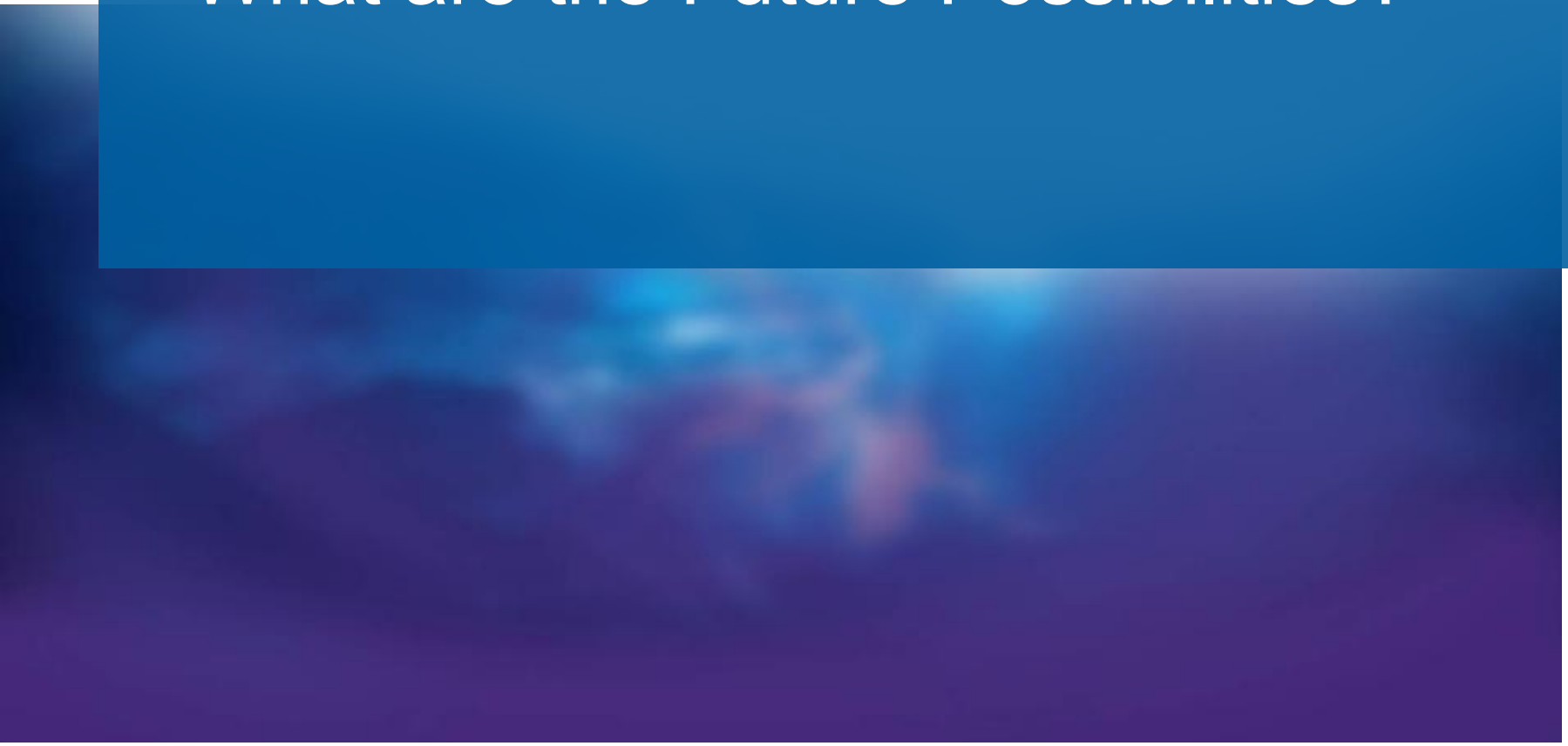
Mass transit stations
- BC Transit - Whistler Station
- Oslo, Norway
- Birmingham, AL -Demo

Materials handling applications
- Walmart
- Coca Cola
- Procter & Gamble

BLUE HYDROGEN
Clean energy solutions

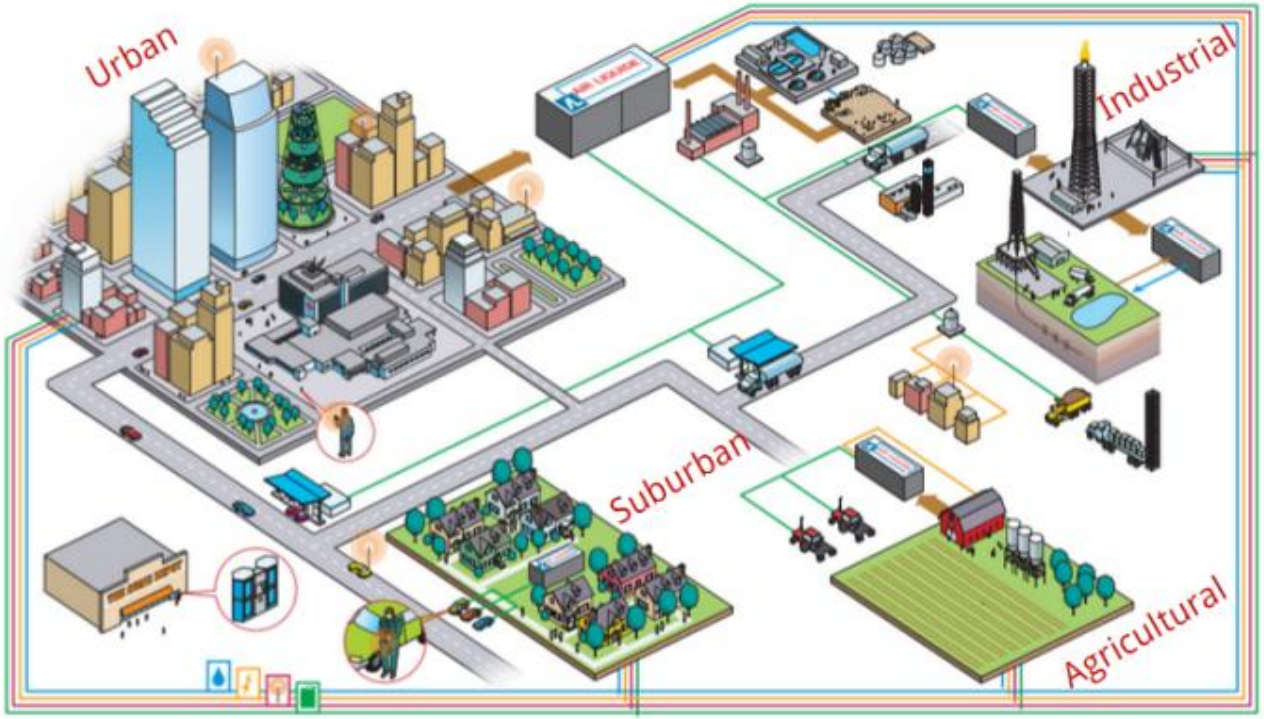
AIR LIQUIDE
ADVANCED BUSINESS & TECHNOLOGIES

What are the Future Possibilities?



Sustainable Communities and Interconnectivity

- Energy
- Water
- Food
- Health
- Mobility
- Connectivity



In the future, we must be **sustainable** to be **profitable**.

We believe that as a **company** and as a **society**, sustainability is not optional, but **imperative**.


Closing the Loop by Turning Waste into Fuel
URBAN
SUBURBAN
WASTE
FUEL
INDUSTRIAL
AGRICULTURAL
AIR LIQUIDE
BIOGAS
BLUE HYDROGEN

The market potential

Global Industrial Gases Business

X 2

10% → **$120B**

"If 10 percent of cars around the world were powered by fuel cells, it would amount to **€100bn ($120B)** in sales, which is **"twice the size of the entire global industry today"***

Benoit Potier – Air Liquide CEO

*M. Stothard,"Air Liquide looks to fuel cells to drive results" Financial Times, 5Jan2014

BLUE HYDROGEN
Clean energy solutions

AIR LIQUIDE
ADVANCED BUSINESS & TECHNOLOGIES

What will it take to get there?

Infrastructure - Autos

Infrastructure Planning

**Air Liquide has built more than 60 hydrogen stations worldwide;
15 additional stations planned to open in the U.S**

Flexible infrastructure products
to supply various markets and offer competitive costs

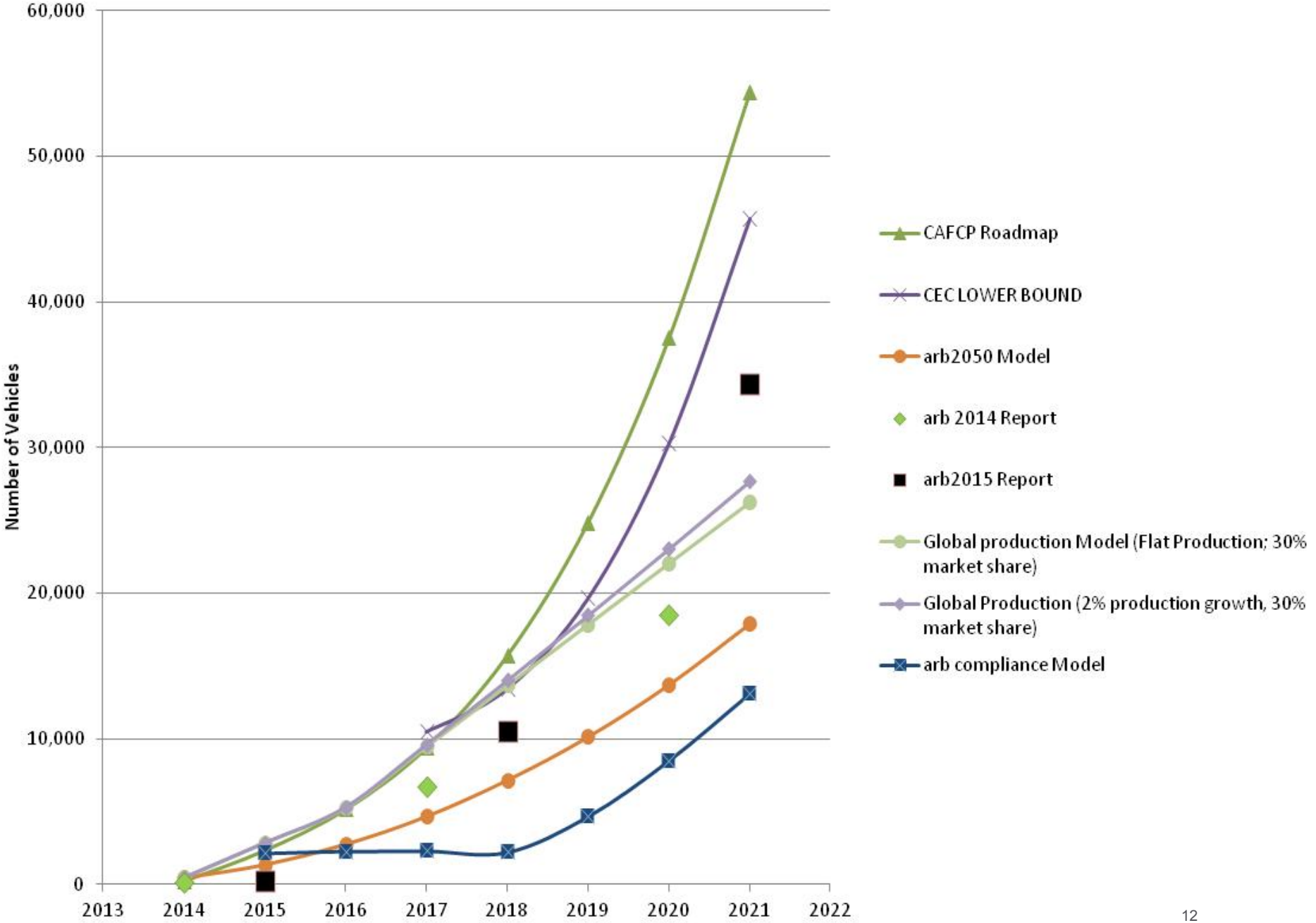
More deployments, helping the societal acceptance

Forklifts
35 MPa
100–300 kg/day

Buses
35 MPa
100–300 kg/day

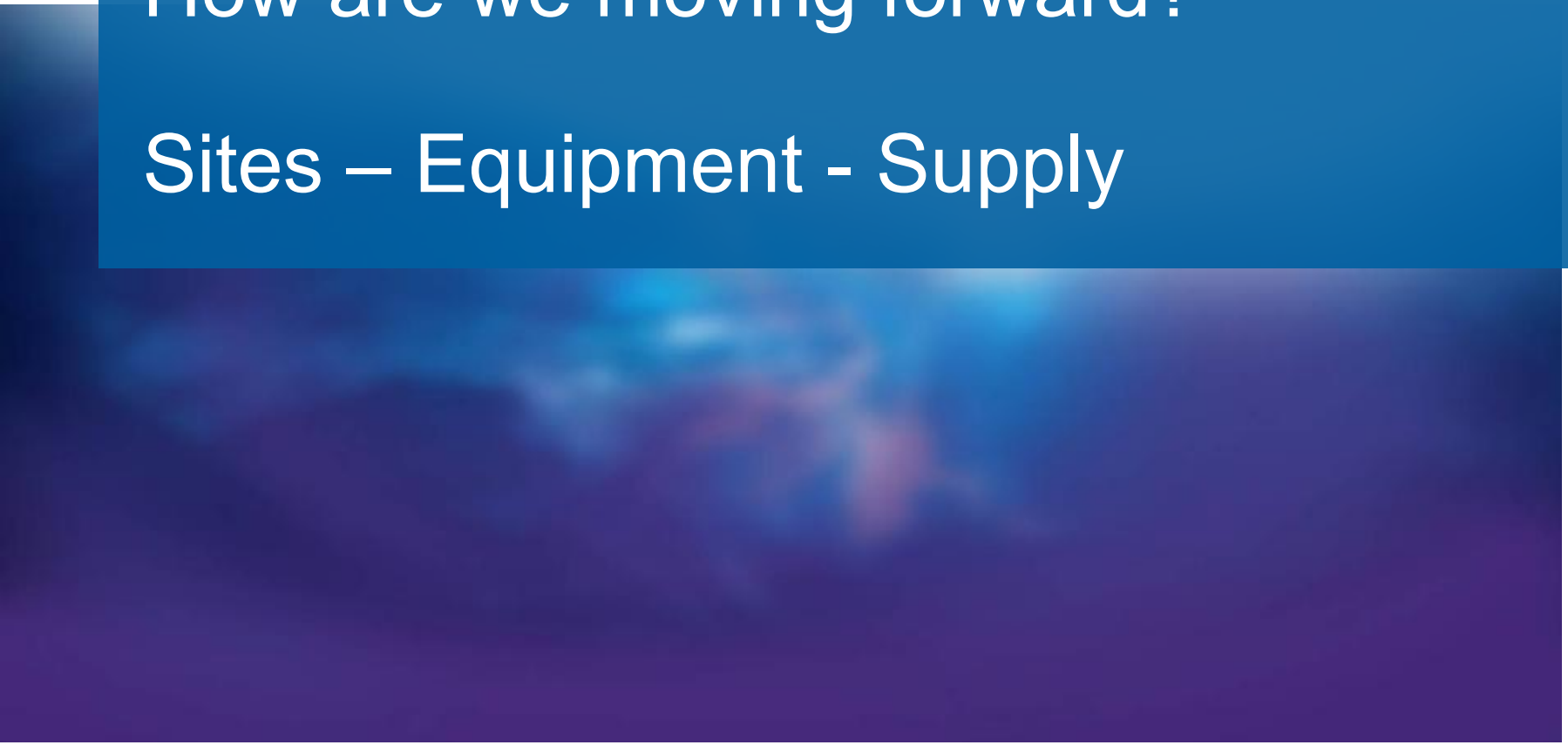
Cars
70 MPa
50–200 kg/day

California Car Population Predictions

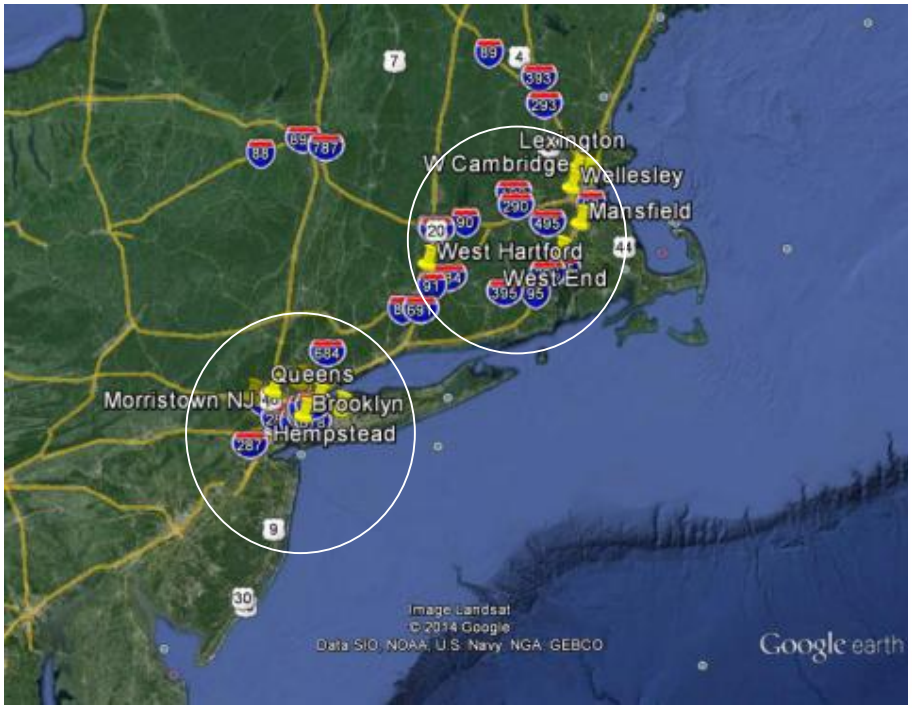


How are we moving forward?

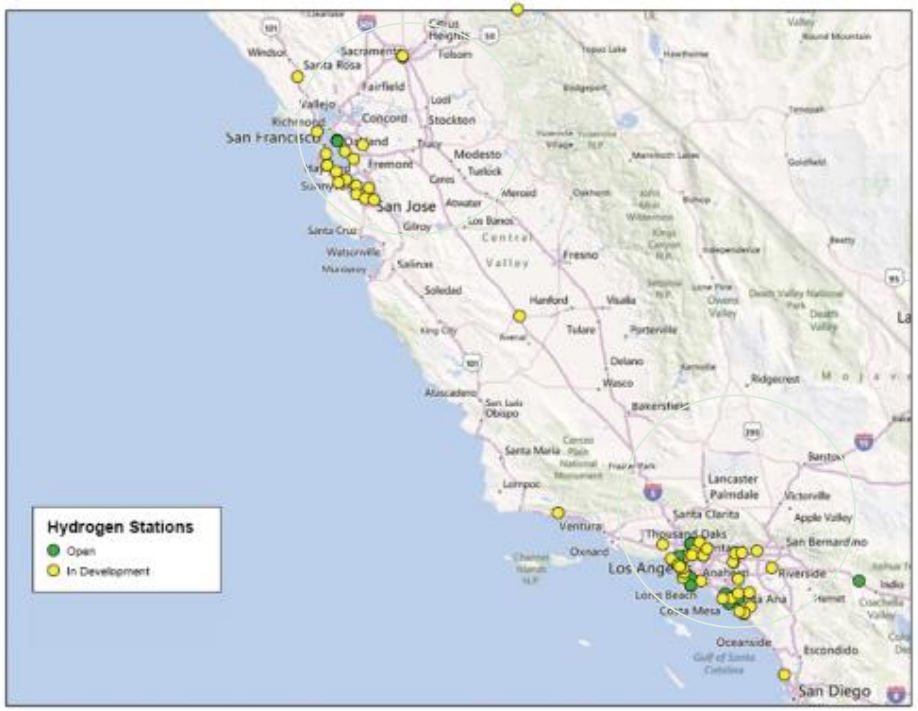
Sites – Equipment - Supply



East and West Coast Planned Fueling networks



12 Stations for the Northeast
Air Liquide and Toyota partnering



48 Total Stations Planned in California
(9 operational today)

- Specific locations/schedule are contingent upon ongoing site negotiations
- Connector stations located on major travel routes between clusters

Permitting and construction

Retrofit of an existing station

Design standards

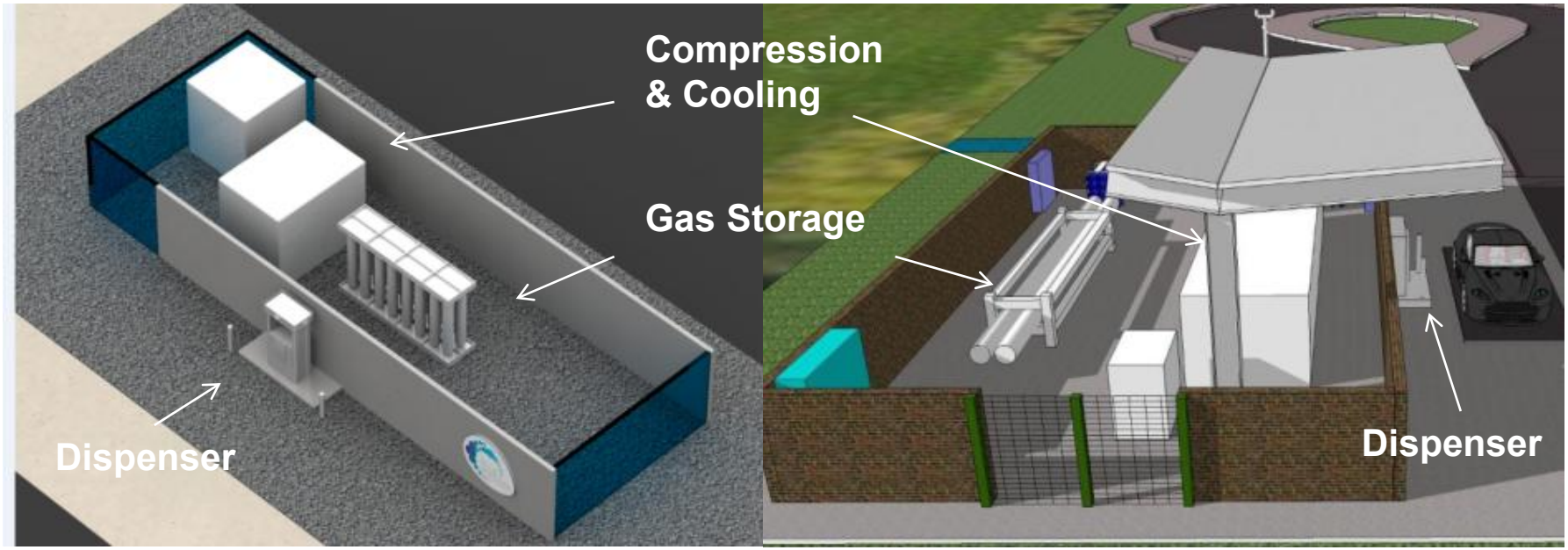
- NFPA, CGA and local fire codes
- Use permits typically not necessary at existing stations
- SAE standards compliance

CGA – Compressed Gas Association; NFPA – National Fire Protection Association


BLUE
HYDROGEN
Clean energy solutions
AIR LIQUIDE

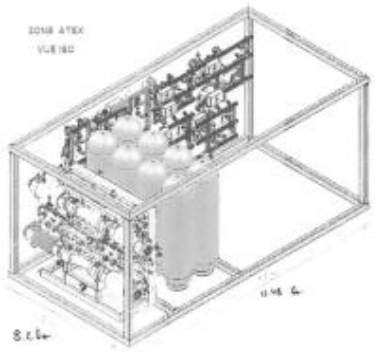
Station Design

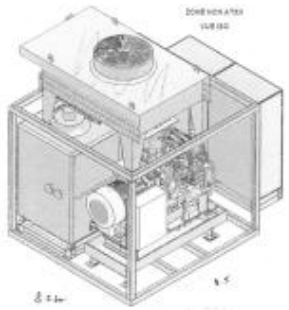
- Small foot print 1,500-2,000 ft^2
- All equipment modular, above ground and expandable
- Fueling time 3–5 minutes
- NFPA 2 and CGA compliant



Station Components

Compression and cooling





Conditions H2 for achieving high density and SAE compliant fills

Dispensers

- Standard retail point of sale system or customized fleet systems
- SAE fueling nozzle and protocol
- Metering systems advancing to weights & measures approvals
- Station status broadcast to the cloud or internet

Typical Business Models

Business Model	Fleet Advantage/Synergies
Retail Gas Stations • Station provider rents space required for equipment from owner • Station provider owns and operates station • Station provider sells fuel to vehicle owners	• Adds stable demand to public station • Improves asset utilization • Point of sale can be customized
Behind the Fence Fleet Stations • Station provider installs station at central fleet location • Station provider owns and operates stations • Fleet operators lease equipment and pay for fuel with monthly invoicing	• Large fleets (50 cars) can have a dedicated station • No point of sale transaction necessary • Permitting is usually easier • Equipment operation can be customized to fleet characteristics

Hydrogen Supply and Distribution

Large Scale Production

H2 Source:
- Steam Methane Reforming
- Waste gas purification
- Electrolysis

Gaseous (200–450 bar)

Liquid

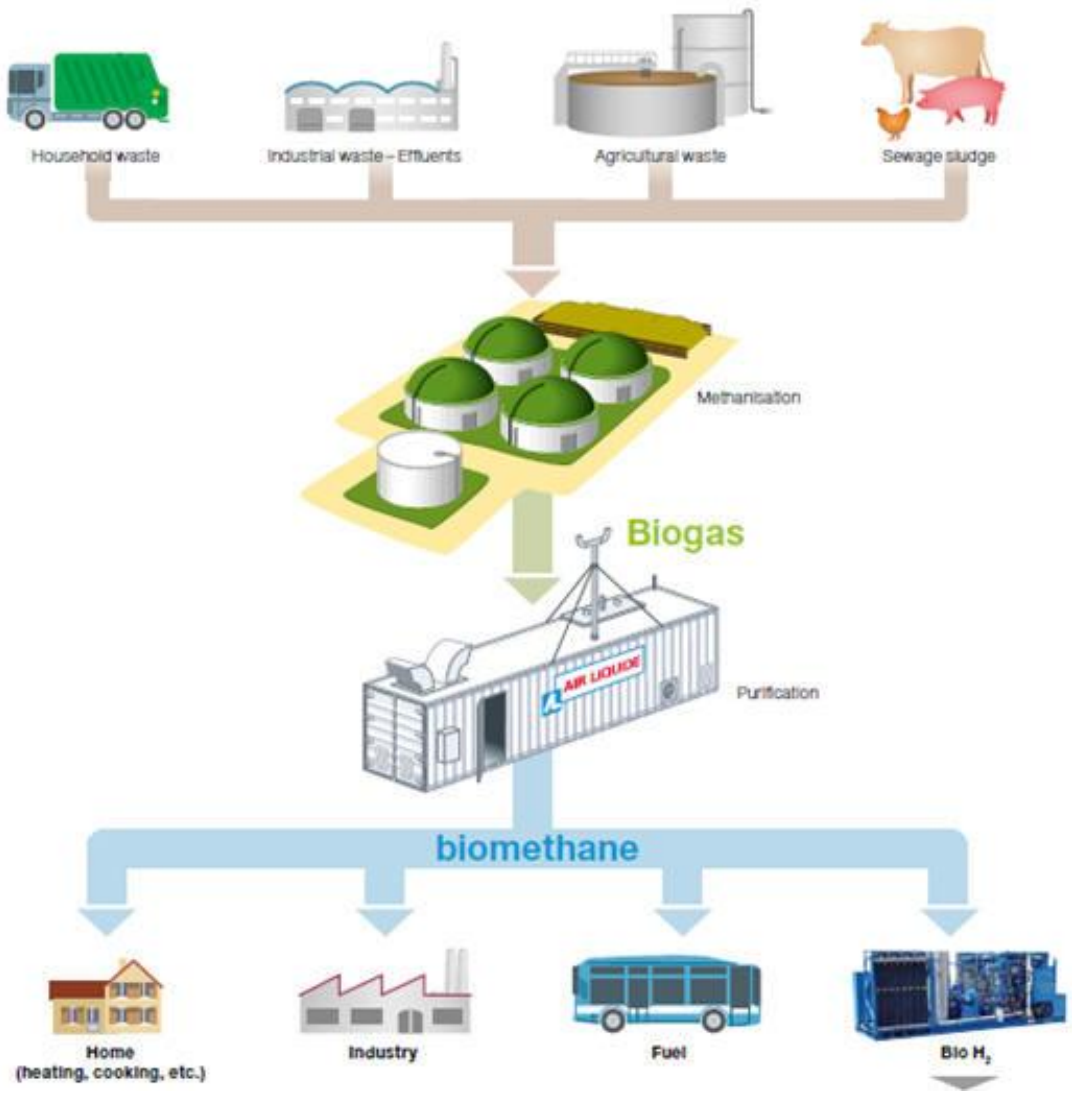
Onsite Production

Reforming NG

Electrolysis

NG – natural gas

Hydrogen Supply and Distribution



Summary and Key Points

- The cars are coming
- The infrastructure will be ready
- California and Northeast states lead the way
- Targeting existing retail sites with enough space
- Hydrogen stations and fueling equipment are commercially available
- Blue hydrogen enables sustainable supply

AIR LIQUIDE
ADVANCED BUSINESS & TECHNOLOGIES

BLUE HYDROGEN
Clean energy solutions

BIOGAS
Natural energy solutions

BLUE HYDROGEN
Clean energy solutions

AIR LIQUIDE
ADVANCED BUSINESS & TECHNOLOGIES

Thank You