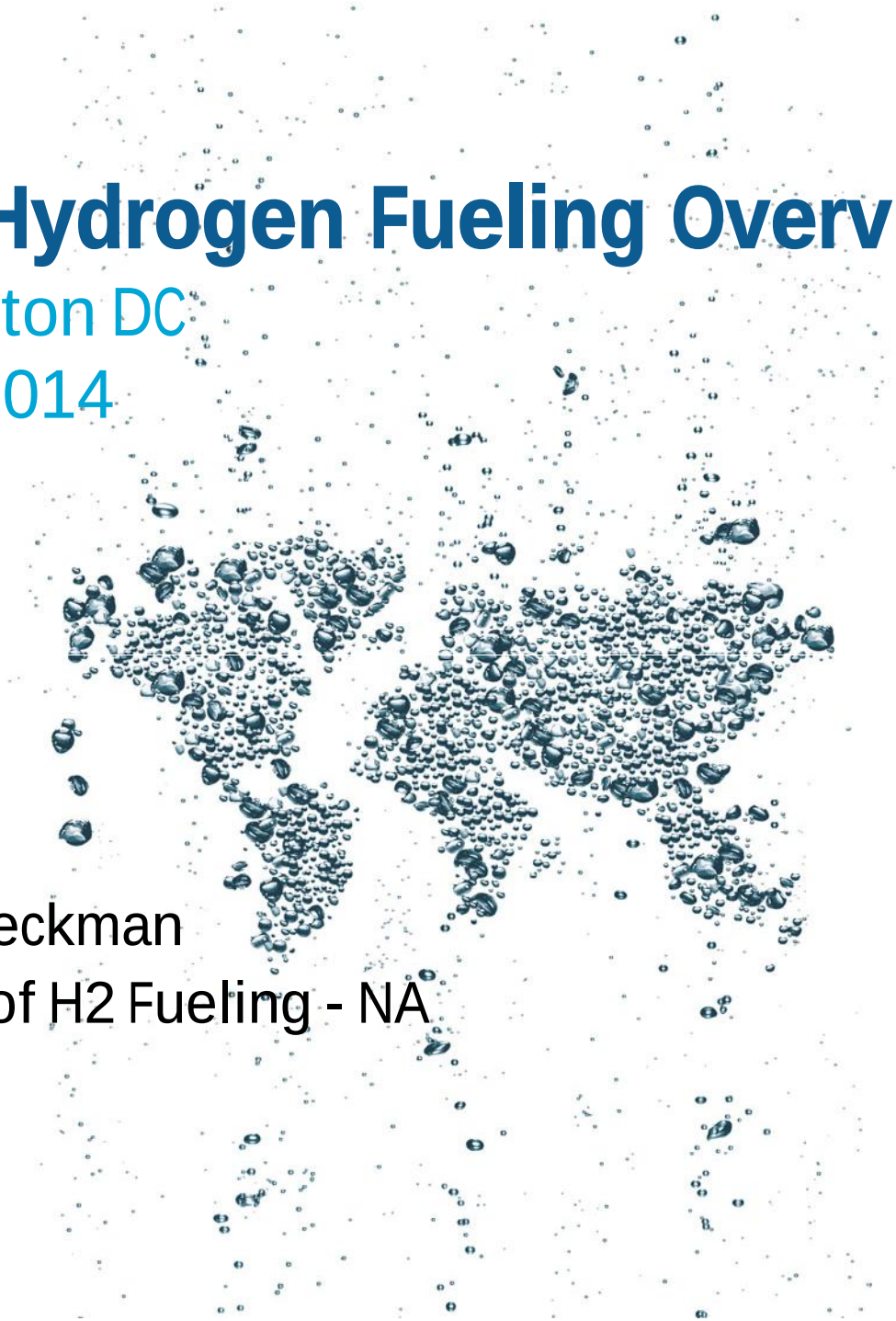
# Linde Hydrogen Fueling Overview

## Washington DC
## 18 Nov 2014



Michael Beckman
VP / Head of H2 Fueling - NA

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# Agenda

- **H2 Value Chain**
- **H2 Forklift Fueling**
- **H2 Bus Fueling**
- **H2 Car (FCEV) Fueling**
  - US (California)
  - Global
- **Hurdles**

# Linde covers the entire hydrogen value chain

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## Production

Conventional $H_2$
(e.g. SMR)

Green $H_2$
(e.g. BTH)

## Supply / Storage

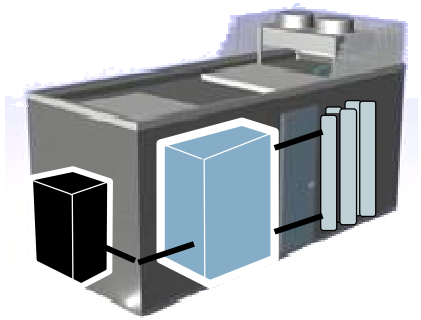
$CGH_2$ storage

$LH_2$ storage

Onsite SMR

Onsite electrolysis

## Compression / Transfer



Ionic compressor

Cryo-pump

## Dispenser

350 bar

700 bar

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# Linde Magog, Quebec Liquid Hydrogen Facility -- Supplying the NE with Renewable Hydrogen

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-Byproduct of Sodium Chlorate production

- Brine as feedstock

- 97% hydro-electric power

# H2 Fuel Cell Forklift Fueling:
# BMW - Hydrogen Forklift Fueling…largest H2 fueling site in the world! >600kg/dy H2 use…and growing

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Equipment:

- 3 x IC45 ionic compressors
- High pressure H2 storage
-18 indoor 350bar dispensers

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# Hydrogen Bus Fueling
## AC Transit – Linde Hydrogen Fueling Stations

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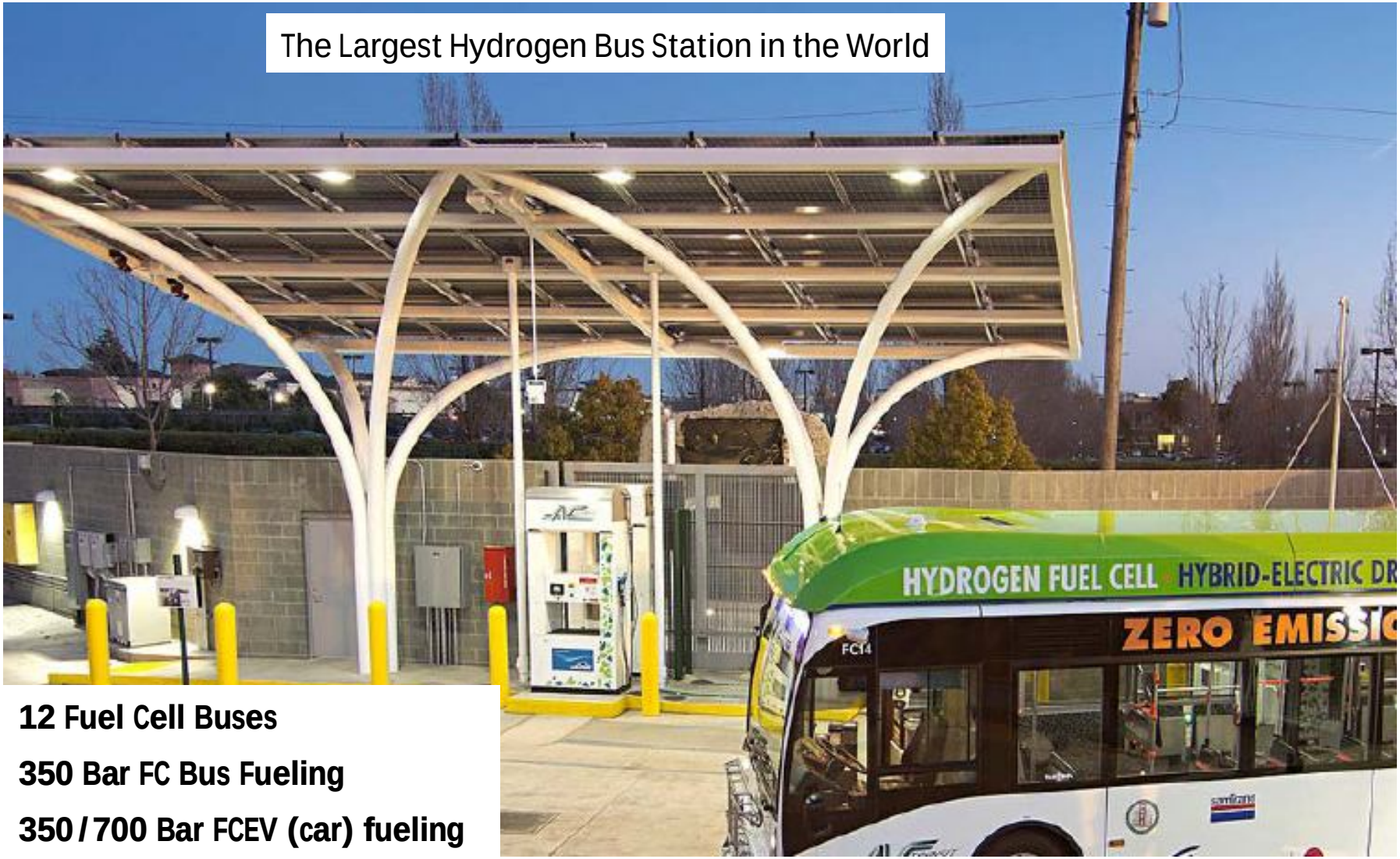


**12 Fuel Cell Buses**

**350 Bar FC Bus Fueling**

**350 / 700 Bar FCEV (car) fueling**

# Hydrogen FCEV (Car) Fueling
## -- California Infrastructure Update

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- **Assembly Bill 8 passed - $20 MM per year in funding for next 10 years**
- **Governor Brown's Zero Emission Vehicle (ZEV) Mandate – 1.5 MM ZEV vehicles in CA by 2025, 25% of State's new vehicle purchases to be ZEV by 2020**
- **Governor's Office has created a position in GoBiz department to facilitate permitting hurdles of hydrogen fueling stations**
- **H2 USA and H2FIRST private / public partnerships established to reduce barriers for infrastructure deployment**
- **CEC awarded $46.6 MM in funding in the most recent round in 2014**
  - $18.6 MM higher than planned based on applications
  - Over 50 applications received
  - 28 successful station awards (7 different companies)
  - Offered up to 85% project funding (up from 60% before AB8 was passed)
  - Up to $100k per year for three years of O&M funding
  - Total number of stations funded by CEC thus far = 49 + 1 mobile refueler

# Industry Projections – CA Roadmap

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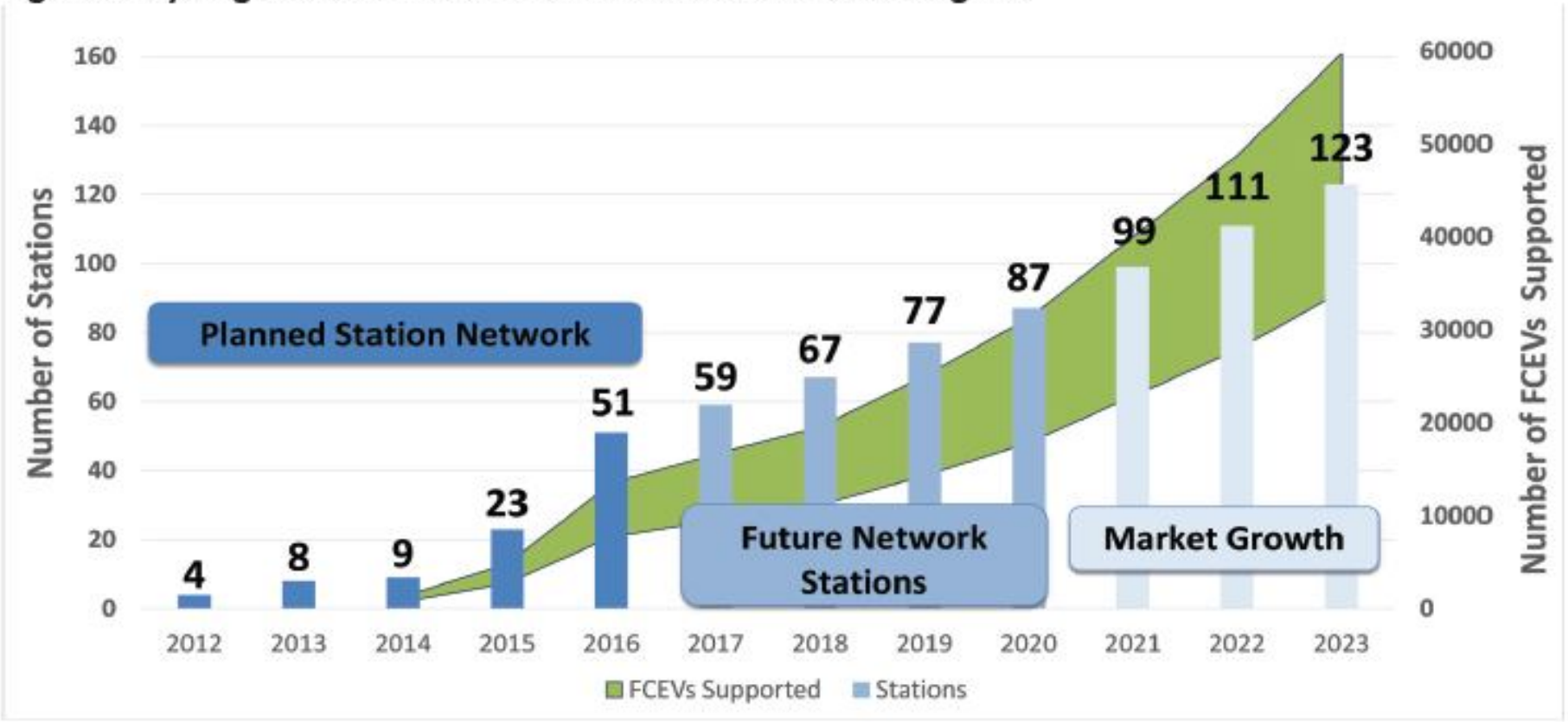
**Figure 6. Hydrogen Station Network – Current & Estimated Progress**




— Past Industry Projections have projected 50,000 vehicles and 100 Stations by 2020

— Latest Projections taking into account station progress and OEM schedules show moderate increase in stations by 2020 ~ 87

— Low Vehicle Estimate by 2020 = 18,465, High Vehicle Estimate by 2020 = 31,244

— Volume assumption in financial case used Low estimates

# H2 Retail Fueling:
# Active Linde California Hydrogen Fueling Project Locations

| Location | Customer | Station Type | Operations Date | Linde Technology |
|---|---|---|---|---|
| Emeryville, CA | AC Transit | Bus / Car | 2011 | IC50, MF90 |
| Livermore, CA | Lawrence Livermore Labs | Research / Testing | Jul-13 | Liquid Pump |
| Oakland, CA | AC Transit | Bus | Nov-14 | IC50 |
| West Sacramento, CA | Public | Car | Oct-14 | IC90 |
| San Juan Capistrano, CA | Public | Car | Feb-14 | IC90 |
| Cupertino, CA | Public | Car | 4Q 2015 | IC90 |
| Foster City, CA | Public | Car | 4Q 2015 | IC90 |
| MountainView, CA | Public | Car | 4Q 2015 | IC90 |
| San Ramon, CA | Public | Car / FLT / Shuttle Bus | Nov-15 | IC90 |
| Oakland, CA | Public | Car / Shuttle Bus | Nov-15 | IC90 |

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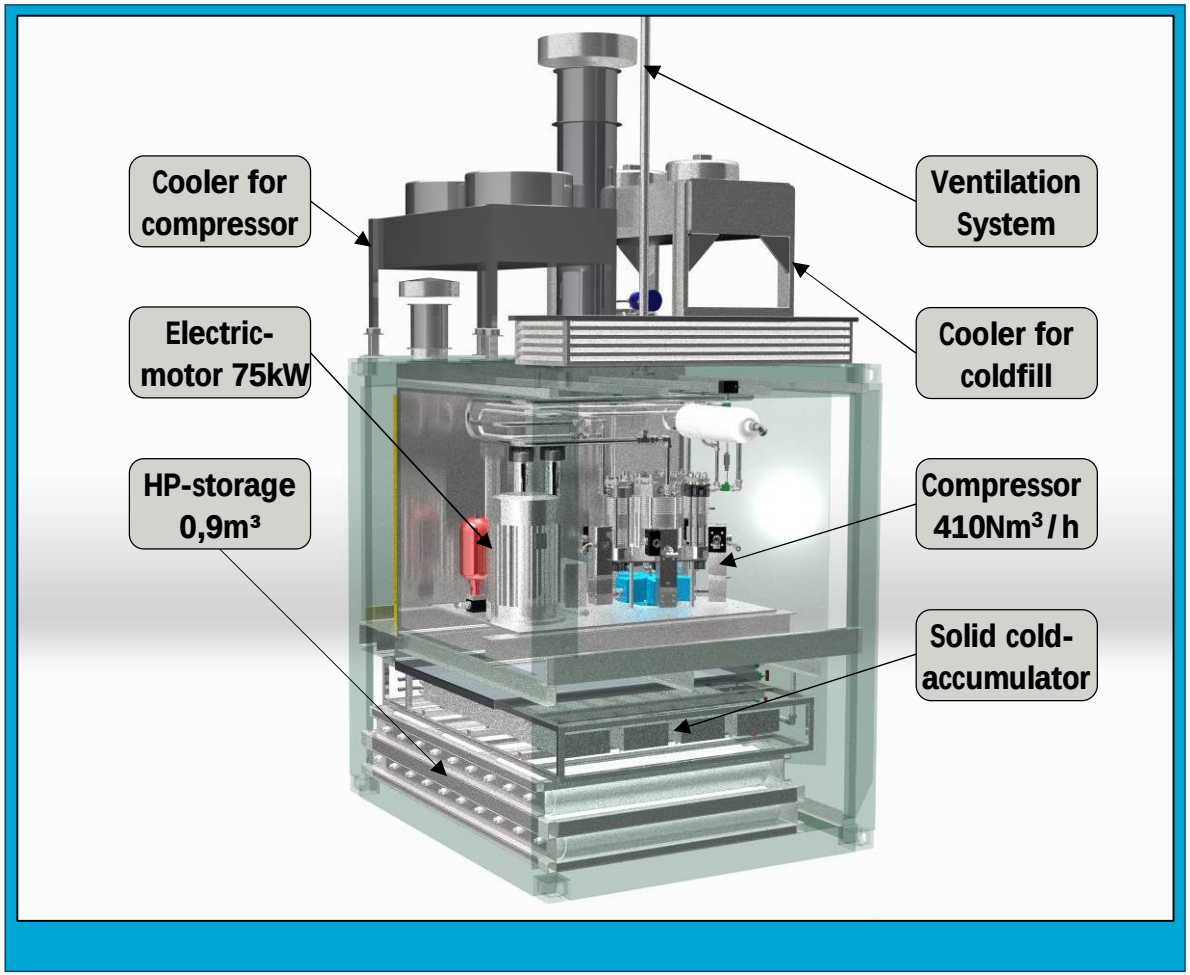
# West Sacramento, CA – First US Linde Retail H2 Station -- First US IC90

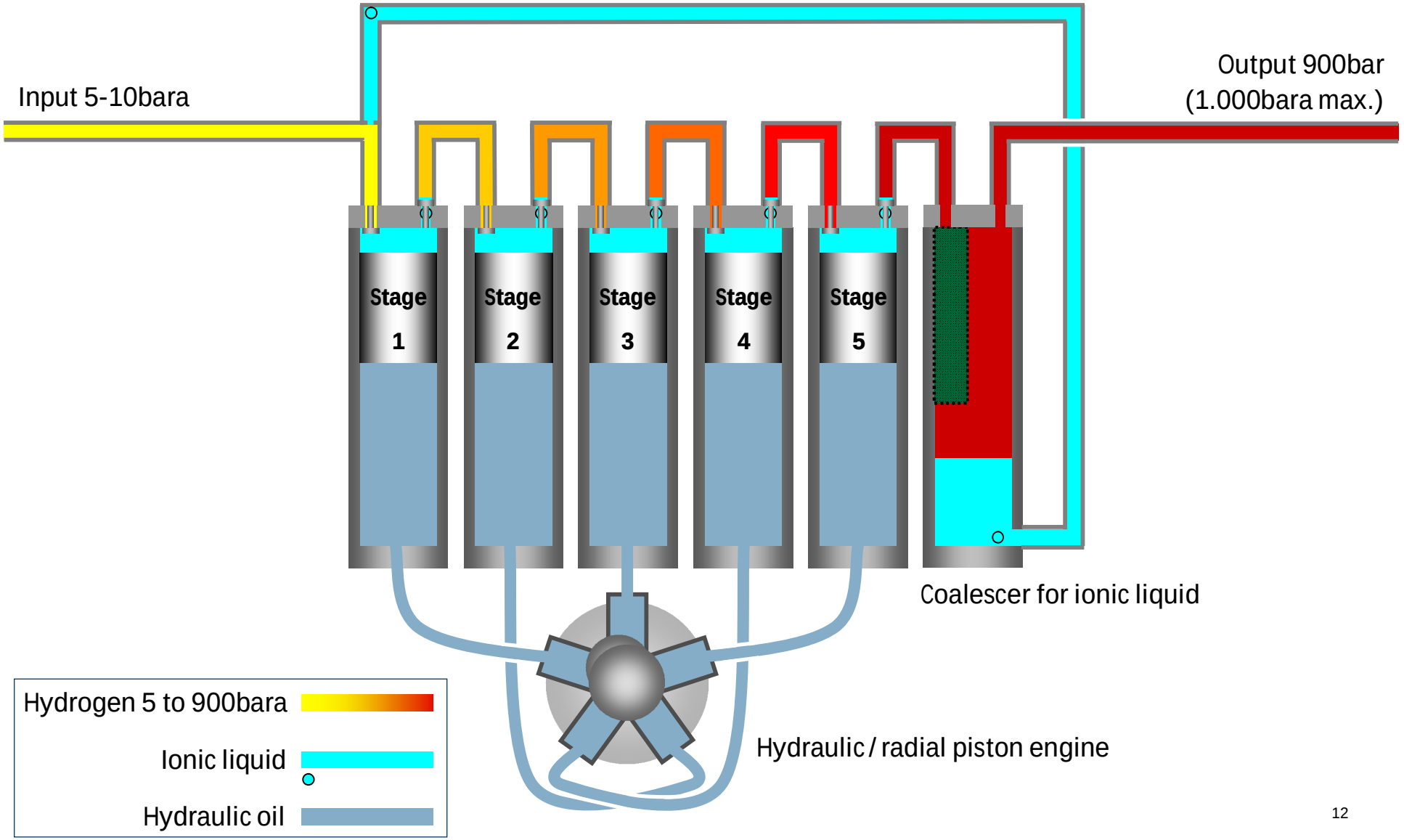
# Overview IC90: layout / performance



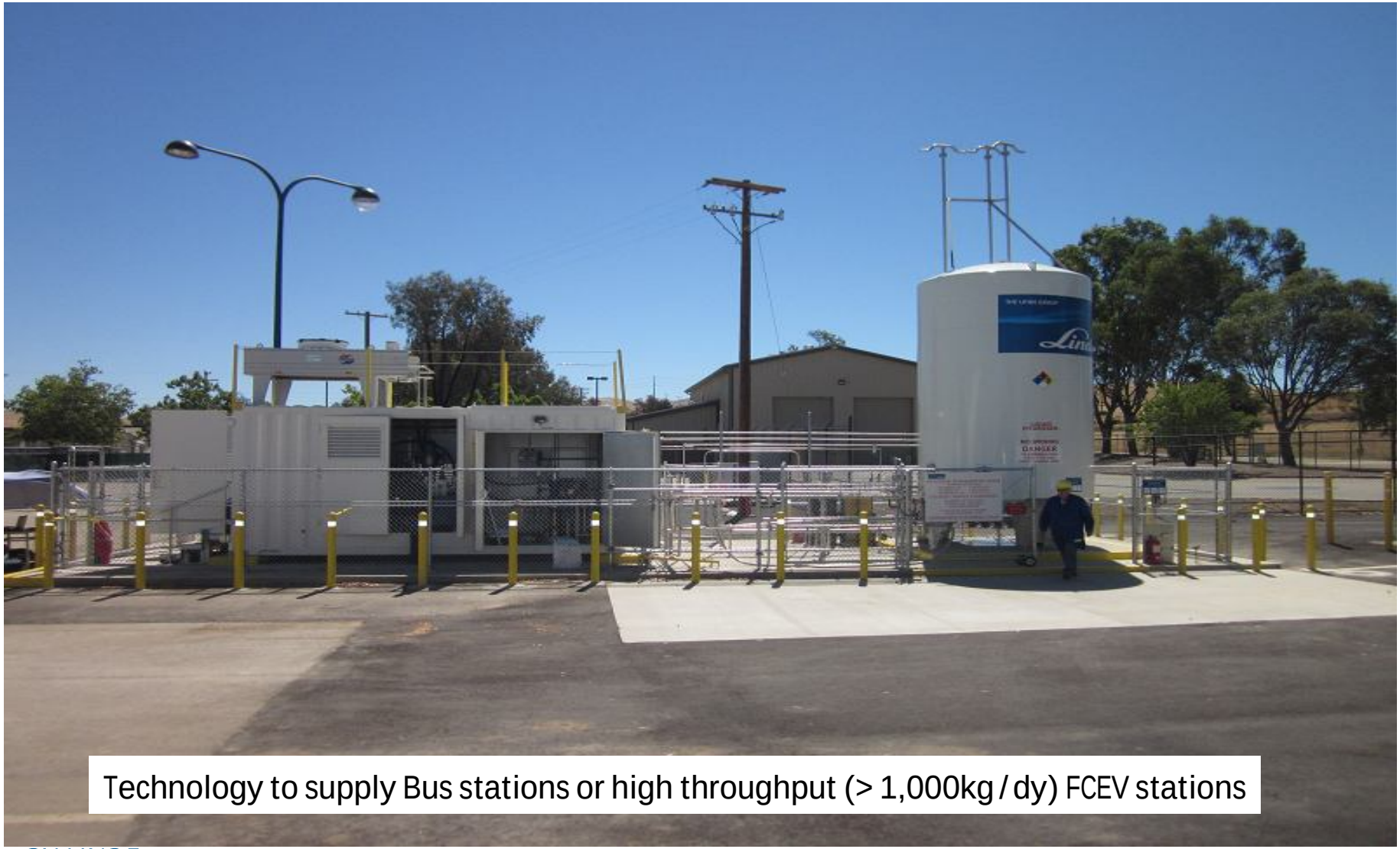

## Layout / Performance

- Small footprint: 2,7m x 3m
- Height: 3m (without roof coolers and vents)
- Noise emission: <65dB(A)
- Supply: gaseous or liquid
- Connected load: 90kW
- 5 Stage compression w/ flexibility
- 30 kg/hr
- Possible option to double capacity
- Low power consumption vs. traditional GH2 compression
- Serial production capability

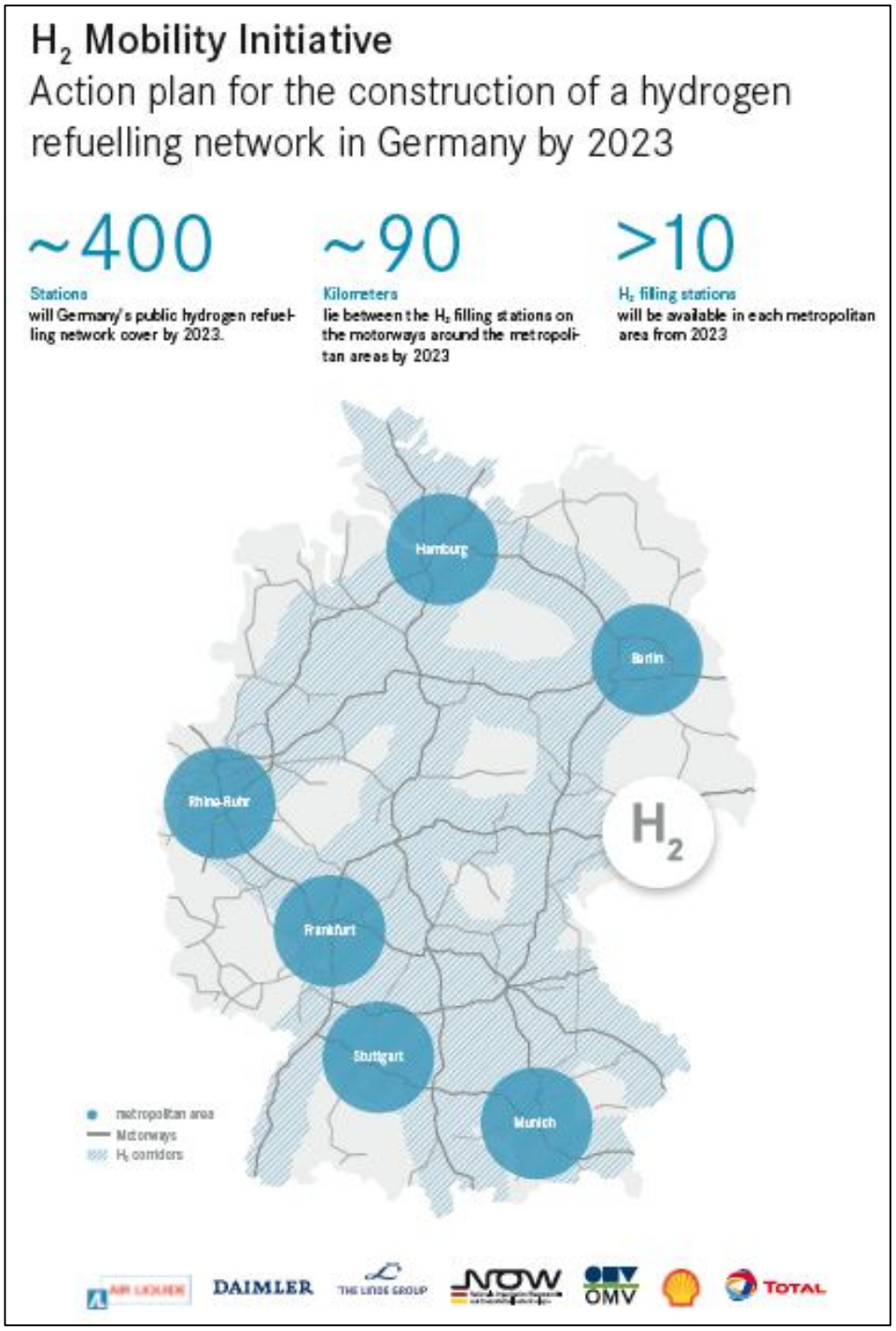
# Overview IC90: functionality



# Lawrence Livermore National Laboratory – Cryogenic Liquid Pump Project (> 100 kg / hr capacity at > 350 / 900 bar)



Technology to supply Bus stations or high throughput (> 1,000kg / dy) FCEV stations

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**Headline:**

**H2 Mobility initiative agrees on $474M plan for hydrogen refueling network in Germany; 400 stations by 2023**

# Realities of locating at a gasoline station: Liquid storage

**Typical 150’ x 150’ gas station (22,500 ft2)**

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**Setback distances are significantly greater for liquid**

**Risk assessments and worst case scenarios much more challenging for increasing storage quantities**

**Impacts on neighbors – reduction in property value, could veto project**

**Sandia National Labs analytical work on liquid / vapor dispersions to support changing code**

# Challenges the industry faces

**Proving infrastructure commercialization can happen…safely**

**Finding good retail sites for deploying stations**

- Space is tight in general
- **Setback distances** in the US for liquid storage is a huge obstacle
- Both gas and liquid storage volumes are limited on sites due to codes and limited space

**Green hydrogen production**

**Equipment component costs are high…need economies of scale**

**Lack of qualified / experienced contractors for installation – limited vendors = higher cost**

**Uncertainty over funding levels and year to year consistent support**

**Overcoming the early lack of cars…and uncertainty on financial case**

**Ramping up production (large scale plant) to meet demand**

# Hurdles w/ H2 Station deployment

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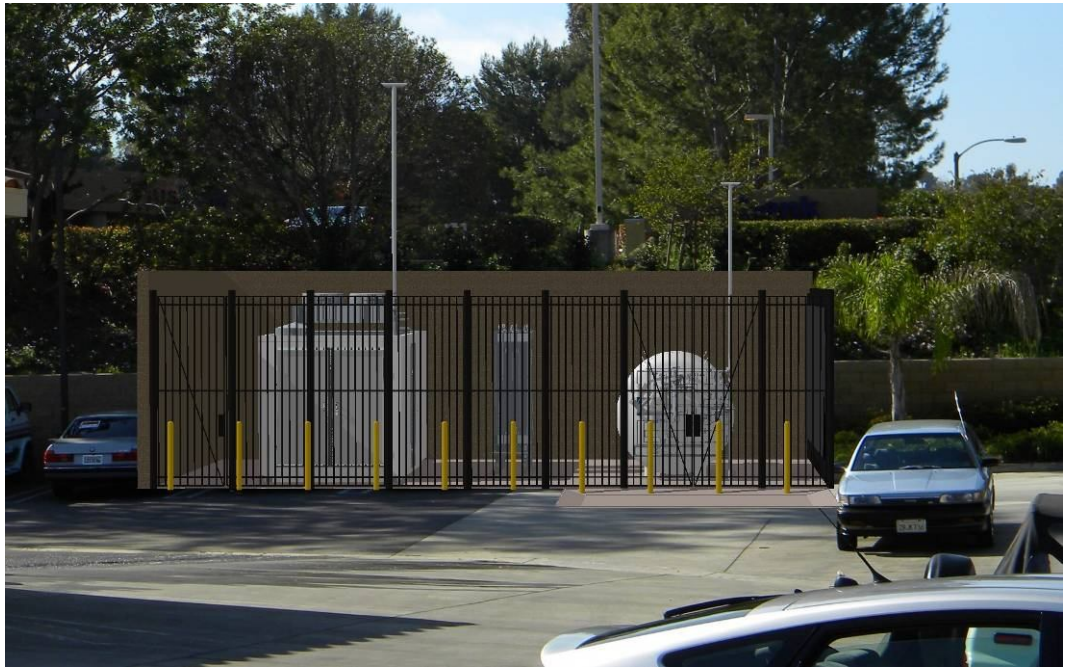
- **Local AHJ interpretation of code and overly conservative (CYA) requests (i.e. berm around LH2 tank, fire-eyes – pressure drop analysis controls this exposure)**
- **Franchisor agreement on retail station sites – need approval to sell and market H2**
  - Energy independence & security act of 2007 (section 241, sub 107) covers ethanol, but not H2…yet?
- **Power required (480V) typically requires new transformer…requires add'l cost AND property owner agreement**
- **Local planning department "aesthetic" requests which add cost/complexity (i.e. artistic walls, landscaping)**
- **Negotiating lease agreements with small business/land owners**
- **ADA compliance costs of entire site that may be triggered by H2 station installation**
- **Property tax potential reassessment due to H2 station installation**
- **Environmental liability concerns of leasing property on existing gas station sites**
- **Existing stations should be grand-fathered into any changes to code (i.e. NFPA2 2016 version)**
- **NFPA 2016 version will add significant cost to HEE (H2 Equip Enclosures) stations**
  - Separation (firewall) btwn storage and compressor (gas tight, flame-proof)
  - 6' 8" of egress the length of the egress (must have headroom to the exit)
- **Accuracy classes will become increasingly more difficult to meet, in part due to issues such as GH2 trapped in dispenser hose and purged**

# Provocative Ideas…

- **A paradigm shift is needed…**
  - Recognized there is a societal cost to gasoline / diesel → Increase the cost of conventional fuel instead of trying to reduce the early cost of H2

- **Recognize that H2 is a better fuel…today! There is a clear pathway to get to green H2, and this will become economically viable with higher volumes**

- **Set up a publically funded "Hydrogen Fueling Company" to overcome early investment hurdles**



# THANK YOU

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