Hydrogen Infrastructure Options

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Far North Transit Symposium

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→ OneGHD

Topics

- Introduction
- H_2 Generation
- H_2 Transportation
- H_2 in Transportation
- Hydrogen – Energy Carrier

OneGHD

90+ years in operation
135+ countries served
200+ offices worldwide
2.0Ⓑ USD revenue 2020
5 global markets
10Ⓚ people
50+ service lines

↳ **Providing engineering, environmental, advisory, architecture, digital and construction services**

WATER

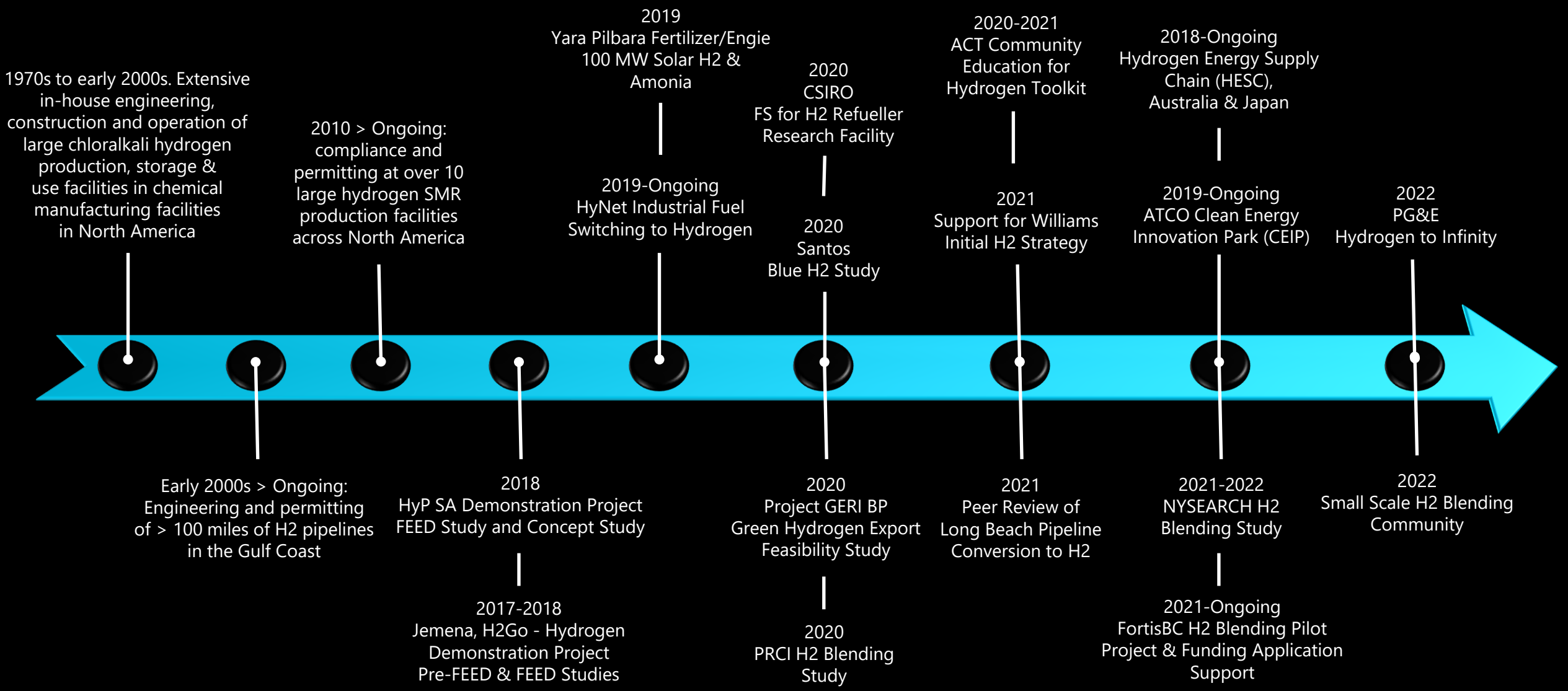
ENERGY & RESOURCES

ENVIRONMENT

TRANSPORTATION

PROPERTY & BUILDING

50 years of Global Hydrogen Experience

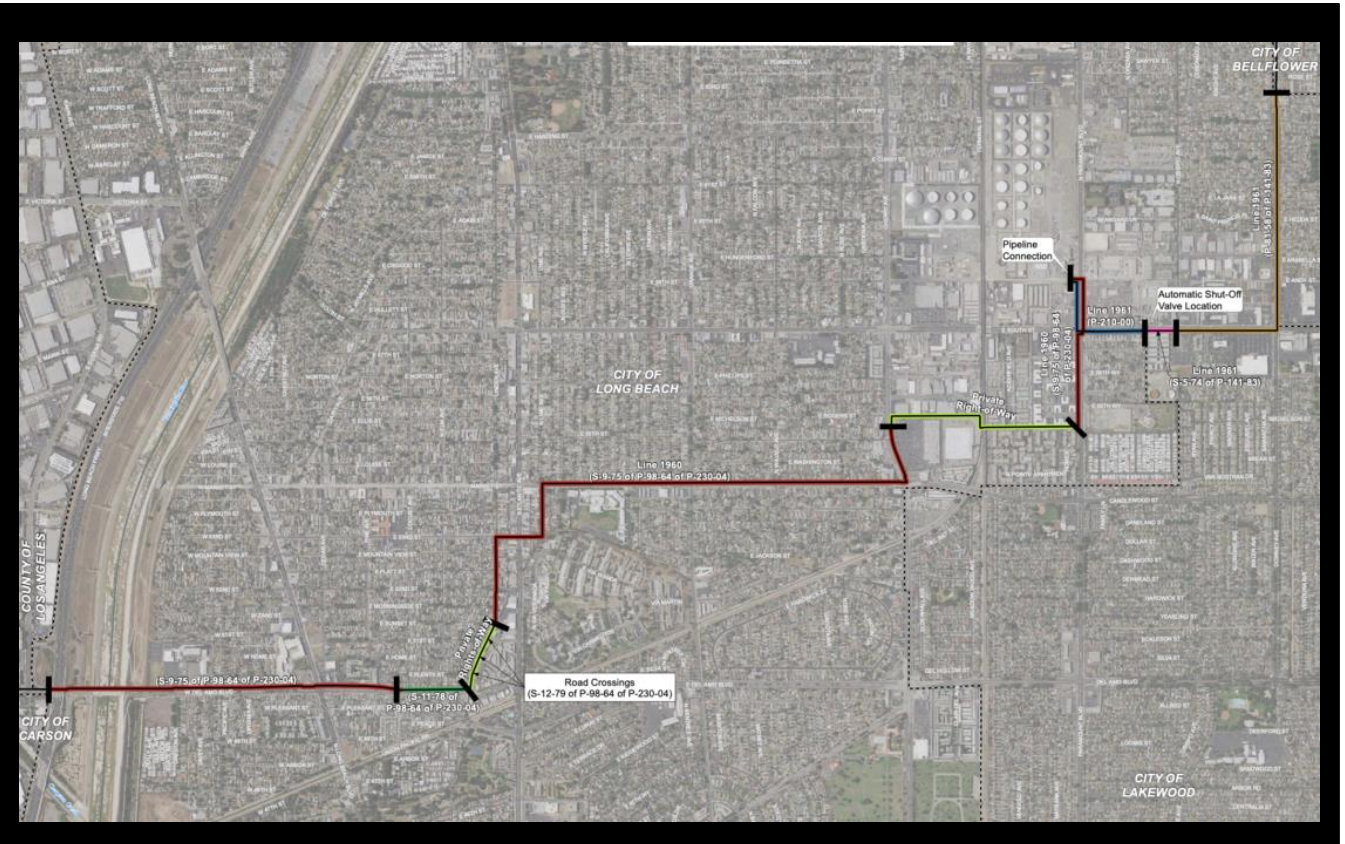


Hydrogen Generation

- Electrolysis - electricity
- Steam Methane Reformation (SMR) – pipeline

Hydrogen Transportation

- Pipeline
  - 100% Gaseous Hydrogen
  - Hydrogen Blend with CH_4



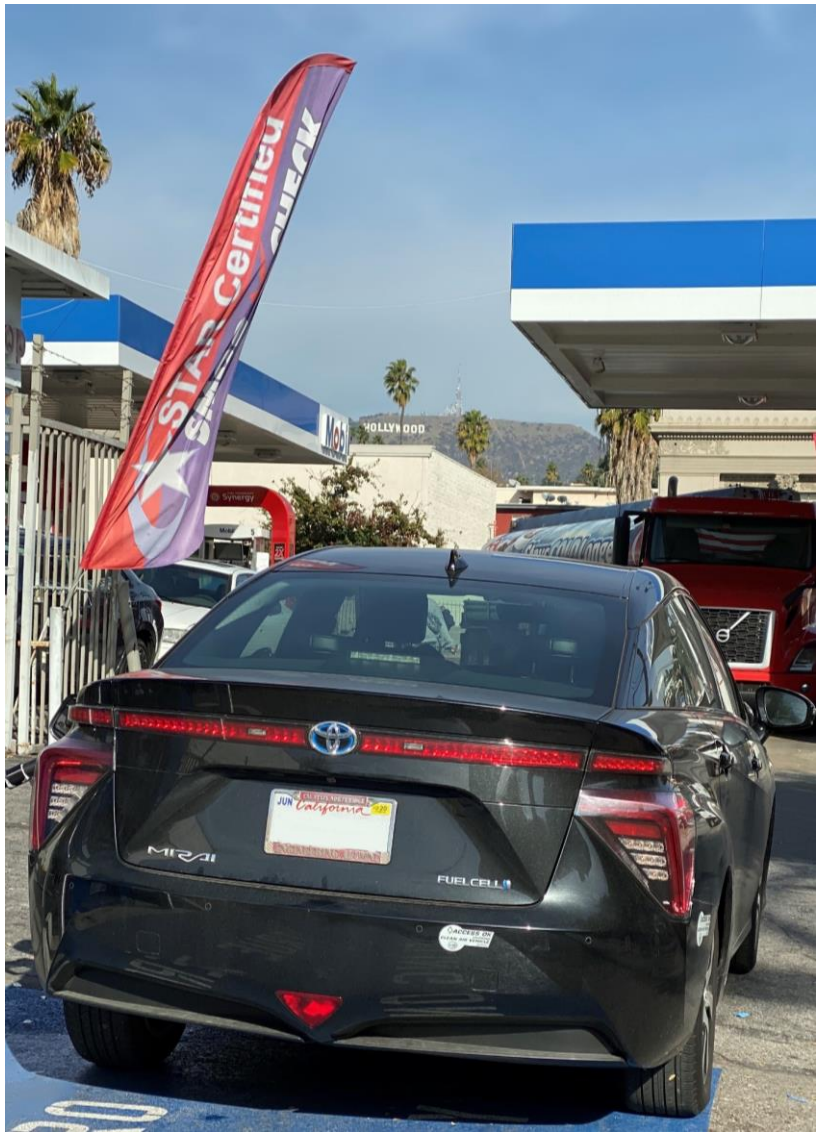
- Truck
  - Gaseous (GH_2)
  - Cryogenic (LH_2)
  - Organic (NH_3, CH_3OH)

- Ocean Vessels
  - Cryogenic (LH_2)
  - Organic (NH_3, CH_3OH)

Hydrogen in Transportation

Refueling Protocols (SAE J2601)

- H35
  - Economical option
  - 350 bar / ~5,000 psi
  - No cooling needed
- H70
  - Double the range
  - 500 bar / ~10,000 psi
  - Cooling needed for “full fill”



Hydrogen in Transportation

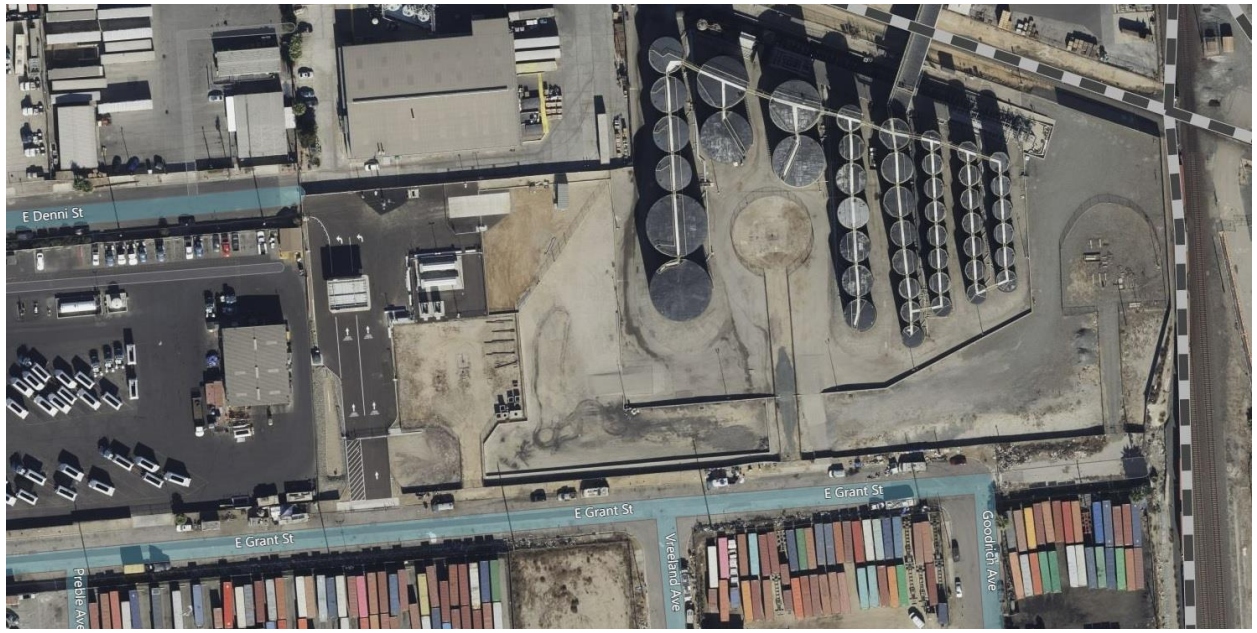
Permitting Considerations

- Education & Outreach
- Set-Backs vs. Engineered Controls
- Code Compliance
  - NFPA 2
  - ASME B31.12

Source: California Fuel Cell Partnership

Refueling Options

- Permanent Refueling
- Delivered Hydrogen
- Temporary Refueling
- Hydrogen Produced On Site
- Delivered/Produced Hydrogen Hybrid
- Hydrogen Export Capabilities



Source: Bing Maps

Hydrogen in Transportation

U.S. Fuel Cell Electric Bus Projects

Created for the U.S. Department of Energy by the National Renewable Energy Laboratory

Last update: 11/3/2020

For updated versions of this file see: https://www.nrel.gov/hydrogen/fuel-cell-bus-evaluation.html

Contact for updates or corrections: Leslie Eudy, 303-275-4412, leslie.eudy@nrel.gov

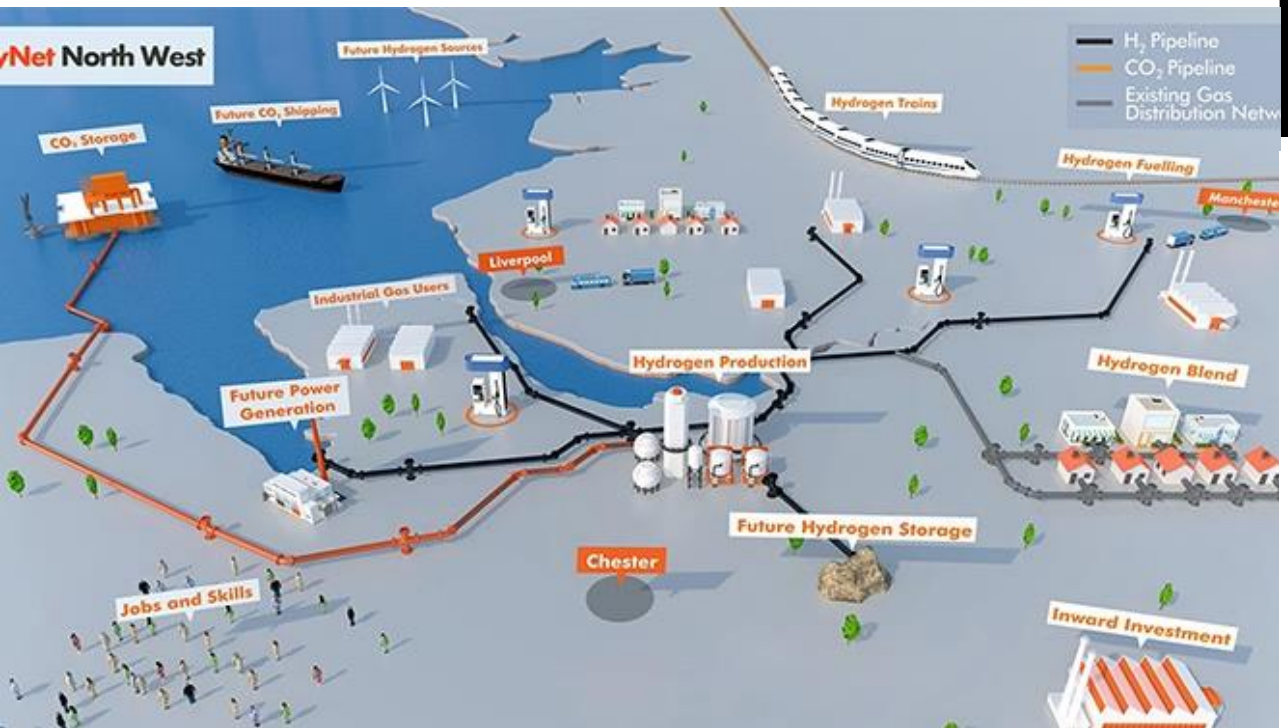
Total Active Fuel Cell Buses	64
Total Fuel Cell Buses in development	30

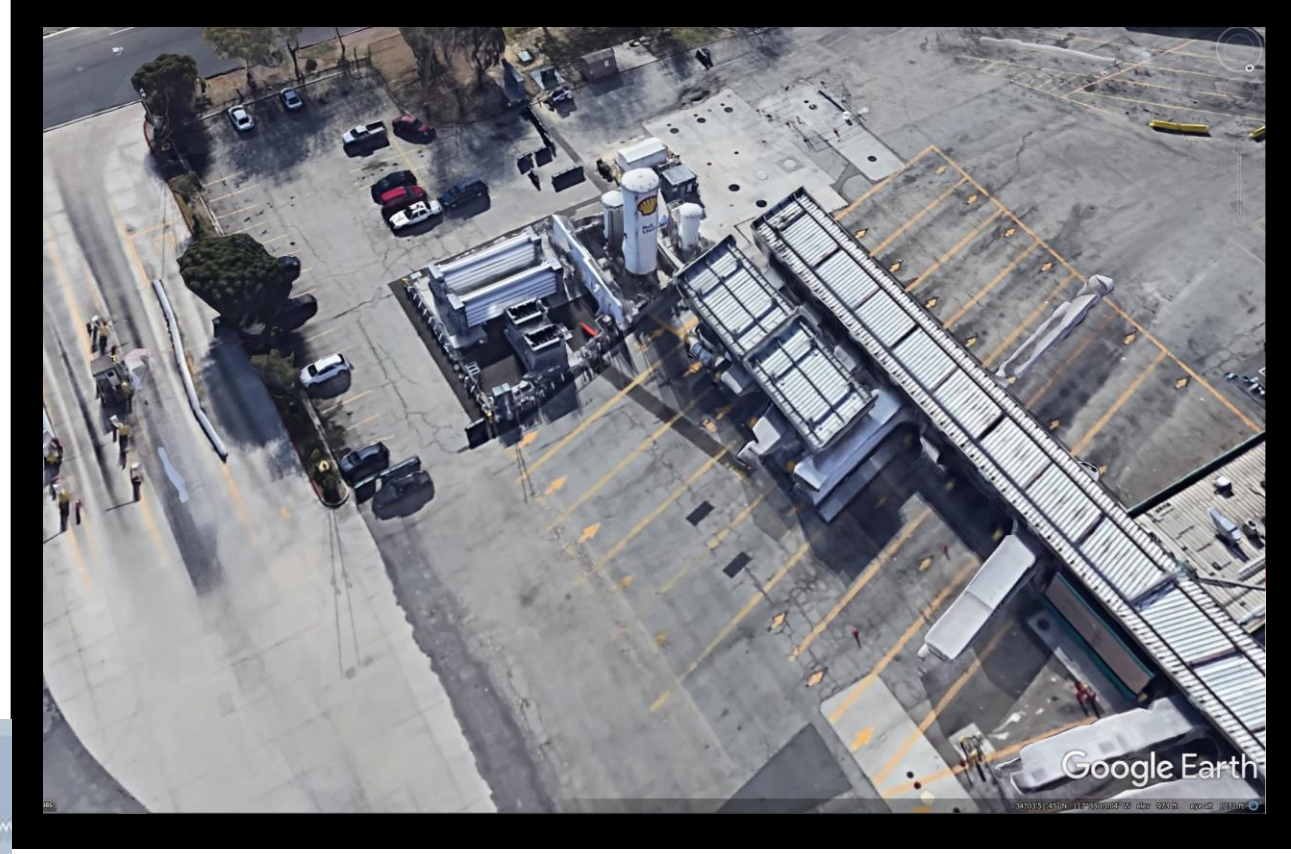
#	Transit Agency / Operator	City	State	Total Buses	Active	In Development	Status of Project	Fuel	Bus System Type	Bus length (ft)	Bus Manufacturer	Hybrid System/ Integrator	Fuel Cell Manufacturer	Fuel Cell Power (kW)	Fueling Location	Station Type	Funding Program	Note
1	AC Transit	Oakland	CA	13	11		Active	Hydrogen	Hybrid	40	Van Hool	Van Hool	UTC Power	120	Two stations (Linde) in Oakland, Emeryville	Liquid H_2 delivery and storage with electrolyzer		Two buses retired
2	AC Transit	Oakland	CA	1	1		Active	Hydrogen	Hybrid	60	New Flyer	Siemens/ New Flyer	Ballard		Two stations (Linde) in Oakland, Emeryville	Liquid H_2 delivery and storage with electrolyzer	FTA NFCBP	Bus used for Altoona testing prior to delivery to AC Transit
3	AC Transit	Oakland	CA	10	10		Active	Hydrogen	Hybrid	40	New Flyer	Siemens/ New Flyer	Ballard	85	AC Transit existing stations	Liquid H_2 delivery and storage with electrolyzer	CARB	
4	County of Hawai'i Mass Transit Agency (Hele-On Bus)	Hilo	HI	3	3		Active	Hydrogen	Electric drive with fuel cell range extender		ElDorado	US Hybrid	US Hybrid	50	Natural Energy Laboratory of Hawaii Authority		State of Hawaii	Buses in commissioning - in service by end of 2020. Fitted with 10 kW 120/220 VAC export power units
5	Orange County Transit Authority (OCTA)	Santa Ana	CA	10	10		Active	Hydrogen	Hybrid	40	New Flyer	Siemens/ New Flyer	Ballard	85	Trillium station	Liquid H_2 delivery and storage	CARB	
6	Stark Area Regional Transit Auth (SARTA)	Columbus, Canton	OH	2	2		Active	Hydrogen	Hybrid	40	ENC	BAE Systems	Ballard	150	SARTA station/ Air Products	Liquid H_2 delivery and storage	FTA NFCBP	One bus operated at Ohio State University for 1 year
7	Stark Area Regional Transit Auth (SARTA)	Canton	OH	10	10		Active	Hydrogen	Hybrid	40	ENC	BAE Systems	Ballard		SARTA station/ Air Products	Liquid H_2 delivery and storage	FTA Low-No	
8	SunLine	Thousand Palms	CA	3	3		Active	Hydrogen	Hybrid	40	ENC	BAE Systems	Ballard	150	SunLine station (Nel)	Electrolyzer	FTA TIGGER	
9	SunLine	Thousand Palms	CA	5	5		Active	Hydrogen	Hybrid	40	ENC	BAE Systems	Ballard	150	SunLine station (Nel)	Electrolyzer	FTA Low-No	
10	SunLine	Thousand Palms	CA	1	1		Active	Hydrogen	Hybrid	40	ENC	BAE Systems	Ballard	150	SunLine station (Nel)	Electrolyzer	FTA NFCBP	Prototype bus, in service 2012
11	SunLine	Thousand Palms	CA	1	1		Active	Hydrogen	Battery-dominant, hybrid FCEB	40	ENC	BAE Systems	US Hybrid		SunLine station (Nel)	Electrolyzer	FTA NFCBP	
12	SunLine	Thousand Palms	CA	5	5		Active	Hydrogen	Hybrid	40	New Flyer	Siemens/ New Flyer	Ballard	85	SunLine station (Nel)	Electrolyzer	CARB	
13	UC Irvine	Irvine	CA	1	1		Active	Hydrogen	Hybrid	40	ENC	BAE Systems	Ballard	150	UCI Station/ Air Products	Liquid H_2 delivery and storage	CEC	
14	US Airforce at Joint Base Pearl Harbor Hickam	Honolulu	HI	1	1		Active	Hydrogen	Electric drive with fuel cell range extender		BYD	US Hybrid	US Hybrid	30	Joint Base Pearl Harbor Hickam		USAF	
15	Champaign-Urbana Mass Transit District	Champaign-Urbana	IL	2		2	Planning	Hydrogen	Battery dominant hybrid	60	New Flyer	Siemens/ New Flyer	Ballard	150	CUMTD - Trillium Station	Electrolyzer	FTA Low-No	
16	Foothill Transit	West Covina	CA	20		20	Planning	Hydrogen							TBD			Board approval for purchase May 2020
17	Golden Empire Transit (GET)	Bakersfield	CA	5		5	Planning	Hydrogen		40					TBD			Board approval March 2020
18	Regional Transportation Commission of Southern Nevada (RTC)	Las Vegas	NV	2		2	Planning	Hydrogen									Awarded funding from FTA Low-No Grant in June 2020	
19	SunLine	Thousand Palms	CA	1		1	Planning	Hydrogen	Hybrid	40	New Flyer	Siemens/New Flyer	Ballard		SunLine station	Electrolyzer	CEC Alternative & Renewable Fuel and Vehicle Technology Program	

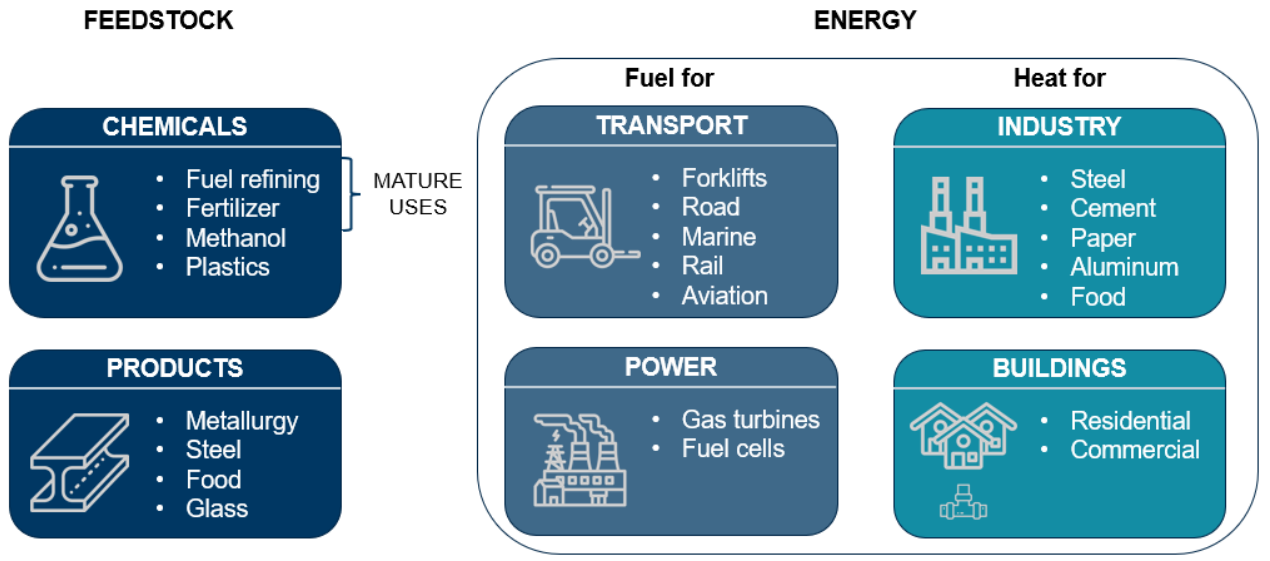
Source: DOE NREL

Hydrogen – Energy Carrier

- Transportation – same time for refueling as diesel & CNG
- Power Generation
- Gaseous blends for process use







Hydrogen – Energy Carrier

Modular Units: Scalable from several KWs to MWs.

Power Generation (peak, emergency and back-up)

Source: Ballard Power

Typical 100 KW PEM Fuel Cell Module

Hanwha Energy's 50 MW Fuel Cell Power Plant Daesan Industrial Complex, Seosan, Korea

Thank You

We are committed to solving the world's biggest challenges in the areas of water, energy and urbanization.

Bridging the gap to a low-carbon future

→ Hydrogen

1. ORIGINATION

- Co-create winning business strategy
- Identify opportunities for capital deployment (public and private capital)

2. COMMERCIAL DEVELOPMENT

- Business case development
- Service delivery options and financing strategy / commercial models for bankability
- Customer strategy and offtake support
- Commercial and technical feasibility
- Due diligence to inform buy side and sell side decisions

3. PLAN & DESIGN

- Environmental planning and approvals
- Risk minimisation
- Environmental compliance support
- Environmental monitoring
- Site selection
- Social licence support: community & stakeholder engagement
- Concept design
- Pre-feasibility studies
- Front end engineering and design
- Multi-discipline engineering management
- Detailed design
- Systems integration
- Technology assessment and selection
- Procurement support and tender development

4. CONSTRUCT & OPERATE

- Systems integration, risk and regulation
- Owners representative/ owners engineer role / Project management
- Adoption of new technology risk
- Construction management & EPCM
- Supply chain resilience

5. DISPOSE / RENEW

- End of life services
- Asset closure strategies
- Alternative revenue streams
- Renewal / disposal strategies

OVERARCHING SERVICES

- Green house gas assessments / Carbon accounting
- Green house gas assurance services
- Life cycle analysis
- Policy development and advice
- Environmental social and governance (ESG) frameworks

Drawing on the best of multi-sector innovation, consulting, data driven insights and technology to build value

Delivery under alternative risk/reward commercial models

ATCO Clean Energy Innovation Park (CEIP)

- GHD's role: Owner's Engineer
- GHD is currently advancing FEED engineering in the lead up to achieving financial close with project financiers and the Australian Renewable Energy Agency (ARENA), who provided $28M in funding.
- Previously we worked with ATCO for 2 years on the feasibility study of the green hydrogen 10MW electrolyzer installation at the Warradarge Wind Farm and concept development for funding applications.
- GHD also brings experience as the owner's engineer on the design and construction of the Warradarge Wind Farm.

ATCO

- Expected to be Australia's first, and possibly largest, commercial-scale green hydrogen supply chain project
- Located in Western Australia, ~250 km north of Perth
- JV between ATCO and Australian Gas Infrastructure Group (AGIG)
- The project includes a 10MW hydrogen electrolyzer unit that will be embedded within the 184MW Warradarge Wind Farm. The project is progressing through the final stages towards financial close before construction, planned to commence in 2022.

Project GERI: BP's Green Ammonia Feasibility Study

BP investment AU$ 2.71M

+ ARENA funding AU$ 1.71M

= AU$ 4.42M Feasibility Study

Geraldton Export-Scale Renewable Investment (GERI)

- Located in Geraldton, Western Australia.
- GHD undertook feasibility study for developing a export-scale renewable hydrogen production facility.
- Incl. detailed techno-economic evaluation of pilot and commercial-scale green ammonia production plant.
- Incl. evaluation of the different technologies and process configurations required to manufacture green hydrogen and green ammonia
- Ebhances the energy industry's understanding of the financial and technical implications for a fully integrated renewable supply chain, with potential domestic and export markets for a demonstration and commercial-scale plant.

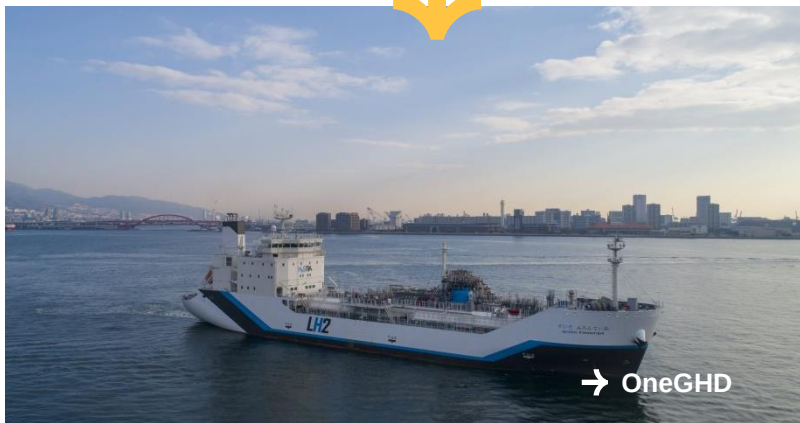
Results of the study released publicly as part of a knowledge-sharing agreement to help progress the use of renewable hydrogen energy.

Hydrogen Energy Supply Chain Project (HESC)

Since 2018, GHD has played an integral role as Lead Technical Advisor and Stakeholder Engagement Lead for the world-class HESC, which is producing hydrogen in Australia and shipping to Japan.

GHD's work completed to date includes:

- Detailed engineering and design, technology selection, control systems, 3D rendering, funding application support, and procurement
- Site selection, approvals, licensing, permitting for landmark hydrogen production and export project
- Public engagement sessions, websites development and maintenance, media and local government relations

HESC Project Highlights:

- ~400 jobs across the Victorian supply chain created in current phase, thousands anticipated during commercial operation
- Operations commenced in February 2021 and the Latrobe Valley facility is currently producing hydrogen, preparing to fill the Susio Frontier which is en route
- GHD provided integral support to achieve $50M in funding from the Commonwealth Gov't and $50M from the Victorian Gov't