Plasma Kinetics

RESPONSIBLE, RENEWABLE, ENERGY STORAGE

Energy Transport

Problem

Existing energy storage is complex and costly

Battery Storage

- Expensive
- Not recycled & toxic waste
- Heavy and potentially flammable

Traditional Hydrogen Storage

- 3,000 -10,000 psi
- -423 °F
- Expensive
- Potentially flammable

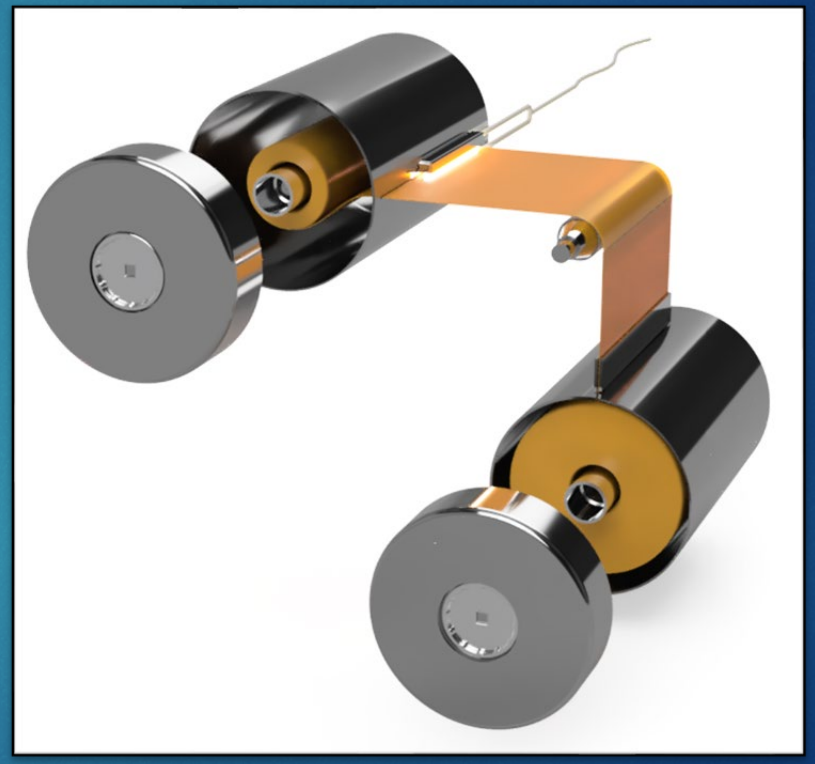
Chemical Hydrogen Storage

- Ammonia
  - Stored at 160 psi
  - Synthesis/cracking costs
- Methanol
  - Synthesis/cracking costs
  - Potentially flammable

Solution

Hydrogen stored in light activated thin film

- Patented technology
- No pressure or cooling needed
- No risk of fire or explosion
- No transportation restrictions
- Lower cost than batteries
- Low cost to store hydrogen
- Low cost to ship hydrogen
- Safe storage of hydrogen



Solution

Hydrogen from:

Wind/Solar/Hydro Electrolysis

SMR/Incineration/Flue Gases

- Gas Temperatures from 70 °F to 500 °F
- Gas Pressures from 15 psi to 580 psi
- CO_2 concentration up to 30% Molar Mass

Electro-Reformer Prototype Syngas Post H_2O Condensation Constituents				
Gas	**%Mol**	**%Mass**	**Sms3/h**	**Kg/h**
CH_4	0.07	0.08	0.04	0.03
CO_2	28.97	80.43	15.8	29.23
CO	6.03	10.66	3.29	3.87
H_2	64.35	8.17	35.09	2.97
H_2O	0.58	0.66	0.32	0.24
Total	**100**	**100**	**54.54**	**36.34**

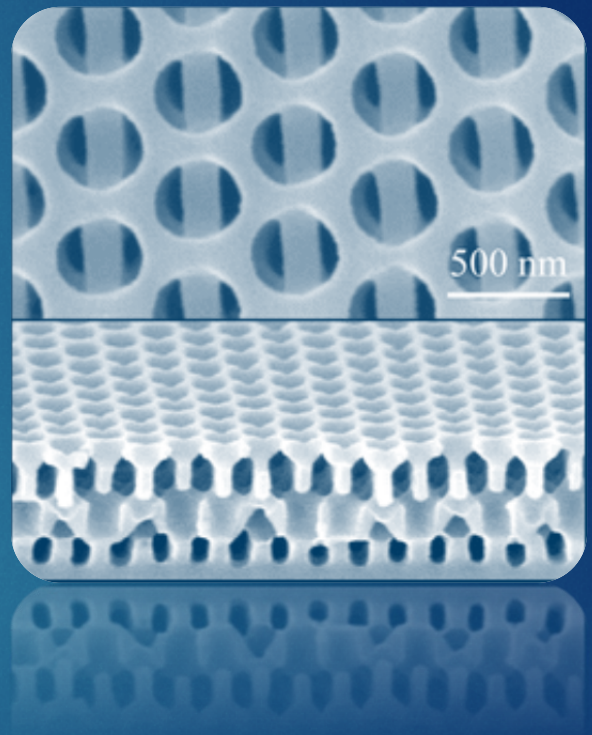
Results

- Non-flammable hydrogen storage.
- 1,000 kg of hydrogen in 20ft intermodal container.
- Safe distribution by inland waterway, truck or rail.
- Specialized ship and certification exempt.
- Infrastructure and safety measures minimized.
- Shipments of any size, to any port, with reduced logistics and increased revenue.

120GWh aboard a single container ship
- 12,000 homes powered for a year
- 9,320,000 miles of truck travel

Technical

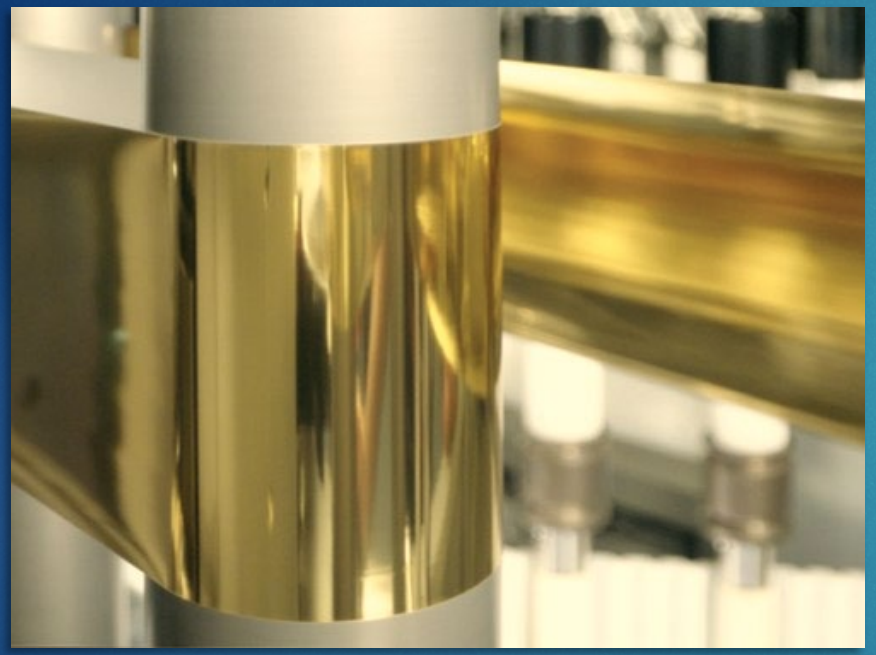
0.028 mm *non-flammable* thin film with a nano-structure which captures hydrogen *without pressure* and interacts with light to release hydrogen at desired pressure.



- 7 constituents (no rare-earths)
- NGF and Polyimide substrate
- Nano-lithography structures
- PVD layering of materials
- High Temperature Shape Memory Alloy
- Low CO_2 fabrication process

Thin Film Overview

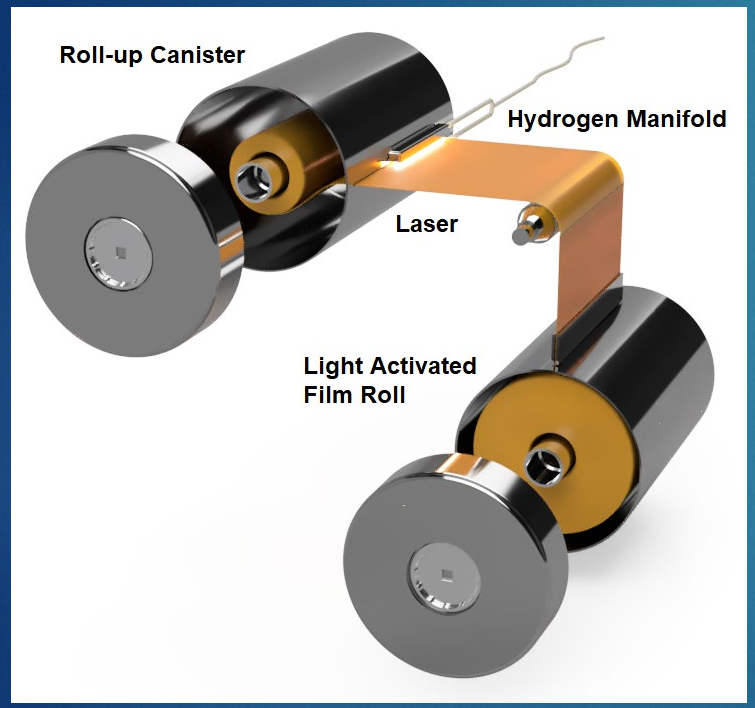
Light activated hydrogen storage film



- UL 94 V-0 non-flammable
- Tensile strength 35kg/cm
- Dielectric strength 8,000 volts
- Resistant to crepitation
- Heat resistant
- Rechargeable without pressure
- H_2 absorption in minutes
- Rechargeable over a hundred cycles
- Recyclable
- No rare-earth elements
- Non-toxic
- Resistant to contamination

Function

Thin film rolls between canisters while a light shines on it (like a movie reel in a projector) to release hydrogen.



Patents confirmed by National Laboratories

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Photons provide plasmonic ‘on-demand’ hydrogen release
- 2019 NREL

Sandia National Laboratories

Lawrence Livermore National Laboratory

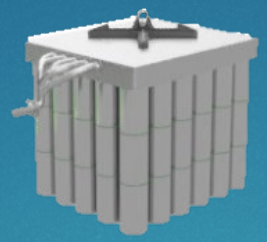
50-fold increase in hydrogen storage with nanosheets
- 2023 Lawrence Livermore and Sandia National Laboratories

Storage and Release

17Kg H_2 Canister

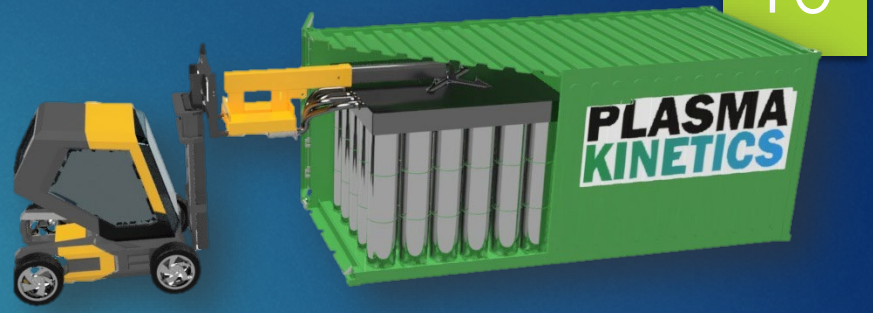
Volume
- 0.04 m^3/kg H_2
- 0.00124 m^3/kWh
- 806 kWh/m^3

Weight
- 400 kg system wt.
- 33.4 kg/kg H_2
- 1.0 kg/kWh



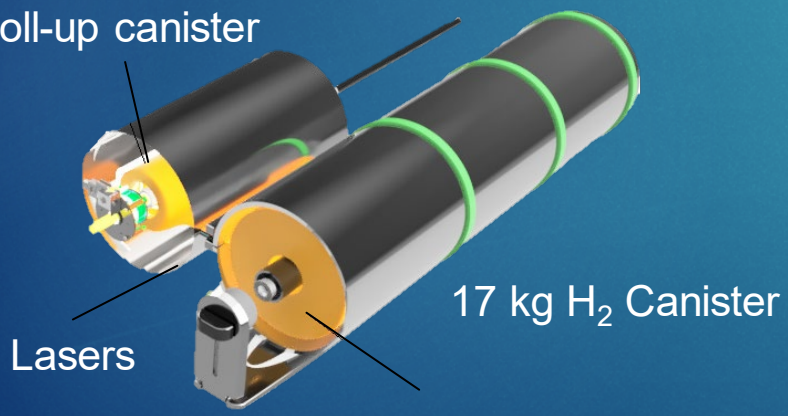
H_2 Charging Hood

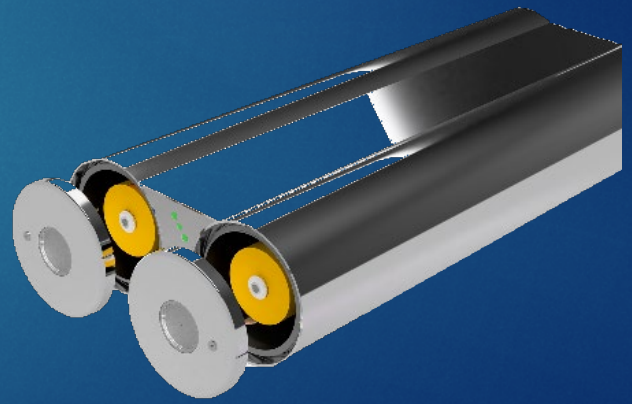
- No pressure
- Multiple canisters
- No fire risk



H_2 Charged in 20ft Container

- 70 canisters (1000 Kg) charged
- Charging time 30 - 60 minutes





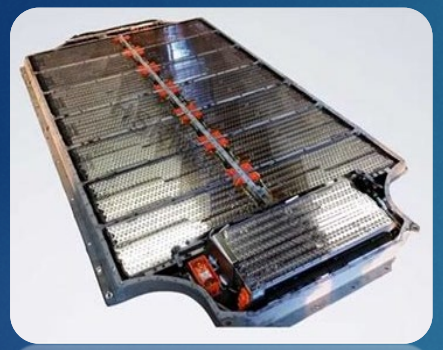
Benefits and Value

- No pressure
- Non-flammable
- Long shelf-life
- Quick recharging
- Multiple fuel sources
- Minimal Infrastructure

- Safe
- Economical
- Transportable
- Quiet
- Zero Carbon
- Distributable

Technology Comparison

Thin Film Energy Density ≈ 5,000 psi compressed H_2 without pressure



Energy Density
Gravimetric:
Volumetric:

Li-ion Battery
130 Wh/kg
474 Wh/l

Light Activated
Solid-State Hydrogen
1000 Wh/kg
806 Wh/l

≈ 5,000 psi
Compressed Hydrogen

10,000 psi
Compressed Hydrogen
1872 Wh/kg
1300 Wh/l

Synthetic Fuel
Methanol
5520 Wh/kg
4380 Wh/l

160 psi or -27°F
Ammonia
5160 Wh/kg
4270 Wh/l

Truck Comparison

Light Activated Thin Film hydrogen truck

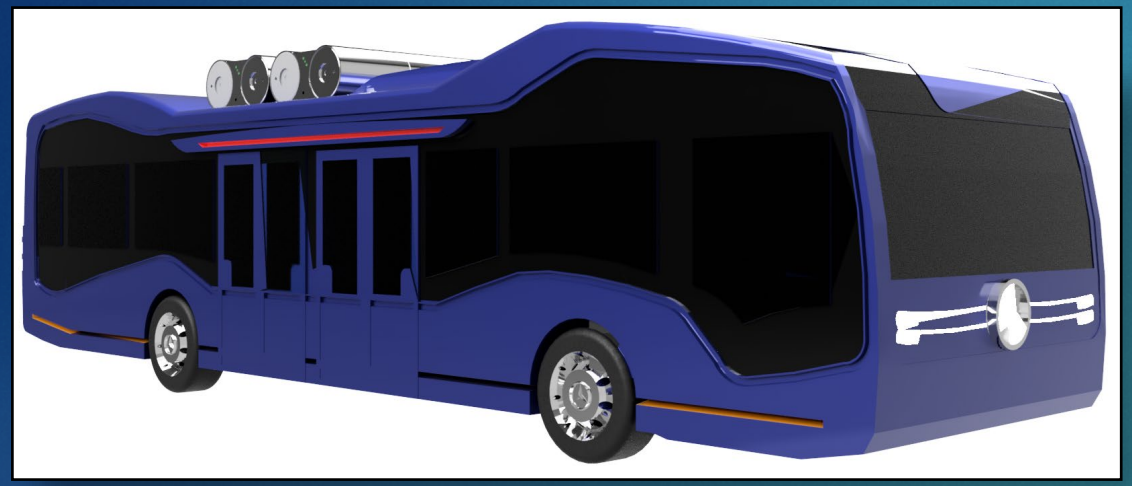
- Vehicle cost $880,000
- Not Compressed
- Fuel cost $0.24/kWh (save $20,000/year)
- CO_2 24k kg/year (save 40,000 kg/year)
- Refueling Infrastructure $2M/station (save $3M/station)
- Non-flammable
- Same canisters for regional/local delivery
- Same canisters for use in trucks

Compressed gas hydrogen truck

- Vehicle cost $880,000
- Compressed to 5,000 psi
- Fuel cost $0.45/kWh
- CO_2 68k kg/year
- Refueling infrastructure $5M/station
- Flammable
- Pipeline or custom truck for local delivery
- Carbon fiber tanks required for use in trucks

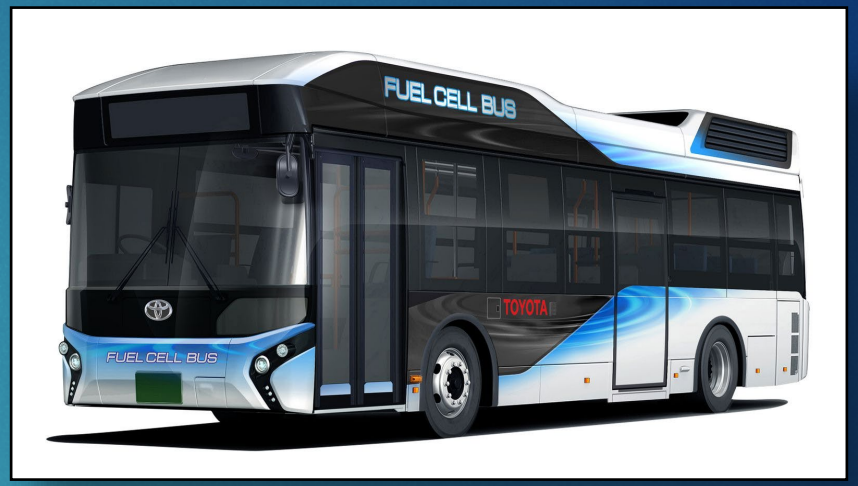
Bus Comparison

Light Activated Thin Film hydrogen bus



- Vehicle cost $990,000
- Not Compressed
- Fuel cost $0.24/kWh (save $20,000/year)
- CO_2 24k kg/year (save 40,000 kg/year)
- Refueling Infrastructure $2M/station (save $3M/station)
- Non-flammable
- Same canisters for regional/local delivery
- Same canisters for use in buses and trucks

Compressed gas hydrogen bus



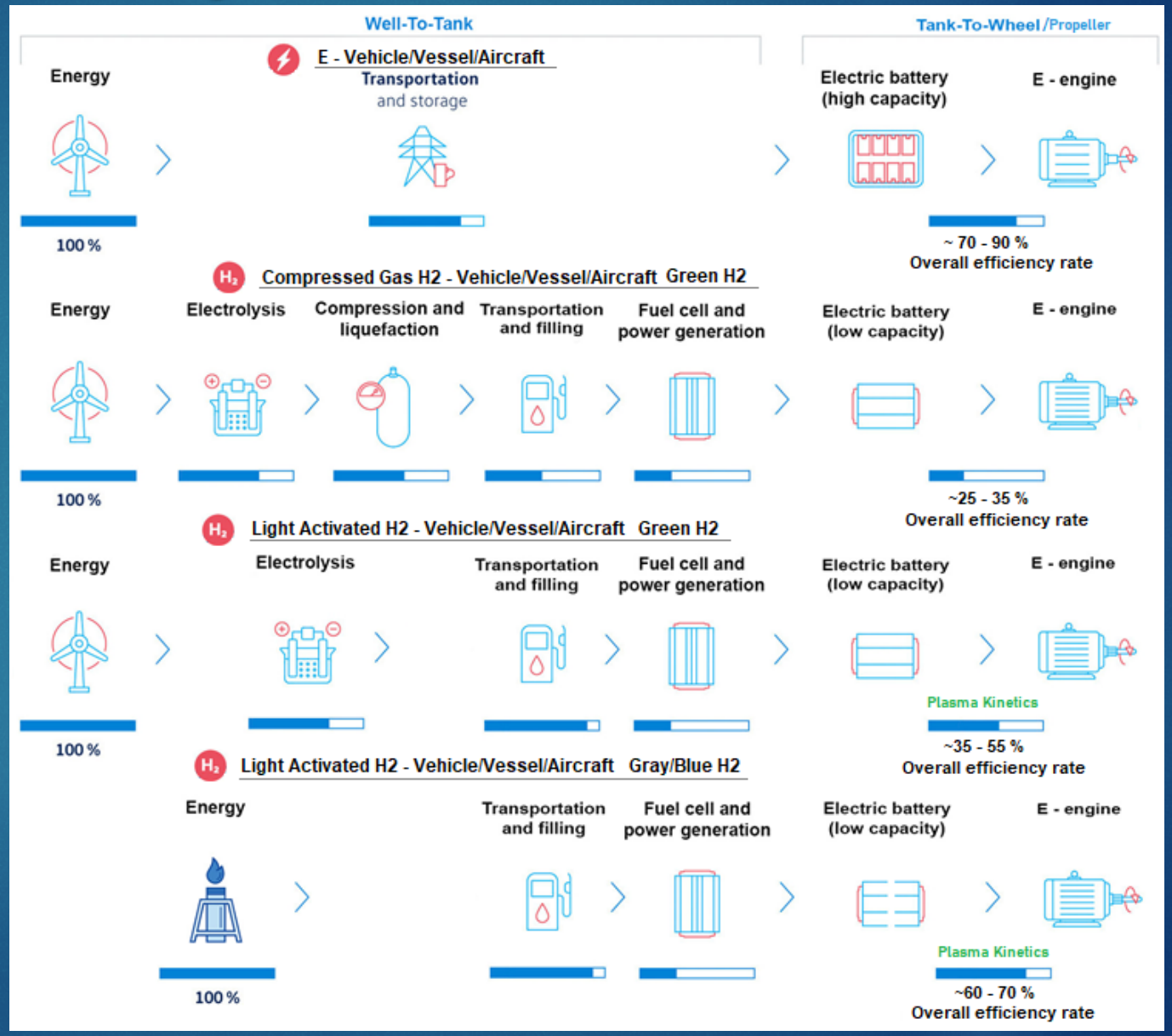
- Vehicle cost $990,000
- Compressed to 5,000 psi
- Fuel cost $0.45/kWh
- CO_2 68k kg/year
- Refueling infrastructure $5M/station
- Flammable
- Pipeline or custom truck for local delivery
- Carbon fiber tanks required for use in buses

Bus Comparison

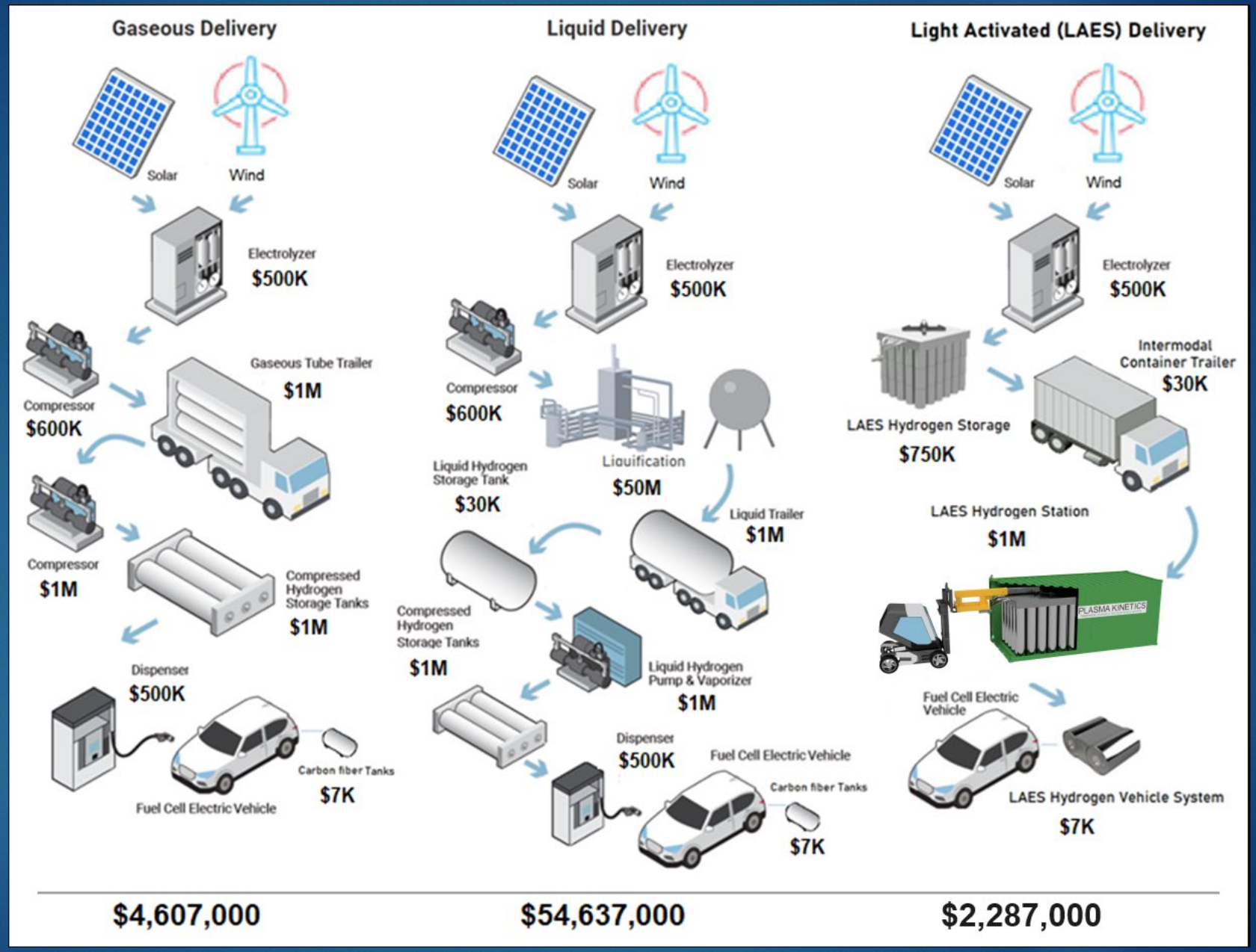
Metric	Diesel City Bus	Electric City Bus	Fuel Cell City Bus	PK Fuel Cell City Bus
Vehicle Cost	$550,000	$850,000	$1,200,000	$1,000,000
Station Cost	$2,500,000	$20,000,000	$5,000,000	$2,000,000
Weight	12,000 kg	16,330 kg	7,900 kg	8,500 kg
kWh/km	6.2 kWh/km	1.4 kWh/km	2.5 kWh/km	2.7 kWh/km
Range	480 km	270 km	425 km	420 km
Power/Weight	17.5 kW/t	19 kW/t	39 kW/t	36.5 kW/t
Fuel	Diesel	Electricity	Hydrogen 350bar gas	Hydrogen solid
Capacity	150 liters (1,500 kWh)	380 kWh	32 kg (1,065 kWh)	34 kg (1,132 kWh)
Consumption	30 l/100km	140 kWh/100km	7.6 kg/100km	8.1 kg/100km
Fuel Cost	$1.2/l ($0.12/kWh)	$0.19/kWh	$15/kg ($0.45/kWh)	$8/kg ($0.24/kWh)
Motor	210 kW	310 kW	310 kW	310 kW
Battery	None	380 kWh	69 kWh	69 kWh
Cost per 100km	$36	$27	$114	$65
CO_2/100km	80 kg	32 kg	70 kg	16 kg
CO_2 from	Diesel ICE	Mixed Electric	Mixed Hydrogen	Green Hydrogen

Energy Efficiency

Plasma Kinetics Light Activated H_2 storage approximates battery efficiency



Cost


Gaseous Delivery
Solar
Wind
Electrolyzer
$500K
Compressor
$600K
Gaseous Tube Trailer
$1M
Compressor
$1M
Compressed Hydrogen Storage Tanks
$1M
Dispenser
$500K
Carbon fiber Tanks
$7K
Fuel Cell Electric Vehicle
$4,607,000
Liquid Delivery
Solar
Wind
Electrolyzer
$500K
Compressor
$600K
Liquification
$50M
Liquid Hydrogen Storage Tank
$30K
Liquid Trailer
$1M
Compressed Hydrogen Storage Tanks
$1M
Liquid Hydrogen Pump & Vaporizer
$1M
Dispenser
$500K
Fuel Cell Electric Vehicle
Carbon fiber Tanks
$7K
$54,637,000
Light Activated (LAES) Delivery
Solar
Wind
Electrolyzer
$500K
LAES Hydrogen Storage
$750K
Intermodal Container Trailer
$30K
LAES Hydrogen Station
$1M
PLASMA KINETICS
Fuel Cell Electric Vehicle
LAES Hydrogen Vehicle System
$7K
$2,287,000

Wind/Solar Overproduction

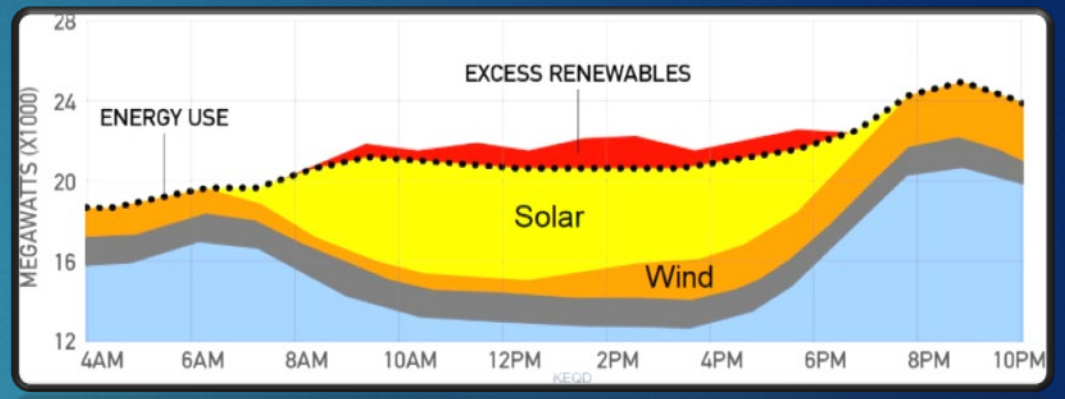
Producers need a way to provide energy 24/7.

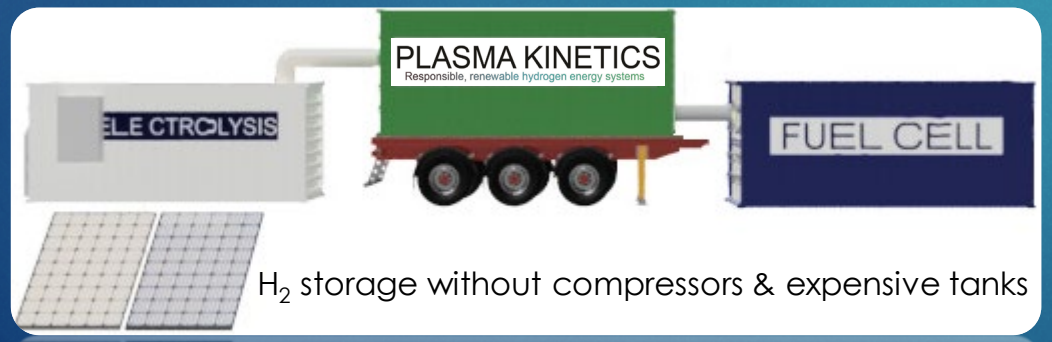
502 federally funded and 416 Utility-Scale Solar Projects in the U.S.

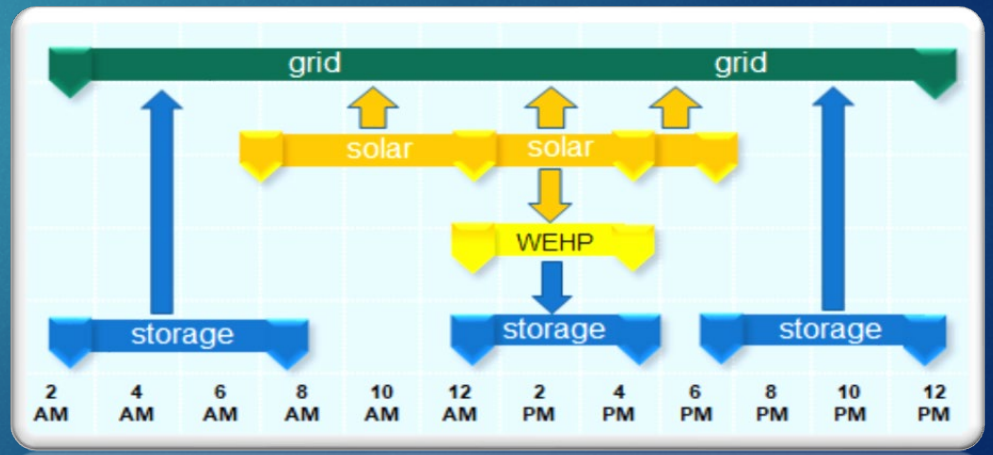
404 GWh of Solar/Wind Energy produced in 2020 with a 20% oversupply during daylight hours.

- US Energy Information Administration (EIA)

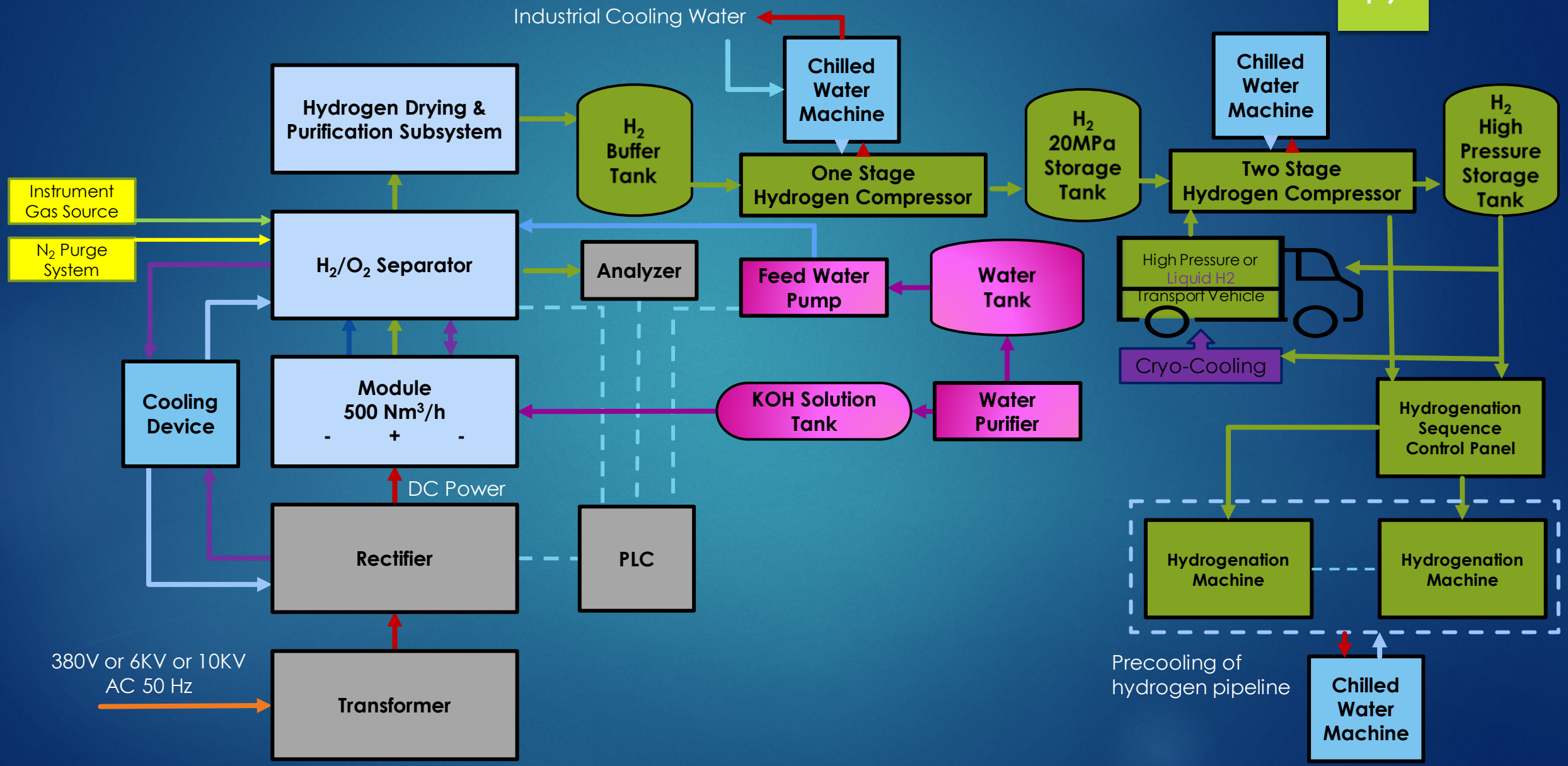
PacifiCorp reports $2 Billion annually would be saved with over generation management.



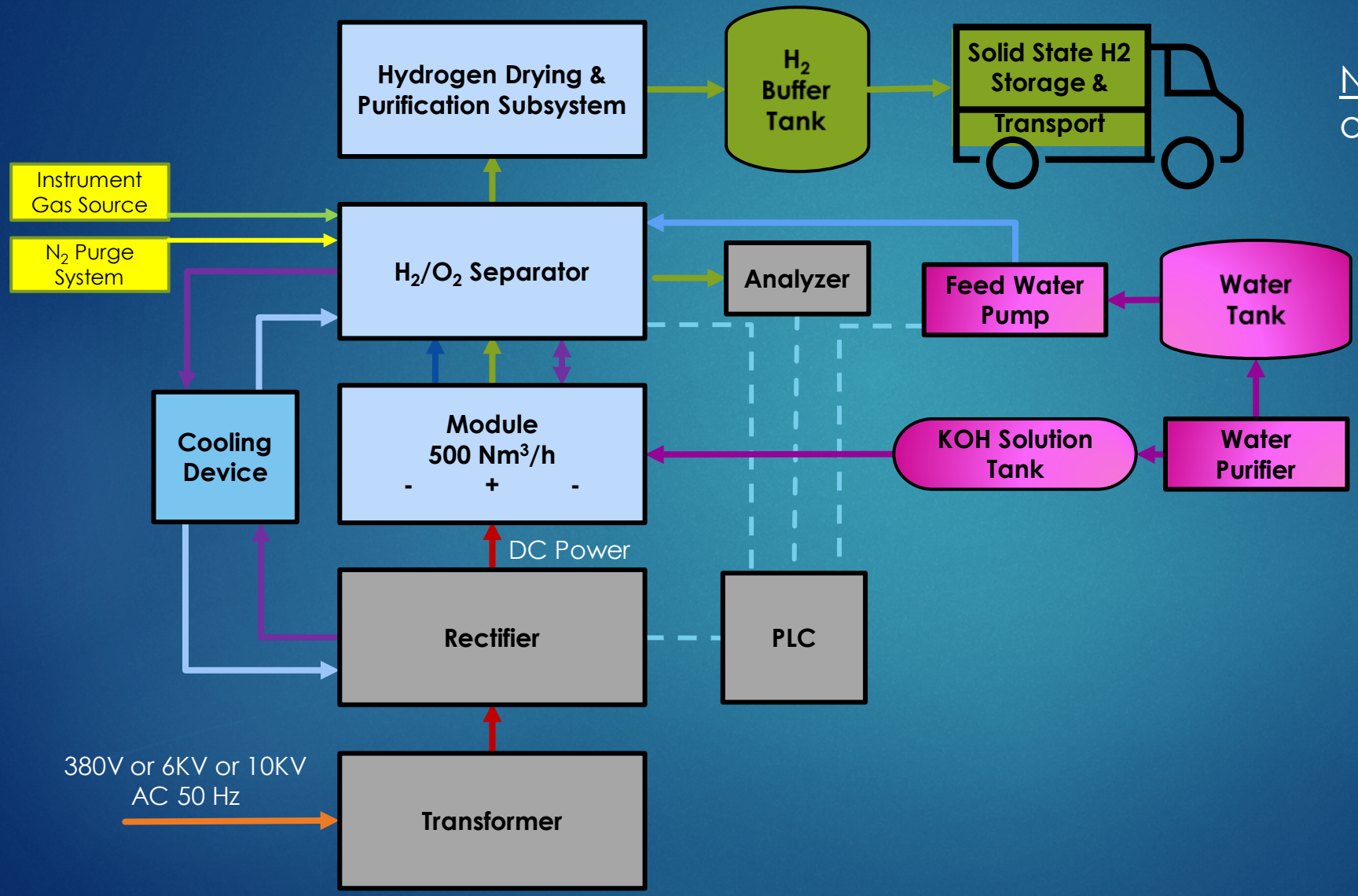




Compressed storage from electrolysis

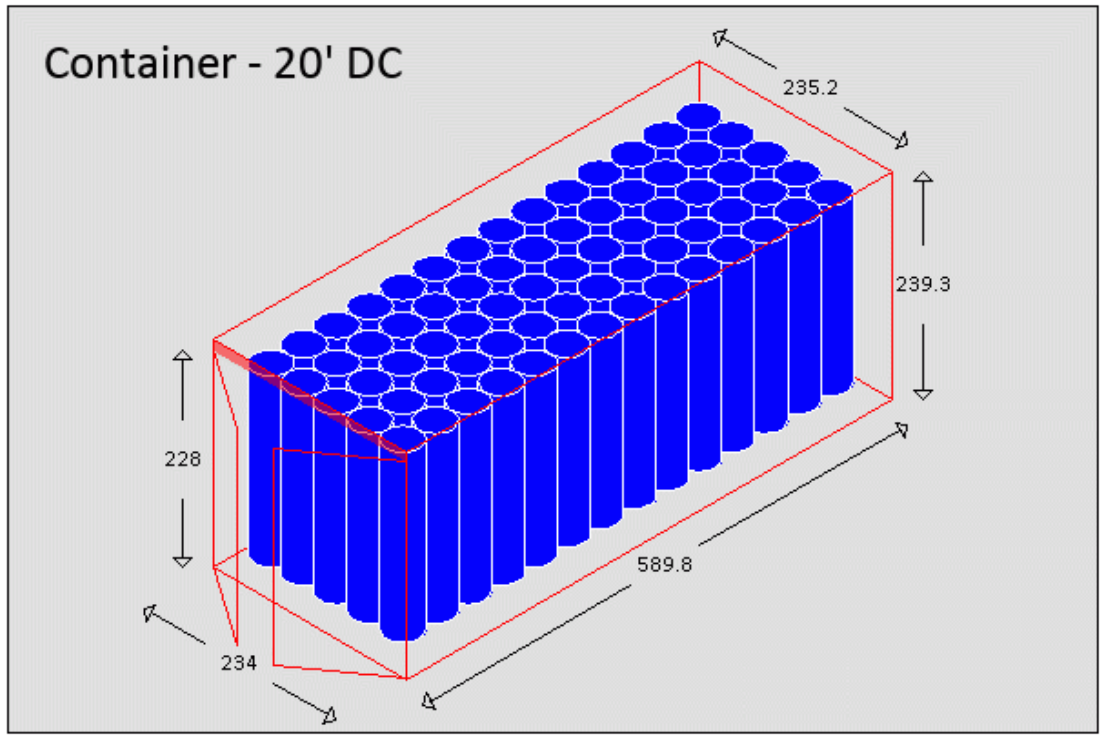


Thin Film Storage from electrolysis



No compression, cooling or high-pressure storage.

Canisters/Container



Equipment : Container - 20' DC

Cargo name	Pieces loading	Pieces total
H2 Canisters	70	70

	Used	Free	Maximum
Weight (payload) in KG	28000	200	28200
Cubic Meter	22.4	10.796	33.196
Floor lenght centimeter	560	29.8	589.8
Floor sqaure meter	11.2	2.672	13.872
Pieces	70		

1000 kg H_2

(1215 kg stored, minimum 850 kg usable)

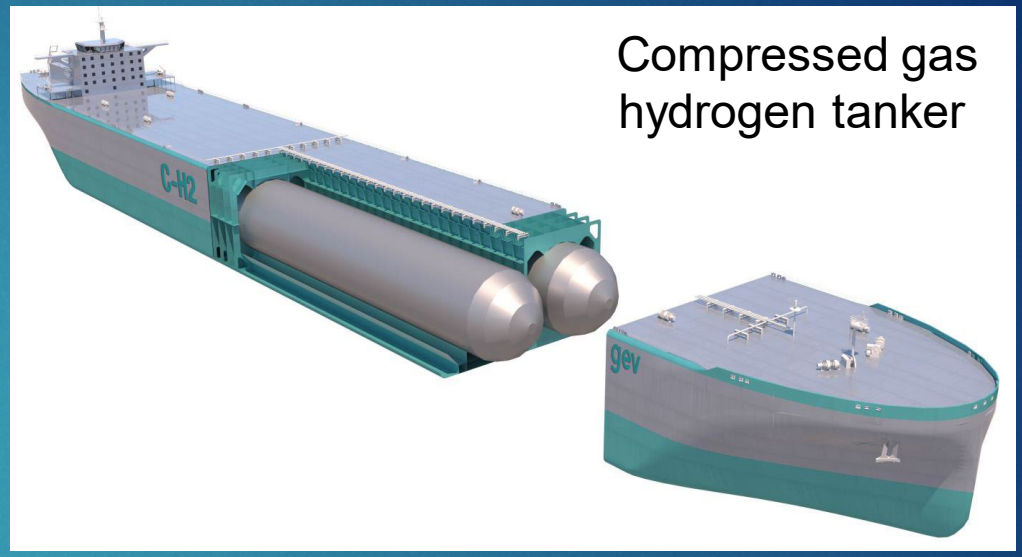
(7005 containers per ship)

Full loading list

Group	Equipment name	Name	PCS	Weight total	Lenght	Width	Height
1	Container - 20' DC	H2 Canisters	70	28000	40	40	200

Industrial Shipping

- **10,000** Tons of Hydrogen
- Not Compressed
- Partial deliveries possible at multiple ports
- Existing infrastructure to load/unload
- No port storage tanks required
- Non-flammable
- Same container for regional/local delivery
- 3,5k Kg CO_2 per ton of H_2 (50% SMR without compression)
- Investment according H_2 production



- **2,000** Tons of Hydrogen
- Compressed* to 250 Bar
- No partial shipments
- Single destination
- Custom Infrastructure Compress/decompress to load/unload
- Port storage tanks required
- Flammable
- Pipeline or custom truck for local delivery
- 6,1k Kg CO_2 per ton of H_2 (50% smr & compression)
- 250M € Investment

Industrial Shipping

- **10,000** Tons of Hydrogen
- Not Compressed
- Partial deliveries possible at multiple ports
- Existing infrastructure to load/unload
- No port storage tanks required
- Non-flammable
- Same container for regional/local delivery
- 3,5k Kg CO_2 per ton of H_2 (50% SMR without compression)
- Investment according H_2 production

- **90** Tons of Hydrogen in 1250 Cm of volume
- Liquefied* to -253° C/1bar
- No partial shipments
- Single destination
- Custom Infrastructure cooling/heating to load/unload
- Port Liquified Hydrogen Receiving Terminal
- Flammable
- Pipeline or custom truck for local delivery
- 6,1k Kg CO_2 per ton of H_2(50% smr & compression)
- Costly Investment for infrastructures

Industrial Shipping

- **10,000** Tons of Hydrogen
- Not Compressed
- Partial deliveries possible at multiple ports
- Existing infrastructure to load/unload
- No port storage tanks required
- Non-flammable
- Same container for regional/local delivery
- 3,5k Kg CO_2 per ton of H_2 (50% SMR without compression)
- Investment according H_2 production

- **580** Tons of Hydrogen in 3500 Tons. of Methanol
- Not Compressed
- Yes partial shipments
- Partial deliveries at multiple ports
- Existing infrastructure to load/unload
- Port storage tanks required
- Highly Flammable - Toxic
- Pipeline or custom truck for local delivery
- 6,0k Kg CO_2 per ton of H_2 (50% smr)
- Costly Investment for infrastructures

Industrial Shipping

- **10,000** Tons of Hydrogen
- Not Compressed
- Partial deliveries possible at multiple ports
- Existing infrastructure to load/unload
- No port storage tanks required
- Non-flammable
- Same container for regional/local delivery
- 3,5k Kg CO_2 per ton of H_2 (50% SMR without compression)
- Investment according H_2 production

- **9,360** Tons of Hydrogen for 60.000 Tons of Ammonia
- Compressed to 11 bar or cooling -33 °C
- Single destination with no partial shipments
- Custom Infrastructure Compress/decompress to load/unload
- Port storage tanks required
- Flammable -Toxic
- Pipeline or custom truck for local delivery
- 5,1k Kg CO_2 per ton of H_2 (50% smr & compression)
- Costly Investment for infrastructures
- Thermal catalytic decomposition or electro-oxidation required.

Hydrogen Storage Comparison

Light Activated has the lowest “up-front” energy requirement.

Light Activated is always at room temperature and pressure.

Storage/Feature	Plasma Kinetics	Compressed	Liquid	Metal Hydride
Temperature K_d	25°C +	25°C +	−252.87°C	175+°C
Pressure K_d	1 bar +	350-700 bar	1 bar +	20 bar
Energy K_d	0.05 kWh/kg +	1.8-6.5 kWh/kg	11.5 kWh/kg	10.4 kWh/kg
Temp/Press stored	25°C/1 bar +	25°C/350-700 bar	−252.87°C/1bar	25°C/1 bar +
Temperature α	25°C +	25°C +	−252.87°C	287+°C
Energy α	8.6 kWh/kg	0 kWh/kg +	0 kWh/kg +	24.4 kWh/kg
Energy Total	8.7 kWh/kg	1.8-6.5 kWh/kg +	11.5 kWh/kg	34.8 kWh/kg
Storage Rate	1 kg/min +	1 kg/min +	1 kg/min +	0.1 kg/min
Flammability	Non-Flammable +	Flammable	Flammable	Flammable
Explosive in air	Non-Explosive +	Explosive	Explosive	Non-Explosive +
Stored Molecule	MgHX Hybrid +	H_2 Covalent	H_2 Covalent	MgH_2 Covalent

Capacity and Convenience

Quick canister exchange & delivery of 1kg to 15kg of H_2 per hour

Class 8 truck (N3/04) canisters
50kg H_2 500 mile range
1.1-ton system weight
5 minute refuel

Capacity and Convenience

Quick canister exchange & delivery of 1kg to 15kg of H_2 per hour

Passenger vehicle canister
3.5kg H_2 280 mile range
200 lbs. system weight
3 minute refuel

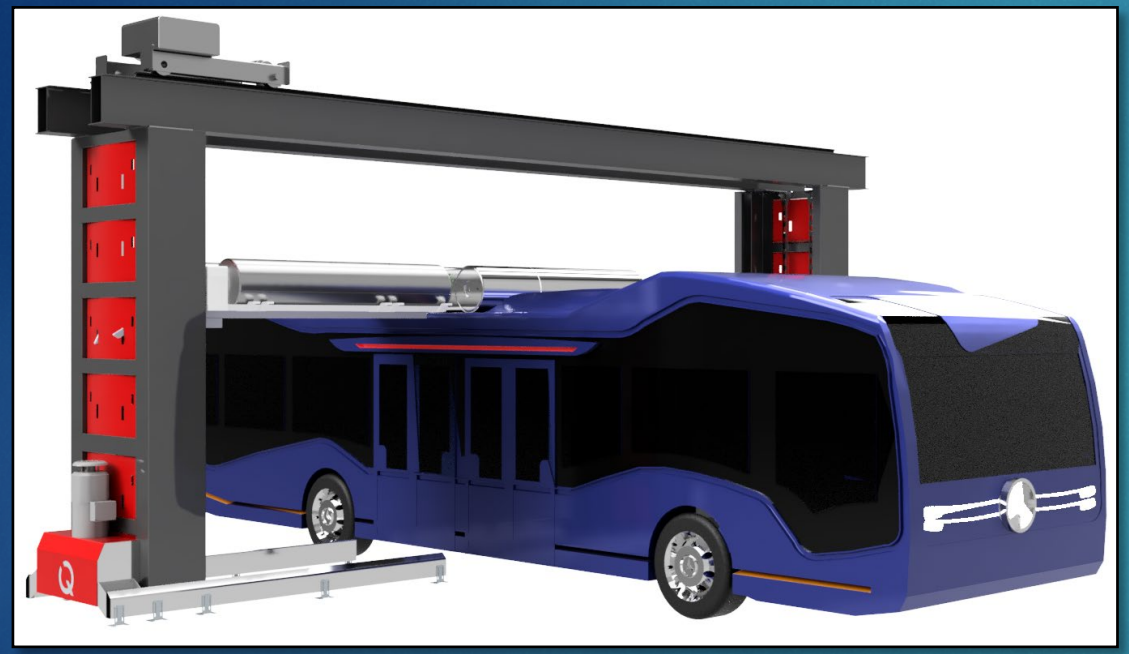
Capacity and Convenience

Quick canister exchange & delivery of 15kg to 45kg of H_2 per hour

Large mining truck
150kg H_2 replaces 275 gal of diesel fuel
20 minute refuel

Capacity and Convenience

Gantry canister exchange 5 minute refuel



City bus (12 Meters)
34kg H_2 260 mile range
5 minute refuel

Class 8 trucks
50kg H_2 500 mile range
5 minute refuel

Thank you!

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