Plasma Kinetics

RESPONSIBLE, RENEWABLE, ENERGY SYSTEMS

Energy Transport

Problem

- Clean energy providers need safe and cost-effective methods to store and distribute energy in a 24-billion-dollar hydrogen market.
- Current energy storage/distribution methods are complex or costly:
  - Battery Storage
    - Expensive
    - Not recycled & creates toxic waste
    - Heavy and potentially flammable
  - Traditional Hydrogen Storage
    - Compressed and stored at pressures between 3,000 and10,000 psi or −423 °F (200 – 700 bar or -252 °C)
    - Potentially flammable or explosive

Solution

- Containers of nano-photonic *light-activated solid-state* hydrogen thin film with no compression, no flammability and easy transport.

- Hydrogen stored in *light activated* (LAH) 17 kg H_2 *solid-state* canisters.
  - No pressure or cooling needed
  - No risk of fire or explosion
  - No transportation restrictions
  - Lower cost than batteries
  - Lower cost to ship hydrogen
  - 1000 kg of H_2 per 20 ft container bulk load

Light Activated Solid-state
1000 kg H_2
20 ft Container
with 70 x 17 H_2 kg
Canisters bulk loaded

Light Activated Solid-state
1220 kg H_2
40 ft Container
with 72 x 17 kg H_2
Canisters on pallets

Results

- Capability to move 20.000 tons of hydrogen on a single container ship without modification or hazard.
- Containerized shipments allow immediate distribution onto inland waterway, truck or rail transportation at destination port.
- No need for compression, decompression, specialized ships, or certifications.
- Hydrogen shipments of any size, at any time, reduces logistics and increases revenue by providing distributed global customers just-in-time deliveries.

20.000 tons of hydrogen
(330 GWh of available energy)
Enough energy to power 25.000 homes for 1 full year
Enough energy to allow large trucks to go 300.000.000 km

Market Opportunity

- Global H_2 market is expected to reach USD 24.5B by 2027. - Allied Market Research
- Global H_2 Storage market will reach USD 992M in 2026. – Prescient and Strategic Intelligence
- Solid H_2 storage is projected to be the most lucrative segment by 2027. - Allied Market Research
- Canisters of light-activated solid-state hydrogen ease shipment and can be directly implemented in applications like trucks, ships, rail, VTOL aircraft and grid stabilization.
- PacifiCorp reports USD 2B annually would be saved with clean energy over-generation management. - PacifiCorp
- Germany is creating 10 GW of electrolysis capacity for green H_2 by 2040. - CSIS
- European Truck manufactures agree to drop diesel by 2040. - ACEA
- U.S. ports restricting diesel use for berthed vessels to less than 20% of time in port and added emission control regulations. – U.S. EIA
- European ports require 55% reduction in emissions by 2023. – ESPO
- Maersk shipping will go carbon free by 2050. - Maersk
- There are 20.5 million intermodal containers world-wide.

Market Opportunity

- The global hydrogen generation market is USD 120.77B. An exponential increase in the demand for green fuel and government regulations to control pollution is driving the market. – Grand View Research

- 95% of the 70 million metric tons of H_2 produced annually is gray hydrogen and over 70% of gray hydrogen is produced from natural gas which yields 10 kg of CO_2 per kg of H_2. Blue H_2 yields 2 to 5 kg of CO_2 per kg H_2. Green hydrogen from solar and wind can be carbon free and needs cost effective storage. - Center for Strategic and International Studies.

- Light Activated Solid State hydrogen requires no energy to store the hydrogen, is less than 50% the cost of batteries, and approximates the cost of compressed or liquid storage without the energy cost of compression or cooling, or risk of fire.

Business Model

- Build real-world green hydrogen storage and transport application prototypes.
- Build pre-ordered green hydrogen storage and transport products.
- Current Interest from
    - U.S. and International Solar/Wind Farms, syngas and bio-gasification facilities.
  - Wind/Solar over-production storage system value $100/kWh or USD 8B world-wide
  - Wind/Solar storage system cost $68/kWh or USD 5.44B world-wide
  - Wind/Solar over-production storage EPITDA Value $32/kWh or USD 2.56B world-wide
- Build relationships with green hydrogen producers to store and ship hydrogen via container-based canisters.
- Build collection and distribution models based on shortlisted green hydrogen producers and shortlisted countries.
- Build relationships with OEM truck manufactures and ship builders to implement distributed hydrogen directly from canisters without the need for compressed or liquid refueling stations.
- License technology for wide base of applications: wind and solar, automotive, aerospace, marine, microgrids, oil refining, forklifts, airport tugs, in-home energy backup, data centers.
  - Current interest from
    - U.S. Military (all branches), NASA, Boeing, Happy Landings, Ehang, Transcend Aero
    - Amazon, Uber
    - Hyzone Motors, Nikola Motors, Great Wall of China Motors, Hyundai Motors, Navistar and Volvo Group.

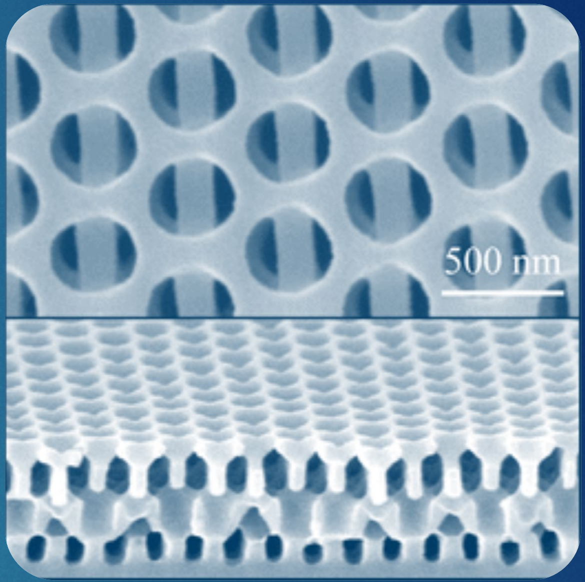
Team

- **Development Team**
  - Paul Smith, Ph.D. — Material/Optics
  - Stacey Smith, B.S. — Process/Facility/Supply
  - Don Gervasio, Ph.D. — Fuel Cell/Electrochemistry
  - David Grant, Ph.D. — Materials/Deposition
  - Nick Botterill, Ph.D. — Materials/Deposition
  - Bernard Coll, Ph.D. — Materials/Deposition
  - Tucker Hair, B.S. — Materials/Deposition
  - Ashwin B, M.S. — System Modeling
  - Peter Smith, B.S. — Electrical Engineering

- **Management Team**
  - Paul Smith — Technology Manager
  - Stacey Smith — Operations Manager
  - Don Gervasio — Strategy Manager
  - JR Song — Business Manager
  - Ashwin B — Advisory Board
  - Peter Smith — Advisory Board
  - John Widjowsky — Advisory Board
  - Brian Rives — Advisory Board

Technical – What is Nano-Photonic H_2 Thin Film?

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



- 7 constituents (no rare-earths)
- PVD layering of materials
- NGF (nano-graphite-film) substrate
- High Temperature Shape Memory Alloy
- Post deposition nano-lithography
- Low CO_2 fabrication process

Technical – How does it work?

Like a movie projector or CD player.
Light shines on the film or disc
to release hydrogen.

Plasma Kinetics CD prototype

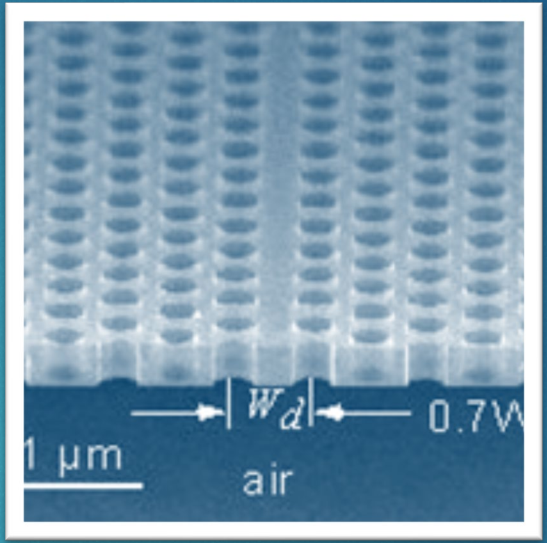
Cassette Film

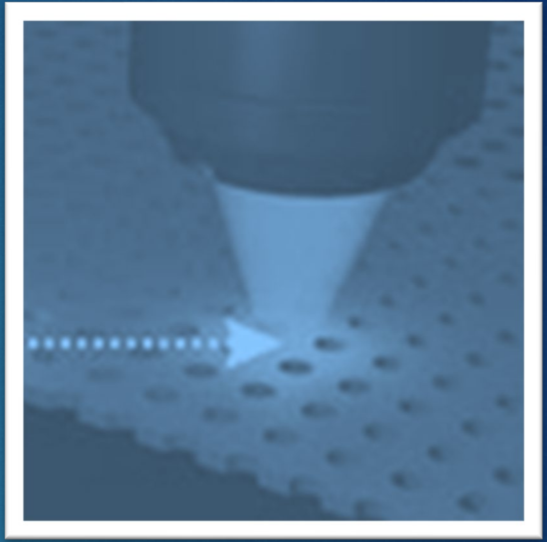
Canister Film

CD Film

Technical – What is the technical basis?

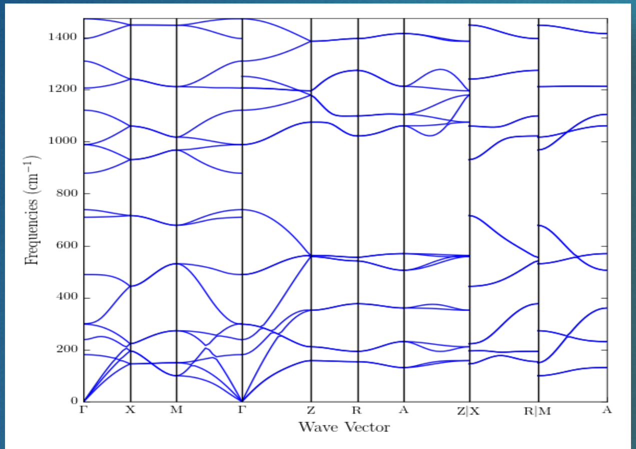
Billions of negative points attract hydrogen.
Light changes electric bond to release hydrogen.

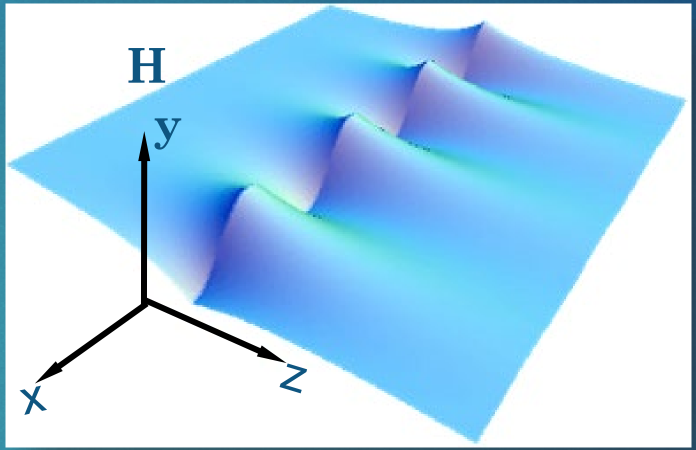




Technical – What is the technical uniqueness?

Photon Dispersion



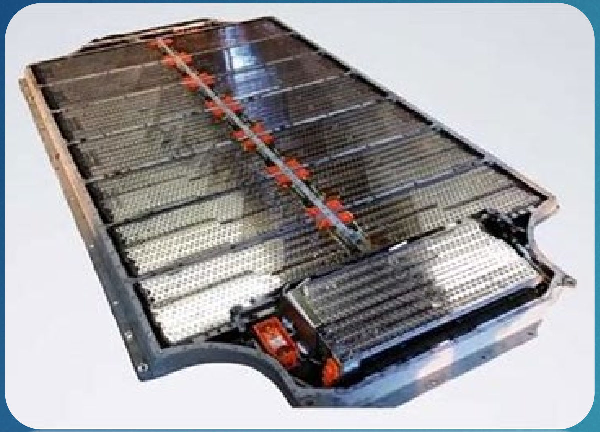


Angstroms thick shape memory alloy layers and metal hydride nanostructured layers provide a dielectric with black state forming constituents and a <u>lower bond energy</u>.

Photon absorption and polariton resonance support dissociative amplitude energies when exposed to photonic irradiation.

The result is <u>safe, efficient, high-density, photo-reactive, solid-state hydrogen energy storage.</u>

Technical – What is the energy storage density?



		Light Activated	700 Bar
Energy Density	Li-ion Battery	Solid-State Hydrogen	Compressed Hydrogen
Gravimetric:	130 Wh/kg	1000 Wh/kg	1872 Wh/kg
Volumetric:	474 Wh/l	806 Wh/l	1300 Wh/l

≈ 350 Bar
Compressed Hydrogen

HCV Fuel

Technical – A comparison in trucking

Light Activated hydrogen truck

- Vehicle cost 180.000 €
- Not Compressed
- Fuel cost 0,15 €/kWh (save 20.000 €/year)
- CO_2 24k kg/year (save 40.000 kg/year)
- No refueling Infrastructure* (save 2,2M €/station)
- Non-flammable
- Same canisters for regional/local delivery
- Same canisters for use in trucks

Compressed gas hydrogen truck

- Vehicle cost 160.000 €
- Compressed to 350 Bar
- Fuel cost 0,29 €/kWh
- CO_2 68k kg/year
- Refueling infrastructure 2,3M €/station
- Flammable
- Pipeline or custom truck for local delivery
- Carbon fiber tanks required for use in trucks

*container & forklift 200k €

Application Class 8 (HCV) trucks

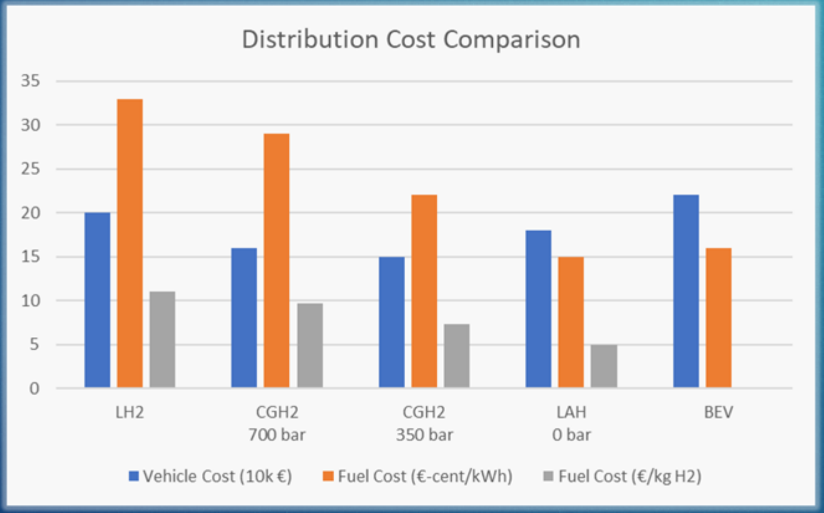
What are the advantages for HCVs?

Easy, safe and economical distribution

- Non-flammable swappable cassettes or canisters allow quick refill without fixed infrastructure fueling stations

Low-cost hydrogen

- 50+% lower fuel cost than compressed H_2



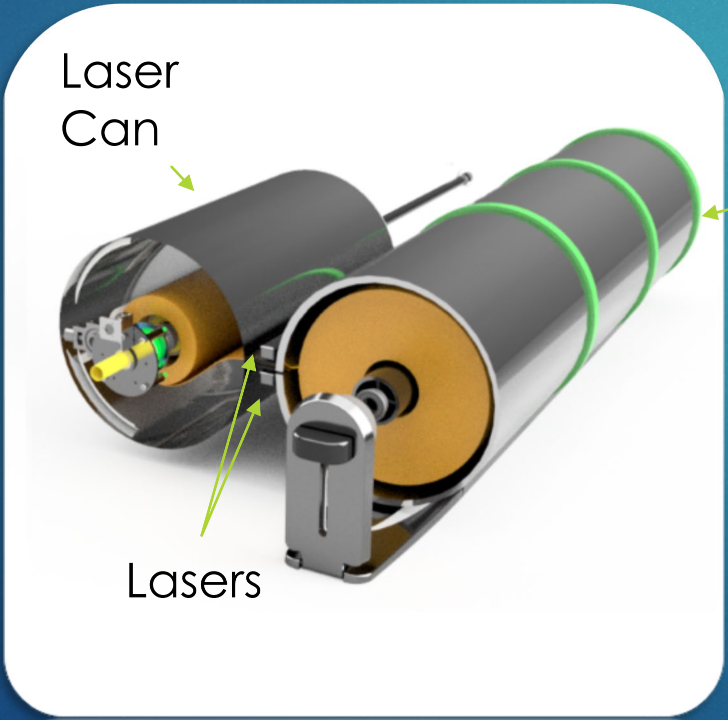
700 Bar
1 Bar

Application Class 8 (HCV) trucks

How is hydrogen thin film integrated in HCVs?

Canisters configured for up to 120 kg of H_2.
Laser cans remain in vehicle (shown removed for illustration).

- Volume
  - 0.04 m^3/kg H_2
  - 0.00124 m^3/kWh
  - 806 kWh/m^3
- Weight
  - 400 kg system weight
  - 33.4 kg/kg H_2
  - 1.0 kg/kWh



H$_2$ Canister

- 17 kg H_2 from each canister.
- 12 kg available for drive energy.
- 12 kg x 21 kWh = 252 kWh = 230 km range.
- 230 km range x 4 cylinders = 920 km range.
- Load variance managed by a battery.
- FC membrane heated by laser system coolant to increase efficiency.

Application Class 8 (HCV) trucks

How much will HCV operators save?

The OEM System monetary cost for thin film is similar to 700 bar compressed H_2 carbon fiber tanks.

Carbon cost saving is more than 40,000 kg of CO_2/year over compressed H_2

Based 100,000 km (5100 kg H_2 compression with 50% NG sourced and 50% solar electricity) yielding 68,000 kg CO2 vs uncompressed reformed gas SMR at 24,000 kg per year) [see notes]

Fuel cost is much lower with savings of 20000 €/year

Based on 100,000 km (5100 kg H_2)/yr at 9.3 € (compressed cost) vs 3.0 € (uncompressed).

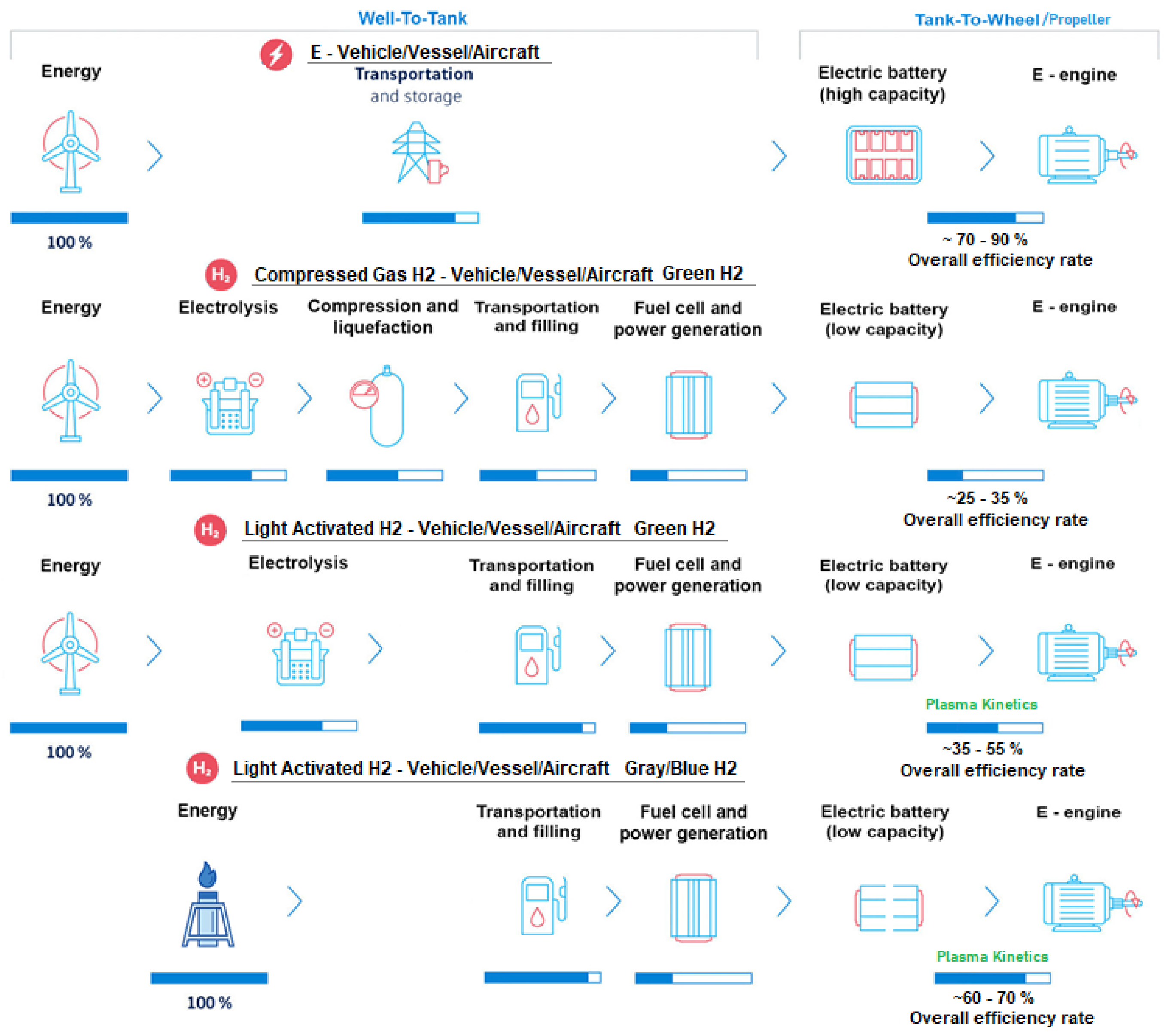
Advantages

- CLEAN ENERGY
- MINIMAL FOOTPRINT
- SAFE NON-FLAMMABLE
- ECONOMICAL
- TRANSPORTABLE
- QUIET
- HUNDREDS OF RECHARGES
- RECYCLABLE

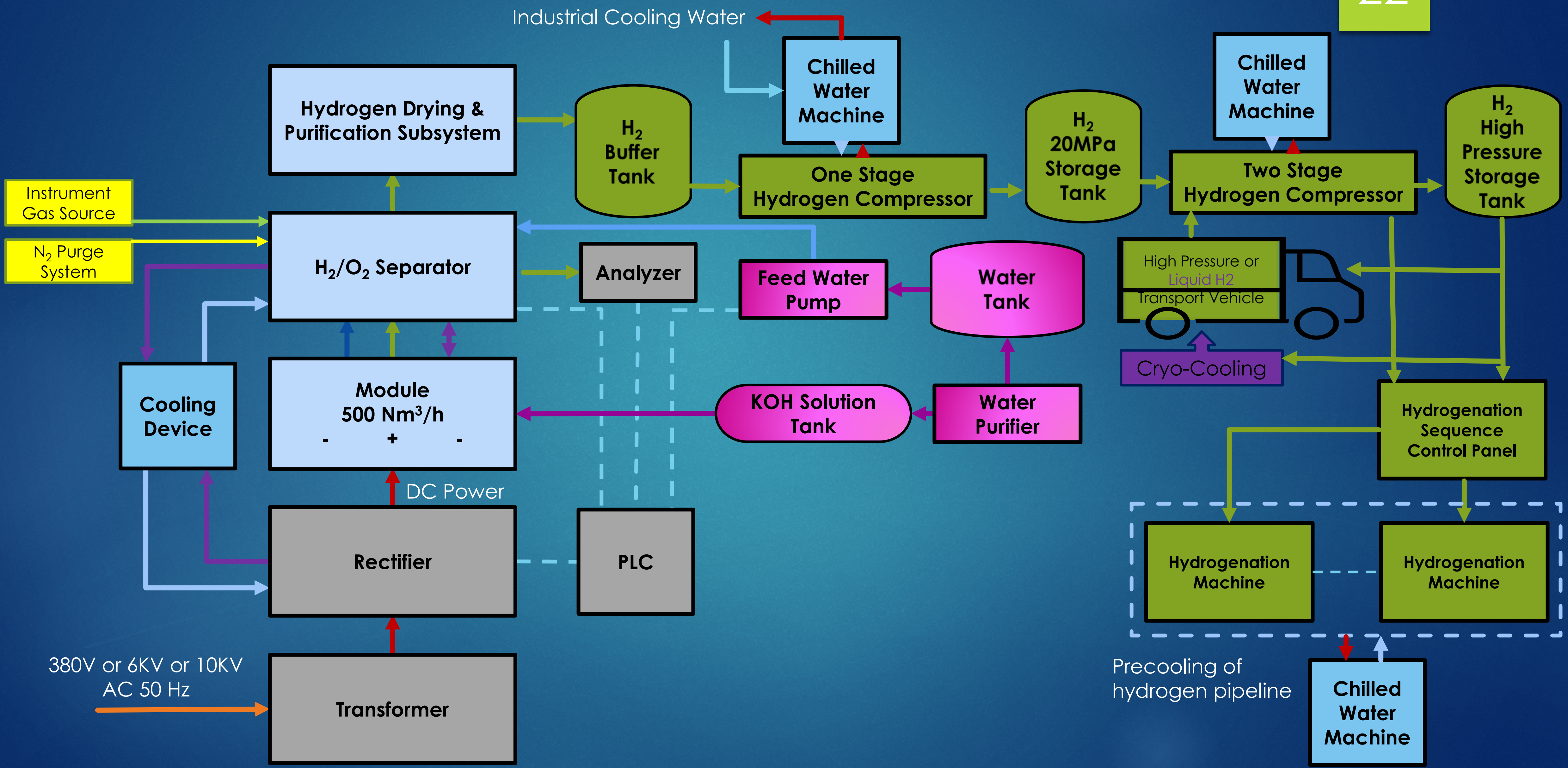
- LOW PRESSURE STORAGE
- HIGH PRESSURE RELEASE
- QUICK RECHARGING
- LONG SHELFLIFE
- MULTIPLE FUEL SOURCES
  - Waste-water treatment
  - Municipal incineration
  - Water electrolysis
  - Industrial H_2 production
- LOW COST REFUELING STATIONS
- LOW-COST FUEL
- EASE OF FUEL DISTRIBUTION

Technical – A comparison of Energy Efficiency

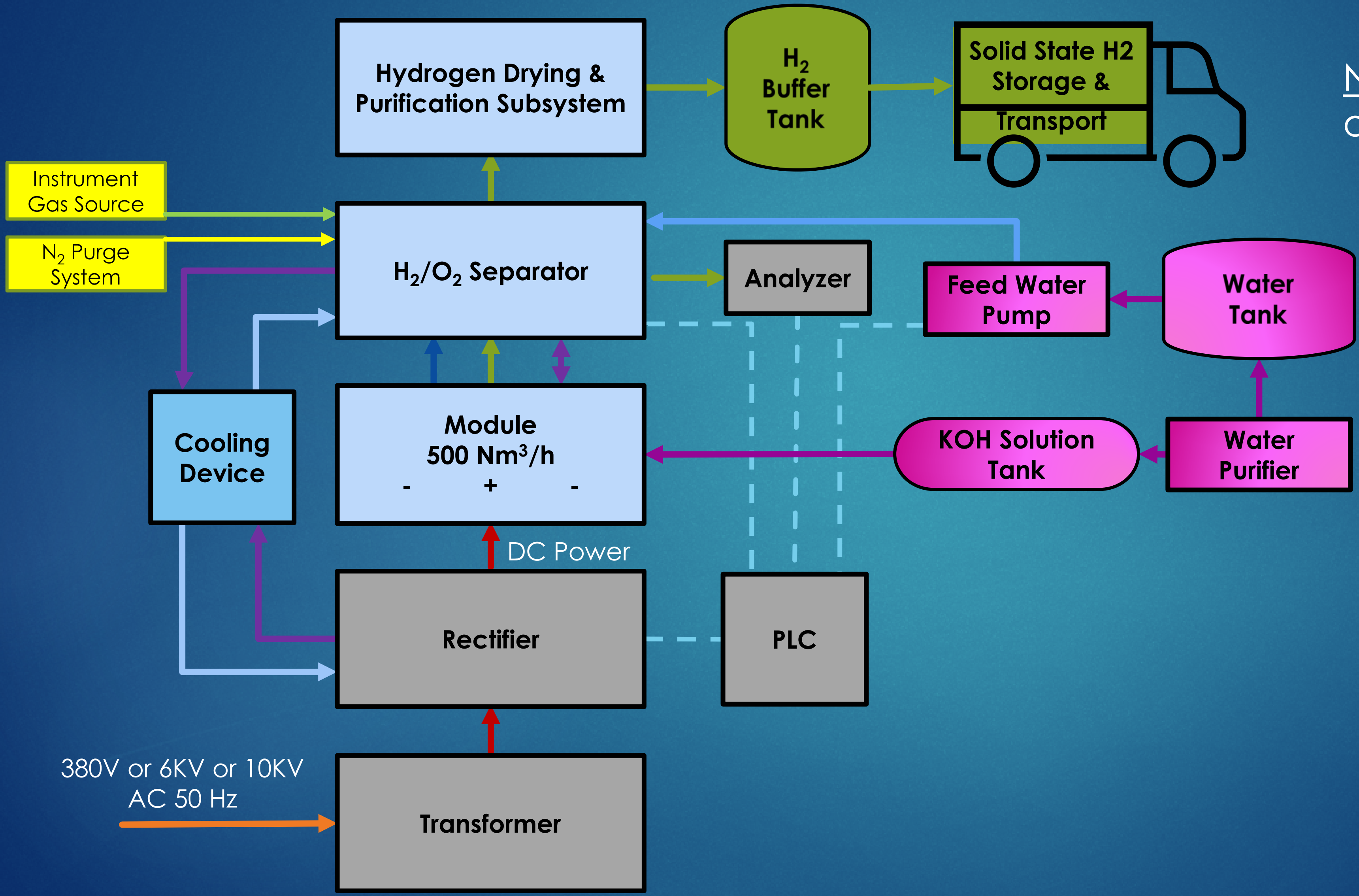
Plasma Kinetics
Light Activated H_2 storage approximates battery efficiency.



Technical – Conventional E-Hydrogen Generation

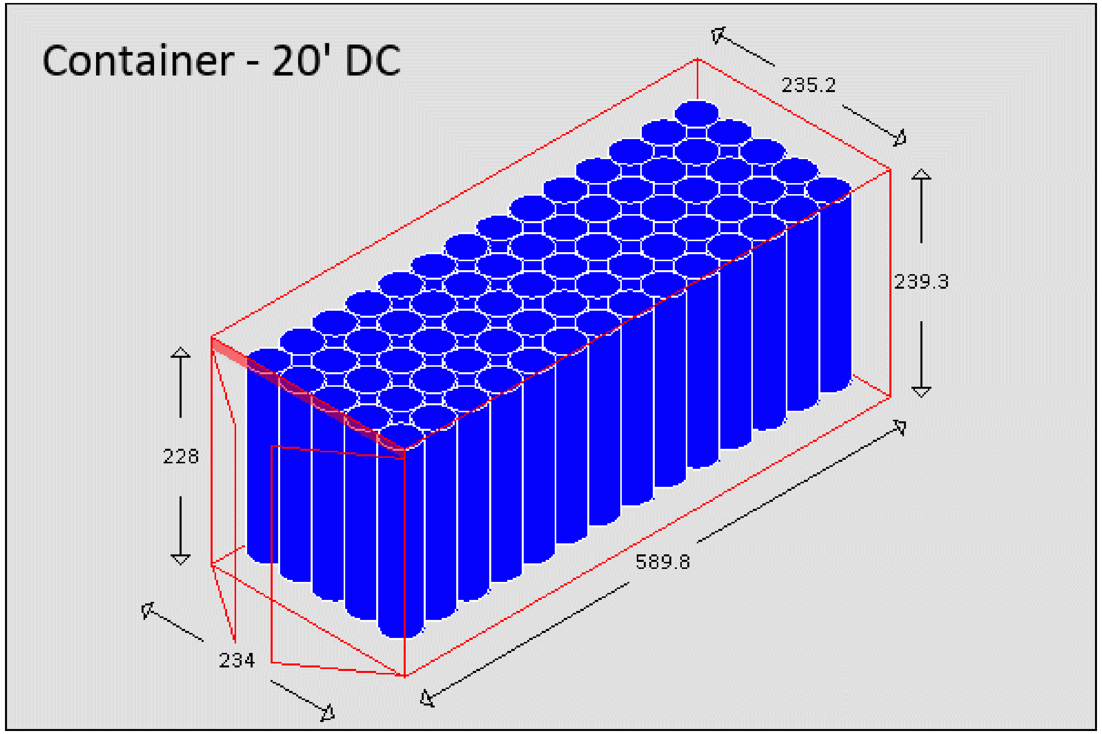


Technical – Solid-state E-Hydrogen Generation



<u>No</u> compression, cooling or high-pressure storage.

Technical - Solid-state Hydrogen 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)

Full loading list

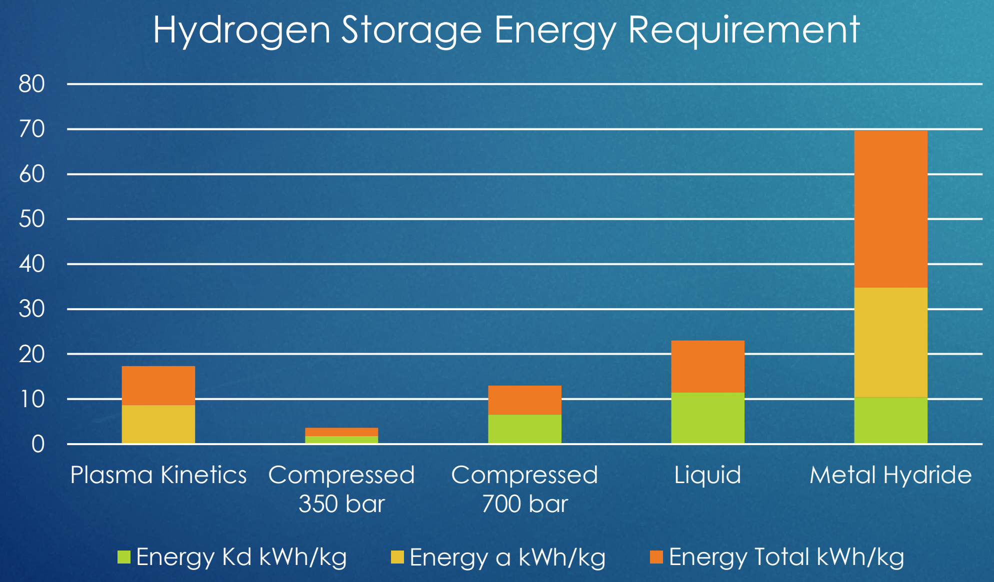
Group	Equipment name	Name	PCS	Weight total	Lenght	Width	Height
1	Container - 20' DC	H2 Canisters	70	28000	40	40	200

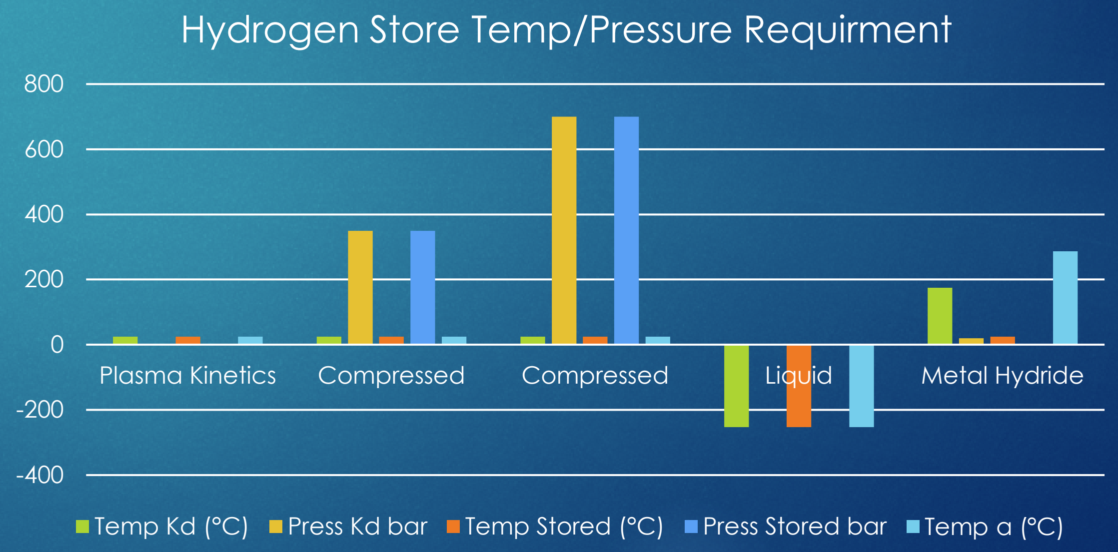
Technical - Solid-state Hydrogen Storage Comparison

Plasma Kinetics has lower energy requirement than Liquid hydrogen and the lowest "up-front" energy requirement.

Plasma Kinetics is at normal atmospheric temperature and pressure at all times.

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





Thank you!

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