

Hydrogen for Complete Zero Emission Freight Train and Goods Movement Network

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Rob Del Core
Director, Fuel Cell Power Systems
Hydrogenics USA



We Generate, Store, Refuel, and Power with *Hydrogen*

OnSite Generation Water Electrolyzers



Industrial hydrogen



Hydrogen fueling

Power Systems Power Modules



Stationary & Backup
power



Mobility power

Energy Storage Load Control, Smart Grid and Remote Communities



Technical Benefits of Hydrogen-powered Freight Trains

- ✓ **Long term zero emission solution**
- ✓ **Fast fuelling like diesel**
- ✓ **Flexibility with Self-Electrification**
- ✓ **Can be integrated with renewable energy source**
- ✓ **Quiet operation**

Global Development of Hydrogen-powered Rail

- **2002 : hydrogen-powered mining locomotive was demonstrated in Val-d'Or, Quebec**
- **2006: Worlds first hyrail railcar by East Japan Railway Company**
- **2006, The Railway Technical Research Institute in Japan conducted tests on a fuel cell hyrail vehicle by Nuvera Fuel Cells.**
- **2007: The mini-hydrail from the Taiwan National Science and Technology**
- **2007: Two hydrogen-powered passenger rail by The Railway Technical research institute in Japan**
- **2009: BNSF unveiled the first hydrail locomotive, powered by hydrogen fuel cells.**
- **2010: China demonstrated their first hydrail prototype.**
- **The Hydrogen Train Project in Denmark is attempting to build Europe's first hydrogen powered train using hydrogen in an internal combustion engine**

Alstom Transport Hydrogen Commuter Rail in Europe Developed by Hydrogenics

- Over €50M contract to supply over 200 units of FC power systems over 10 years
- Recognition of Hydrogenics' technical ability to supply fuel cell power systems for Heavy Duty mobility application
- 400kW PEM Fuel Cells for 100 train sets
- Delivering prototype in 2015
- Alstom already has LOI from 5 cities to purchase the train



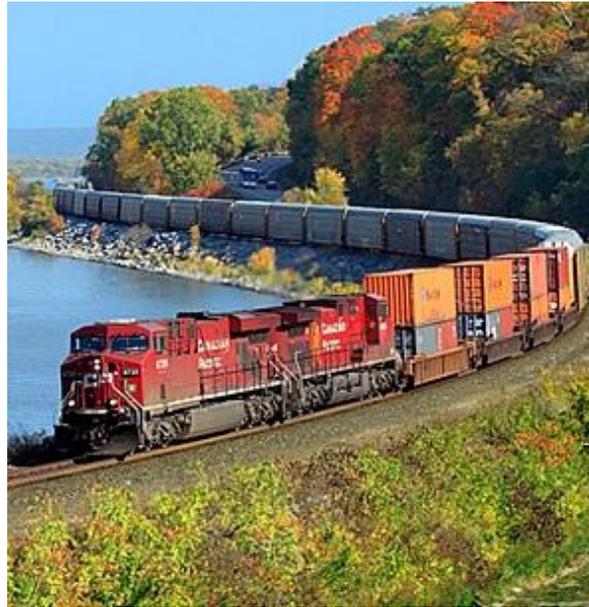
Same Fuel Cell Power Technology can be Transferred to Freight Trains

Hydrogen Power and Fueling Technology is Ready for Freight Rail

Heavy Duty Fuel Cell Power System



Hydrogen Storage



Courtesy photo from
<http://transportationcommunicationcanada.weebly.com/references.html>

Hydrogen Generation



Hydrogen Refueling

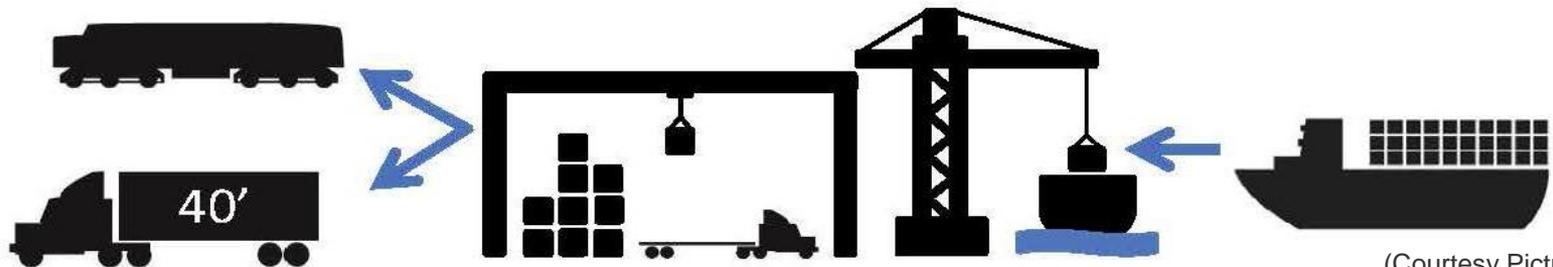


No Technical Barrier!

Hydrogen Freight Network

Hydrogen fuel is a feasible fuel to provide renewable zero emission power for a **Complete Zero Emission Goods Movement Network:**

- Hydrogen-powered RTG cranes at ports
- Hydrogen-powered port drayage trucks
- Hydrogen-powered over-the road long haul trucks
- Hydrogen-powered freight locomotives



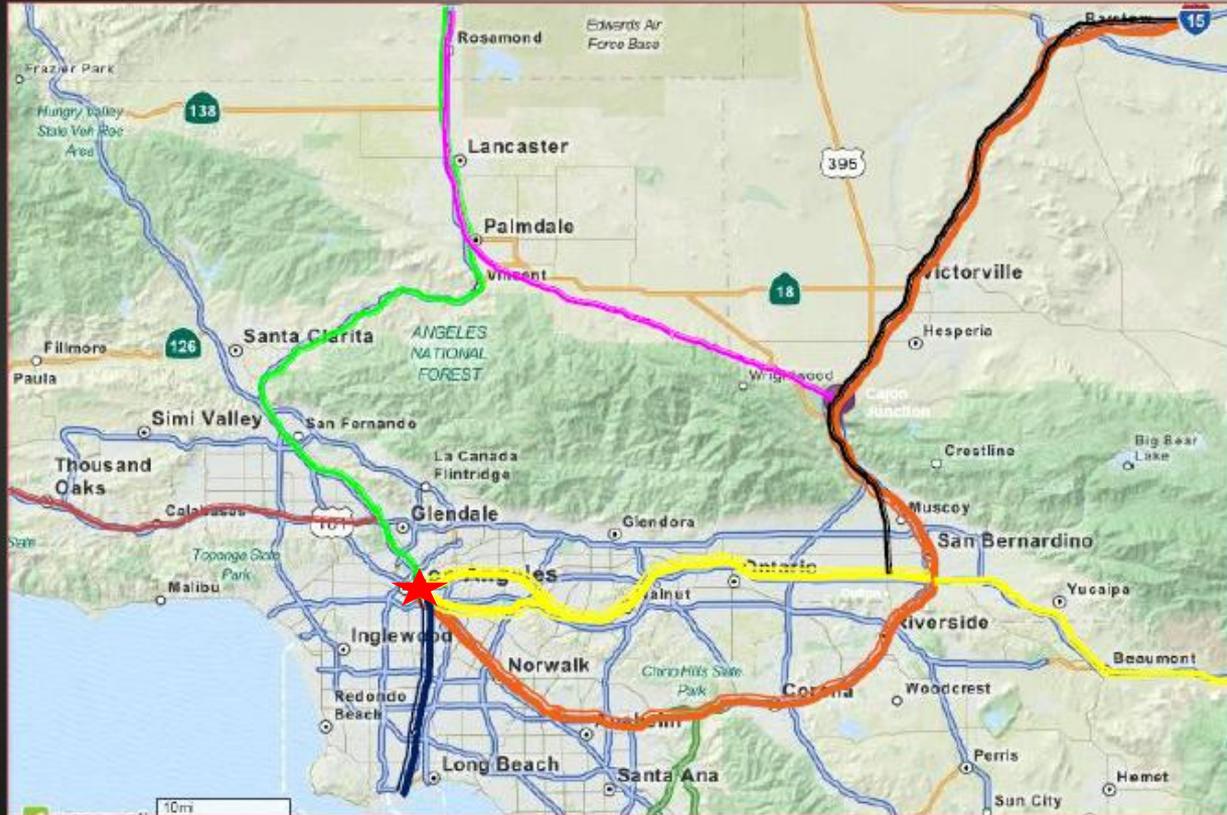
(Courtesy Picture of CARB)

Benefits of a Complete Hydrogen Freight Network:

- ✓ Long term zero emission solution with significant reduction in carbon footprint
- ✓ Can integrate with renewable energy such as solar and wind
- ✓ Achieve economies of scales of hydrogen fuel production and stimulate commercialization of hydrogen-powered heavy duty transportation

Hydrogen Freight Network (Courtesy of CARB)

UP and BNSF Major Freight Train Routes to South Coast Air Basin



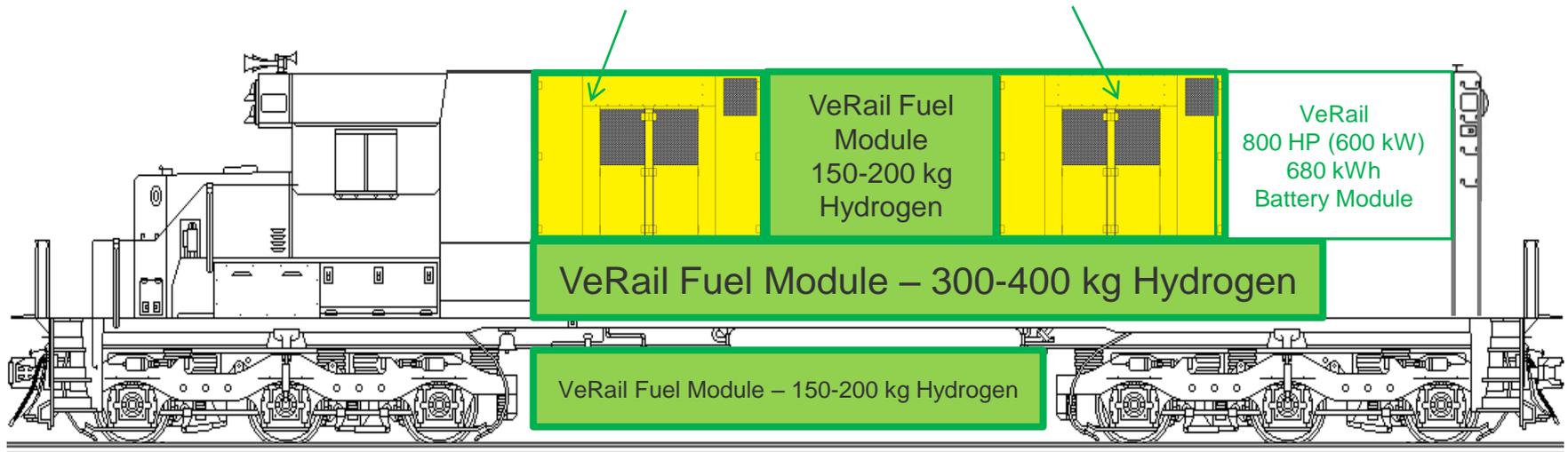
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Possible Fueling Hub for hydrogen-powered transport

- UP Cajon / Palmdale (8 trains per day)
- BNSF Transcon (66 trains per day)
- UP Cajon / Cima (9 trains per day)
- UP Coastal (1 train per day)
- Alameda Corridor (UP and BNSF: 45 trains per day)
- UP Sunset (40 trains per day)
- Northern UP, Metrolink Valley Sub (9 trains per day)

Sample Switching/Transfer Hydrogen Fuel Cell Locomotive

VeRail VR30C2-Hfc (3,000 HP)
Switching/Transfer Fuel Cell Locomotive
100% Zero Emission Track Miles

Each VeRail/Hydrogenics **Fuel Cell** Power Module produces 1,280 HP of **Zero Emissions** clean power, reducing CO2 output by 100% over diesel.



Module drawings not to scale

3,000 HP Local/Transfer Service Locomotive Fuel Consumption = 150,000 gallons per year = ~410 gallons per day
Four locomotives per train = 12,000 HP = ~1,640 gallons per day

Four VeRail VR30C2-Hfc locomotives = 12,000 HP with 2,400-3,200 kg hydrogen fuel
= 2 day refueling interval with no fuel tender needed

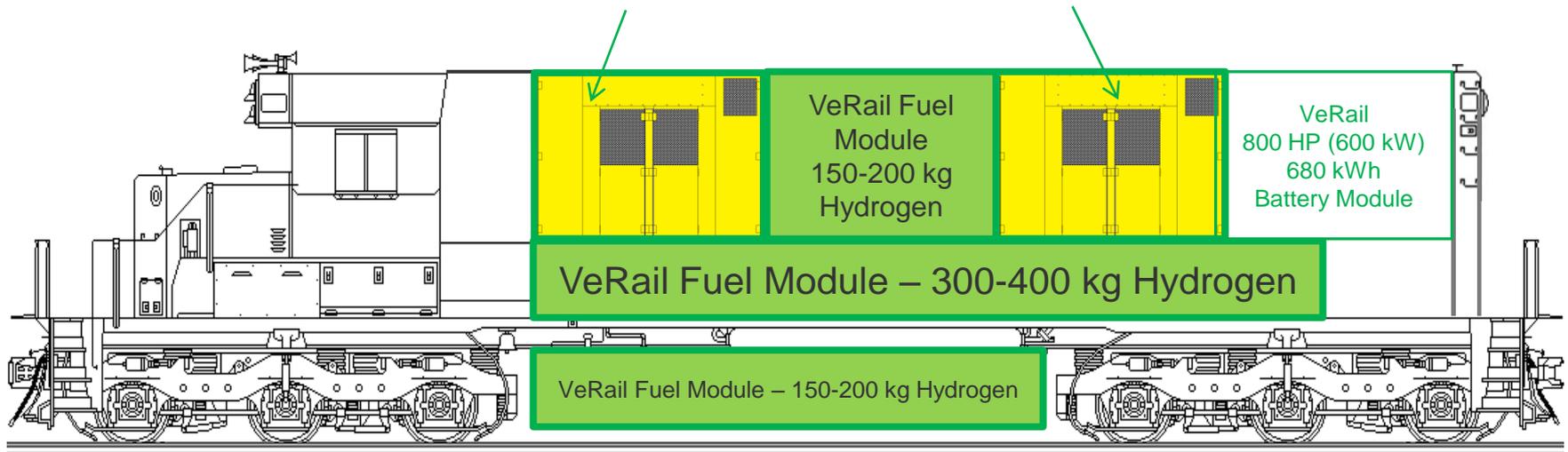
All Engineering Information on this slide provided by VeRail



Sample Line Haul Hydrogen Fuel Cell Locomotive

VeRail VR36C2-Hfc (3,600 HP)
Line Haul Fuel Cell Locomotive
100% Zero Emission Track Miles

Each VeRail/Hydrogenics **Fuel Cell** Power Module produces 1,600 HP of **Zero Emissions** clean power, reducing CO2 output by 100% over diesel.



Module drawings not to scale

4,400 HP Line Haul Locomotive Fuel Consumption = 300,000 gallons per year = ~820 gallons per day
Four locomotives per train = 17,600 HP = ~3,280 gallons per day

Five VeRail VR36C2-Hfc locomotives = 18,000 HP with 3,000-4,000 kg hydrogen fuel
= 1 day refueling interval with no fuel tender needed

All Engineering Information on this slide provided by VeRail

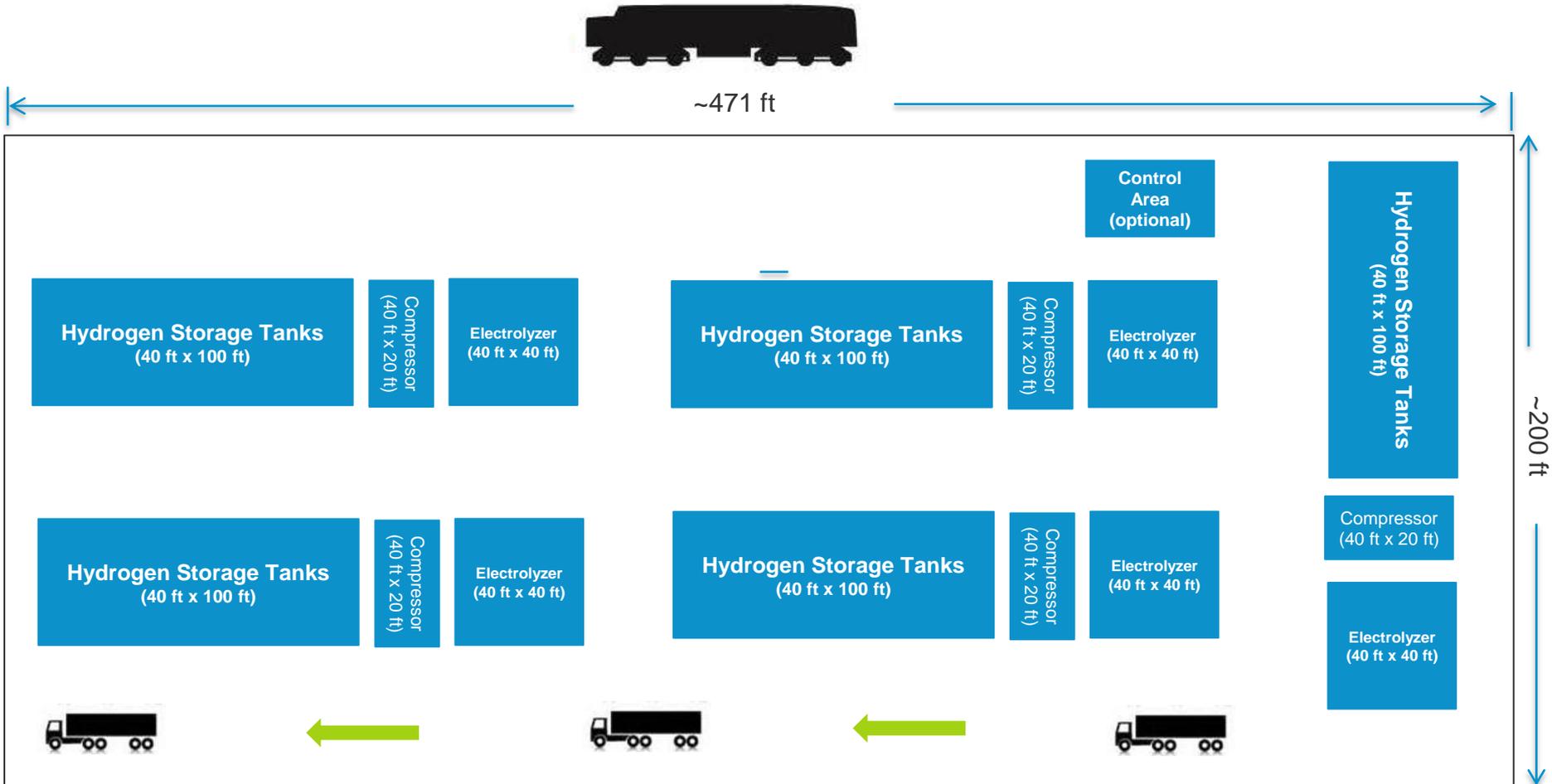


Economics of Hydrogen Power Freight Train

- Costs: Capex, fuel, maintenance, come down with volume
- Performance (power, emissions reductions, efficiency)
- No need for idle
- Optimal energy management
- Fast load time
- No tender required

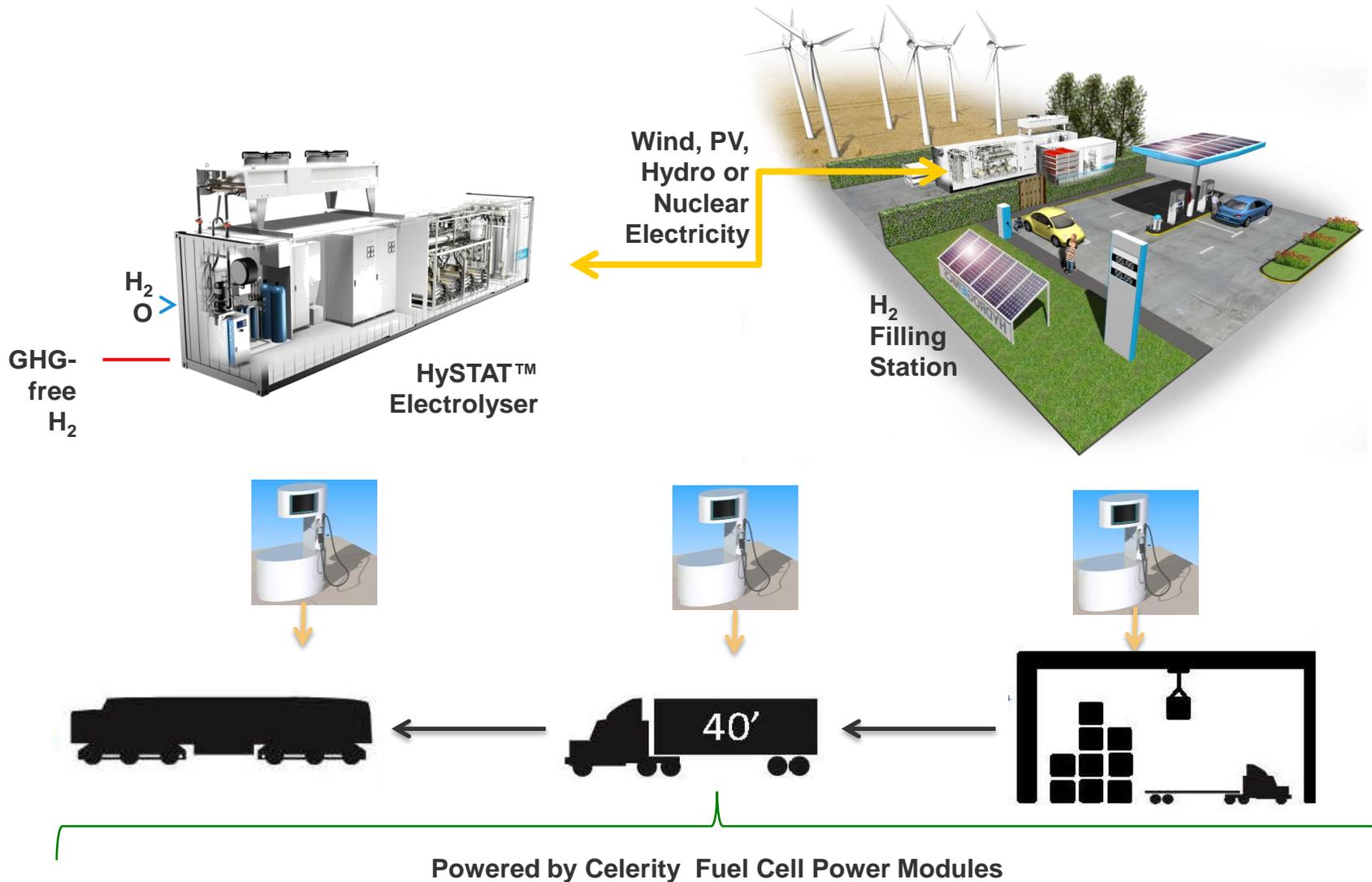
**We are giving back rail operators
all they love about diesels with zero emissions !**

Preliminary Hydrogen Infrastructure Footprint Estimation: 4000 kgpd Hydrogen for 5 Locomotives per 1 Line Haul Train



Disclaimer: Above layout is conceptual. Actual space and layout will depend on local codes/standards and other requirements.

Long Term Goal: Renewable Zero Emission Hydrogen Freight Network



 WE'RE
READY