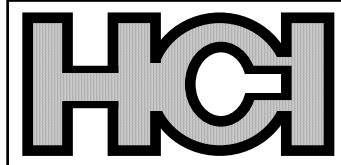


“If the earth were 1 big oil droplet, it would be gone in 200 years, at the present escalation rate in petroleum consumption.” **-- an oil co. scientist**



SOMETHING MUST CHANGE!

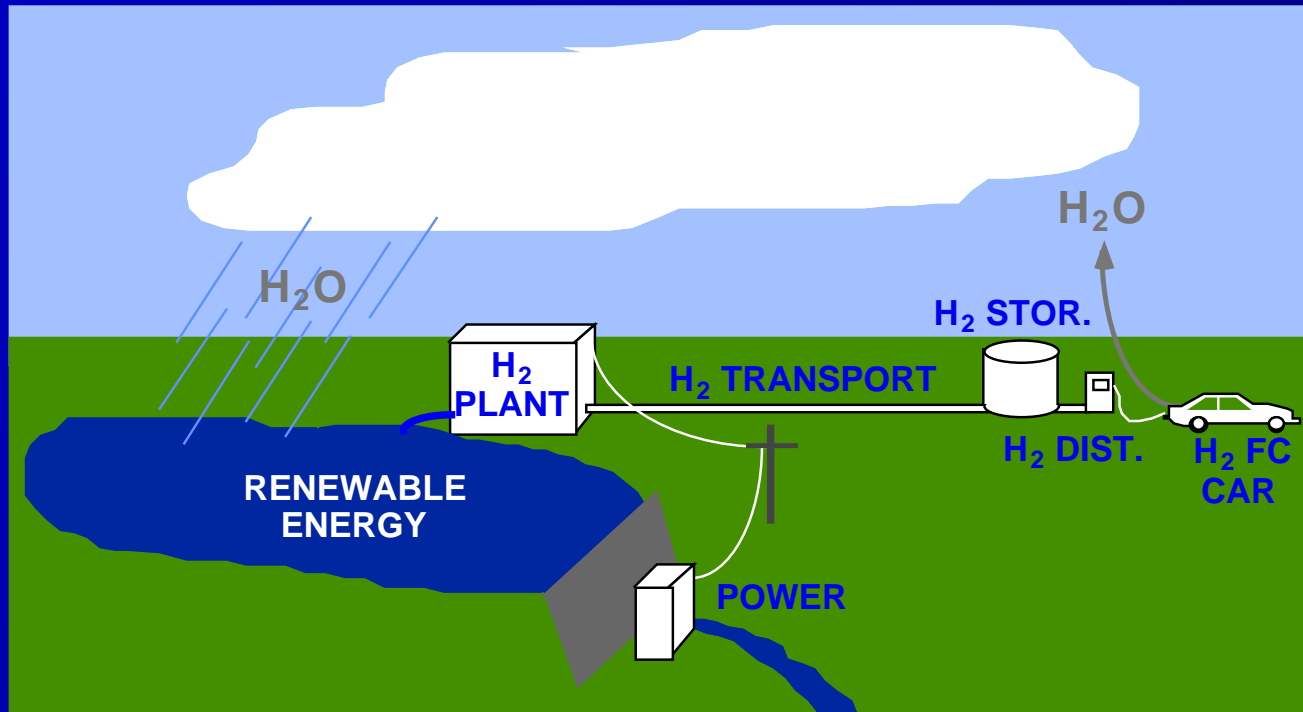




Frank's 1st Hydrogen-Fueled Car, UCLA 1972

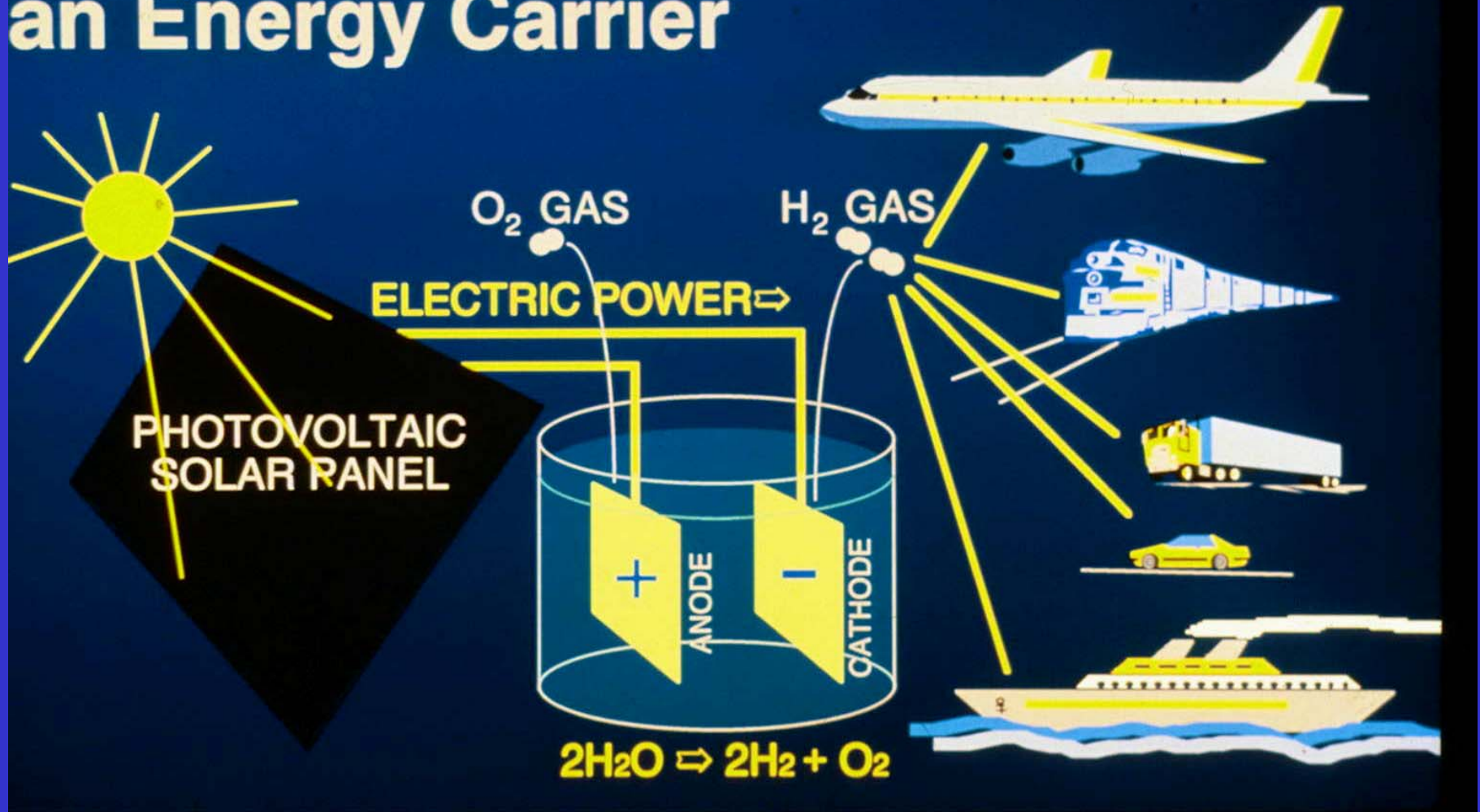
Any energy source can make hydrogen fuel from water

RENEWABLE H₂ ENERGY SYSTEM



**Hydrogen Energy System Goal:
Make Energy Use Part Of Earth's Water Cycle**

Hydrogen: an Energy Carrier



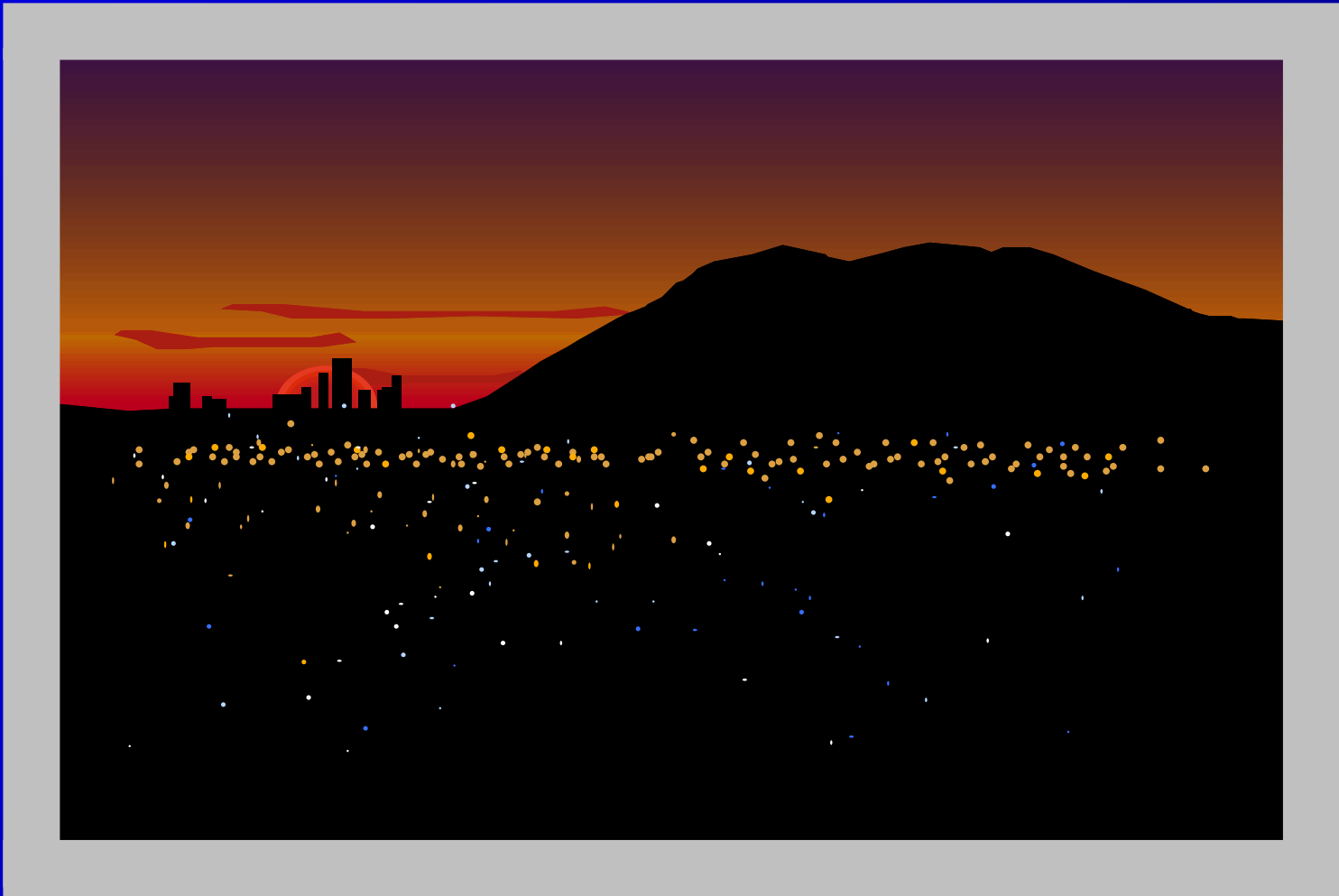
Hydrogen, like electricity, carries energy—it is not a source of energy



Photo Courtesy of Stuart
Energy Systems

**Solar-powered Electrolyzer And H₂ Fuel Cell Bus
At SunLine Transit, Thousand Palms, Ca**

Sustainability is not yet H₂'s main driver--



--urban air quality is.

IMMEDIATE THREATS TO PUBLIC HEALTH ARE TOP PRIORITY



- Most hydrogen is made by steam-methane reformers and used on-site to make fertilizers, methanol and other chemicals
- Some of the largest reformers are used at oil refineries for processing petroleum
- So-called “merchant hydrogen” is produced at one location and is transported to an end-user by truck, rail or barge
- Most merchant hydrogen is liquefied at the plant and stored for filling -400°F “cryo” tank trucks

35 Million Ft³/day

Martinez, Ca

Photo Courtesy Air Products



13,000 Gallons
-400°F Inside

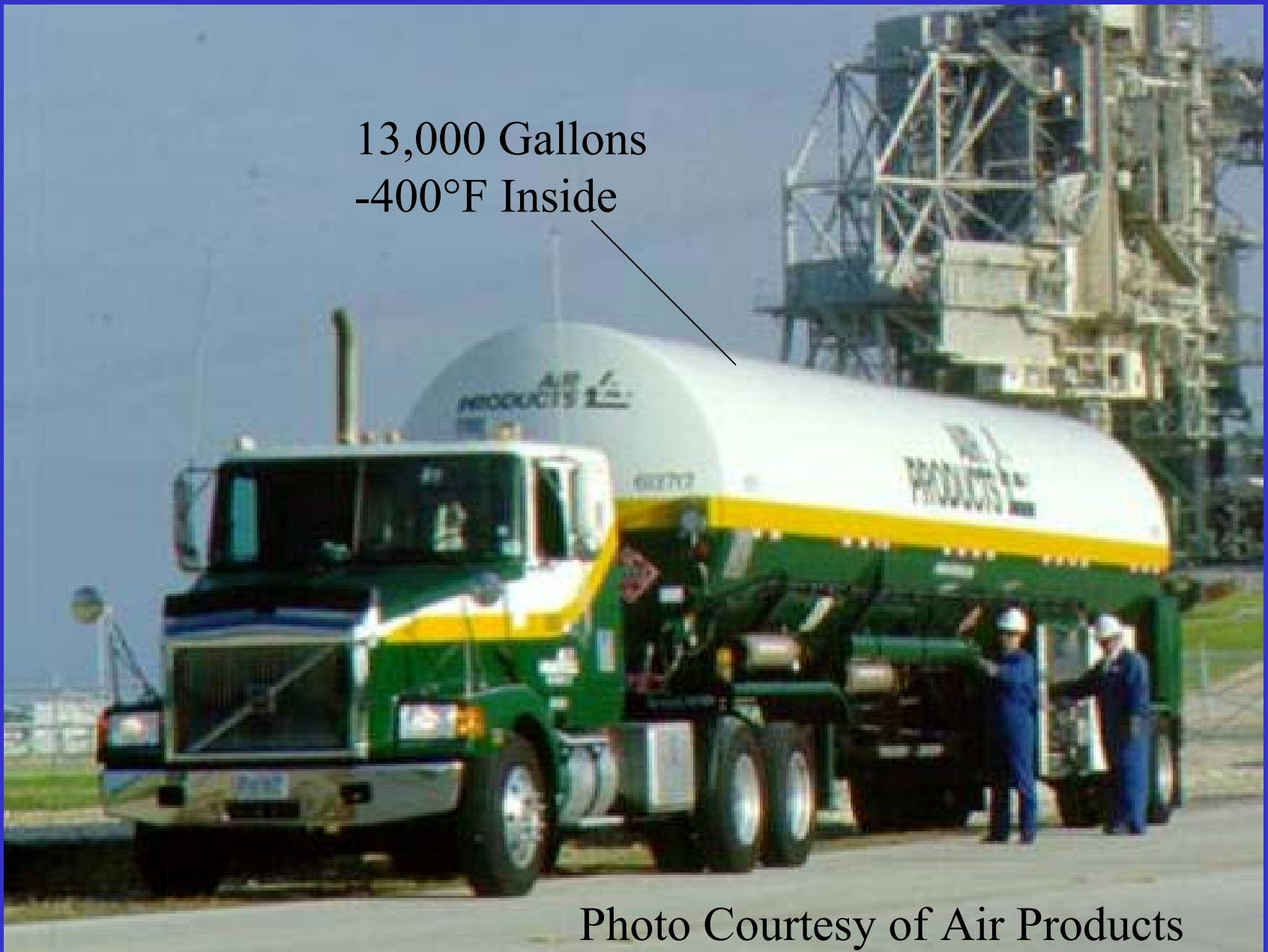
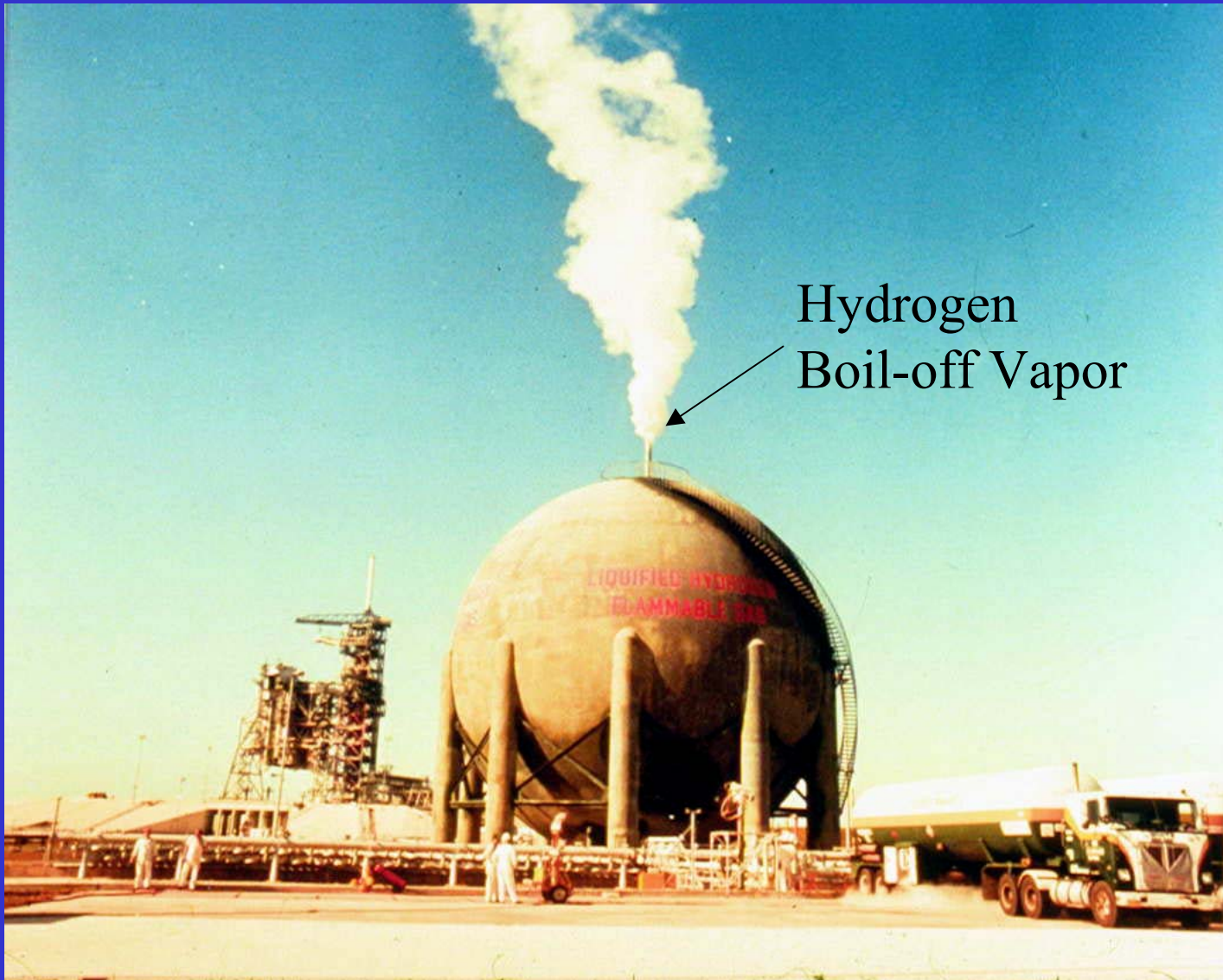


Photo Courtesy of Air Products

Liquid Hydrogen Tankers Distribute Most Merchant Hydrogen



More than half of the liquid hydrogen purchased by NASA is lost!



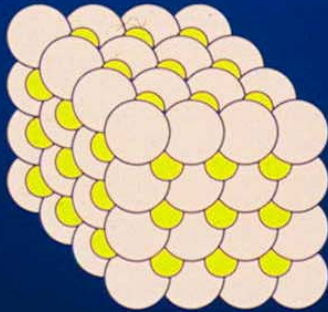
**Hydrogen Fuel Cell Car Refueling at
Ford Motor Company, Dearborn, Mi**



Hydrogen Fuel Station For Fuel Cell Buses at Chicago Transit Authority

Metal Hydrides

● = Hydrogen
● = Metal

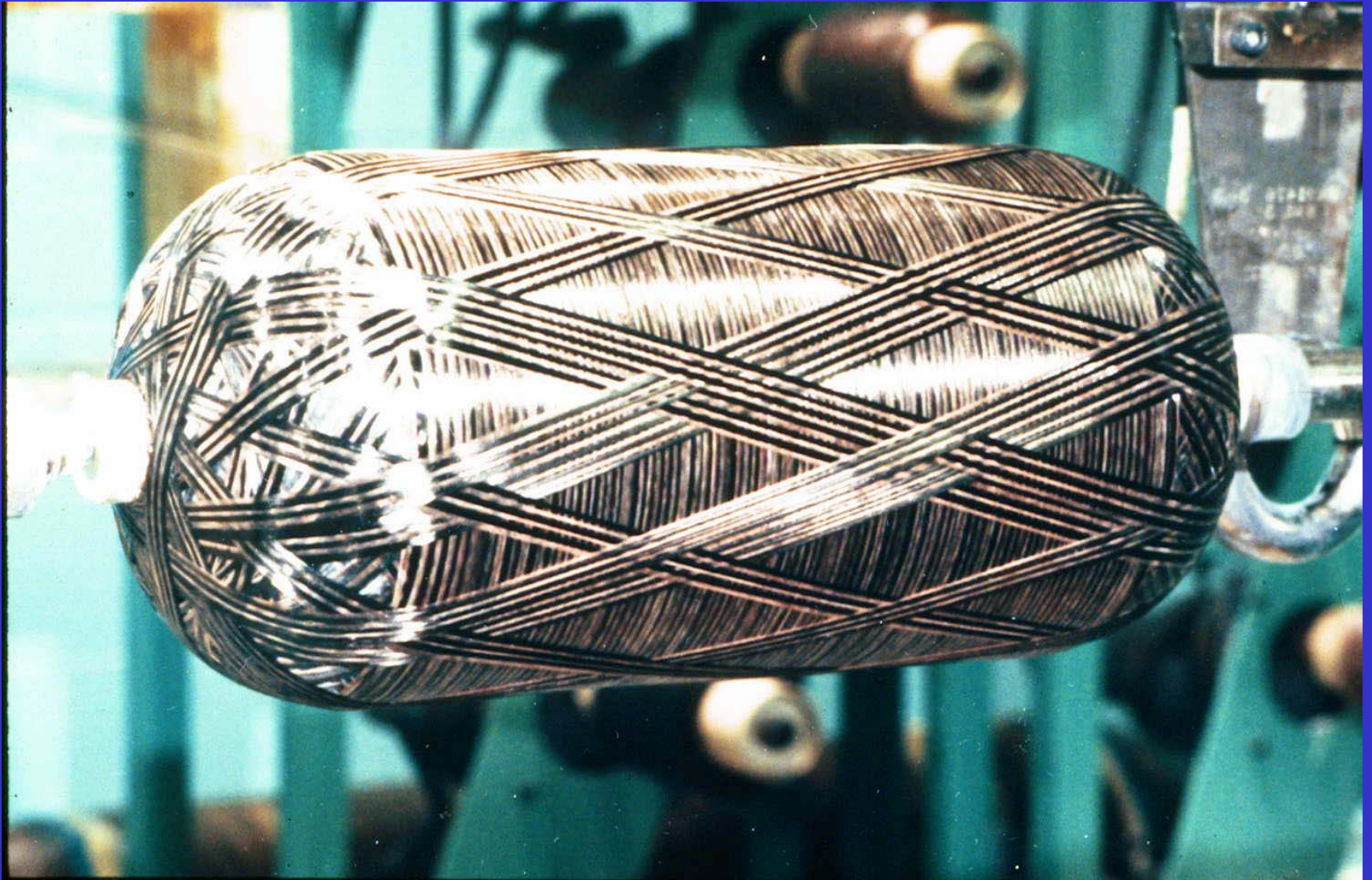


- **H Density Exceeds Liquid H₂**
- **Indefinite Storage Without Insulation**
- **Ultra Safe Low Pressure Storage**

Hydrides are compact, but heavy and expensive



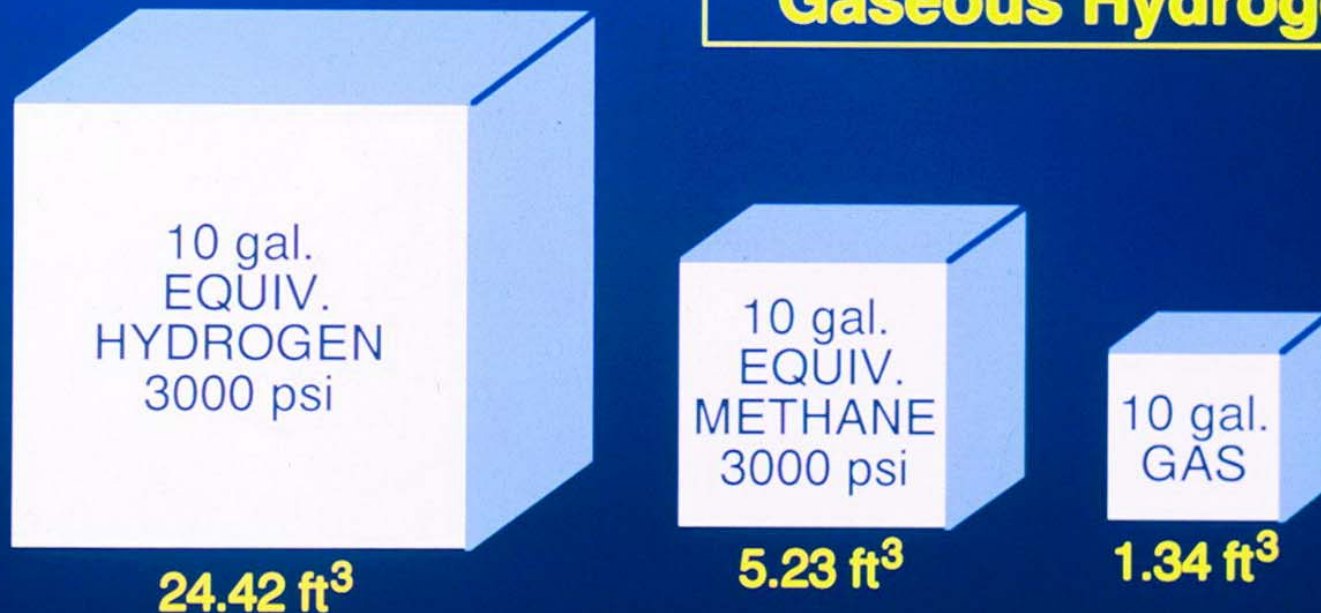
Hydrides are well suited to heavy vehicles, like this mining truck completed in 1985, still in operation at NIOSH in Spokane, WA



Modern composite pressure vessels hold gaseous fuels at 5000 psi. These tanks are very strong and crash-resistant.

Fuel Storage Volume

**Motor Vehicles
Designed for Gasoline
Do Not Have Enough
Space Available for
Gaseous Hydrogen**

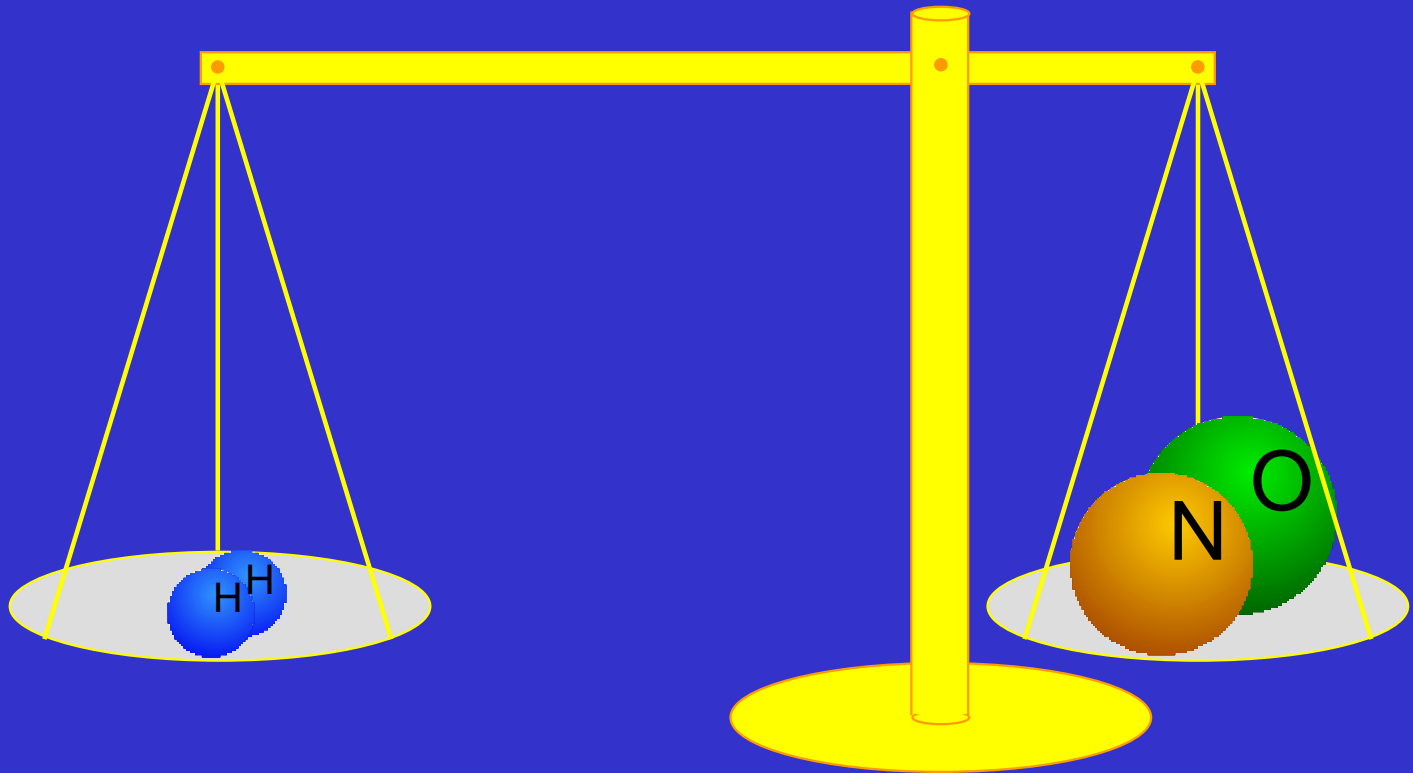


Car manufacturers must design from scratch to make room for hydrogen tanks

Introducing Hydrogen

- At first, H₂ will be used sparingly in fleets fueled mostly by diesel and natural gas.
- The main reason for introducing H₂ is emissions reduction.
- Disincentives of H₂ include high vehicle cost and high fuel cost.
- The challenge is to get the greatest emissions reduction per dollar of hydrogen expense.

LEVERAGED USE OF HYDROGEN IN INTERNAL COMBUSTION ENGINES





Ribbon-Cutting at the 1st *Hythane*® Station: L-R Frank Lynch (HCI), Tim Knowlton (Xcel), Mayor Webb, Jim Hansel (Air Products)

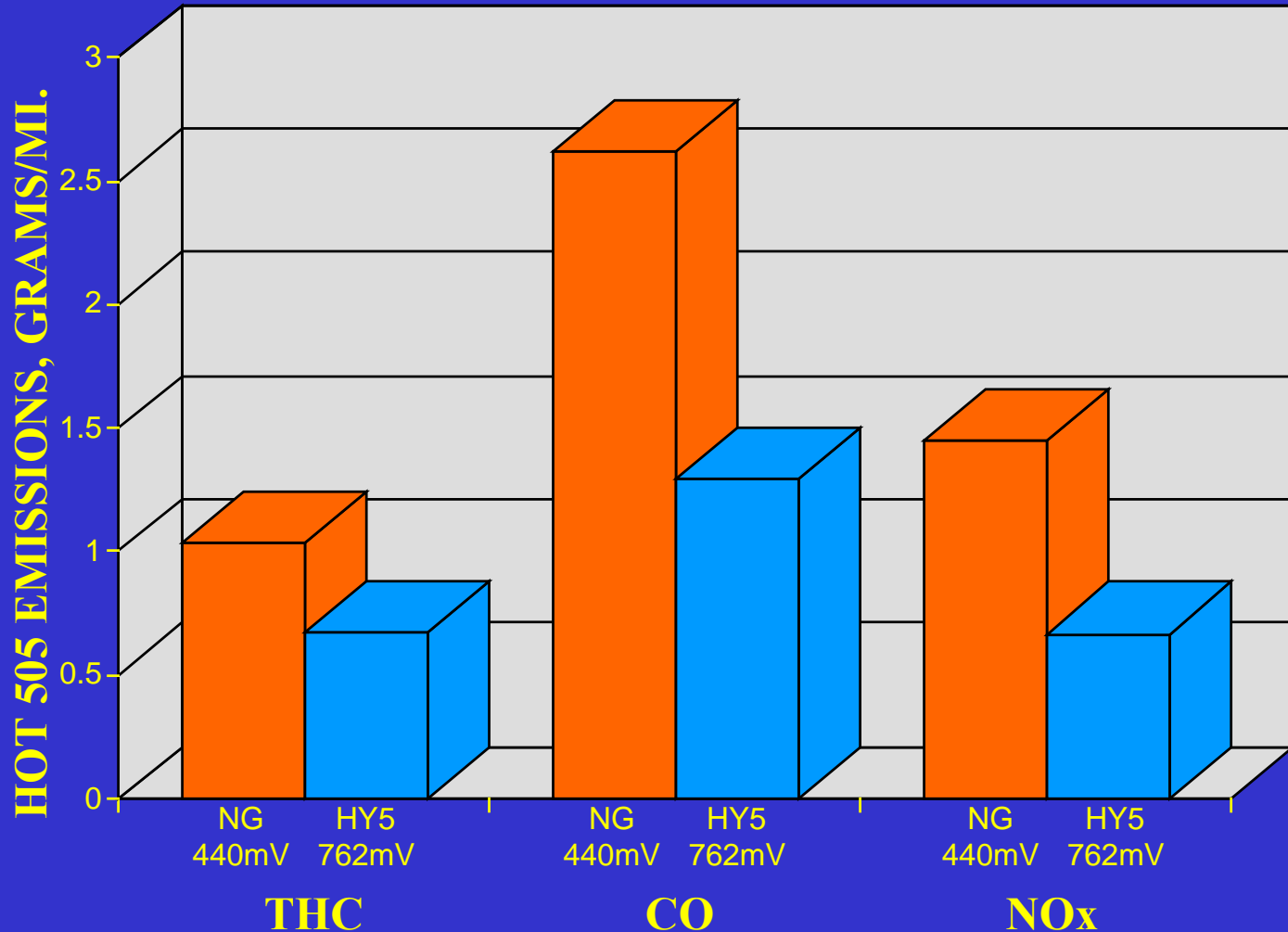
3-VEHICLE DENVER *HYTHANE*® PROJECT



Gasoline Truck, Compressed Natural Gas (CNG) Truck and “HY5” Truck (5 energy % H₂ in CNG)

Denver Hythane® Project Results

Two-test averages from Denver Hythane Project.
Courtesy of Colorado Department of Health, March 1993.



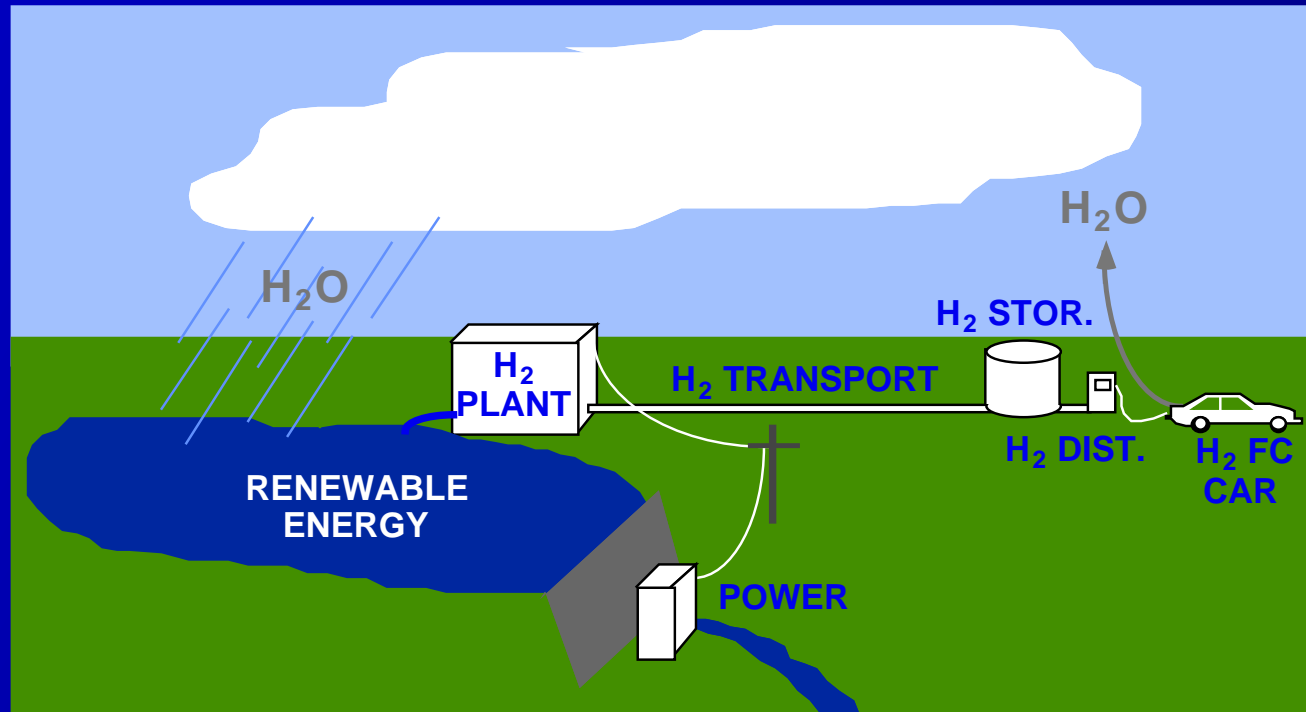
50% Reductions in CO and NOx, 5% H₂: Leverage Factor = 10!

2-BUS MONTREAL *HYTHANE*® PROJECT



The 2 Buses are now at SunLine Transit, Thousand Palms, CA
They burn 93% CNG, 7% Solar Hydrogen, by Energy Content

RENEWABLE H₂ ENERGY SYSTEM



HYTHANE® is a cost-efficient, highly leveraged way to introduce H₂.
The ultimate goal is the same: renewable zero-emission energy system