Could Hydrogen help us operate Juneau entirely on CO_2-emission-free energy ? How ?

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Innovation

World's first liquid hydrogen fuel cell cruise ship planned for Norway's fjords

Retrofitted by 2023. Combines a 3.2MW hydrogen fuel cell with battery storage.

Hydrogen-fueled,
Fuel cell electric drive
Now, or soon

6 Ballard Fuel Cell-Powered
Vessel Projects Underway Today

MAERSK promises CO2-emission-free fleet by 2050

- **Hydrogen-fueled**
- **Ammonia-fueled (NH_3)**

Yanmar / Toyota hydrogen fuel cell boat

250 kW electric drive train: Whalewatch size

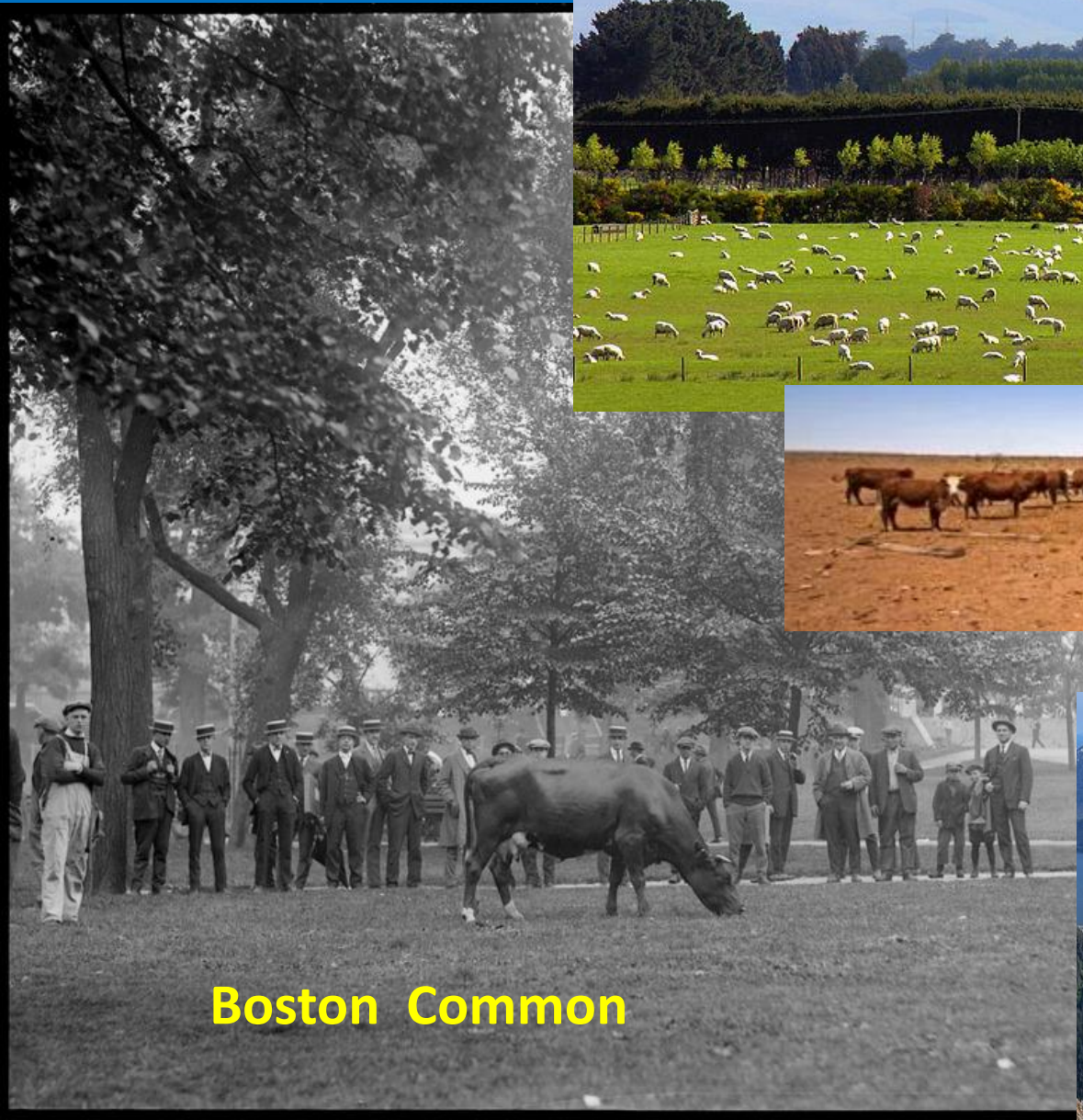
Paul Crutzen
1933 – 2021

Nobel Prize,
Chemistry
“Ozone Hole”

Holocene →
Anthropocene

Innovation failure

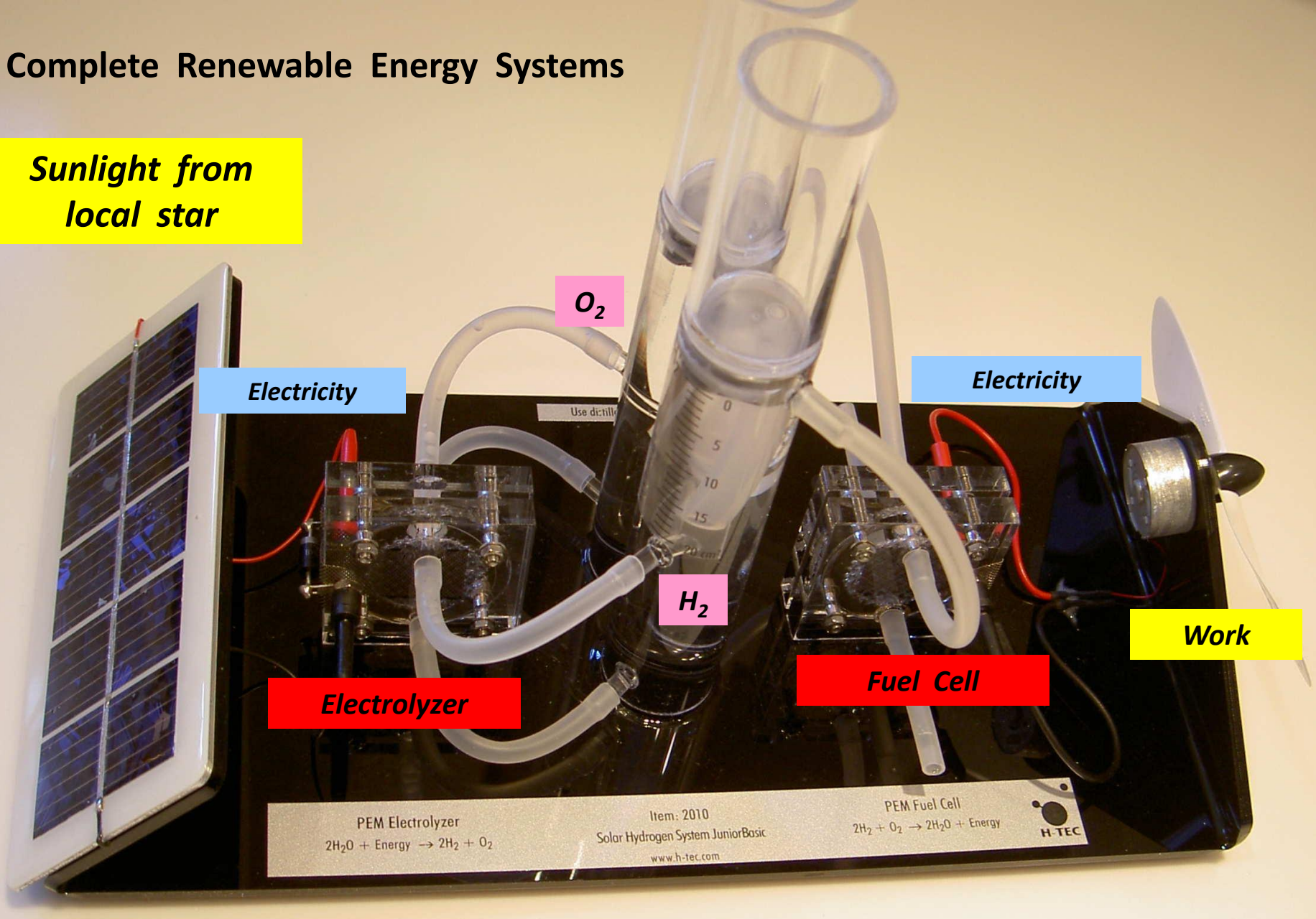
Tragedy of the Commons: Unpriced, free, abused



Tragedy of the Commons

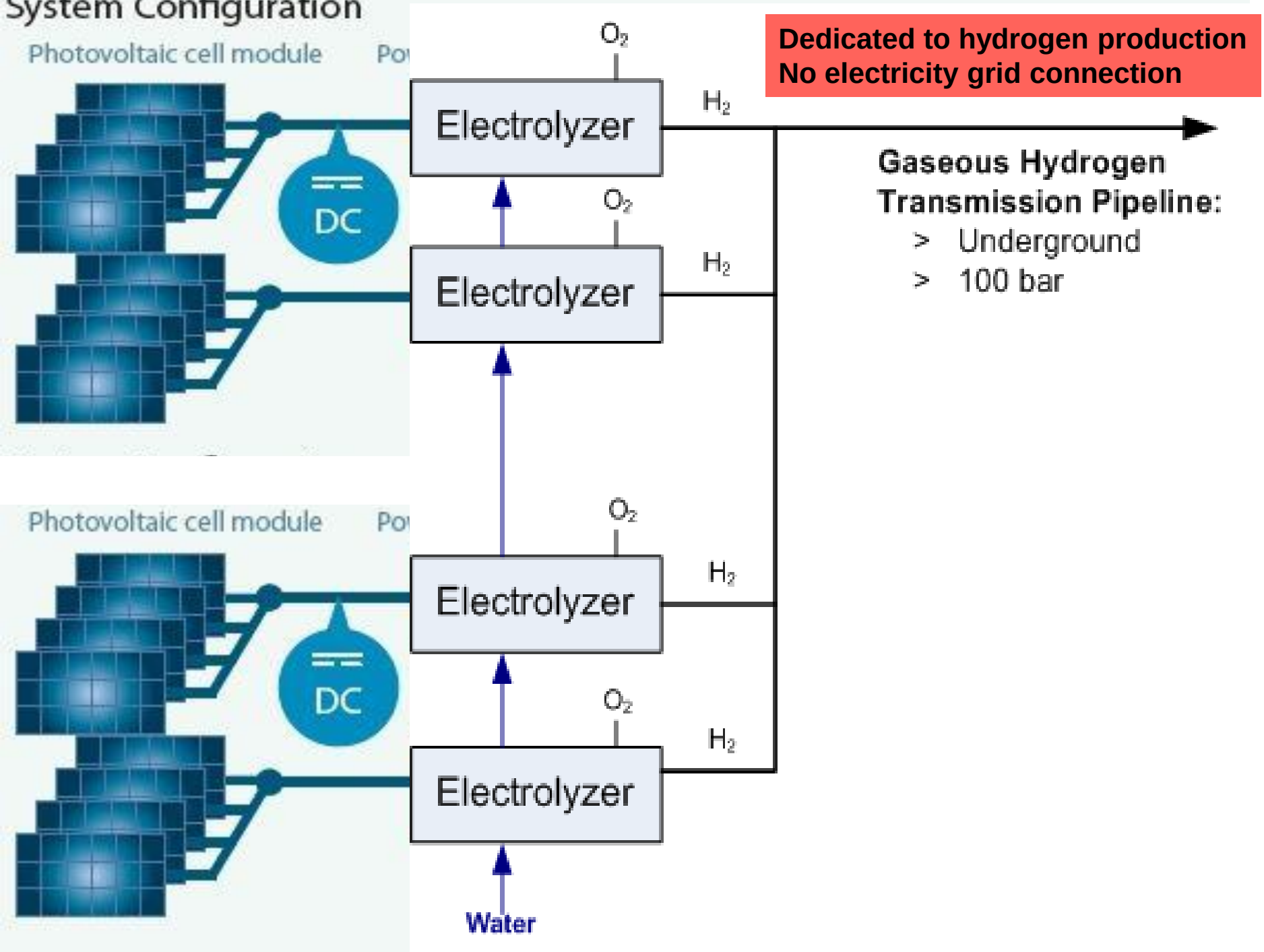
- COVID-19 a rehearsal for GCC
- Transform world's largest industry
- Total de-carbonization, de-GHG-emission, by 2050
- Entire human enterprise
- CO2-emission-free energy
- Complicated: watch your language !

Complete Renewable Energy Systems



Solar Hydrogen Energy System

System Configuration

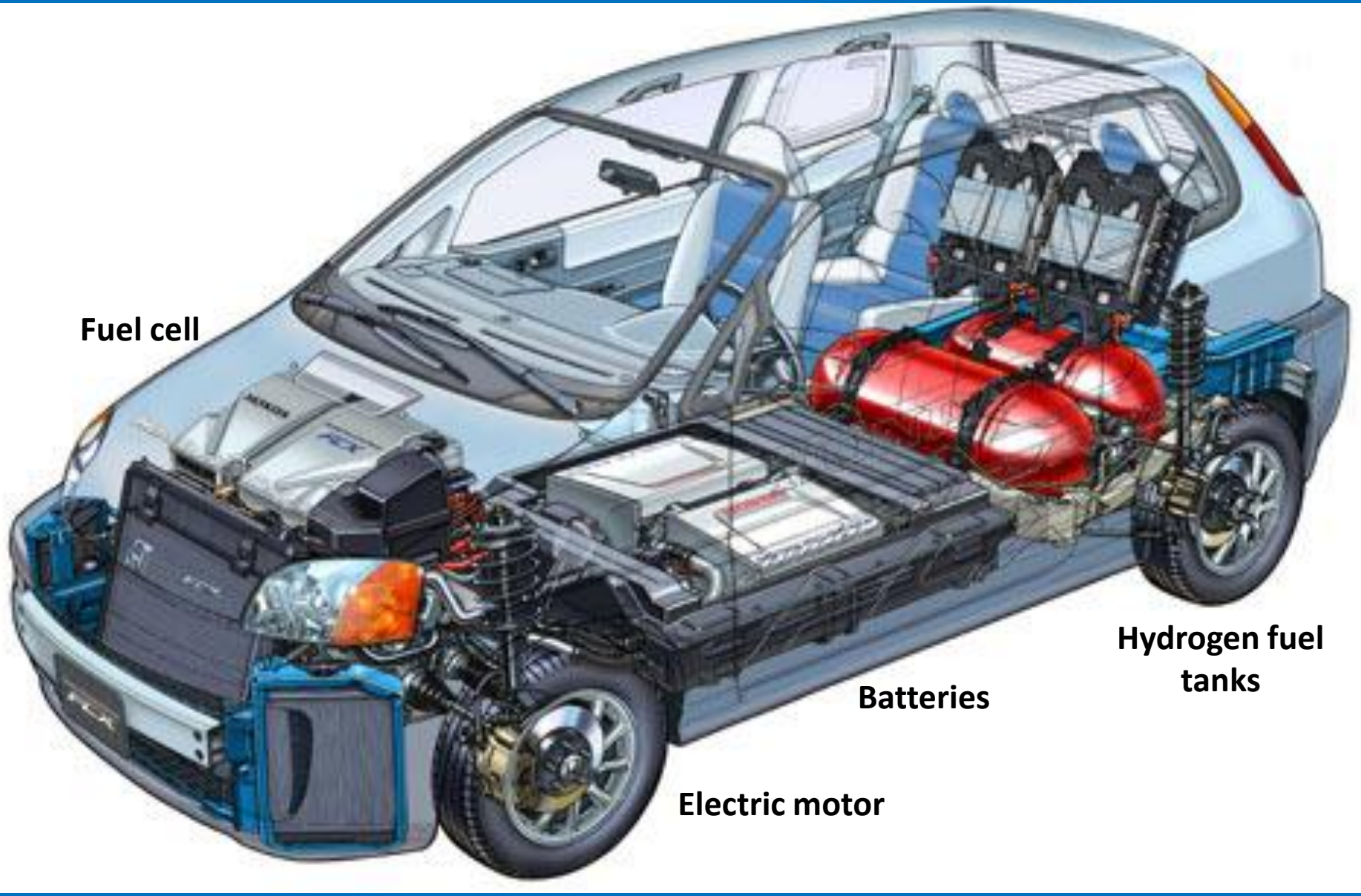


Dedicated to hydrogen production
No electricity grid connection

Gaseous Hydrogen Transmission Pipeline:

- Underground
- 100 bar

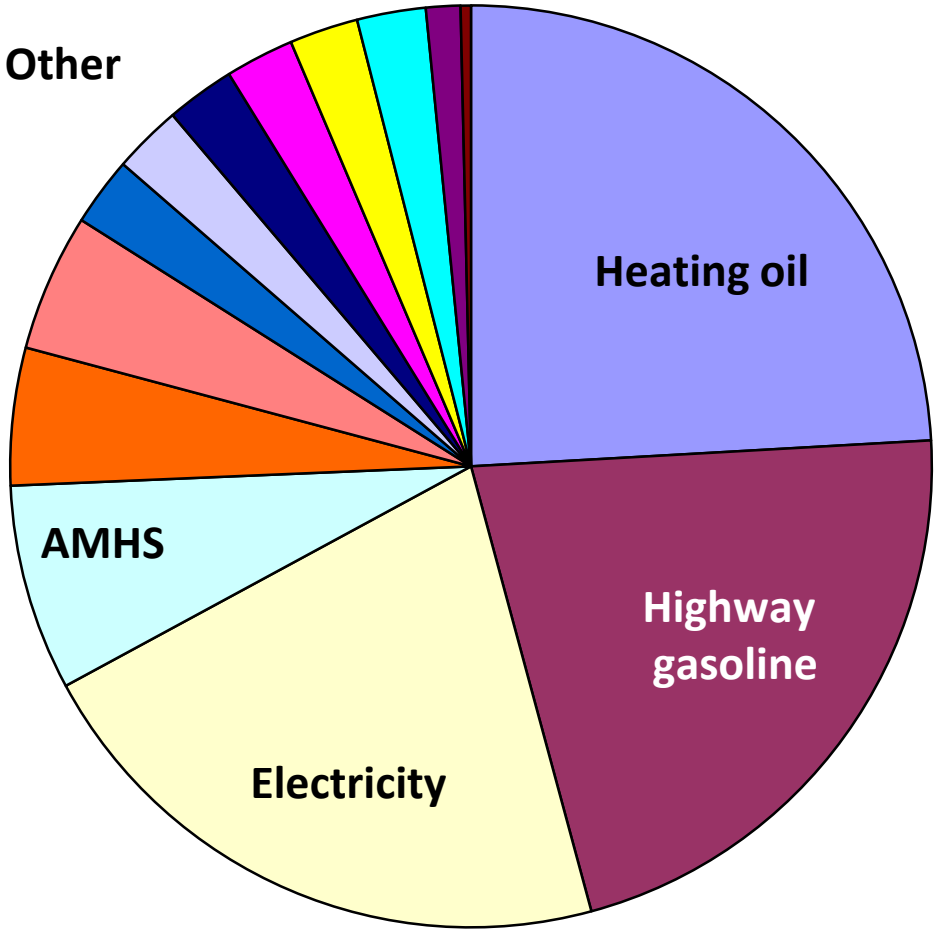

Snettisham Hydro:
Store spilled water as Hydrogen or Ammonia



Inside a Fuel Cell Car – or bus, train, truck

Juneau INTERNAL energy 2009

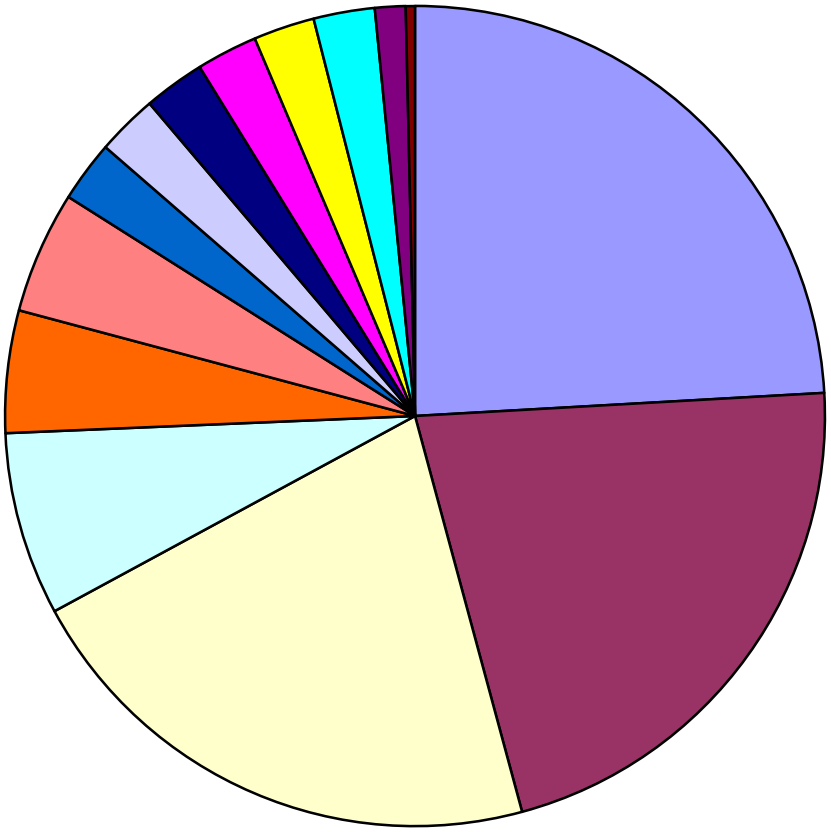
~ 30 million gallons liquid fossil fuels / year imported



Heating Oil	Hiway Gasoline	Electricity	AMHS	Av Turb AS
Av Turb Other	Hiway Diesel	Other Diesel	Av Gas	Marine Other
Other	Propane	CapTransit Diesel	Wood	

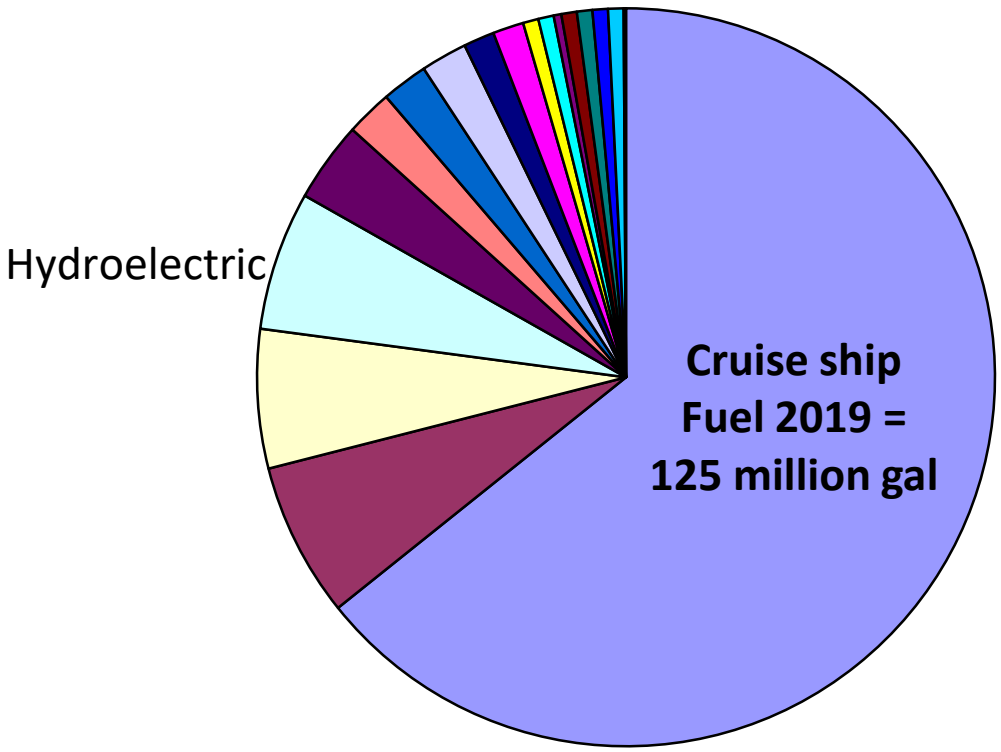
Juneau INTERNAL energy 2019, Estimated
[assumed same as 2009, but tourism up]

~ 30 million gallons liquid fossil fuels / year imported



Heating Oil	Hiway Gasoline	Electricity	AMHS
Av Turb AS	Av Turb Other	Hiway Diesel	Other Diesel
Av Gas	Marine Other	Other	Propane
CapTransit Diesel	Wood		

Juneau TOTAL Energy 2009
[assume 2019 tourism up]



Cruise Ships	Heat Oil	Hiway Gas	Electric	Barge
AMHS	AS (external)	AMHS	Av Turb AS	Av Turb Other
Hiway Diesel	Other Diesel	CapTrans Diesel	Av Gas	Marine Other
Other	Propane	Wood		

“ Run On Rain ” no emissions

Juneau’s first battery-electric (BEV) bus. About $ 800,000
Innovation: Another ~ 80 for summer visitors; coach seating
$ 64 million CAPEX
Innovation, financing: public-private, crowdsourcing, local co-op

Hydrogen Fuel Cell Bus


~ 80 coaches in Juneau @ $ 800,000 = $ 64 million
ORCA ENTERPRISES
Gray Line of Alaska
"Solo buses": MCI "Coach" ~ 50 seats + baggage under high floor
Need the baggage level ?

Fixed Guideway System (FGS)

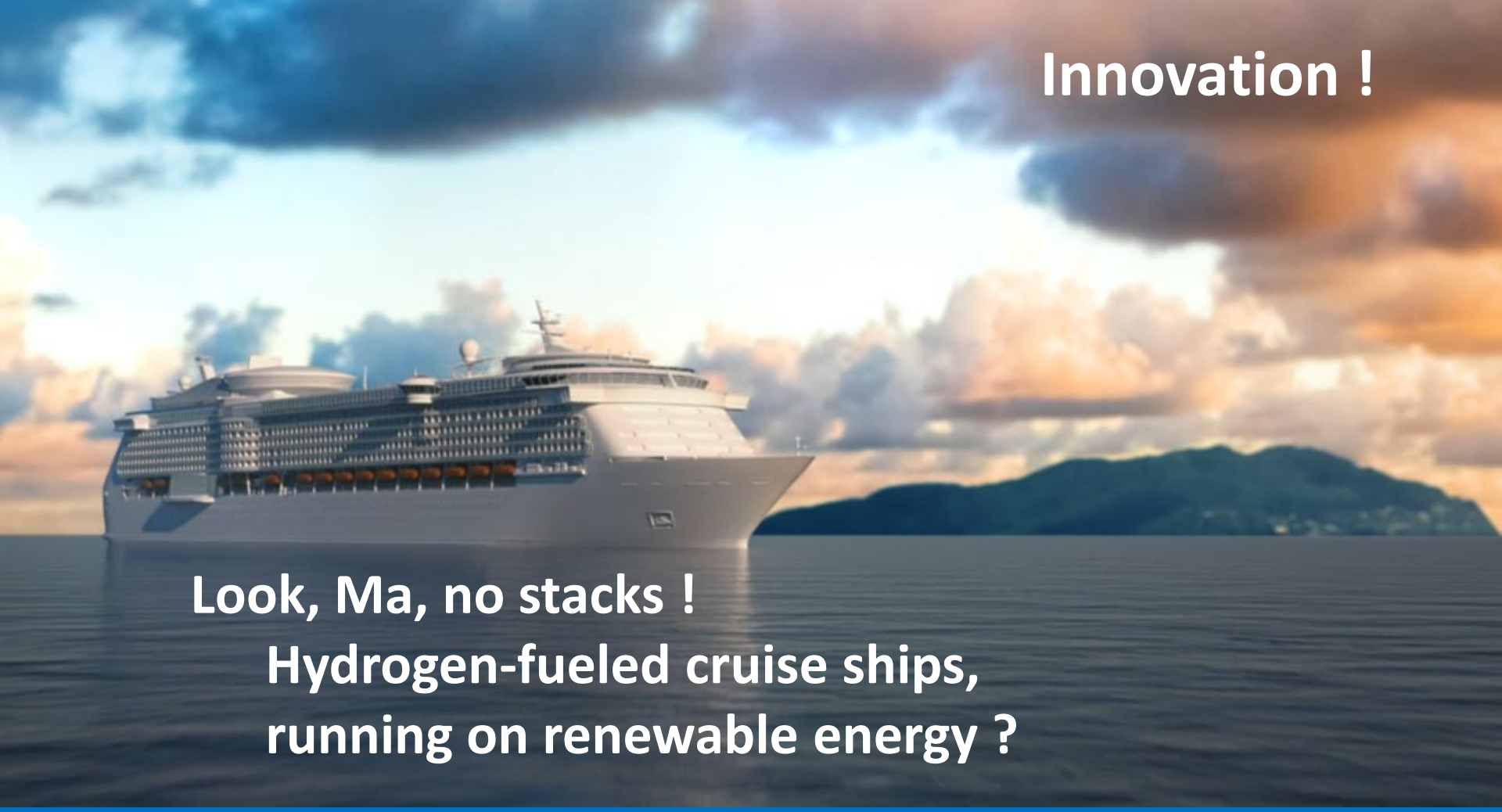
- Light Rail Transit (LRT)
- Streetcar
- Hybrid: LRT – Streetcar
- Bus Rapid Transit (BRT)

INNOVATION

Alstom Hydrogen-fueled, Fuel Cell Train

- No overhead wires
- 200 mile range
- 20 minute fueling
- Hydroelectric-source Hydrogen fuel: Zero Emission Vehicle (ZEV)

Light Rail Transit (LRT)
Fixed Guideway System (FGS)



Concept: Liquid Hydrogen (LH2) fueled, Fuel Cell electric drive

Zero emissions:

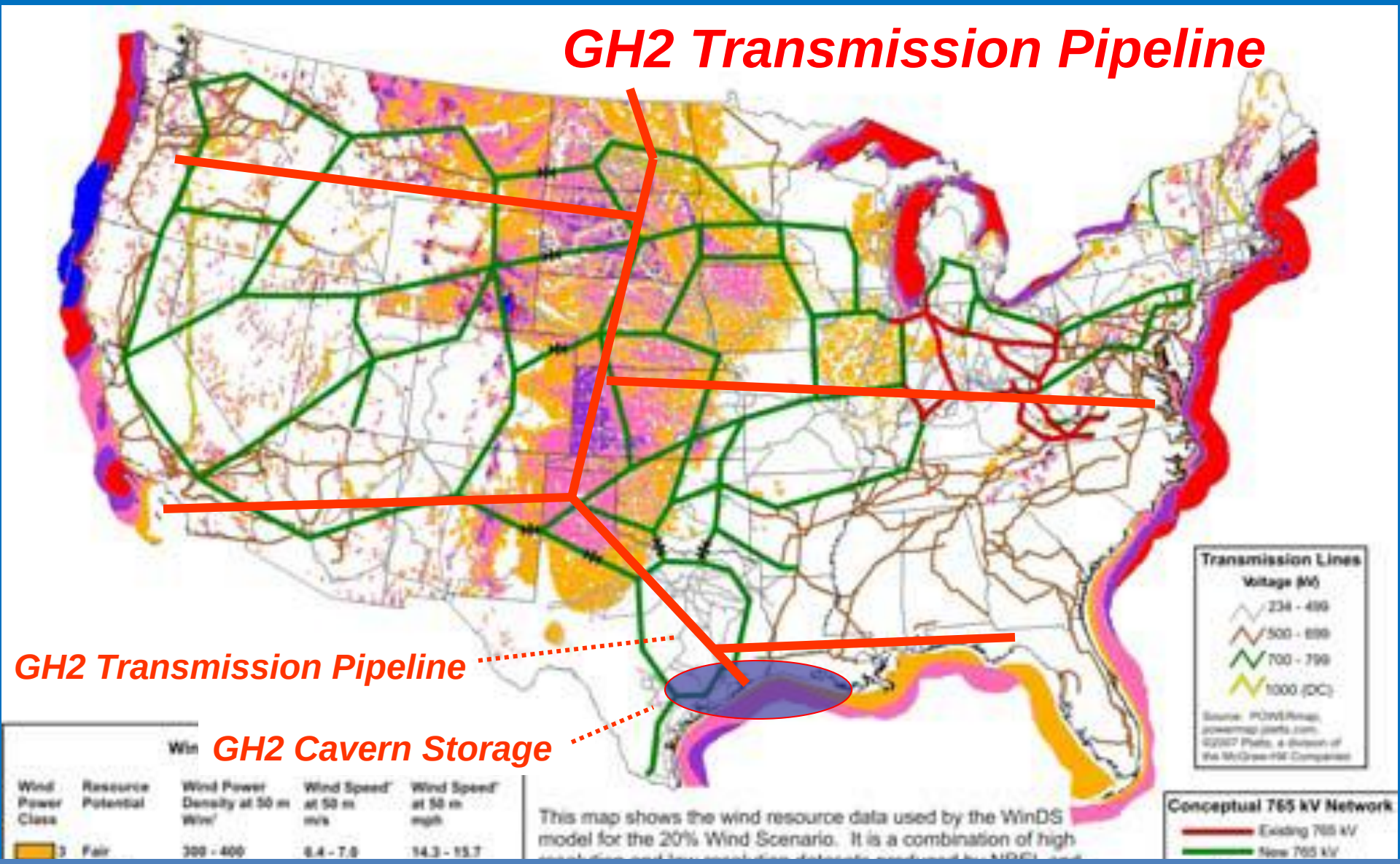
- **No "stacks"**
- **Must use LH2 fuel from "green" CO2-emission-free energy sources**
- **Bunker fueling in SE AK and BC ?**

Hydrogen-fueled, Fuel cell electric drive cruise ship

Hydrogen fueled, Fuel cell electric drive container ship

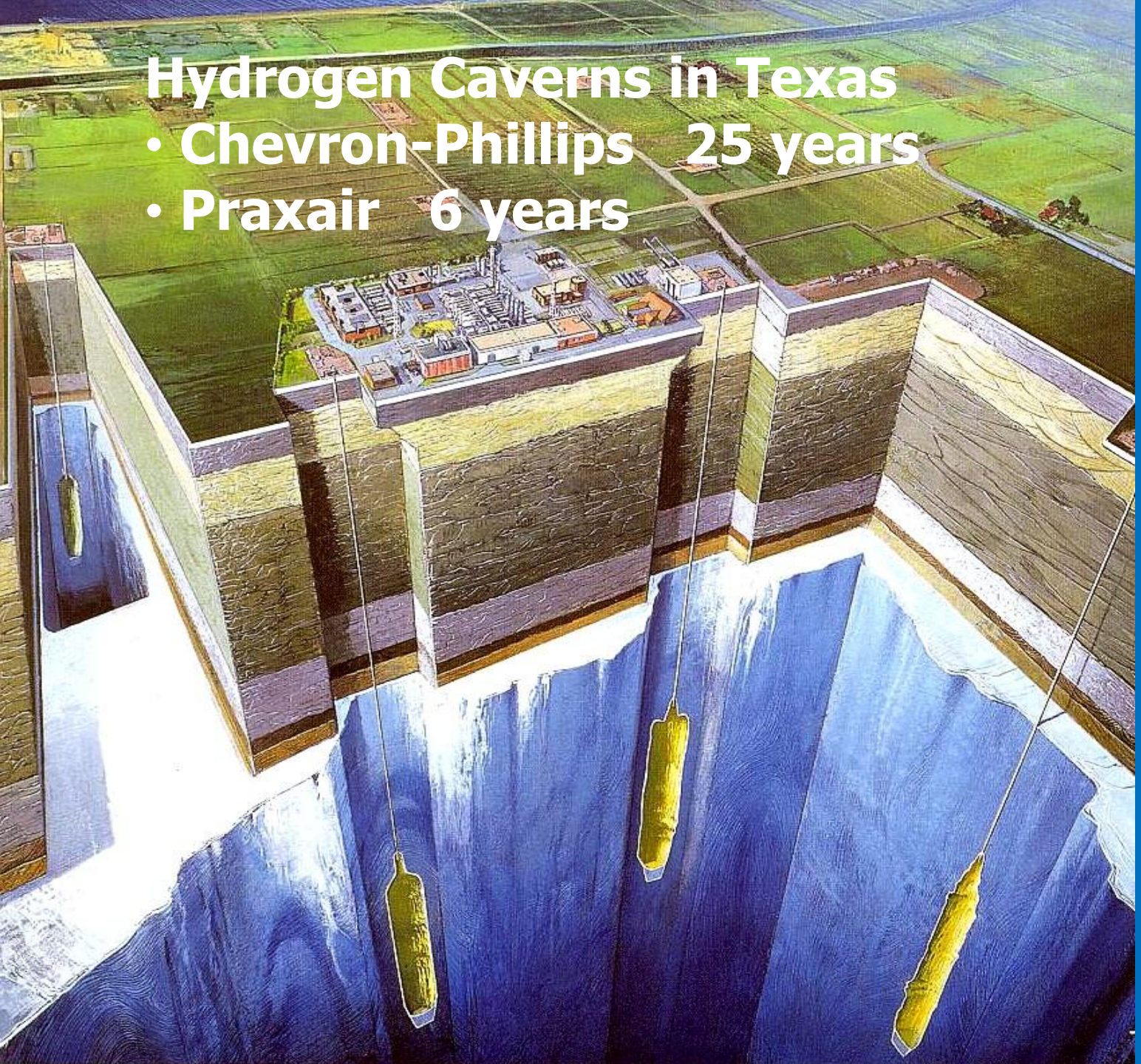
December 2019
World's first liquefied hydrogen (LH2) carrier: Kawasaki, in Japan

- " Suiso Frontier "
- HySTRA demonstration project
- 9,000 km from SE Australia to Kobe, Japan



Wind Potential ~ 10,000 GW

12 Great Plains states



Domal Salt Storage Caverns

Each:

90 GWh

$ 15 million capex

$ 0.20 / kWh

Global total 2017 = 103 GWh / year (Bloomberg)
Global total 2021 = 278 GWh / year

- **Hydrogen: 1 salt cavern @ $ 15-20 million = 90 GWh**
- **Ammonia: 1 liquid tank @ $ 15-20 million = 200 GWh**

’09 ARPA-E “Grids” Goal: $100 / kWh

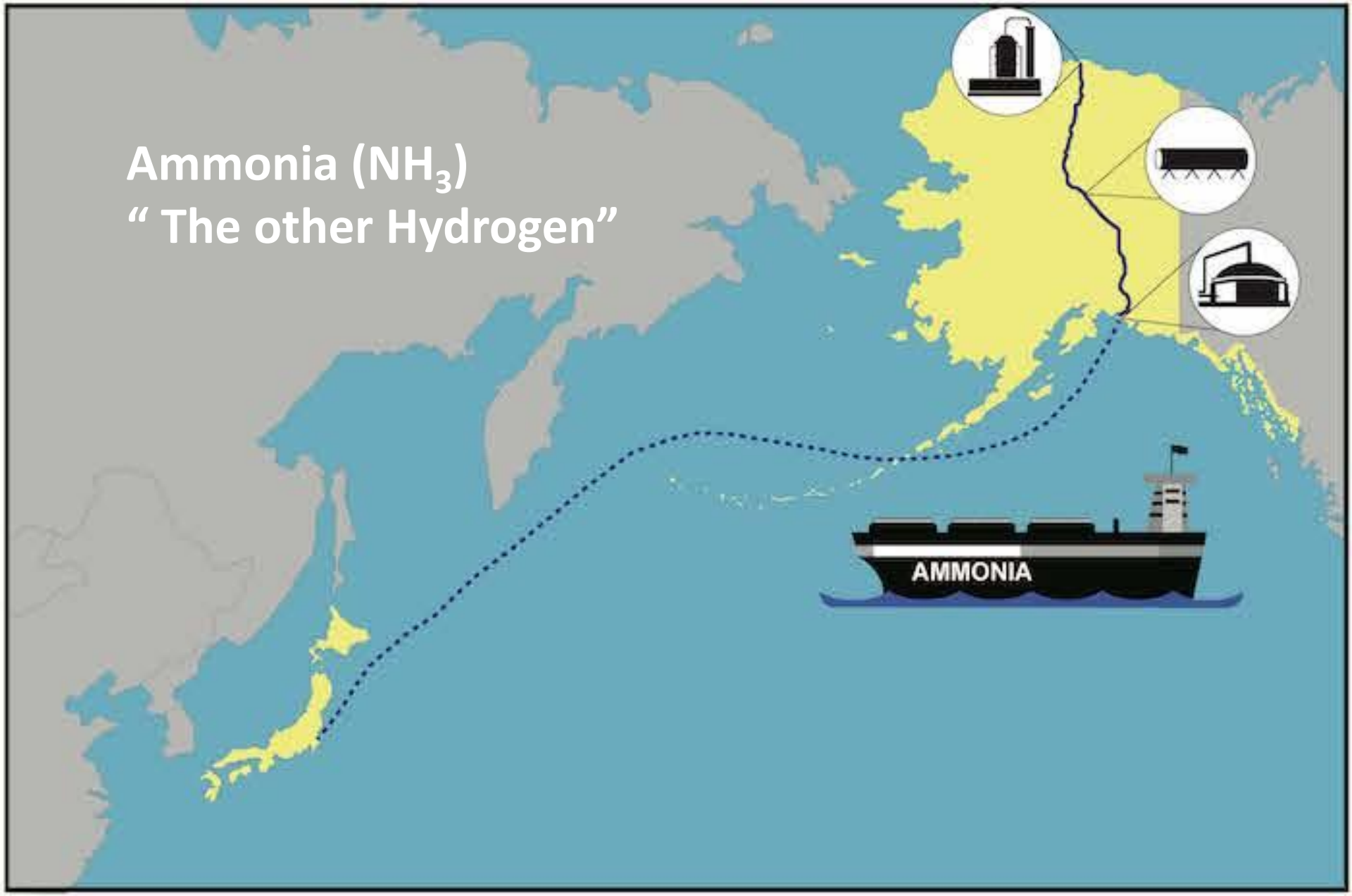
Total storage = 380 GWh

“Atmospheric” Liquid Ammonia Storage Tank (Corn Belt)

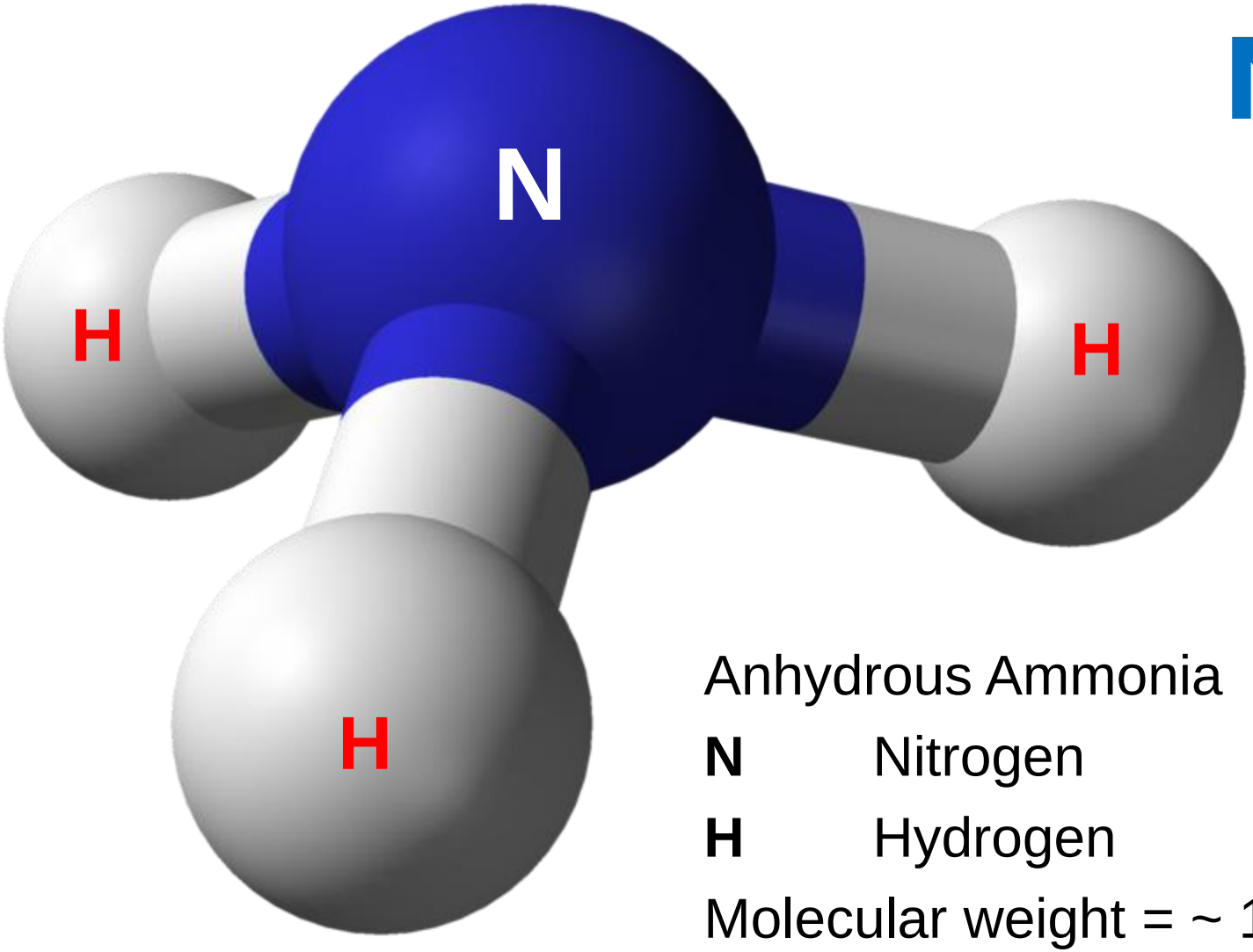
-33 C 1 Atm

Each: 30,000 Tons, 190 GWh $ 15 M turnkey

$ 80 / MWh = $ 0.08 / kWh capital cost



ANS gas-to-NH_3 to Japan, world markets



NH_3

Anhydrous Ammonia **NH_3**

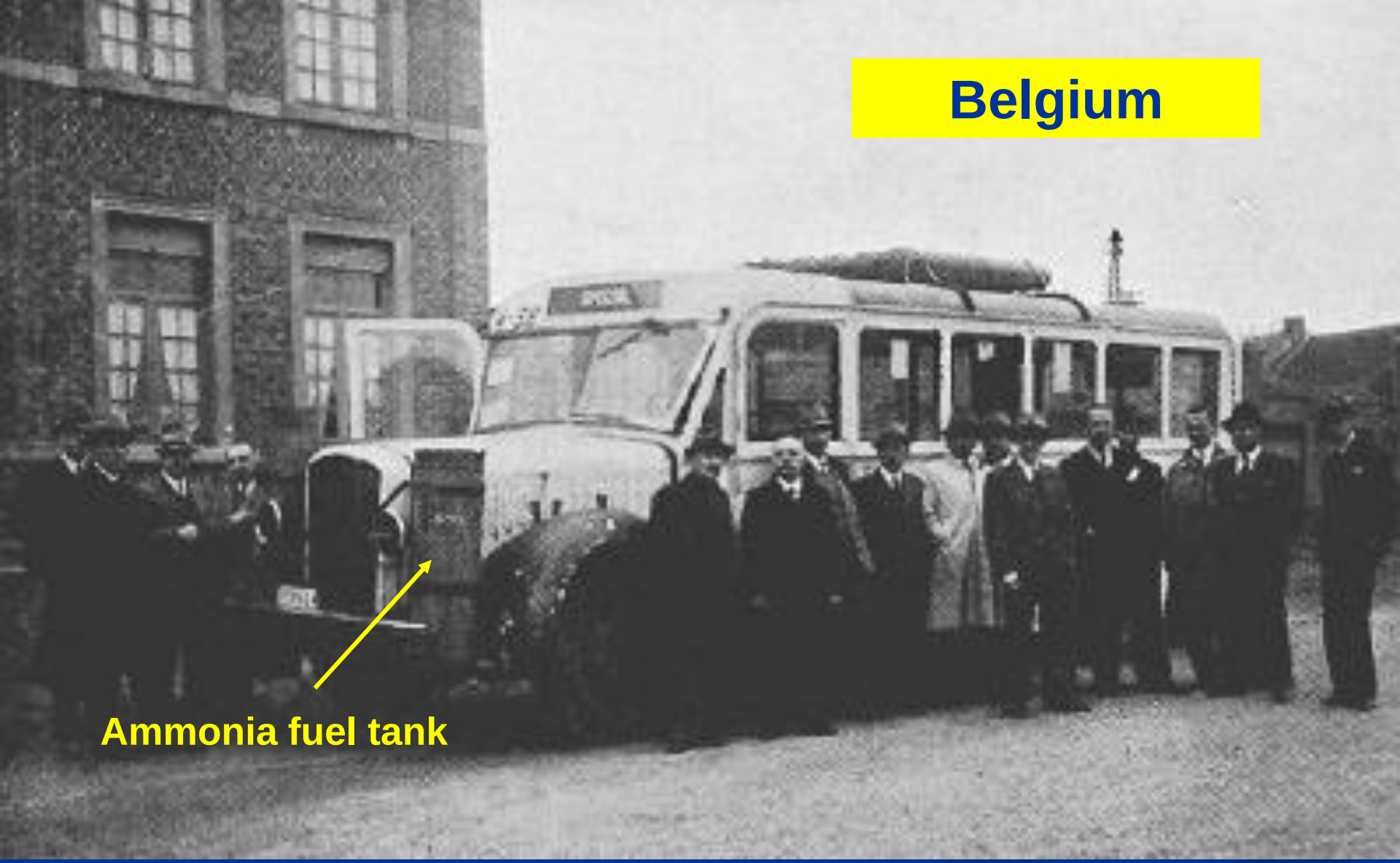
N Nitrogen

H Hydrogen

Molecular weight = ~ 17

18% **H** by weight: “other hydrogen”

$NH_3 + O_2 = N_2 + H_2O$



Ammonia Fueled Bus: Thousands of Problem-free Miles

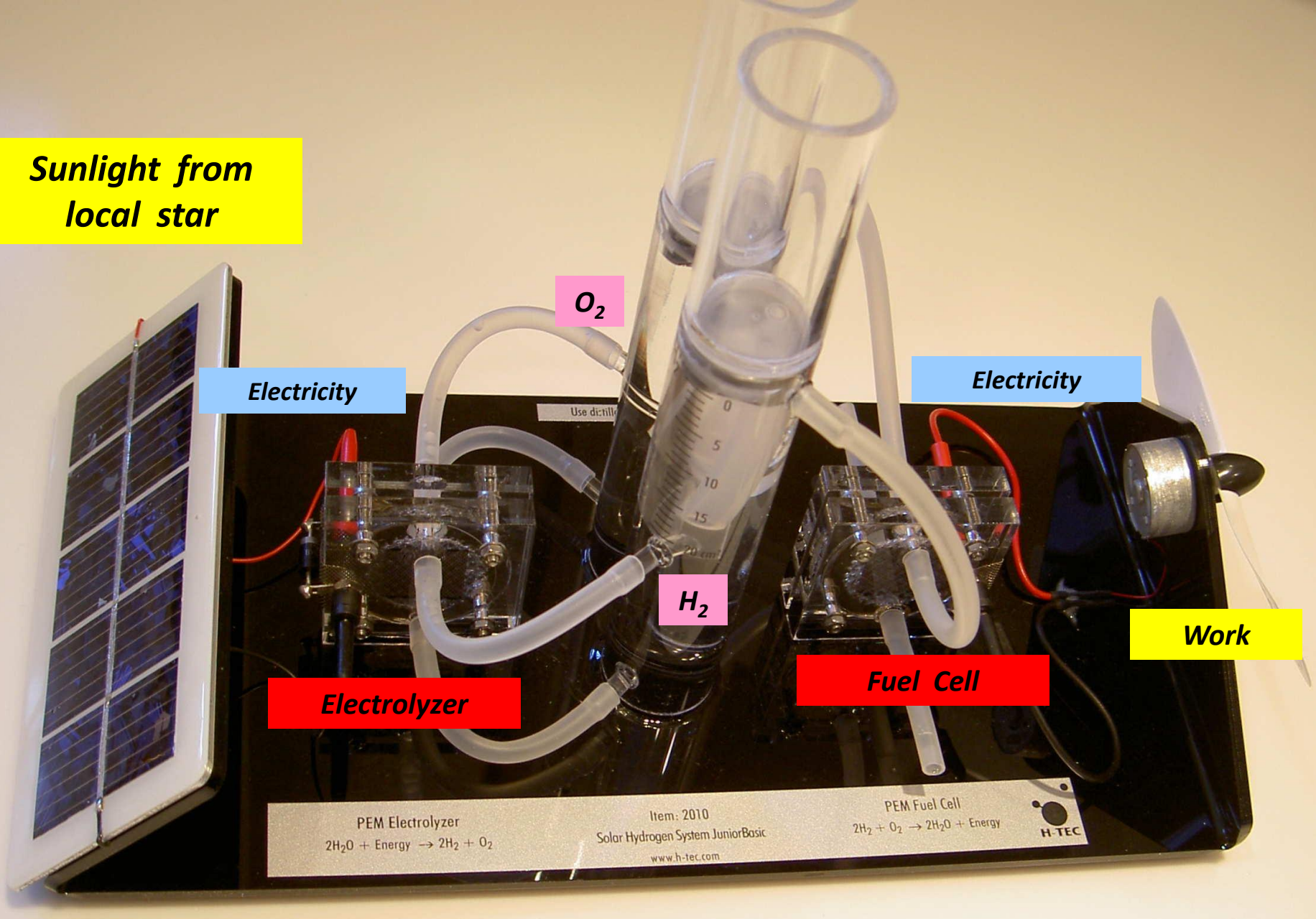
1943

X-15 rocket plane: NH3 + LOX fuel

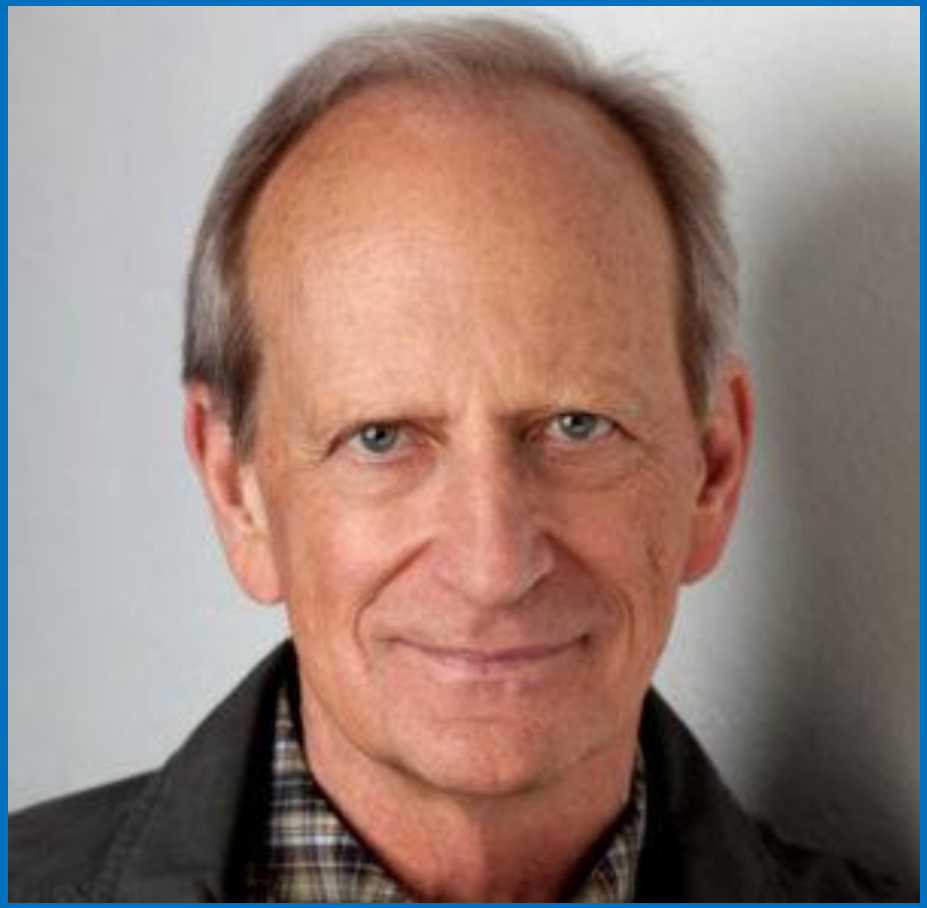
Mach 6.7 on 3 Oct 67

199 missions

1959 - 68



Solar Hydrogen Energy System



Earth Day April 22

Denis Hayes, CEO
Bullitt Foundation, Seattle

- **Founder, organizer, Earth Day 1970**
- **Engineering professor, Stanford**
- **Director: SERI → NREL**
- **CEO, Bullitt Foundation, Seattle**
- **Inspiration: Bullitt Center, Seattle**

Innovation !

Look, Ma, no stacks !

Hydrogen-fueled cruise ships,

running on renewable energy, zero emissions ?

Could Hydrogen help us operate Juneau entirely on CO_2-emission-free energy ? How ?

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