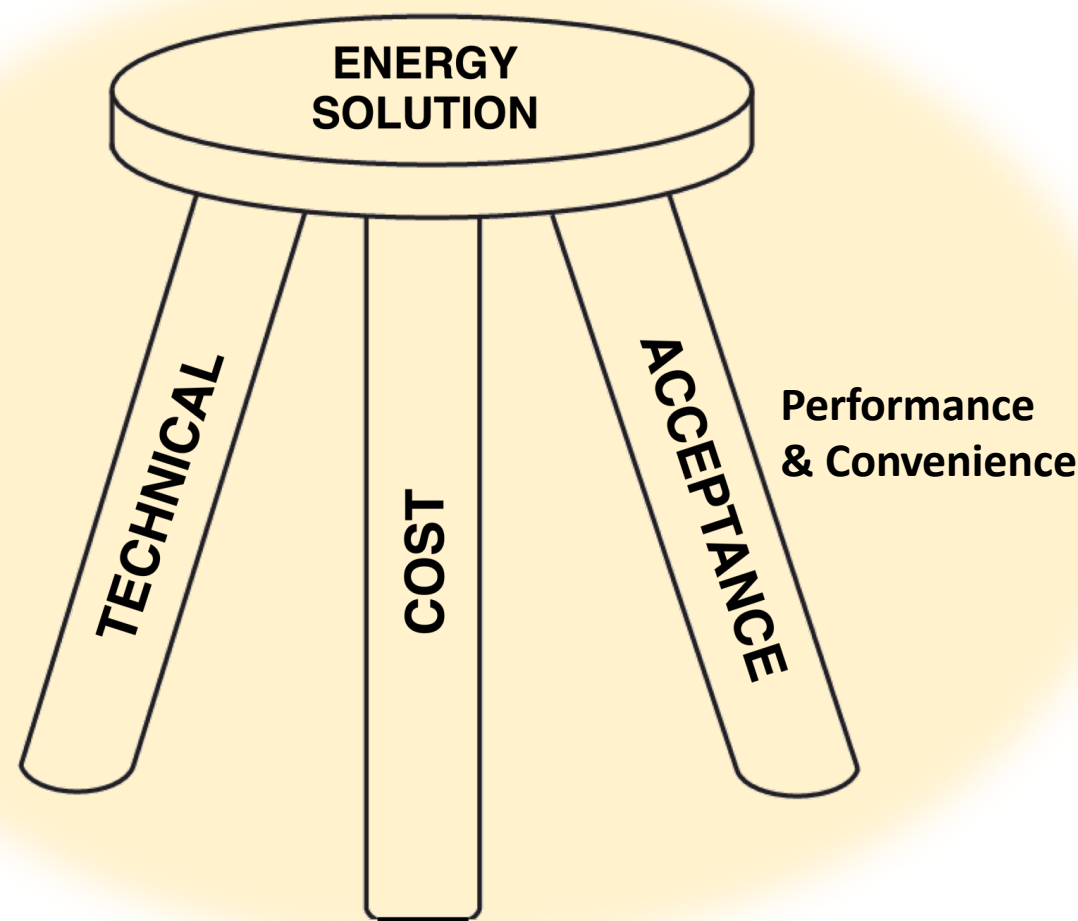


The Path From Fossil Fuels to Clean Energy

1. Identify Clean Energy Replacements

To convince people to switch from petroleum to Clean Energy, replacements must:

- Be technically mature (high TRL)
- Similar or lower cost
- Provide the same (or better) performance and convenience



Three Criteria for Clean Energy Solutions

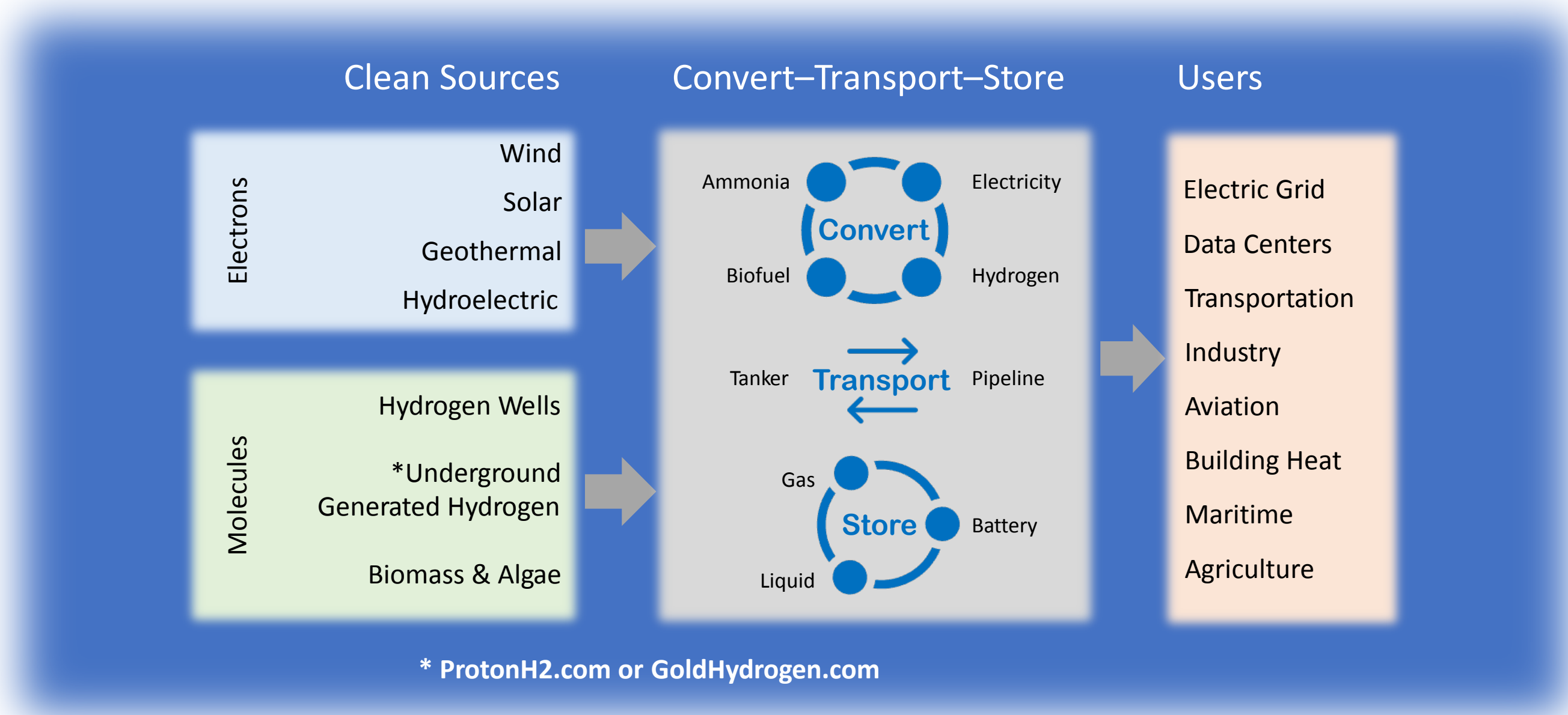
Fuels That Meet Our Three Criteria

Use	Electricity	Hydrogen	Biofuel	Key Discriminator
Electric Grid	✓			
Data Centers	✓	✓		Technical & Cost
Transportation	✓	✓		Performance & Convenience
Industrial Heat		✓		Technical
Aviation		Short Range ✓	Long Range ✓	Technical
Building Heat	New Construction ✓		Existing Buildings ✓	Cost
Maritime			✓	Technical & Cost

- Biofuel may be needed to obtain the energy density needed for some uses like ships & long-distance aviation
 - Although biofuel contains carbon, that carbon was pulled from the atmosphere by plants making biofuel carbon-neutral

2. Creating a Clean Energy market

- o Virtually no market exists, so we must create one for each project
- o Bringing together sources, infrastructure, users, and funding
 - o At the same time
 - o At the same scale
 - o For each project



3. Hydrogen Cost-Price Analysis

- o Where does hydrogen need to be priced to compete?
 - o It depends on the use – diesel, gasoline or natural gas
- o For natural gas – same cost per BTU
- o For transportation, it depends on the vehicle type
 - o Each vehicle type has a different “Efficiency Ratio”
Efficiency Ratio = Hydrogen MPkg ÷ Petroleum MPG
 - o Four Types (efficiency categories)
 - o LD/MD Gas – LD/MD Diesel
 - o HD Diesel Local – HD Diesel Highway

50-mile Delivery Cost	ROI (\$/kg)	OPEX (\$/kg)	Total Cost (\$/kg)
H ₂ Delivered (Gas)	\$1.25	\$2.65	\$3.90*
On-Site Electrolysis	\$4.23	\$4.52	\$8.75

$$\$5.00 / \text{kg} - \$3.90 / \text{kg} = \$1.10 / \text{kg}$$



Sources that can meet the price target

- Natural Hydrogen
- H₂ from old petroleum wells
 - ProtonH2.com process
 - GoldHydrogen.com process

Target Prices – Hydrogen for Transportation				
Class	LD/MD Gas	LD/MD Diesel	HD Diesel Local	HD Diesel Highway
Petrol. \$/gal	\$3.00	\$3.35	\$3.35	\$3.35
Vehicle Efficiency Ratio	2.5	1.9	1.5	1.1
Target Price \$/kg	\$7.50	\$6.37	\$5.00	\$3.69
H ₂ Transport Cost \$/kg	\$3.90	\$3.90	\$3.90	\$3.90
H₂ Must-Cost at source	\$3.60	\$2.47	\$1.11	(\$0.23)

Ratio = MPkg ÷ MPG

Implies Geologic Hydrogen

Hydrogen Price Target to Replace Natural Gas To Provide the Same Cost per BTU	
Item	Value (at H ₂ Source)
Nat Gas cost per 1,000 SCF	\$10.00
kg H ₂ equiv. to 1,000 SCF Nat Gas	8.03
Price per kg H₂ equiv. to CH₄	\$1.25
Pipeline cost OPEX + ROI (\$/kg)	\$0.20 to \$0.80
Hydrogen Must-Cost at source (\$/kg)	\$1.05 to \$0.45

Implies Geologic Hydrogen

Take-Aways:

- Sources of hydrogen must be developed that cost between 45¢ to \$3.60 per kg at the source
- On-site electrolysis can't compete