Hydrogen Roadmap
Future of Transportation – Part 2
Alternative Fuels – Efficiency & Safety

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W|EPC Key Takeaways

- ***Trillions* Or *Billions* In Renewable Energy – Vehicles Decide?**
  - A Carbon Neutral transportation network could require significant capital spending for a new renewable energy production and distribution systems.
  - Some renewables (e.g. Solar and Wind energy) are variable daytime resources not available during peak energy demand. Hydrogen, Methanol, and Ammonia from electrolysis (eFuels) can be utilized to store this energy.
  - A vehicle's efficient use of that energy will determine the required energy production and supporting infrastructure costs.

- **BEV Energy Efficiency Is Unchallenged**
  - Battery Electric Vehicle's (BEV's) are ~3-10x more efficient in the use of energy across nearly all vehicle segments. (page 5, 6)
  - Real world conditions (i.e. AC, weight, aerodynamics, temperature of the battery, high speeds, etc.) limit BEV efficiency in different regions.
  - Vehicle batteries can lose up to ~30% of their storage capacity by ~100k-150k miles. The cost to replace a semi-truck battery may be ~$100k. Long-haul truckers can average more than 100k miles a year.

- **Hydrogen Fueling Networks: Risks & Potential Legislation**
  - U.S. Hydrogen fueling station *spacing* is currently determined by NFPA-2 (Flammability), which has a narrow scope relative to international standards.
  - **Lessons From Canada:** Under *relatively* similar dynamics, safety issues (Sunrise Petroleum, etc.) led Canada to materially shift propane fueling regulations, largely at the expense of early adopters. We see similar regulatory uncertainty as a potential risk for H2 fueling infrastructure.
  - ***Canadian Propane Comp:*** Applying Canada's revised Propane Fueling regulations to existing US fueling infrastructure highlights the potential hurdles in play: *a 1.0psi pressure wave from 250kg of H2 storage could cause damage over a ~50kft^2 area, roughly 2x footprint of the avg. US gas station (~28kft^2)* – bringing an assessment of the surrounding environment into play (buildings, schools, homes, etc).
  - However, we note the rate and (potentially) limiting impact of H2 dispersion is still in debate. (page 11, 12)

W|EPC Rankings – Fuels vs Fuel Cells From Current Available Tech & Pricing

Power System	Vehicle Range	Energy Efficiency	Safety	Emissions		Implementation Cost			Average Score
				TTW[4]	WTW[5]	Feedstock	Gas Station	Vehicle Production	
Methanol FC [1]	4	3	4	4	4	4	4	2	***3.6***
Diesel	5	2	4	1	2	5	5	5	***3.6***
Biofuels (FAME) [3]	4	1	5	4	5	3	2	4	***3.5***
BEV [2]	2	5	3	5	2	4	2	4	***3.4***
CNG Hybrid [1]	5	2	2	3	5	5	2	3	***3.4***
Hydrogen FC [1]	3	3	2	5	2	3	1	3	***2.8***
Ethanol FC	2	1	3	2	5	4	4	1	***2.8***
Ammonia FC [1]	2	2	1	3	3	4	3	1	***2.4***

1) Assumes from Natural Gas
2) Assumes from USA electric grid
3) Assumes Blended with Diesel
4) Tank-to-wheel
5) Well-to-wheel

Score rankings: 5=Best & 1=Worst

Part 2 Of Our Hydrogen Transportation Series Is Focused On Energy Efficiency And Safety.

Source: Company & Regulatory Filings, W|EPC Analysis

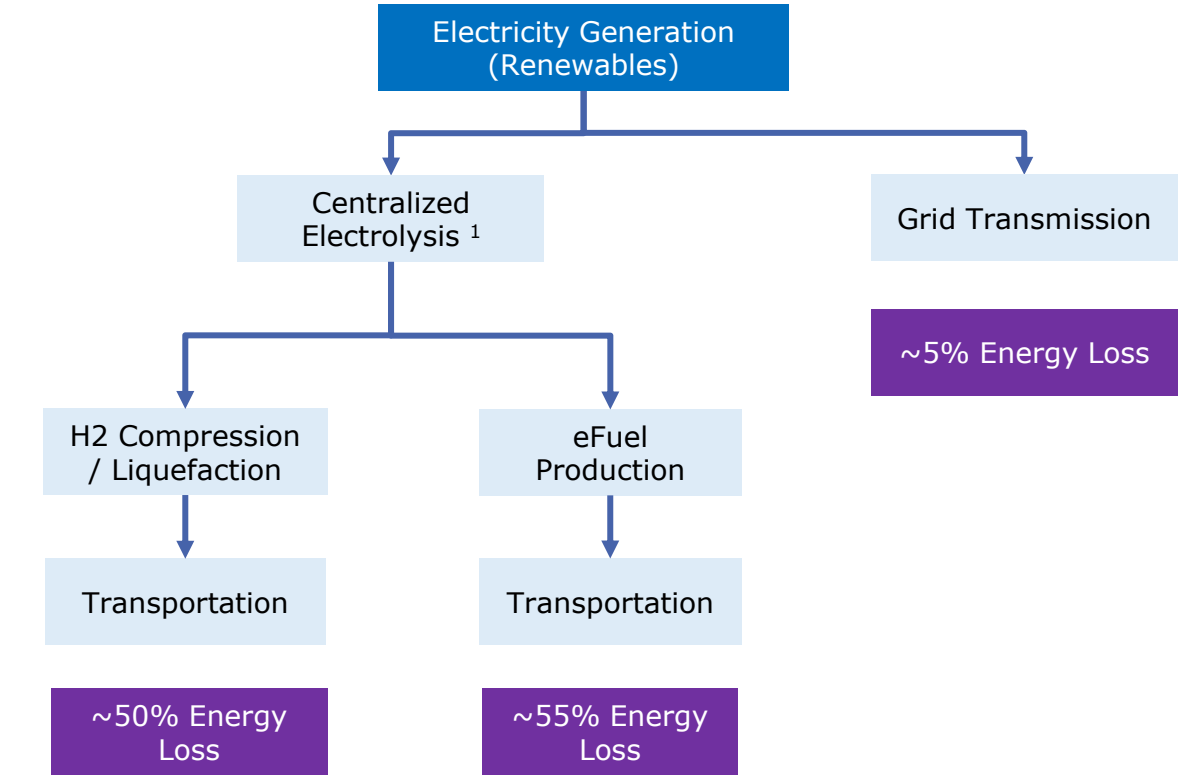
Vehicle Transportation – Efficiency

Production Efficiency – Grid To Tank

Overview

- **Industry Focus:** Compressed hydrogen is seen as the way to store excess renewable energy and power vehicles.
- **Why Does That Matter:** *Hydrogen loses 70-85% of it's energy from upstream through the wheels, like an Internal Combustion Engine running on Diesel.*
- **What's The Impact**: Electric vehicles are efficient because they provide efficient use of energy and are commercially available.
- **Key Thoughts & Takeaways**: Energy loss will be a concern for renewable power until large scale applications are more thoroughly developed..

Energy Loss To Vehicles

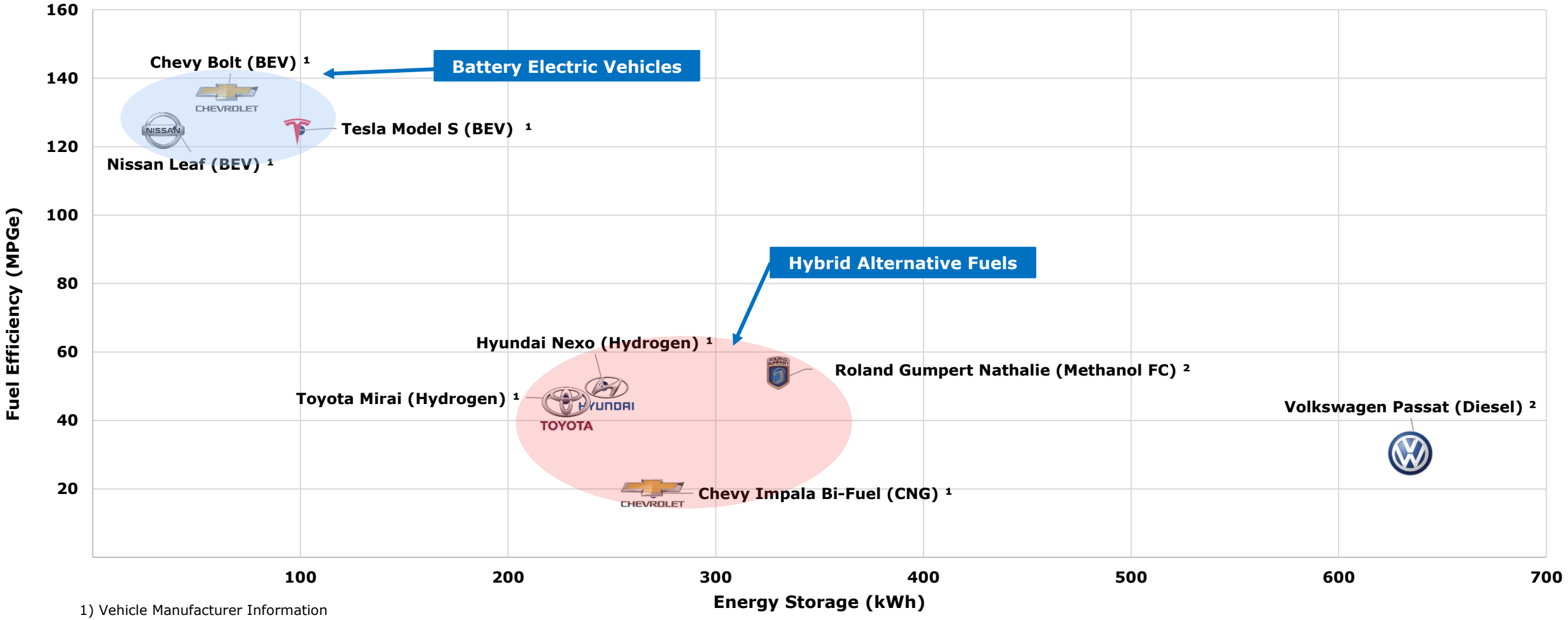


1) Electrolysis on site at the gas station could save up to 10-20% energy loss

Small Vehicle BEVs Are ~10x More Efficient Than eFuels And Hydrogen Using Power From The Grid.

Source: Company & Regulatory Filings, W|EPC Analysis

Vehicle Efficiency vs Energy Storage – Small Vehicles

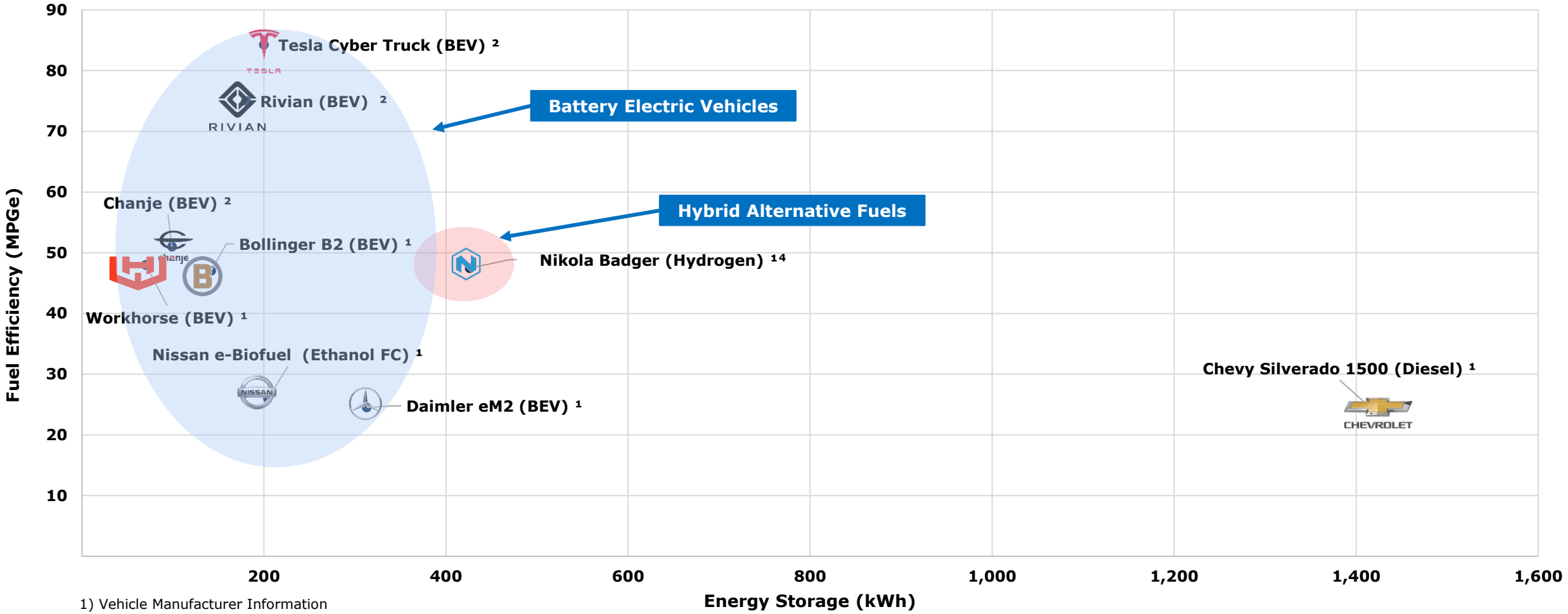


1) Vehicle Manufacturer Information
2) 3rd Party Information
3) W|EPC Estimate

BEVs Are 5x More Fuel Efficient Than Diesel In Small Vehicle Applications.

Source: Company & Regulatory Filings, W|EPC Analysis

Vehicle Efficiency vs Energy Storage – Mid-Sized and Truck

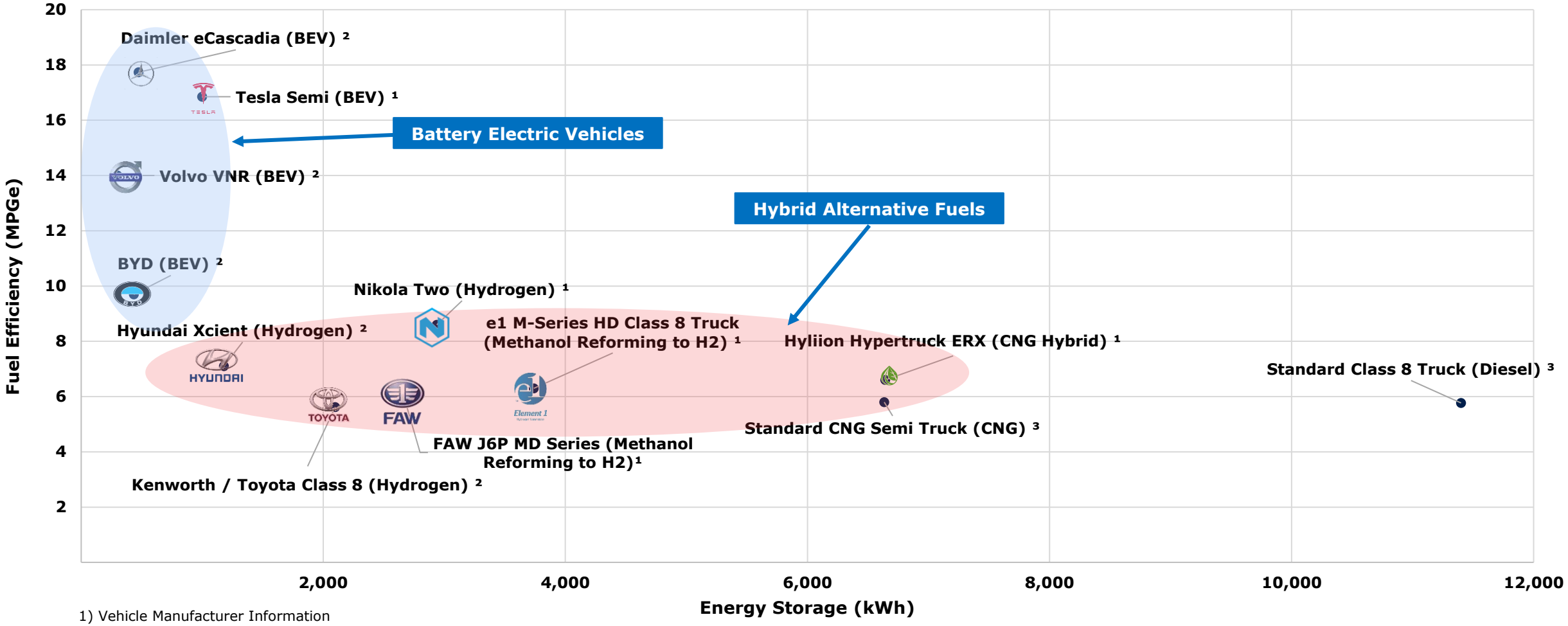


1) Vehicle Manufacturer Information
2) 3rd Party Information
3) W|EPC Estimate
4) Production and related range data may be in question

BEVs Dominate The Mid-Sized Space But Energy Dense Fuels Have An Opportunity To Grow.

Source: Company & Regulatory Filings, W|EPC Analysis

Vehicle Efficiency vs Power – Semi Trucks



1) Vehicle Manufacturer Information
2) 3rd Party Information
3) W|EPC Estimate

BEVs Are Only 3x More Efficient Than Diesel In Larger Applications.

Source: Company & Regulatory Filings, W|EPC Analysis

Vehicle Transportation – Safety

OSHA Ratings

Overview

- **The Bottleneck:** Gas station will need to accommodate new fuels that are passenger friendly and easy to handle.
- **Why Does That Matter:** *OSHA identified hazardous products will become uneconomical in public spaces due to increased costs.*
- **What's The Impact**: Ammonia's health concerns and CNG/Hydrogen's flammability issues create roadblocks to public implementation.
- **Key Thoughts & Takeaways**: Biofuels and Methanol are liquids and have a better safety rating that will reduce cost at the pump by using existing infrastructure.

OSHA Material Safety Data Sheet Scores

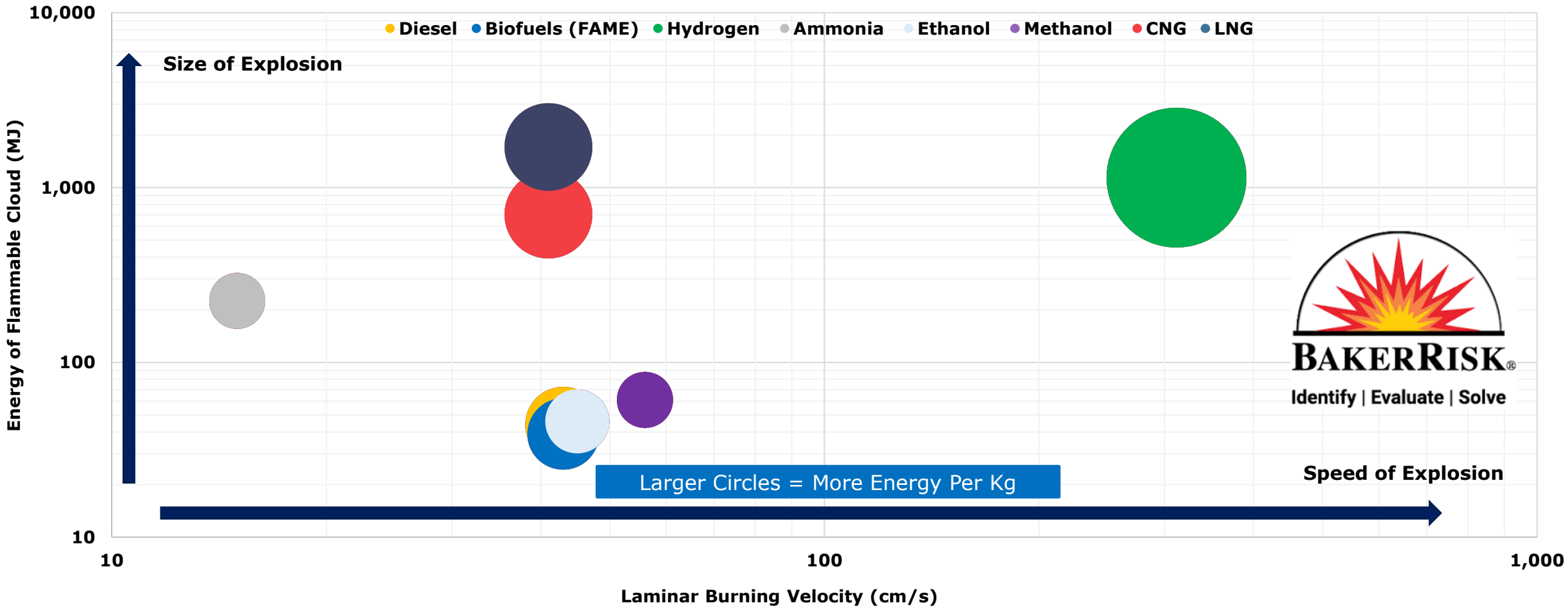
Products	Health Hazard	Fire Hazard	Reactivity
Diesel	1	2	0
Biofuels (FAME)	0	2	0
BEV	1	1	1
Hydrogen	0	4	0
Ammonia	3	1	0
Ethanol	2	3	0
Methanol	1	3	0
CNG	2	4	0

High Public Safety Risk
(4=Worst & 0=Best)

Hydrogen, CNG, and Ammonia Are All A Vapor And Pose The Highest Public Risk.

Source: Company & Regulatory Filings, OSHA, W|EPC Analysis

Fuel Analysis From Baker Risk



1) Conditions for these fuels include: Methanol – 70F, 15psi, Ethanol – 70F, 15psi, Biodiesel – 70F, 15psi, Diesel – 70F, 15psi, Hydrogen – 70F, 250bar, Ammonia – 70F, 20psi, CNG – 70F, 250bar, LNG - -300F, 75psi

Hydrogen Has ~5x The Potential Force/Risk Relative To Other Fuels.

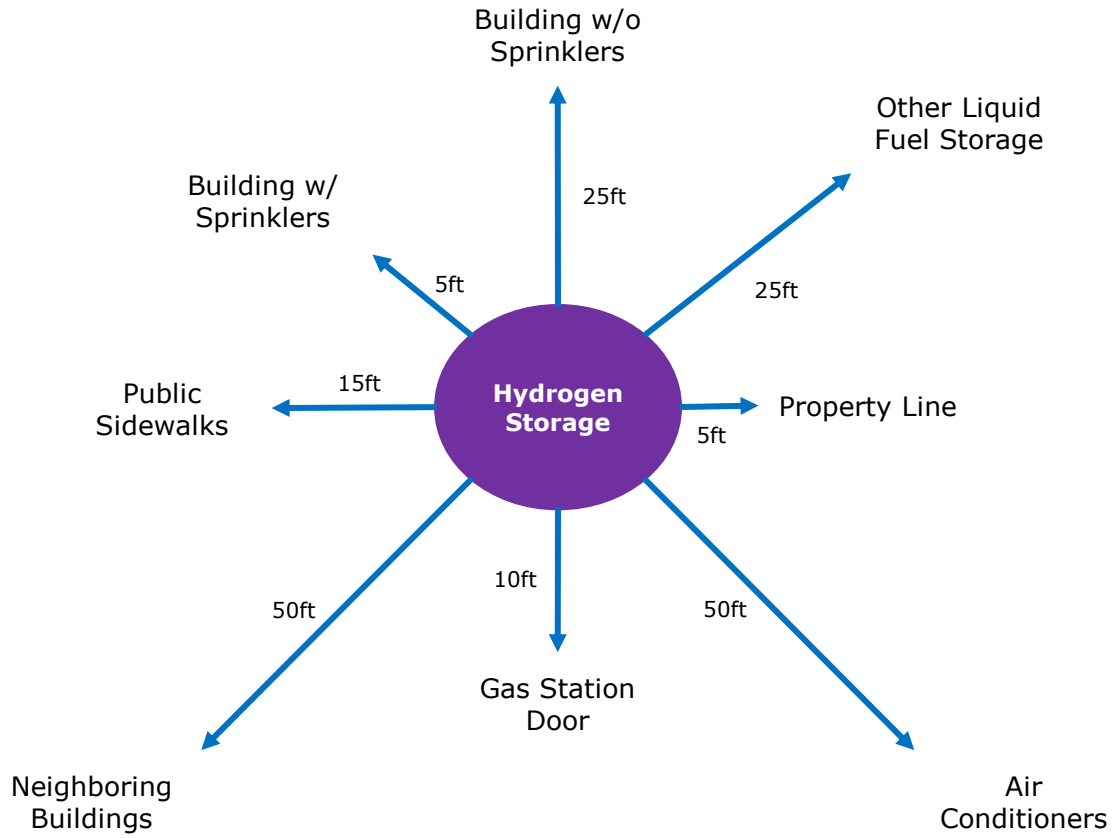
Source: Baker Risk

NFPA Spacing Considerations

Overview

- **What is NFPA:** National Fire Protection Association is an international nonprofit organization devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards.
- **Why Does That Matter:** CA's Hydrogen stations utilize the NFPA-2 guidelines to determine spacing and risks to public for fuel storage.
- **What's The Impact**: This spacing guideline does not consider the explosive potential of fuels, which in Hydrogen's case, is much larger than it's NFPA spacing.
- **Key Thoughts & Takeaways**: For Hydrogen, CNG, LNG, and Ammonia, spacing away from adjacent properties and public spaces will have to be considered to limit risk of vapor clouds and explosions.

Hydrogen NFPA Spacing Guidelines



Ignition Sources Only Have A 50ft Spacing In NFPA.

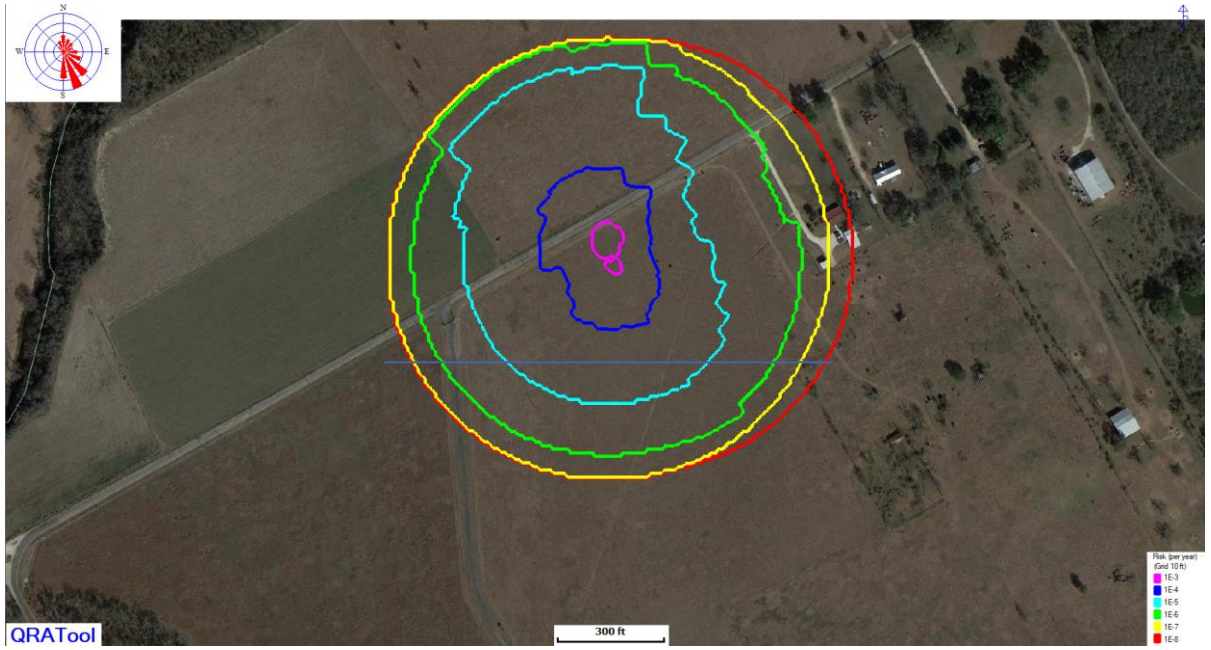
Source: Company & Regulatory Filings, OSHA, W|EPC Analysis

Ignition Contours From Baker Risk

Overview

- **What Are Ignition Contours:** These contours show how far potential ignition sources may be from the Hydrogen storage source.
- **How Are Contours Formed:** Contours change based on surrounding buildings, wind/weather, and product type.
- **What's The Impact**: Higher risks of the ignition of Hydrogen happens within the first 250 ft (Blue) of the storage and extends to ~750 ft (Red).
- **Key Thoughts & Takeaways**: *NFPA codes have a 50ft setback to ignition sources and a ~25ft setback for parked vehicles, which cause ignition on start-up.*

Risk Contours Of A Hydrogen Fueling Station



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Identify | Evaluate | Solve

Hydrogen's Ignition Source Can Extend 10x To 30x Beyond NFPA Spacing Guidelines.

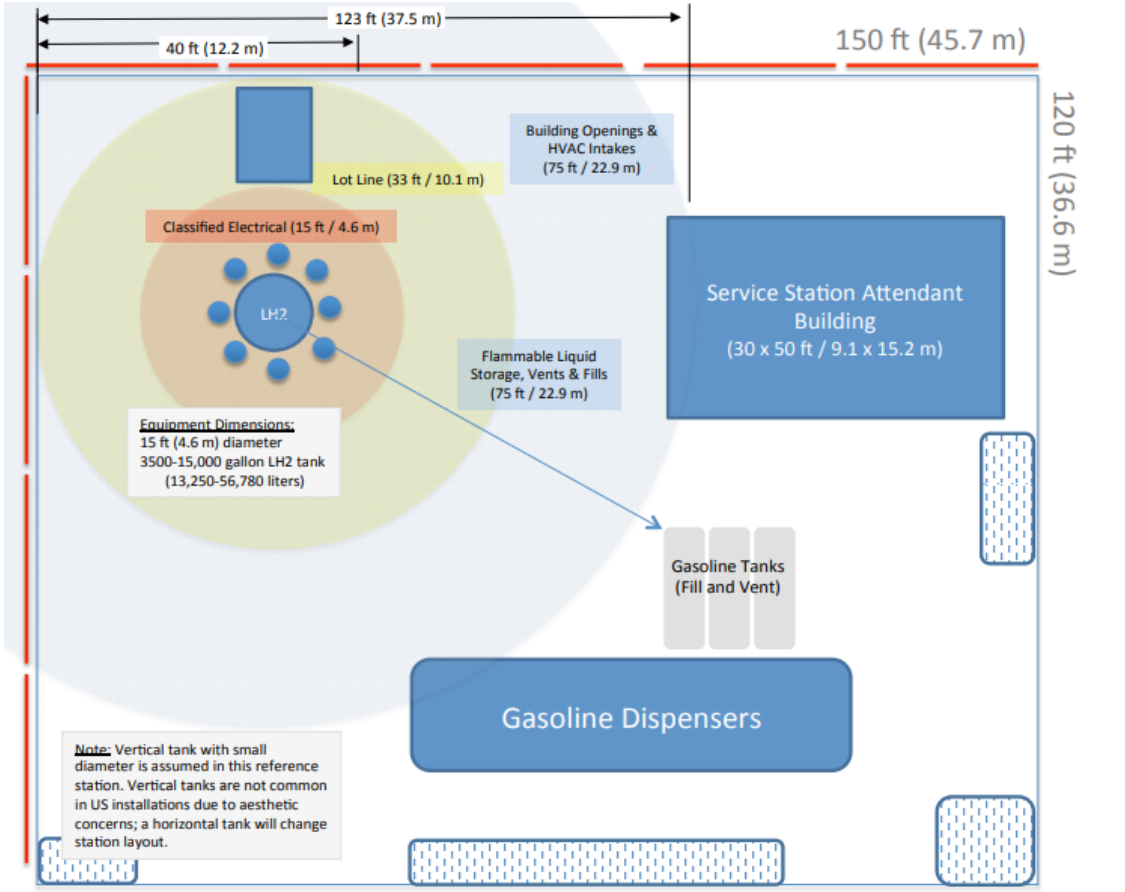
Source: Company & Regulatory Filings, OSHA, W|EPC Analysis

Comp - The Sunrise Propane Station

Overview

- **Our Focus:** Hydrogen fueling infrastructure is being built at a fast rate using the NFPA spacing guidelines.
- **Comparable Situation:** In 2008 the Sunrise Propane station in Toronto Canada exploded *resulting in fatalities, $5.3 million in fines, and a $23 million class action lawsuit by nearby residents.*
- **The Result**: The incident caused Canada to implement their Risk and Safety Management Plan that analyzes a 1psi explosive damage radius of Propane gas stations. *Many Propane stations couldn't comply with revised spacing requirements and were forced to shut down operations.*
- **Key Thoughts & Takeaways**: An average gas station's property size is ~28,000ft^2 (~180ft x 160ft). A 1psi pressure wave from an ignition of 250kg of Hydrogen could be ~50,000ft^2.

Hydrogen NFPA Radius (Property: 18,000 ft^2)

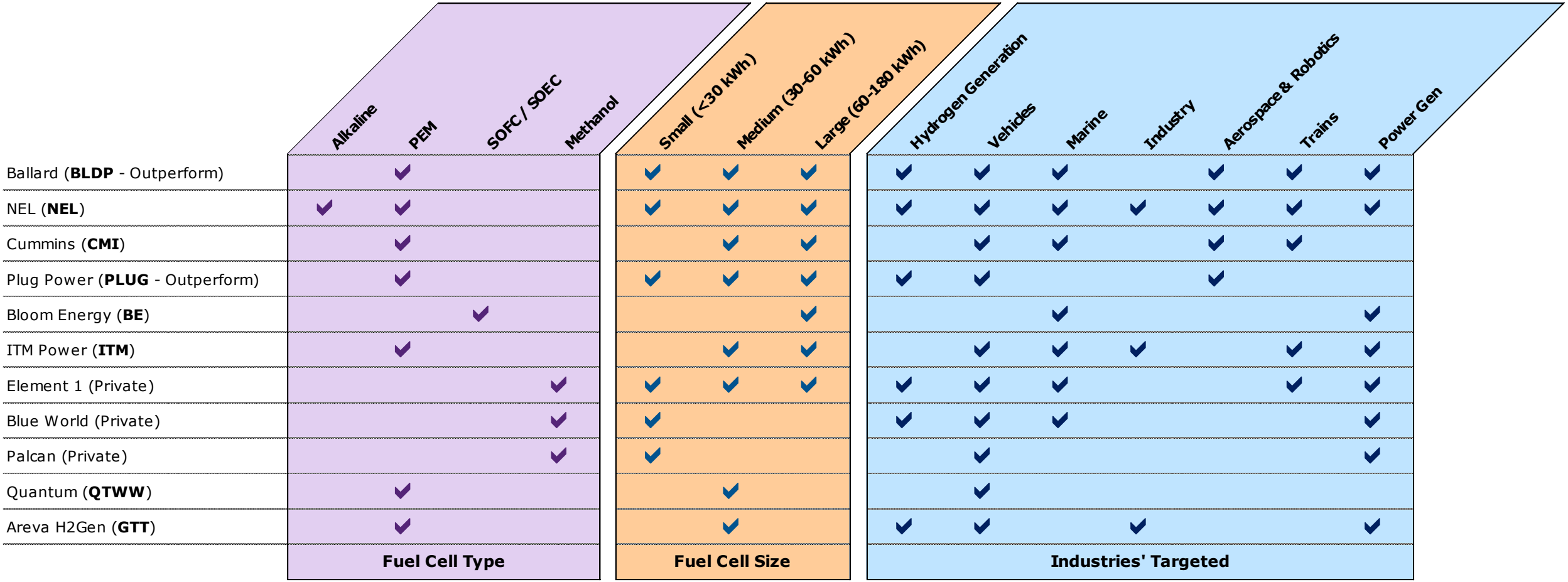


The 1psi Explosive Radius Of Hydrogen Can Be 2x The Size Of A Standard Gas Station.

Source: Company & Regulatory Filings, Sandia National Lab, W|EPC Analysis

Vehicle Transportation – Technology

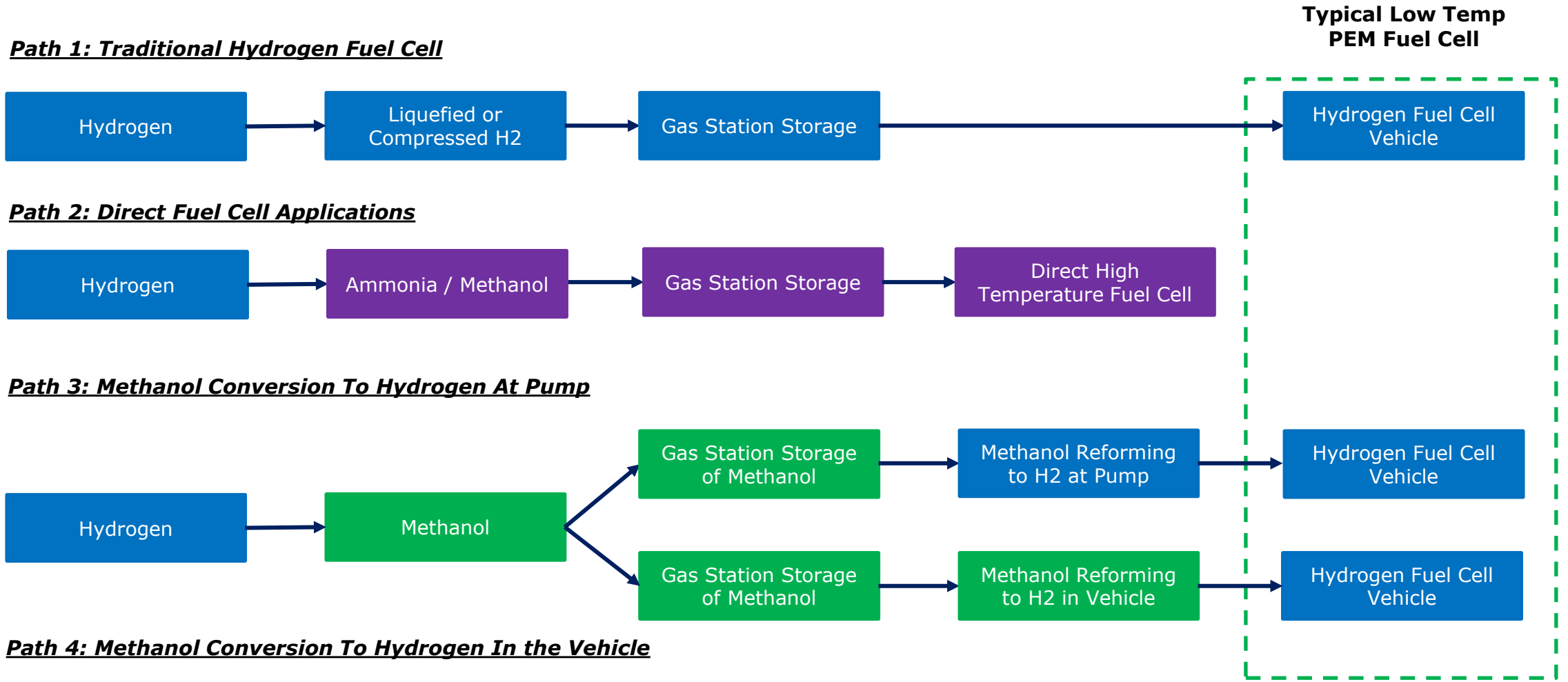
Fuel Cell Companies & Applications



The Hydrogen Fuel Cell Market Is Consolidating And Experiencing A Large Shift In Capabilities.

Source: Company & Regulatory Filings, W|EPC Analysis

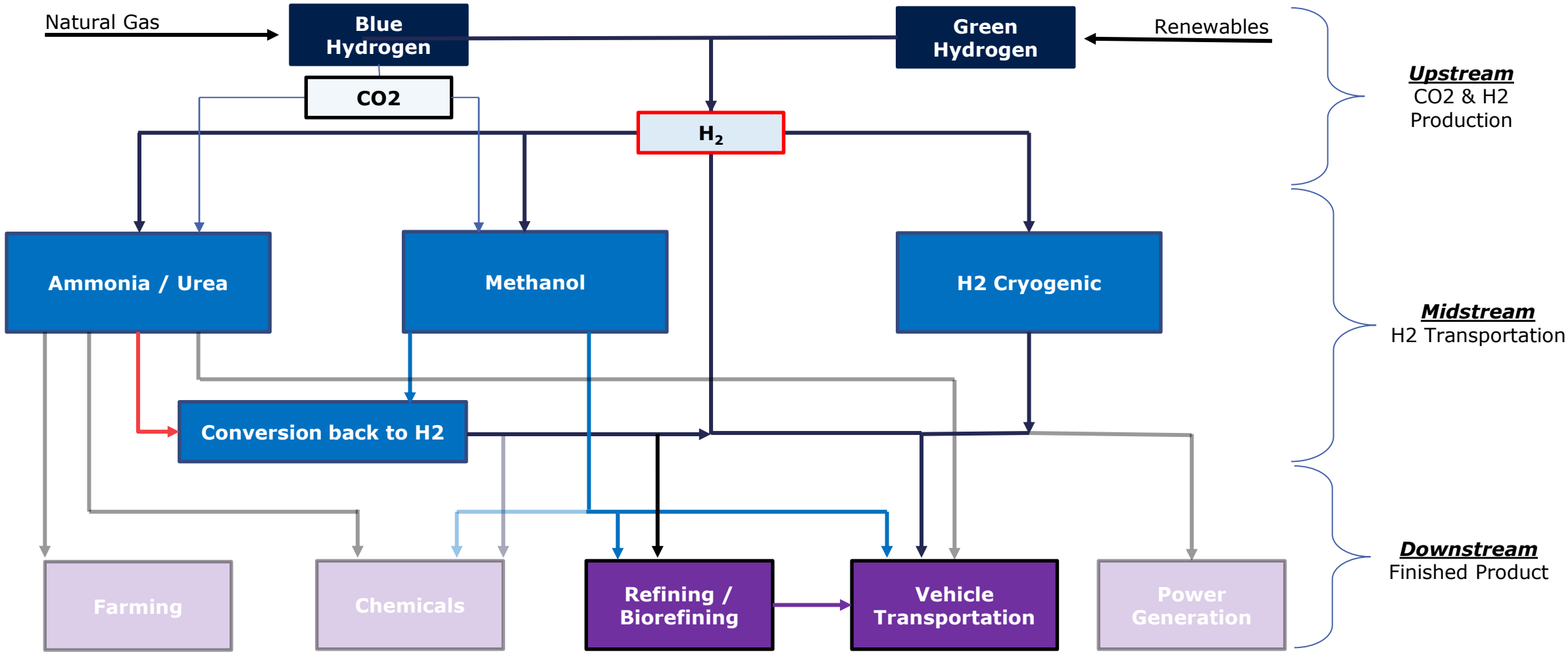
Hydrogen And Hydrogen Carriers Use In Vehicles



Of The 4 Typical Pathways For Fuel Cells, Low Temperature Fuel Cells Will Be Used In 3:4 Applications.

Source: Company & Regulatory Filings, Methanol Institute, W|EPC Analysis

Upstream, Midstream And Downstream Markets Of Hydrogen



Ammonia And Methanol Support A Hydrogen Economy After Conversion.

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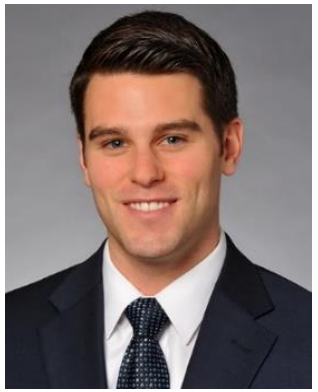

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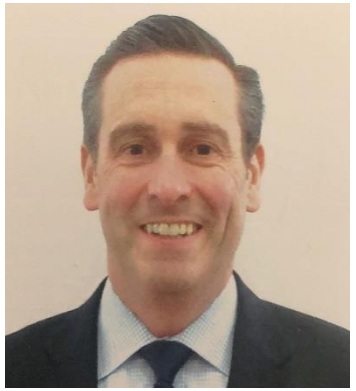

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