Lithium Car Batteries

The Competition

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Previous presentation on Li batteries for cars

- Environment
- Efficacy
- Cost

No exhaust pipe emission

Brine Ponds in Chile

Efficacy-EV

95% of all electric cars are still on the road

The other 5% made it home

Problems with cold charging

Infrastructure issues

Cost-EV

- Cost/mi can be significantly cheaper than fossil fuels (dependent on elec. source and timing)
- Replacement batteries are very expensive (offset by mileage savings?)
- Recent reports of batteries lasting > 400,000 km

The Competitors

- Hydrogen Fuel Cell
- ammonia Fuel Cell

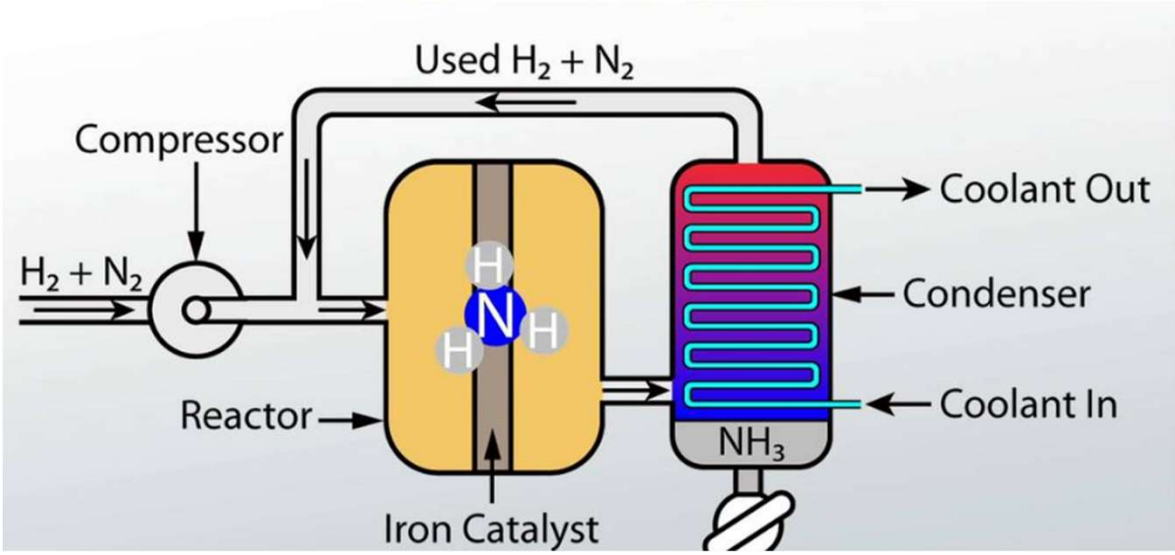
Hydrogen Production and storage

- Creating pure hydrogen for vehicles requires using a great deal of energy to "crack" a compound like natural gas (CH_4) into pure H_2, with CO_2 as a byproduct. (Most hydrogen today is derived from fossil fuels like natural gas.)
- Can also be created by electrolysis of water by electricity (either green energy or “grey” energy)
- Often stored at 10,000 psi and very cold temperature

NH_3 Production/storage

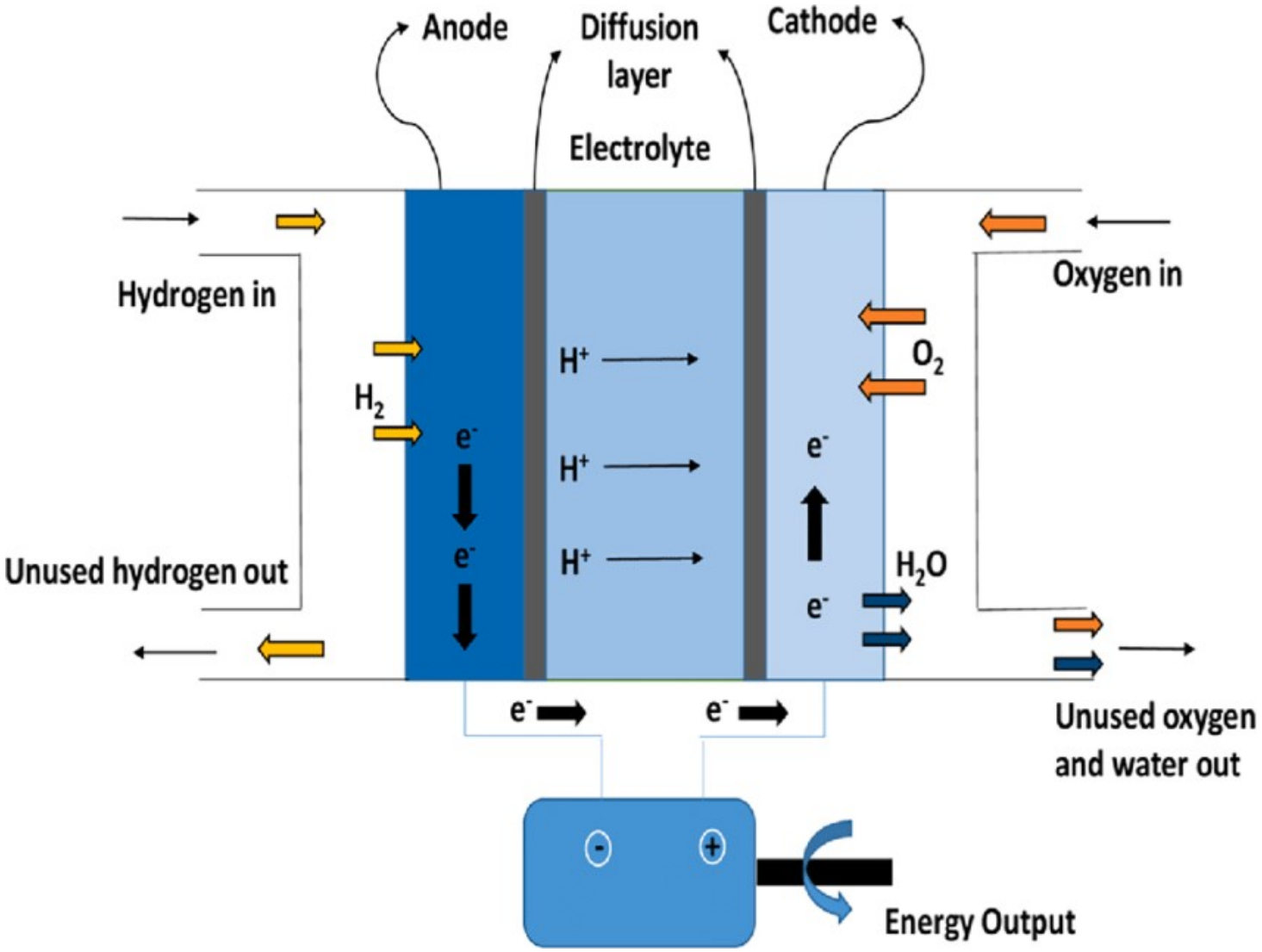
- Hydrogen and nitrogen are reacted together at high temperatures and pressures to produce ammonia, NH_3. However, the process is not a "green" process.

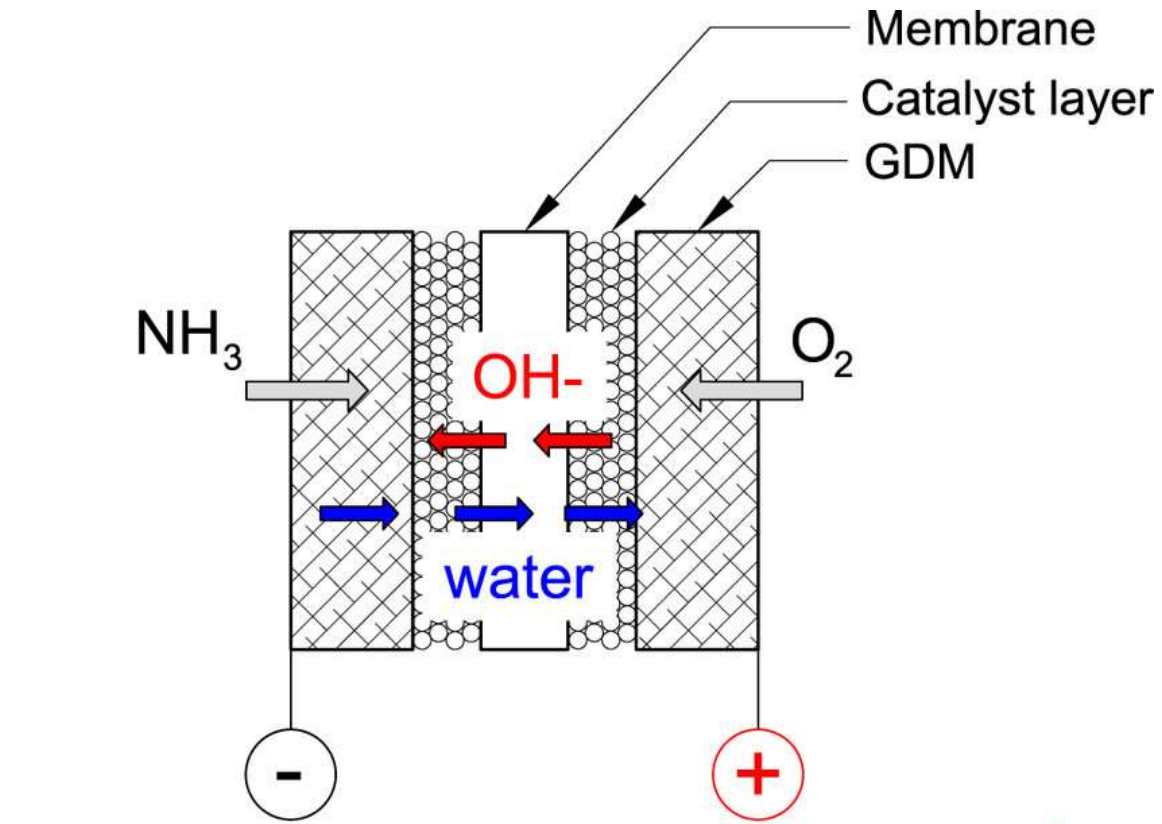
- Liquid ammonia can be stored state at 25°C and 150 psi in standard steel tanks



Hydrogen vs Ammonia

- Ammonia being a liquid under low pressure at ambient T, the infrastructure of fuel distribution and refueling should be much simpler and significantly less costly vs. the infrastructure for compressed hydrogen delivery and refueling.


Anode
Diffusion layer
Cathode
Electrolyte
Hydrogen in
Oxygen in
H_2
O_2
H^+
H^+
H^+
e⁻
e⁻
e⁻
e⁻
e⁻
e⁻
H_2O
Unused hydrogen out
Unused oxygen and water out
-
+
Energy Output

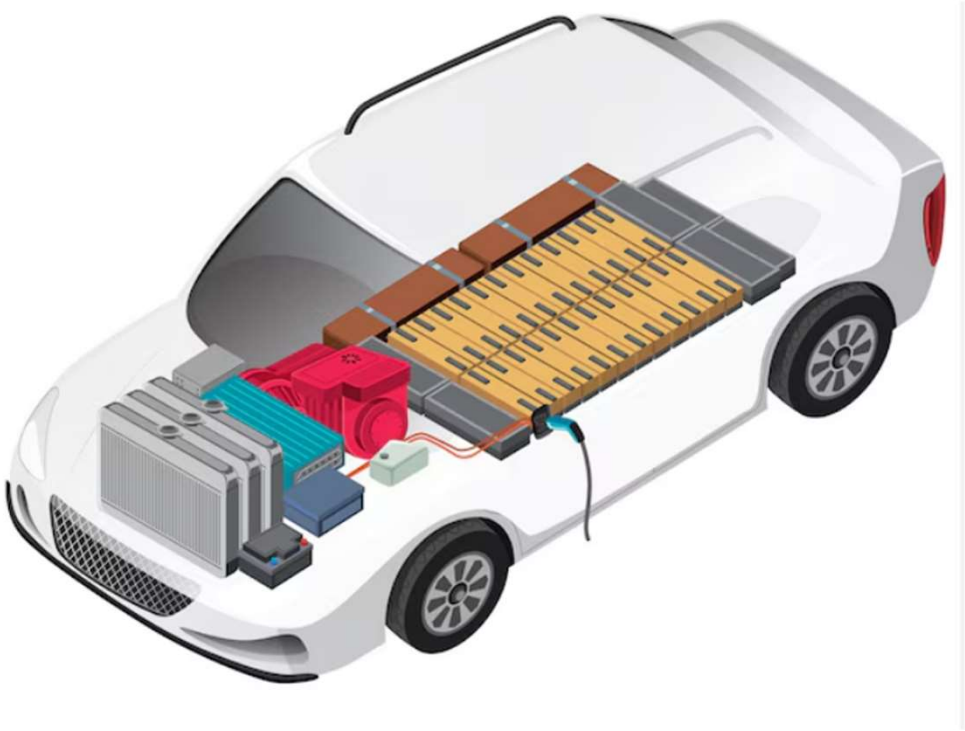


$2NH_3+6OH^- \rightarrow N_2+6H_2O+6e^-$ $O_2+2H_2O+4e^- \rightarrow 4OH^-$

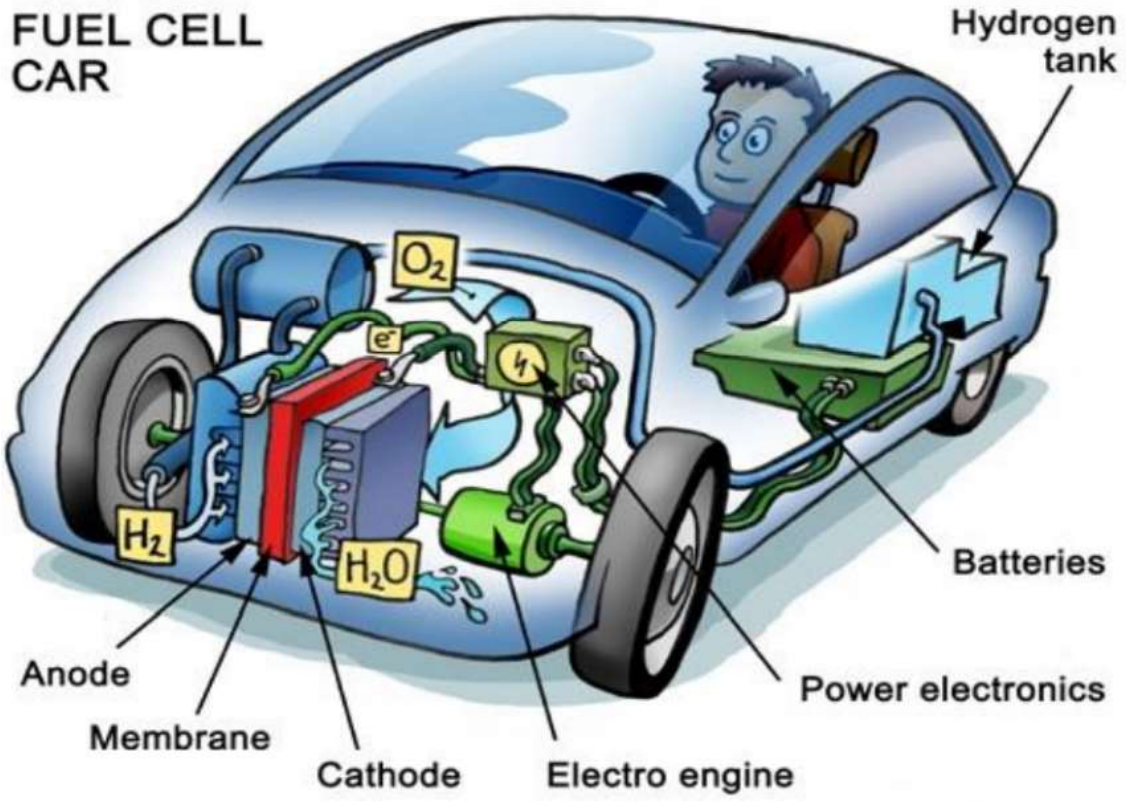
$4NH_3+3O_2 \rightarrow 2N_2+6H_2O$

EV Battery Weight

- On average EV batteries weigh around 454 kg (1,000 pounds),



Hydrogen/NH_3 Fuel Cell Car



Hydrogen Driving Range

- The first commercially available fuel cell cars came out in 2002, the Honda FCX Clarity in 2008 was the first car designed solely as a fuel cell vehicle, the Nexo was released in 2018, the Toyota Mirai in 2014
- The Hyundai website lists the Nexo range as 666km,
- Other hydrogen ranges are 300-400 miles,
- It is much, much more expensive to drive a hydrogen car a given distance than it is a EV or an ICE, and that's despite most Hydrogen now produced coming from fossil fuels, a cheaper system than electrolysis, in a process that produces greenhouse emissions.
- Hydrogen is not the answer

Ammonia cars

- Toyota owns 50% of a Chinese vehicle manufacturer, the GAC Group. In 2023 it launched its first ammonia-powered model, a four-cylinder car that produces 161 horsepower and a very small carbon footprint.

Advantages of Hydrogen/NH_3 vs. ICE

1. It is a clean fuel

- Hydrogen is a perfectly clean fuel, because the only waste it produces is water vapour/nitrogen.
- Hydrogen is obtained through electrolysis of water or cracking methane.
- Hydrogen defined as green is the only sustainable hydrogen because it is obtained through electrolysis of water powered by electricity produced from renewable sources. Grey hydrogen, on the other hand, uses fossil fuel sources, mainly natural gas, which produce greenhouse-gas emissions

Advantages of Hydrogen/NH3 vs. ICE

2. It uses more efficient technology

- The ICE uses only 20/25 % of the energy introduced and consequently 75/80% of the fuel is dispersed, producing heat.
- In the electric engine, 80% of the energy is used and only 20% of the energy dispersed. However, hydrogen must first be converted into electrical energy to power the engine which consumes 50% of the energy and so this 80% is halved, reducing the amount of energy used to 40% which is twice as much as an ICE.

Advantages of Hydrogen/NH_3 vs. Li EV

3. It is convenient for heavy transport and trains

- Require enormous, heavy batteries with long charging times.
- Hydrogen is a more compact propulsion system with a long travel range, which can be powered at charging docks located along the motorways, without the creation of a capillary distribution network, or along the railway lines at all the main stations.
- Germany has almost 100 stations located along the motorway arteries, making it possible to travel within the country. In Paris, hydrogen is produced locally, allowing a taxi network to run efficiently with half the fleet powered by hydrogen.
- In South Korea some industrial vehicle manufacturers offer a turnkey service by providing HGVs and guaranteeing the distribution network of green hydrogen. It is easier for heavy goods vehicle manufacturers to do this than for car manufacturers because the HGVs travel along standardized routes, and the rail haulage is organized in a very similar way

Refueling Infrastructure

Country	No. of Hydrogen Refueling Stations
China	387
South Korea	159 (only 41 are open at present due to hydrogen shortages)
Japan	161
The U.S.	59

Advantages of Hydrogen/NH_3 vs. Li EV

4. Quick Refueling

- It takes approximately five minutes to refuel a hydrogen/NH_3 car's tank.

Disadvantages of Hydrogen/NH_3 vs. ICE

1. If it is “grey”, it pollutes

- If it is not produced using renewable sources, hydrogen pollutes. To date, more than 96% of the hydrogen used is grey
- Ammonia is produced by grey energy

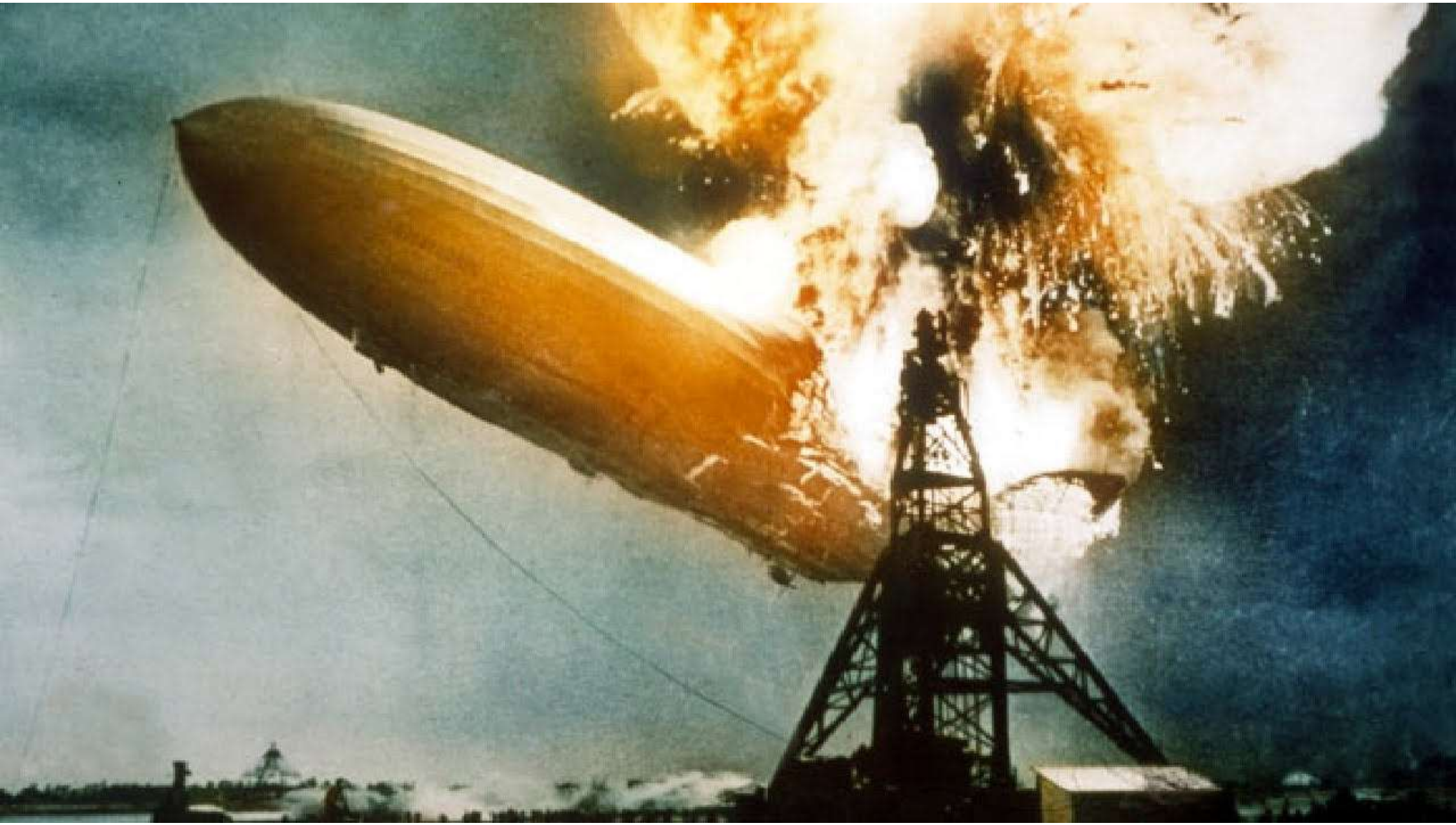
Disadvantages of Hydrogen/NH_3 vs. ICE

2. It is a gas (Hydrogen) that is difficult to handle

- Hydrogen is a difficult gas to handle because, it has to be compressed at high pressures (from 350 to 700 bar ~10,000 psi)
- Another difficulty lies in transport. Special pipelines are necessary because those intended for methane and natural gas are not fully compatible. Liquid hydrogen is reached at a temperature of -253^{o} C.
- Ammonia doesn't need the high pressure and low temp of hydrogen

Disadvantages of Hydrogen/NH_3 vs. ICE

- it is currently cheaper to charge an electric car than to refill on hydrogen. Grey hydrogen production costs $1-2 per kg, while green hydrogen production costs $5-7 per kg
- suppliers sell green hydrogen at a price of around €14 per kg, which can fall to €9 per kg where infrastructure is more developed such as in Germany.
- But the hydrogen engine still remains much more efficient than a conventional petrol/diesel engine
- hydrogen is less beneficial for light road transport compared to electric power from renewable sources. The environmental benefits are the same, but the cost of refueling and the availability of a network for charging are better




Car Wash
CNG
TOTAL

Hydrogen Car Costs

- **Toyota Mirai**
  - Its base price is around $58,000, but with available incentives and rebates, the cost can be significantly reduced.
- **Honda Clarity Fuel Cell**
  - starting price of around $59,000. As with the Mirai, government incentives can help lower the overall cost of ownership.
- **Hyundai Nexo**
  - a stylish SUV with a starting price of around $60,000. Government incentives can also be applied to the Nexo, making it more accessible for potential buyers.

Hydrogen Car Costs

- it takes just five minutes or so to refuel for 300- to 400-mile.
- A kilogram of hydrogen costs between $10 and $17 at California hydrogen stations, which equals about $5 to $8.50 per gallon of gasoline" to cover the same distance. (A Toyota Mirai hydrogen car holds about five gallons of hydrogen.) Note that charging an EV overnight usually equates to gasoline at just $1 to $2 a gallon
- In 2023, True Zero, California's largest hydrogen supplier, **raised its price to $36/kg**—from $13.14. A full 5-kg refill in a Mirai could cost up to $180.
- It is currently almost 14 times more expensive to drive a Toyota Mirai in California than a comparable Tesla battery-electric car after a massive hydrogen fuel price hike, according to calculations by *Hydrogen Insight*.

BY JOHN VOELCKER Apr 30, 2024

Fuel Cell Lifespan

- Lifespan is about 150,000–200,000 miles
- The fuel cell stacks are designed to last the lifetime of the vehicle, about 150,000–200,000 miles. At the end of its lifespan, the fuel cell will be disassembled and the materials recycled, similar to what happens with vehicle components today. A fuel cell stack is about the size of a roll-aboard suitcase.

EV Battery Replacement Costs

- Labour $1,200 to $3,000 (42,000 to 105,000 Baht)

- Chevrolet Bolt $990/cell, 10 cells, $9,900
- Hyundai Ioniq Electric $17,845
- BMW i3 $3,054/cell, 8 cells, $24,432
- Nissan Leaf $10,000 list price actual is cheaper
- Volkswagen e-Golf $27,000
- Ford Mustang Mach-E $17,588
- Tesla Model 3 $13,000 to $20,000 (https://www.way.com/blog/tesla-battery-replacement-cost/)

https://www.thedrive.com/guides-and-gear/these-replacement-battery-costs-for-these-six-normal-evs-is-staggeringly-high

Fuel Cell vs EV Costs

- One of the hydrogen tanks in a Mirai had a very prominent label “Do Not Fuel after 2029”. Since the tanks are a composite structure, rated for 10,000 PSI, they have a finite life. It also won’t be a cheap replacement, it’s 90 kg of carbon and Kevlar composites, the materials alone are $2,000. (Carbon fiber is $22/kg in quantity).
- A hydrogen fuel cell car is an EV (with a battery) plus an additional fuel cell. Fuel cells are expensive to make, using rare elements. So fuel cell vehicles end up significantly more costly than an equivalent EV.

Hydrogen vs Li battery

- The Nexo tanks hold 6.3 kg of hydrogen or roughly 95 kWh, with a curb weight of 4059 lbs. (1841 kg)

- The Tesla Model S with a 100KWHr battery, has a curb weight of 4,883 lbs. (2,215kg), 1,056 lbs (479 kg) of that are batteries. The Tesla batteries are about 4 times the weight of the Nexo's hydrogen tanks and hydrogen.

- 6.3 kg of hydrogen does roughly the same amount of work as 479 kg of lithium batteries

Hydrogen Fuel Cell Vehicle

- Fuel cell cars can carry enough hydrogen fuel for 300-400 miles of range and their tanks can be refilled as quickly as that of a standard car's gas tank.
- Hydrogen-powered cars are not really expected to replace EVs. Instead, hydrogen is intended to complement pure-electric power, and there's a good reason for this: it is the cleanest fuel possible.
- The production of hydrogen using renewable energy sources, such as solar or wind power, is not yet commercially viable on a large scale.
- Storage and transportation of hydrogen is also very costly, with complex engineering and materials involved in keeping it contained.

Hydrogen Vehicle cost

- The challenges facing the use of hydrogen in vehicles include its storage on board the vehicle. As of September 2023, hydrogen cost $36 per kilogram at public fueling stations in California, 14 times as much per mile for a Mirai as compared with a Tesla Model 3. *Wiki*

- In late 2022, “A kilogram of hydrogen costs between $10 and $17 at California hydrogen stations, which equals about $5 to $8.50 per gallon of gasoline” to cover the same distance. (A Toyota Mirai hydrogen car holds about five gallons of hydrogen.) Note that charging an EV overnight usually equates to gasoline at just $1 to $2 a gallon. *Car and Driver 2024*

EV Incentives

- There’s a glut of EVs in the market, and even Cadillac needs incentives to move the capable Lyriq. From thousands off due to “consumer cash programs,” conquest offers, and the Federal EV tax credit of $7,500, buyers are often getting as much as $13,000 off the sticker, or qualifying for very attractive lease offers since the federal EV tax credit applies there too, regardless of income level.

- This is the Year of the EV for consumers looking for deals. And the Cadillac Lyriq is one of the best ones out there.

Review: Cadillac's Lyriq is a great EV and a good deal too. The Nation. 16 Sept. 2024

Summary-Environment

	ICE	Li EV	H_2	NH_3
Exhaust	CO, CO_2, NOx, SOx, PM2.5	None	Water	N_2
GHG-ren	Bad	Excellent	Excellent	NA
-grey	NA	Poor	Bad	Bad

Summary-Efficacy

	ICE	Li EV	H_2	NH_3
Recharge time	Excellent	Poor	Excellent	Excellent
Infrastructure	Excellent	Moderate-Home is good	Bad	Bad
Distance/fill	Great	Bad-Moderate	Moderate	??????

Summary-Cost

	ICE	Li EV	H_2	NH_3
Capital	Excellent	Moderate	Moderate	???????
Operating	Moderate	Moderate-Home is good	Bad	Bad
Maintenance	Moderate	Moderate-good (battery life)	Moderate-good (fuel cell cost)	

Conclusion

- Hydrogen and ammonia fuel cells are not yet ready for full scale availability
- H_2/NH_3 are not competitors to Li EV; infrastructure and cost
- Choice between Li and ICE
- Situational considerations
  - Where you live and how/where you drive