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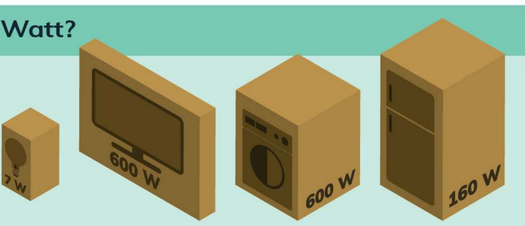
ENERGY COMMON KNOWLEDGE

What is Watt?

Watt (W) = Unit of power

How much power an appliance requires to work

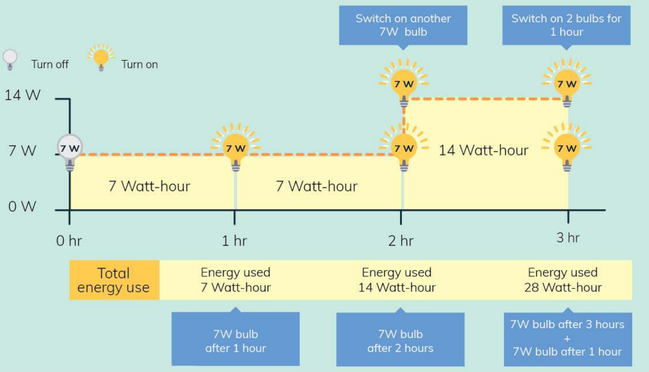


What is Watt-hour(Wh)?

Watt-hour(Wh) is

Unit of power when

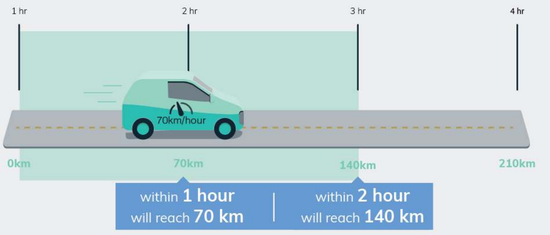
used for an hour



Another example to illustrate what is a Watt(W) and Watt-hour(Wh)

Flow rate = rate of energy transfer = Watt(W) **Which you can compare to speed**

Amount of energy in a period of time = Watt-hour(Wh) **Which you can compare to distance**

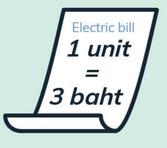


(if it keeps running at 70km/hour)

1,000 Wh = 1 kWh

Appliances and Energy Consumption

Watt (W)	7 W	160 W	400 W	600 W
Time	6 hour	24 hour	6 hour	1.5 hour
Wh (W x Hour)	42 Wh	3,840 Wh	2,400 Wh	900 Wh
kWh	0.042 kWh	3.84 kWh	2.4 kWh	0.9 kWh



In Thailand, our electric bill counts 1 kWh = 1Unit or 1 หน่วย

600 W ▶ 6 hour ▶ 3,600 Wh or 3.6 kWh ▶ ใช้เครื่องซักผ้า 600 W เป็นเวลา 6 ชั่วโมง ค่าไฟคิดเป็น 3.6x3 = 10.8 บาท

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WHAT IS HYDROGEN?

Hydrogen Facts

1

H

HYDROGEN

HENRY CAVENDISH DISCOVERED THE ELEMENT IN 1766

2

THE FIRST HYDROGEN POWERED CAR WAS INVENTED IN 1806

BY FRANCHOIS ISAAC DE RIVAZ

3

2014 1 st MASS-PRODUCED FCEV: HYUNDAI TUCSON FUEL CELL

4

MOST ABUNDANT CHEMICAL STRUCTURE IN THE UNIVERSE.

LIQUID HYDROGEN WAS USED BY NASA TO LAUNCH SHUTTLES IN TO SPACE

5

40 - 60%

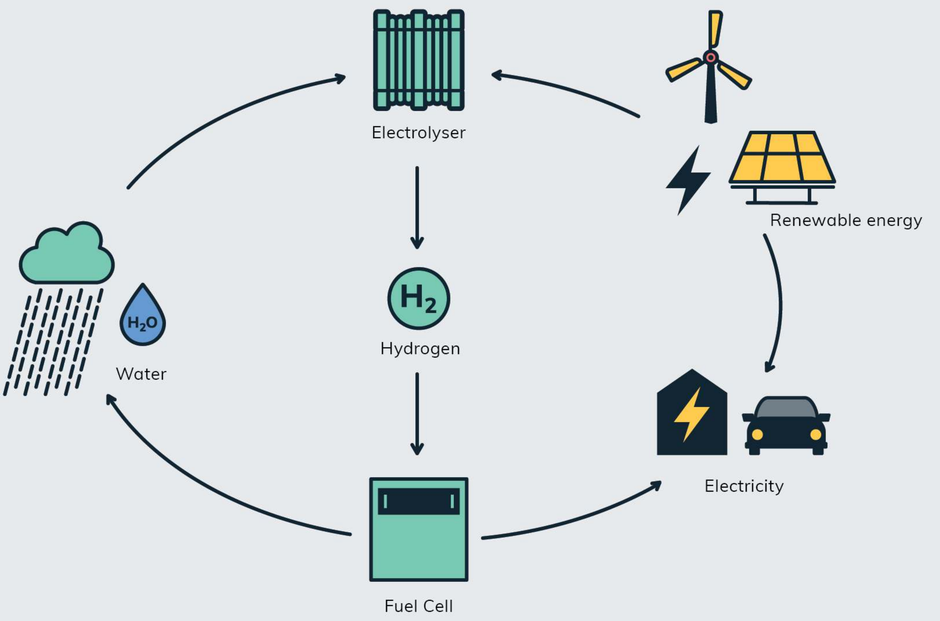
EFFIENCY OF HYDROGEN ENERGY BY FUEL CELL DRIVETRAINS

INTERESTING FACT

INTERNAL COMBUSTION ENGINES USE ONLY ABOUT 20% OF ENERGY FROM GASOLINE

Hydrogen contain a lot of Energy!

Hydrogen Cycle



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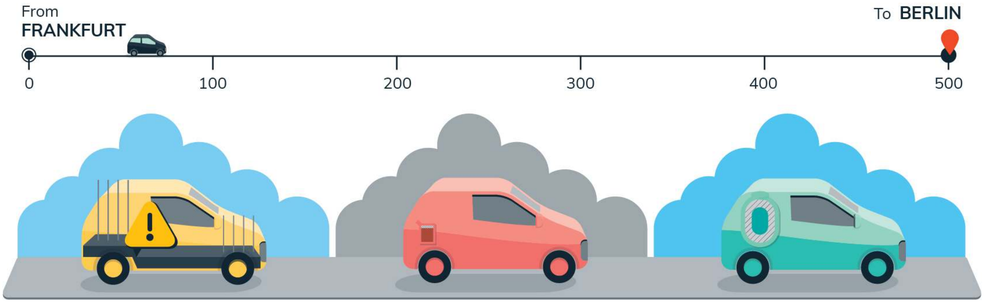
VEHICLE COMPARISON FOR 500 KM DISTANCE

Energy for a Passenger Car of 500 km Range



	ELECTRICITY	DIESEL	HYDROGEN
Fuel Usage	100 kWh	37 Litre	6 Kg @ 700 bar pressure
System weight & capacity	weight 830 Kg, volume 760 L	weight 43 Kg, volume 46 L	weight 125 Kg, volume 260 L
Fuel weight & volume	weight 540 Kg, volume 360 L	weight 33 Kg, volume 37 L	weight 6 Kg, volume 170 L
Time to refill	12 hour / 50 min	3 min	3 min

Recycle and Environmental Issue

	BATTERY	DIESEL TANK	HYDROGEN TANK
Life span of energy source	Short	Long	Long
Recyclability	Difficult disposal	Can recycle the tank	Can recycle the tank
Carbon emission	0 emission locally	500km will give 6.6 kg of CO2 emission	0 emission locally

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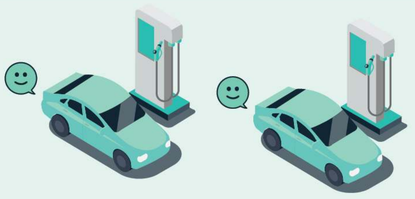
VERSATILE APPLICATIONS IN TRANSPORTATION

Transportation

The transportation sector will be a key enabler of the hydrogen economy



Fuel Cell Electric Vehicles (FCEV) will complement **Battery-Electric Vehicles (BEV)** to achieve decarbonisation of the transport sector.

Fuel Cells' applications are best suited for:

- long-range requirements
- heavier loads
- when in need of flexibility

Perfect for ships, trains, trucks

FCEVs Great Advantages:

- Short refueling times
- The manufacturing and refueling of FCEVs can use the same established process and infrastructure as conventional cars

Applications

More than 350,000 hydrogen trucks could transport goods, and 50,000 hydrogen buses, thousands of trains, and passenger ships could transport people, ***without carbon and local emissions.***

Ship

Vlking Cruises to build the world's 1st Hydrogen-powered cruise ship

Heavy load ship

Ferries

Passenger cars

Honda Clarity

Toyota Mirai

Hyudai Tucson FC

Mercedes GLC F-Cell 2018

Passenger Trains

Coradia Train 2017
First produced hydrogen-powered train "Corodia iLint" runs its first passenger test in Germany in 2018

Plane

Boeing 2010
High altitude, long endurance (HALE) liquid hydrogen-powered unmanned aerial vehicle for military usage

Airport Shuttles

in Japan, France and Germany

Rideshare and Taxi

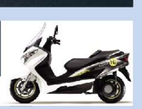
Hype. Paris

Lotus-built cab, UK

South Korean

Motorcycles

Suzuki Burgman Fuel Cell Scooter 2012



Bicycles

Buses

CUTE - Clean Urban Transport for Europe

Material Handling Fleet

By 2032,
we can expect about 5,000 refueling stations in the world.

In 2017, there are over
49 public hydrogen refueling stations in Europe,
90 in Japan and 39 in the US.

Source: Information Trends, Hydrogen Fueling Stations: A Global Analysis, October 2017
https://www.cio.com/article/3159680/car-tech/hydrogen-refueling-stations-for-cars-to-reach-5000-by-2032.html

Sources for stations by country
Europe: https://h2me.eu/about/hydrogen-refuelling-infrastructure/
Japan: https://asia.nikkei.com/Politics-Economy/Policy-Politics/Japan-to-speed-growth-of-hydrogen-refueling-stations
USA: https://www.afdc.energy.gov/fuels/hydrogen_locations.html

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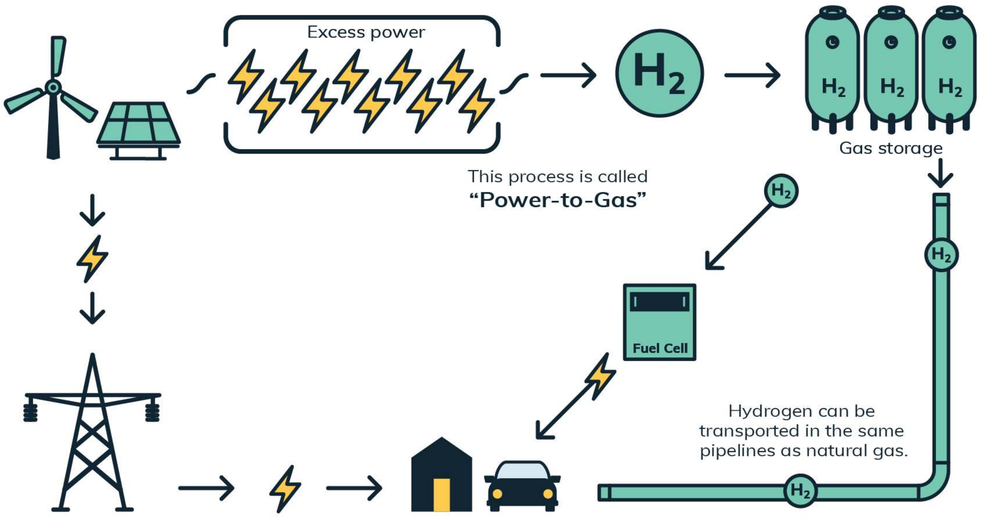
VERSATILE APPLICATIONS

Power-to-Gas



Grid & Renewables Integration

Hydrogen acts as a **buffer** to increase **grid resilience**, and **grid balancing (matching supply to demand.)**

Large-scale renewable integration because it provides cost-effective long-term and seasonal storage. Lossless Distribution of energy across sectors and regions.

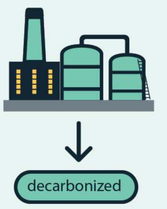
Renewable Energy Storage

- Hydrogen mountain shelter in the Col du Palet (2,600m)
- European islands gain energy independence and security by utilizing wind and solar power to create hydrogen. Isolated from the mainland, they are empowered to create their microgrid
  Example: The Orkney islands, from the Scottish archipelago

Backup Power

- Telecommunications industry
- Communication centers
- First response, hospitals
- Control center, traffic signals
- Disaster prone areas

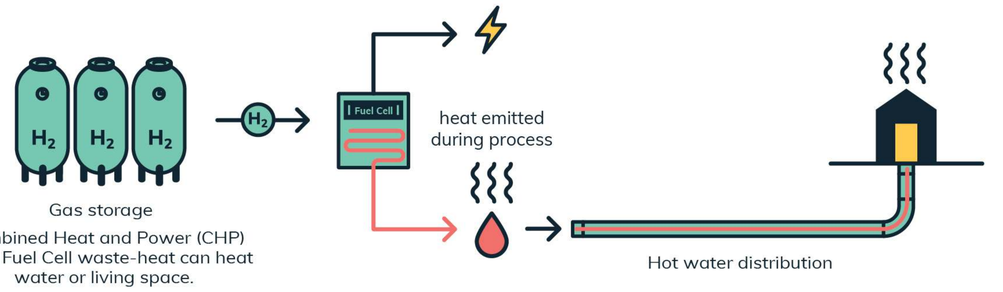
Industrial Use



55 Million tons of hydrogen is used in refining, fertilizer, and chemical production.

Combined Heat and Power (CHP)

Hydrogen is a cost-effective option to decarbonize buildings' heat and power.



Combined Heat and Power (CHP) from Fuel Cell waste-heat can heat water or living space.

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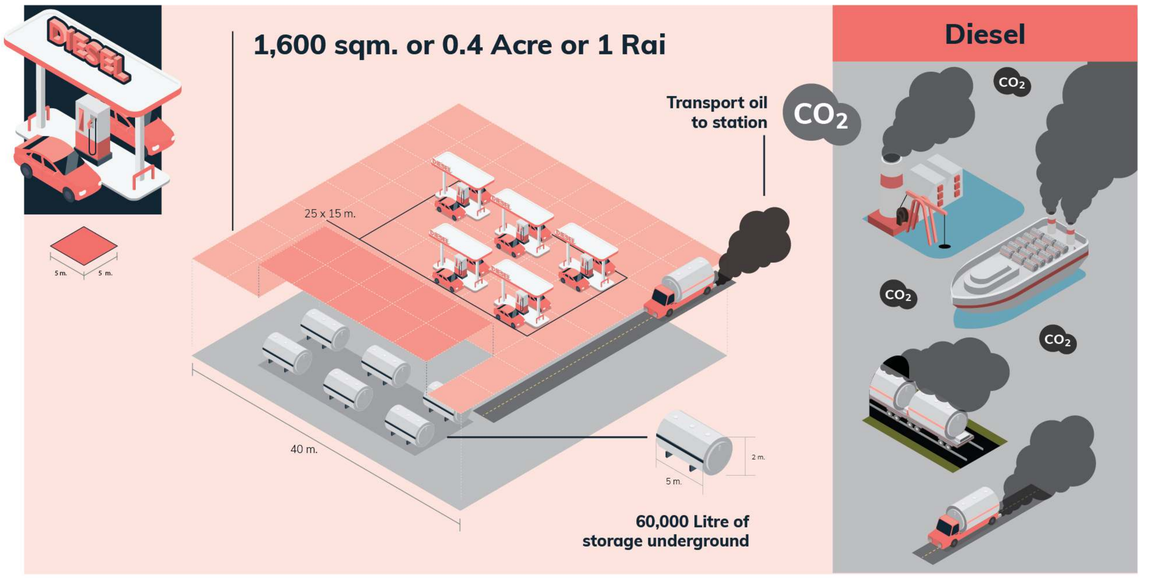
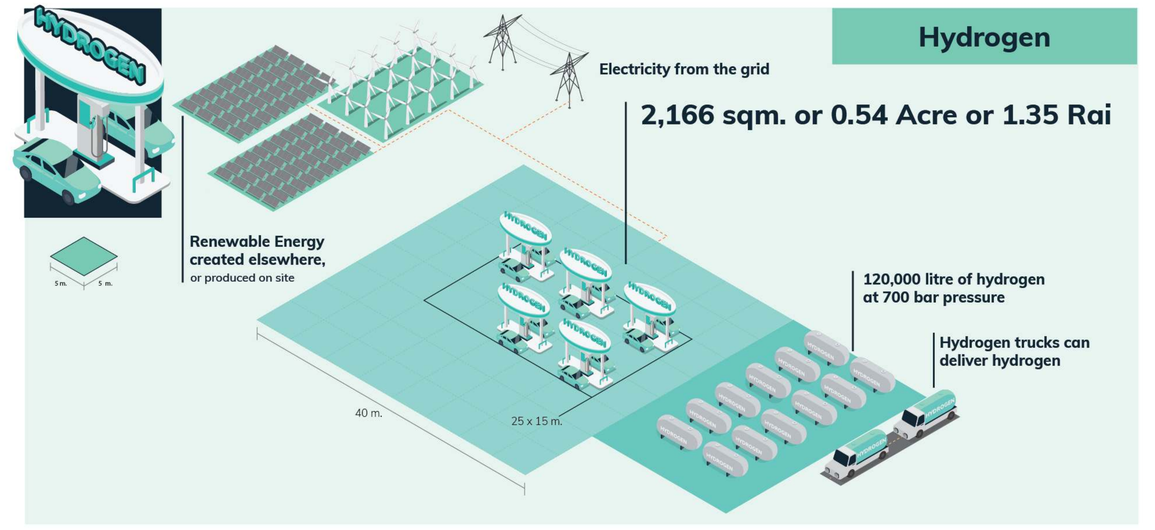
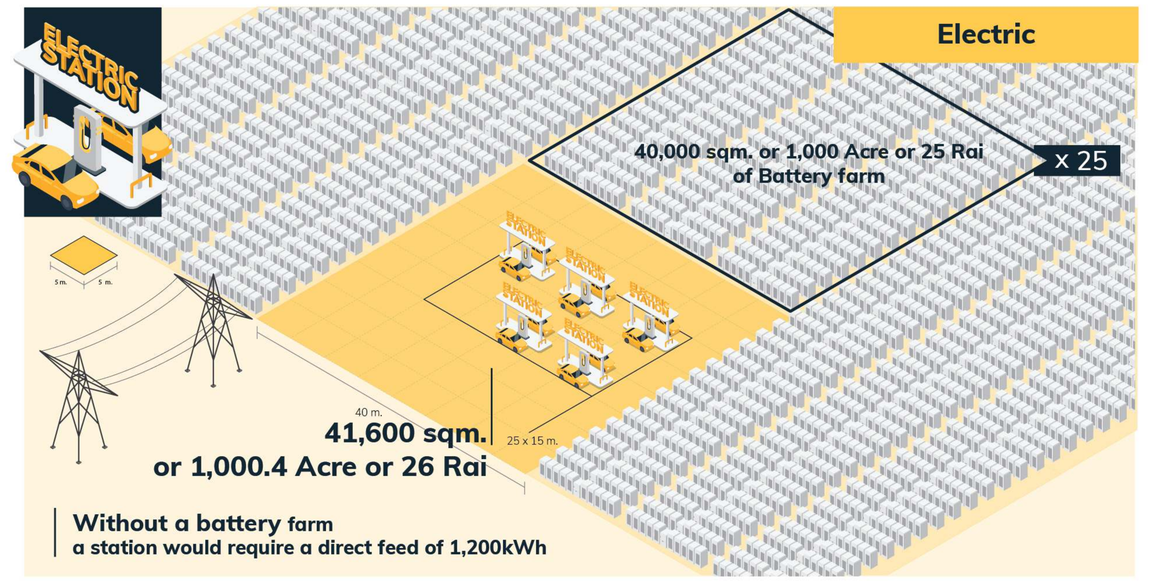
SETTING UP ENERGY STATIONS WITH DIFFERENT ENERGY SOURCES

Energy storage for 1,000 cars







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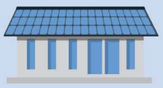
PHI SUEA HOUSE ENERGY FACTS

Solar

Phi Suea House Monthly Energy Demand : 200 kWh / day



Energy Building
75 panels
330W

Guest House A & B
64 panels
315W

Main House
84 panels
250W

Total of
347 solar panels

Peak capacity
86kW (PV installed)

Average daily production
326.8 kWh per day

Hydrogen

130 kWh

Can supplies the house with **4kW of continuous power**

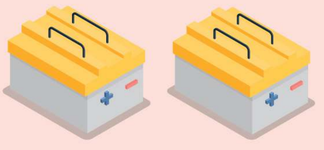
0 6 12 18 24 30

30 hour
(1 day and 6 hour)

H2

Hydrogen gas production rate
MAX: 2,000L / hour

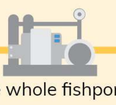
Battery



2 x 2,000 Ah. 48V
Lead acid battery banks

Solar Pump

24 panels
on the garden house



1 solar pump runs the whole fishpond ecosystem

36 panels
on pool house

1 solar pump filters the pool daytime

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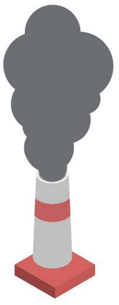
CLIMATE CHANGE

Current Situation

Human Activities

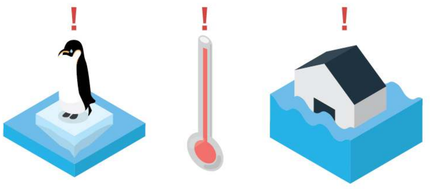


- Car driving release CO_2

- Smoke from factories
- Forest burn

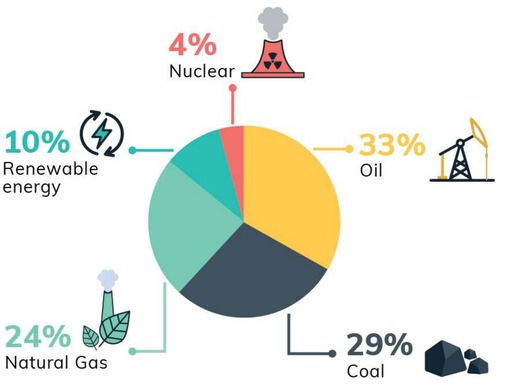
cause

Greenhouse Effects



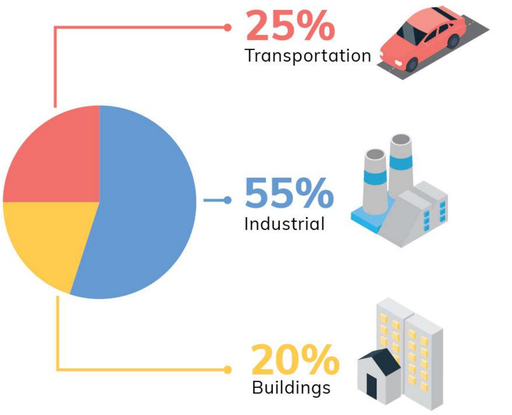
- Temperatures will keep rising
- Arctic will become ice-free
- Frost-free seasons will lengthen
- More droughts and heat waves
- Sea level will rise
- Hurricanes will become stronger

2016 Energy Consumption



Source: World Energy Council, 2016
https://www.worldenergy.org/wp-content/uploads/2016/10/World-Energy-Resources-Full-report-2016.10.03.pdf

CO_2 Emission by Sector



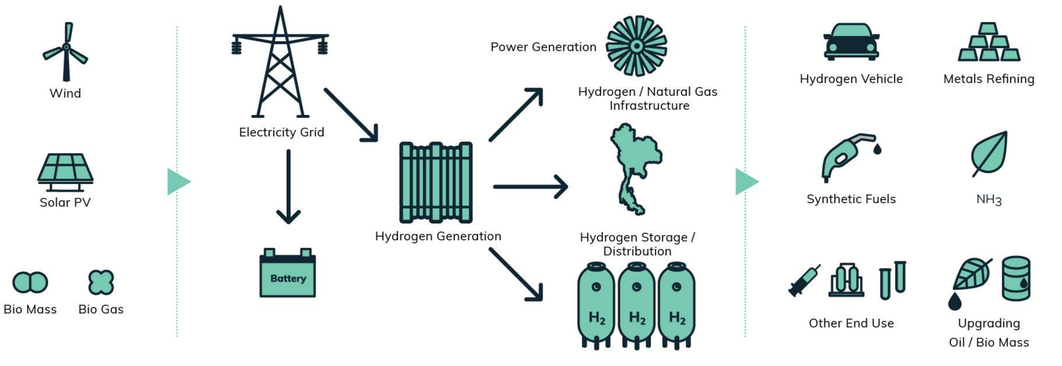
How to stop Climate Change?

To limit global warming to 2°C, we need to increase share of renewables from

Source: Hydrogen Council, Hydrogen scaling up, November 2017 (p.58)

Hydrogen is the solution

The transportation sector would consume 20 million fewer barrels of oil per day, and domestic energy security would rise significantly. Hydrogen would contribute roughly 20% of the additional abatement required to limit global warming to two degrees Celsius.



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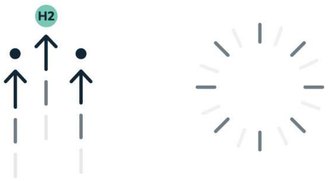
HYDROGEN SAFETY

Hydrogen is Safe

HIGH DIFFUSIVITY



Smallest and lightest element
It rises and disperses very quickly.
It travels at 50 meters per second.

LOW RISK IGNITION

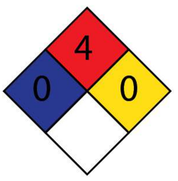
Extremely safe if located in ventilated space

Hydrogen can ignite ONLY IF it reaches at least 4% concentration in the air AND IF there is a spark, flame, etc.

HYDROGEN VS GASOLINE

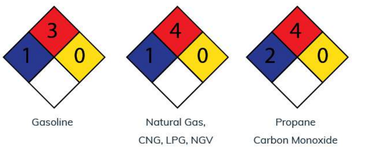
“
Relief valve failure (leaking tank) with electrical spark to ignite fuel
”

Fire Diamond



Hydrogen

- Flammability — Flammable gas
- Health — No health hazard
- Reactivity — Normally stable, not reactive with water
- Special notice — None



HINDENBURG Example


HINDENBURG DEATH TOLL PLACED AT 32

3 JURORS ARE SELECTED FOR MURDER TRIAL OF STRANTZ

Midair Explosion Sets Giant German Dirigible Ablaze

66 REPORTED AS SURVIVING AIR DISASTER

Experts Gather To Inquire Into Cause Of Explosion That Sent Giant German Dirigible Crashing In Flames At Lakehurst

CHAOTIC SCENES RECORDED AS SHIP BLOWS UP WHILE PREPARING TO LAND

DRIVER GETS CENTURY AC

HINDENBURG CRASH CANNOT HAPPEN AGAIN IN MODERN HYDROGEN SYSTEMS AND FUEL CELL CARS

- Hindenburg was originally designed to be operated with helium, but the Helium Control Act prohibited its export outside of the US.
- Its structure was defective, so there was a hydrogen gas leak
- The airship was not pressurized, so the leak was slow and flames travelled inwards
- Weather conditions caused an electrostatic discharge (spark), which ignited the leaking gas

Such a disaster is *not possible if hydrogen is contained properly in pressurized* tanks and surrounding materials do not catch fire easily

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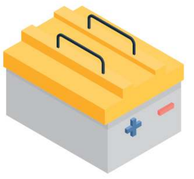
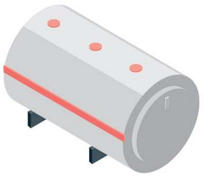
ENERGY STORAGE COMPARISON

Characteristics


	BATTERIES	DIESEL	HYDROGEN STORAGE
Energy density	0.05 kWh/kg	13 kWh/kg	33.3 kWh/kg
Safety	• Complicated management system • Small window of safe operation condition	Safe and easy to handle	Safe and easy to handle, similar to CNG, LPG, etc
Environmental impact	Some dangerous materials, no recycling concept for lithium battery enabled	Dirty, noisy	No concerns
Degradation	Degrades happen, performance drops over time, required replacement every few years	High maintenance, short lifetime, frequent replacement	10,000hr+ 100 years tank Degrades slowly, 10,000hr+ lifetime for machines, 100 years for steel tanks
Strorage time	Loses charge over time	Diesel will degrade through time within 6-12 months	Can store energy indefinitely

Applications

Short-term backup (less than 4 hours)	Suitable	Suitable	Available power is determined by fuel cell
Long-term backup (more than 4 hours)	Big and expensive	Dirty, noisy, high maintenance	Suitable
Seasonal storage	Impossible	Dirty, noisy, high maintenance	Suitable