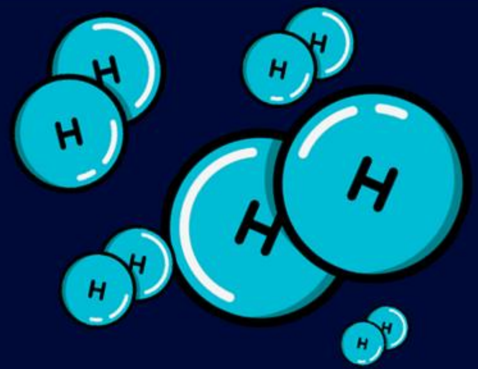


Hydrogen Technology And Fuel Cell

Visarn Lilavivat, Ph.D.
Renewable Energy and Energy Efficiency Research Team
Energy Innovation Research Group
National Energy Technology Center (ENTEC)

Thailand Long-term GHG Emission Development Strategy

THAILAND

2030 : NDC 40%

2050 : Carbon Neutrality

2065 : Net Zero Emission

COP27

2022

2021

COP26

Paris Agreement

2016

2015

COP21

Why Hydrogen

Current State

Coal

Oil

Gas

Energy

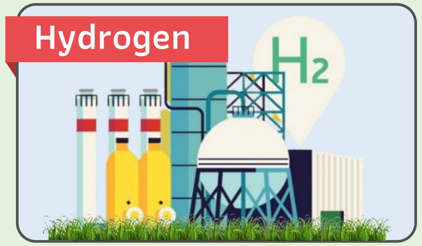
+

CO_2

$$C_xH_y + O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

Future State

Hydrogen



1
H
Hydrogen
1.008

Energy

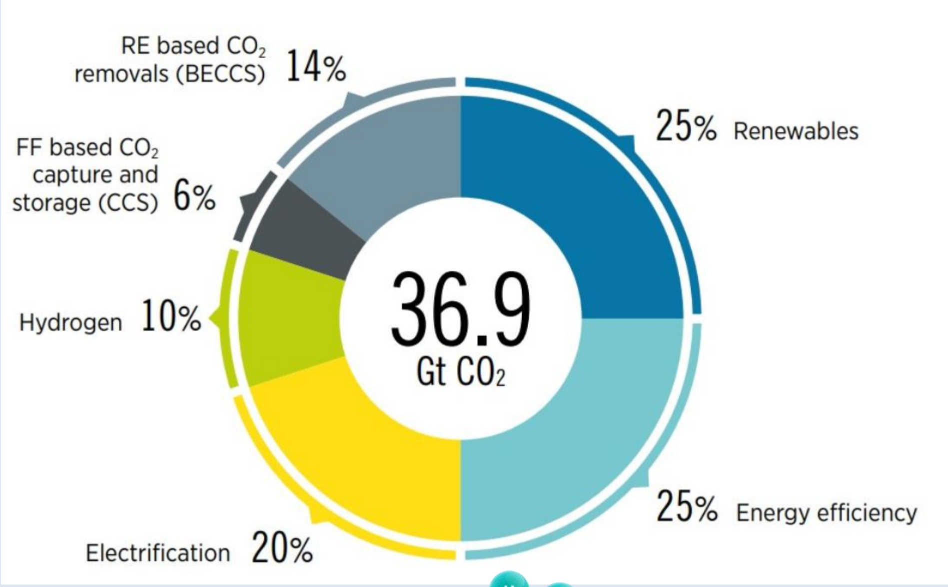
+

H_2O

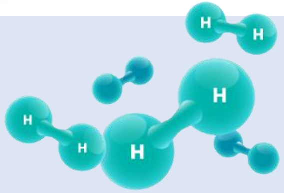
$$2H_2 + O_2 \rightarrow 2H_2O$$

H_2

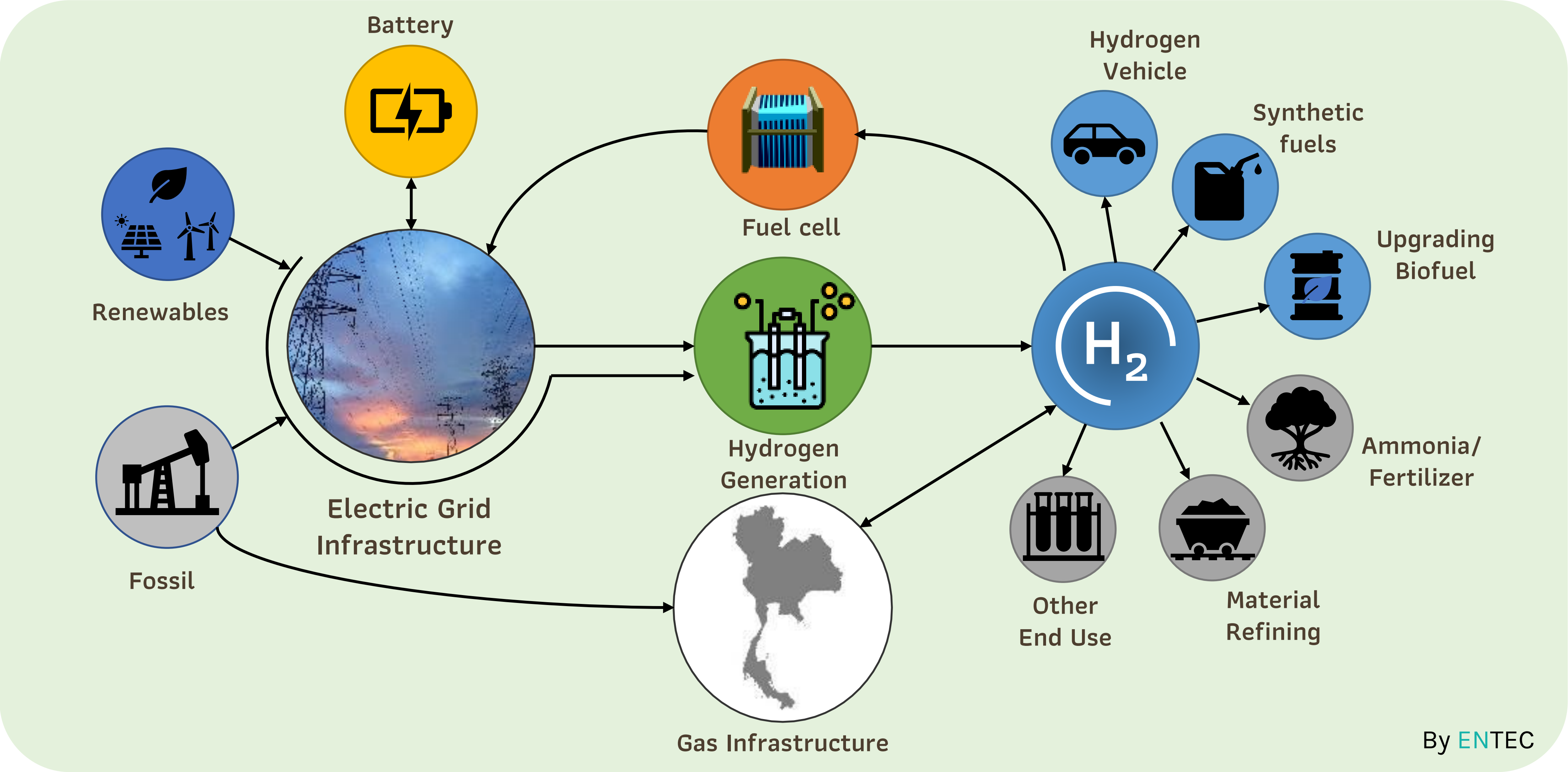
Hydrogen one of six technology for decarbonization



Source: IRENA



Hydrogen Economy



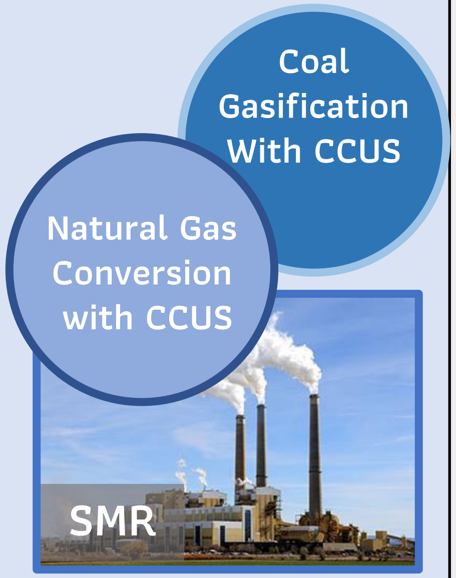
H_2: Enabling affordable, reliable, clean, and secure energy across sectors

Hydrogen Production

Terminology	Technology	Feedstock	GHG footprint
White	By-product	Mixed	N/A
Green	Electrolysis	Renewable energy	Minimal
Pink	Electrolysis	Nuclear	Minimal
Yellow	Electrolysis	Mixed grid energy	Medium
Blue	Gasification + CCUS	Natural gas	Low
Turquoise	Pyrolysis	Natural gas	Solid carbon
Grey	thermochemical	Natural gas	Medium-high
Brown	thermochemical	Brown coal (lignite)	High
Black	thermochemical	Black coal	High

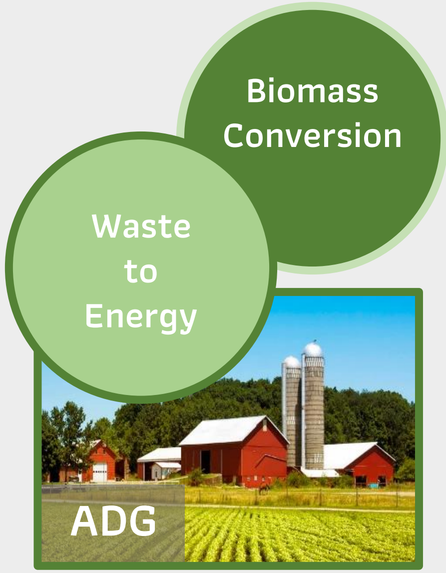
FOSSIL RESOURCES

- Low-cost, large-scale hydrogen production with CCUS
- New options include byproduct production, such as solid carbon



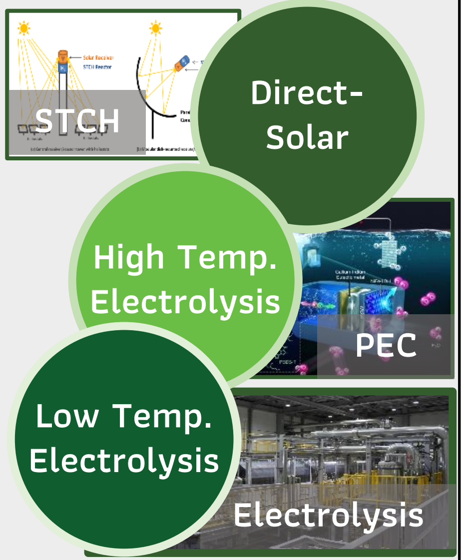
BIOMASS/WASTE

- Options include biogas reforming and fermentation of waste streams
- Byproduct benefits include clean water, electricity, and chemicals

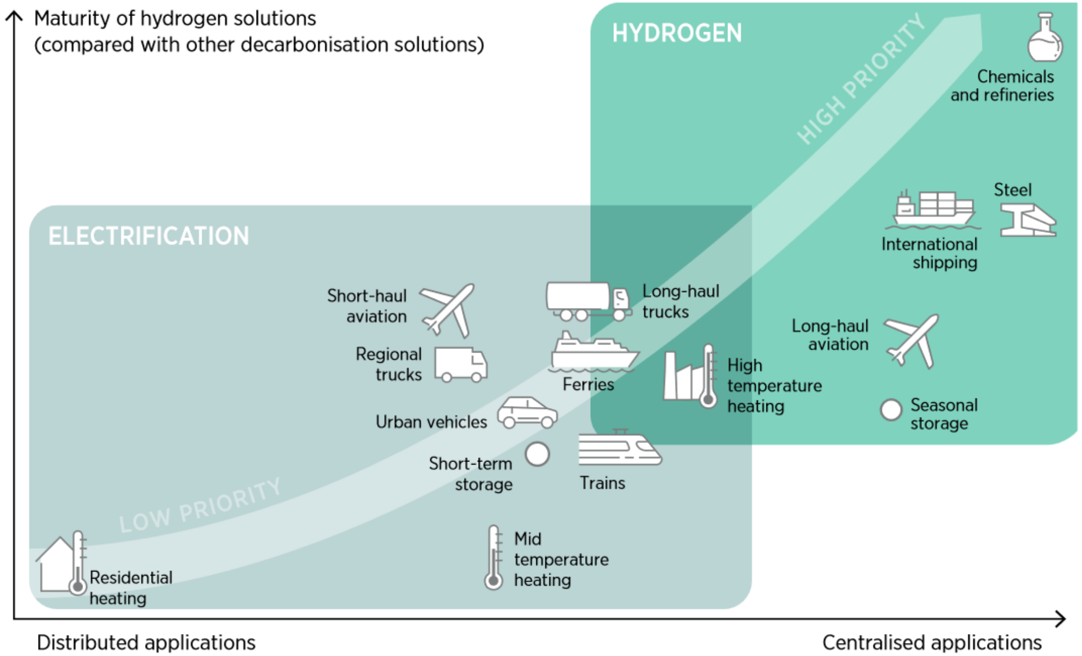


H_2O SPLITTING

- Electrolyzes can be grid-tied, or directly coupled with renewables
- New direct water-spitting technologies offer longer-term options



Priority settings for hydrogen applications across the energy system

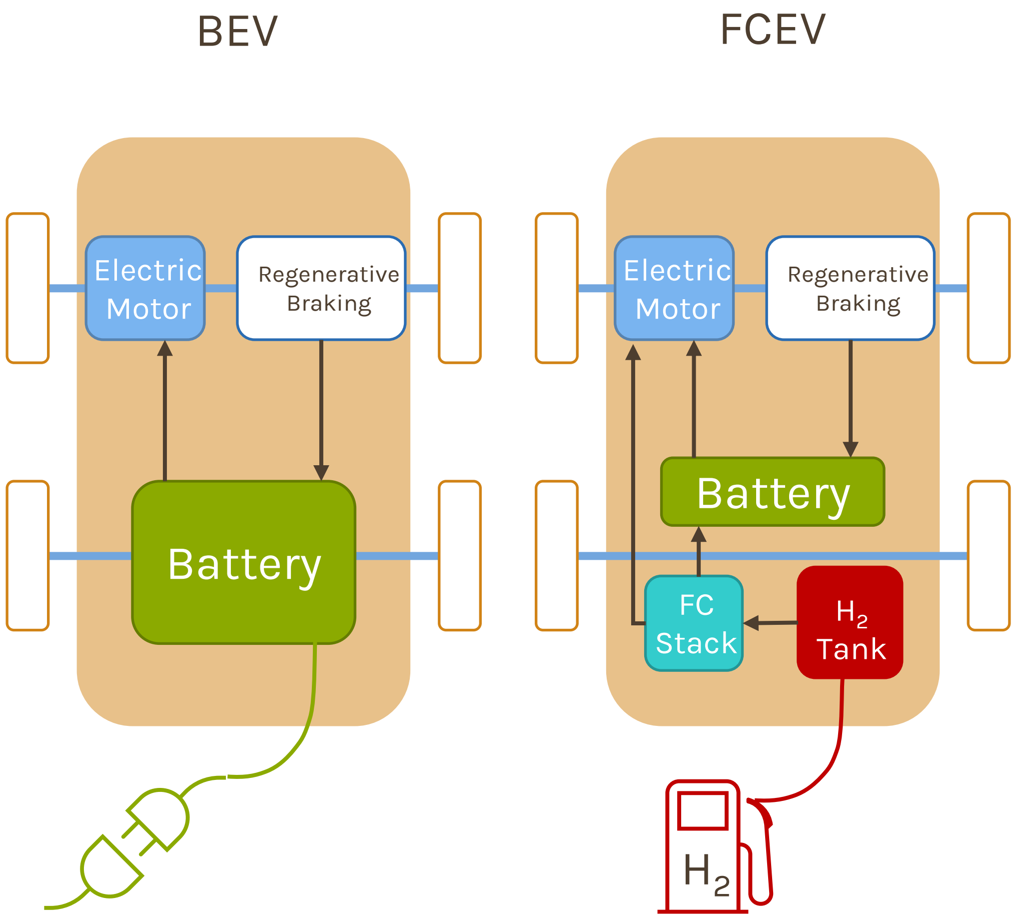


Source: IRENA (2022e).

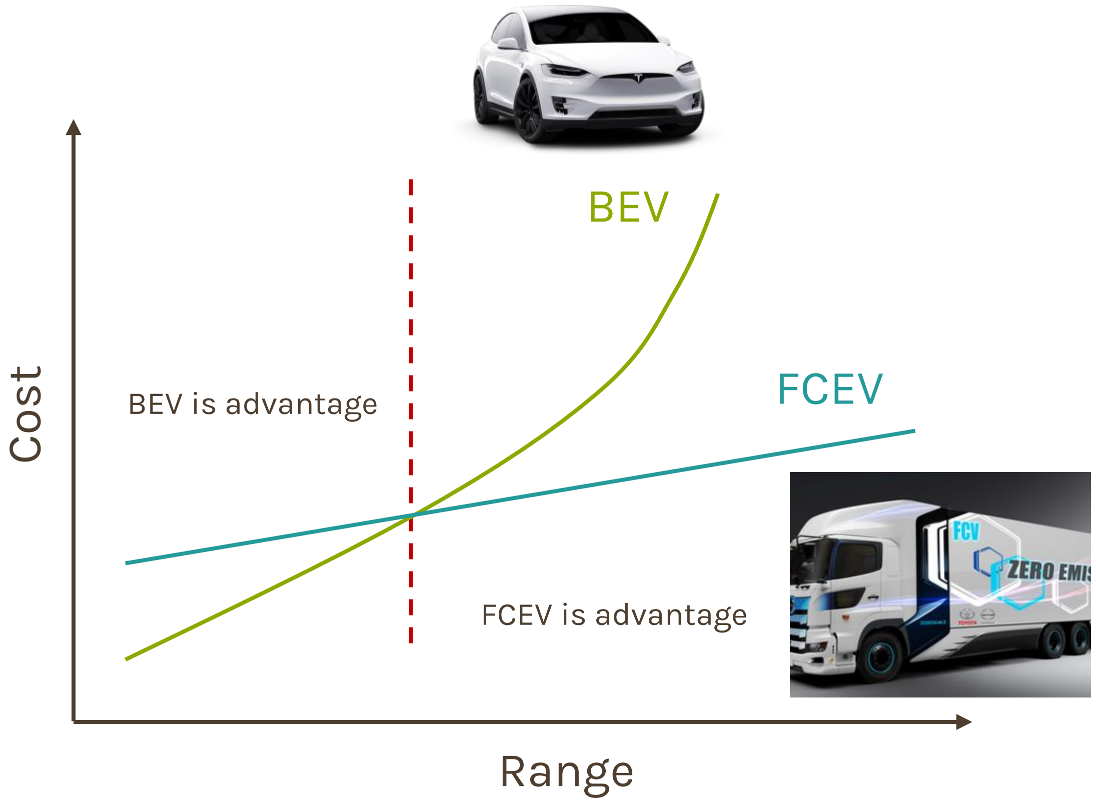
https://ptx-hub.org/

https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Jul/IRENA_Global_hydrogen_trade_part_1_2022_.pdf

FCEV vs. BEV

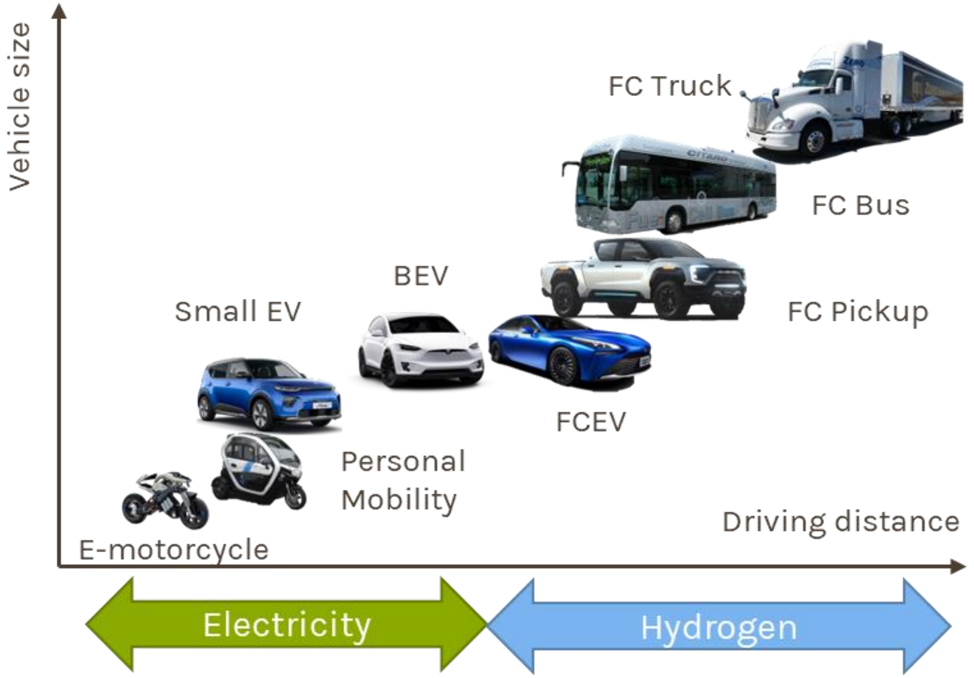


BEV
FCEV
Electric Motor
Regenerative Braking
Battery
Electric Motor
Regenerative Braking
Battery
FC Stack
H_2 Tank
H_2



Cost
Range
BEV
FCEV
BEV is advantage
FCEV is advantage
FCV

Battery & Hydrogen



Hydrogen vs battery electric trucks - Regional delivery

Trips up to 400 km represent 62% of EU truck activity

Parameters	Fuel cell electric truck (H_2 / O_2) Today	Fuel cell electric truck 2030	Battery electric truck Today	Battery electric truck 2030
Total cost of ownership over first 5-year user period (based on France)	€ 437 k	€319 k	€353 k	€256 k
Vehicle purchase costs	€ 160 k	€ 115 k	€216 k	€122 k
Annual renewable fuel costs[1]	€ 39 k	€ 25 k	€21 k	€15 k
Cost parity with diesel without subsidies	Early 2040s		Mid 2020s	
Economies of scale with cars	Low		High	
Refuelling / recharging time (full)	3 - 8 minutes		8 hours (overnight) 60 minutes (opportunity)	
Net payload loss (weight)[2]	None		None	

1: Renewable fuel costs are incl. taxes, levies and charges, transport and distribution costs for electricity and fuel; assuming renewable hydrogen cost for the end user of € 6.36/kg (2020) and € 5.40/kg (2030), and renewable electricity cost for the end user of €-cent 17.25/kWh (2020) and €-cent 15.26/kWh (2030).

2: Additional weight from the onboard battery pack (assumed energy density of 183 Wh/kg in 2020 and 318 Wh/kg in 2030) of 3.9 t (1.8 t in 2030) is compensated for by the additional ZEV weight allowance (2 t) under the EU Weights & Dimensions Directive and net savings from replacing a conventional with an electric drivetrain (2.4 t).

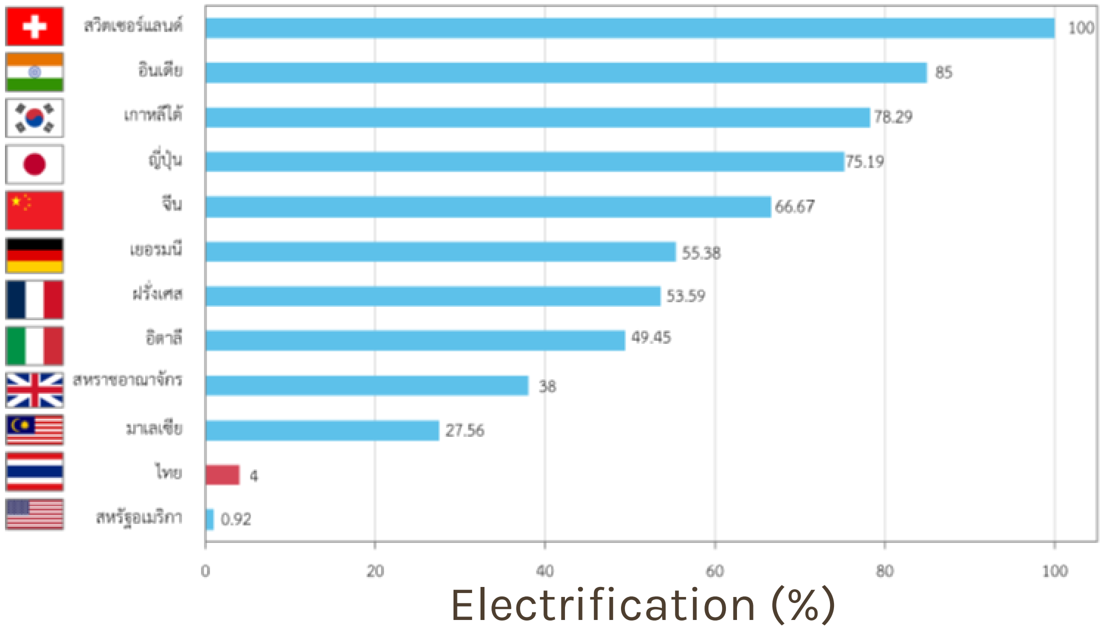
Better →

TRANSPORT & ENVIRONMENT transportenvironment.org

For methodology and sources see also: https://www.transportenvironment.org/sites/te/files/2020_06_TE_comparison_hydrogen_battery_electric_trucks_methodology.pdf

Thailand railway

Train Line	Total distance [km]
Eastern	255
Northern	751
Northeastern	621
Southern	990



Green-powered train

Hydrogen-powered train

The Coradia iLint trains can run for about 600 miles (1,000km) on a single tank of hydrogen, similar to the range of diesel trains.

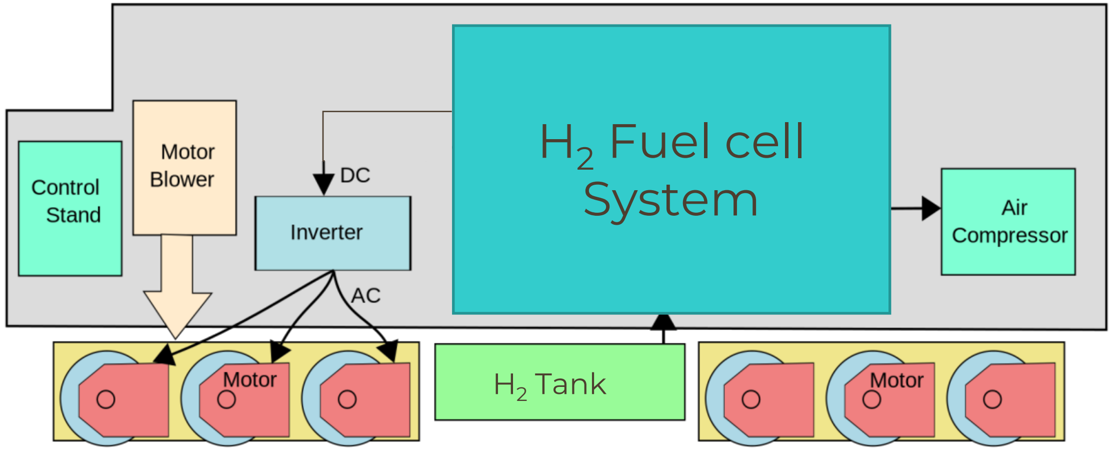
https://www.theguardian.com/environment/2018/sep/17/germany-launches-worlds-first-hydrogen-powered-train

Battery-powered train

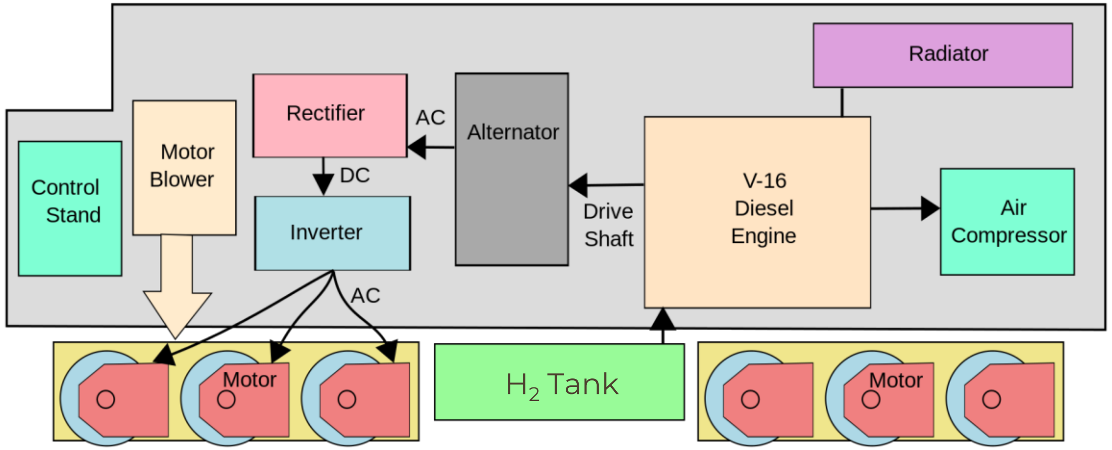
Range 150-200 km
Battery capacity 4 MWh
Ultra Fast Charge
1MW x 4 Charger

Converted diesel to hydrogen

Fuel Cell



ICE



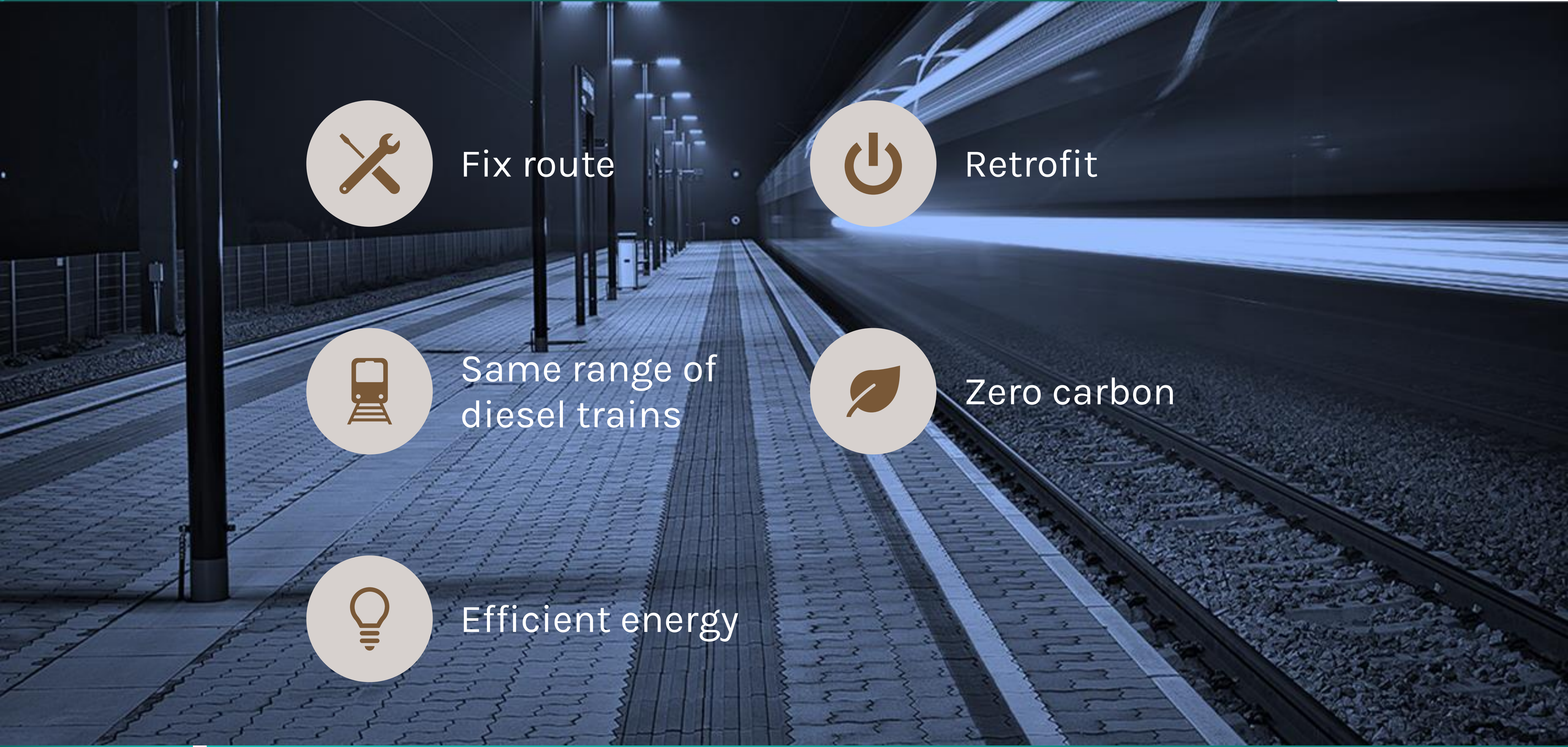
Pro
- Higher efficiency

Con
- FC Stack
- Cost

Pro
- Easy to convert

Con
- Emission

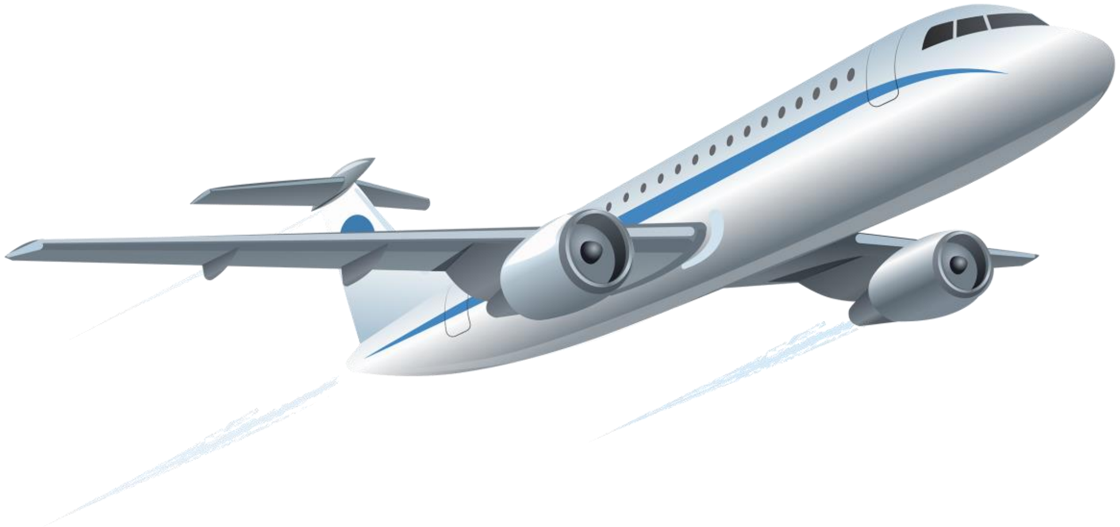
Advantages of Hydrogen Train



- Fix route
- Retrofit
- Same range of diesel trains
- Zero carbon
- Efficient energy

What is SAF?

- SAF stands for sustainable aviation fuel.
- SAF produced from sustainable feedstocks to traditional fossil jet fuel.
- Using SAF results in a reduction in carbon emissions

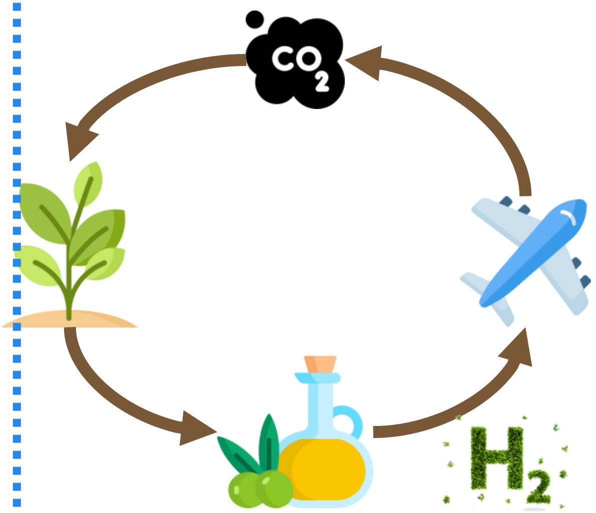


SAF Pathway



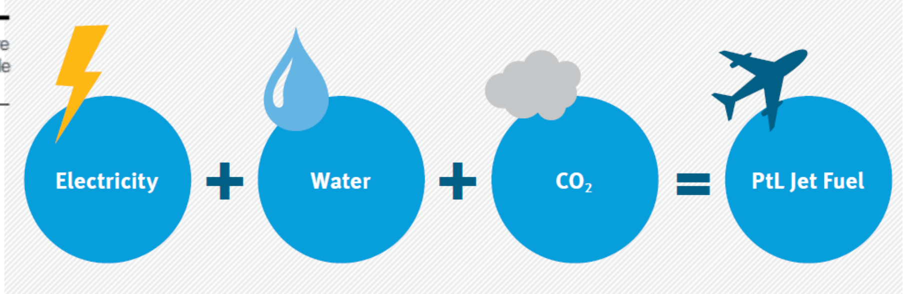

	HEFA	Alcohol-to-jet[i]	Gasification/FT	Power-to-liquid
Opportunity description	Safe, proven, and scalable technology		Potential in the mid-term, however significant techno-economical uncertainty	Proof of concept 2025+, primarily where cheap high-volume electricity is available
Technology maturity	Mature		Commercial pilot	In development

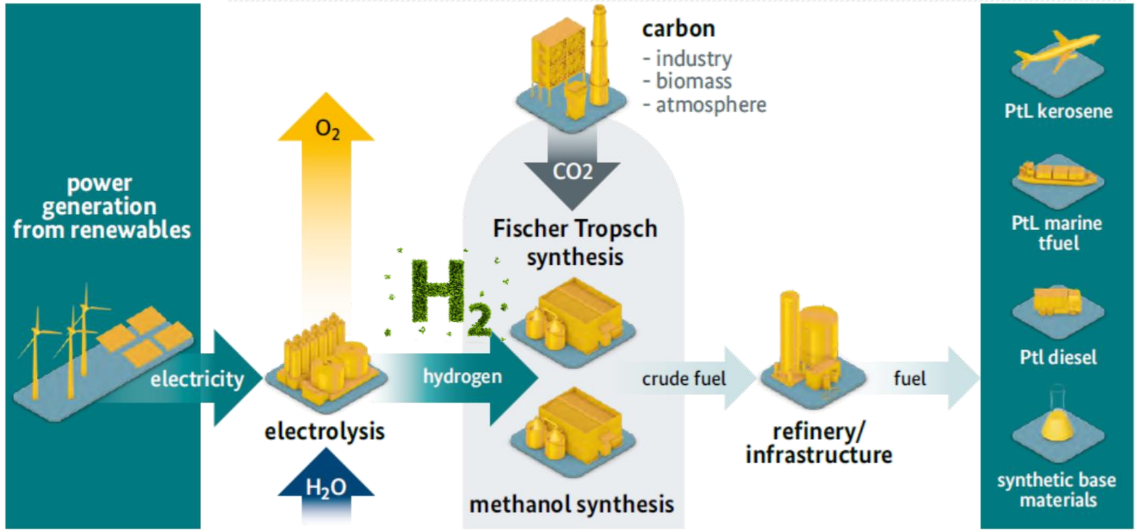
Biofuel



- Oil: Virgin/used animal or plant oils
- Sugar: sugar/starch/cellulosic crops
- Agricultural and forestry residues, municipal sold waste

Synthetic Fuel

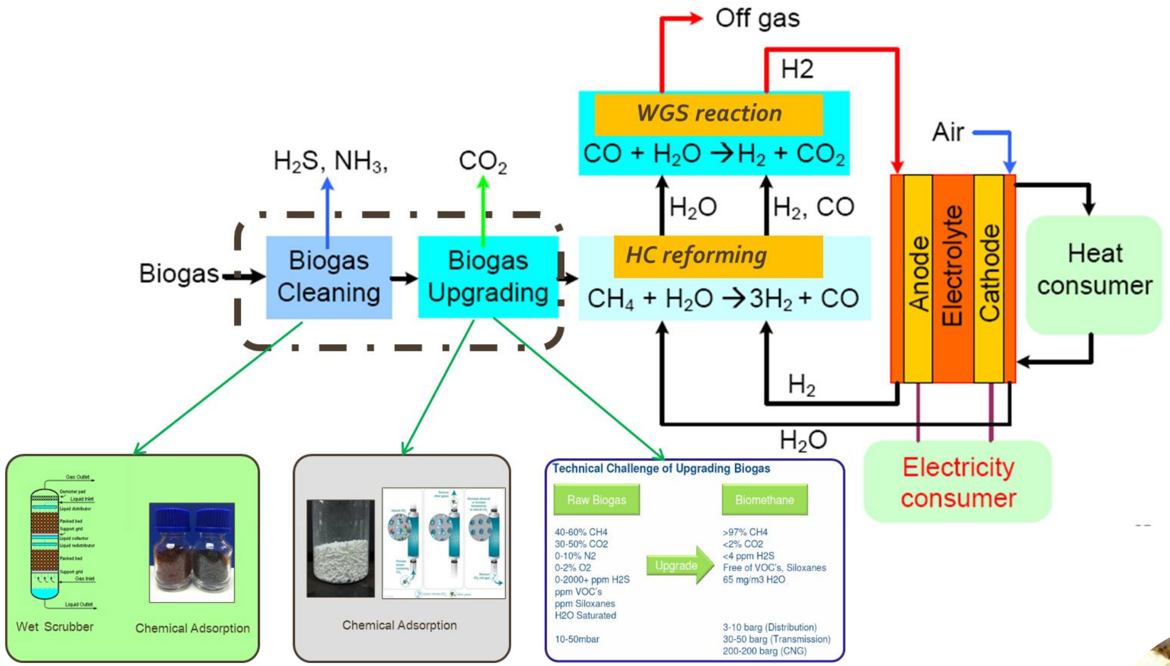




https://www3.weforum.org/docs/WEF_Clean_Skies_Tomorrow_SAF_Analytics_2020.pdf
https://nordicelectrofuel.no/wp-content/uploads/2021/06/The-German-Federal-Government-BtL-Roadmap-Sustainable-aviation-fuel-from-renewable-energy-sources-for-aviation-in-Germany-MAY-2021.pdf

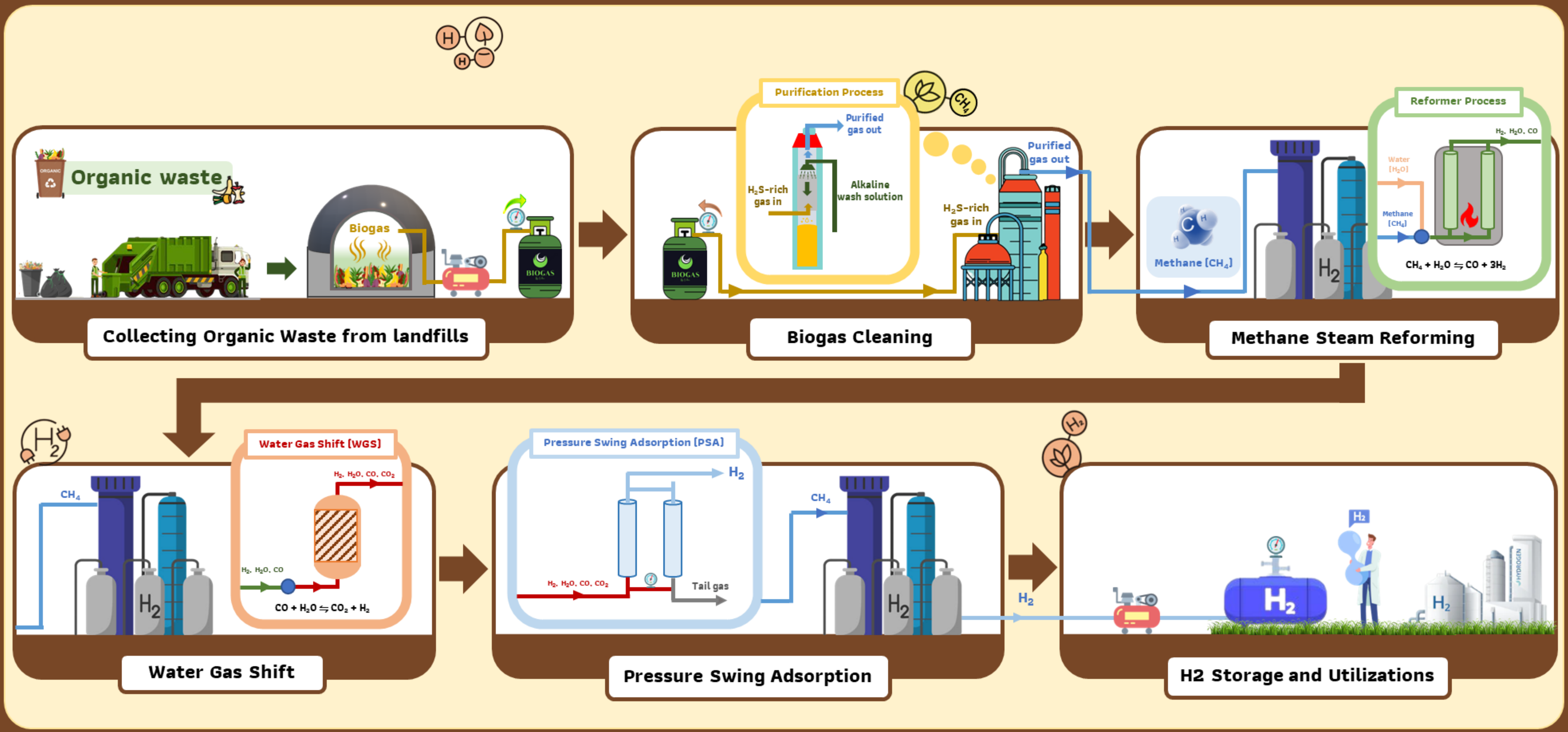
ENTEC Research

H2 from Biomass/Biogas



- Biomass is an **abundant domestic resource**
- Biomass/Biogas **"recycles" carbon dioxide**
- Waste to energy
- CH_4 is 28 times Global warming potential than CO_2

H2 production using biogas from municipal waste



Comparison of the H2 production

ENTEC a member of NSTDA

Terminology	Feedstock	Energy	Technology	Product	C Footprint [$kgCO_2/kgH_2$]
White	Natural/ By-product	Mixed	PSA	H2	0.7-1.0
Green	Water	Renewable energy	Electrolysis	H2+O2	0.5-2.5
Green	Biomass /Biogas	Biomass /Biogas energy	thermochemical	H2+CO2	-26.5-10
Blue	Natural gas	Natural gas	SMR + CCUS	H2+CO2 (capture)	1.5-5
Grey	Natural gas	Natural gas	SMR	H2+CO2	10-20

Source: Decarbonising Europe's hydrogen production with biohydrogen, European Biogas Association (2023)
Bareiß, K., et al., Applied Energy (2019)
Towards hydrogen definitions based on their emissions intensity, IEA (2023)

Conclusions

ENTEC a member of NSTDA

- **Low-cost clean hydrogen** is the key for decarbonization.
- **Research on green hydrogen** is the key for low-cost hydrogen.
- **Biogas** is a **sustainable energy resource** (organic waste materials that are continuously generated).
- **Produce hydrogen** from biogas **reducing overall carbon emissions.**
- **Cost and durability** are the main challenges for **green H_2 technology.**
- **Emission tax** must be used to make **Green hydrogen competitive.**

“Hydrogen is the most common element in the universe, and has the potential to become an inexpensive source of energy for neighborhoods, light and heavy-duty vehicles, and industry”

Charlie Dent

Thank you