# HYSYTECH

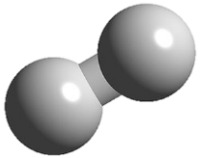
FILLING THE GAP

## UNITED COLOURS OF HYDROGEN

# What is hydrogen?

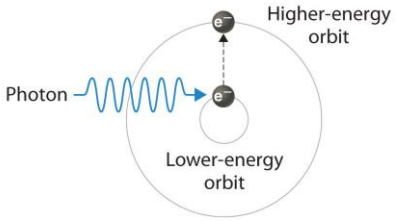



- Hydrogen is the first element of the periodic table and most abundant element of the universe (~75%).
- At ambient condition hydrogen is a **colourless**, odourless and tasteless bi-atomic gas ($H_2$).

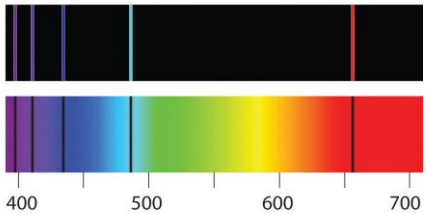


| Fuel | State @ ambient temp. and pres. | HHV (MJ/kg) | LHV (MJ/kg) | HHV (MJ/l*) | LHV (MJ/l*) |
|---|---|---|---|---|---|
| Hydrogen | gas | 141,9 | 119,9 | 2,3 | 1,9 |
| Methane | gas | 55,5 | 50,0 | 7,2 | 6,5 |
| Gasoline | liquid | 47,5 | 44,5 | 32,3 | 30,3 |
| Diesel | liquid | 44,8 | 42,5 | 38,1 | 36,1 |
| Methanol | liquid | 20,0 | 18,1 | 15,8 | 14,3 |

* @25°C & 200 bar for gases




(a) Electronic absorption transition

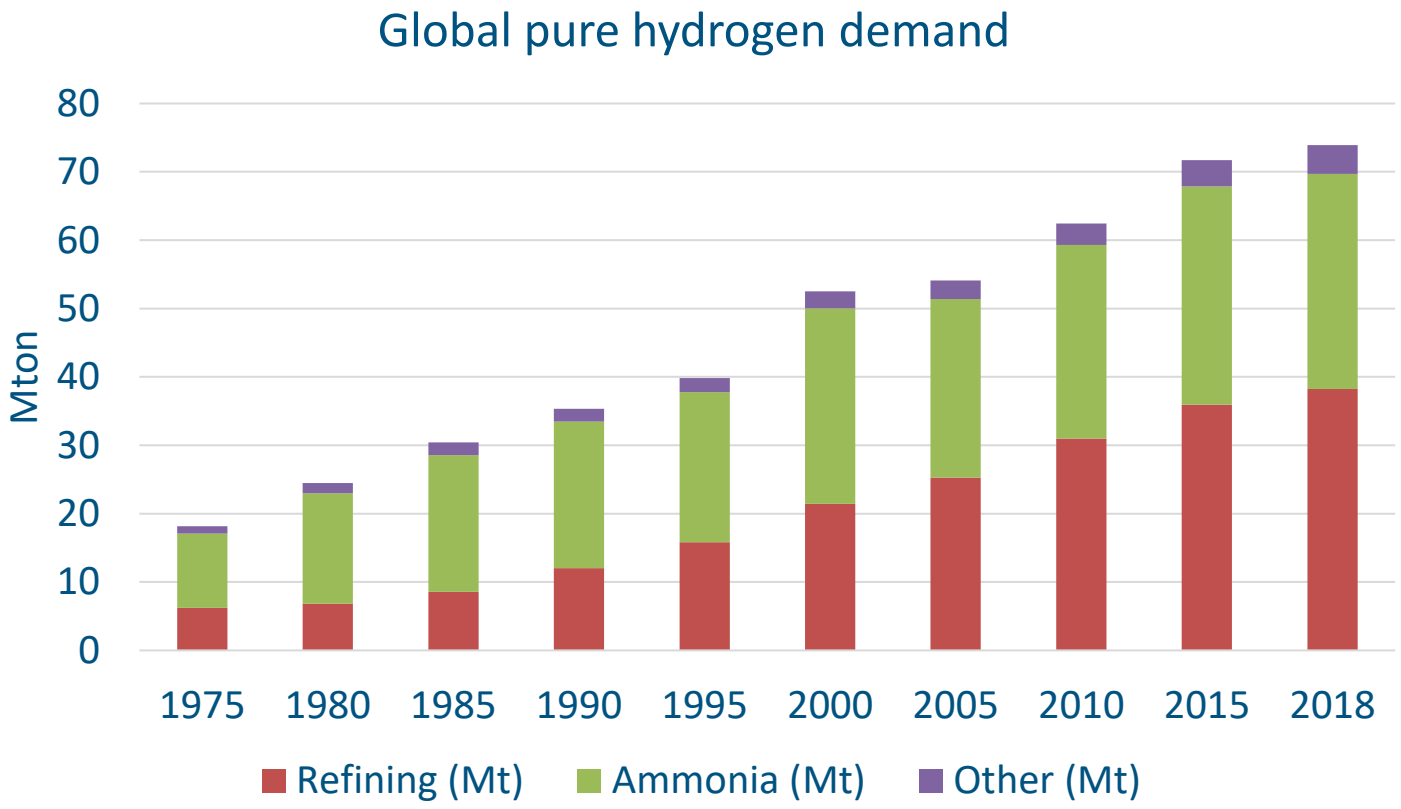



(b) $H_2$ emission spectrum (top), $H_2$ absorption spectrum (bottom)

# What is hydrogen being used for today?



Around **74 million tons/year** worldwide $H_2$ production (2018)[1].




Future use case as energy carrier → transportation sector decarbonization

[1] https://www.iea.org/reports/the-future-of-hydrogen

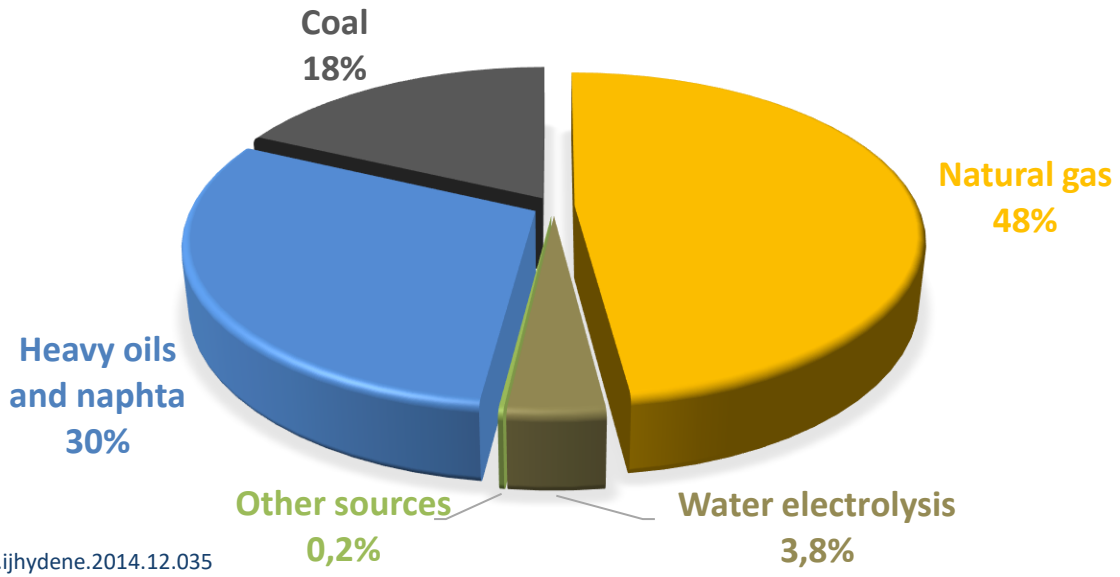
# How is hydrogen produced today?



Unlike fossil fuels, hydrogen is not readily available in nature. It can be however produced from any primary energy source, for e.g.:

- **Steam reforming** + WGS method: $C_nH_m + 2nH_2O \xrightarrow{heat} nCO_2 + \left(2n + \frac{1}{2}m\right)H_2$
- **Partial oxidation** + WGS method: $C_nH_m + nO_2 \rightarrow nCO_2 + \frac{1}{2}mH_2$
- **Water electrolysis**: $H_2O \xrightarrow{e^-} H_2 + \frac{1}{2}O_2$

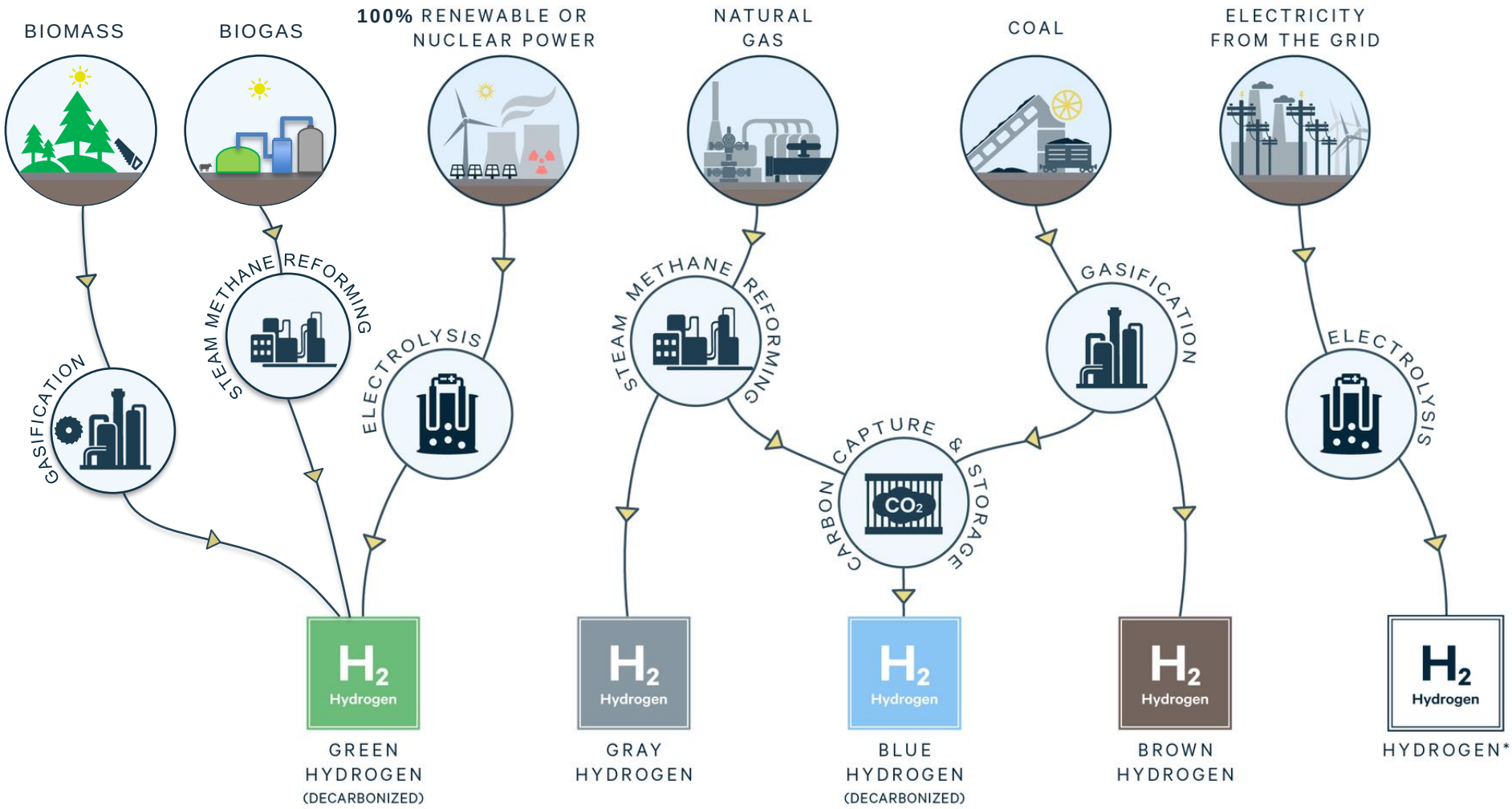
**Hydrogen production by source[2]**




[2] Dincer et al. (2014), International Journal of Hydrogen Energy; DOI: 10.1016/j.ijhydene.2014.12.035

# Why are we talking about colours of hydrogen?

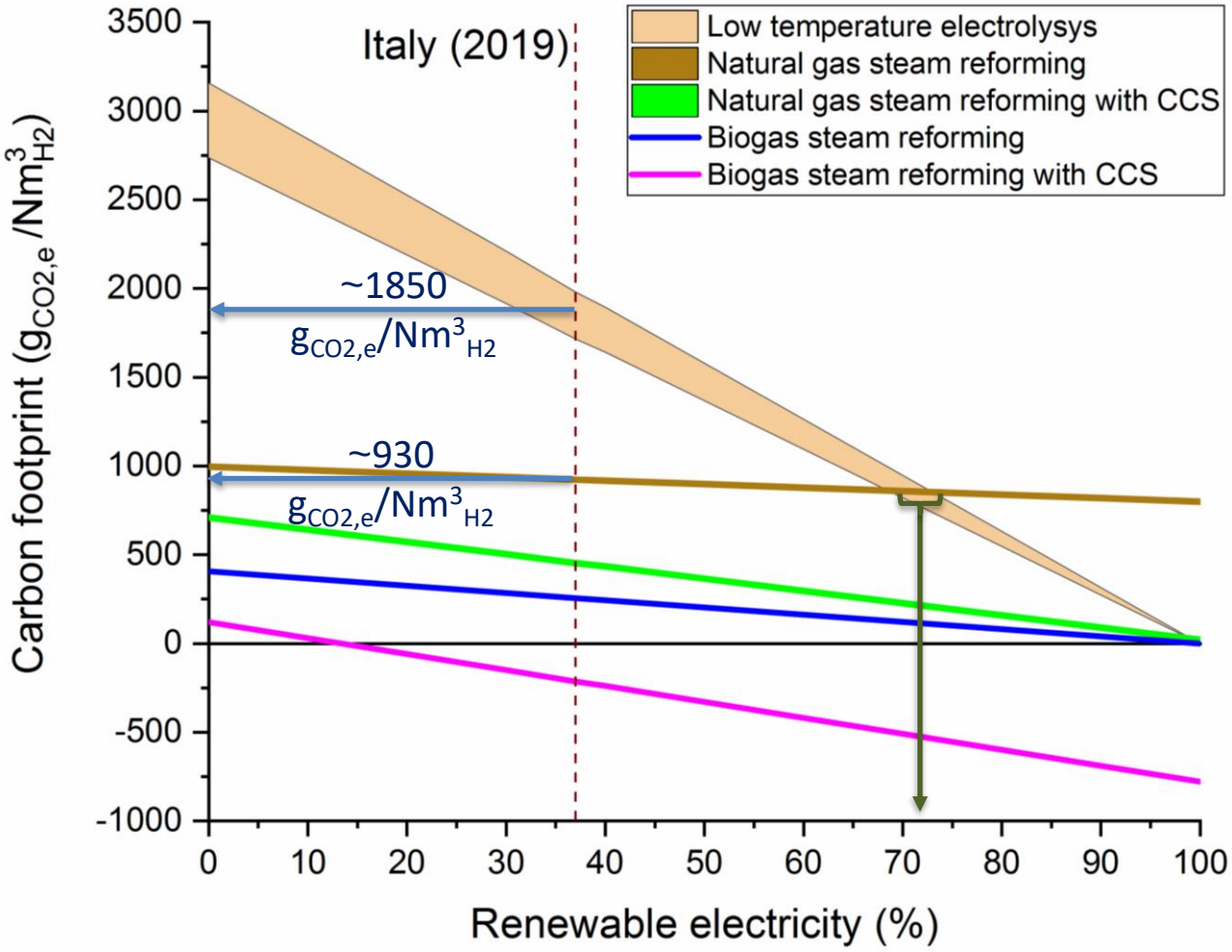





Adapted from: https://www.rff.org/publications/issue-briefs/investment-tax-credits-hydrogen-storage/

# Hydrogen production carbon footprint






## How is the situation today?

**Gray hydrogen** is the **less impactful** hydrogen production method (0,93 $kg_{CO2,e/}Nm^3_{H2}$ vs 1,85 $kg_{CO2,e/}Nm^3_{H2}$)

**When will Electrolysis be competitive with Gray Hydrogen in terms of emissions?**

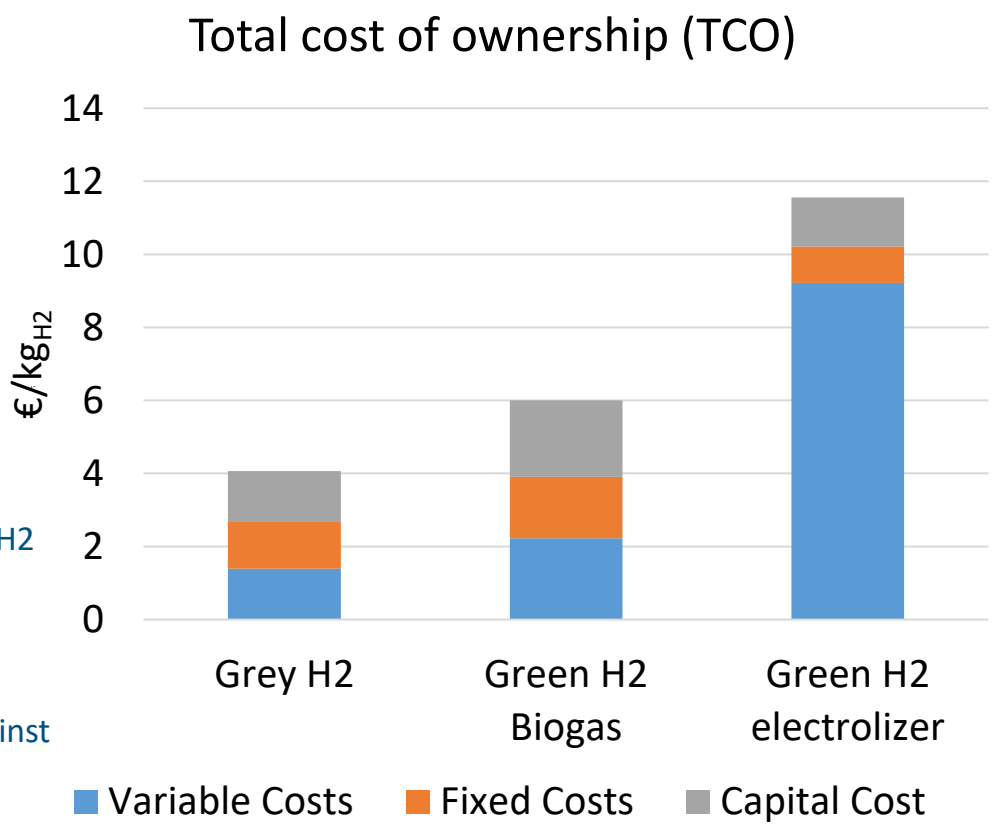
Over 70% of renewable electricity in the energy mix.

# But how much does it cost?



## Main assumptions:

- **Plant capacity:** 1 M $Nm^3/y$
- **Up-time:** 8300 h/y
- **Electricity cost:** 0,14 €/kWh
- **Natural gas cost:** 0,18 €/$Sm^3$
- **Electrolyser efficiency:** 5,4 $kWh/Nm^3_{H2}$
- **Depreciation time:** 10 years
- **Specific electrolyser cost:** 1200 €/$kW_{inst}$

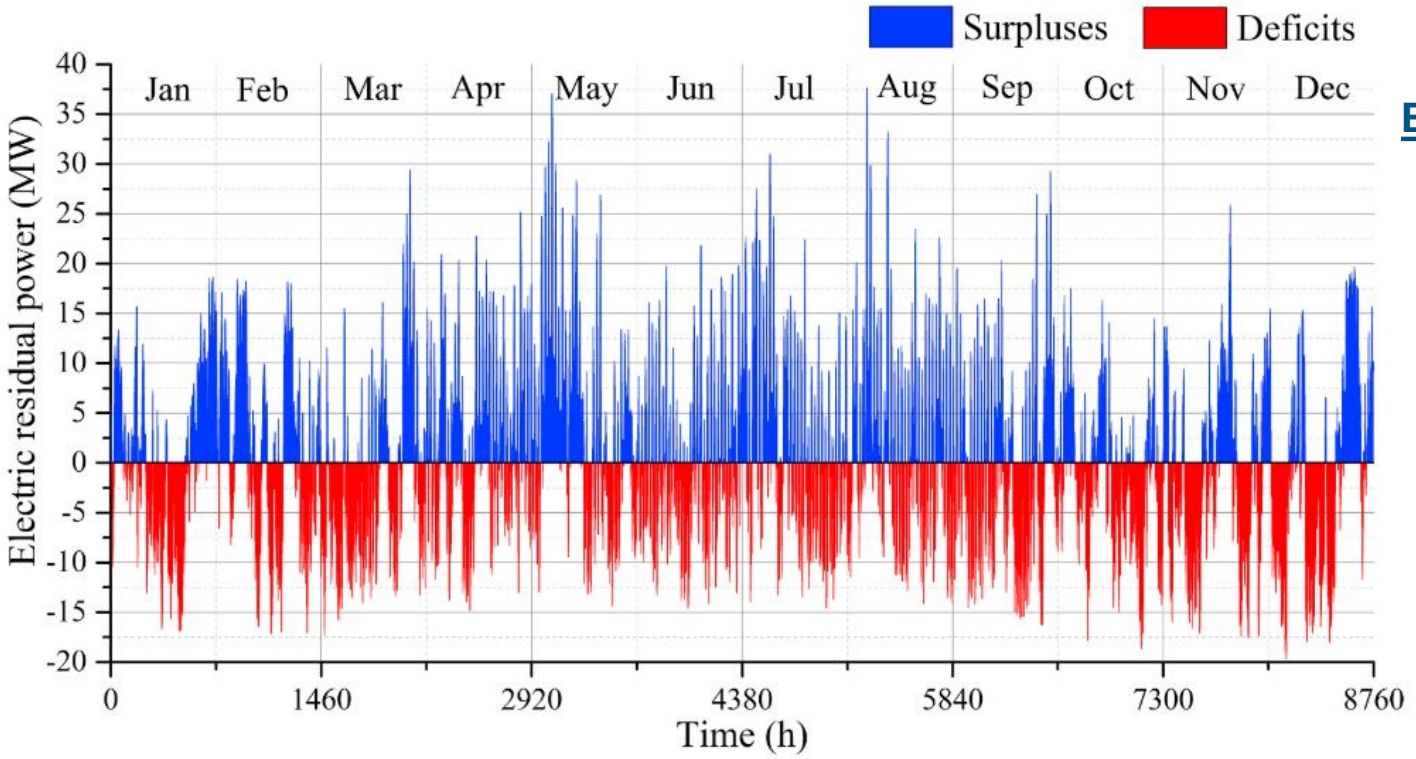



**Optimistic → Current prices >1800 €/$kW_{inst}$**

# Renewable production scenario

## Electricity production residuals in a high renewables production scenario (2050 scenario[3])

*Residual = Production - Consumption*




**Electr. Surplus periods**

**Current Italy:**

*~1000 h/y*

**Future scenario:**

*~3500 h/y*

[3] Salomone et al. (2018), Chemical Engineering Journal; DOI: 10.1016/j.cej.2018.10.170

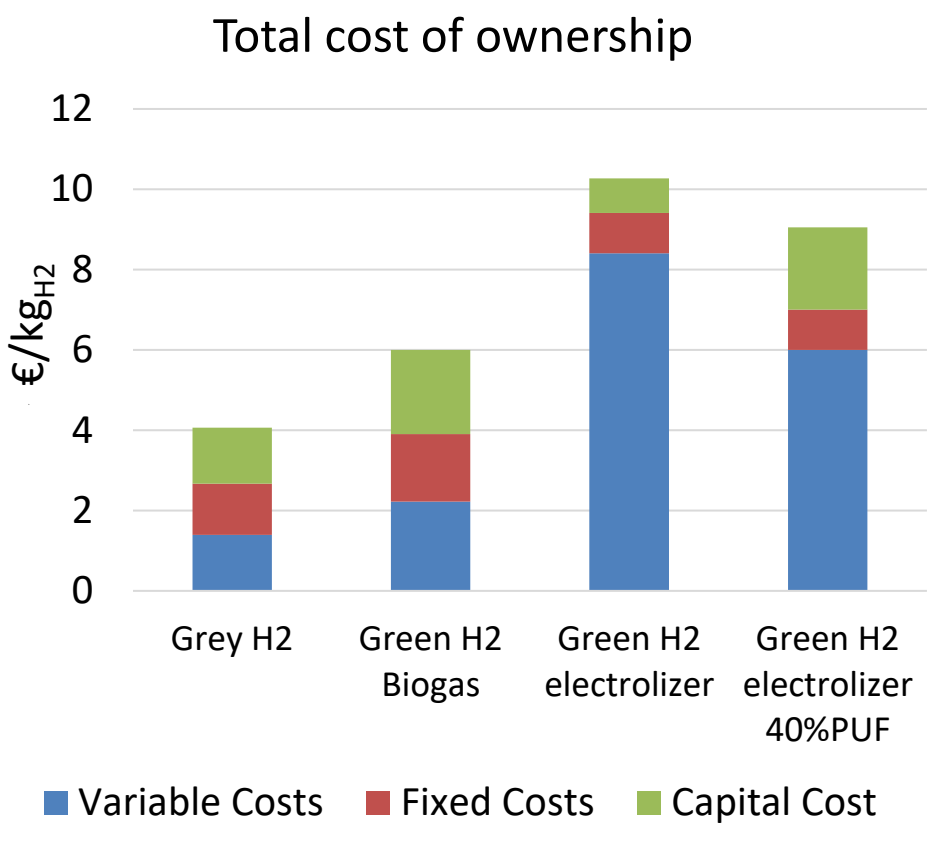
# How much does it cost?



**Main assumptions electrolysis only surplus:**

- **Plant capacity:** 1 M $Nm^3/y$
- **Up-time:** 3500 h/y
- **Electricity cost:** 0,10 €/kWh
- **Electrolyser efficiency:** 5,4 $kWh/Nm^3_{H2}$
- **Depreciation time:** 10 years
- **Specific electrolyser cost:** 1200 €/$kW_{inst}$

**Electrolysis installed capacity increase:**
650 kW → 1500 kW




**Optimistic → Current prices >1800 €/$kW_{inst}$**

# EU Green Deal



- The target is to install **40 GW** of electrolysers
- The subsidy program to allow the installation is the biggest plan ever seen to help a technology development
- The electrolysers have to be fed by 100% Renewable electricity (otherwise a significant increase of $CO_2$ emission will be obtained)
- Assuming that the electrolysers will operate 8400 hours/year (requiring huge installation of renewable sources plus huge storages for electricity) the overall production will be around 5,5 Million tons/year, which is the **7% only** of the actual Hydrogen industrial demand
- The energy transition is going to be a pretty **long way**....

# EU Green Deal



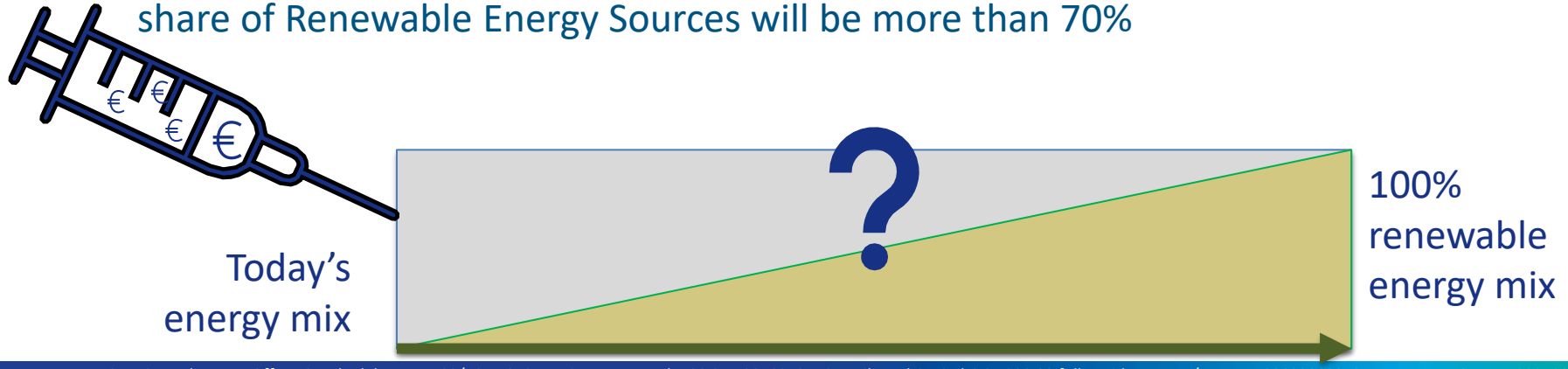
- The experience developed already 20 years ago is clearly stating that a new technology can penetrate the market and diffuse only if it's both **economically competitive** and **beneficial for the environment**
- Electrolysers today need an **enormous amount of subsidies** for the **CAPEX** and even for the **OPEX**
- Electrolyser indirect emissions today can be **two times worse for the environment** compared to the Hydrogen obtained from fossil Natural Gas without any CO2 capture.

- The **very first priority** for the environment is not the electrolyser, but is the **increase of the Renewable Energy Sources**.

# What can we do in the meantime?



- The demand for hydrogen in the short to medium term is expected to grow, if cheap hydrogen will be available
- **Gray hydrogen** is today and in the mid term the **most environmentally friendly** and **cost efficient** hydrogen production technology if compared to electrolysis fed with electricity from the grid
- Using **biogas and biomass gasification** has the biggest potential in the short to mid term to produce **green hydrogen**
- Retrofit grey hydrogen facilities with CCUS to produce blue hydrogen, when the share of Renewable Energy Sources will be more than 70%



# What can we do in the meantime?




## H2 Genio

Hydrogen generation directly on site, simply starting from Natural Gas, from small flow rates and up to industrial sizes.

*Plants in Italy*


## Biomethane

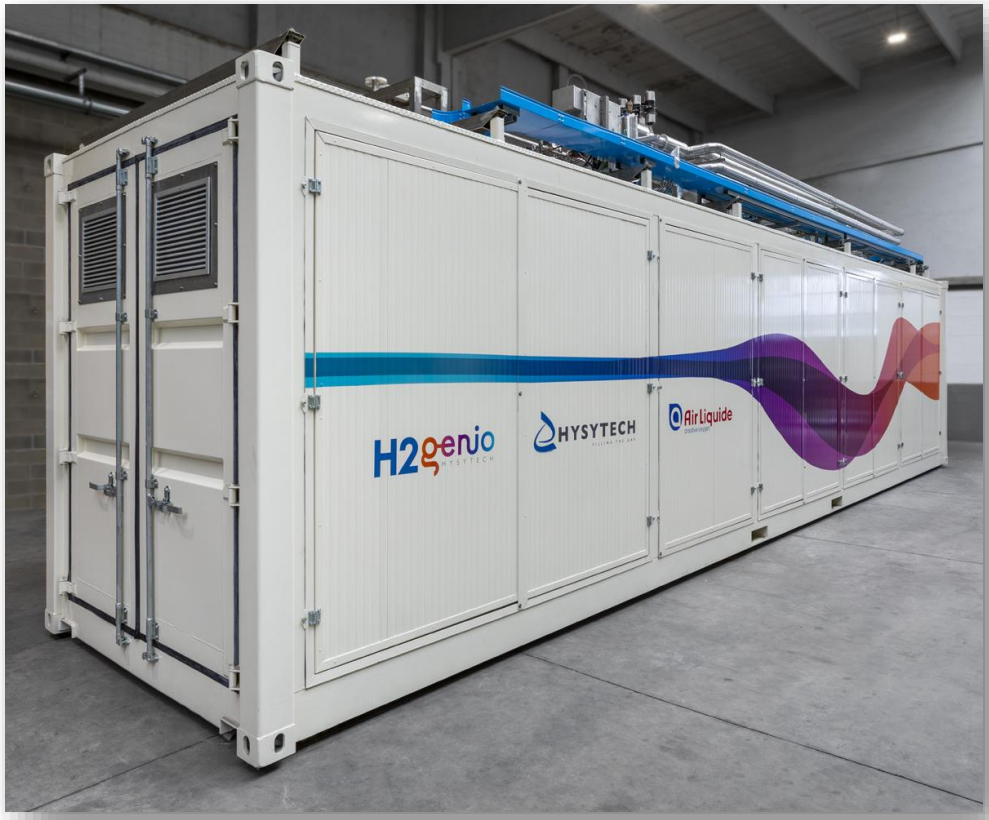
Biomethane from raw biogas.

*Plants in Italy from MSW and Biomass*

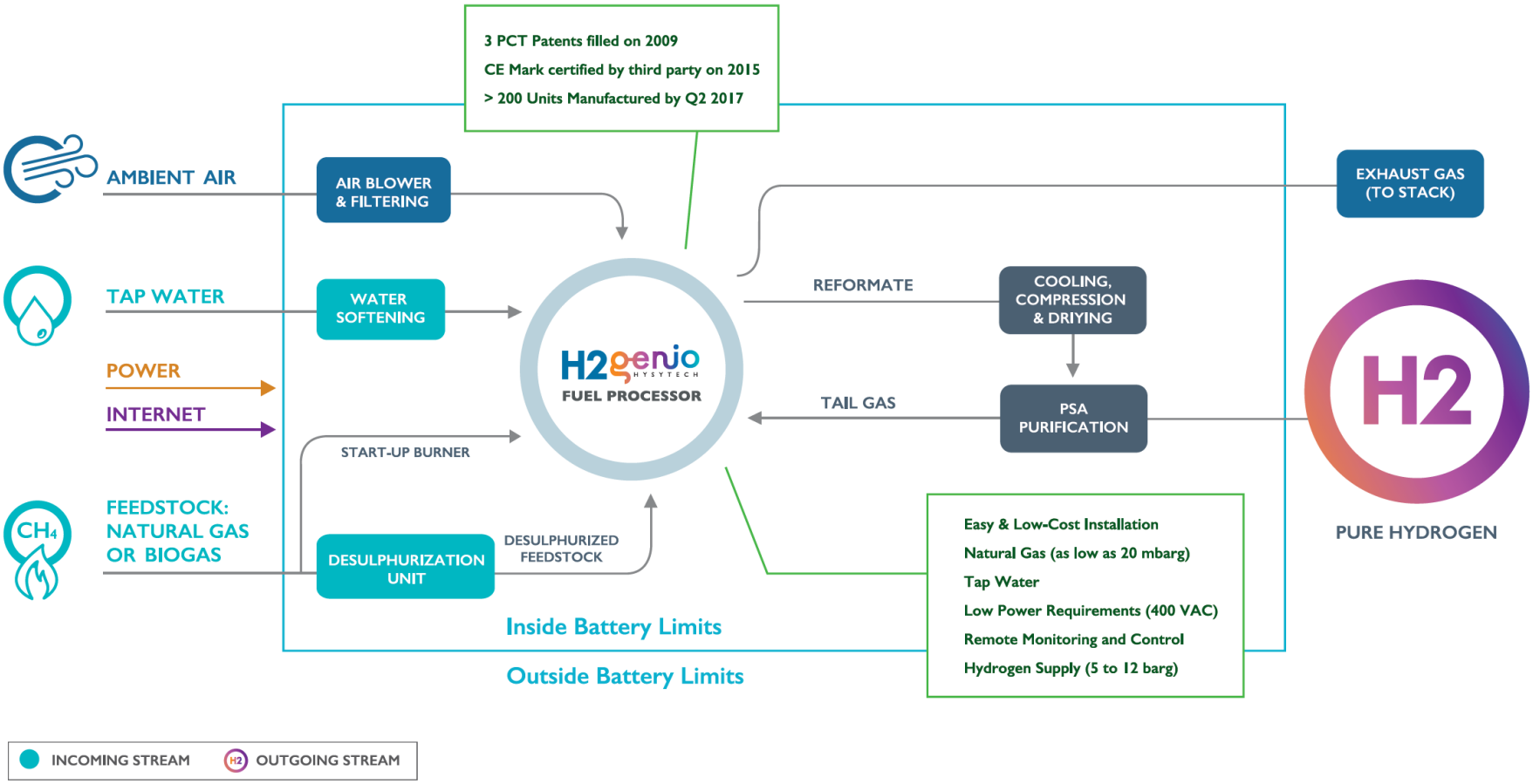
# Hight Purity Hydrogen for Steel Industry (120 $Nm^3/h$)

**Features:**

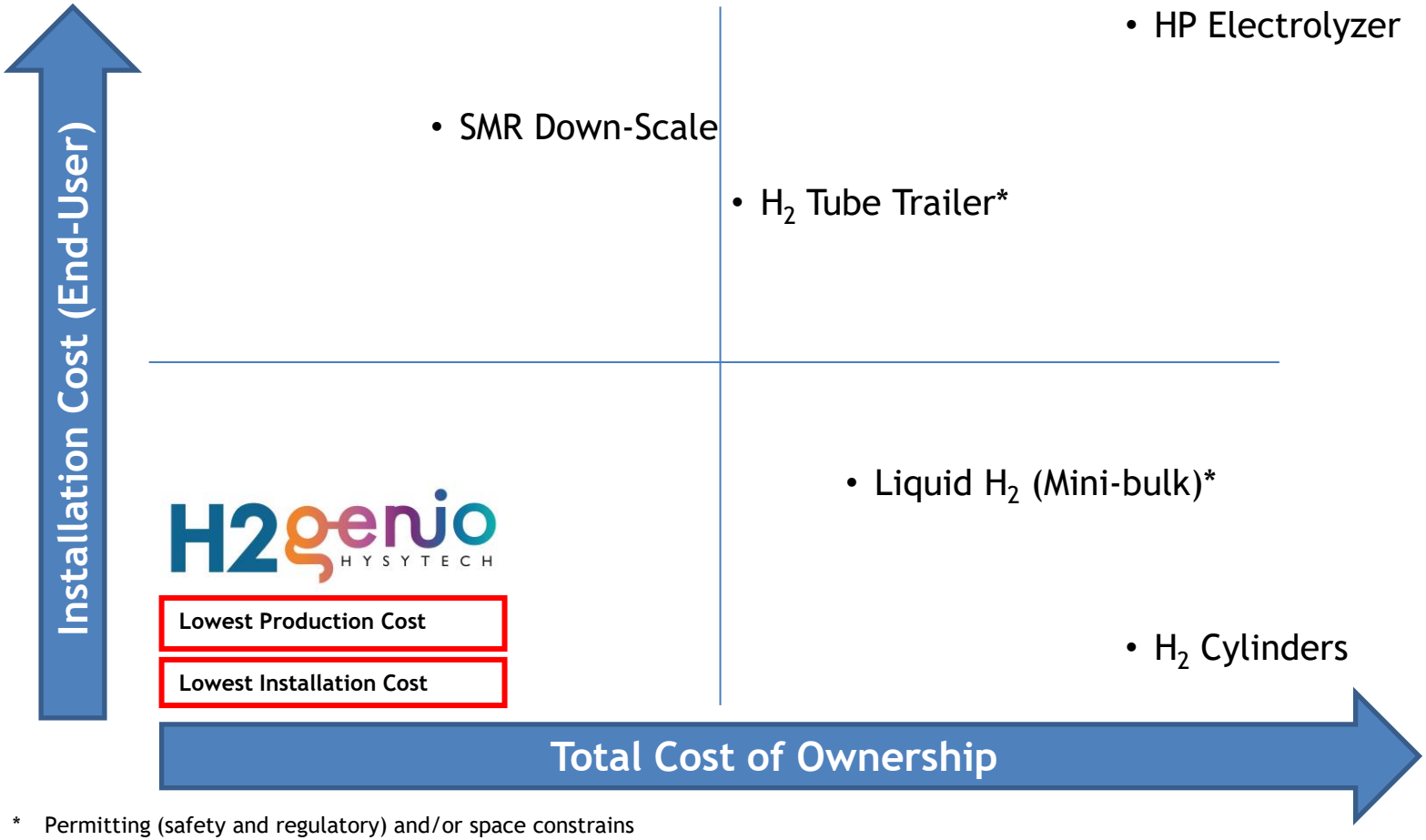
- High Purity Hydrogen >99,995%vol
- Capacity up to 120 Nm3/h
- Power Consumption <40 kW
- Delivery Pressure 11 barg
- Natural Gas feed:
  - Pressure <0,350 mbarg
  - Odorized Gas
- Fully automatic & unmanned



# Turn-key Product Battery Limits



# Known Competitors & Alternatives




* Permitting (safety and regulatory) and/or space constrains often make this kind of delivery not possible

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