# Pyrolysis

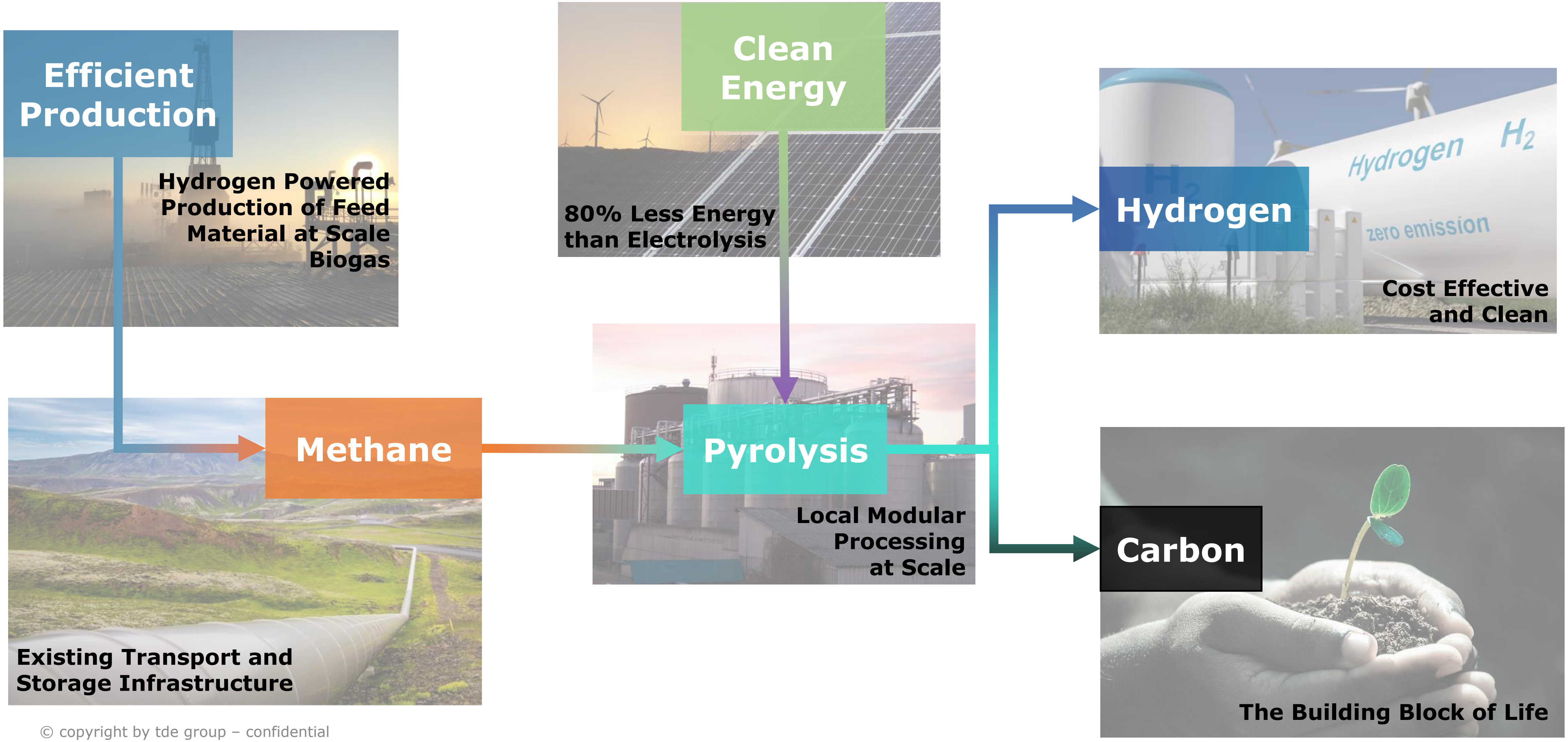
## Methan Pyrolyse: Eine ökonomische Alternative zur Elektrolyse?

# hydrogen and carbon technology

## Content

# hydrogen and carbon technology

## Methane Pyrolysis Input and Output



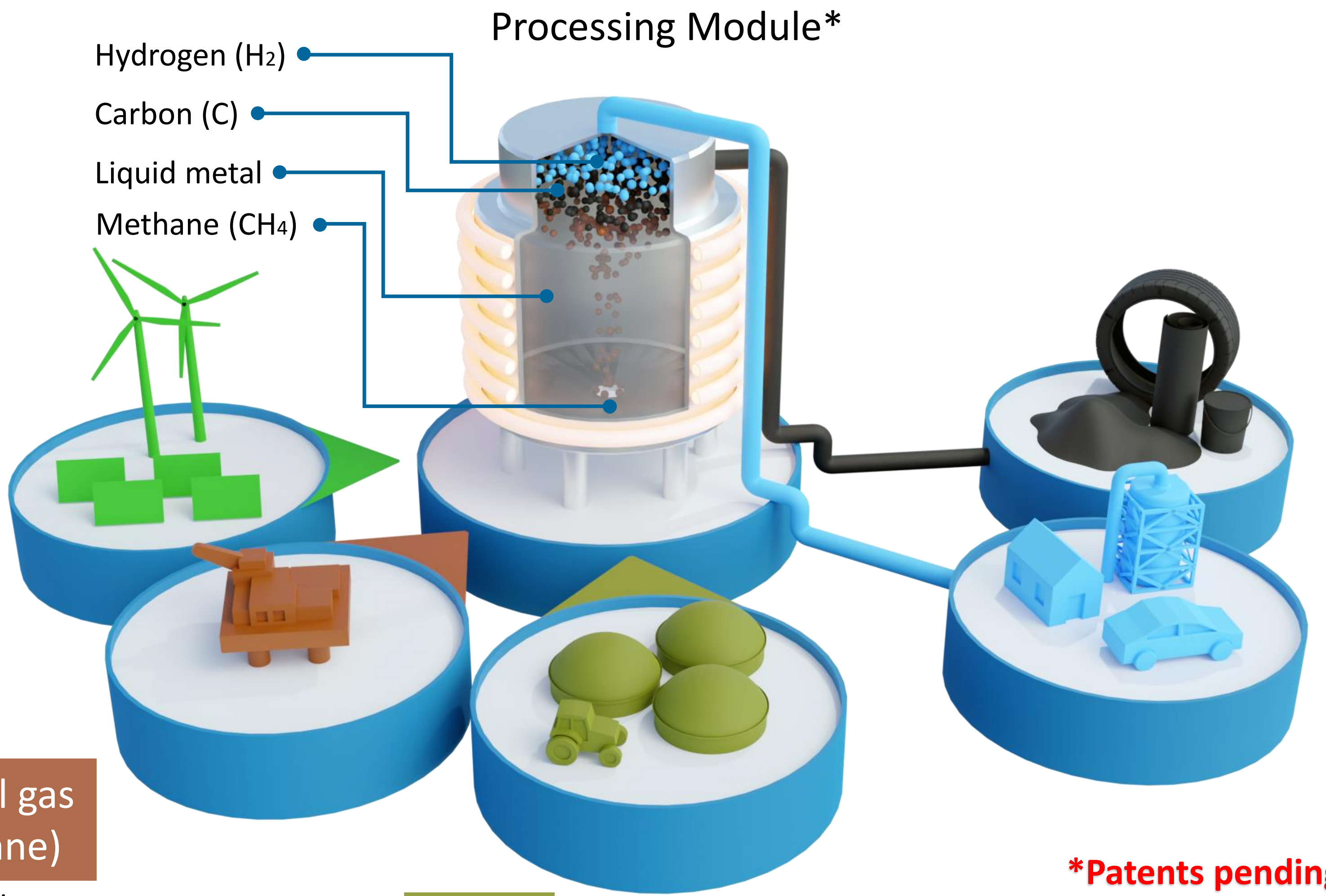

 

# hydrogen and carbon technology

## Ecosystym

### Methane pyrolysis

Decomposition of methane at high temperatures in a reactor with liquid metal to hydrogen and solid carbon




### Energy for process heat

20 to 25% of energy of electrolysis required

### Natural gas (methane)

Use of existing infrastructure

### Biogas

Negative emission balance

### Solid carbon

- Agriculture
- Lightweight construction
- Food industry
- Industry (e.g. colors, tyres, batteries)

### Hydrogen

- Chemical industry
- Ammonia and fertilizer
- Heavy transport
- Hydrogen storage

***Patents pending, with growing patent family around processing and C-quality)**

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## A sustainable path to scalable energy supply

- **Supplying the heavy industry** with **$CO_2$ neutral** and **affordable** hydrogen at industrial scale
- **Utilize existing** natural gas infrastructure
- **Utilize carbon** – the building block of life – as valuable secondary raw material

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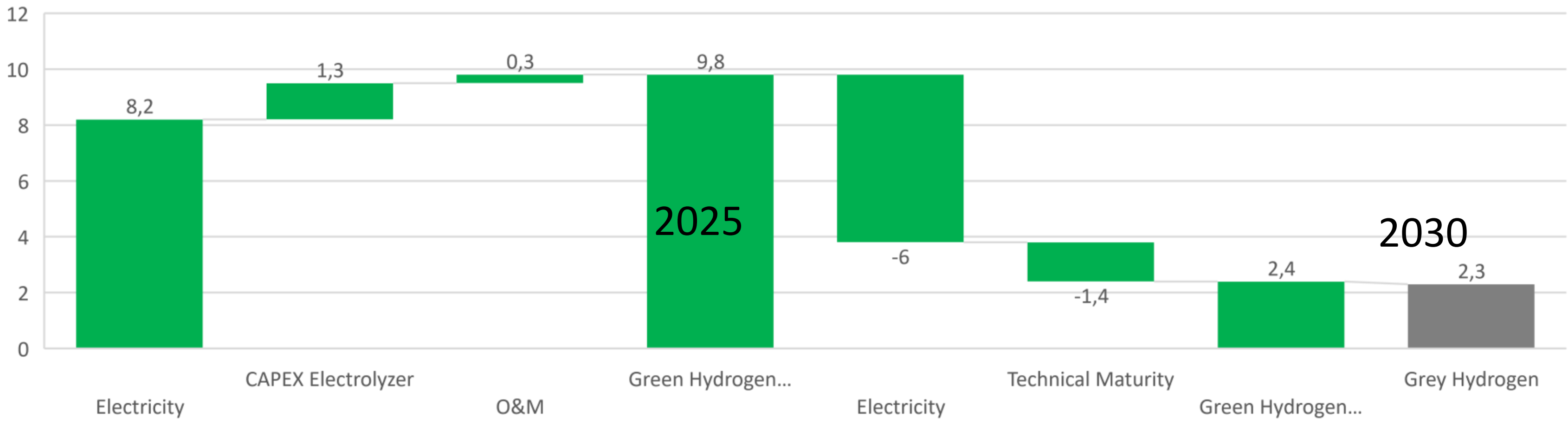
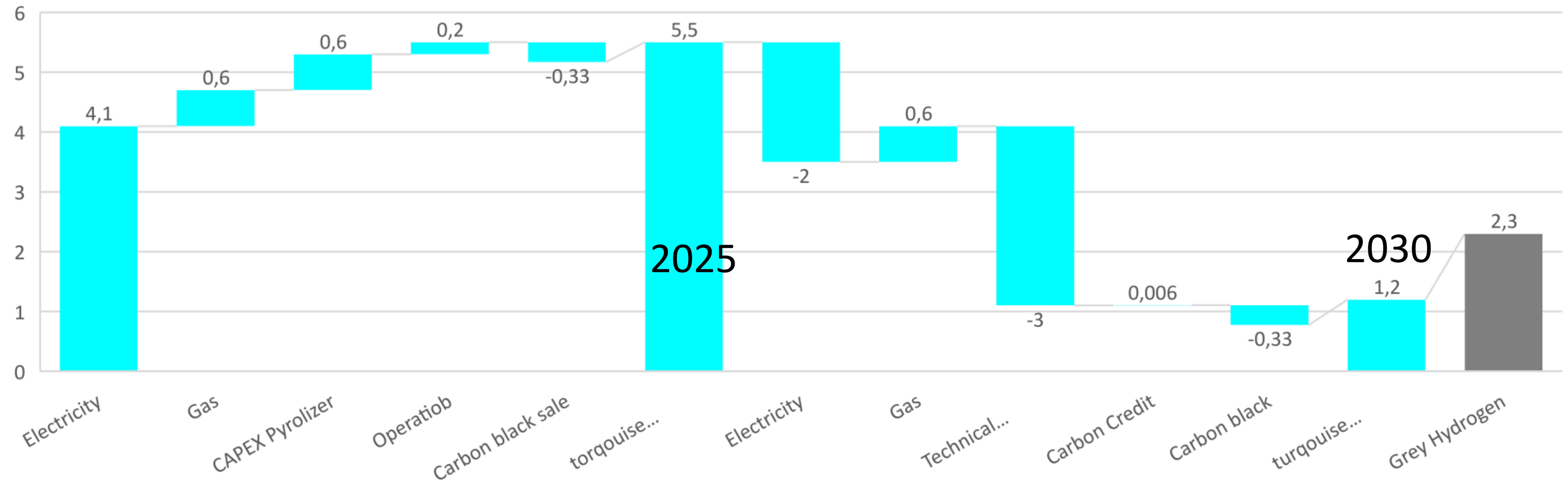
## Cost to produce 1kg turquoise hydrogen in Europe

**Comparison:**

- Turquoise $H_2$ approx. 44% cheaper to produce in 2025 and 50% in 2030
- \> 50% less renewable energy demand



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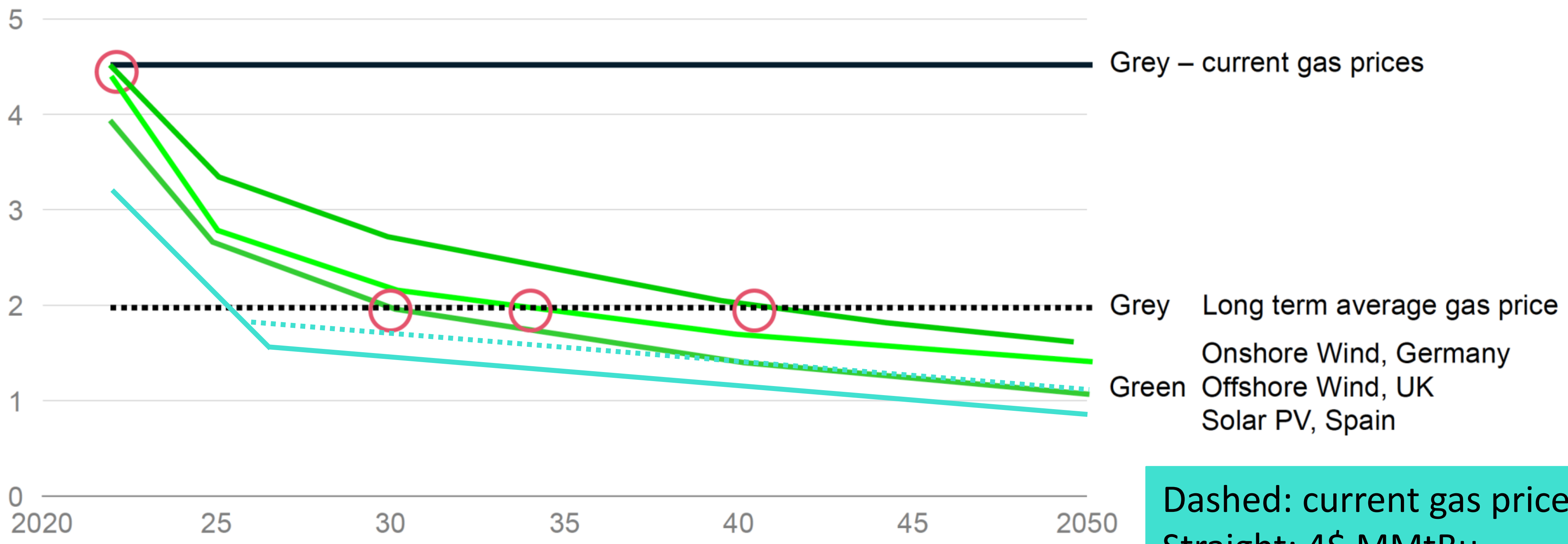
## **tde energy** pyrolysis: today and future outlook
## Pyrolysis is resilient toward gas price fluctuations

**Currently, green hydrogen already outcompetes grey on costs**

**Hydrogen production costs by supply route,**
USD/kg

Gas Price Today Sept 2022: 8 $ MMtBu




Dashed: current gas price
Straight: 4$ MMtBu

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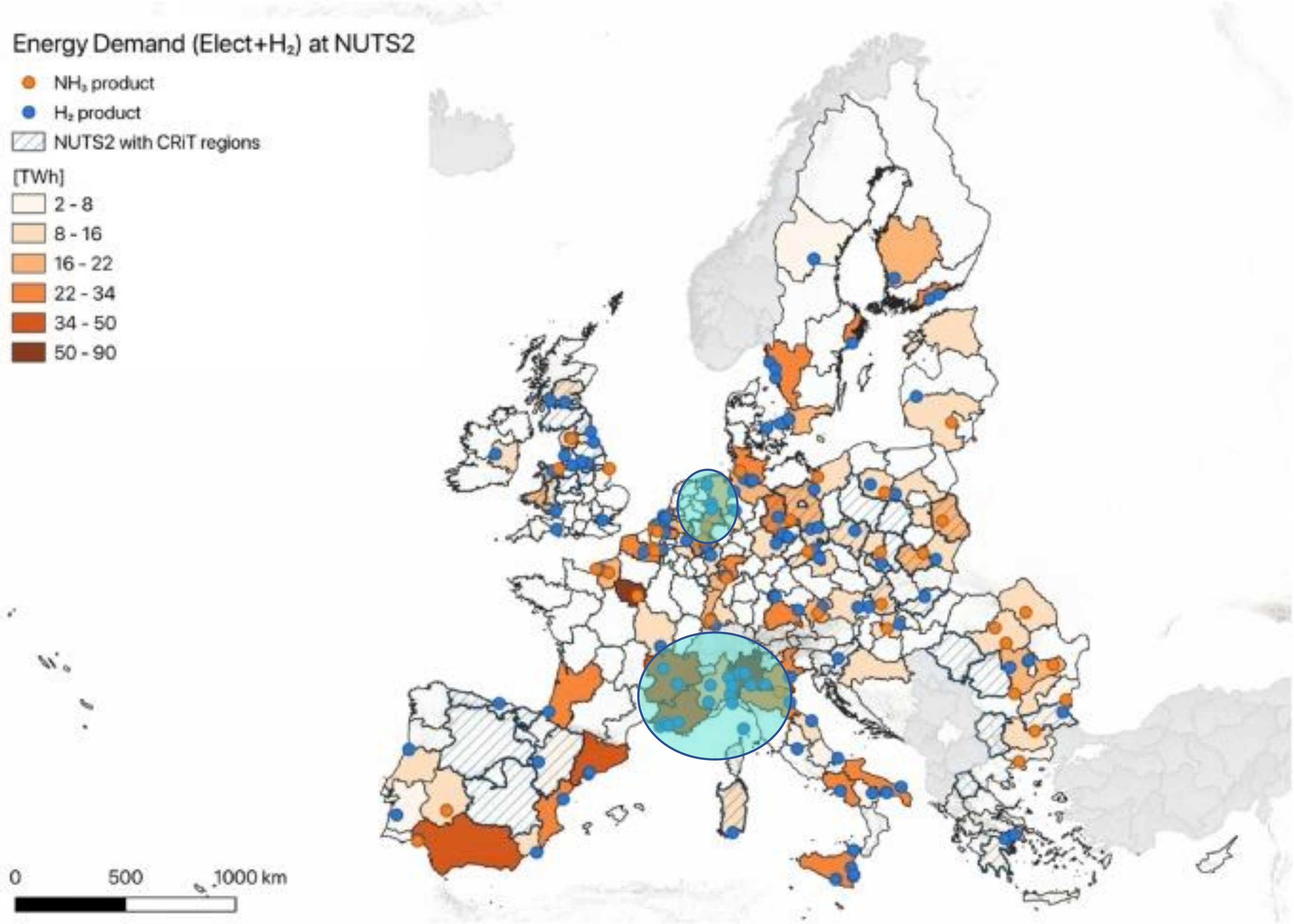
## Hydrogen Demand Europe

**European Market**
currently 9.7 million tons hydrogen production

2030 est. 16.9 million tons

Distribution of main hydrogen production hubs in EU27 + UK. Green and blue dots represent chemical industries with hydrogen and ammonia production. Shaded polygons show EU coal regions in transition (CRiT). Background colors represent total demand in TWh per year i.e. the sum of electricity consumption and the potential demand for electrolysis only in hydrogen producing regions.



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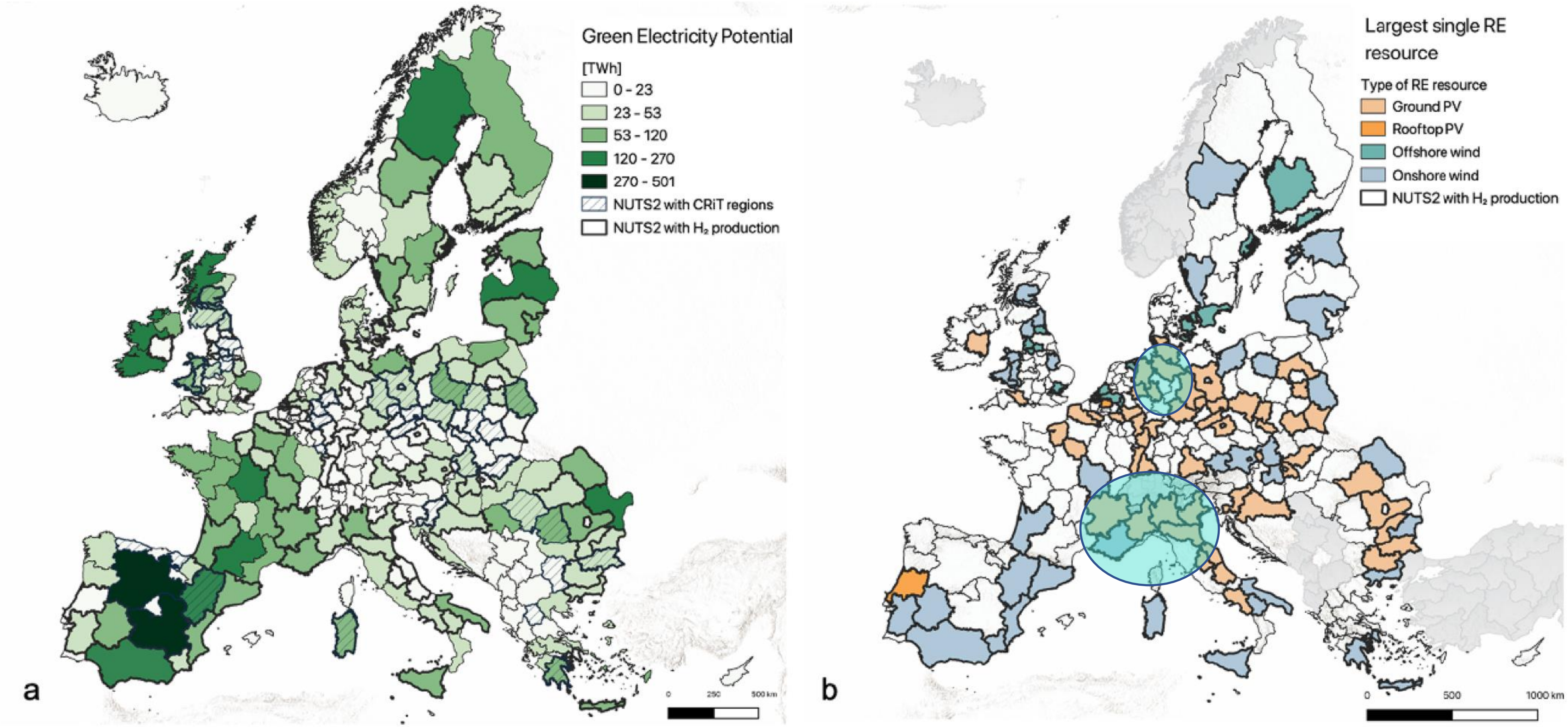
## Hydrogen Demand Europe



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## Germany: 62 new funded projects onwards from 2021 (€8Bn):2GW $H_2$ via green electrolysis for 2030.


This is only 40% of the German goal of 5GW for 2030!

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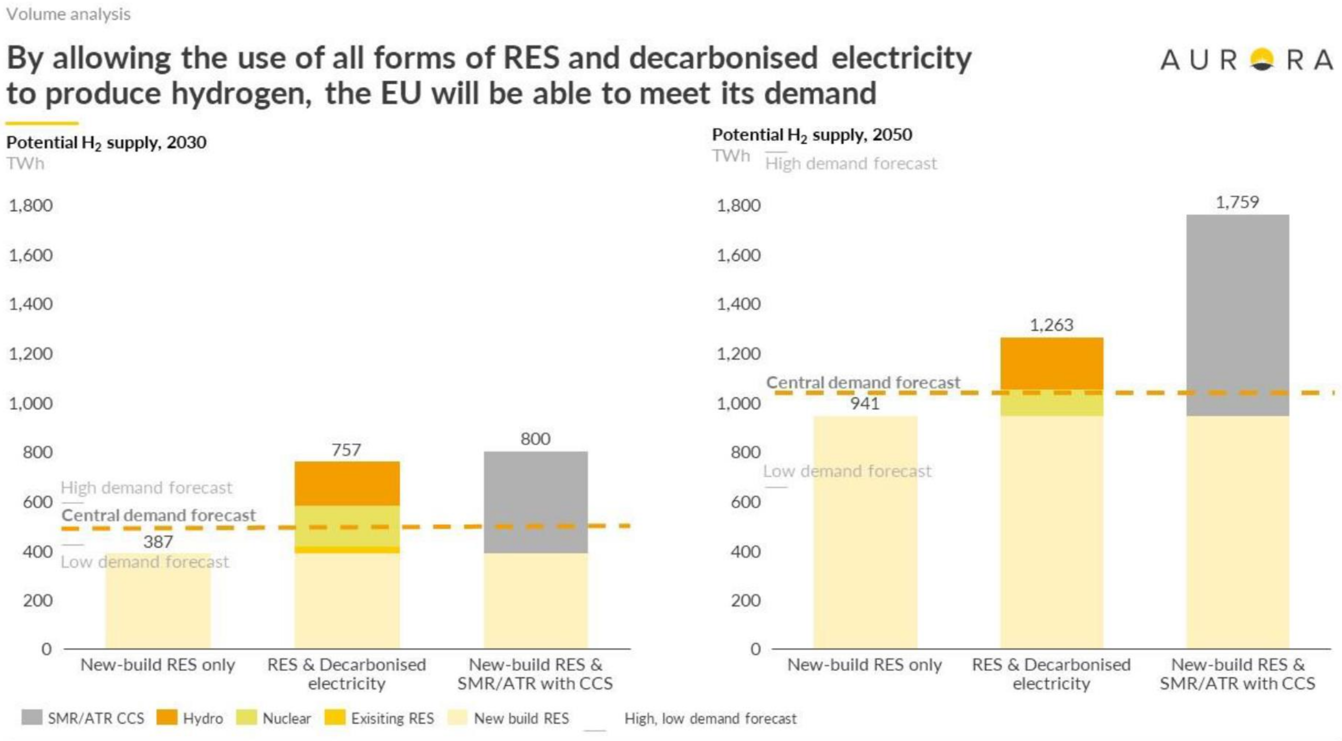
## Current Scenario using green electrolysis

- Volumes of green $H_2$ that could be produced from new-build renewable capacity only, will not be sufficient to meet central demand forecast
- By allowing all (!) forms of renewable and decarbonized electricity, the EU could produce enough hydrogen in both 2030 and 2050, avoiding imports and reliance on fossil fuel derived hydrogen.
- Pyrolysis will be advantageous and accelerate decarbonization driven by 50 to 80% less energy demand
- Transport will be reduced and capitalize on existing natural gas infrastructure



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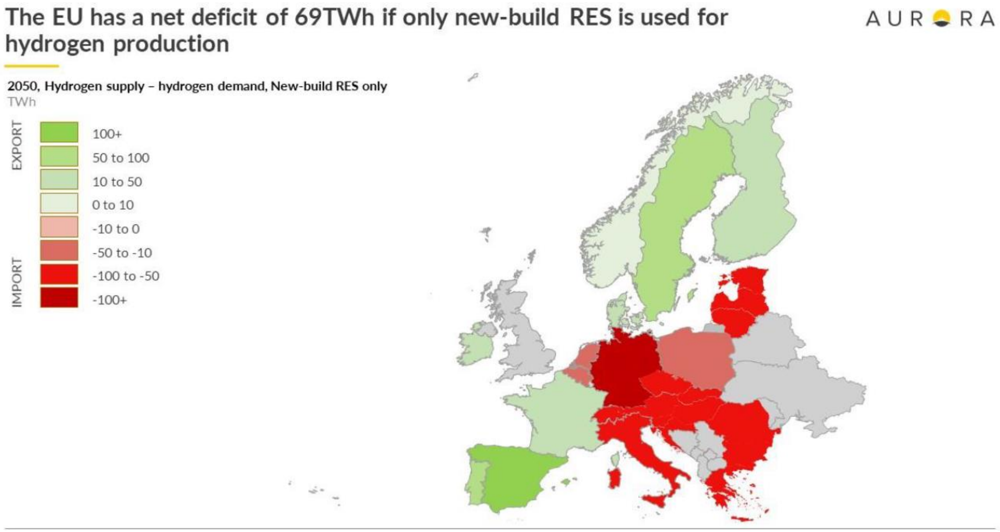
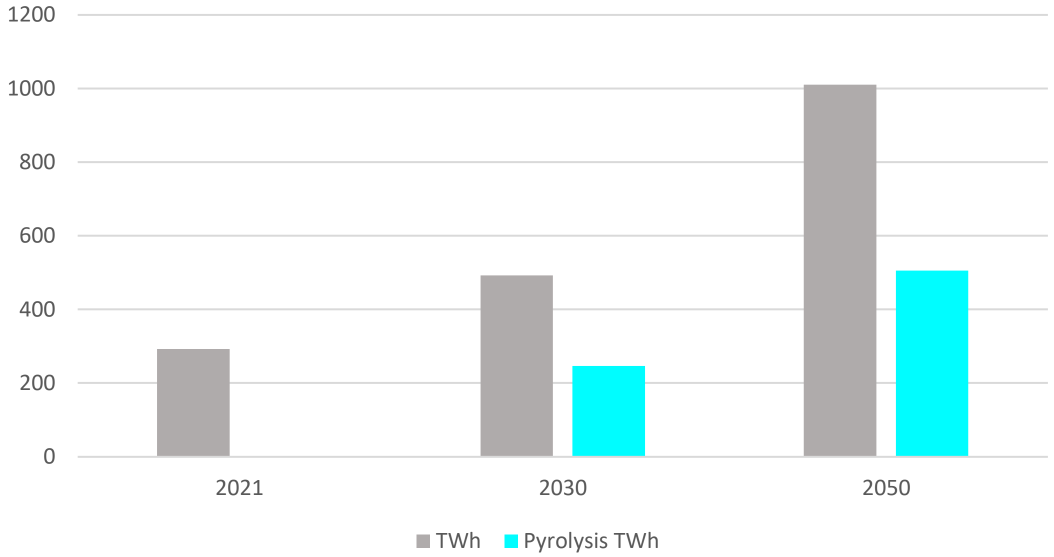
## Impact of 30% hydrogen production via pyrolysis

Pyrolysis can minimize this predicted deficit of 69TWh:

- It can save 48.6 million tons of $CO_2$ emissions.
- This enables the use of RES for other sectors other than hydrogen production such as heating, power generation etc.
- Pyrolysis can help in regions with low RES



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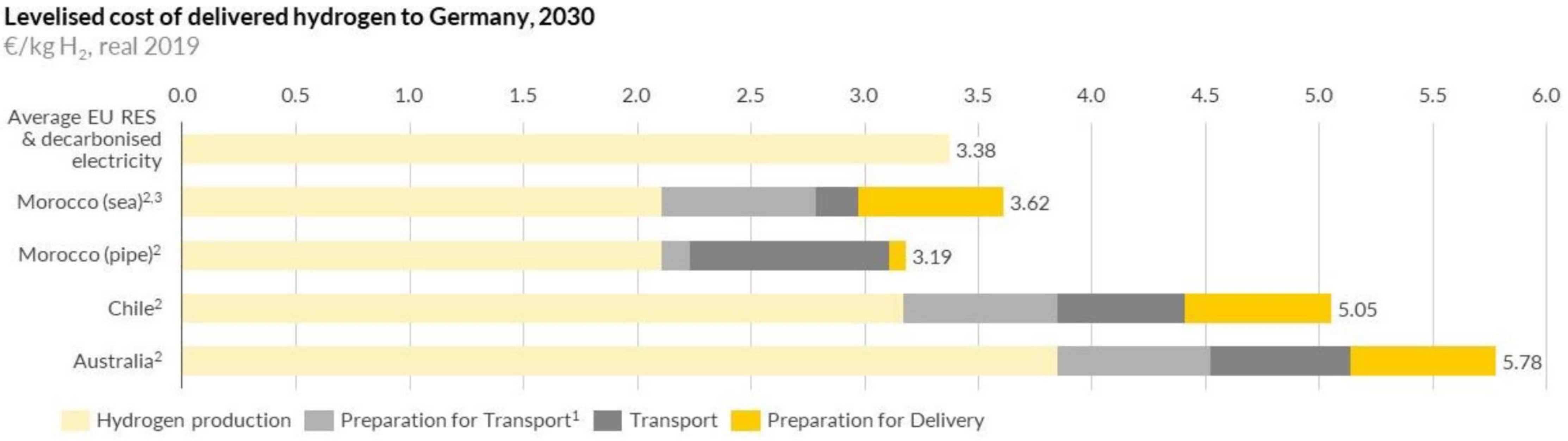
## Cost of hydrogen imports to Europe

Cost of hydrogen imports are significant and may change the economics




1) Preparation for transport includes conversion into ammonia, preparation for delivery includes conversion from ammonia to H2. 2) H2 production costs in Morocco, Australia & Chile were calculated based on a discounted wholesale price. 3) Transports costs assume new-build pipeline
Source: Aurora Energy Research, IEA

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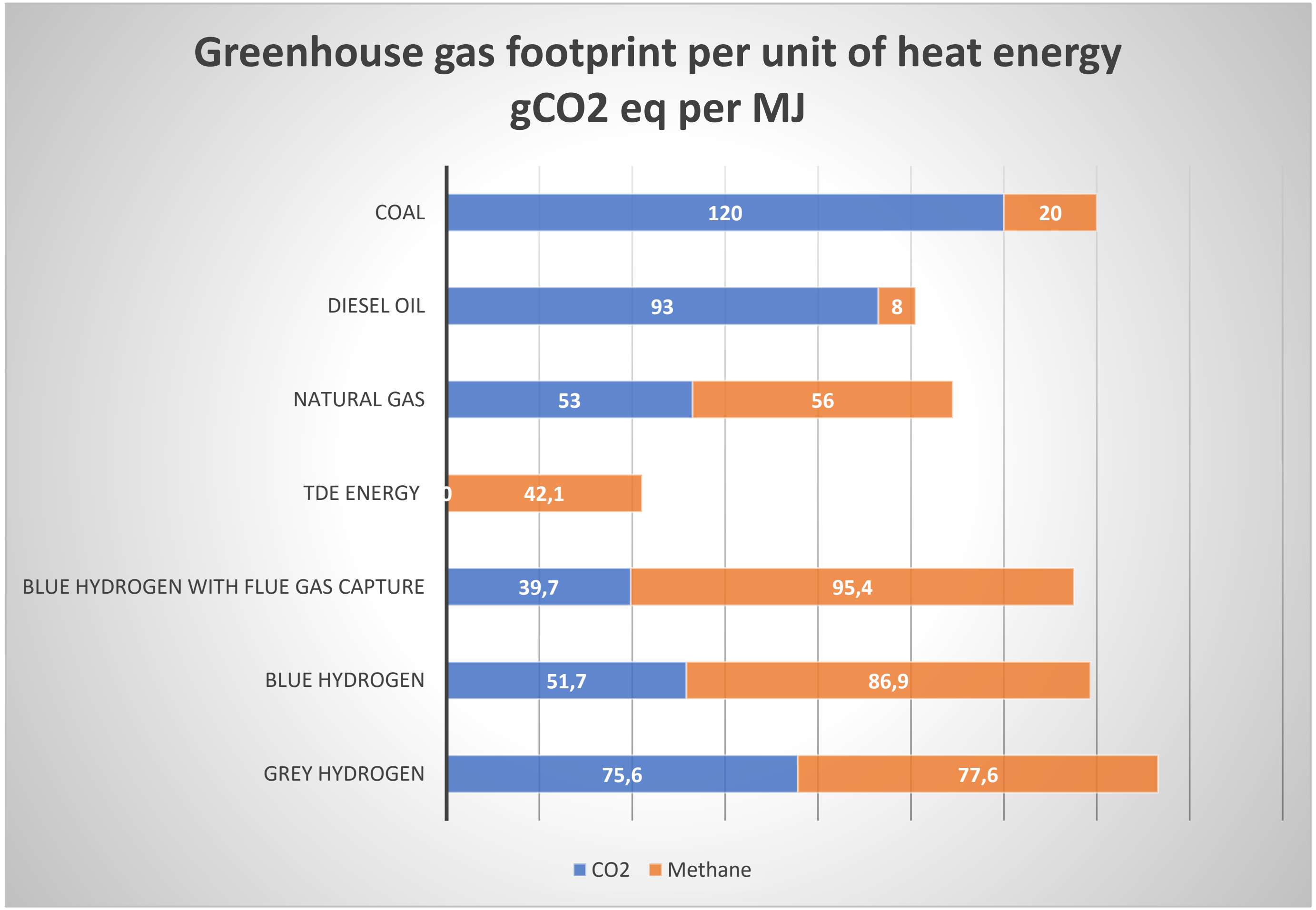
## Green house gases comparison
## „worst case scenario after Horwarth et al.“




Note:

- tde energy process driven by green energy
- tde process demands lower temperature compared to other pyrolysis processes resulting in lower emission
- Howarth et al. [https://doi.org/10.1002/ese3.956](https://doi.org/10.1002/ese3.956)

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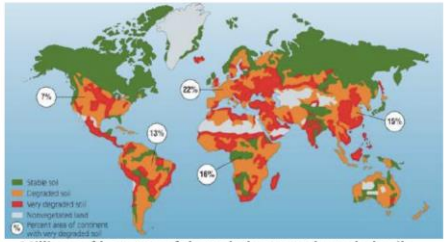
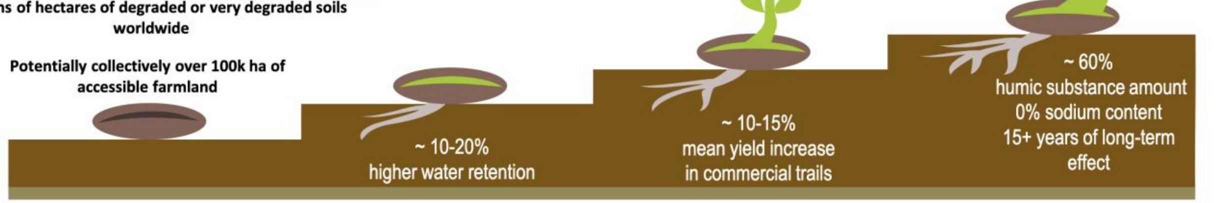
## Value Product Carbon

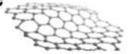
- Soil Improver: Carbon Credits for addition of agricultural areas
And improvement of fertilization?
- Construction: Substitution of cement?



Millions of hectares of degraded or very degraded soils worldwide

- ➢ Greatly increases the health of soils and the plants that grow in them. It also contributes to CO2 emission reduction in agriculture (fertile soils require fewer inputs and produce more biomass).
- ➢ Accelerated and stronger plant growth




| Type of Carbon | Types of Applications | Expected Price for Carbon |
|---|---|---|
| Carbon Black  | Tires, printing inks, high perfomance coating and plastics | $0.4-2+/kg depending on product requirements |
| Graphite  | Lithium-ion batteries; Graphite electrodes used in steel furnaces, | $10+/kg |
| Carbon Fiber  | 3D printing, Aerospace, automobiles, sports and leisure, construction, wind turbines, carbonreinforced composite materials and textiles | $25-113kg depending on product requirements |
| Carbon nanotubes  | Polymers, plastics, electronics, lithium-ion batteries | $0.10-600.00 per gram depending on application requirements |
| Needle coke  | Graphite electrodes for electric arc steel furnaces | ~$1.5/kg |
| Graphene  | Graphene used in flexible electronics, batteries, solar cells | ~ $50 -85$ / kg |

# hydrogen and carbon technology

## European Business Strategy

- Turquoise hydrogen fits very well in Europe:
  - Cost competitive
  - Less energy demand
  - Not cannibalizing on RES resources
  - Less dependency on hydrogen imports
  - Easy to implement into existing industrial and pipeline networks
  - Technical easier to handle compared to CCS and CCU
  - No water demand