

**24 - 28 October 2022**

**Brussels, Belgium**

[euhydrogenweek.eu](https://euhydrogenweek.eu)

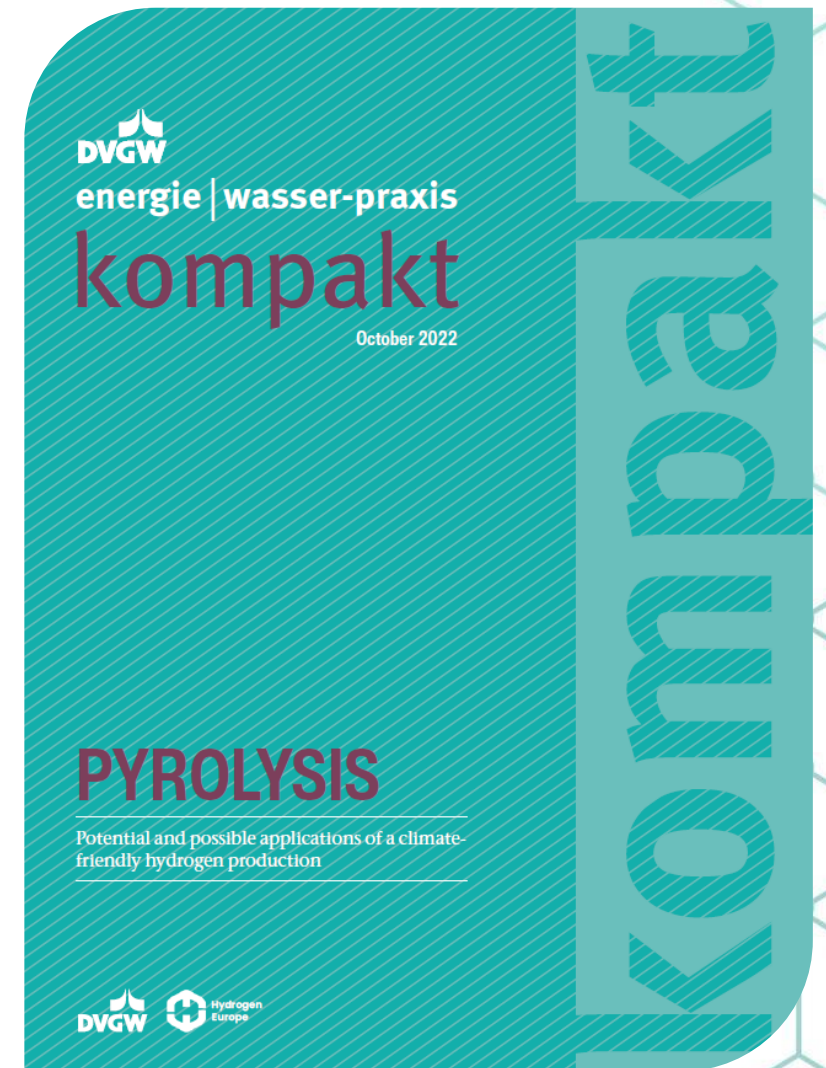


Flagship Expo



# Pyrolysis

Joint DVGW – HE publication:  
Potential and possible  
applications of a climate-friendly  
hydrogen production



# Welcome remarks



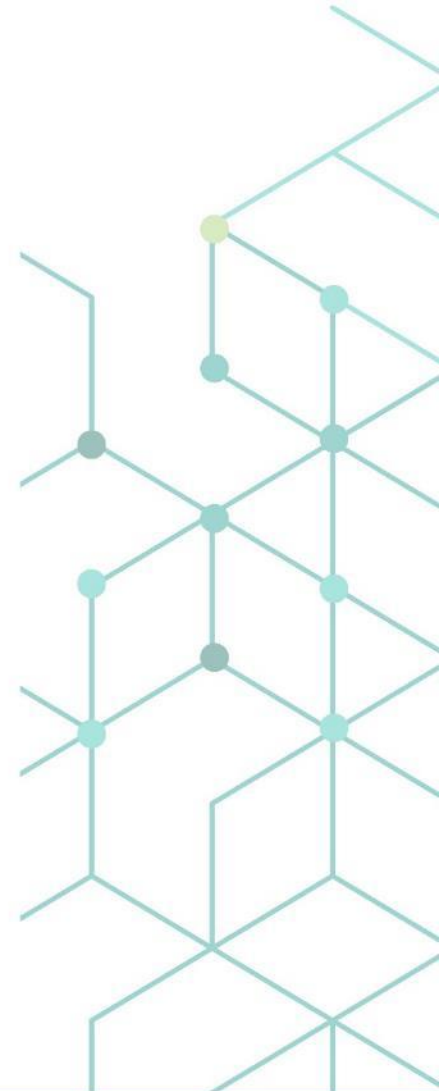
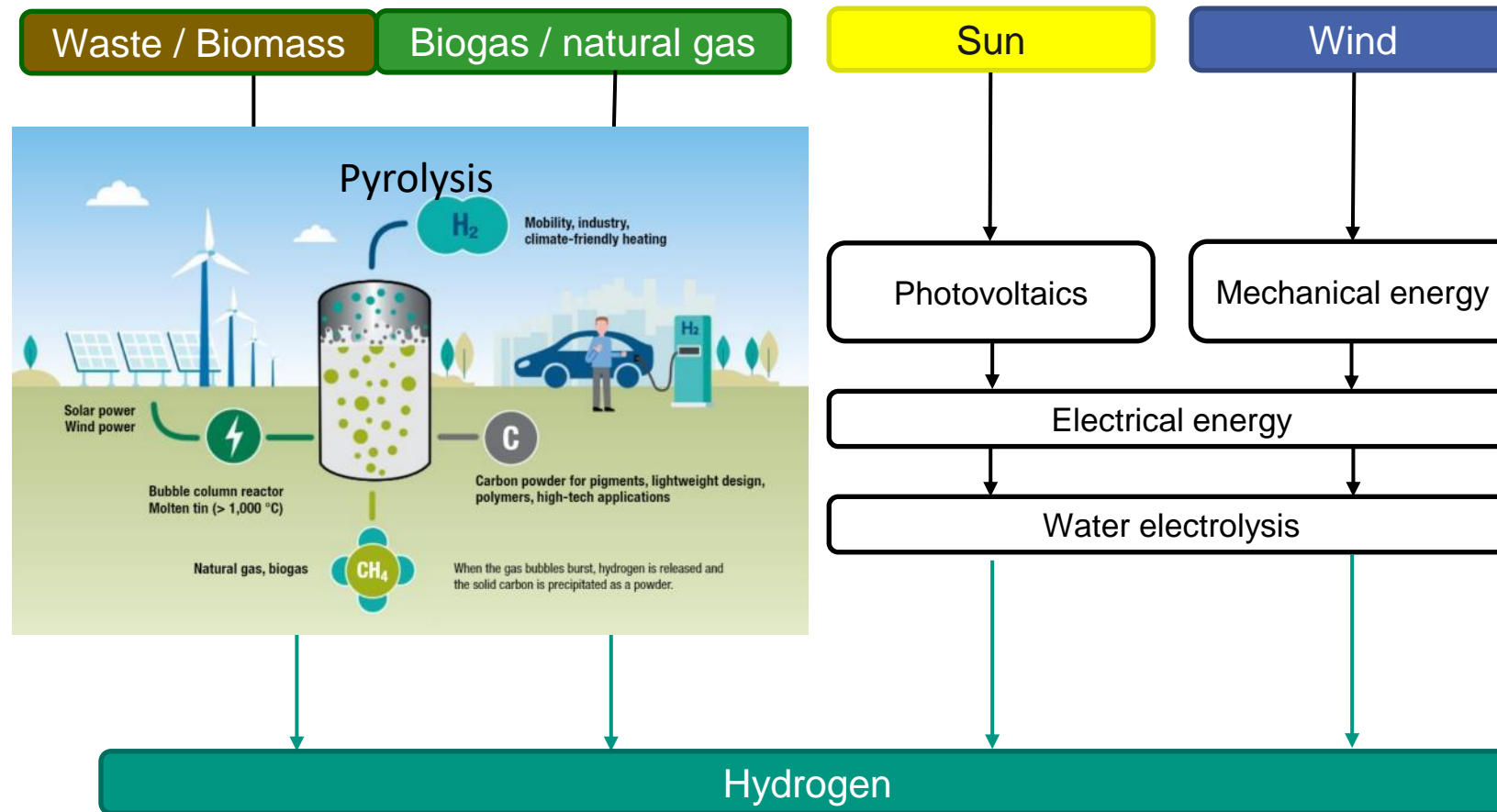
**Gerald Linke**

CEO

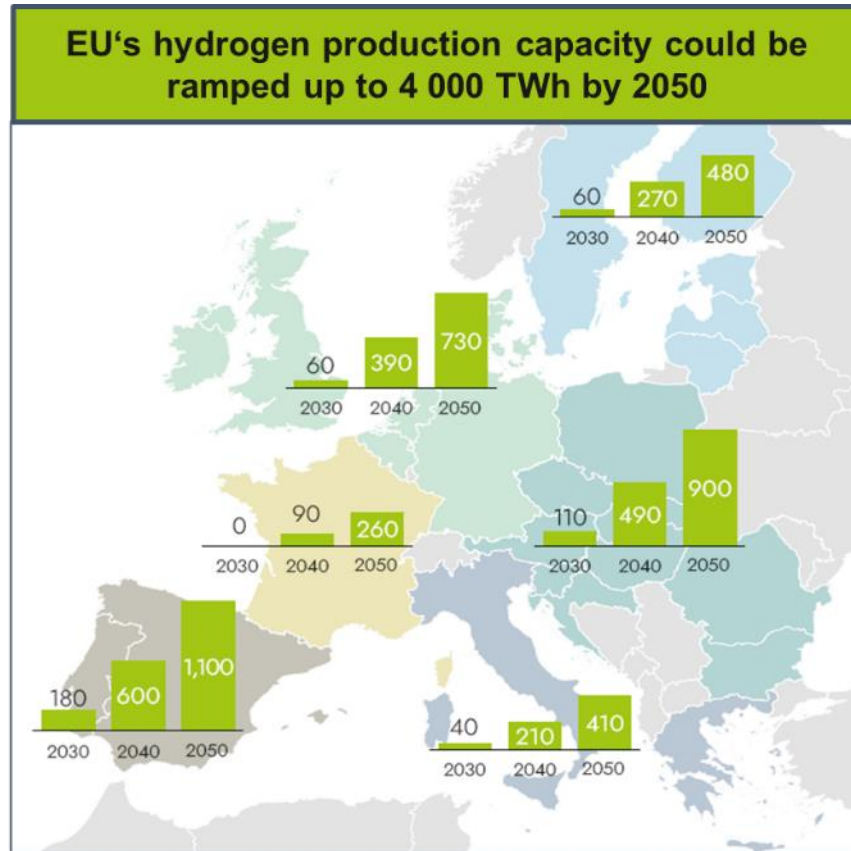
German Technical and Scientific  
Association for Gas and Water  
(DVGW)



# Various option of hydrogen production



# Studies show a rapid hydrogen ramp-up potential if all options are used



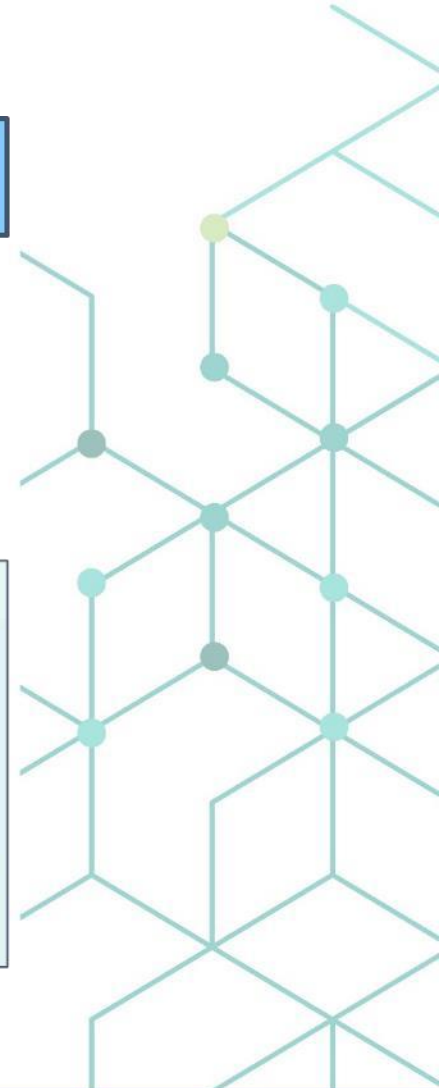
Source: Guidehouse, June 2021

## Green or blue?

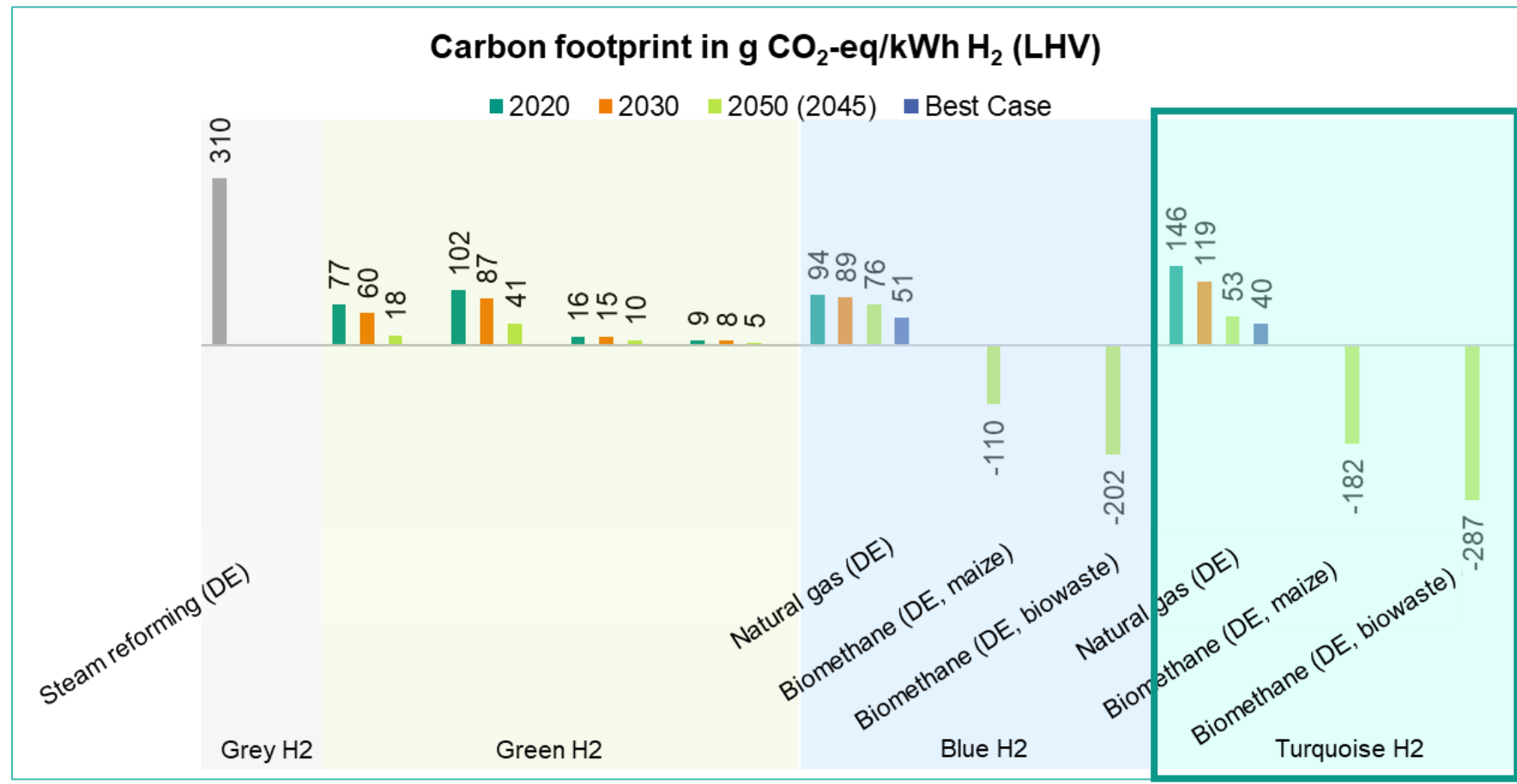
Whereas some opportunistic studies state that there will be enough generation capacity for a pure green hydrogen economy others predict a more balanced colour distribution (Hydrogen4EU)



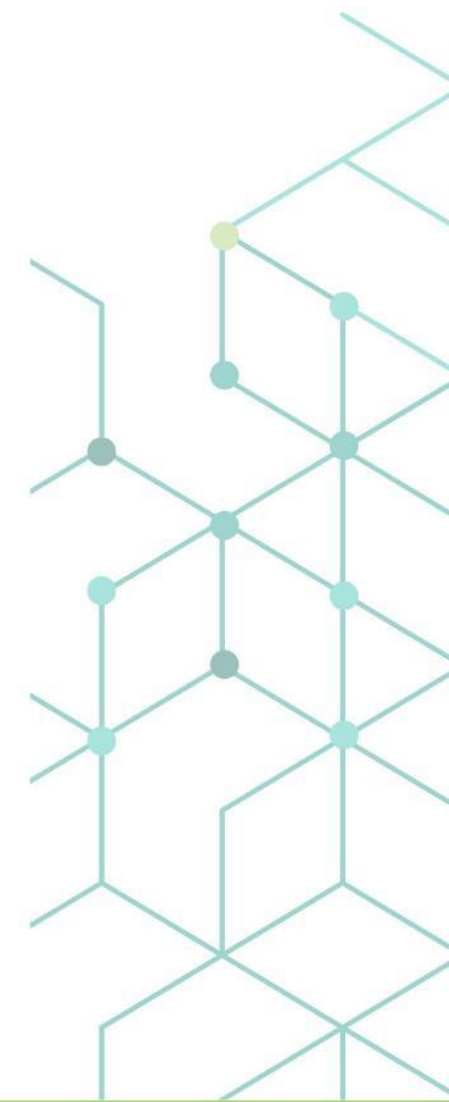
Source: Hydrogen4EU, June 2021



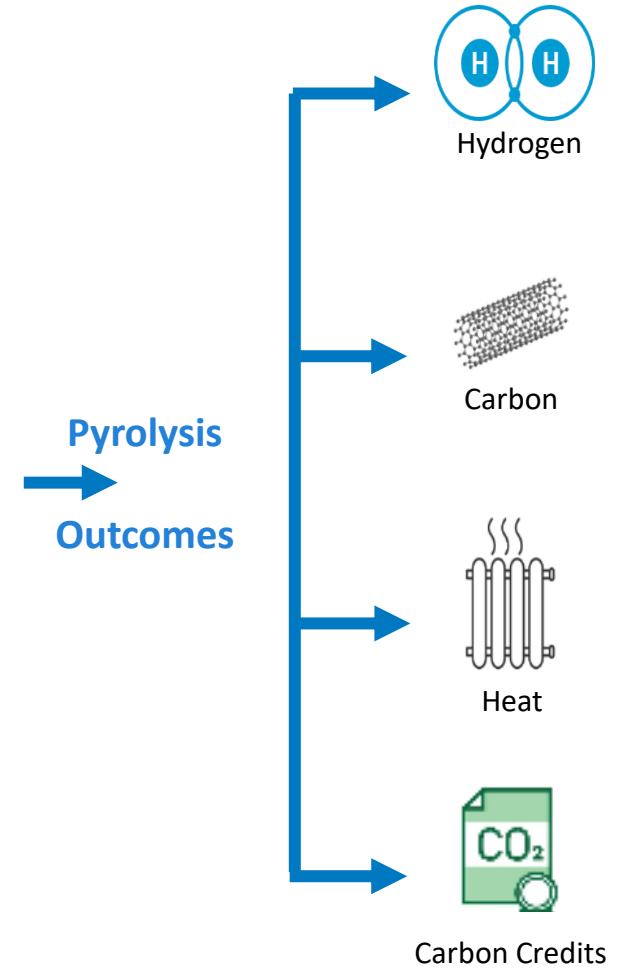
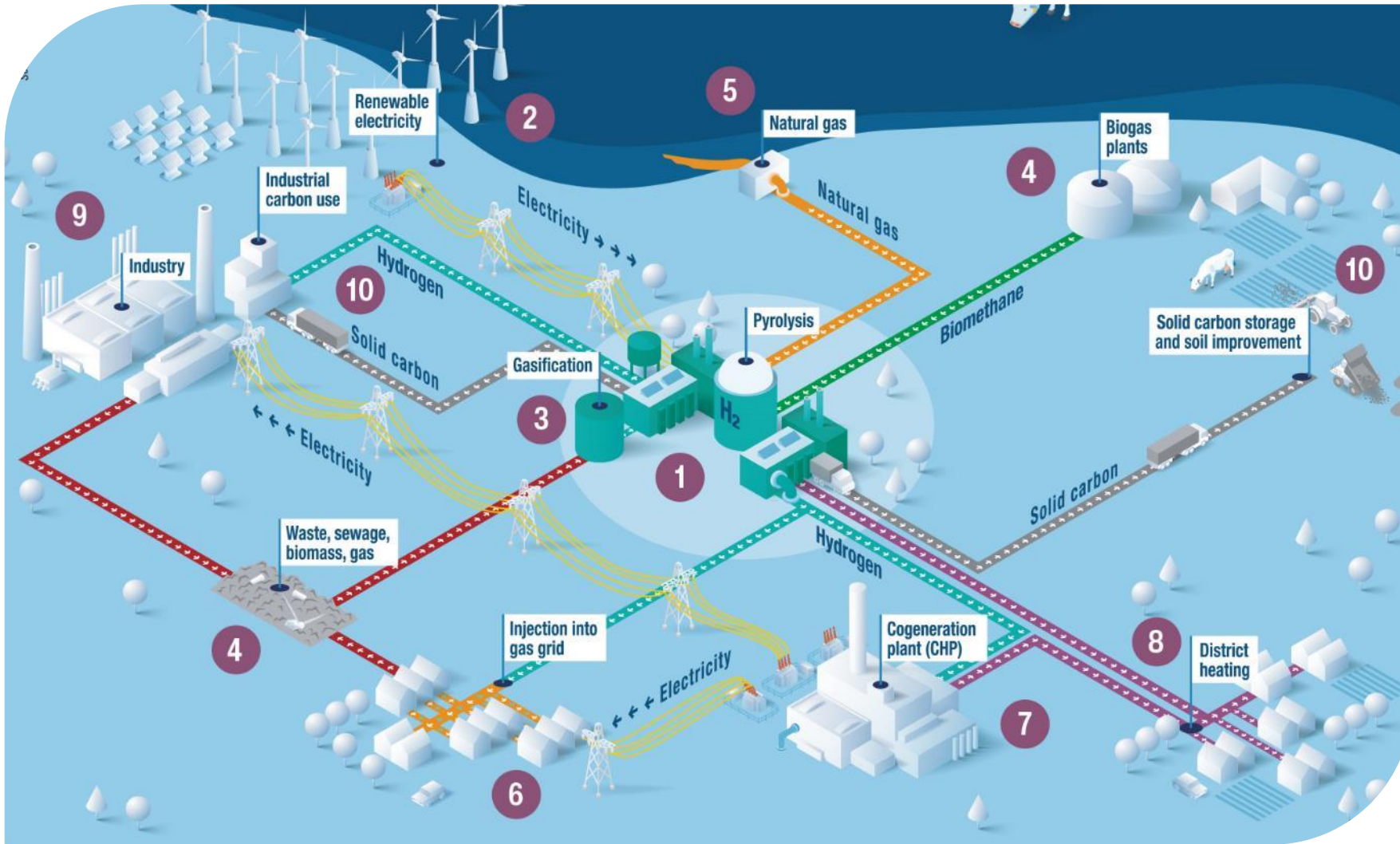
# Footprint & quantity-wise turquoise is a pillar of a hydrogen economy



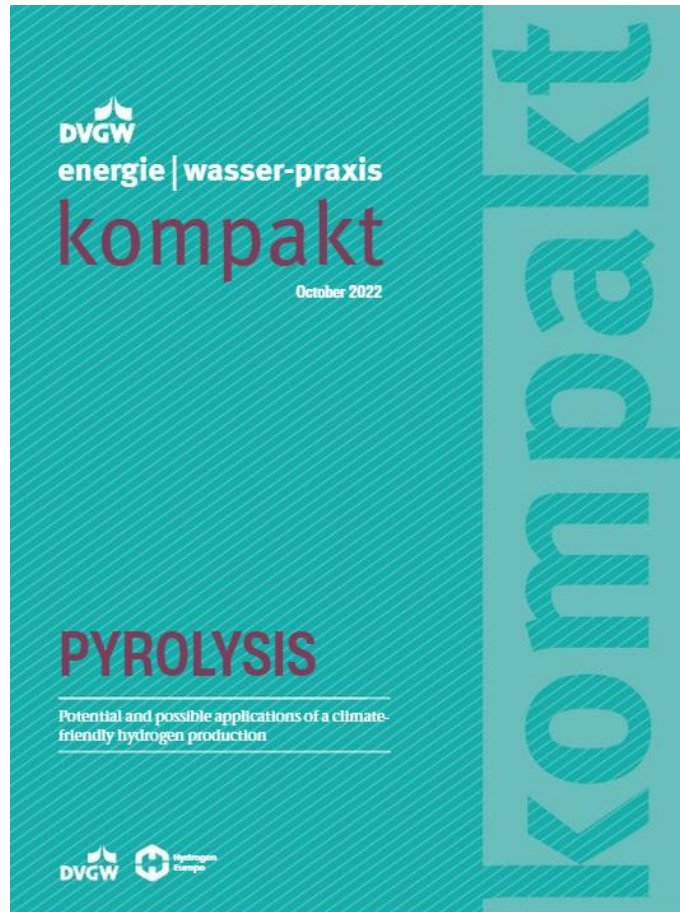
Source: Friedmann et al. (EBI): Ecological evaluation of hydrogen supply, Sensitivity analysis on GHG emissions of hydrogen, May 2022



# The world of methane pyrolysis at a glance



# State of the art of pyrolyse and project descriptions in a brand-new joint DVGW – HE brochure



## *We must use all options!*

An introduction to the perspectives for transforming the energy supply by Prof. Dr Gerald Linke, Chairman of the Board of DVGW e. V. and Jorgo Chatzimarkakis, CEO of Hydrogen Europe.



**Europe's energy supply** is to become independent, diverse and climate-neutral - and that in just a few years. While the climate goals are to be achieved quickly in order to minimise the consequences of climate change, geopolitical risks due to dependence on energy imports from a few supply countries must be taken into account in parallel and the energy supply must be placed on a broad basis.

DOWNLOAD:

[https://wvgw.de/dyn\\_pdf/ewp/2022/kompakt\\_Pyrolysis/](https://wvgw.de/dyn_pdf/ewp/2022/kompakt_Pyrolysis/)





# Table of content: The world of pyrolysis

## 4 “We must use all options!”

*Prof. Dr Gerald Linke (Chairman of the Board of DVGW e. V.) & Jorgo Chatzimarkakis (CEO of Hydrogen Europe)*

## 6 “Turquoise” hydrogen from pyrolysis - what is it?

## 8 Nature’s heir of residual energy

*Stefan Petters (Consulting Committee Member of Green Transformation & Bio Economy Platform Lower Austria Business Agency EcoPlus)*

## 10 “The reaction that would change the world”

*A conversation with Prof. Alberto Abánades (Universidad Politécnica de Madrid)*

## 12 On assessing the greenhouse gas emissions of turquoise hydrogen: it’s the feedstock that counts!

*Friedemann Mörs, Maximilian Heneka, Dr Frank Graf (all: DVGW Research Unit at the Engler-Bunte Institute), Miriam Bäuerle & Jörn Benthin (both: Gas- und Wärme-Institut Essen e. V.)*

## 14 Production of hydrogen from gases containing methane without CO<sub>2</sub> emissions

*Dr-Ing. Jörg Nitzsche, Alexandra Müller & Michael Kühn (all: DBI - Gastechnologisches Institut gGmbH Freiberg)*

## 16 Multiple applications for carbon from methane pyrolysis

*Robert Obenaus-Emler (University of Leoben)*

## 18 “A world without CO<sub>2</sub> emissions from human activities is not utopian”

*A conversation with Gérard Gatt, President at Sakowin Green Energy*

## 20 The world of methane pyrolysis at a glance

## 22 Graphene and hydrogen - two materials to power the decarbonization

*Ian Hopkins (CPO Levidian)*

## 24 Joining the rainbow: turquoise hydrogen

*Raimondo Giavi (Vice President - Hydrogen Growth Area, Baker Hughes)*

## 26 “Methane plasmalysis can already be integrated into solutions fit for everyday use”

*A conversation with Dr Jens Hanke (founder and CTO of Graforce GmbH)*

## 28 Thermo-catalytic hydrocarbon decomposition technologies for hydrogen production

*Klaus Mauthner (Carbotopia) & Matti Malkamäki (Founder, Chairman of the Board, Hycamite TCD Technologies Ltd.)*

## 30 H<sub>2</sub>-Innovation and H<sub>2</sub>-ramp up - technology development in the Ruhr valley

*A conversation with Bernd Meyer, Dortmund*

## 32 Decarbonised hydrogen from waste - a regulatory framework to climate neutrality

*Dr Maximilian Kuhn (Hydrogen Europe)*

## 36 “Pyrolysis-based island solutions could become established in Bavaria”

*A conversation with Dr Gregor Neunzert (Head of Gas Participations of Stadtwerke München)*

## 38 “Pyrolysis is a transitional technology that can be rolled out rapidly”

*A conversation with Dr Andreas Breuer (Head of Hydrogen with Westnetz GmbH)*

# Intro presentation



**Stefan Petters**

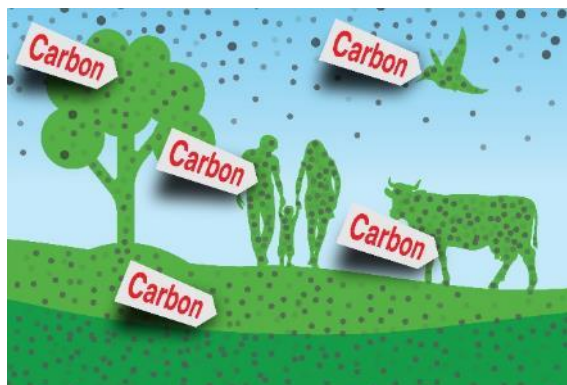
Business Development Consult

Carbotopia<sup>®</sup> Syndicate



# Why squander our Wastes' CH<sub>4</sub>-like total Hydrogen : Carbon Ratio?

Hydrogen can be dissociated from its Carbon-bonds and out of Water



$$\text{H}_2:\text{C} = 1.2 + 50\% \text{H}_2\text{O}$$

$$\Sigma 2.0 \text{H}_2/\text{C} \rightarrow 0.2 \text{CO}_2/\text{H}_2$$



$$\text{H}_2:\text{C} = 1.6 + 40\% \text{H}_2\text{O}$$

$$\Sigma 2.2 \text{H}_2/\text{C} \rightarrow 0.14 \text{CO}_2/\text{H}_2$$



➤ Why co-fire Fuel with extinguishing agent → Water?

➤ We can build wealth from what we pay to be burned!

➤ Waste Transformation into new energy carrier Molecules can come at just 37% the CO<sub>2</sub>-intensity of Oil!

$$\text{H}_2:\text{C} = 0.9$$

$$\rightarrow 0.5 \text{CO}_2/\text{H}_2$$

# Resource-Efficiency [SDG12] of Waste versus W2E equiv. onshore Wind

measured in No E-Vehicles 100km/day refueling

1 plant per 160 000cpt



24/365 @  $\eta_{avail} = 90\%$

Waste incineration

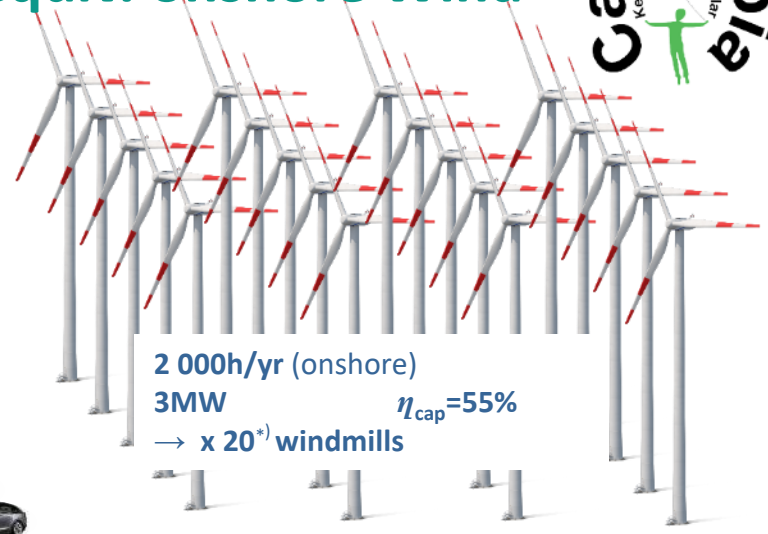


9MWh<sub>electric</sub>

equivalent



10 000 BEV



2 000h/yr (onshore)  
3MW  
→ x 20\*) windmills

$\eta_{cap} = 55\%$

9MWh<sub>electric</sub>

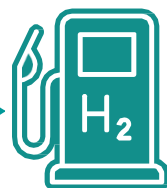
43MWh<sub>chem</sub>

refine

50km Radius  
EU27  $\phi$ 1mln capita

from intrinsic  
H<sub>2</sub>:C ratio incl. H<sub>2</sub>O

+ 10mln Liter auxiliar H<sub>2</sub>O



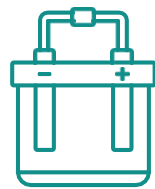
12 500 HFCV

1 300tpy ← 60MW

+

12mln Liter auxiliar H<sub>2</sub>O

??



3 600

W2H<sub>2</sub>  $\eta_{chem} = 50\%$  → 4 500tpy

\*) EIT Europe Statistics

# Resource-Efficiency of waste derived Syngas versus W2E equiv. E-Fuel

measured in No ICE-Vehicles 100km/day Synthetic Fuel fill-ups

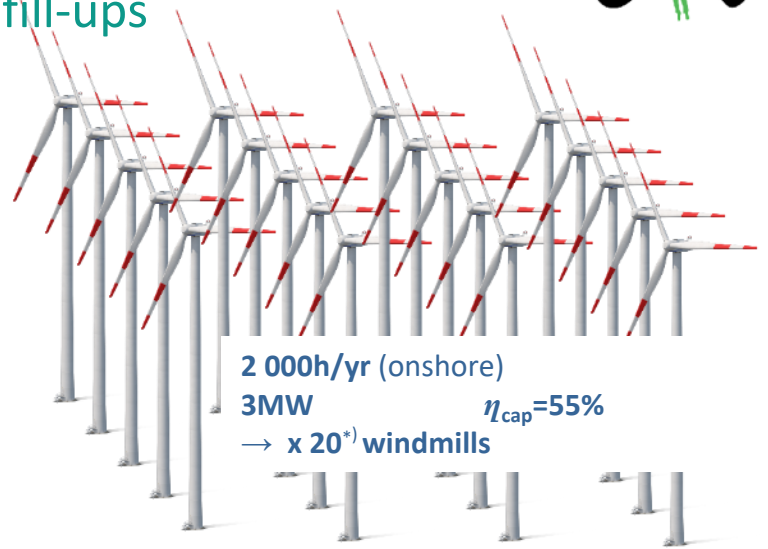
1 plant per  
160 000cpt  
100 000tpy

24/365 @  $\eta_{avail} = 90\%$

43MWh<sub>chem</sub>  
-1

50km Radius  
EU27  $\phi$ 1mln capita

W2E<sub>lectricity</sub>  
equivalent



**Syngas Platform**  
Vienna at MA48  
1110 Pfaffenau

from intrinsic  
H<sub>2</sub>:C ratio incl. H<sub>2</sub>O  
5mln Liter auxiliar H<sub>2</sub>O



1 300tpy H<sub>2</sub> ← 60MW  
7 150tpy CO<sub>2</sub>

+  
12mln Liter  
auxiliar H<sub>2</sub>O  
??



Fischer Tropsch Synthesis



→ 13.7mln Liter/yr

→ 5 400



ICEV



870 ← 2.2mln Liter E-Fuel/year

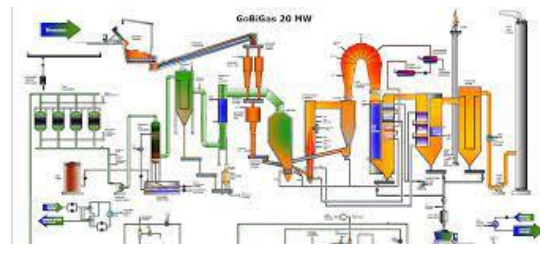
\*) EIT Europe Statistics

# Resource-Efficiency by waste Methanization combined with CH<sub>4</sub> Pyrolysis

derived Synthetic Fuel No ICEVs plus HFCV for 100km/day each

1 plant per  
160 000cpt  
 100 000tpy

Wood 2 Methane  
Gothenburg



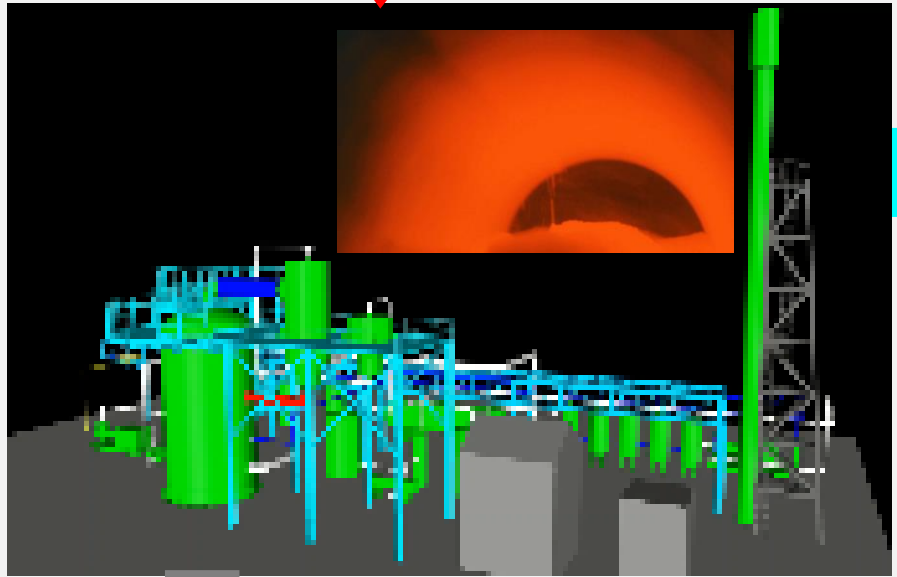
50km Radius  
EU27 ø1mln capita

43MWh<sub>chem</sub>

28MWh<sub>Bio-SNG</sub>

3MWh<sup>-1</sup>  
Flue Gas Heat

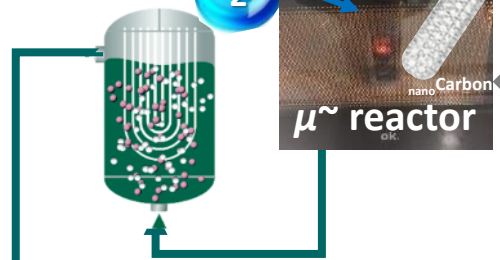
CH<sub>4</sub> TCD



15MWh<sup>-1</sup> H<sub>2</sub>

3 000tpy

-4MWh<sup>-1</sup><sub>RE</sub> → + 2mln Liter  
auxiliar H<sub>2</sub>O



12MWh<sup>-1</sup> Carbon

CO+H<sub>2</sub>

9mln Liter/yr SF

3 500 ICEV



+



Σ 12 500 Cars

9 000 HFCV



# The advantages of Molecules2Molecule over Electrons2Molecules

measured in No Vehicles 100km/day refueling

## Waste 2 ..... Electricity



## Hydrogen



10 000 BEV

Total 12 500 HFCV

versus

≡ 20 x 3MW onshore Wind + 60MW Electrolysis



3 600 from Electrolysis



- 3.5 times Electrolysis H<sub>2</sub>
- @ 22% auxiliary Water
- Adding Value to Waste
- eliminating incinerators' uncovered Cost overruns

## Waste 2 Synthetic Fuel



2.3kg CO<sub>2</sub>-mitigation per Liter Syn-Fuel



Total of 5400 ICE Cars

versus

3.25kg CO<sub>2</sub>-Use per Liter E-Fuel



870 from E-Fuel



- 6.2 times E- Syn Fuel
- @ 6.7% auxiliary Water
- Adding Value to Waste
- Eliminating incinerators' uncovered Cost overruns

## Waste 2 Pyrolysis Hydrogen & Syn Fuel off Carbon



optional 3 500 ICEV plus 9 000 HFCV, in Total 12 500 Cars or HFCV only



USP n.a. for electric



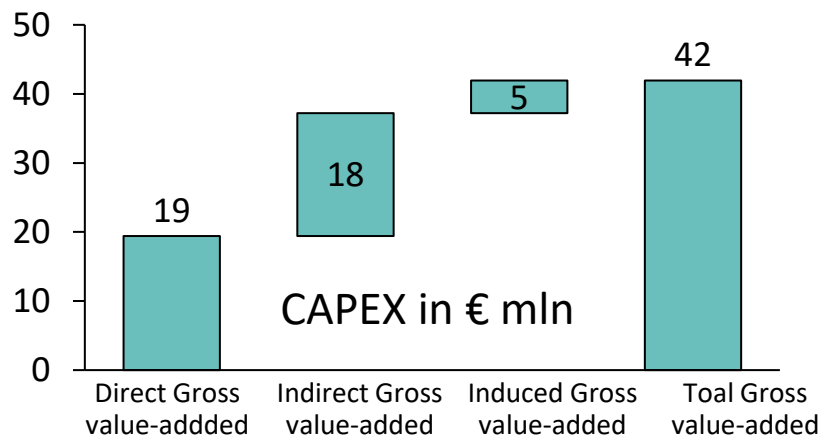
- Flexible for existing ICEVs
- @ 60% aux. Water of SF
- All European Technology
- supply chain autonomy
- Compatible for Bio- & Hybrid- Gas feedstocks

# Socio-economic value Impact of combined gasification & pyrolysis

Macro-Economics study of a 43MW Carbotopia® Bio-Refinery (Economica Institute)

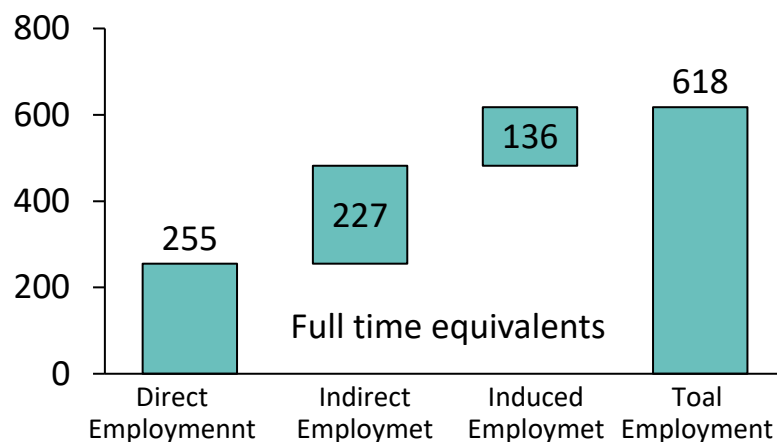
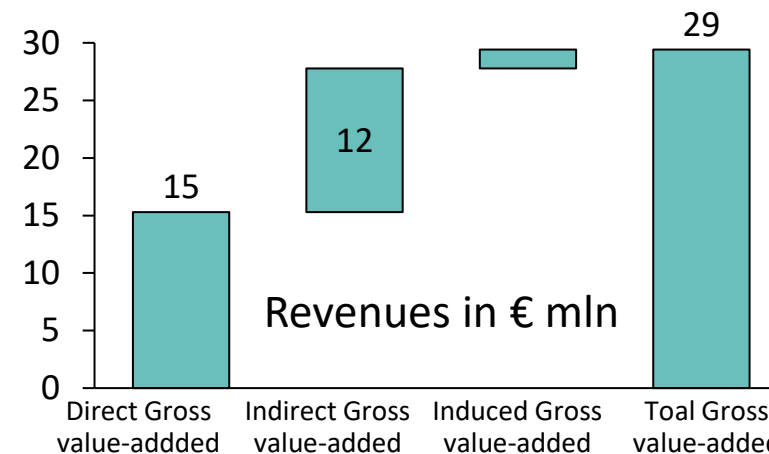
## Investment Phase

at e.g.:  
5 yrs  
Amoritzation

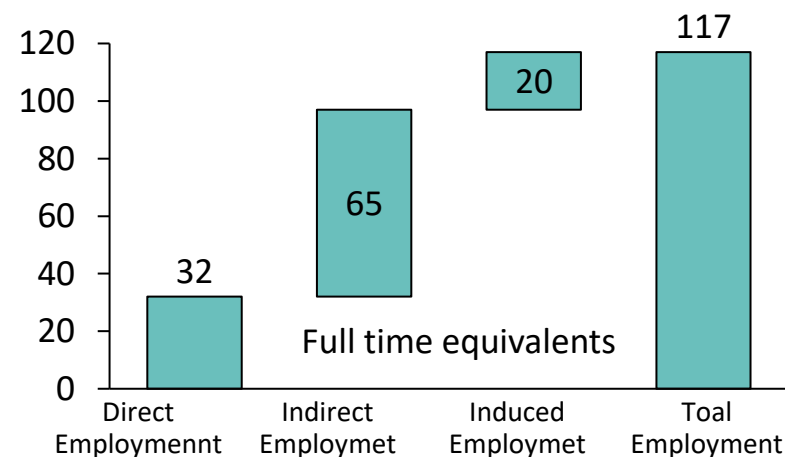


## Operations Phase

at e.g.:  
**1kg H<sub>2</sub> = €5.0**  
**1ltr SF = €1.6**  
**20% Profit**



**plus**  
**14% Fiscal**  
**Return from**  
**Employment**  
**Charges (in AT)**



Source: Economica Institute 2012 for Carbotopia®



# Europe incinerates 26% and still landfills 25% of its Household Wastes

Why not become World Market Leader in Self- refinancing Waste-Valorization?

## 10 Plants versus Landfills:

2.2 Million Tonnes of CO<sub>2</sub> Equivalents/yr

65 Hectares of Landfill Area =



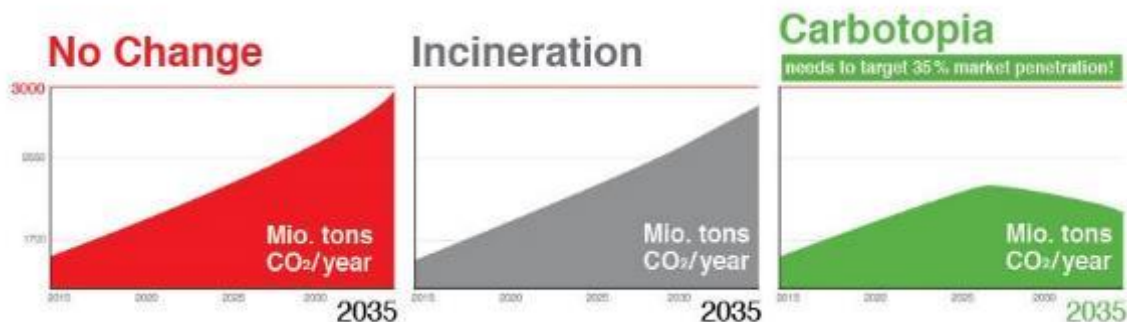
## 4,500 plants until 2035 can save:

cumulated 5 Giga-ton CO<sub>2</sub> equivalents

4.3 km<sup>3</sup> less landfill space =



## Turning around Climate Impact until 2035



## Ramping towards 35% Market Penetration in 2035

Profit from waste-valorization driving roll-out; €56 bln waste transformation revenues and €20 bln plant equipment industry from:

4,500 plant licensees

540,000 new job creations

elimination of 1 Giga-ton CO<sub>2</sub> per year

### Isn't Waste-Valorization a must in times of Energy-Supply security concerns?

- Waste is an available resource with a total H<sub>2</sub> : Carbon ratio of  $\geq 2$  (alike CH<sub>4</sub>) that shouldn't be wasted
- Utilizing waste-2-hydrogen via FCEV and ICE are 25% more effective than BEV (from W2E)
- Hydrogen can be split from and over Carbon at 20-35% of its Energy by pyrolysis or reforming
- Carbonaceous residues can be refined at 3-fold Carbon- & 5 times the Water- Efficiency than oil
- Today's PPP-socialization of incineration's uncovered Cost-overruns is like getting someone paid the value of a sellable house to just burn it down – but people don't know what they're forced to pay for!
- Why transform Molecules into not-storable Electrons that we lose when not synchronously used
- Water is an increasingly scarce resource and shouldn't just be co-fired with biomass or trash

Moderated by Luigi Crema, Director, Centre Sustainable Energy, Foundation Bruno Kessler (FBK)



Vjekoslav Majetić, CEO, Indeloop



Nadia Romdhane, Head of Process Engineering, Green Hydrogen Technologies



Matti Malkamäki, Chairman of the Board, Hycamite TCD Technologies Ltd

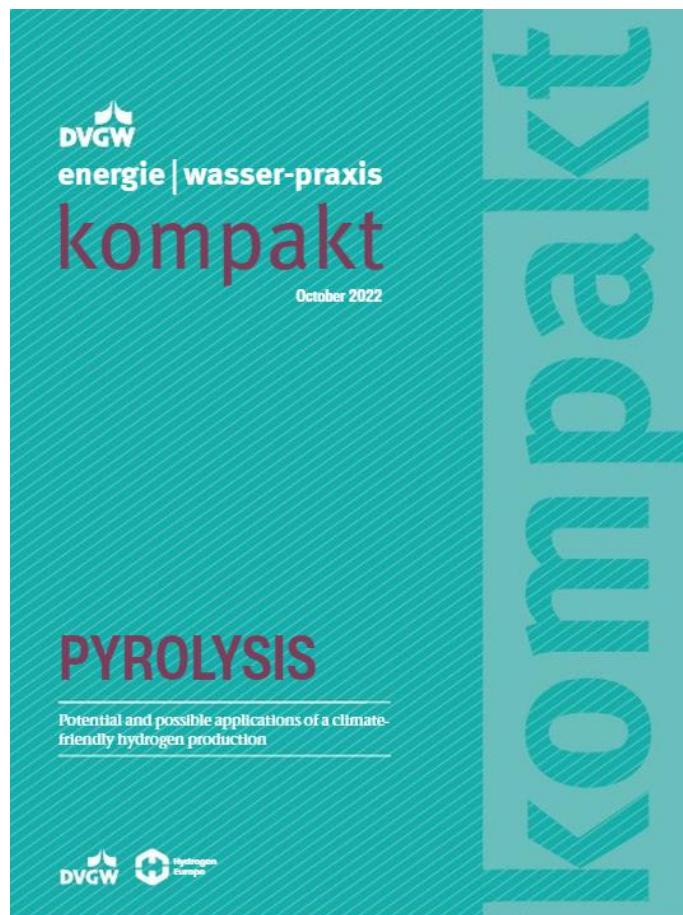


Christian Bestien, Director, Business development, Sales and Marketing at Haffner energy



Stefan Petters, guo – Business Development Consult

# Brand-new joint DVGW – HE brochure



## *We must use all options!*

An introduction to the perspectives for transforming the energy supply by Prof. Dr Gerald Linke, Chairman of the Board of DVGW e. V. and Jorgo Chatzimarkakis, CEO of Hydrogen Europe.



**Europe's energy supply** is to become independent, diverse and climate-neutral - and that in just a few years. While the climate goals are to be achieved quickly in order to minimise the consequences of climate change, geopolitical risks due to dependence on energy imports from a few supply countries must be taken into account in parallel and the energy supply must be placed on a broad basis.

DOWNLOAD:

[https://wvgw.de/dyn\\_pdf/ewp/2022/kompakt\\_Pyrolysis/](https://wvgw.de/dyn_pdf/ewp/2022/kompakt_Pyrolysis/)



Deutscher Verein des  
Gas- und Wasserfaches e.V.



Hydrogen  
Europe

**Gerald Linke**

[www.dvgw.de](http://www.dvgw.de)

Gerald.Linke@dvgw.de

**Jorgo Chatzimarkakis**

[www.hydrogeneurope.eu](http://www.hydrogeneurope.eu)

j.chatzimarkakis@hydrogeneurope.eu