Funded by the European Union

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THE ELECTRIC DECADE

Discover how electrification technologies support the EU's climate goals

1st JOINT ONLINE WORKSHOP of Horizon Europe projects

17th of January 2024 | 9.00 - 12.00 CET

STORMING PROJECT

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STORMING

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STructured unconventional reactors for C**O**$_2$ -f**R**ee **M**ethane catalytic crack**ING**

HORIZON-CL5-2021-D2-01-09: Methane cracking to usable hydrogen and carbon

HORIZON-WIDERA-2022-ACCESS-07 (2nd cut-off)

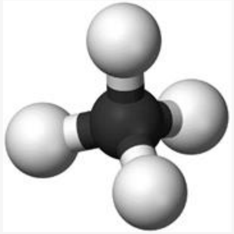
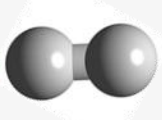
Starting date: 1st September 2022

Project duration: 36 months

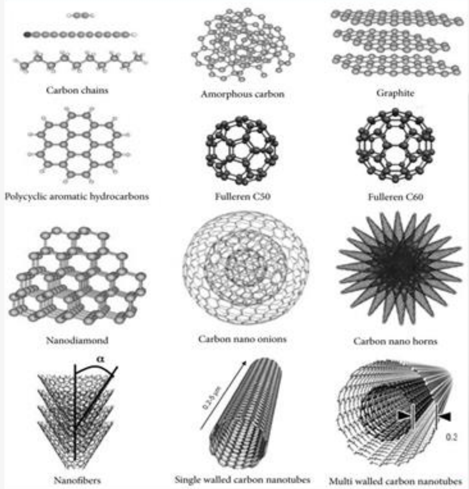
Budget: 3 125 714.75 Euro

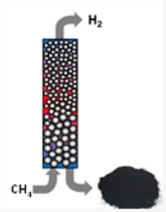
305 833.00 Euro for UK partner

Decarbonization of H_2 production by bio(methane) decomposition

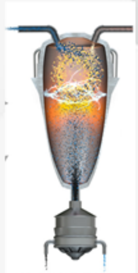
 ⇆ 2  + Carbon

Carbon black





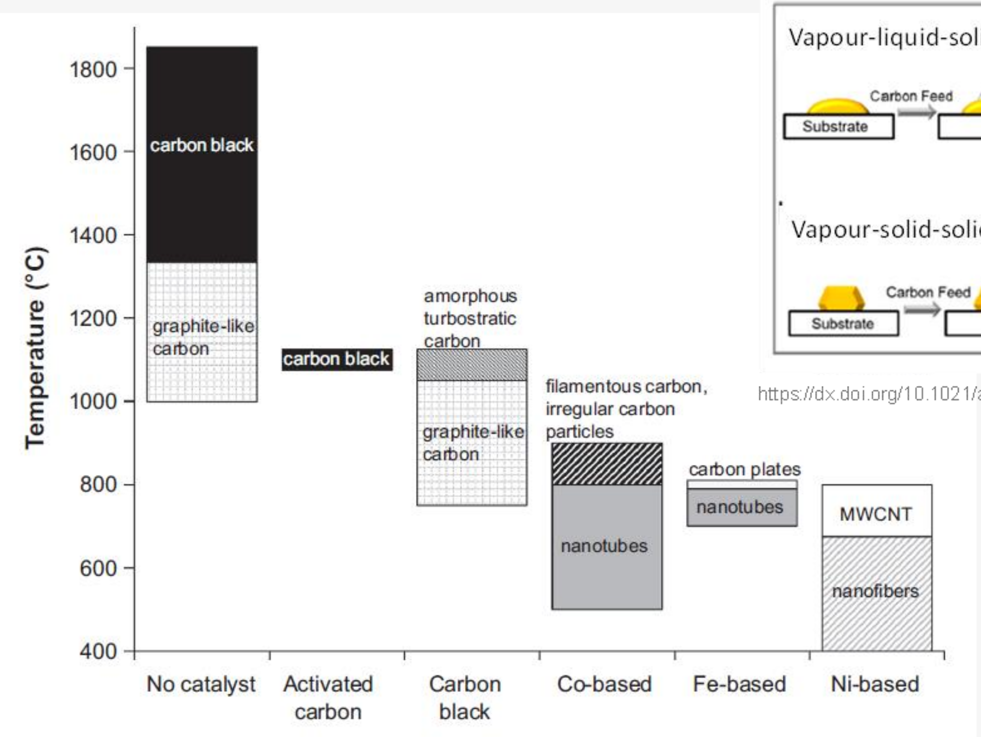
	Reactor type	Temp	Regeneration	Type Carbon	Energy	Development Status
BASF[a]	Moving bed carbon granules	1000°C-1400°C	Carbon recycling	Black carbon	Renew. electr. Electrodes	Pilot plant
Monolith[b]	Plasma reactor	Ca. 2000°C		Carbon black	Renew.energy	Commercial
C-Zero[c]	Liquid bubble column reactor	900-1000°C		Carbon black		Pilot plant
Hazer[d]	Fluidised Bed	900°C	No	graphite	Renew. Electr.	Commercial
Hycamite[e]	Fixed bed Fluidized bed	500-800 ºC	n.a.	Several allotropes	H_2, renew. electricity	Test facility

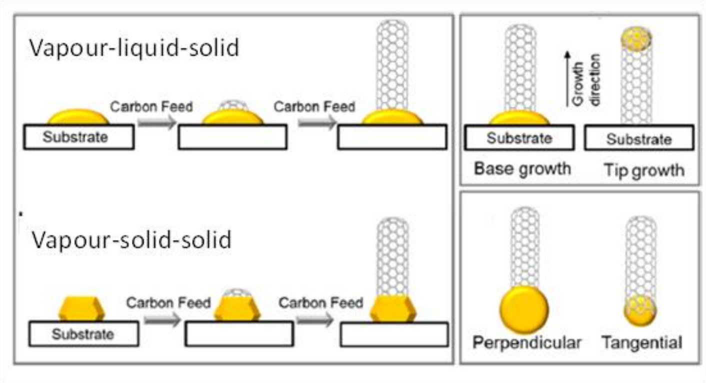


Catalytic Methane decomposition

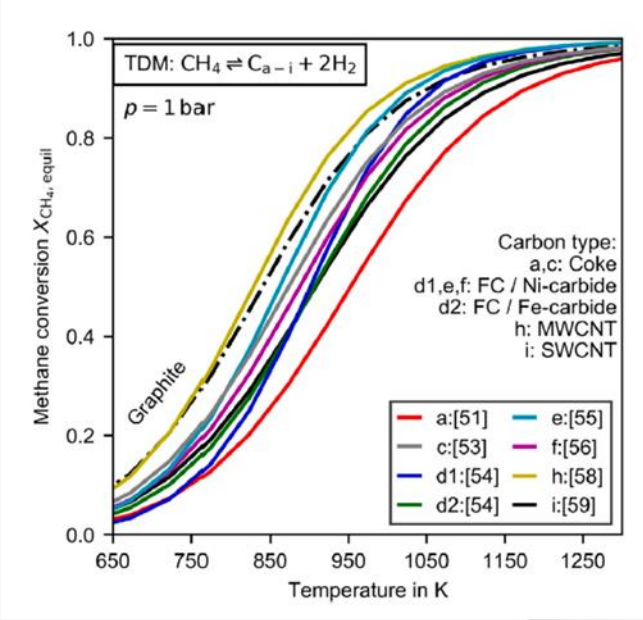
$$CH_{4(g)} \leftrightarrows C_{(s)} + 2H_{2(g)} \quad \Delta H^0_{298K} = 74.5 \text{ kJ/mol}$$

- Type of carbon depends on reaction conditions and catalyst





https://dx.doi.org/10.1021/acs.chemrev.9b00835

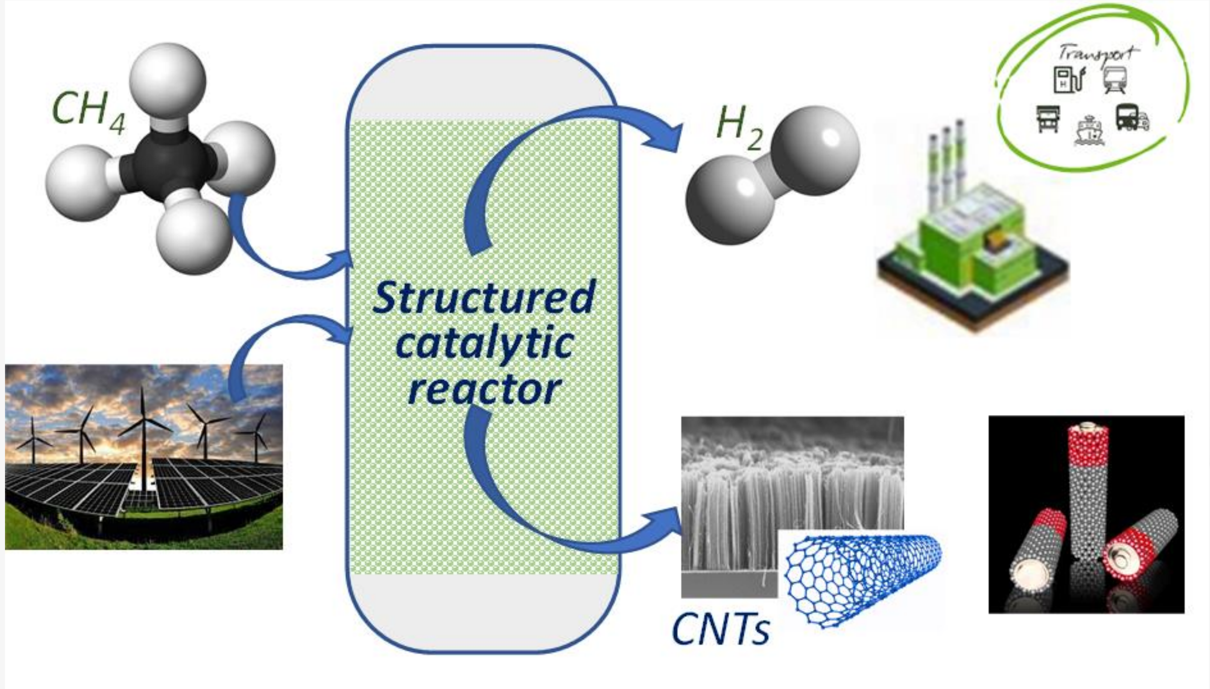


Challenges:

- **Carbon has a twofold deactivation** effect:
  - Deactivation catalytic sites
  - Clogging of the reactor
- **Heat transfer**

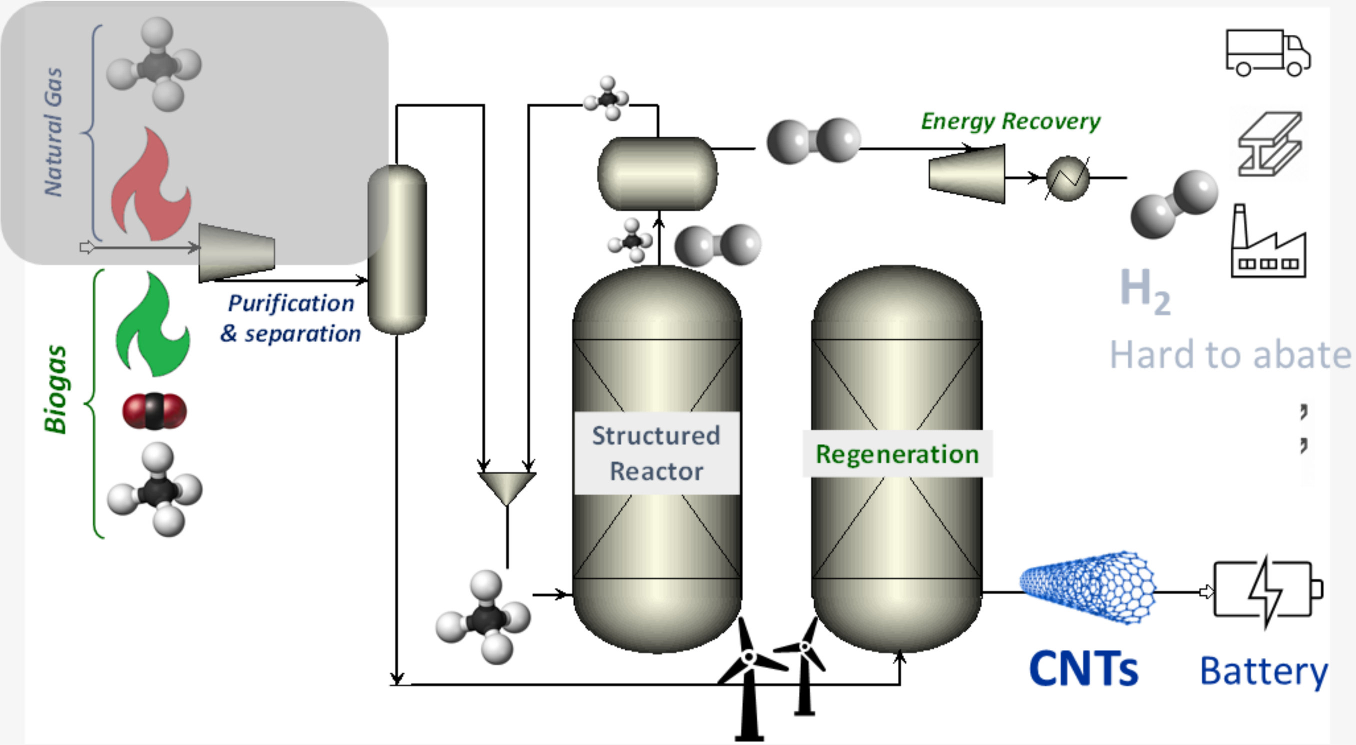
STORMING

STructured unconventional reactors for CO_2 -fRee Methane catalytic crackING



To develop breakthrough **structured catalytic reactors** powered by **renewable electricity** to simultaneously produce CO_2-free or CO_2-negative **H_2** and **high-quality carbon nanotubes, CNTs**, in a **continuous technology** that could be deployed in a sustainable manner.

Production of **captive H_2** (on-site production) and the **capture of C** from the CH_4 as **CNTs,** an economic credit that reduces the delivered net cost of H_2.



Early-stage breakthrough **catalytic technologies powered by renewable energy** to

- ↘ overcome CH_4 catalytic cracking challenges
- ↘ match with the final H_2 application and the supply of renewable energy
- ↘ be easily and quickly scalable to produce H_2 at similar prices to those of grey H_2

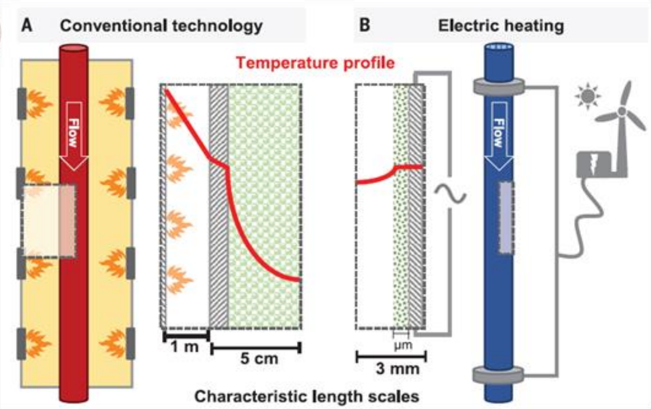
Catalysts and catalytic reactors operating in a **continuous mode** with maximized efficiency.
Parallel reactors: cyclic mode (switching feedstock feed and regeneration agent stream between the reactors)

Heat transfer: Electrified reactors

Electrification of structured reactors

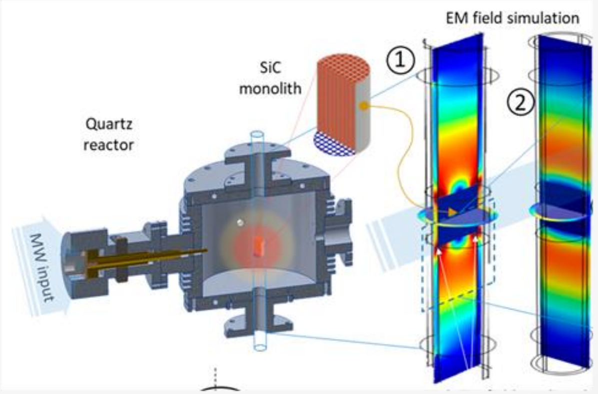
Three complementary **structured** catalytic **reactors** powered by **renewable energy**

Joule heated fixed bed



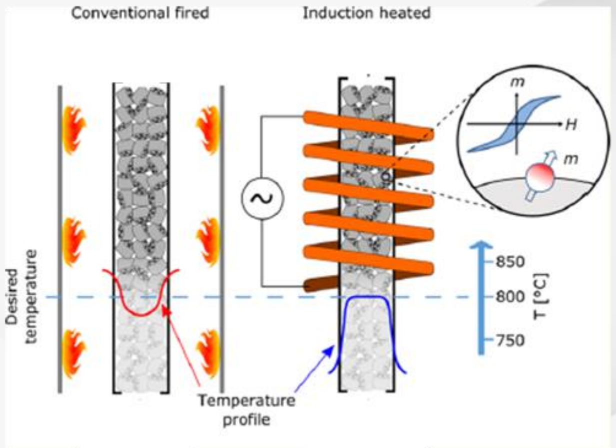
↘ Heat generated by passing a current through a **resistive** material.
↘ Avoid wall effect and few to no thermal gradients.

Microwave heated fluidized bed



↘ Selective **dielectric** heating of catalytic materials.
↘ Gas-solid temperature control

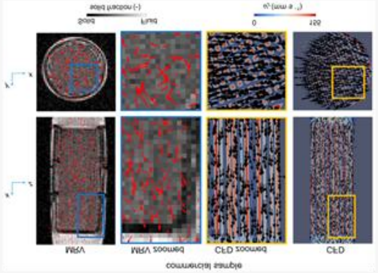
Induction heated fluidized bed



↘ Selective heating of **electrically conductive** and **ferromagnetic** materials.
↘ Fast heating, enhance heat transfer.

Direct heating of the catalyst → Decrease of temperature gradients and heat losses → Increasing heating efficiency
Quick start-up time

Structured catalysts/materials



Computational Fluid Dynamics (CFD)

Devices with **advanced design**, **easy production**, and **high adaptation**.

Combination of **geometry** and **composition** to better **control:**

- Heating:
  - Resistance for Joule Heating
  - Dielectric properties to absorb MWs
  - Ferromagnetic materials for Induction Heating
- Pressure drop
- Heat and mass transfer
- Mechanical stability
- Activity

Complex process dynamics

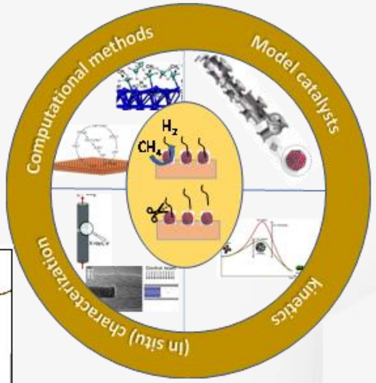
Smart rational design

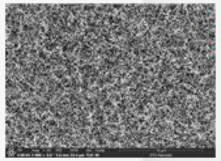
Fe-based catalysts selective for controlled **CNTs growth**

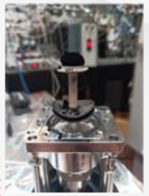
↘ non-toxic & easily available

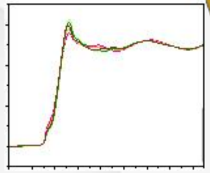
↘ more active and stable at high temperature than Ni

Chemical scissor protocols (waste-free) **to harvest** CNTs and **regenerate** the catalyst









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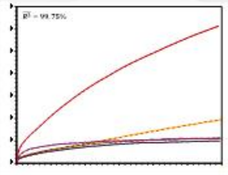


Impacts STORMING technology

Switching to **renewable energy**

Improved energy efficiency (60 % efficiency, > 95 % considering CNTs) **& Selectivity** (100% H_2)

Directly heat the catalyst

Accurate thermal control

Operate at < 800°C no side-products

Process intensification

Operating under **transient conditions** (quick start-up and shut-down) determined by supply (feedstock, renewable energy)/demand requirements.

Avoid GHG emissions (CO_2 and NO_x)

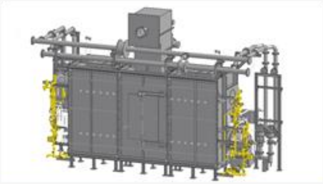
10 % decrease cost than SMR + CCS

Heavy-transport

↘ Fuel cell

Hard to abate industry

High temperature heat
Combustion

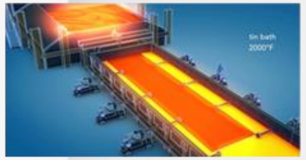


Steel manufacturing
Brightening (DRI)

Chemical companies

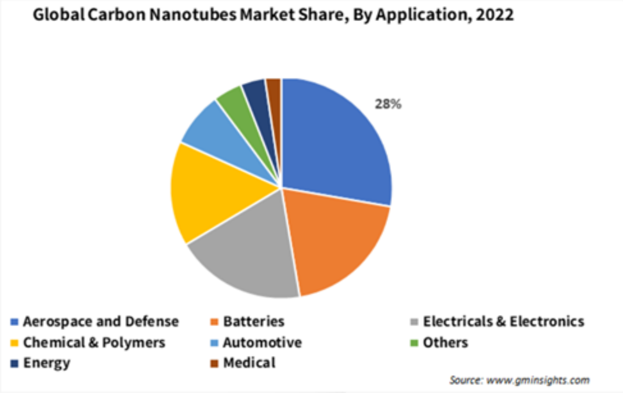
$N_2 + H_2 \leftrightarrows NH_3$

Float glass
Tin bath

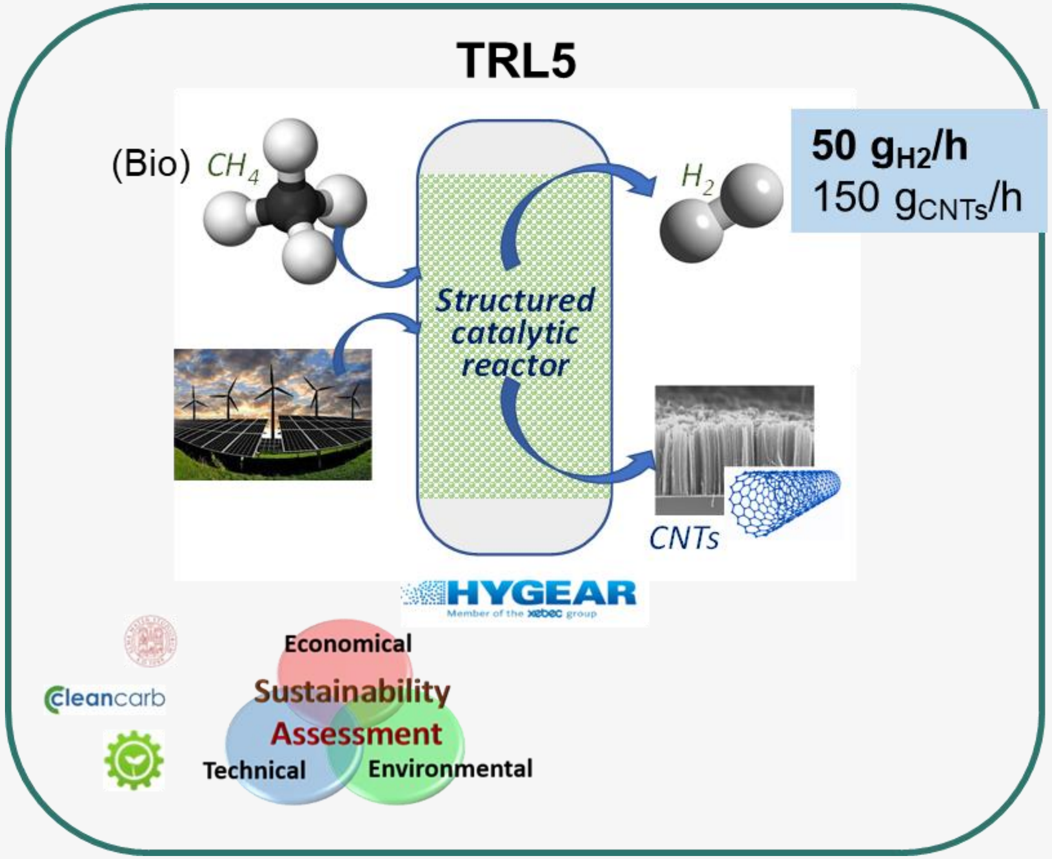


(MW)CNTS for **batteries** to replace graphite (CRM)

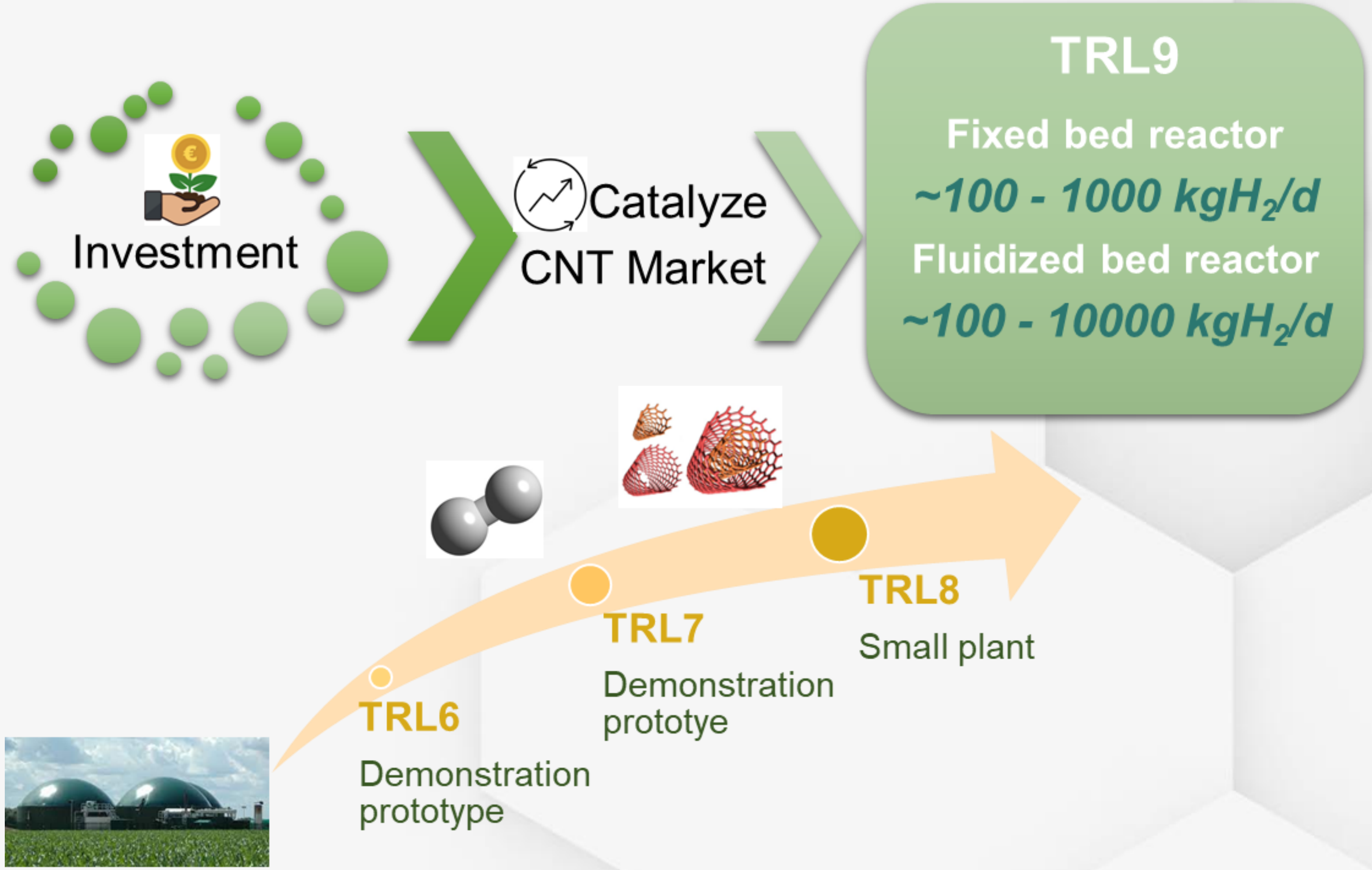
MWCNTs prize in current market (from 0.4 to 285 US$ /g)



Pathway to TRL9



Validation of the most promising catalytic technology



Thank you for your attention!

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