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ARPA-E Methane Pyrolysis Annual Program Review  
Virtual Meeting Jan 12&14, 2021

## **Methane Pyrolysis – a potential new process for hydrogen production without CO<sub>2</sub> emission**

**Dr. Andreas Bode**

BASF SE, Carbon Management R&D

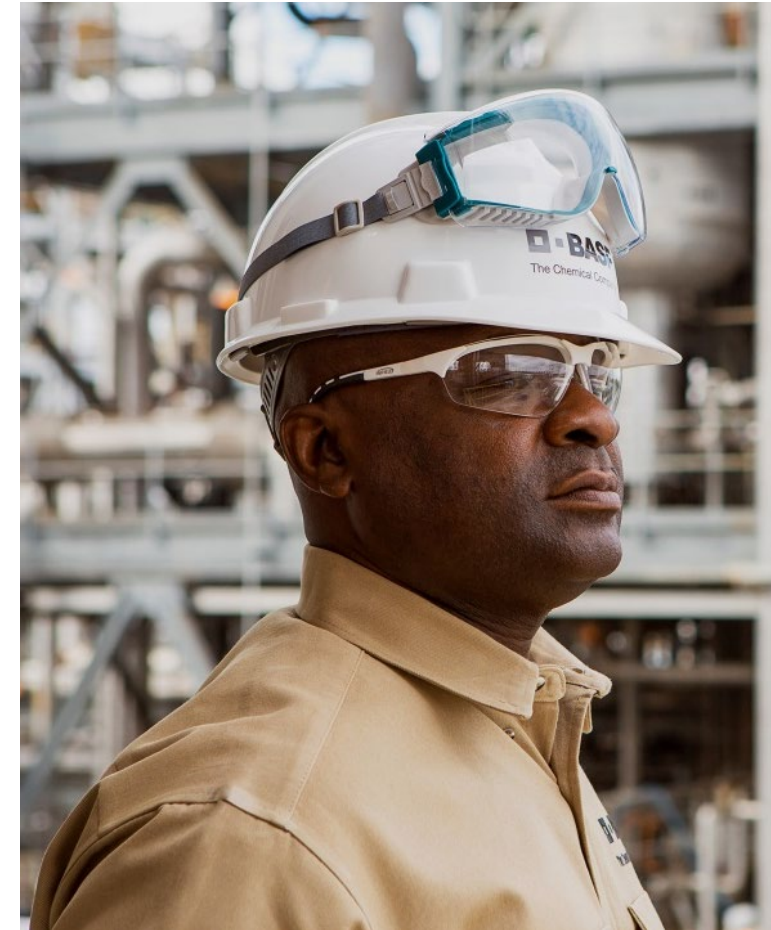
**Dieter Flick**

BASF SE, Methane pyrolysis



# BASF – We create chemistry

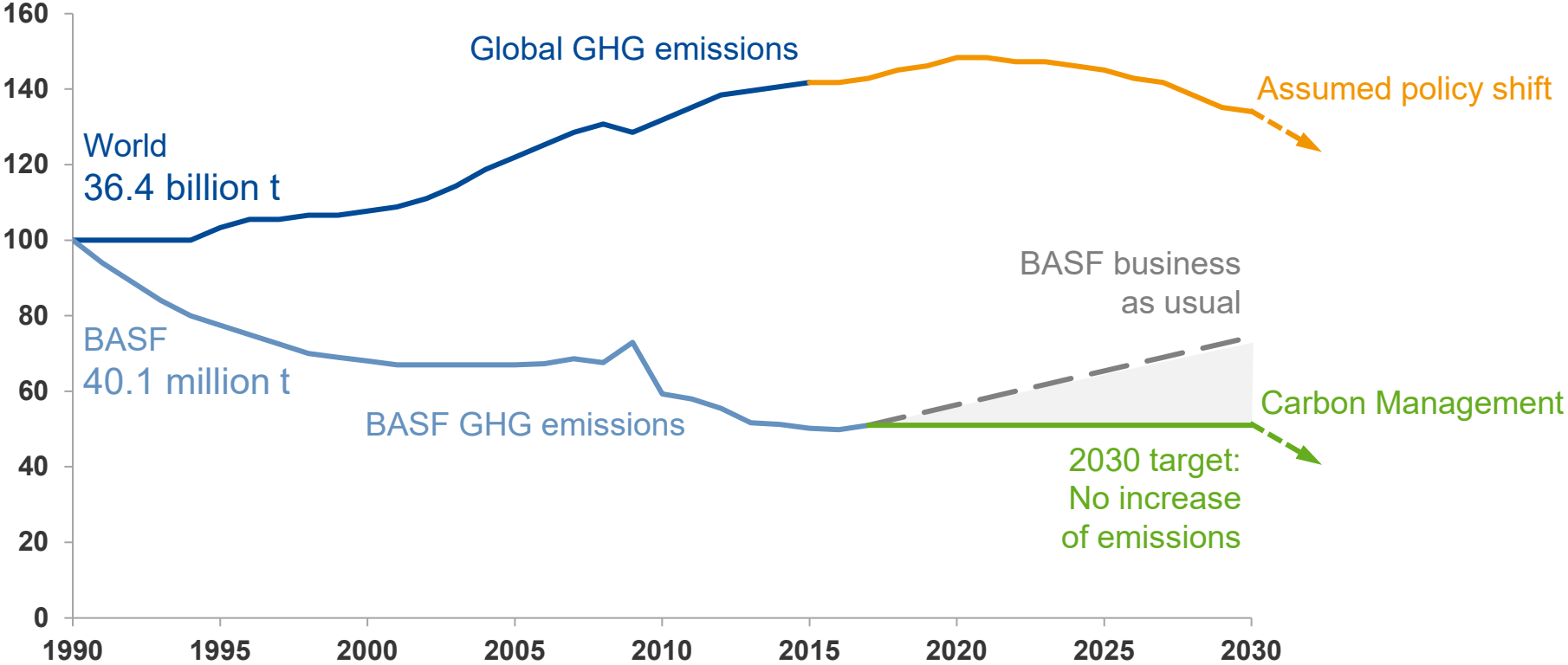
- Our chemistry is used in almost all industries.
- We combine economic success, social responsibility and environmental protection.
- Sales 2019: €59.3 billion
- EBIT before special items 2019: €4.5 billion
- Employees (as of December 31, 2019): 117,628
- 6 Verbund sites and 361 other production sites
- Around 100,000 customers from various sectors in almost every country in the world



# Our target: CO<sub>2</sub>-neutral<sup>1</sup> growth until 2030

## Absolute GHG emissions

Indexed (1990 = 100)

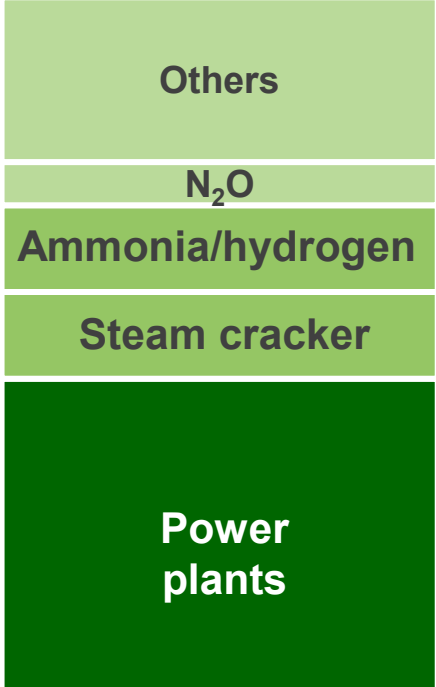


<sup>1</sup> BASF operations excluding the discontinued oil and gas business. The goal includes other greenhouse gases according to the Greenhouse Gas Protocol, which are converted into CO<sub>2</sub> equivalents.



# BASF's Carbon Management Measures at a glance to avoid CO<sub>2</sub>

CO<sub>2</sub> emitters:



Measures:



Process optimization, energy management, N<sub>2</sub>O decomposition



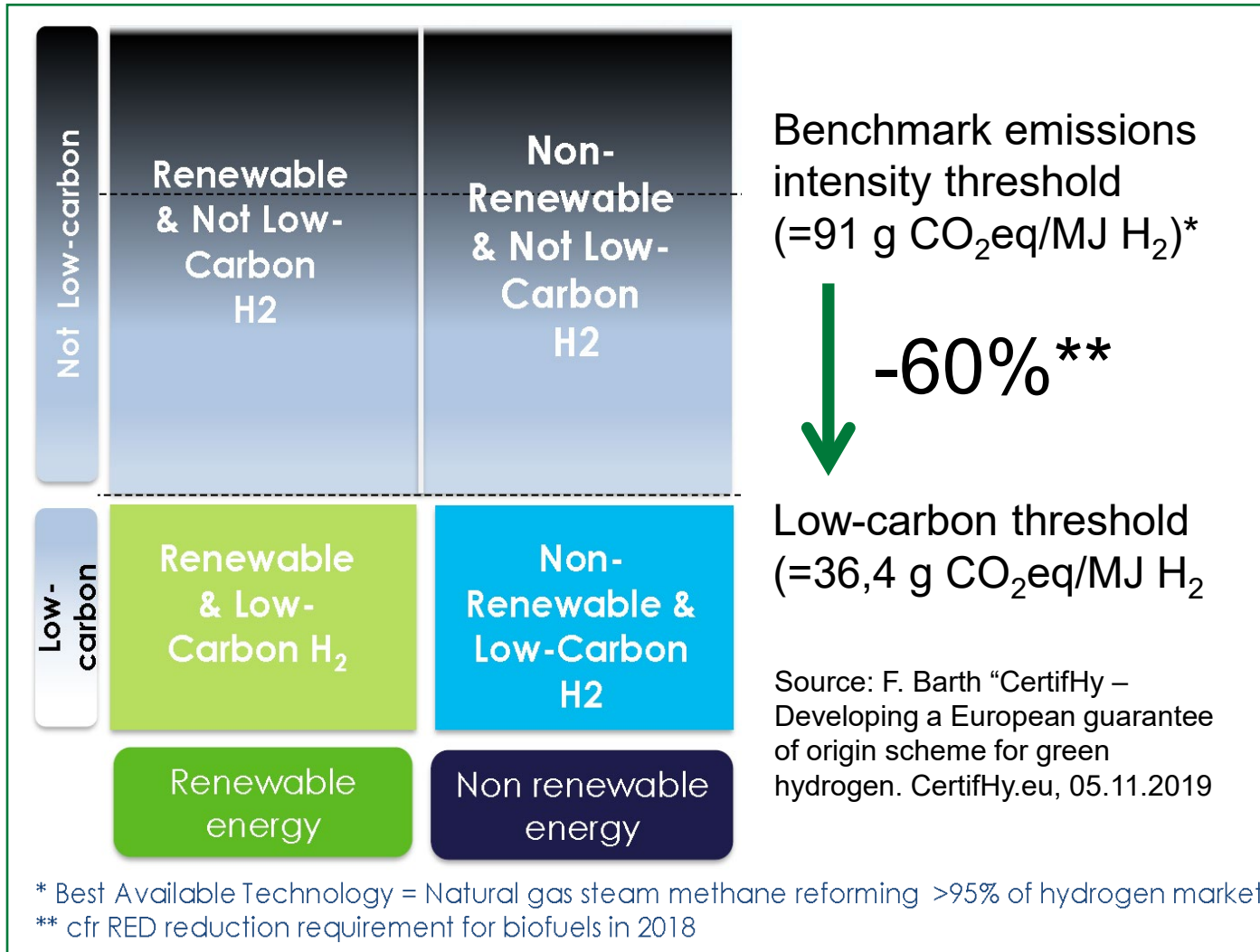
Clean hydrogen research, E-Furnace research, clean olefins research



Purchase of renewable energy

BASF's Carbon Management includes process optimization, technology research and the supply of renewable energy.

# H<sub>2</sub> from methane pyrolysis allows for green or blue certificate application depending on power source and feedstock



- Certification scheme by CertifHy is active
- New definitions for green and decarbonized gases are under discussion
- Methane pyrolysis using
  - grey electricity and natural gas would apply for blue certification
  - Green electricity and biogas for green certification

# BASF leads a consortium evaluating methane pyrolysis since 2013

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thyssenkrupp

THE LINDE GROUP

Linde

hte  
the high throughput experimentation company

BFI

tu technische universität  
dortmund

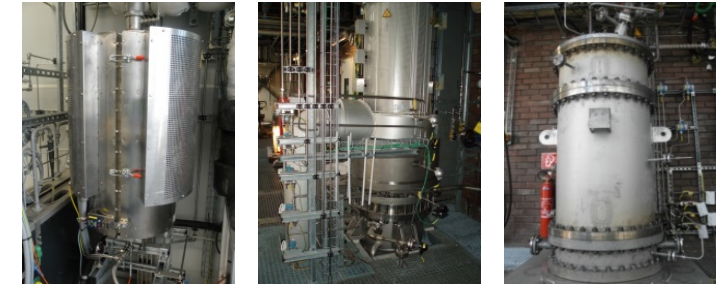
## 2013 – 2017 Basic, ambitious R&D

Theoretical and experimental assessment of various reactor concepts

Carbon sample production on 100 kg scale

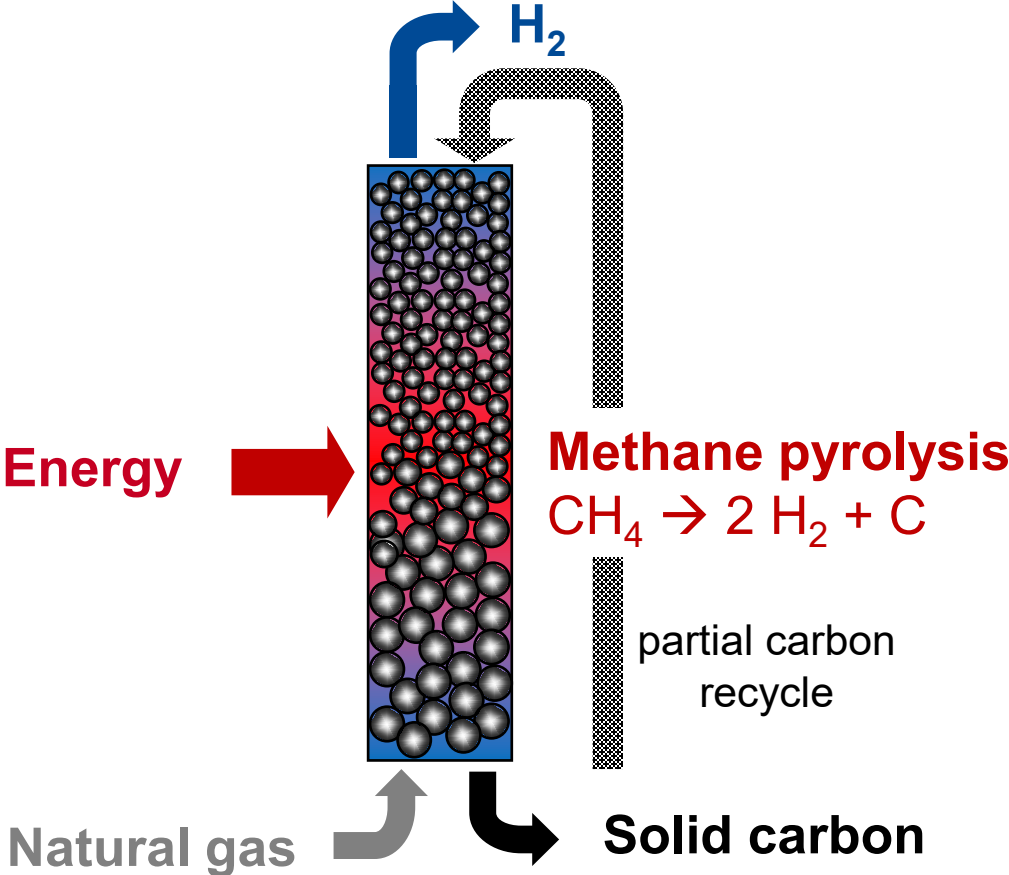
## Results

- Successful operation on lab scale
- Identification of promising reactor concepts
- **Successful carbon sample production and application testing**
- But: reactor was ruined during sample production

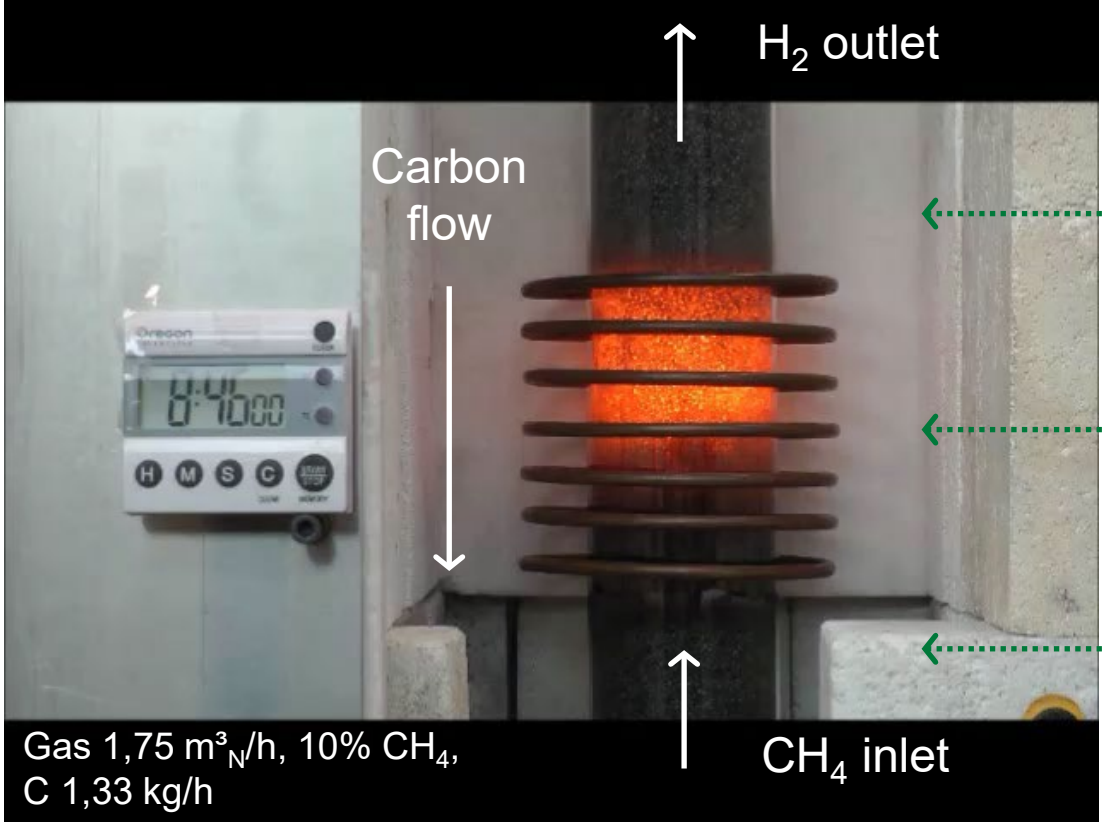


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# First moving carbon beds for methane pyrolysis: Combined reaction and heat integration



# First video observation of methane pyrolysis on a moving carbon bed in glass lab reactor



Reactor is operated at BFI in Düsseldorf

- ← H<sub>2</sub> cooling and carbon pre-heating
- ← Reaction zone heated by induction
- ← Carbon cooling and CH<sub>4</sub> pre-heating



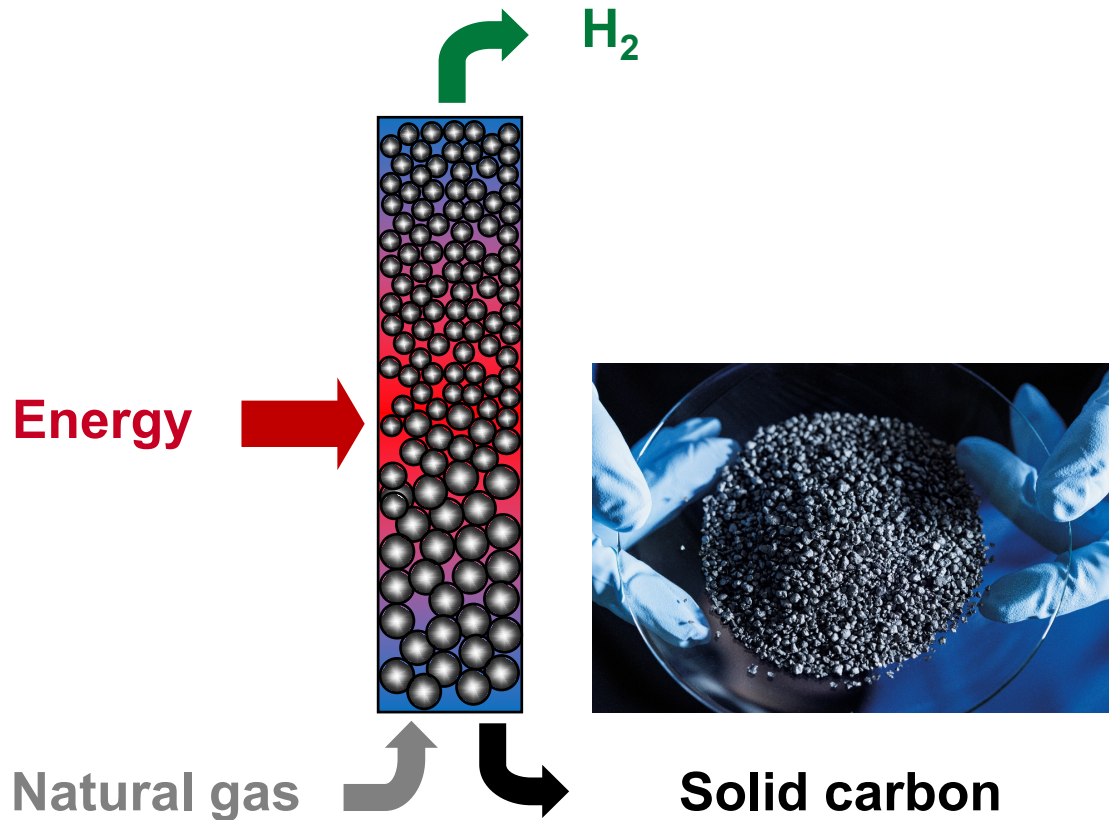
# From lab to pilot scale: Process challenges



- Need for basic R&D and **new reactor design**
- Heating concept needed to overcome the low radial heat transfer from the wall into the reactor core
- Manage inhomogeneous flow and pulsations
- High-temperature materials required

**BASF** strives for first stable operation on large lab scale

# Is the solid carbon the showstopper?



## Options for carbon utilization and storage

### 1. Utilization in major carbon markets

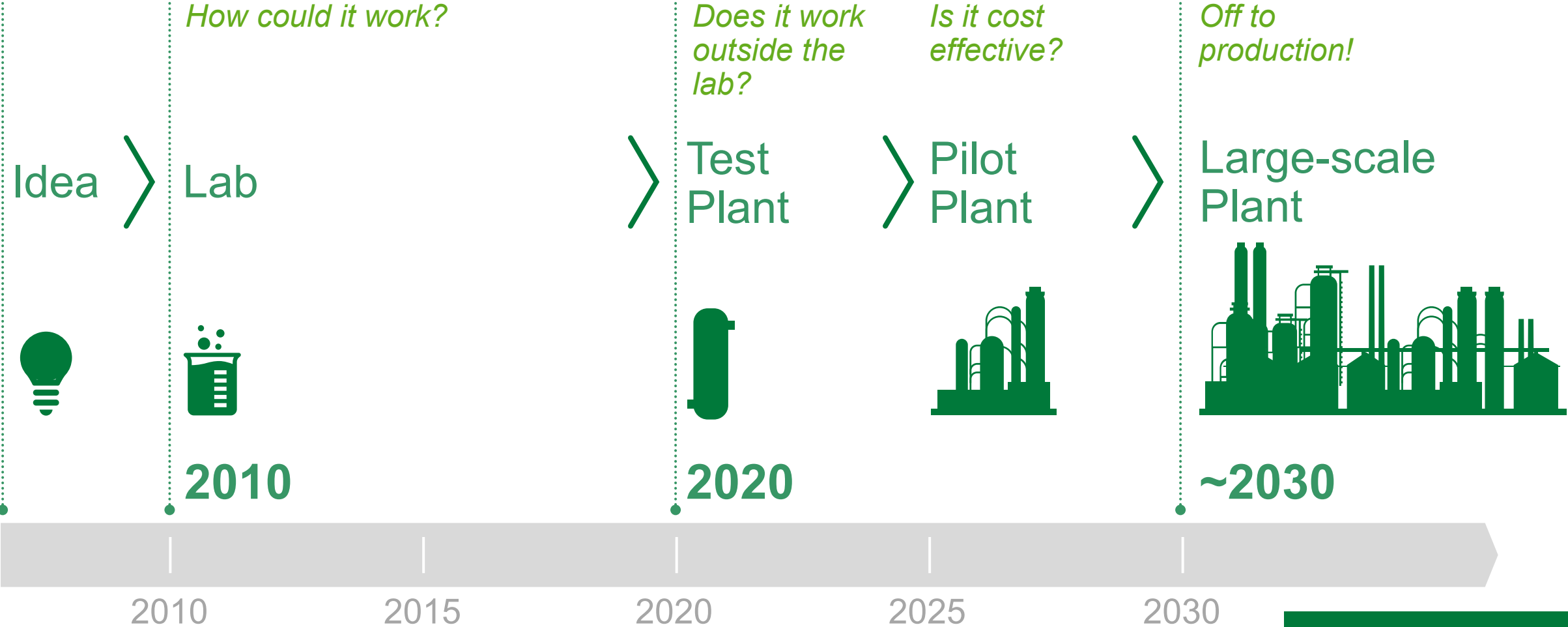
- Aluminum – positive tests
- Steel – positive tests
- Others (tires, concrete admixtures, ...)

### 2. Storage/sequestration

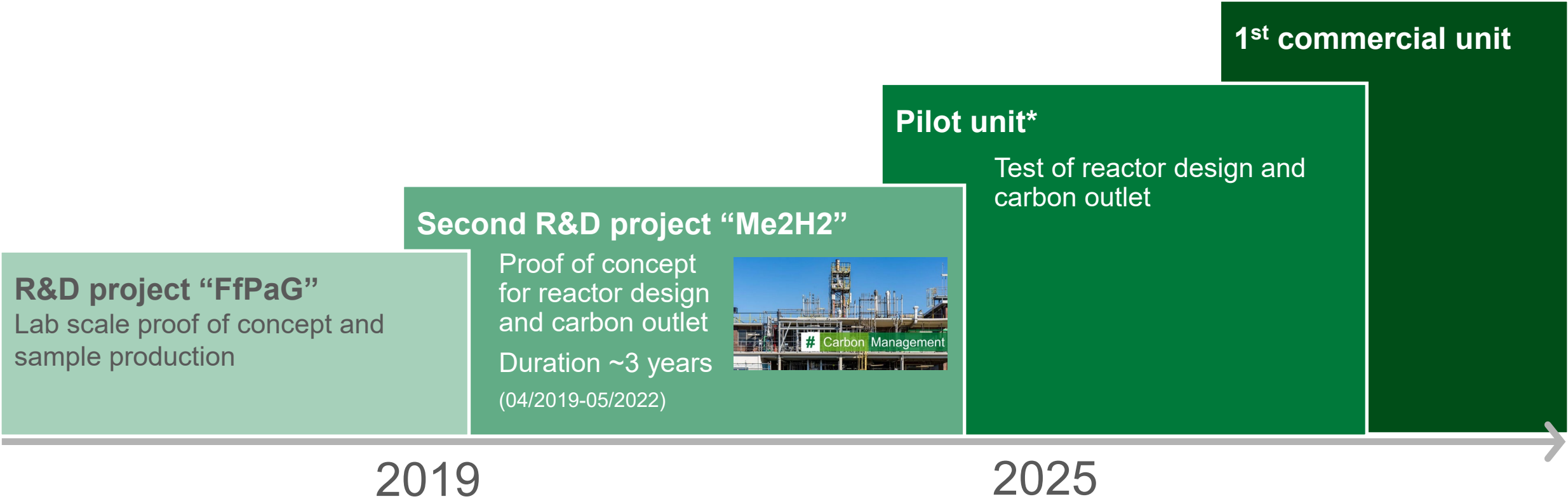
- Soil improver / Terra preta
- Filling material

Outlet needed for 3 kg carbon per kg hydrogen

# Methane pyrolysis: the path to a large-scale plant



# Project outlook – methane pyrolysis for clean hydrogen



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Second R&D project with



FKZ 03SF0571A

\* Government funding will be necessary due to high technological and commercial risk





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