

We create chemistry

IEA workshop ETP-2020, December 18, 2019, Paris

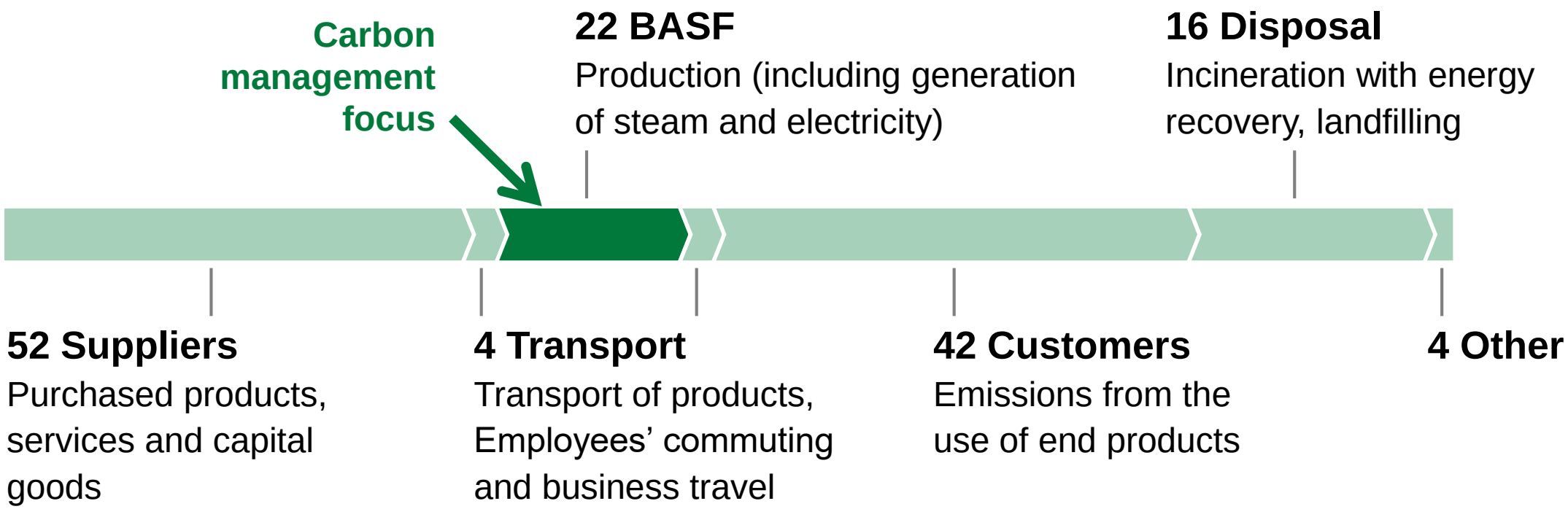
BASF's Carbon Management R&D Program

Dr. Andreas Bode
BASF SE - Program leader Carbon Management R&D

We assume responsibility along the entire value chain

Greenhouse gas emissions along the BASF value chain in 2018
(in million metric tons of CO_2 equivalents)

In total 140 million metric tons

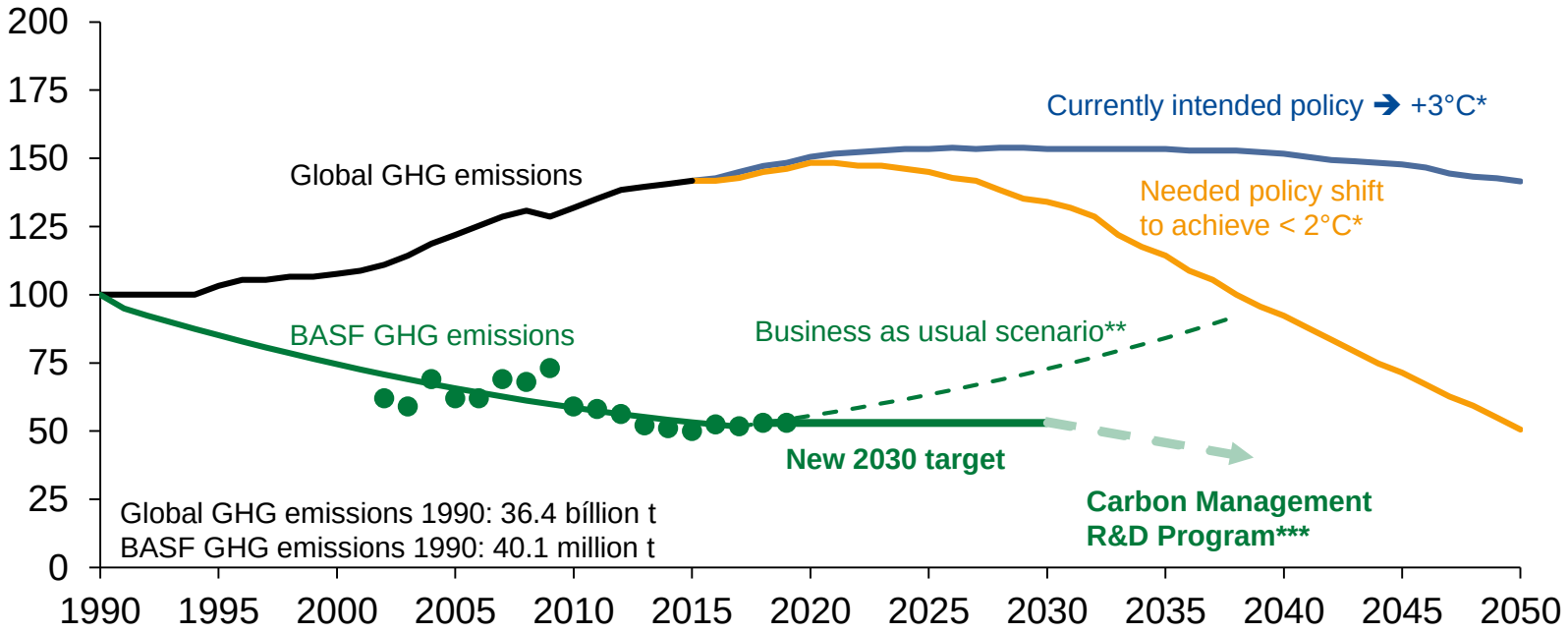


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Carbon Management will enable our CO_2-neutral growth until 2030

In addition, we develop breakthrough technologies to drastically reduce CO_2 emissions

Absolute GHG emissions
Indexed (1990 = 100)



We will **decouple** our greenhouse gas **emissions from** organic **growth.** Our Carbon Management includes

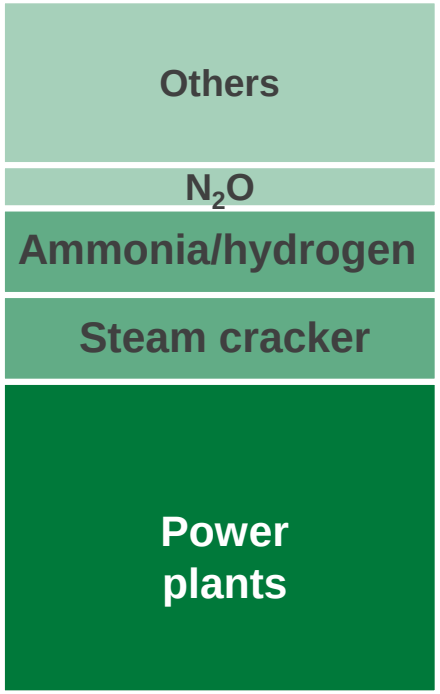
- continued **operational excellence** to improve energy and process efficiency,
- shifting our energy mix towards **renewable energies**, and
- an R&D program to develop **breakthrough technologies** addressing major CO_2 sources.

* Source: GECO study 2016 by JRC, in blue: implementation of Nationally Determined Contributions as expressed in Paris Agreement.
** Assumes 4%/y volume growth and includes continued operation excellence measures to reduce BASF's product specific GHG emissions.
*** Path forward depends on factors such as R&D results, carbon pricing, renewable energy availability and cost, etc.

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BASF's Carbon Management measures at a glance to avoid CO_2

CO_2 emitters:



Measures:

- Process optimization, energy management, N_2O 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.

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Hydrogen production without direct CO_2 emission at low energy demand – a development project

Energy demand for new processes for hydrogen production

Standard reaction enthalpy as approximation

Hydrogen H_2

Natural gas CH_4

Methane decomposition/-pyrolysis



Water H_2O

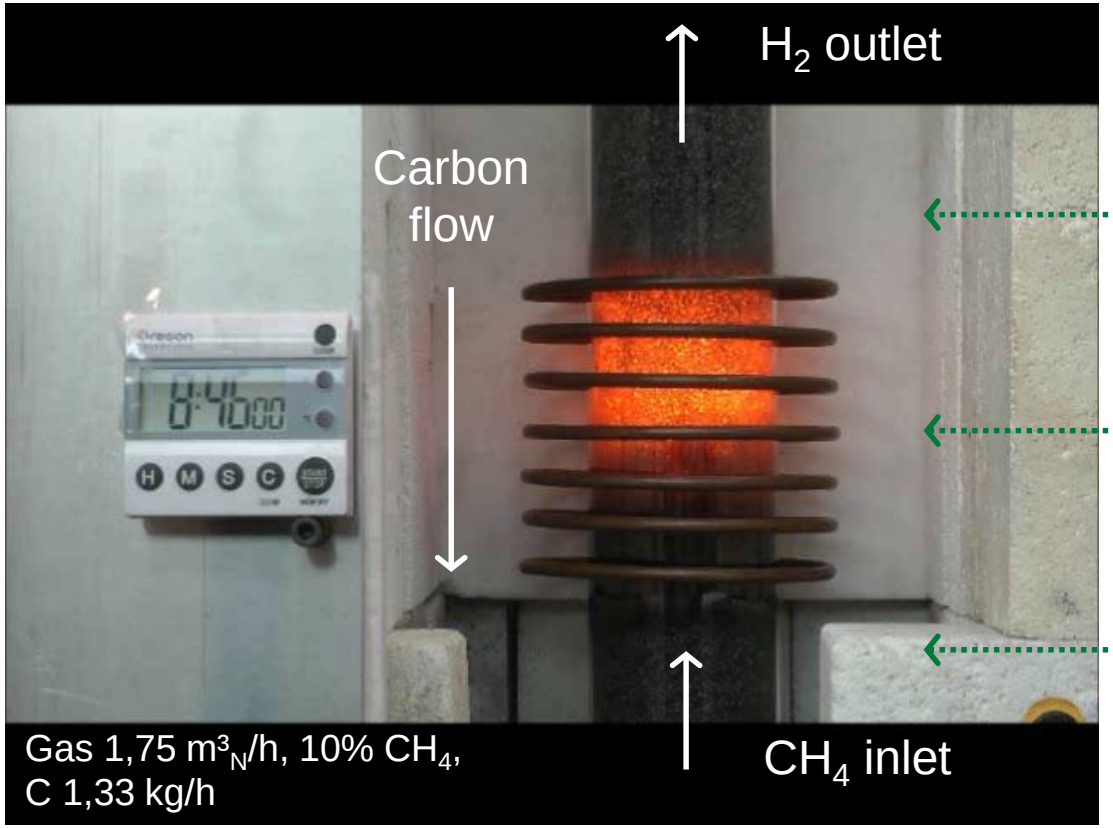
Water electrolysis



New: Carbon is separated as solid
→ no CO_2 emission!

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



H_2 cooling and carbon pre-heating

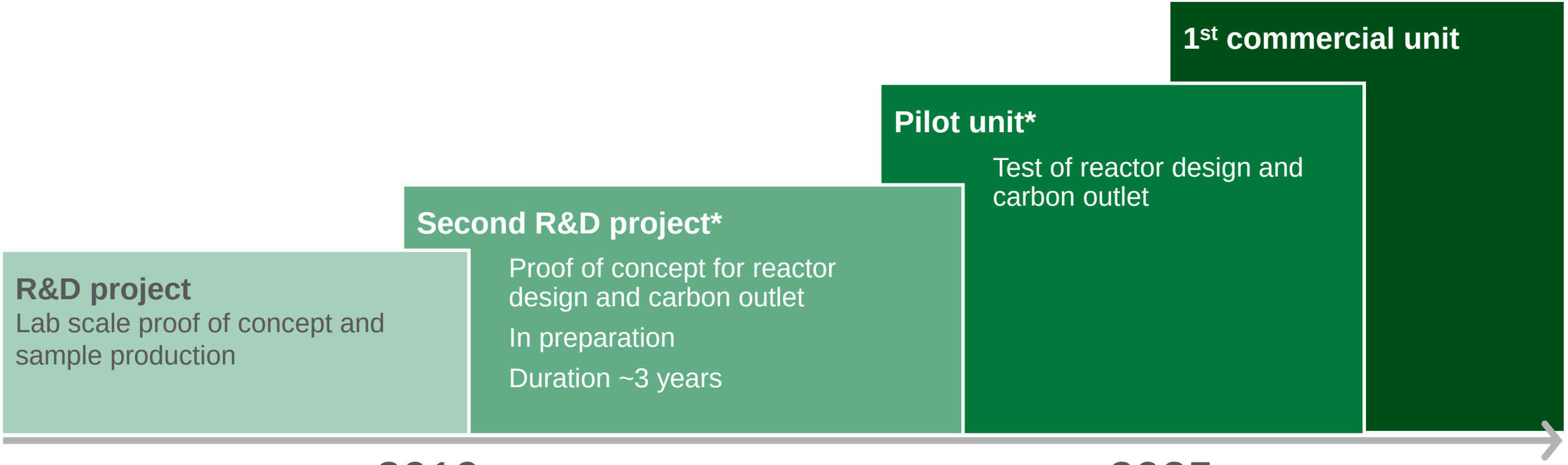
Reaction zone heated by induction

Carbon cooling and CH_4 pre-heating

Reactor is operated at BFI in Düsseldorf

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Project outlook – methane pyrolysis for clean hydrogen



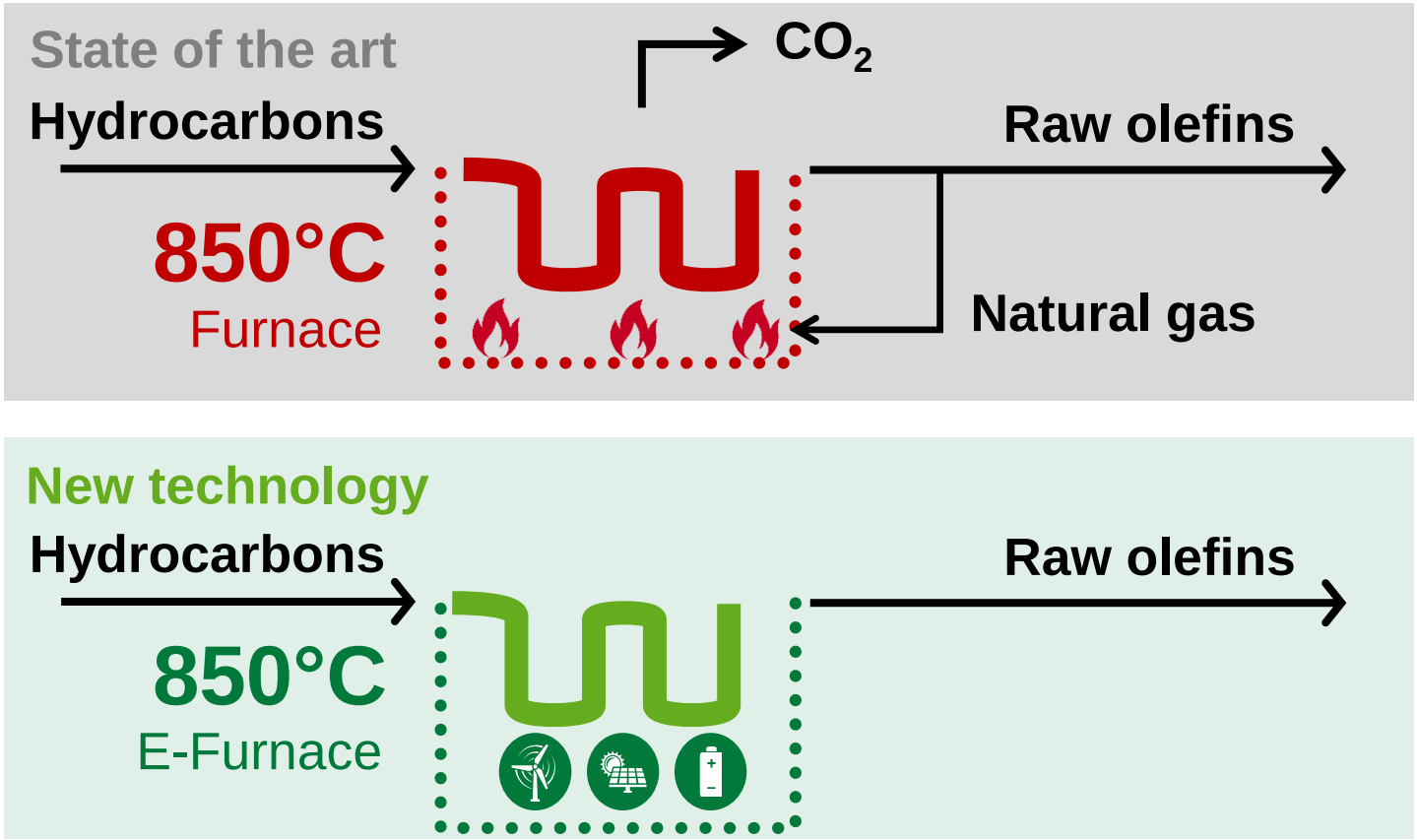
Second R&D project with

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

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Electrical heating might become an option to avoid CO_2 emissions from heating of high temperature processes like steam cracking



Facts

Olefins production by steam cracking generates natural gas as by product which is used for furnace heating.

CO_2 footprint

1 mio t CO_2 p.a.

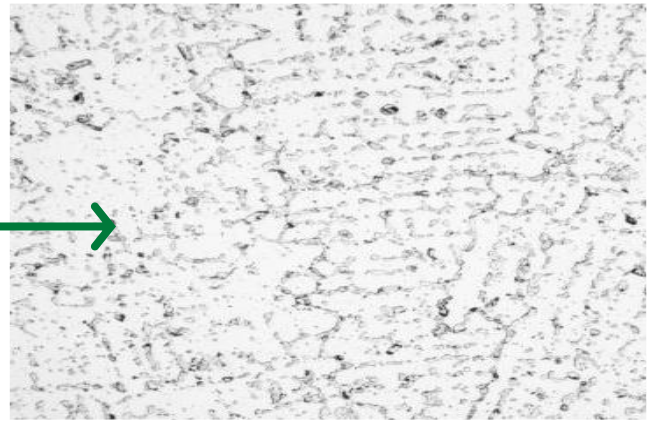
Approach

Replace gas fired furnace by e-furnace.

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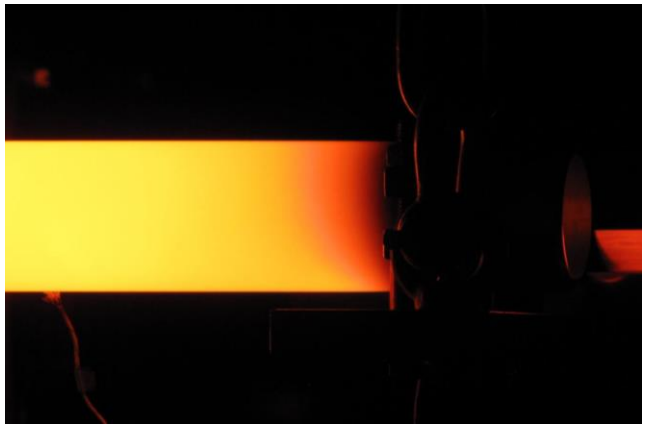
First evidence: E-Furnace lab tests

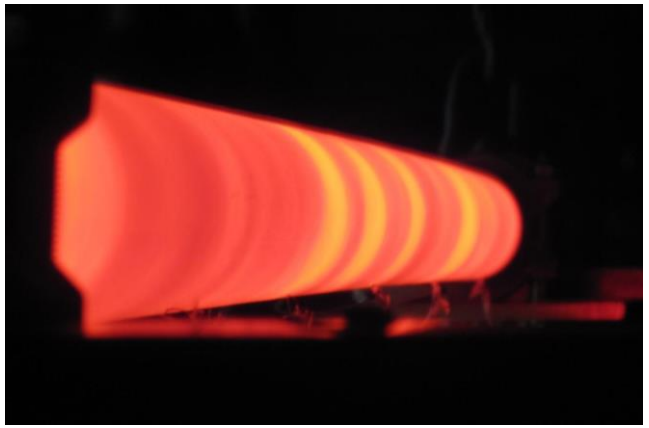




Facing the challenges of metallurgy and temperature

Inhomogeneous microstructures with varying melting point





Electrically heated steam cracker coil

“Proof of material” for E-Furnace

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BASF suports collaborative innovation – Kick-off meeting in Ludwigshafen in July 2019



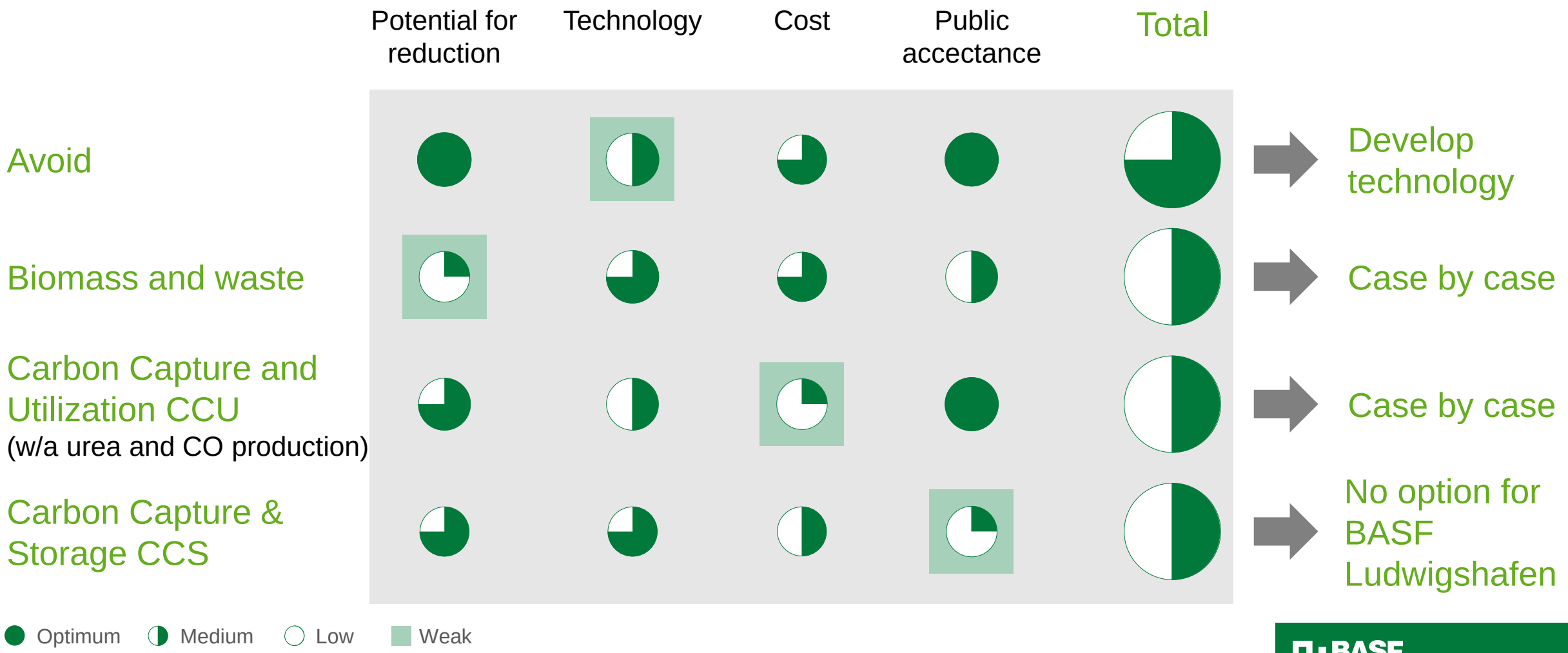


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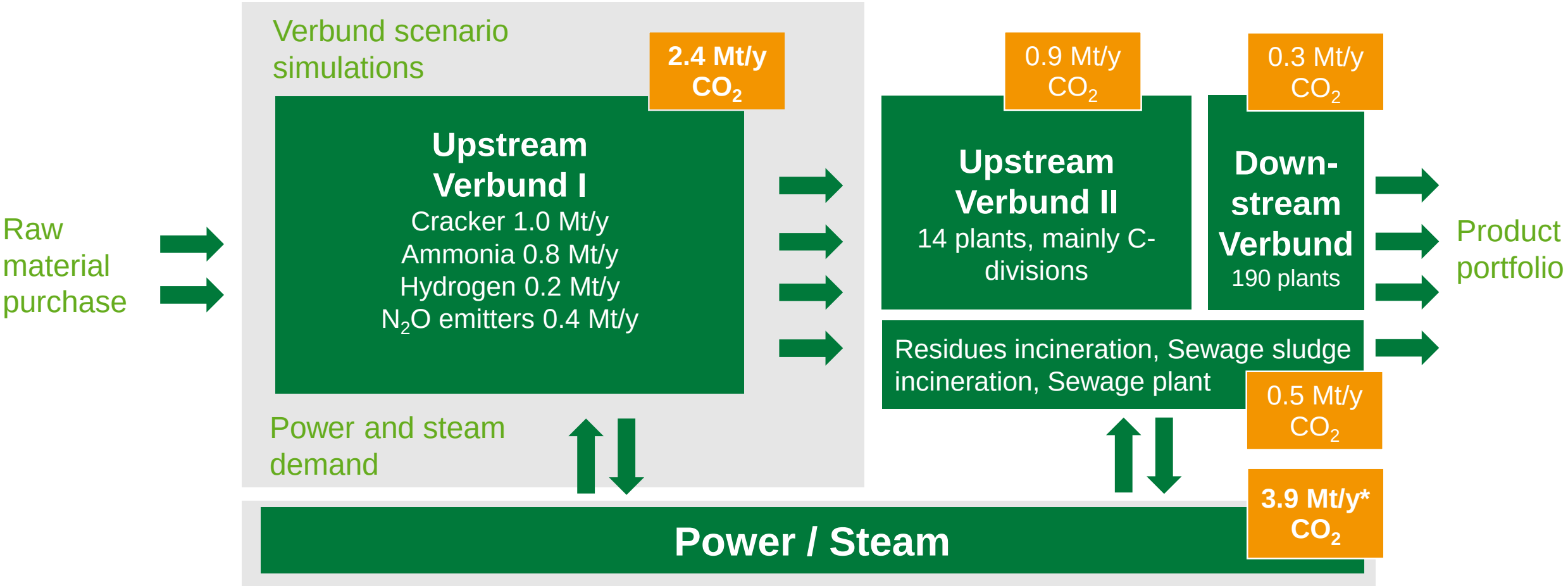
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BASF strategy: Avoid is core, other options case by case



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Example BASF Ludwigshafen: 80% out of 8 Million t/y from power and steam production and basic chemical production



*Numbers shown are based on 2016 data plus adjustment for TDI and acetylene ~2020: Σ8.0 Mt/y. Power / Steam comprises CHP-plants, Kraftwerk Nord, steam boilers and gas turbine plus 12% for TDI and acetylene.

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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

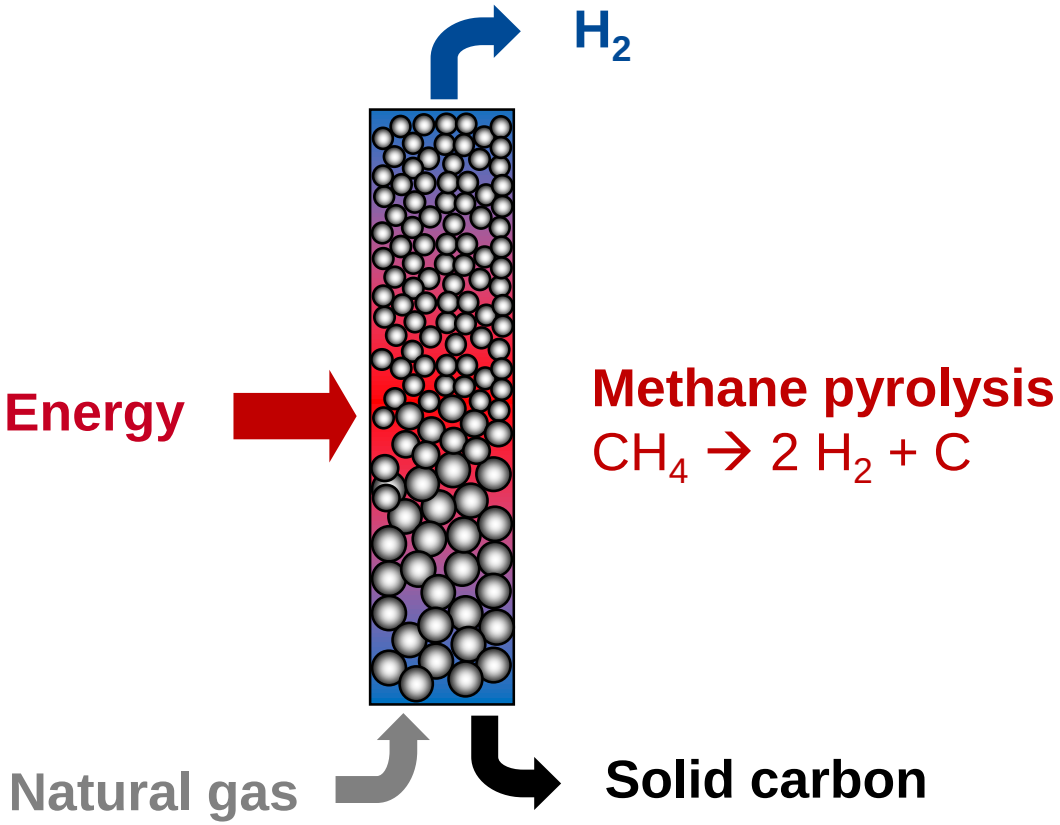
Results

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





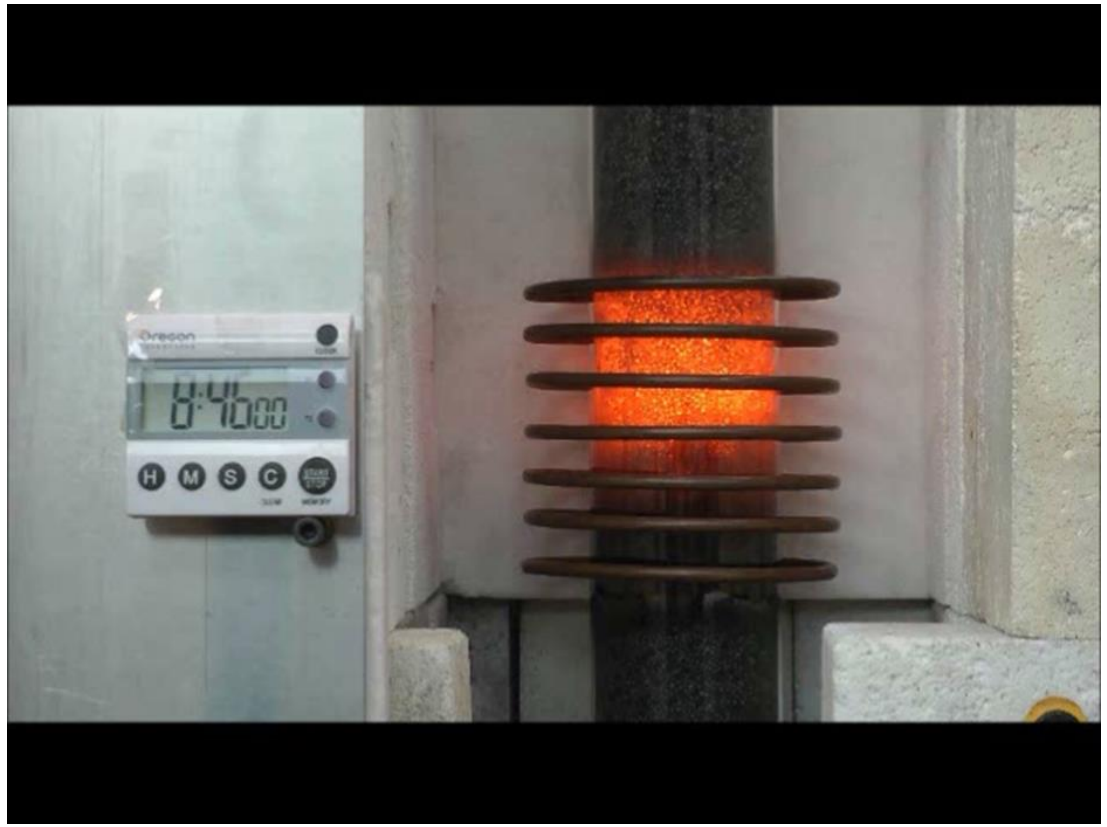
First moving carbon beds for methane pyrolysis: Combined reaction and heat integration





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From lab to pilot scale: Process challenges

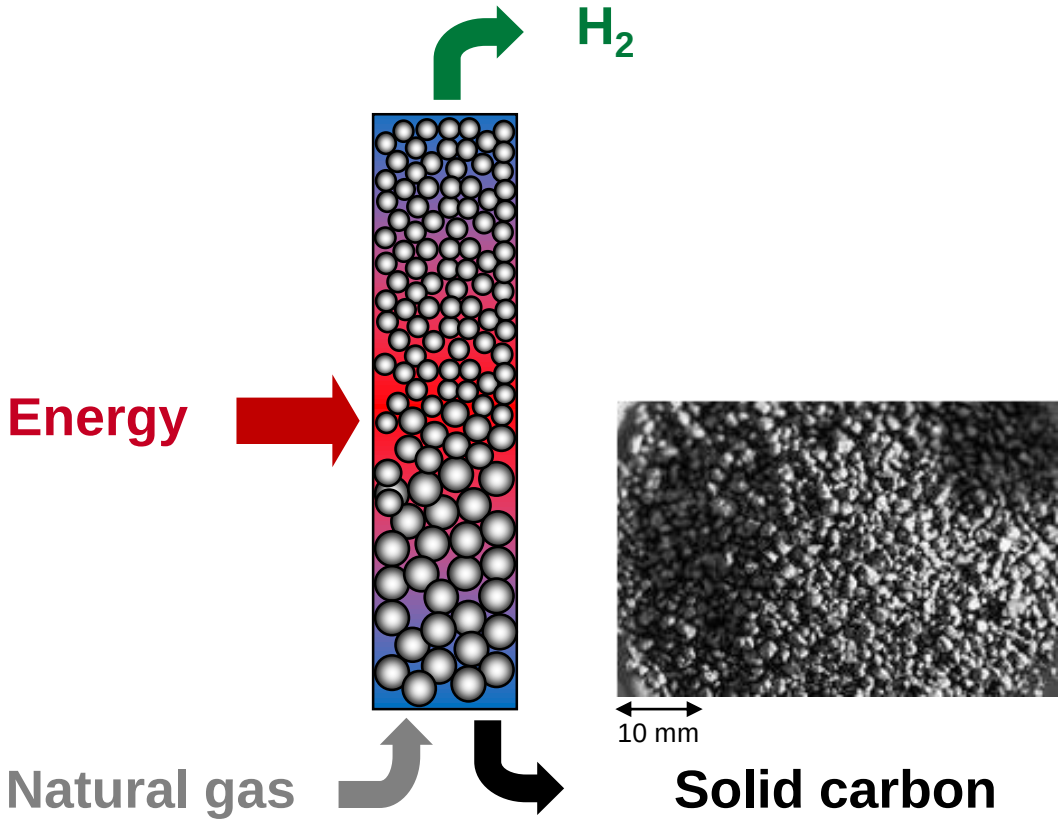


- Need for basic R&D and **new reactor design**
- Heating concept needed to overcome the low radial heat transfer from the wall into the reactor core
- Manage inhomogeneous flow and pulsations
- High-temperature materials required

BASF strives for first stable operation on large lab scale

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Is the solid carbon the showstopper?



Solid carbon

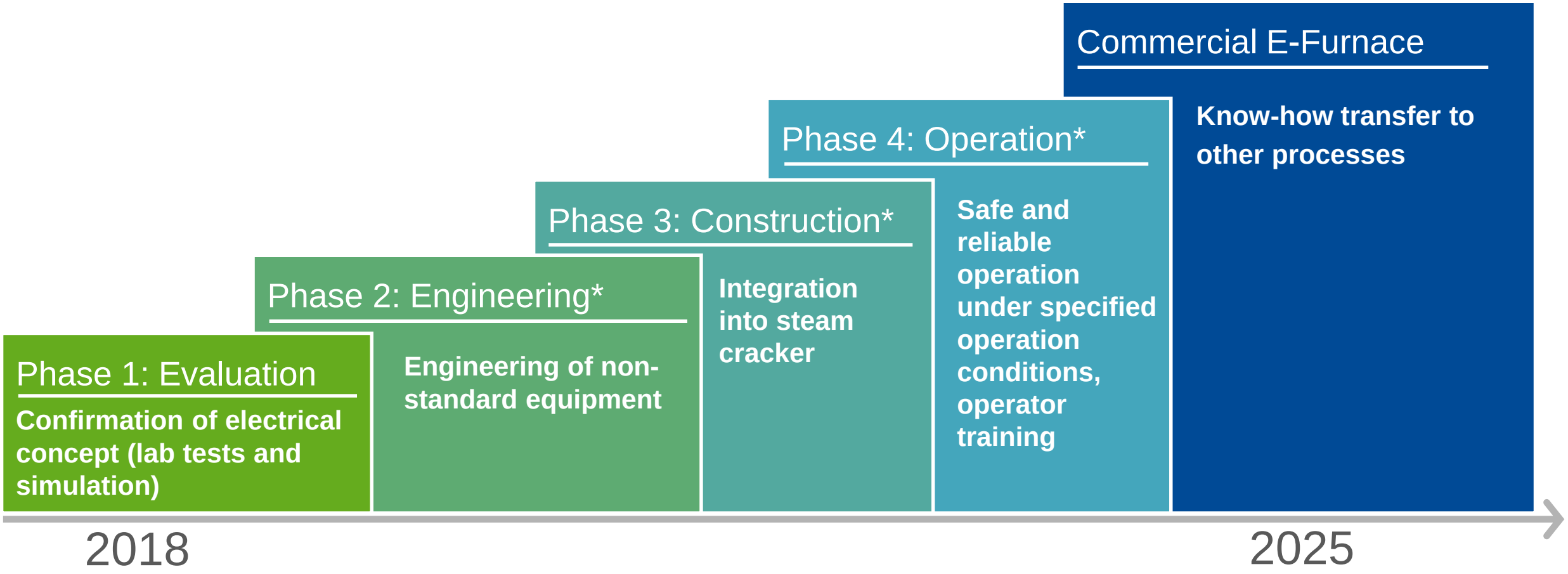
Options for carbon utilization and storage

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

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E-Furnace: Path forward and Go criteria of phases



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

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