
# 100% Renewable Energies for Industries

www.re4industry.eu

# At a glance

**RE4Industry: 100% Renewable Energies for Energy Intensive Industries**

**11 partners from 6 countries (AT, BE, DE, ES, GR, NL)**

**Project Coordinator:**
**FUNDACION CIRCE - CENTRO DE INVESTIGACION DE RECURSOS Y CONSUMOS ENERGETICOS**

**Starting date: 1st September 2020 - Duration: 36 months**

**Type of the project: Coordination and support actions (CSA)**

RE4iNDUSTRY

# Consortium

## TECHNOLOGICAL AND SOCIAL EXPERTS

circe

btg biomass technology group

CERTH CENTRE FOR RESEARCH & TECHNOLOGY HELLAS

WIP RENEWABLE ENERGIES

WHITE

## RENEWABLE ENERGY-ORIENTED ASSOCIATIONS

Bioenergy EUROPE

ENERGY EFFICIENCY in Industrial Processes

eseia european sustainable energy innovation alliance

## ENERGY INTENSIVE INDUSTRIES

sidenor

MYTILINEOS

Corbion

# Context

The EU has started a progressive decarbonisation with the **aim to become carbon neutral by 2050**. Energy Intensive Industries (EII) are expected to play an important role in this transition as they represent 24% of the final energy consumption, but **a clear long-term vision and strategy is required** in order to remain competitive while contributing to the decarbonization targets of the EU.

RE4Industry has been conceived under this framework with a twofold aim:

- to support EII in the **identification and integration of renewable energy (RE) solutions** together with the definition of **Action Plans for decarbonisation**
- to transform the EU industrial landscape into **a large market niche for the uptake of RE** while defining the appropriate framework conditions for **short- and long-term scenarios.**

# Goals

1. To set a multi-actor collaborative network, involved and actively compromised to gather and identify the needs of the sector, in order to make possible this transition

2. To show the RE technologies with more potential to be utilised by EIIs or integrated in their industrial processes, and mark the path in the short (2030) and long term (2050)

3. To identify, visualise and share success stories of EIIs already adopting RE with the innovations

4. To promote the early transition of EIIs by means of a direct accompaniment within companies

5. To achieve a common understanding and vision of the role that EIIs have to play towards 2050 a RE consumers and potential RE promoters

6. To promote a more favourable policy and market framework to allow the competitiveness of RE based EIIs goods

7. To ensure a growing interest and alignment of European society by means of a strong and coordinated communication campaign coherent with EII sector messages

8. To empower the sector and key organizations through knowledge transfer, strategic positioning and cross-border actions

RE4iNDUSTRY

# Project workflow

**WP1** Management and Coordination

**WP2** Engagement of target and key actors

**WP3** Status and best practices for RE integration in EIIs

**WP4** Case studies on innovative solutions for RE adoption in EIIs

**WP5** Short and long term innovative energy solutions for full EIIs decarbonisation thorugh RE

**WP6** Knowledge transfer through replication activities

**WP7** Dissemination and communication

# Collaborative Network – 13 Advisory Groups

## RE4Industry clusters: GR/ES/NL/DE

**Technical** feedback at national level, multi-thematic

## RE4Industry Expert Group: sector oriented

EIIs

Renewables

Regulations

Society

**Thematically focused** with a **strategic perspective** at an **EU** level

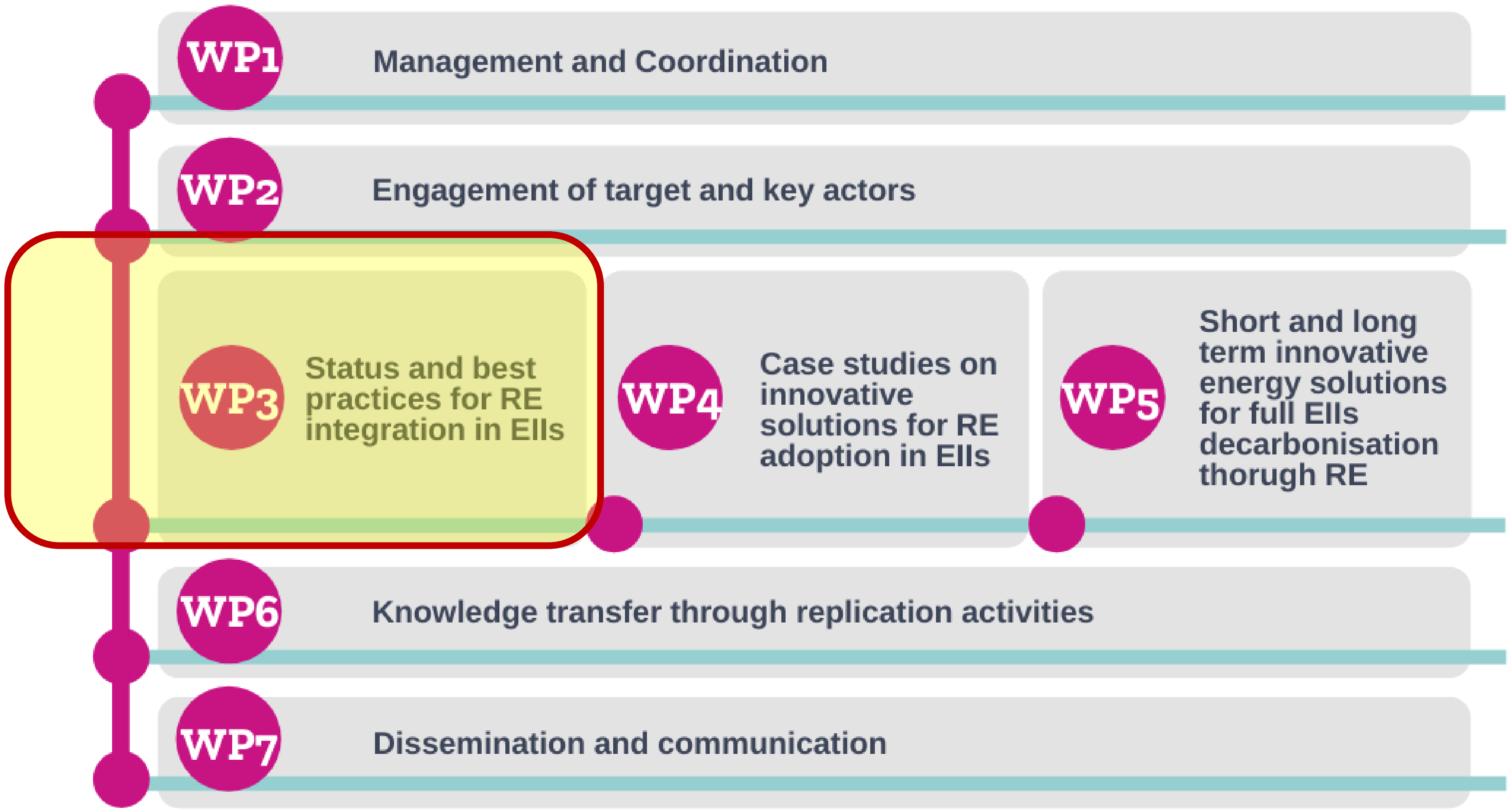
## RE4Industry Committee GR/ES/NL/DE

**Policy and landscape insights, advocacy-oriented** group at national level

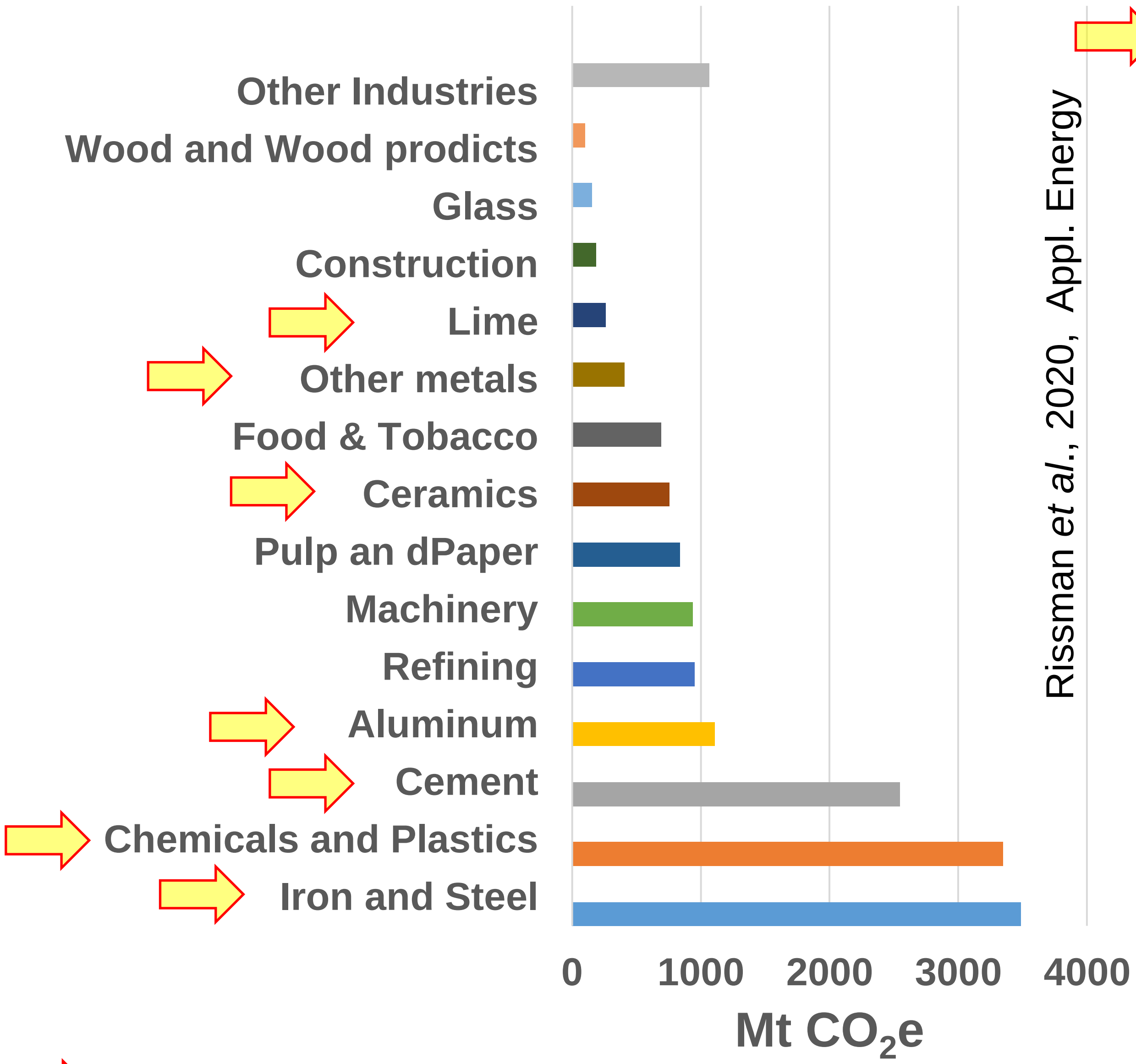
## RE4Industry Committee EU

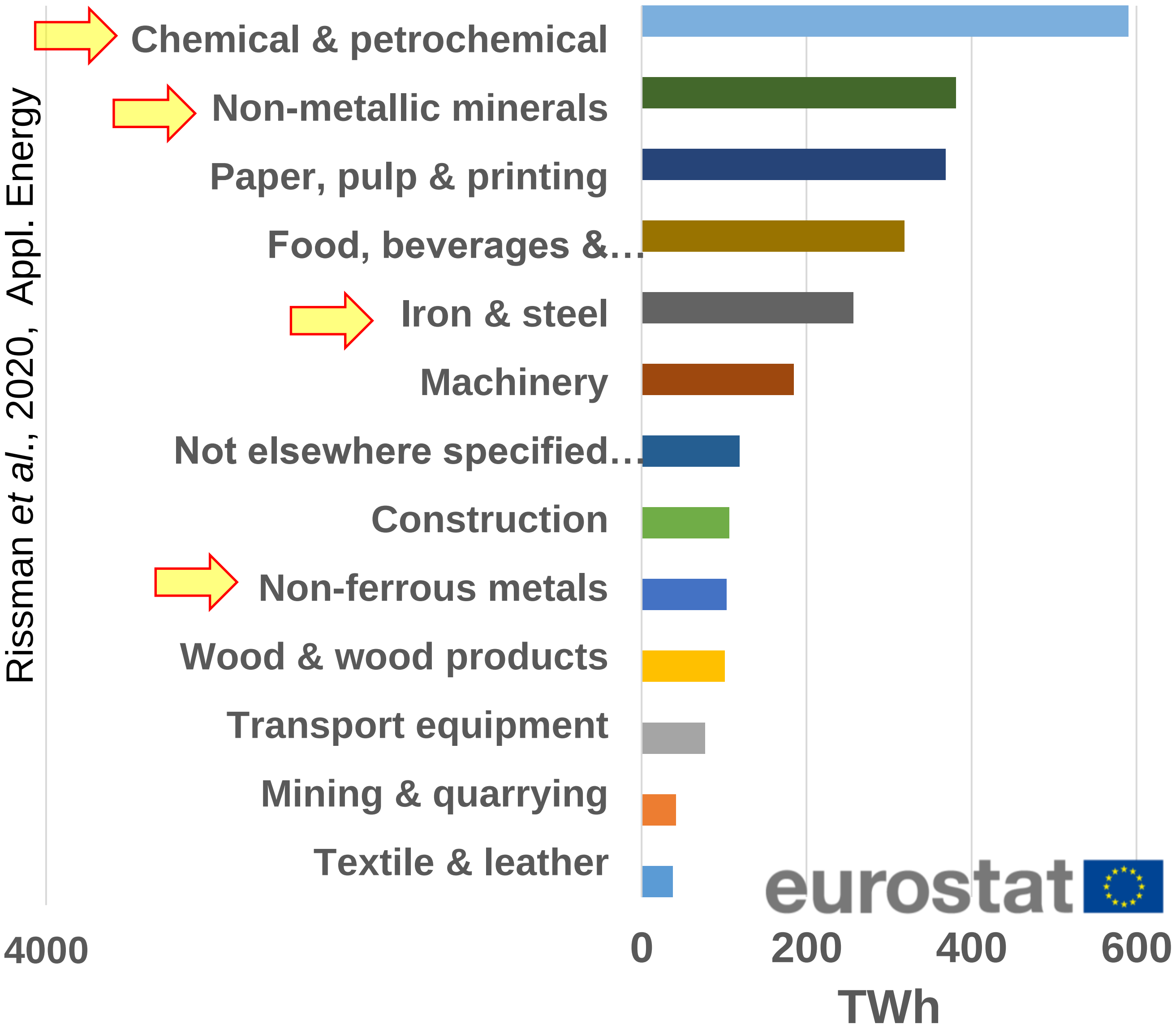
**Policy and landscape insights, advocacy-oriented** group at **EU level**

# Project workflow



# Context: $CO_2$ emissions and energy consumption by the industry



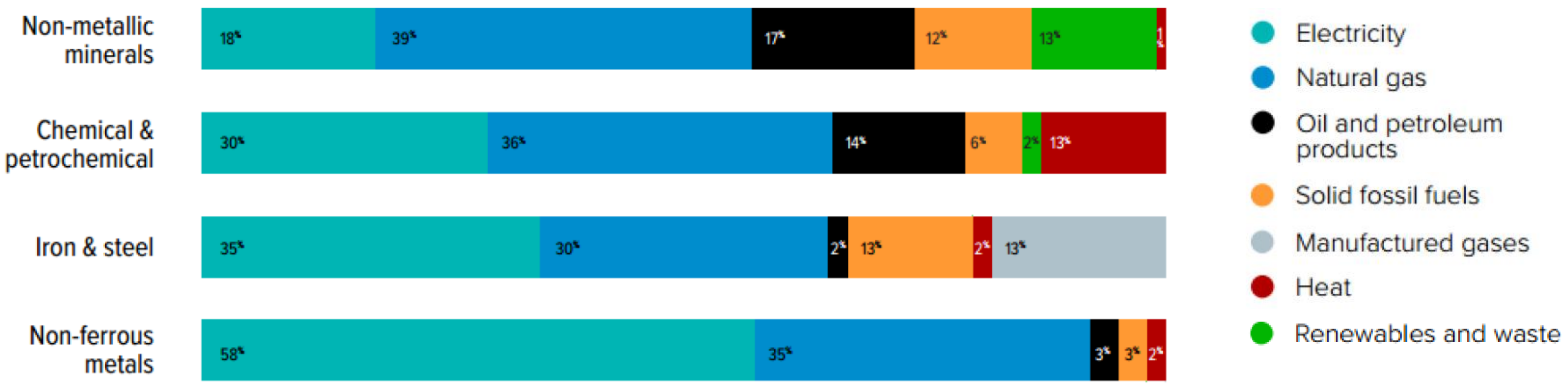




*The arrow indicates avialable analysis on this sector*

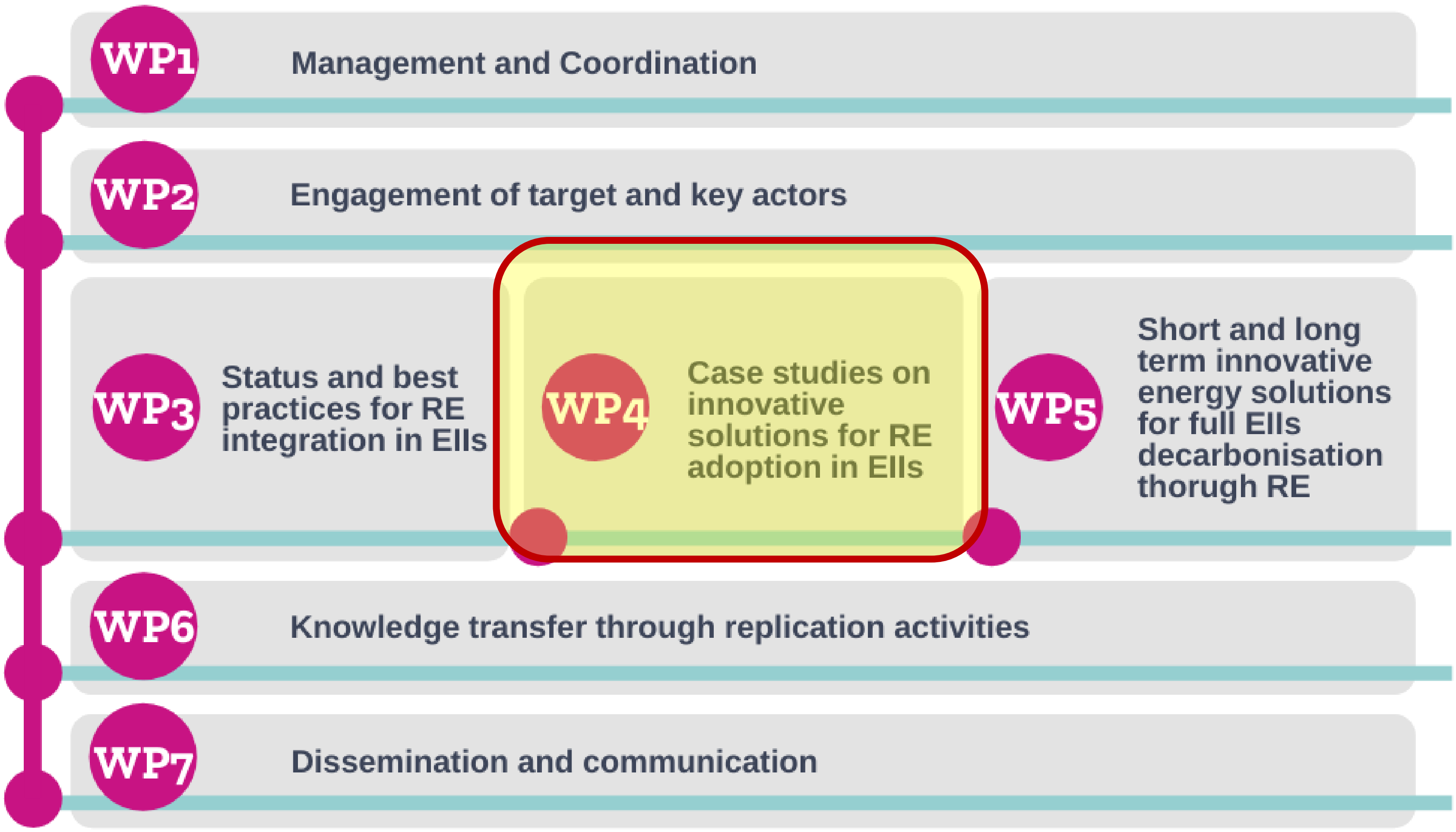
Source: Plotted from information found in the Eurostat database: https://ec.europa.eu/eurostat/web/energy/data/energy-balances (accessed on May, 2022)

# Outcome of the analysis on the status of the EU Industry

- EU has decided that by 2050 will have succeed to fully decarbonize the industrial European sector fulfilling the ambition for carbon neutrality
- Up to 2050 only one investment cycle away, and any further delays will hugely complicate the transition
- Resource and energy intensive industry holds a central place in this vision
- The production of key materials and chemicals –steel, plastics, ammonia and cement – emits some 500 million tons of CO2 per year, 14% of the EU total
- The European industry consists of many different industrial sectors who need electricity and heat for their production processes



# Project workflow



# Industrial case studies

## Energy sources:

- **Electricity** → • Green electricity (PPAs, photovoltaics, etc.)
- **Natural gas** → • Biomethane (no modification), Green $H_2$ (needs modifications)
- **Coal** → • Biochar (lower efficiency)
- **Steam** → • Electric boiler



# Project workflow

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- WP6 Knowledge transfer through replication activities
- WP7 Dissemination and communication

## Vision

## SHORT-TERM VISION

# 2030

### TECHNOLOGY OPTIONS

Conventional RE heating
- Biomass
- Bioenergy carriers
- Solar (high temperature)
- Geotherm

### ACHIEVABLE RATES

- $CO_2$ balance > 0 (reduced according to RE use)
- RE use <50%

### CURRENT SECTOR NEEDS

- Existing options for retrofit
- Cases already implemented
- Lessons learned
- Insight in cost / economics
- Opportunities (e.g. for financing, long term RE contracting)
- Positive social perception
- Influence for a better framework

## LONG-TERM VISION

# 2050

### TECHNOLOGY OPTIONS

- Conventional RE heating / power
- New RE (solar thermal, bio syngas)
- $H_2$ (electrolysis / syngas)
- E-fuels (synthesis fuels from RE based hydrogeneration of $CO_2$ captured)

### ACHIEVABLE RATES

- $CO_2$ balance ≤ 0
- RE use = 100%

### CURRENT SECTOR NEEDS

- Scope to understand the future options on RE
- Implications for retrofitting to produce and adopt e-fuels
- Energy balances and key indicators of adopting each RE alternative (for an early decision making in short-medium term)
- Expected costs for RE use

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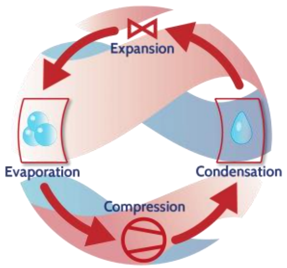
# 1. Heat

Solar thermal




Heat pumps

Geothermal

Biomass

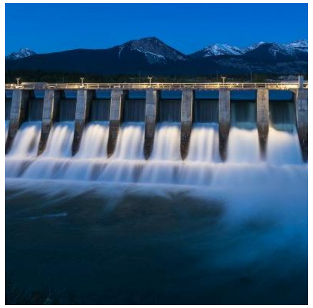
Biofuels

Green hydrogen

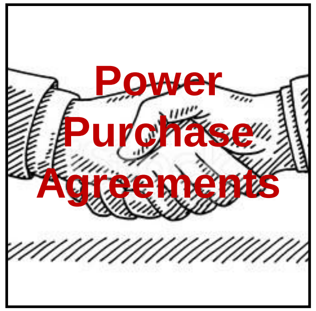
# 2. Electricity

Photovoltaics

Wind



Hydraulic




Renewable PPAs

# RE4Industry actions

**RE4Industry methodology can be expressed through 7 action axes targeted to generate confidence, facilitate vision, provide support and ensure market options to EIIs.**

A strong engagement strategy following a multiactor approach

A dialogue with and within EIIs and EII organizations

A thoughtfully review of RE technologies and options for a 100% RE production by 2050

Insights into industry retrofitting and promotion of RE integration

Recommendations for the uptake of RE by EIIs and advocacy

Multiplication and replication

A solid dissemination and communication strategy

# Thank you!

Olgu Birgi
Project Manager
olgu.birgi@wip-munich.de

www.re4industry.eu

RE4Industry EU project

RE4Industry - EU project
@eu_industry EU

# BUNDESVERBAND GLASINDUSTRIE E.V.

Stand Februar 2022

BV GLAS

# Federal Association of the German Glass Industry

- BV Glas represents the economic policy interests of the German glass industry.
- BV Glas represents around 85 percent of glass production in Germany from the following sectors:
  - Flat glass
  - Container glass
  - Special glass
  - Glass fibres
  - Tableware
  - Water glass
  - Processing and finishing


Dorothée Richardt
PR
Christiane Nelles
Energy and Climate
Dr. Johann Overath
General Manager
Sheryl Webersberger
Product Policy
Stephan Mieth
Statistics
Marion Beißel
Assistenzce
Ulrike Aldenhoff
Environment

# Key Data: German Glass Industry

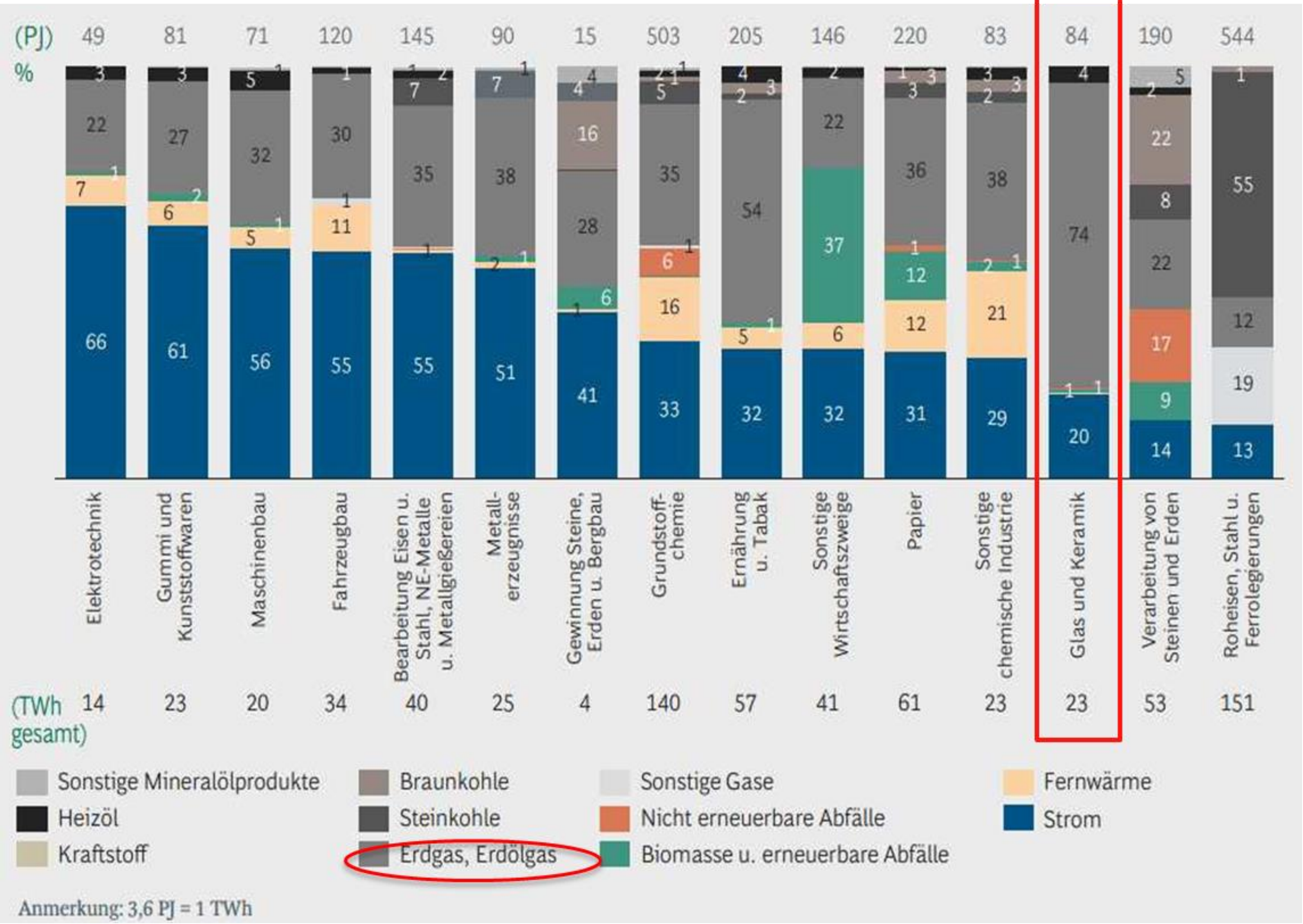
- *The German glass industry is the biggest in Europe.*
- *Glass industry in NRW is the biggest in Germany.*

| ERHEBUNGSMERKMAL *SURVEY CHARACTERISTIC* | MASSEINHEIT *UNIT OF MEASUREMENT* | 2019[r] | 2020[v I p] | VERÄND. IN % *CHANGE IN %* |
|---|---|---|---|---|
| Betriebe > 20 Mitarbeiter *Businesses > 20 employees* | Anzahl I *Number* | 394 | 388 | –1,5 |
| Beschäftigte I *Employees* | Anzahl I *Number* | 56.022 | 53.690 | –4,2 |
| Produktion[1] I *Production[1]* | Mio. EUR I *EUR m*<br>1.000 t | 9.488<br>7.457 | 9.153<br>7.356 | –3,5<br>–1,4 |
| Umsatz gesamt I *Total revenue* | Mio. EUR I *EUR m* | 9.808 | 9.354 | –4,6 |
| Inland I *Domestic* | Mio. EUR I *EUR m* | 5.736 | 5.508 | –4,0 |
| Ausland I *Foreign* | Mio. EUR I *EUR m* | 4.071 | 3.846 | –5,5 |
| Ausfuhr I *Exports* | Mio. EUR I *EUR m* | 6.897 | 6.317 | –8,4 |
| Ausfuhrquote[2] I *Export quota[2]* | % | 54,6 | 53,4 | – |
| Einfuhr I *Imports* | Mio. EUR I *EUR m* | 5.686 | 5.042 | –11,3 |
| Einfuhrquote[3] I *Import quota[3]* | % | 49,8 | 47,8 | – |

r = revidiert I *revised* v I p = vorläufig I *provisional*
[1]Einschl. Steinwolle. I *including rock wool.*
[2]Anteil des Exportwertes an Inlandsumsatz + Exportwert. I *Proportion of export value in relation to domestic revenue + export value.*
[3]Anteil des Importwertes am Inlandsverbrauch (= Inlandsumsatz + Import).
*Proportion of import value in relation to domestic consumption (= domestic revenue + imports).*
Abweichungen sind aufgrund von Rundungsdifferenzen möglich. I *Discrepancies possible due to rounding.*
Quellen: Statistisches Bundesamt, eigene Erhebungen. I *Sources: Federal Statistics Office, own surveys.*

BV GLAS

## Final energy consumption in various industries



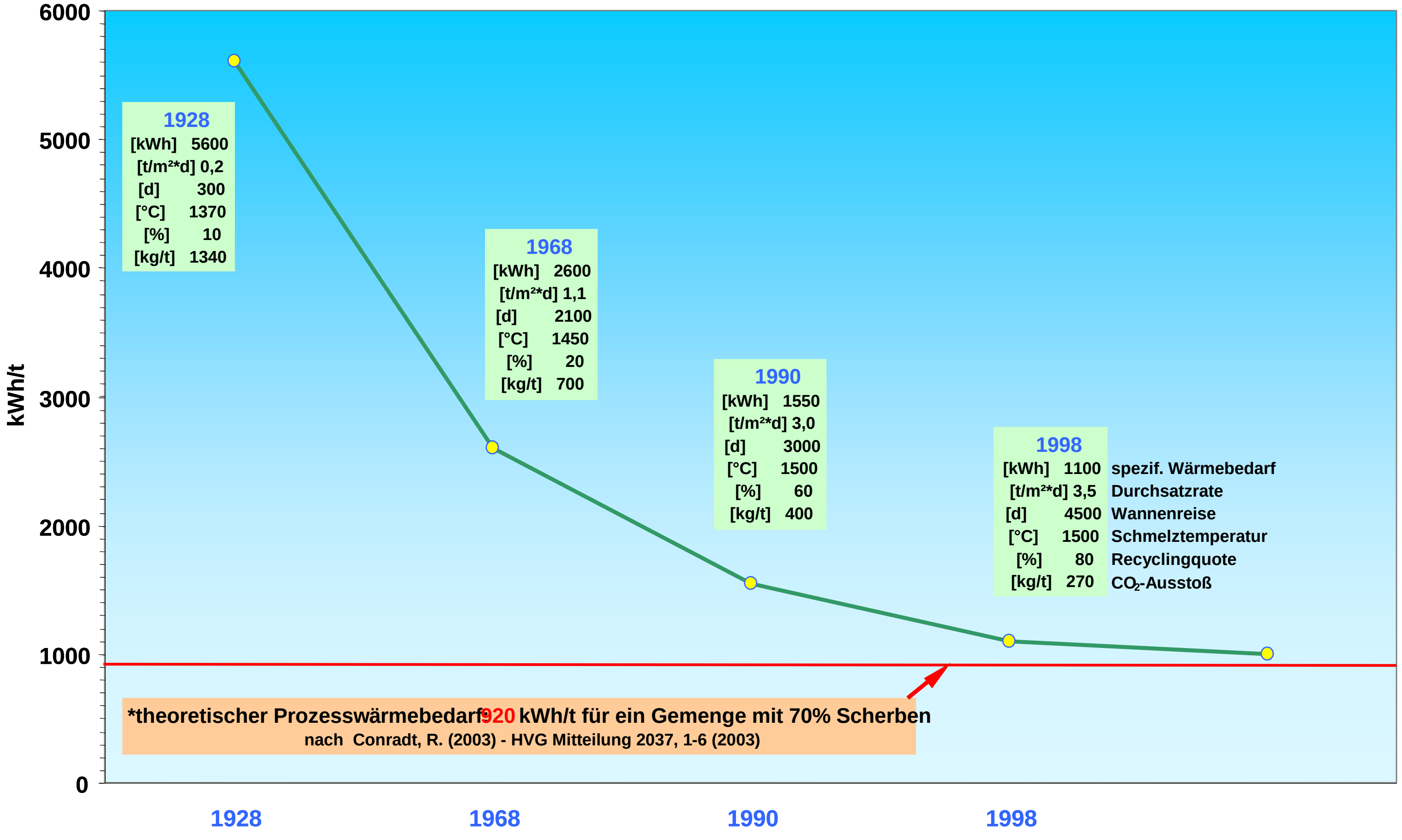

- 74 % of the final energy consumption of the glass industry is covered by natural gas.
- About 85 % of this energy is required for the melting process.
- Glass quality is very sensitive to changing fuel gas compositions (e. g. due to hydrogen admixture).

Quelle: BDI-Studie, Klimapfade für Deutschland, 2018

# Reduction of specific energy consumption

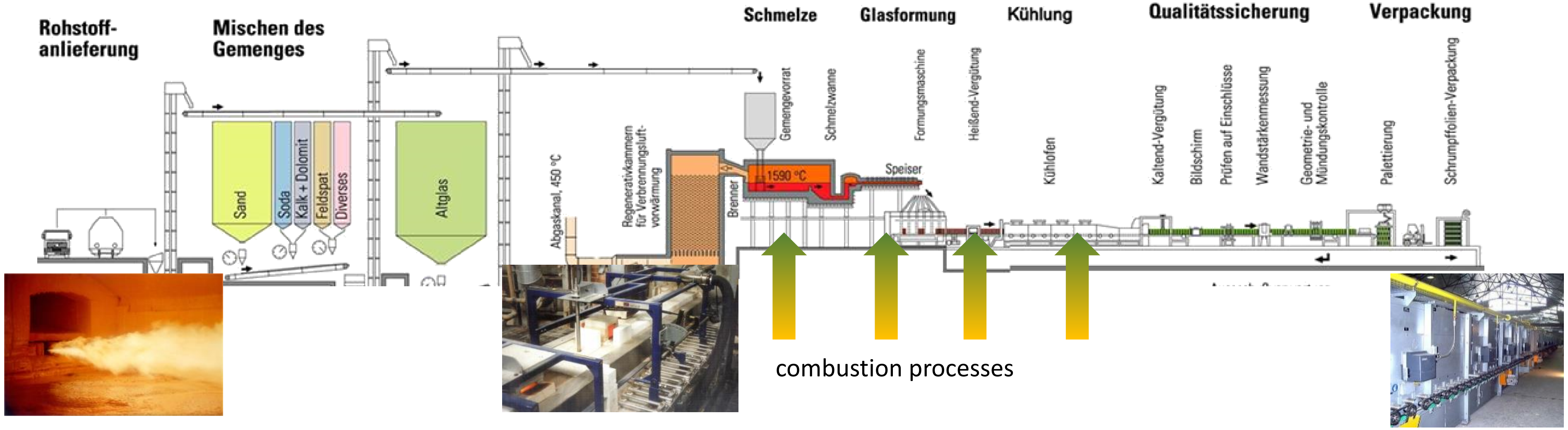
The glass industry has already exploited most of ist energy saving potentials.

**Decarbonization** can only be achieved using renewable energies and CCS.




Zahlenangaben für 1928, 1968, 1990, 1998 nach
nach Conradt, R. (2003) - HVG Mitteilung 2037, 1-6 (2003)

# Glass Manufacturing




- Long, luminous, turbulent non-premixed flames
- Regenerative air preheating up to 1,400 °C or oxy-fuel
- <u>Purpose of the melting furnace:</u>
  -melting of the raw materials, homogenization of the melt at a required temperature

-> sufficient energy, high temperatures, effective heat transfer (radiation) into the load.

- many small premixed burners
- <u>Purpose of the feeder:</u>
  Transport of the melt to the shaping machines and thermal homogenization of the melt (0.1 K)
- <u>Shaping:</u>
  homogeneous and constant temperature since viscosity is exponentially dependent on temperature

-> stable combustion, temperature as well as radiation characteristics

- Usually forced-draught burners with high excess air
- <u>Purpose of the lehr:</u>
  stress-free cooling with a prescribed temperature-time profile

-> strict temperature control (± 1 K)

-> stable combustion…

# Green energy for the glass industry

**Decarbonizing process heat** in energy-intensive industries (glass, ceramics, steel, NF metals, …) is a **crucial** but often neglected aspect of the **energy transition**. Electrification (with „green“ electricity) is one approach, but many applications in the thermal processing industries will still require **combustion processes**, e. g. **high-temperature processes in the glass industry.**

**Syngas and Power-to-X** (PtX), i. e. the production of hydrogen from regenerative electricity,
can be one pathway towards the decarbonization of such industries.

- Within a project (HyGlass), the suitability of a partial substitution of natural gas with syngas i.e. green hydrogen was investigated for typical applications in the glass industry in terms of efficiency, heat transfer, pollutant emissions (NOX), operational and safety aspects, GHG reduction potential. The chart evaluates the CO2 reduction potential.

| $H_2$ admixture rate [vol.-%] | $CO_2$ Reduction Potential in t/a | | |
|---|---|---|---|
| | typical glass melting process | NRW | Germany |
| 10 | 2,640 | 34,320 | 108,900 |
| 50 | 18,720 | 243,360 | 772,200 |
| 75 | 38,400 | 499,200 | 1,584,000 |
| 100 | 80,000 | 1,040,000 | 3,300,000 |

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NYSE: EVA

# RE4Industry

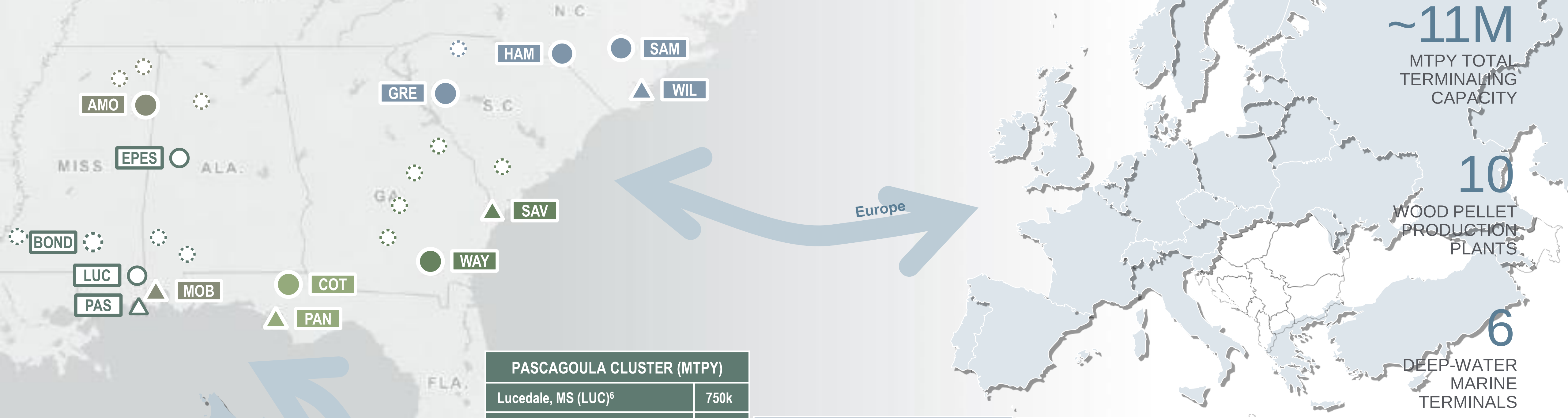
## Green Carbon Security. Cross-sectoral, bio-based defossilisation of hard-to-abate industries

— October 24, 2022 —

# ENVIVA INC.

# STRATEGICALLY LOCATED ASSETS[1]

OPERATIONS LOCATED IN THE SOUTHEAST U.S., WHERE ROBUST NATURAL RESOURCE GROWTH DRIVES SUSTAINABLE, STABLE, LOW-COST SUPPLY




**~6.2M** MTPY TOTAL NAMEPLATE PRODUCTION CAPACITY[2]

**~11M** MTPY TOTAL TERMINALING CAPACITY

**10** WOOD PELLET PRODUCTION PLANTS

**6** DEEP-WATER MARINE TERMINALS

| PASCAGOULA CLUSTER (MTPY) | |
|---|---|
| Lucedale, MS (LUC)[6] | 750k |
| Port of Pascagoula, MS (PAS)*[6] | 3.0M |
| Amory, MS (AMO) | 115k |
| Port of Mobile, AL (MOB)[3]* | 115k |
| Cottondale, FL (COT) | 780k |
| Port of Panama City, FL (PAN)[3]* | 780k |

| WILMINGTON CLUSTER (MTPY) | |
|---|---|
| Hamlet, NC (HAM) | 600k |
| Sampson, NC (SAM) | 600k |
| Greenwood, SC (GRE)[5] | 600k |
| Port of Wilmington, NC (WIL)[3]* | 3.0M |

| CHESAPEAKE CLUSTER (MTPY) | |
|---|---|
| Southampton VA (SOU)[4] | 760k |
| Ahoskie, NC (AHO) | 410k |
| Northampton, NC (NOR)[4] | 750k |
| Port of Chesapeake, VA (CHE)[3]* | 2.5M |

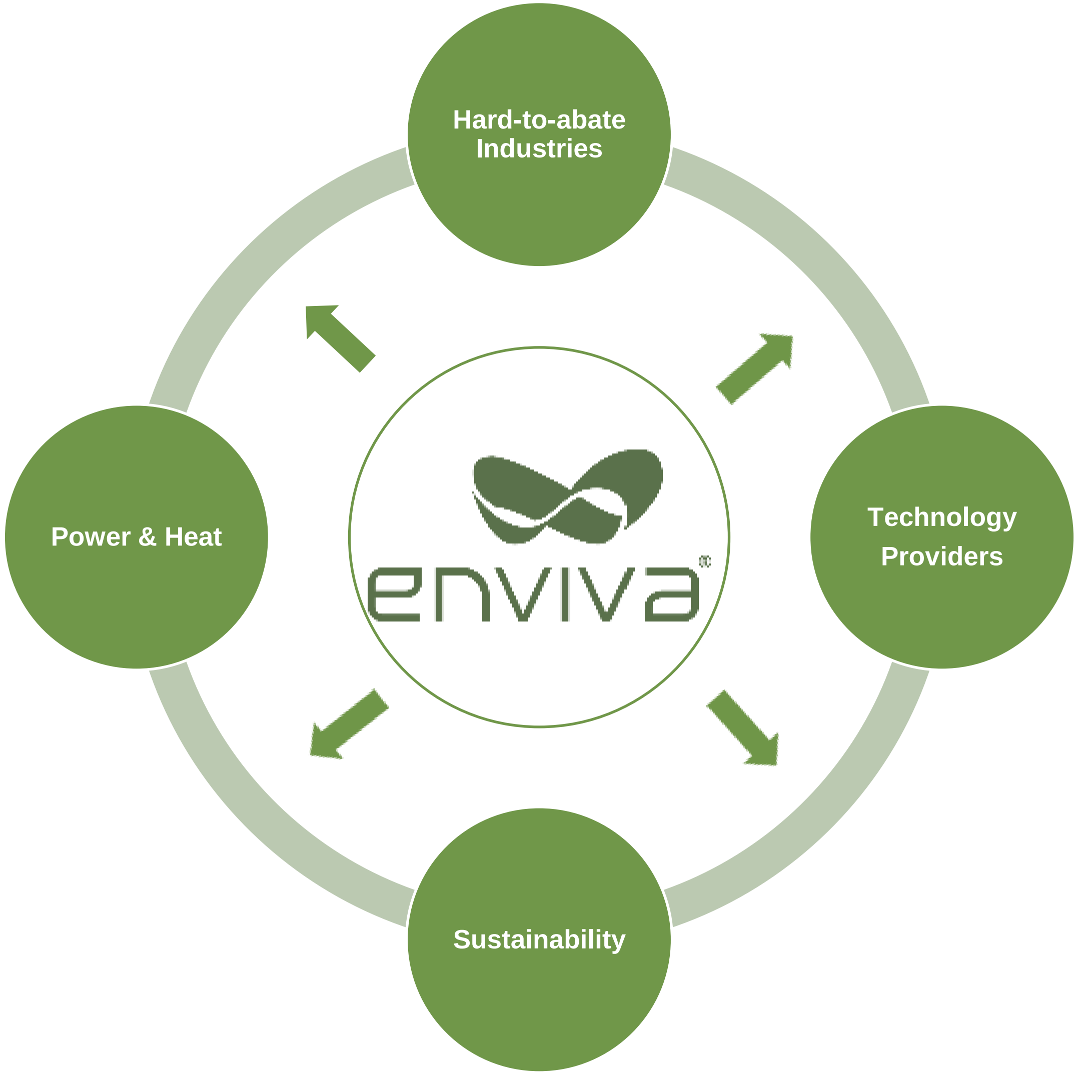
| SAVANNAH CLUSTER (MTPY) | |
|---|---|
| Waycross, GA (WAY) | 800k |
| Port of Savannah, GA (SAV)[3]* | 1.5M |

- ▲ TERMINALS OWNED OR LEASED
- ● PLANTS OWNED AND OPERATED
- ○ PLANTS UNDER DEVELOPMENT / CONSTRUCTION
- △ TERMINALS UNDER CONSTRUCTION
- PLANT SITES UNDER CONTROL / ASSESSMENT[7]

**terminal throughput capacity*

# ENVIVA BRINGS TOGETHER TURNKEY SOLUTIONS FOR DEFOSSILIZATION

- Enviva brings global expertise and best practices to de-risk investments, ensure security of supply, sustainability, and long-term fixed prices
- Provides biogenic feedstock to unlock the global bio-based economy, from power & heat to new green industrial applications
- Enviva can connect all relevant stakeholders to enable a smooth transition

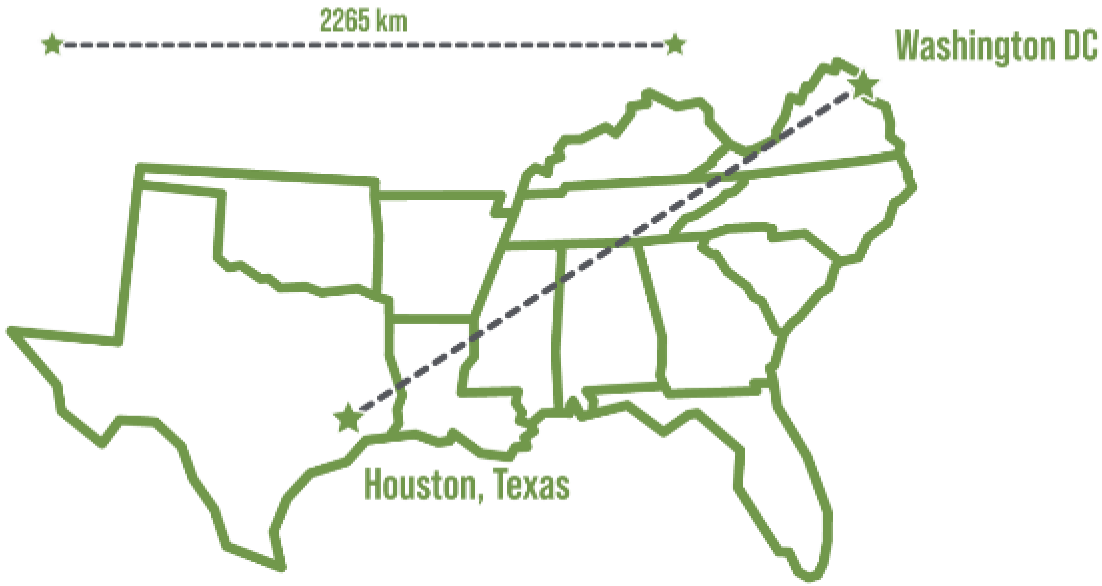


# THE US SOUTHEAST IS ONE OF THE WORLD'S LARGEST FOREST REGIONS…

**U.S. SOUTH**

1.1 million $KM^2$ of forested land which is

**300x** the forested land of the Netherlands.

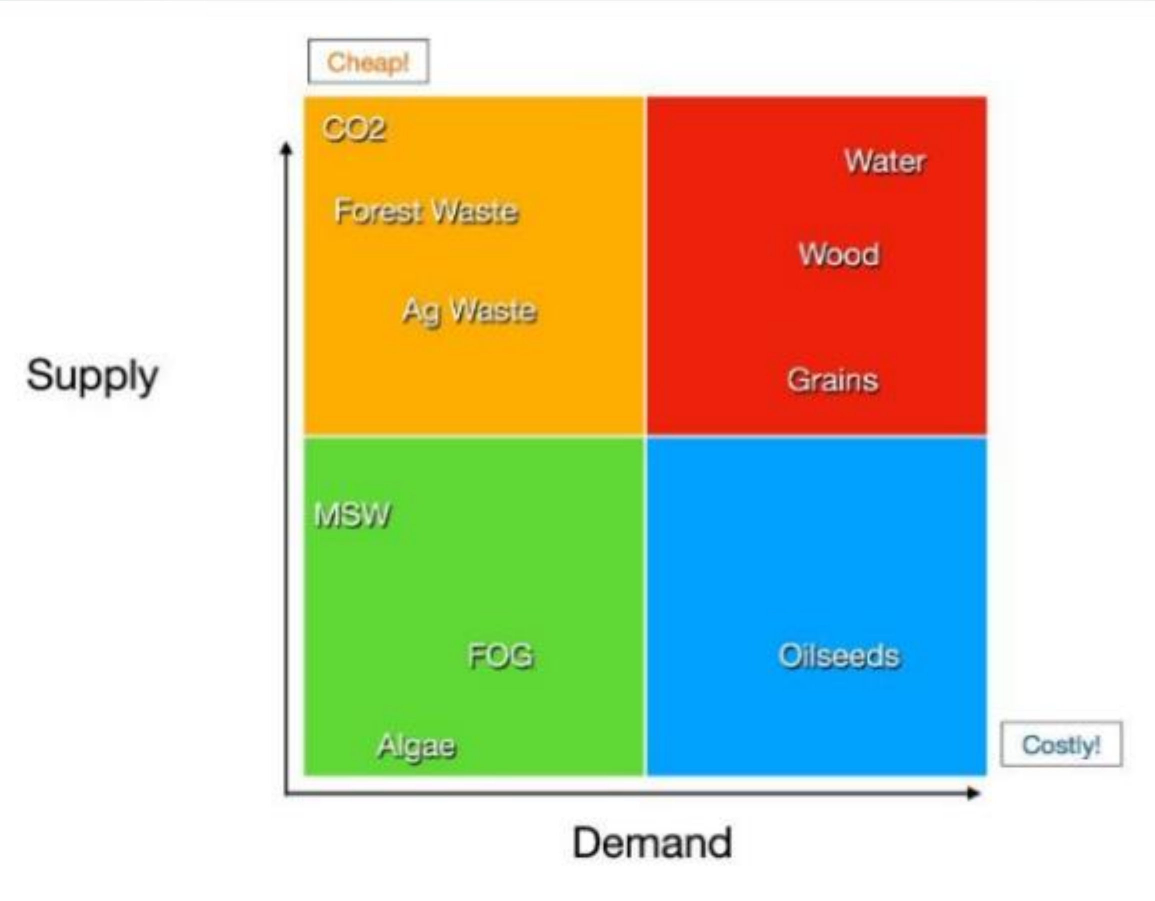



Forested land area in the Southeast U.S. > Total land size of Germany, Spain and Italy COMBINED.

Southeast U.S. forested land = Forested land in Sweden, France, Finland, Spain, Norway and Germany COMBINED.


Long-term sustainable supply

# Conceptual hierarchy for fossil substitution in Germany, according to Agora Industry's "Climate positive chemical industry"* *Enviva Inc. has contributed to assessing Priority IV potentials*




**Priority I: Optimisation of the recycling rate:** Resource-efficient integration of reverse logistics, material and chemical recycling with (BE)CCUS as an alternative energy recovery.

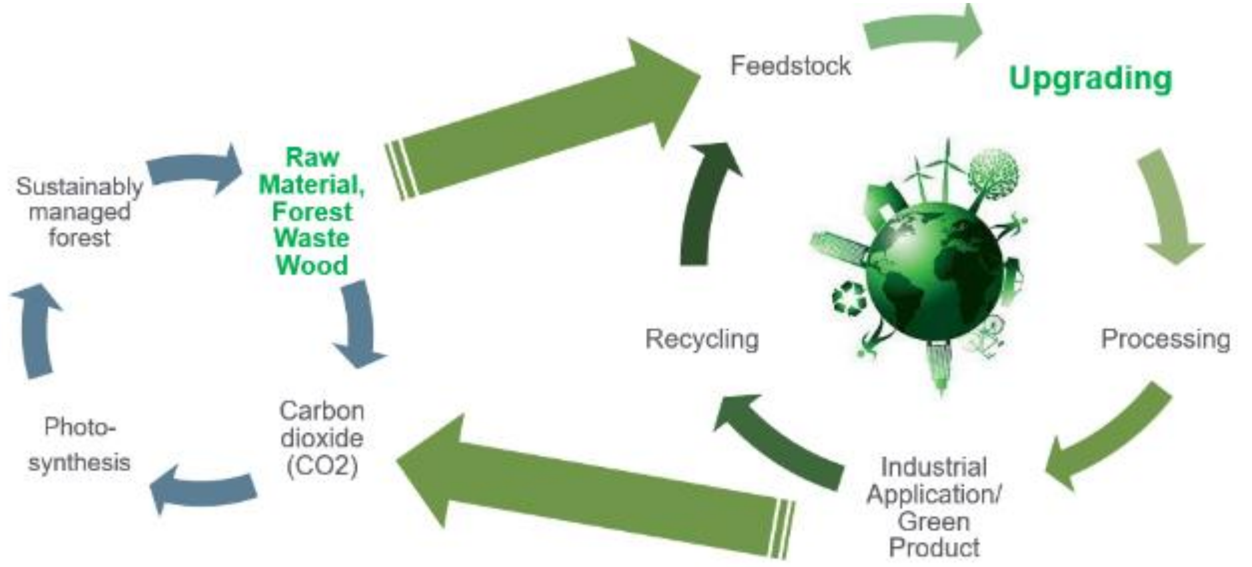
**Priority II: Use of biogenic C sources:** Material use of biogenic energy sources and promotion of climate-intelligent forestry & agriculture through demand for residues.

**Priority III: PtX with domestic and global C sources:** The H2-supported use of residues from recycling or biogenic nature can be used to produce further C-containing raw materials.

**Priority IV: Imports PtX or biomolecules:** Remaining demand for renewable C primary raw materials is met by imports based on corresponding sustainability criteria.

1Carbon Minds: Own modelling based on the "cm.chemicals" database.

# ENABLING A CIRCULAR BIO-ECONOMY




**On a ‘bio-systemic’ level:**

- ✓ Production strategies, environmental sustainability, mobilization strategies, distribution strategies, optimization strategies - cascade factor.
- ✓ Transnational import strategies – global biomass potentials
  - ✓ **Energy – partnerships (US)**

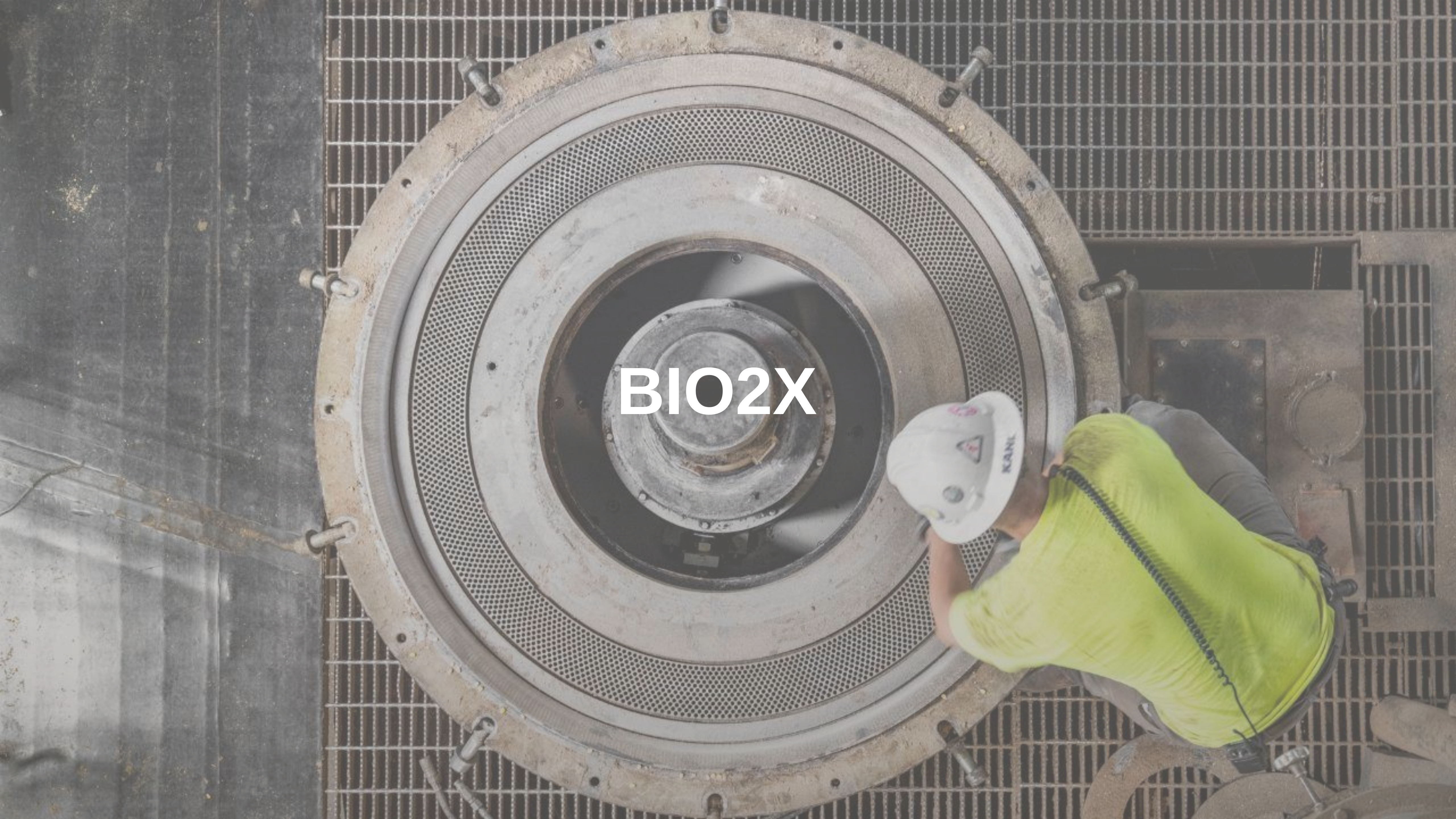
***Germany:***

A. **Theoretical biomass potential**: 236 million tons **Technical biomass potential**: 112.7 million tonnes**. Used technical biomass potential:** 83.4 million tonnes. Equivalent to 29.3 million tons of mobilizable technical biomass potential. 12.8 – 45.5 Mio. tTM - range Energetic use amounts to 31.7 million tons.

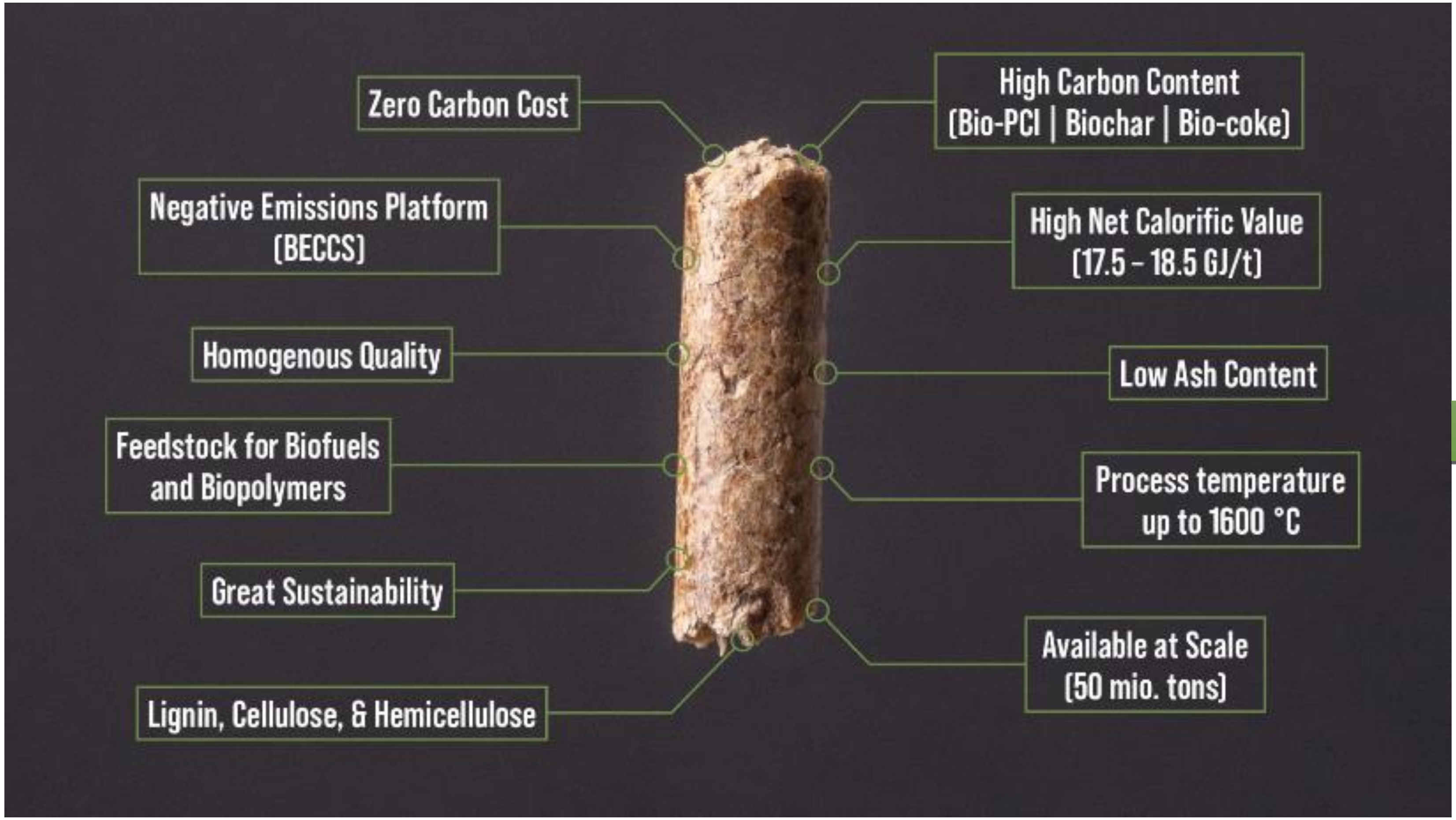
B. Demand: 2026 at 26-30 million tonnes of biogenic carbon. This means that a potential gap of at least 20 million tonnes of biogenic carbon could arise here, if one applies a factor of 0.5

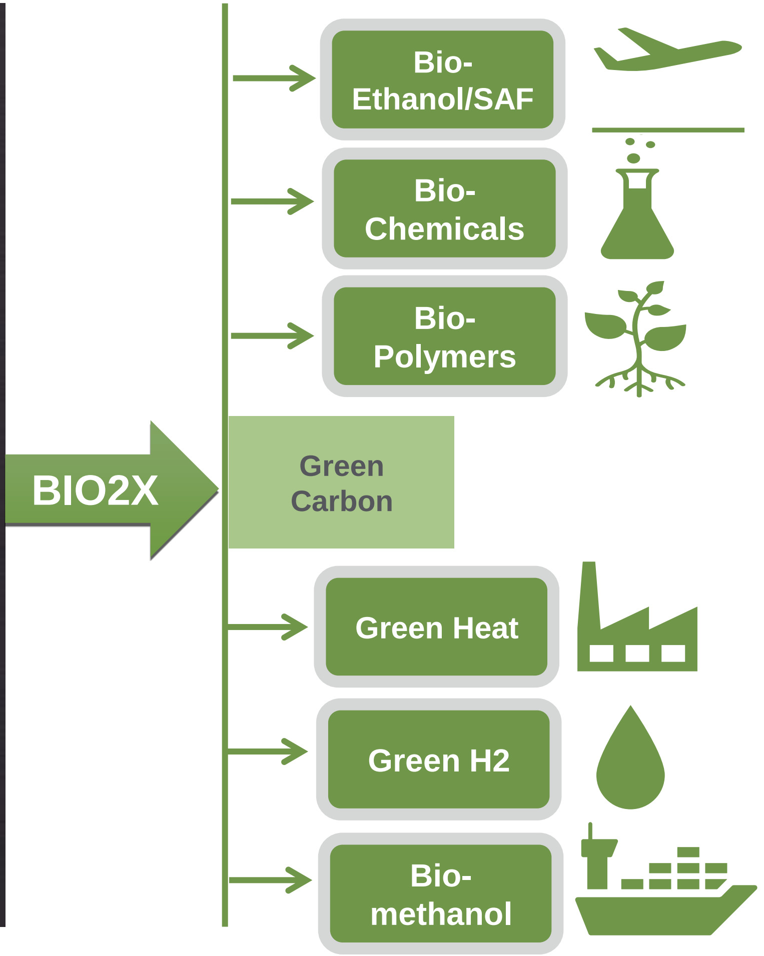
Source: DBFZ, Chem4Climate

# BIO2X



# BIO2X - CLIMATE CHAMPION WOOD PELLET



# SUSTAINABLE **LIGNOCELLULOSIC BIOMASS** IS CRUCIAL FOR DEFOSSILISING THE glass and hard-to-abate INDUSTRIES IN GERMANY

## Sustainable biomass strengths

**Wood pellets: BIO2X platform**

**Fast and low-cost implementation of renewable infrastructures -hybrid**

**Global supply and reliable deliveries - investors security**

**Sustainability at the heart of the transformation**

## *BIOMASS AS A STRATEGIC INDUSTRY-TRANSITION RESSOURCE*

- **In a carbon-constrained world, with a carbon-intensive economy** aiming to significantly reduce fossil $CO_2$ emissions, biogenic carbon is a sought-after resource with high economic value. Scalable, globally available sustainable biomass, enables the production of large quantities of basic and higher chemicals, fuels, heat and energy for the green energy-intensive industry. It is an indispensable tool for 2045.
- The conversion of large-scale fossil installations to green energy installations or the comparably low capex investments necessary to bring fossil-based energy infrastructure up to speed for climate targets are key for rapid transformations. The bio-based technological solutions to transform a fossil-based chemical industry are already there but need to be tapped into.
- Woody biomass can provide energy security and sustainability. Sustainably managed forests in regions such as the Southeast U.S., the Baltics, and Canada provide abundant independently certified residual material that is perfect for wood pellets. Importing large-scale biomass produced in a sustainable manner can ensure the security of supply needed to make large-scale defossilisation possible.
- The sustainability criteria in RED II (and assured by independent certification, such as SBP) ensures only the right source of biomass is used in the EU´.

# MULTIMODAL DEFOSSILISATION PLATFORM: GREEN CARBON

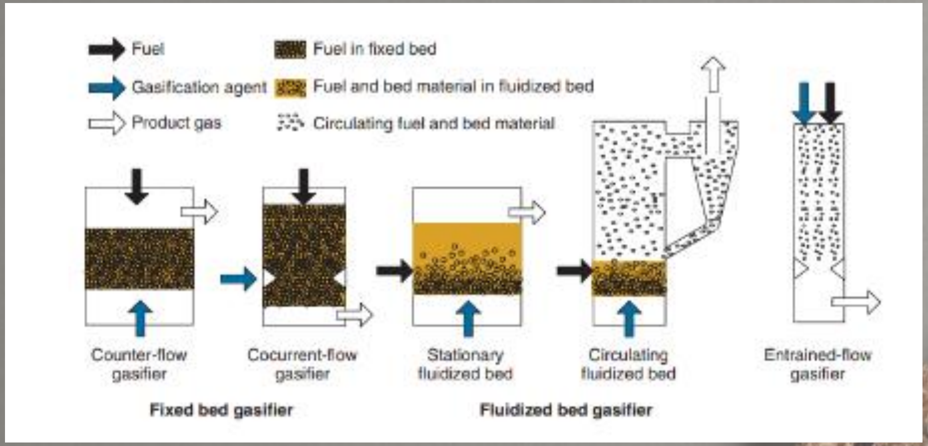
| | Wood pellets | Medium roast | Dark roast | Biochar | Syngas |
|---|---|---|---|---|---|
| **Possible application** | Process heat | Process heat<br>Reducing agent<br>(≤20% replacement) | Reducing agent<br>(>20% replacement)<br>Carbon addition | Carbon addition<br>Reducing agent | Process heat<br>Reducing agent |
| **Fixed Carbon** | 15-20% | 25-30% | 50-55% | 80-90% | n/a |
| **NCV,** in GJ/t | 17-19 | 20-23 | 26-29 | ~30 | 10-12 GJ/Nm³ |
| **Wood pellet equivalent, per tonne of biomass** | 1 | 1.4 | 2.3 | 3.3 | 0.4[3] |
| **Technical complexity** | | | | | |

1. Number derived from research paper: Effects of pyrolysis temperature, feedstock type and compaction on water retention of biochar amended soil
2. Includes CAPEX cost for wood yard, grinding, drying, milling, pelletising, torrefaction and common with margin included for each | 3. 1kg of wood pellets results in 2.4 kg of syngas due to use of additional steam

# ENVIVA's BIOMASS CAN BE USED IN EXISTING TECHNOLOGIES TO DEFOSSILISE THE GLASS INDUSTRY & CROSS- SECTORAL

**Scalable biomass gasification:** The process flow of biomass gasification forms a highly modal synthesis gas, which can be converted to **bio-SNG**, bio-methanol, green ammonia, urea, DME, biogas, SAF, bio-gasoline/liquefied petroleum gas, bio-diesel/naphtha, green hydrogen, (poly) lactic acids, etc. :

- Many of the gasification steps are either present in upstream value chains in the or can be integrated into a new in-house value creation or on the basis of a contracting model, rely on external expertise, further accelerating the transformation processes. This makes it possible, among other things, to produce low-sulphur fuels for the defossilisation of the glass, ceramics, lime, steel and cement industry.



# STATUS QUO: INDUSTRIAL DEFOSSILISATION

**Mobility** – container ships, aircraft, passenger cars, long-haul transport, etc.

**Fertilizer** - Support of the production process of fertilizers: ammonia and biochar

**Industrial Chemistry** – From the production of green naphtha to the production of phenols, Lactid acid, polymers or plastics.

**Health** – Biopolymers as raw materials for pharmaceutical production

**Biorefineries** – replacement of the refining of all existing gas & petroleum-based fuels (petrol, diesel, jet, heavy fuel oil, renewable diesel, sustainable aviation fuel)

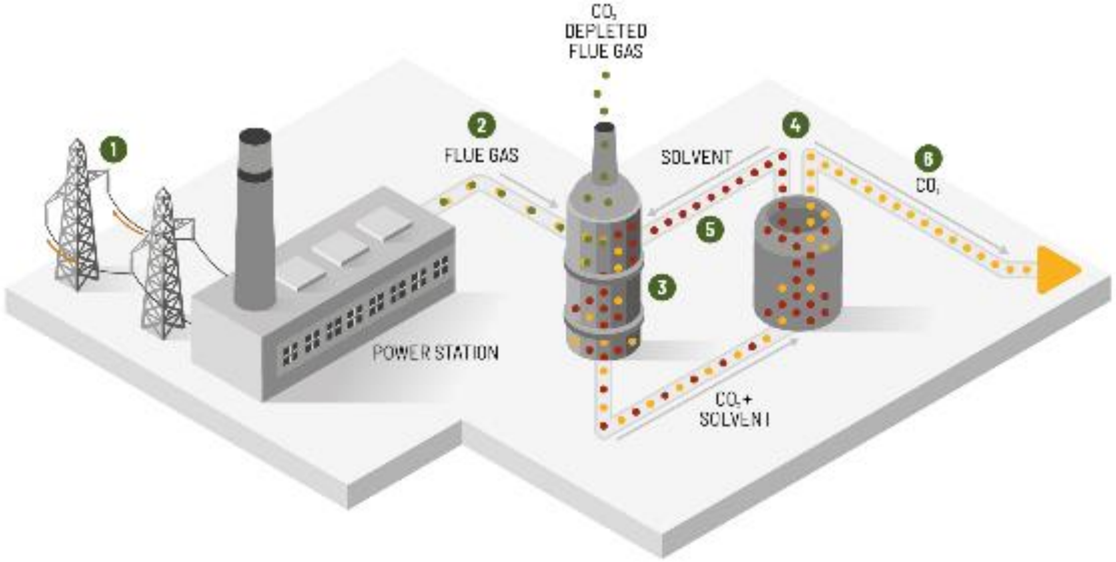
**Green steel & aggregates** - Biogenic substitutes in bio-PCI, recarbonization, bio-coke, sintered fuel, etc., but also in the field of lignin-based textiles, carbon fibers, cement and lime.

**Green process heat** - for the defossilization of energy-intensive processes in the cement-, lime-, glass-, ceramics-, pupl-, tile-, sugar- and asphalt industry.

**Bio- /Synthetic Fuels** – Biomass-based green hydrogen, biomethanol, bioethanol, etc.

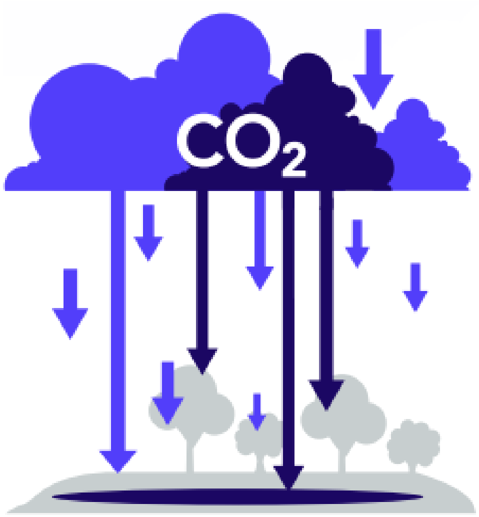
# UNLOCKING CLIMATE POSITIVE INDUSTRIES

## Climate neutrality pathway: CCS




**+ Biomass**

## Climate positive pathway: BECCS




- **BECCS** can deliver large amounts of **negative emissions** with geological storage, without land use change and at **moderate cost**.
- Accumulating **negative emissions-certificates** can become a solid source of **income** for the soon-to-become **climate positive industry**.


SUSTAINABILITY

# ENVIVA'S ACTIVITIES SUSTAIN HEALTHY, **THRIVING FORESTS**

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***"An industry that can reduce greenhouse gas emissions, increase forest growth, and create jobs sounds too good to be true. But that is the reality of the emerging wood pellet market in the Southern U.S."[1]***

*- Former USDA Chief Economist Robert Johansson*

### What is the source of Enviva's wood?[2]

| | |
|---|---|
| 35% | Pine forests with hardwood understory[3] |
| 26% | Mix pine and hardwood forests |
| 17% | Pine forests |
| 17% | Mill and industry residues |
| 3% | Other hardwood forests |
| 2% | Bottomland hardwood forests |
| <1% | Arboricultural sources |

enviva

# CONTACT


**Hendrik Steinort**

**Senior Associate, Industry Solutions and PR**

**hendrik.steinort@envivabiomass.com**

Gas- und Wärme-Institut Essen e.V.

I www.gwi-essen.de

# Investigations into the use of natural gas / hydrogen blends, hydrogen and „raw“ biogas for decarbonization in the glass industry

RE4Industry Webinar

Jörg Leicher, Anne Giese, Bledar Islami,
Klaus Görner, Johann Overath

October 24, 2022

# The challenge of decarbonized process heat

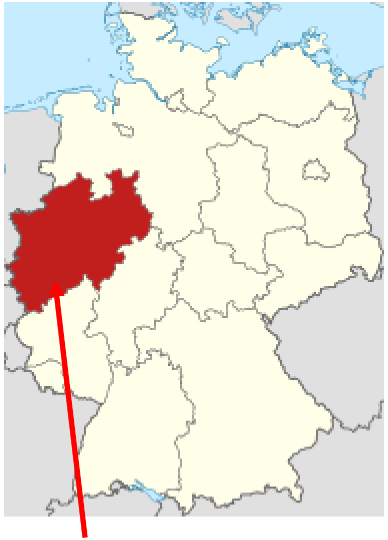
- In 2019, the industrial sector accounted for about **28 %** of the **final energy consumption** in Germany, and about **19 %** of the country‘s **GHG emissions**.
  (High-temperature) process heat is a major contributing factor, in many industries. In the glass industry, the melting process is responsible for about 75 % of the total energy consumption.
- There are various options to produce carbon-free or carbon neutral process heat, e. g. electrification with green power, CCUS, biogas/biomethane or **hydrogen**.
  Hydrogen has recently gained a lot of momentum, with many nations publishing national hydrogen strategies.
  At the same time, the European gas industry is moving forward with plans to **inject hydrogen directly into natural gas grids** as well as establishing **dedicated $H_2$ pipelines**.
- The glass industry will have to think about how their sensitive processes respond to natural gas/hydrogen blends or even pure hydrogen.


Quelle: GWI, 2020

# The HyGlass project

**Objective:** Hydrogen in the glass industry – impact on glass manufacturing, development of solutions and potentials in NRW

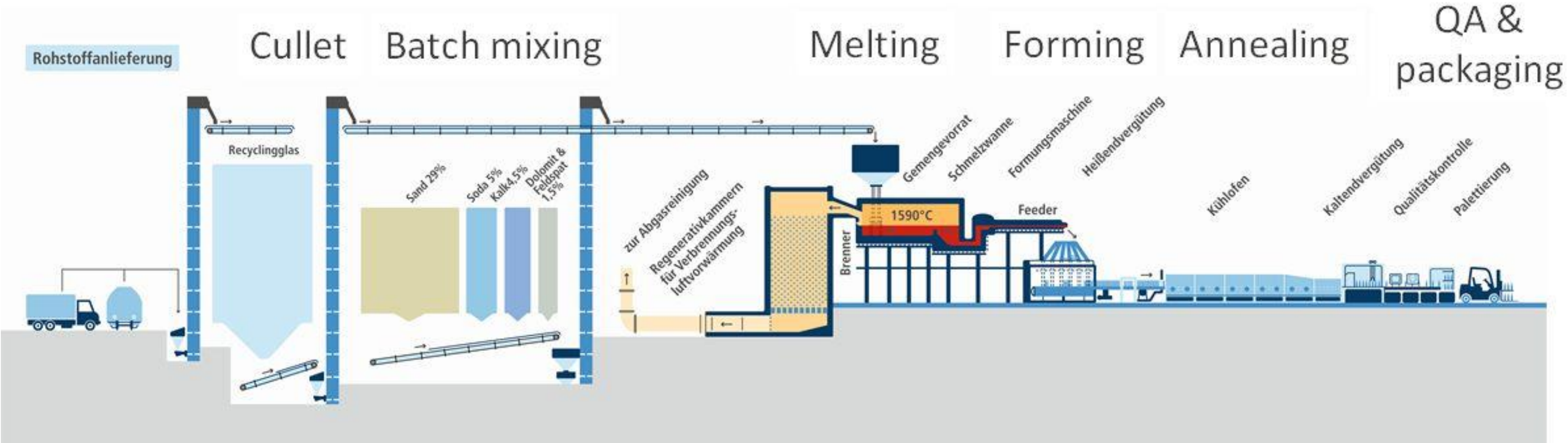
- Investigation of the impact of different levels of hydrogen admixture (up to **100 % $H_2$**) on the different combustion processes in glass manufacturing in terms of efficiency, heat transfer, pollutants, temperatures, $CO_2$ emissions, economic considerations, safety aspects, on product quality, lifetime, plant operation. …
- **Transfer** of the results **to real-life plants** using **CFD simulation** and **semi-industrial test rig experiments**
- **GIS analyses** and **gas grid simulations** for various scenarios of hydrogen admixture with spatial and temporal resolutions for glass production sites in NRW.



about 20 % of the turnover of the German glass industry is generated in NRW.

 Quelle: GWI, 2020

# The container glass manufacturing process






Quelle: GWI, 2020

# Fuel properties: $CH_4$ vs. $H_2$

| | Unit | 100 % $CH_4$ | 80 % $CH_4$ / 20 % $H_2$* | 100 % $H_2$ |
|---|---|---|---|---|
| **$W_S$** | $MJ/m_N^3$ | 53.37 | 50.76 | 48.24 |
| **$H_{i,vol}$** | $MJ/m_N^3$ | 35.89 | 30.87 | 10.79 |
| **$H_{i,m}$** | MJ/kg | 50.03 | 58.13 | 120.01 |
| **d** | - | 0.5571 | 0.4596 | 0.0698 |
| **$Air_{min}$** | $m_N^3/m_N^3$ | 9.524 | 8.095 | 2.381 |
| **$T_{ad}$ ($\lambda = 1$)** | °C | 1,951 | 1,960 | 2,106 |
| **$s_L$ ($\lambda = 1$)** | cm/s | 38.57 | 45.22 | 209 |
| **$V_{flue, wet}$ ($\lambda = 1$)** | $m_N^3$/MWh | 1,055 | 1,049 | 961 |
| **Specific $CO_2$ emission**** | g $CO_2$/MJ | 55 | 51 | 0 |

Reference system: 25 °C / 0 °C

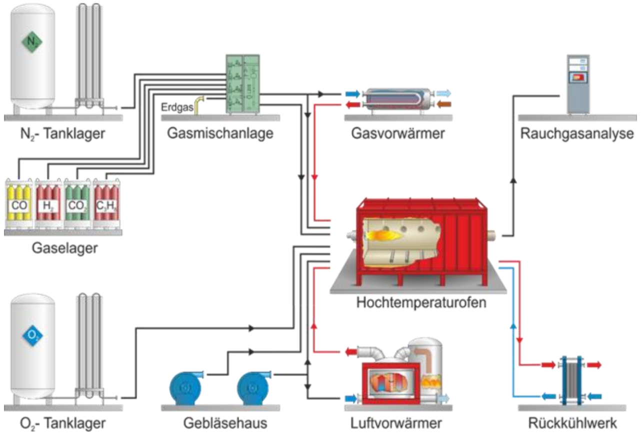
*: vol.-%

**: only $CO_2$ emissions due to combustion are considered



Quelle: GWI, 2020

# Application and semi-industrial testing


**High temperature test rig:**
Firing rates up to 1.2 MW
Air preheating up to 1,250 °C
Furnace temperatures up to 1,600 °C
Hydrogen admixture up to 330 m³/h ( 1MW)

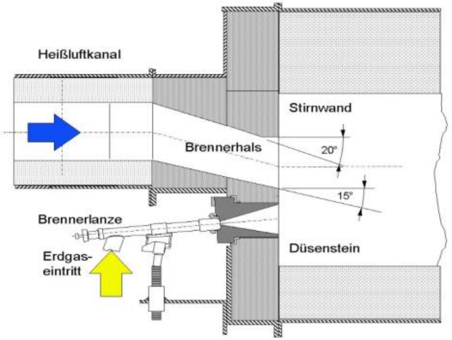

**Mobile test rig:**
Melting of samples
Glass quality analysis

BV GLAS gwi


Quelle: GWI, 2020

# 1st measurement campaign, December 2020

## Impact on the combustion process



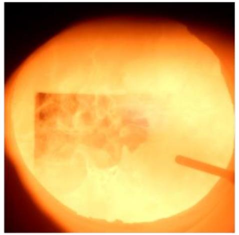
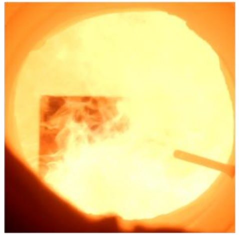
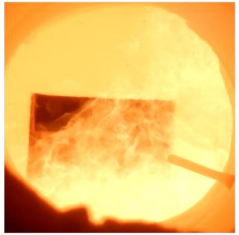
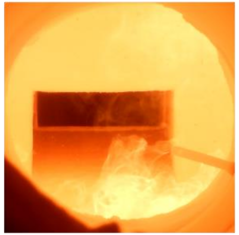
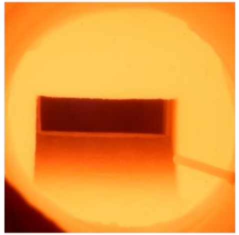
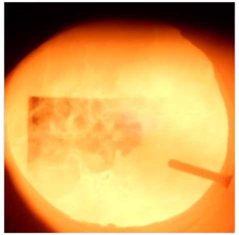
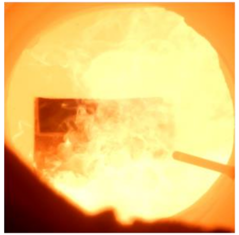
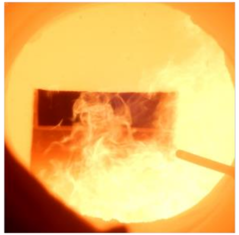
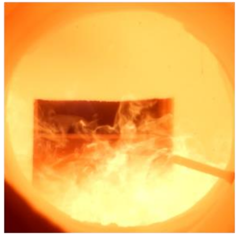
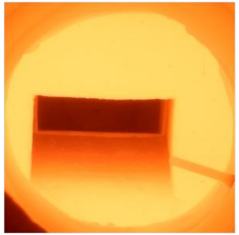

**Measurement campaign:**

- Underport configuration, variable-momentum lance
- 0 - 100 vol.-% $H_2$ admixture (0, 10, 30, 50 and 100 vol.-%)
- 2D field measurements (CO, $CO_2$, $NO_x$, $O_2$. temperature)
- Different control scenarios
- P ≈ 500 kW, λ ≈ 1.1, $T_{air}$ = 1,150 °C

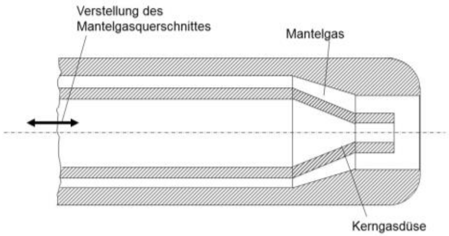

Quelle: GWI, 2020

# Impressions from the GWI high-temperature test rig

$H_2$ - Anteil im Brenngas
(volumetrisch)

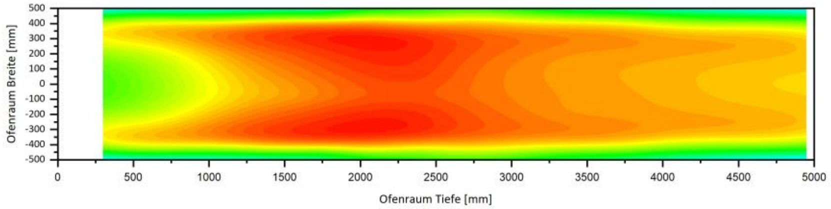
| | Brenngasverteilung | 0 % | 10% | 30 % | 50 % | 100 % |
|---|---|---|---|---|---|---|
| Center flow 40 % of total fuel flow for NG | **nicht optimiert:** Verteilung von Kern- und Mantelgas wurde nicht angepasst. |  |  |  |  |  |
| Center flow **always** 40 % of total fuel flow | **optimiert:** der Kerngasvolumenstrom wurde auf 40 % der Brenngasmenge (gesamt) eingestellt. |  |  |  |  |  |

Variable momentum lance:

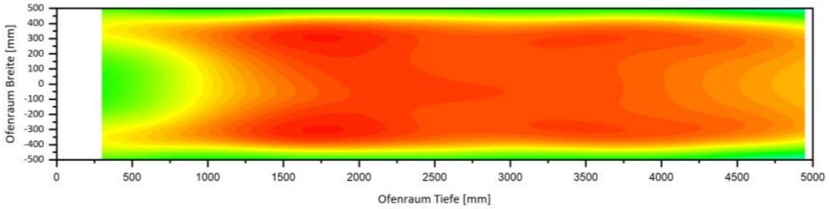


# Test rig experiments: temperature distributions

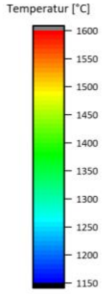
## Impact of $H_2$-admixture on the temperature distribution (horizontal burner plane)

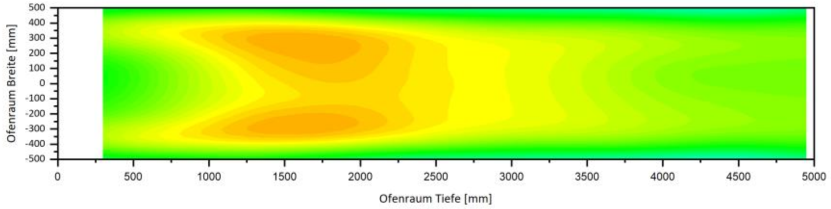



0 vol.-% $H_2$

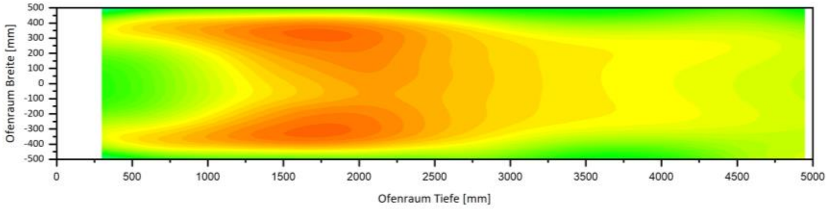



10 vol.-% $H_2$

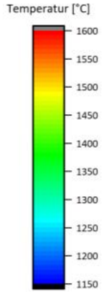



50 vol.-% $H_2$




100 vol.-% $H_2$

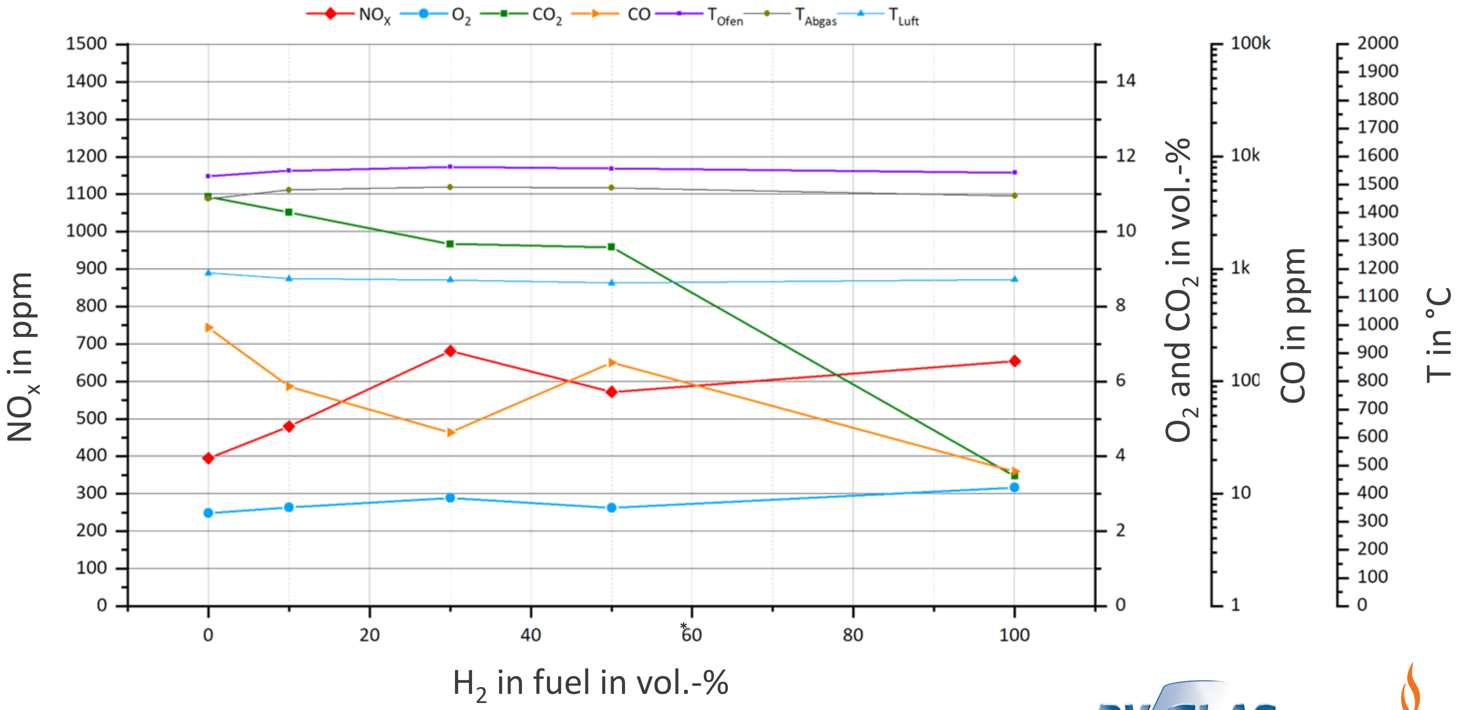



 Quelle: GWI, 2020

# Measurements at the GWI test rig

## Impact of the $H_2$-admixture on flue gas temperature and composition

Firing rate: ≈ 500 kW
Air excess ratio: ≈ 1.1
$T_{air}$: ≈ 1,150 °C



# 2nd measurement campaign, 2nd quarter 2021

## Impact on glass quality


**Mobile test rig:**

Melting of industrial batches (green, amber, flint, float) with different operating parameters and $H_2$ admixture rates.

Investigation of the effects on **glass quality** (HVG)

Charging and discharging batch crucibles during burner operation



Quelle: GWI, 2020

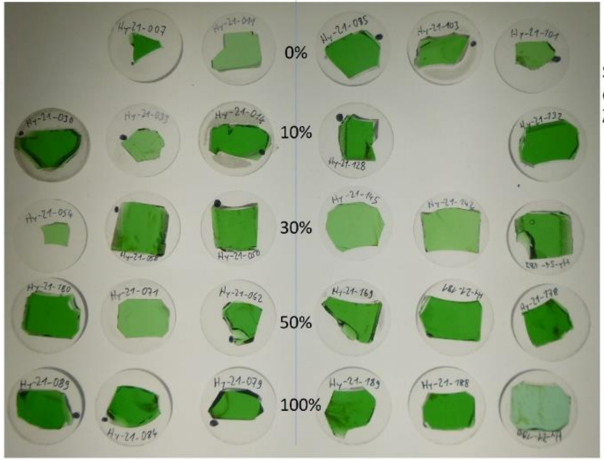
# Glass quality investigations

## green glass

green glass melting temperature ≈ 1450°C

4h | 2 + 2h | 2h | 2h | 2 + 2h | 4h

Hyperstoichiometric combustion λ=1,05



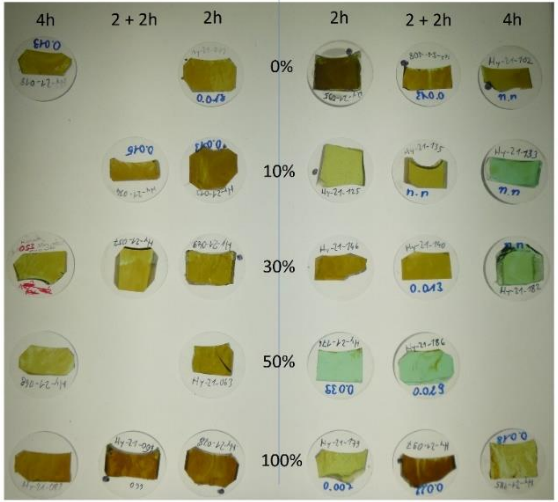

Substoichiometric combustion λ =0,97

Vol.-fraction of hydrogen in burnable gas

## amber glass

Amber glass melting temperature ≈ 1450°C

Hyperstoichiometric combustion λ=1,05

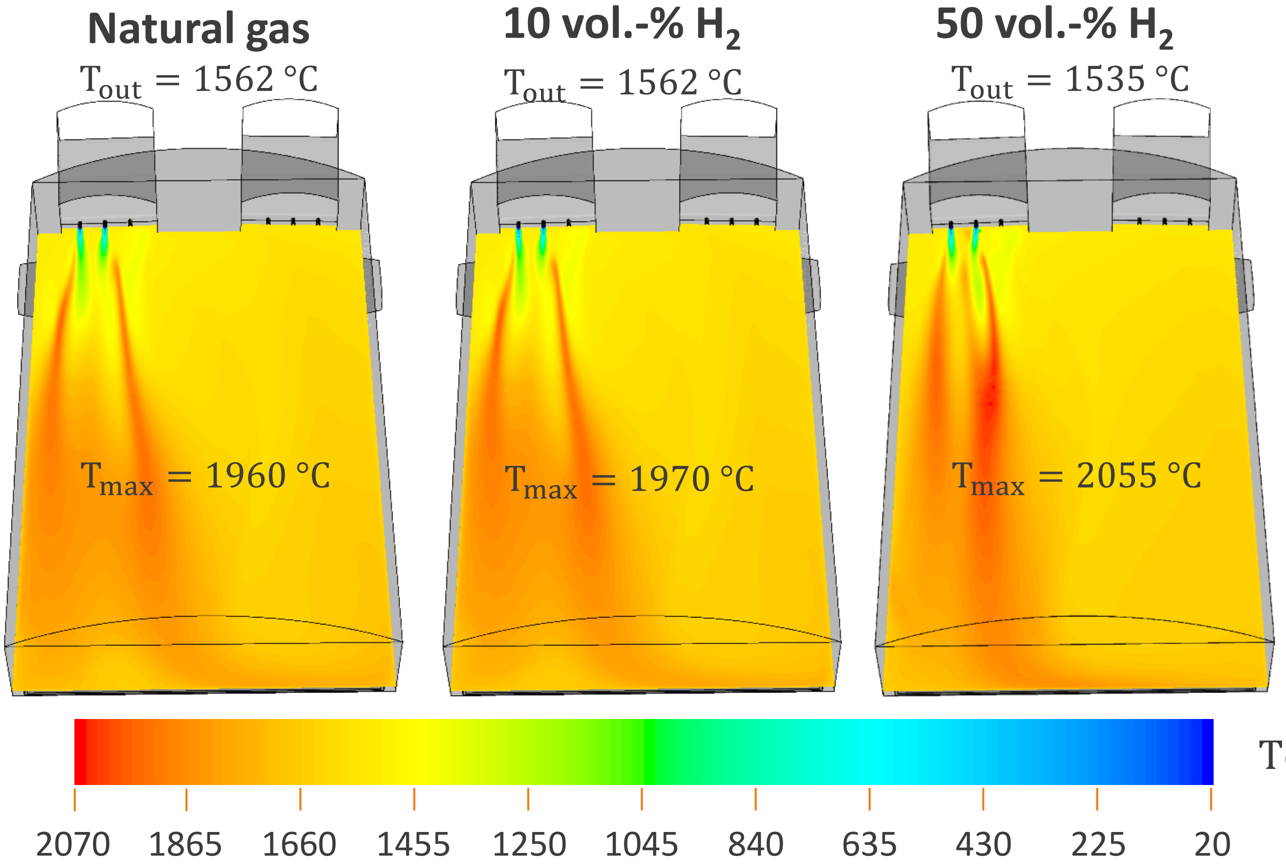



Substoichiometric combustion λ =0,97

Vol.-fraction of hydrogen in burnable gas

In some operational points, **soot formation** was detected both in the samples and at the crucibles with higher levels of hydrogen admixture.
Preferential diffusion effects? Chemical kinetics?

# CFD simulations: Impact of $H_2$ on a regenerative glass melting furnace ($P$, $\lambda$ und $T_{air}$ constant)

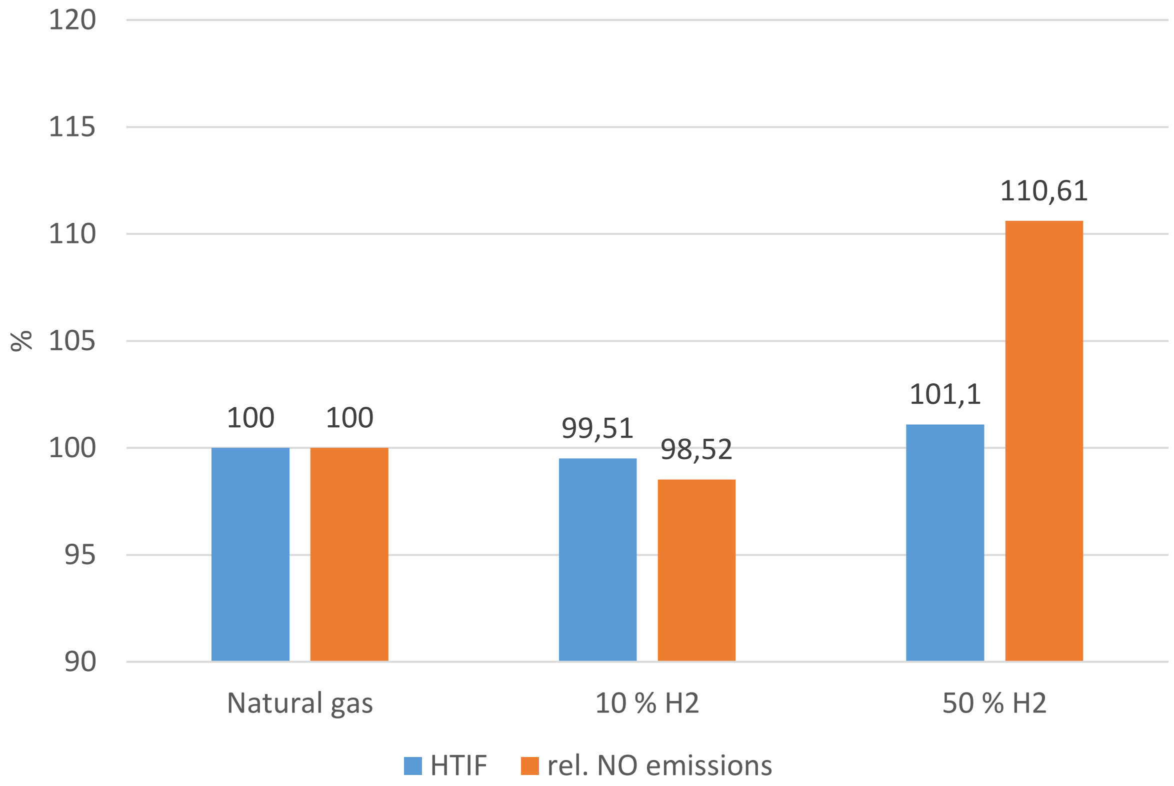



**Operational parameters**

$P$ = 12 MW
$\lambda$ = 1.05
$T_{air}$ = 1.400 °C


Quelle: GWI, 2020

# CFD simulations: Heat transfer and $NO_X$ in a regenerative furnace (P, λ und $T_{air}$ constant)




## Heat Transfer Impact Factor:

$$HTIF[\%] = \frac{\dot{Q}_{Glas}}{\dot{Q}_{Glas.Reference}} \cdot 100$$

## Relative NO emissions:

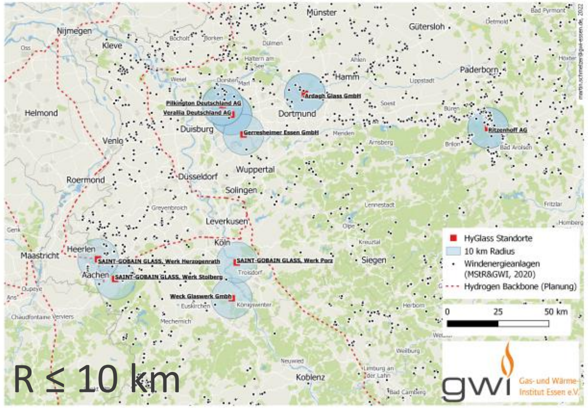
$$\Delta NO[\%] = \frac{X_{NO}}{X_{NO.Reference}} \cdot 100$$

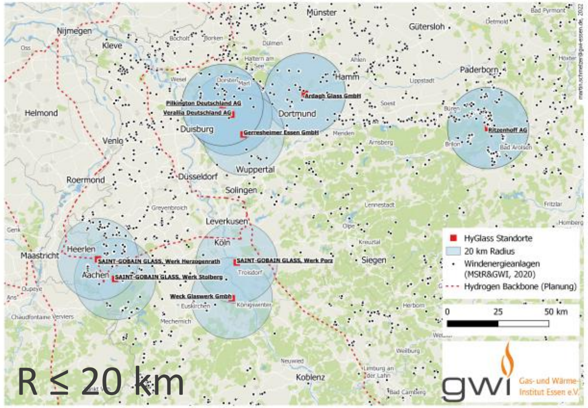


Quelle: GWI, 2020

# GIS analysis of local decarbonization potentials

- **GIS analysis** (GIS: **G**eographic **I**nformation **S**ystem) was used to determine whether wind turbines and PV panels in the vicinity of glass production sites (max. distances 10 and 20 km) can **potentially** generate sufficient „green“ electricity to produce the required $H_2$.
- Even with the **very optimistic assumption** that local wind turbines **exclusively serve the glass manufacturing sites**, **only 1 site** (out of 9) could be supplied with sufficient $H_2$ in a 10 km radius. If the radius is extended to 20 km, **3 sites** could potentially be sufficiently supplied.
For PV, no site even comes close.
- This means that full decarbonization via hydrogen will usually require either a **completely green power grid** with **local electrolysis** or a **dedicated $H_2$ grid.**




BV GLAS gwi

 Quelle: GWI. 2020

# Biogas – an option?

# Biogases vs. natural gas

| Property | Unit | Typical values (biogas from energy crops) | Typical values (recycled biowaste) | Requirements DVGW G260/262 |
|---|---|---|---|---|
| **gross calorific value*** | kWh/m³<br>MJ/m³ | 5.5 - 6.5<br>19.8 - 23.4 | 6.6 - 7.8<br>23.8 - 28.1 | 8.4 - 13.1<br>30.2 - 47.2 |
| **relative density** | - | 0.99 - 1.04 | 0.85 - 0.94 | 0.55 - 0.75 |
| **Wobbe Index*** | kWh/m³<br>MJ/m³<br>kWh/m³<br>MJ/m³ | 5.4 - 6.1<br>19.4 - 22.0 | 6.8 - 8.4<br>24.5 - 30.2 | **H-Gas:** 10.8 - 15.7<br>49.0 - 56.5<br>**L-Gas:** 10.5 - 13.0<br>39.6 - 46.8 |
| **dew point water** | °C | saturated at $T_{fermenter}$, $p_{fermenter}$ | saturated at $T_{fermenter}$, $p_{fermenter}$ | maximum at $T_{ground}$, $p_{pipeline}$ |
| **$CH_4$** | Vol.-% | 50 - 55 | 60 - 70 | - |
| **$CO_2$** | Vol.-% | 43 - 50 | 30 - 40 | 6 |
| **$O_2$ (dry grid)** | Vol.-% | 0 - 2 | 0 - 1 | 3 |
| **$O_2$ (wet grid)** | Vol.-% | - | - | 0.5 |
| **carbon acids** | mg/m³ | <220 | traces | - |
| **alcohols** | mg/m³ | traces | <22 | - |
| **BTEX** | mg/m³ | traces | <10 | - |
| **$C_xH_y$, rest** | mg/m³ | <2 | <1,250 | condensation @ $T_{ground}$ |
| **$H_2S$** | mg/m³ | <600 (rough de-sulphurization) | <30,000 | 5 |
| **mercaptanes** | mg/m³ | <10 | <5 | 6 |
| **COS** | mg/m³ | <8 | <0.6 | - |
| **$NH_3$** | mg/m³ | <10 | <10,000 | - |
| **$H_2$** | Vol.-% | <0.3 | <1 | 5 |
| **$Si_{total}$** | mg/m³ | <15 | 5 | - |

*** @German reference temperatures 25 °C / 0 °C**

German gas quality specifications

- Flow field
- Mixing
- Combustion
- Heat transfer
- …

- Pollutants
- Interaction with glass melt and refractory


Quelle: GWI. 2020

# BioGasGlas I+II

- GWI and its partners (HVG, FGF und Verallia Saint-Gobain Oberland) investigated whether the utilization of biogas for glass melting is feasible both technologically and economically.

- **Part I** addressed fundamental questions about combustion, pollutant emissions, glass quality and the impact of trace components on refractory materials.

- In **Part II**, biogas co-firing was implemented in a real-life medium-sized regenerative glass melting furnace

gwi Gas- und Wärme-Institut Essen e.V. (Part I+II)

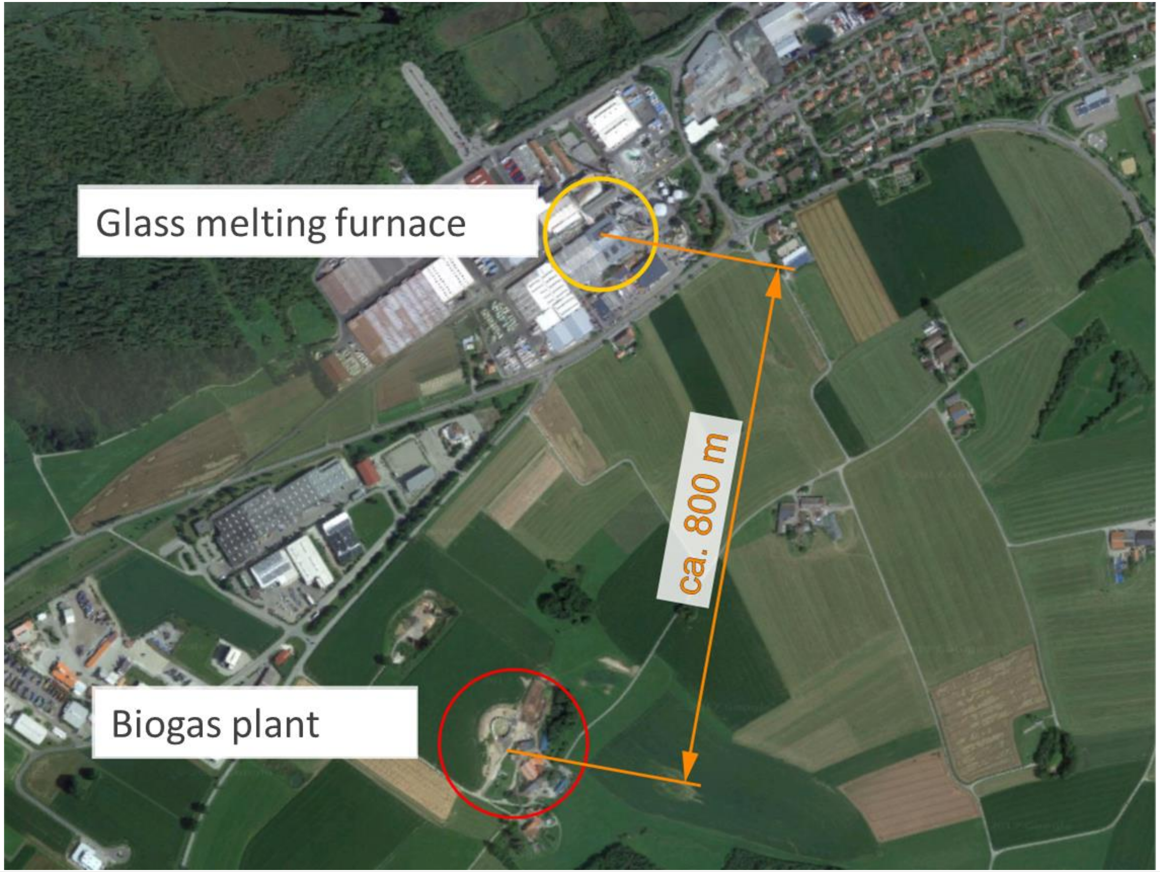
(Part I+II)

FGF Forschungs-Gemeinschaft Feuerfest e.V. (Part I)

verallia (Part II)

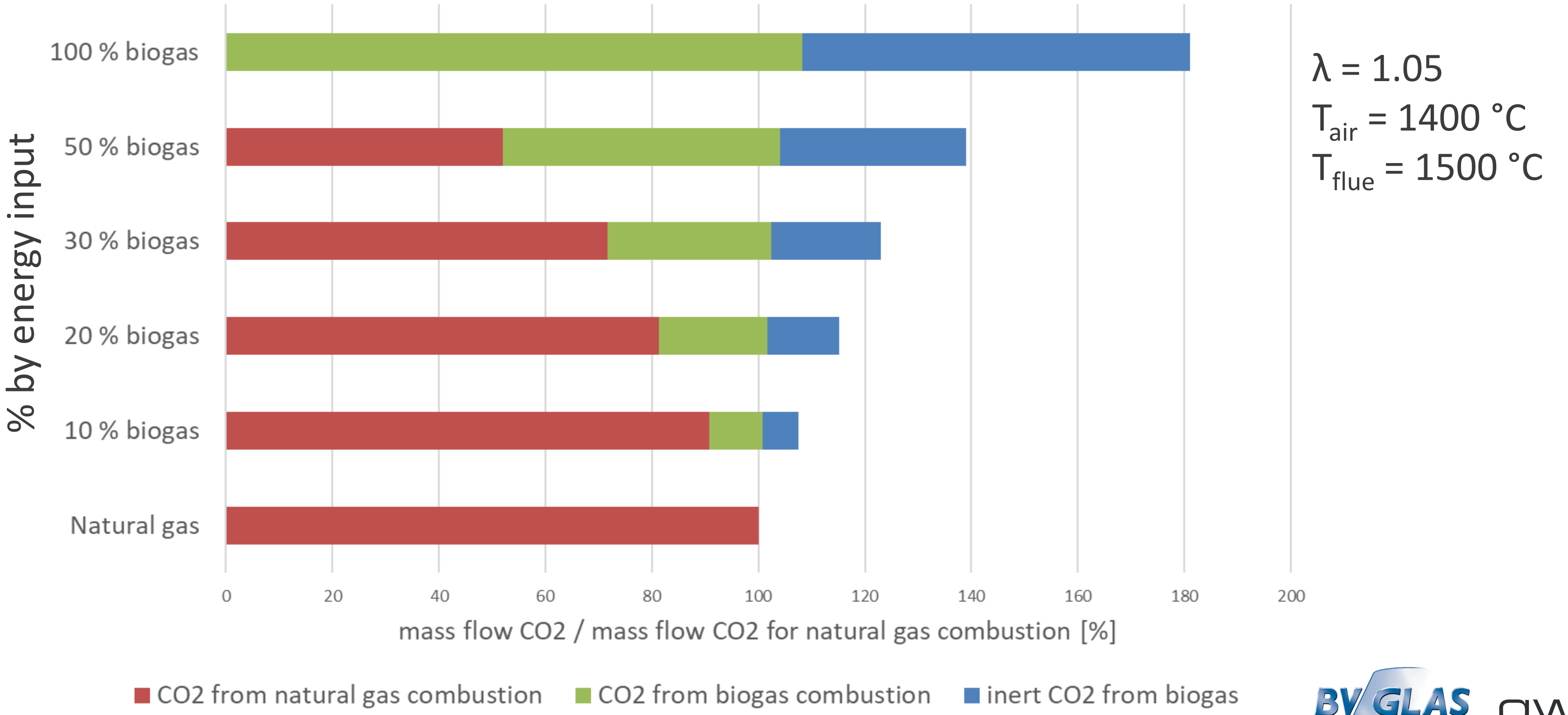
 Quelle: GWI. 2020

# Aerial view




 Quelle: GWI. 2020

# $CO_2$ balance of biogas co-firing (regenerative furnace, constant boundary conditions except for P and fuel composition)



# Conclusion

- Decarbonizing (high-temperature) process heat is a major challenge for many energy-intensive industries. Partially or completely substituting natural gas with hydrogen is one option to reduce GHG emissions.
  At the same time, the gas industry is discussing both hydrogen admixture into existing natural gas grids and creating dedicated $H_2$ infrastructures.
  **One way or the other, the glass industry has to think about hydrogen.**

- Investigations so far indicate that natural gas / hydrogen blends and $H_2$ can be viable options to produce process heat. There is, however, still a lot of R & D to be done. There are concerns about product quality and $NO_X$, but **appropriate measurement** and **control technologies** seem to be able to mitigate many issues.

- The **origin of hydrogen** is crucial in the context of decarbonization. Procuring huge amounts of „green“ or at least „blue“ hydrogen is likely to be **the real challenge**.


Quelle: GWI. 2020

# Conclusions Biogas

- Roughly pre-treated biogas is also an option to decarbonize process heat in the glass industry. Experiments on test rigs show no negative impact on glass quality or refractory.

- This was confirmed by investigations in an industrial site where up to 30 % of the firing rate was provided by biogas over a testing period of 6 months.

- Providing sufficient biogas is again the bottleneck, and there are regulatory hurdles: Authorities (in Germany) stated that they do not know how to classify a combined biogas / natural gas firing system and therefore had to consider this furnace as a **municipal incineration plant**… which was unacceptable to the furnace operator (emissions, plant monitoring, …).


Quelle: GWI. 2020

# Thank you for your attention

Dr.-Ing. Jörg Leicher
Gas- und Wärme-Institut Essen e. V.
Hafenstrasse 101
45356 Essen, Germany
Tel.: +49 (0) 201 36 18 278
Mail: joerg.leicher@gwi-essen.de

HVG-DGG
Service und Forschung für die Glasherstellung

DLR Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

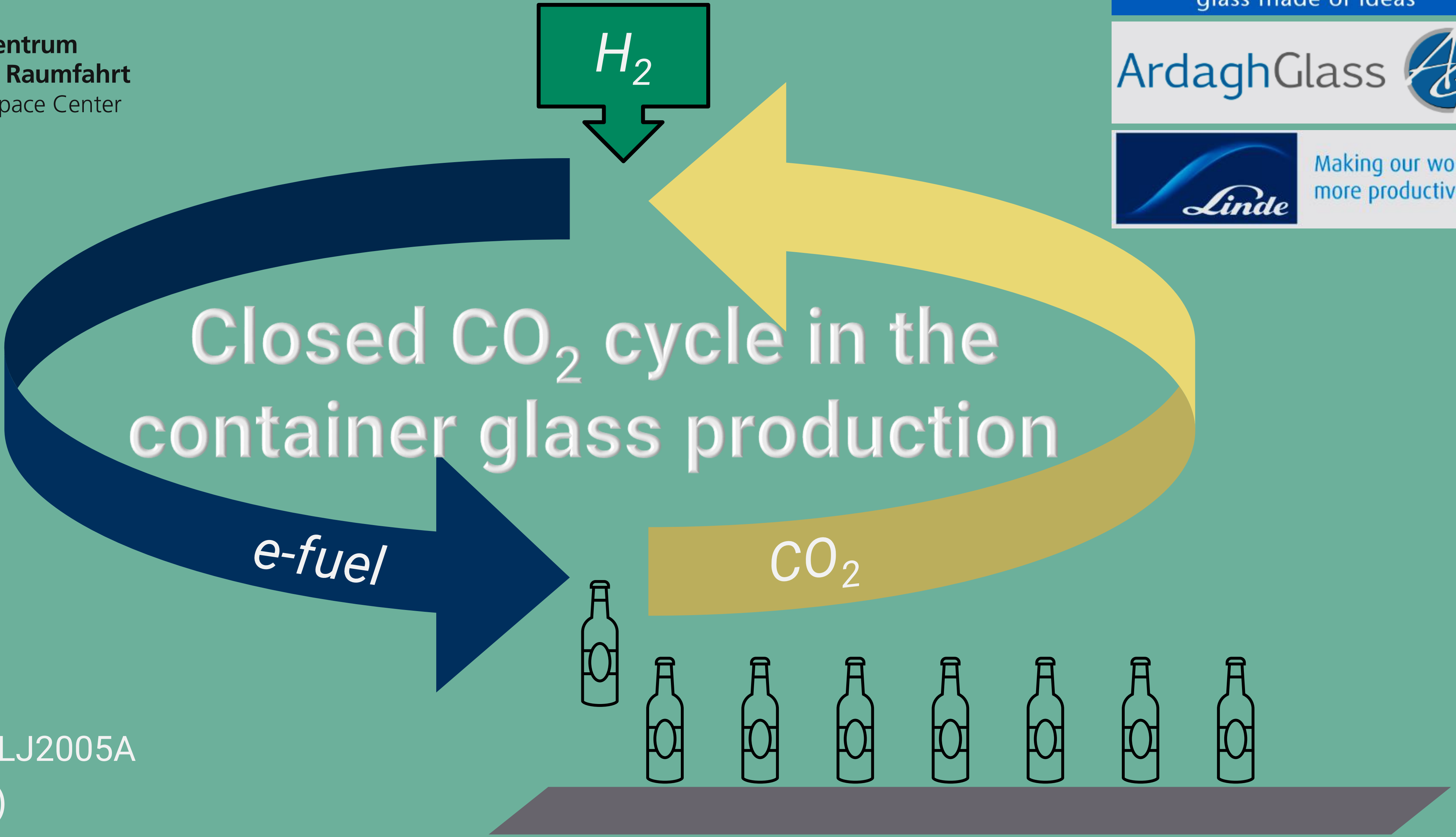
Our partners:

SCHOTT glass made of ideas

ArdaghGlass

Linde Making our world more productive

# Closed $CO_2$ cycle in the container glass production




## Glas-CO2

KlimPro BMBF 01LJ2005A

F. Drünert (HVG)

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

# OUR OBJECTIVE:
# $CO_2$-Neutral Glass Production

HVG-DGG
Service und Forschung für die Glasherstellung

Feasibility study

Technology chains

Cost estimation

Focus: Needs of glass industry

Deutsches Zentrum
für Luft- und Raumfahrt
German Aerospace Center

HVG-DGG
Service und Forschung für die Glasherstellung

# OUR OBJECTIVE:
# $CO_2$-Neutral Glass Production

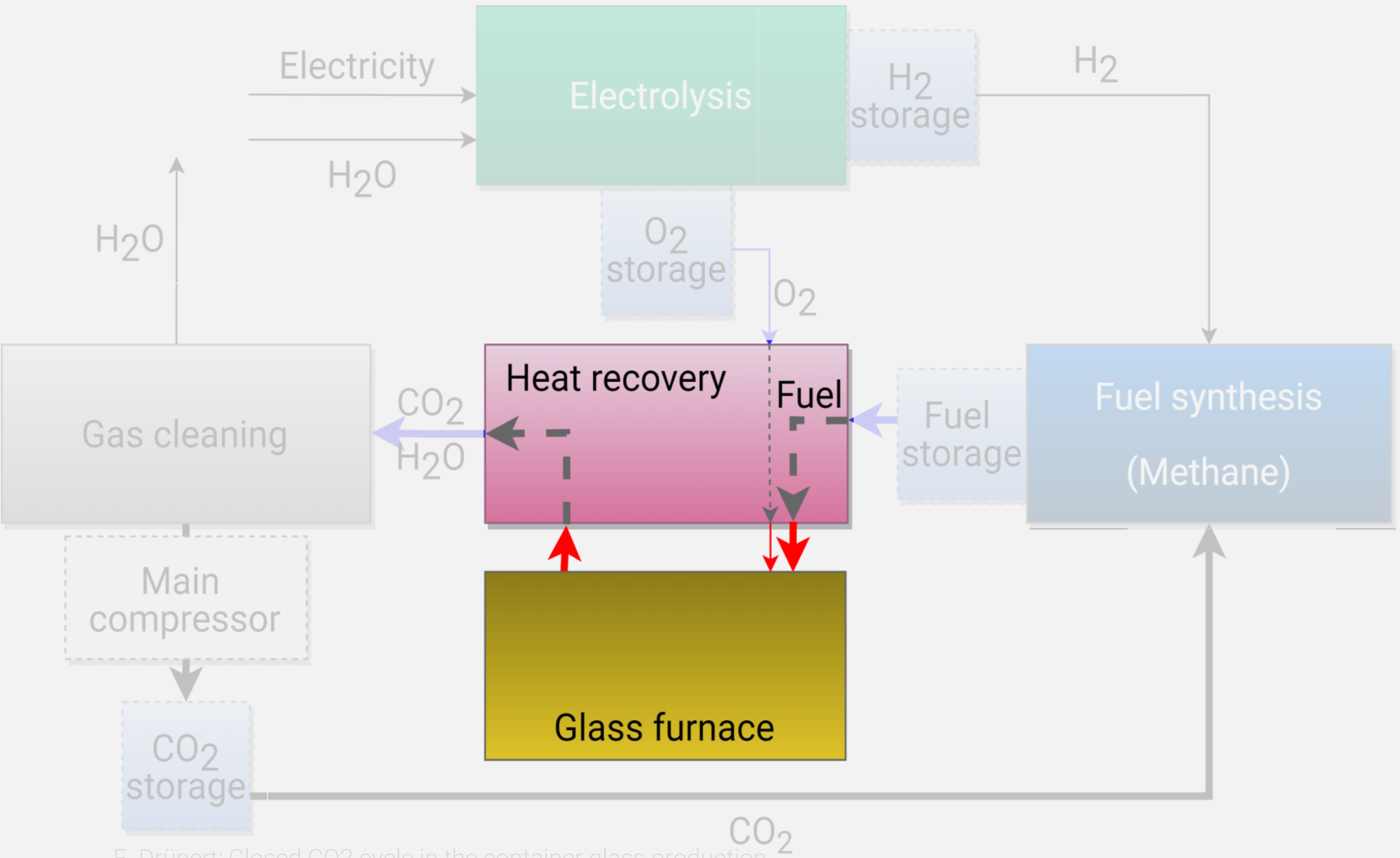
- Zero $CO_2$ emission
- Fuel net production
- Electricity only
- Modular build

- Low efficiency
- High investment
- High complexity

# BASE SETUP
## First Technology Chain



- Oxyfuel Process
- Heat recovery
- Methane synthesis
  - TREMP™-process
- PEM-Electrolysis
- Gas cleaning:
  - Wet scrubber
  - Hydrogenation
  - Guard beds



# GENERAL APPROACH



Python simulation

AspenPlus®

TEPET

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German Aerospace Center

# ECONOMIC ASSESSMENT

HVG-DGG
Service und Forschung für die Glasherstellung

| Evaluation input | |
|---|---|
| Plant production | 300 [$t_{glass}$/day] |
| Synthetic fuel | Methane |
| Base year | 2020 |
| Interest rate | 7% |
| Glass furnace operation | 24/7/365 |
| Full load hours of methanation plant | 8000 [h/a] |
| Plant lifetime | 30 [a] |
| Electricity price(1) | 41.93 [€/MWh] |

✓ Backup supply through gas grid

✓ Costs of glass furnace are excluded



(1) Based on the spot market: Smard, Marktdaten, in: B.-S. Strommarktdaten (Ed.) Großhandelspreise, https://www.smard.de/, 2020.

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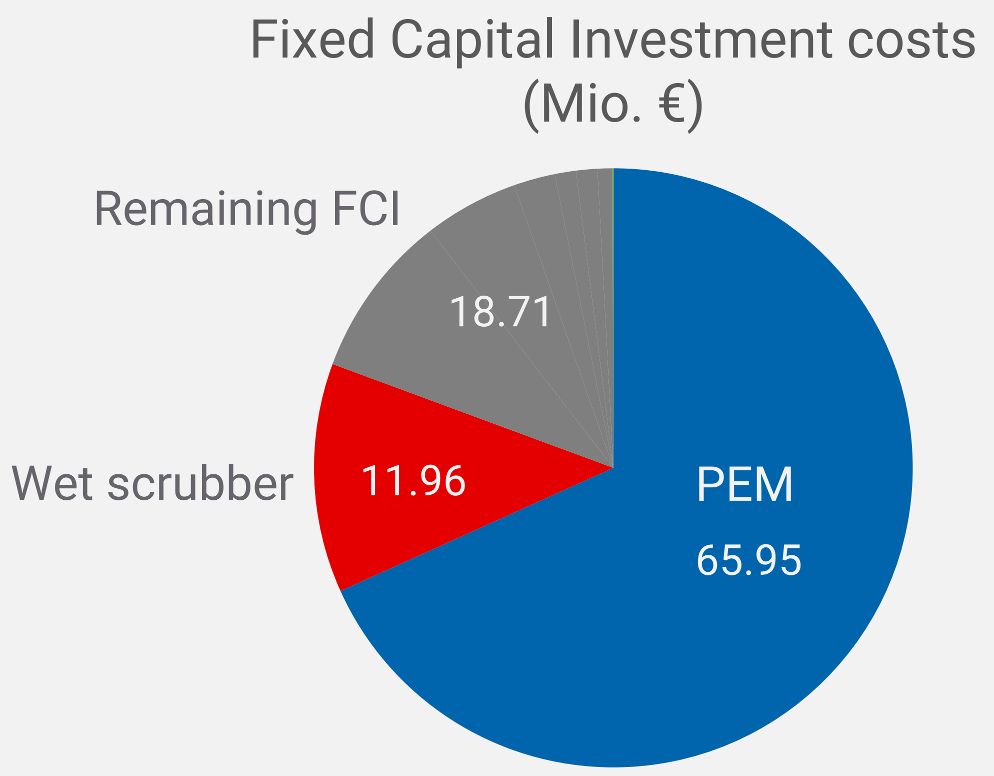
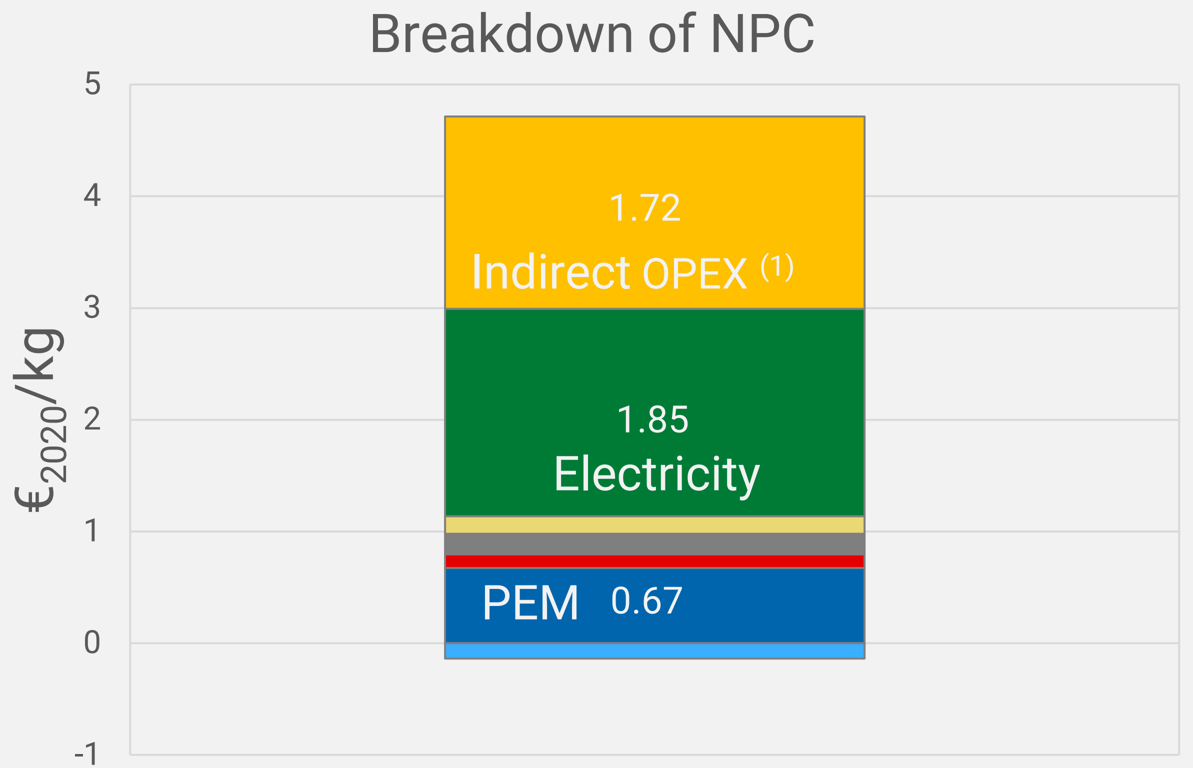
# ECONOMIC ASSESSMENT

## Investment- and Net Production Costs

HVG-DGG
Service und Forschung für die Glasherstellung




FCI: 96.7 $[Mio\ €_{2020}]$




NPC: 4.57 $[€_{2020}/kg_{SNG}] \leftrightarrow$ 0.40 $[€_{2020}/kg_{Glass}]$

Price NG [1] (2020): 0.17 $[€/kg_{NG}] \rightarrow$ 0.29 $[€/kg_{NG}]$



(1) M. Peters, K. Timmerhaus and R. West, Plant design and economics for chemical engineers, New York, United States: McGraw-Hill, 2004, ISBN 007-124044-6.
(2) Erdgaspreis - Natural Gas." Retrieved 29.06.2022, https://www.finanzen.net/rohstoffe/erdgas-preis-natural-gas

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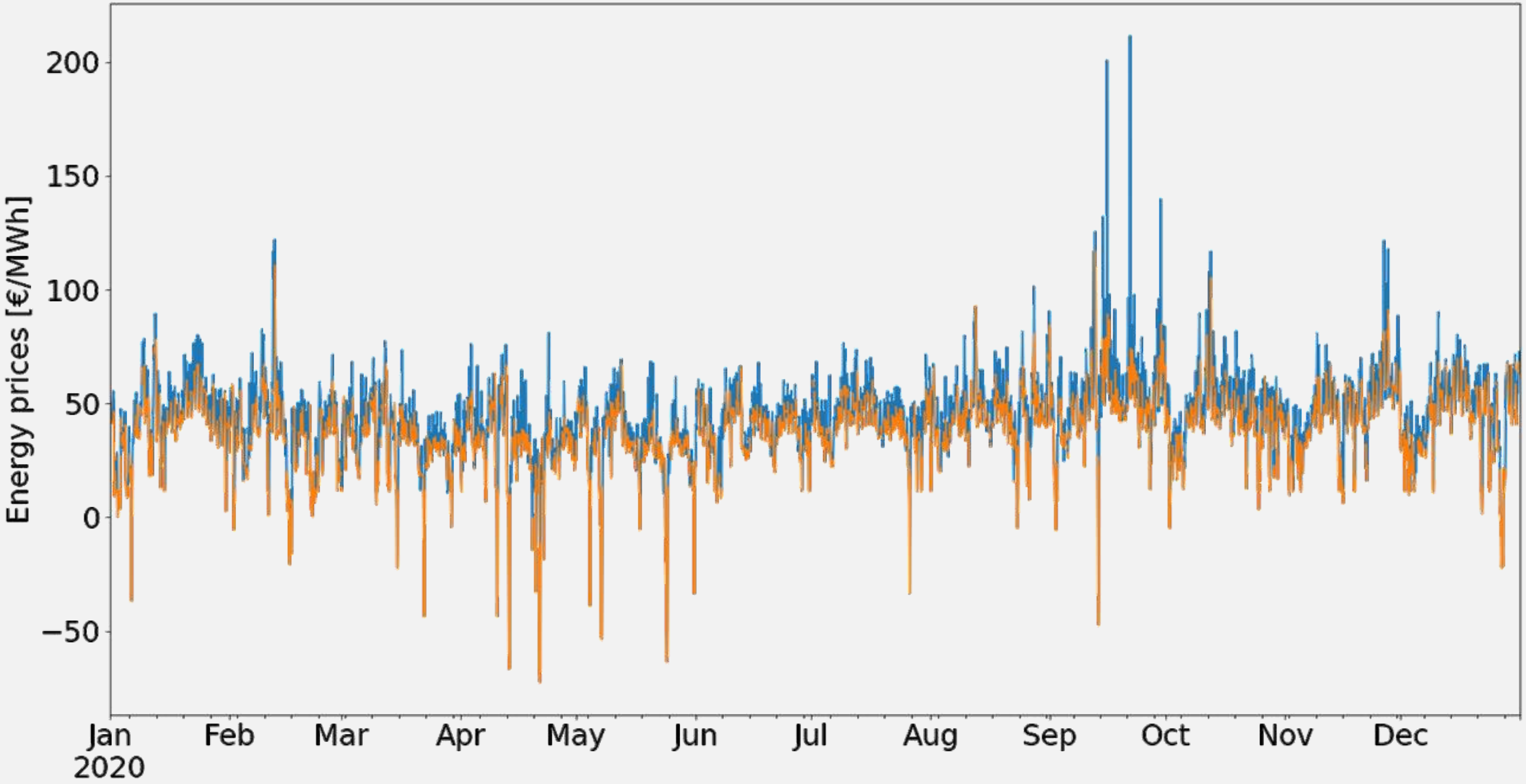
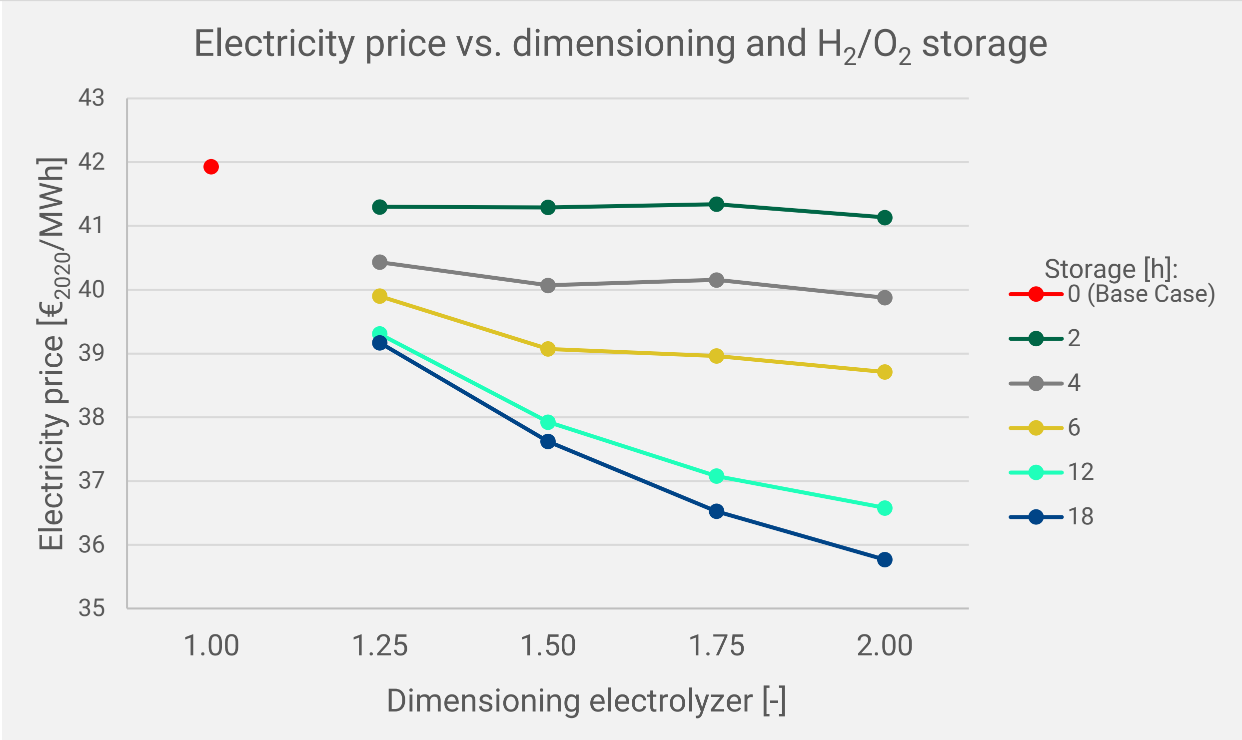
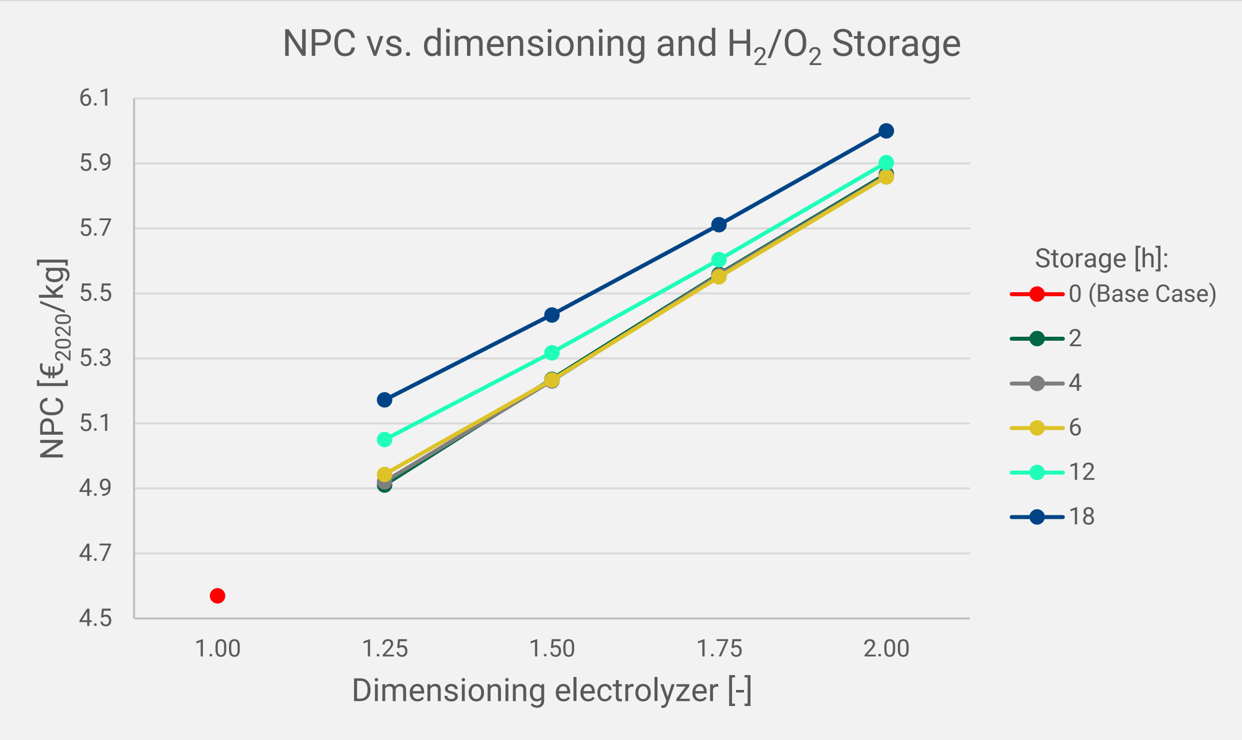
# WHAT IF…

## …we want to exploit low prices?



# ECONOMIC ASSESSMENT
## Sensitivity Analysis




- Storage increase leads to a higher NPC

# SUMMARY



- NPC: 4.57 $€_{2020}/kg_{SNG} \leftrightarrow$ 0.34 $€_{2020}/kWh_{SNG}$
  - Electricity: 40%
  - PEM 15%

- Storage is not economically viable 2020

  … but what if there is more fluctuations (like 2021 / 2022)?

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# OUTLOOK
## Assessment with further technologies

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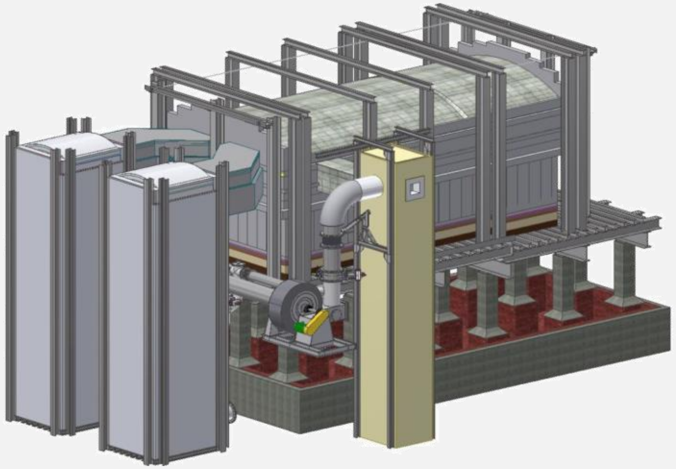
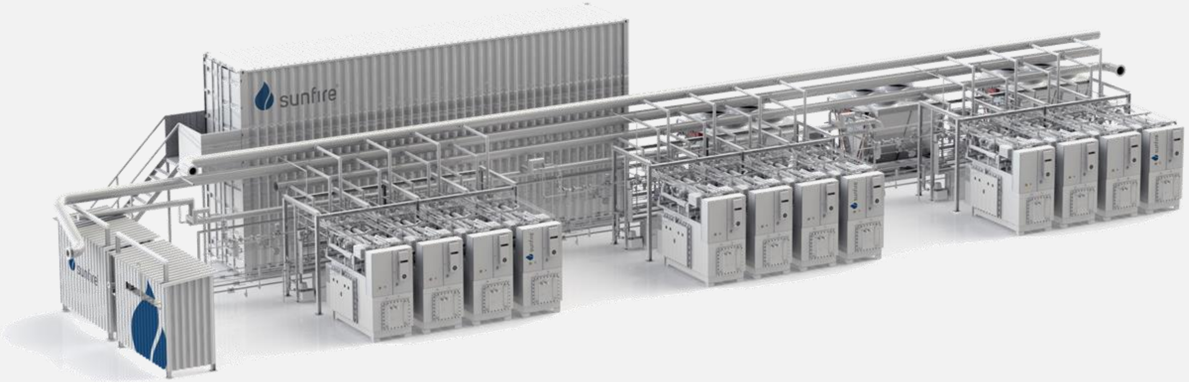
Service und Forschung für die Glasherstellung

Fluidized bed gasification for methanol synthesis; Advanced Methanol Amsterdam. Foto: Wikimedia Commons User Bysalt, CC-BY-SA 4.0



Linde's Model of the OPTIMELT Thermochemical Regenerator System implemented at Libbey®, Leerdam. Image: v. Valburg et al. (2017), 78th Conference on Glass Problems, Columbus, USA




Schema of a solid oxide electrolysis cell by Sunfire®,.CC-BY-ND 2.0

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HVG-DGG
Service und Forschung für die Glasherstellung

SCHOTT glass made of ideas

ArdaghGlass

Linde – Making our world more productive


# Thank you for your attention!

druenert@hvg-dgg.de

Our Co-authors:
Petra Boehm (HVG), Dominic Walter (HVG), Bernhard Fleischmann (HVG)
Simon Maier (DLR), Ralph-Uwe Dietrich (DLR)

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# ELECTRICITY & HEAT

## GENERATED FROM WOOD

**Spanner Re² GmbH**

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# SPANNER-GROUP

EMPLOYEES: > 350

**OTTO SPANNER GMBH**

Bayerbach
> 200 employees

**SPANNER RE$^2$ GMBH**
Neufahrn in NB
70 employees

RENEWABLE ENERGIES
(2004)

**SPANNER SK**
Slovakia
40 employees

AUTOMOTIVE

**URSATRONICS GMBH**
Berlin
40 employees

ELECTRONICS

# 40,000,000
# HOURS EXPERIENCE

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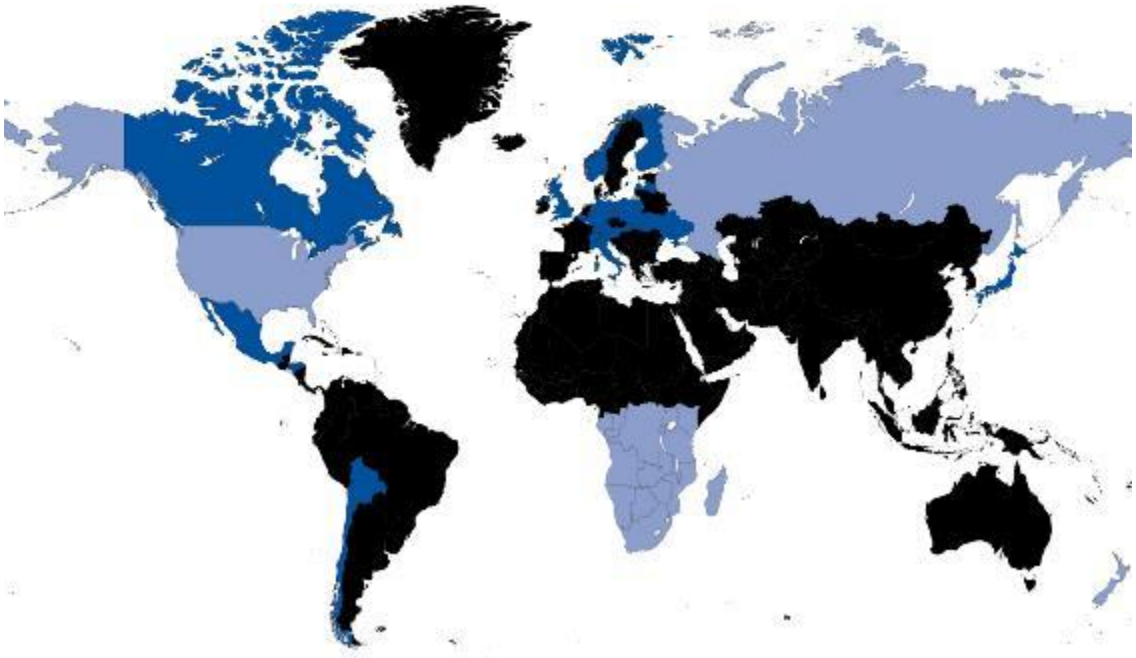
Biomass power plants in operation………………………… **> 900**
Installed electrical power…………………………………………… **> 40 $MW_{el}$**
Installed thermal power……………………………………………. **> 88 $MW_{th}$**
Operating hours per year………………………………………….. **> 7,500 h**
Active markets ………………………………………………………… **23 countries**



Countries with installed Re² Biomass power plants

Projects in the planning stage

# BIOMASS POWER PLANT

## PLANT SCHEMATIC

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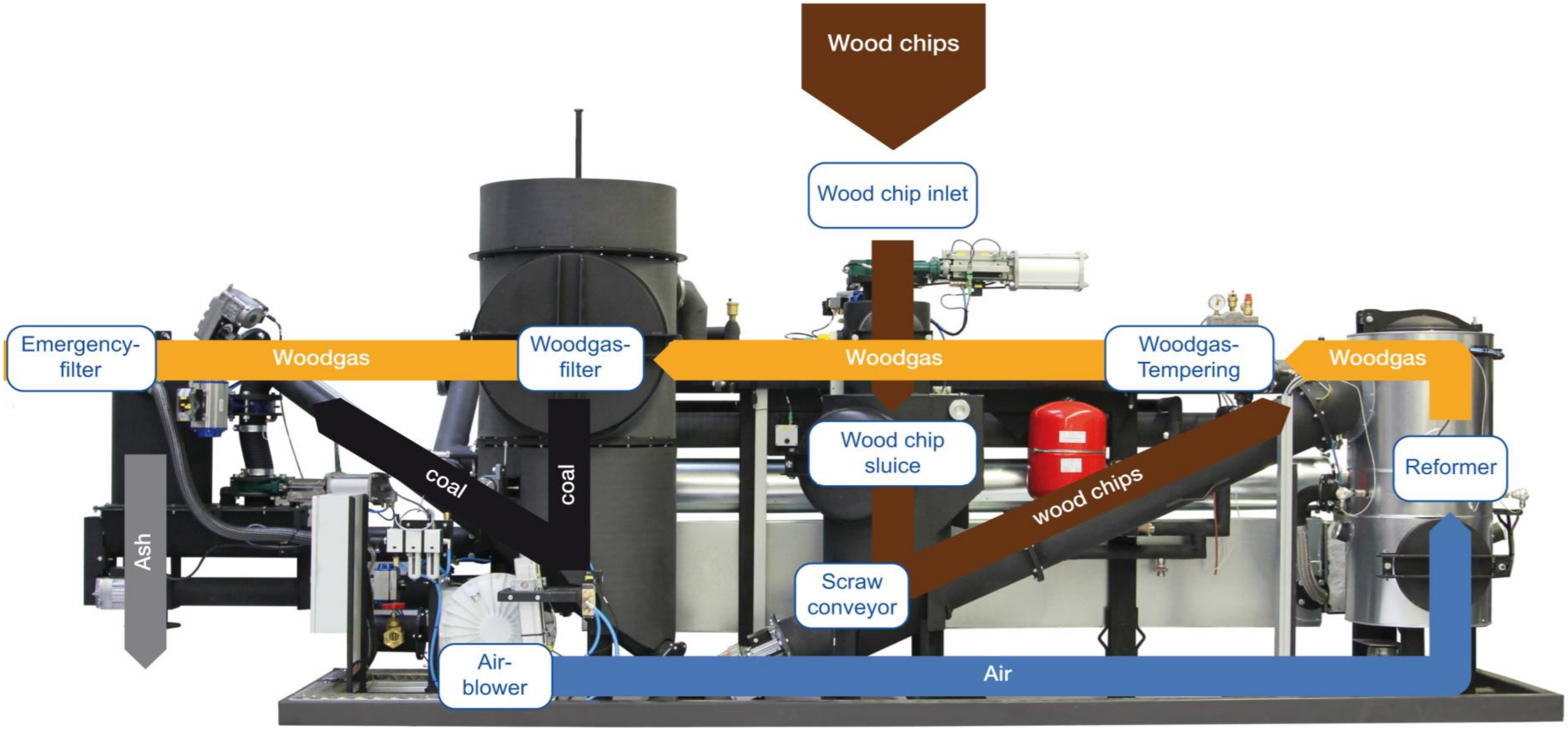

# BIOMASS POWER PLANT: IMPORTANT COMPONENTS

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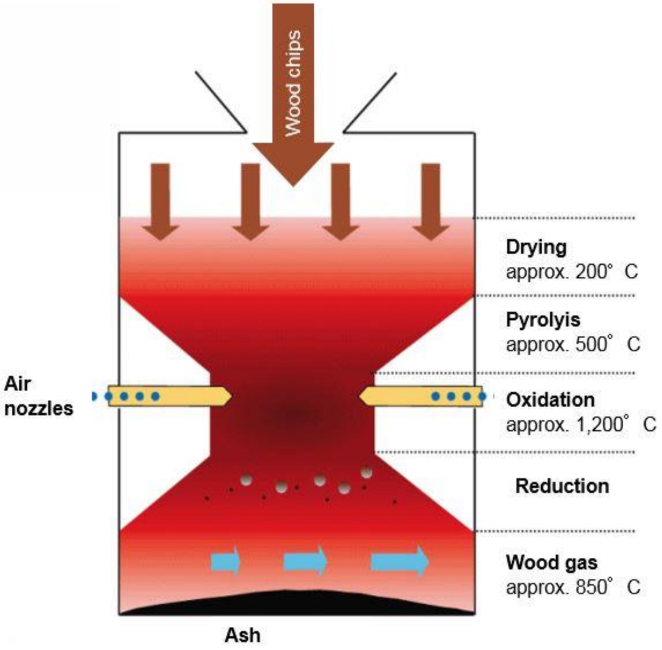
## 1. Feed of fuel at biomass power plant

The conveying screw from Spanner Re² automatically transports the fuel (biomass) from the fuel bunker to the biomass power plant. An integrated metal interceptor in the fuel sewer port separates foreign material. A second conveyor screw transports the biomass to the reformer of the wood gasifier unit.

## 2. Reformer in gasifier for clean wood gas

The reformer is the heart of the biomass power plant. It produces almost tar-less wood gas from biomass in a controlled process, which works on the downdraft principle: the wood chips and the wood gas moves in the same direction. The innovative structure of the reformer offers high fuel flexibility. Using a compact fire bed with temperature monitoring, we guarantuee a regulated wood gas production that ensures the efficiency of our biomass power plant. With our patented and proven biomass gasification technology we produce an extremely clean wood gas, which we can prove.



# FUEL
# BIOMASS POWER PLANT

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- Natural wood chips, according to DIN ISO 17225-1
  (Size: P31S, fines content: F10, water content: M10, ash content: A1.0)
- Water content  < 13 %
- Maximum fines content (< 4 mm Körnung) 30 %
- Avoidance of impurities such as metals, stones or sand

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# FROM WASTE MATERIAL TO VALUABLE RECYCLED RESOURCE

## PALETTES, CRATES

Shredded, sieved and cleanend
with metal seperators

# ALTERNATIVE FUELS

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- Successful trials for admixing styrofoam, plastics and cleaning gasoline
- Use of up to 50 % energetically in combination with wood chips
- Possibility for industrial companies to profitably utilize their residual material
- First pilot projects being implemented

# SPANNER RE² GMBH - ECOLOOP

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# FUTURE FUELS

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# SPANNER RE2 SYNGAS

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## Properties

- Syngas with air produced – Burner T = 1400 Celsius
- Syngas pruduced with O2 and Watersteam – Bruner T = 1800 – 2000 Celsius
- A set up with 7,5 MW can produce anything between 0 % - up to 100 % in seconds
- Nox have to be watched

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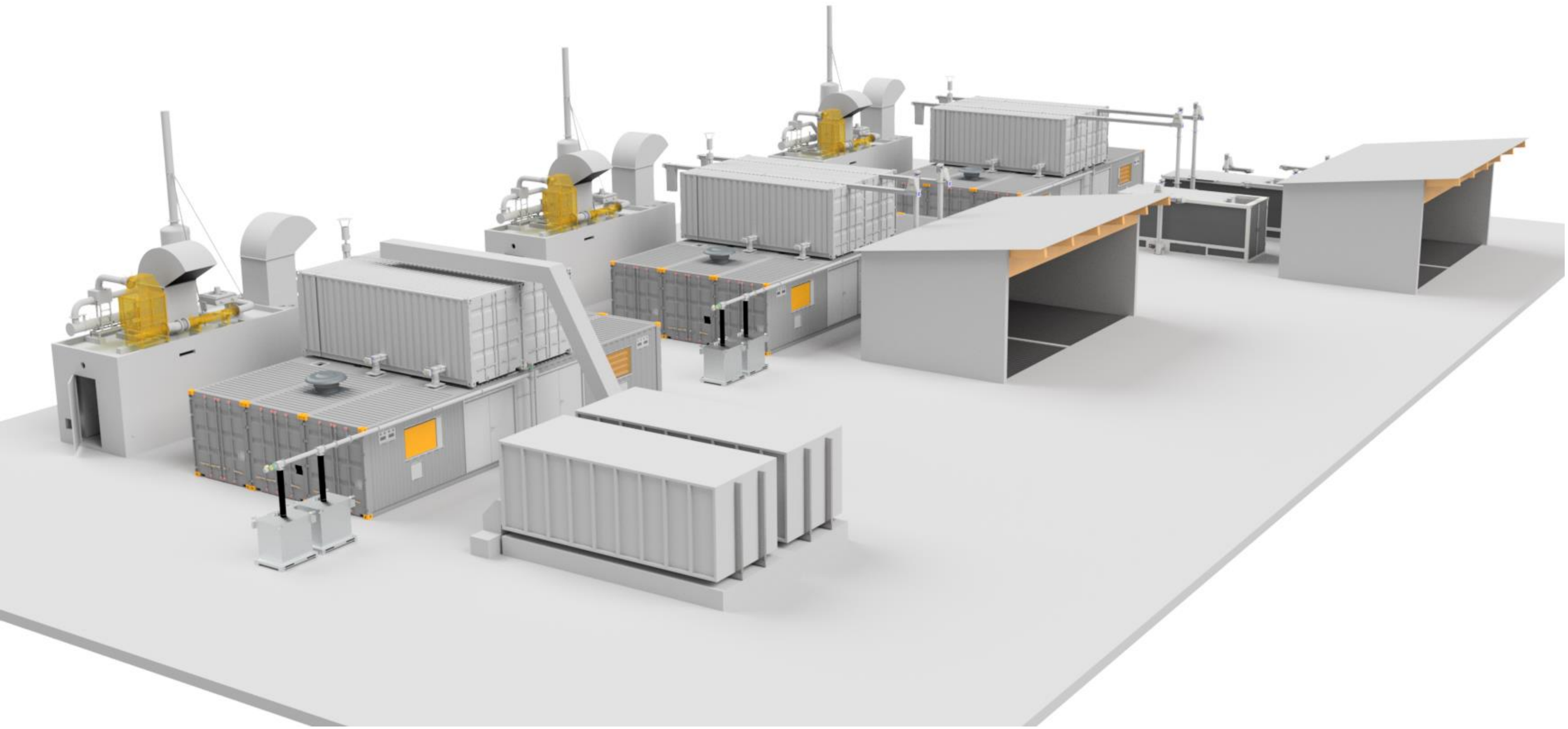

# PLANNING EXAMPLE HV600

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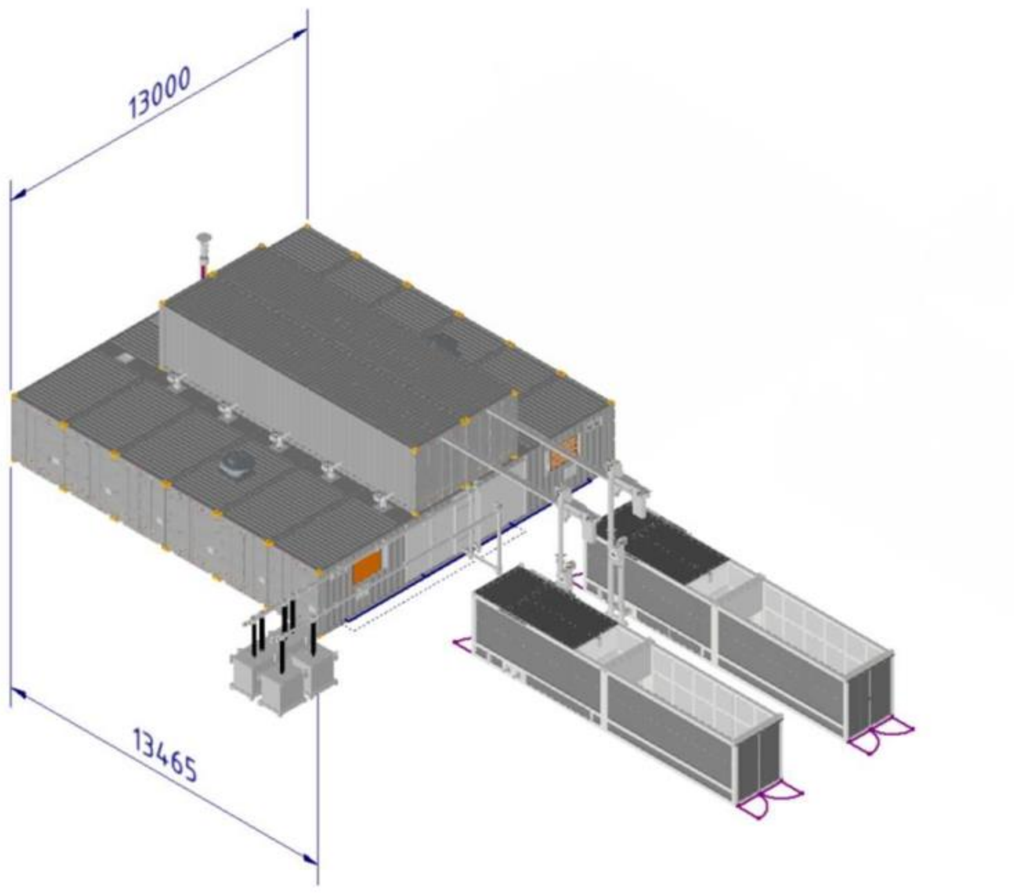

# PLANNING EXAMPLE WOOD GAS BLOCK

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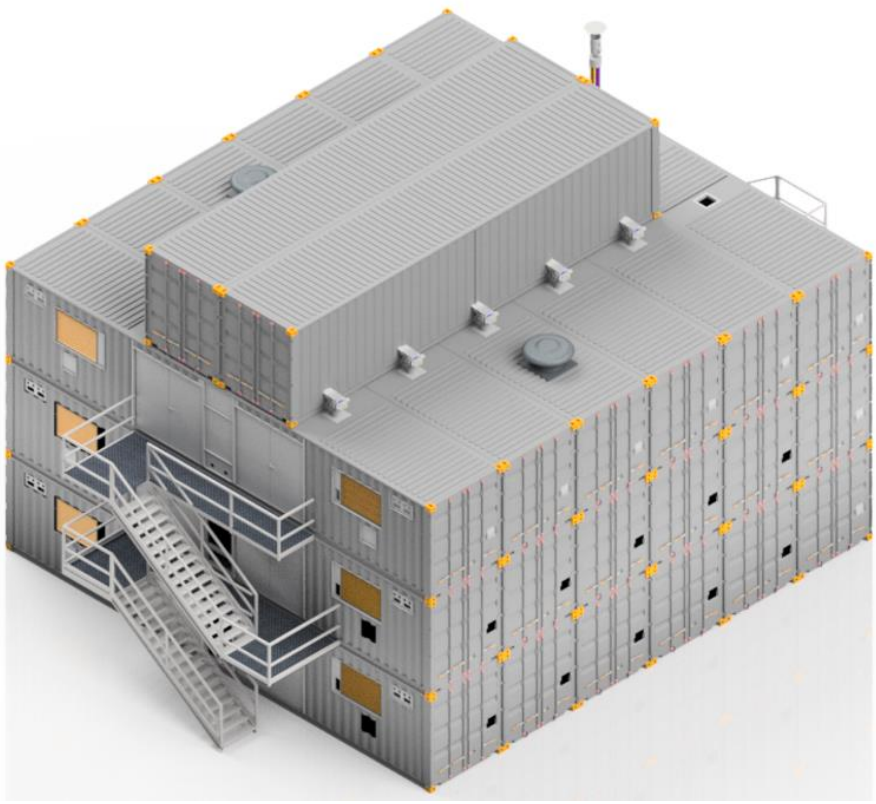

30 Wood gasifier

# PRACTICE EXAMPLE:
# 2 MW$_{EL}$-PROJECT IN JAPAN

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# 2 MWEL-PROJECT IN JAPAN

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# 2 MW$_{EL}$-PROJECT IN JAPAN

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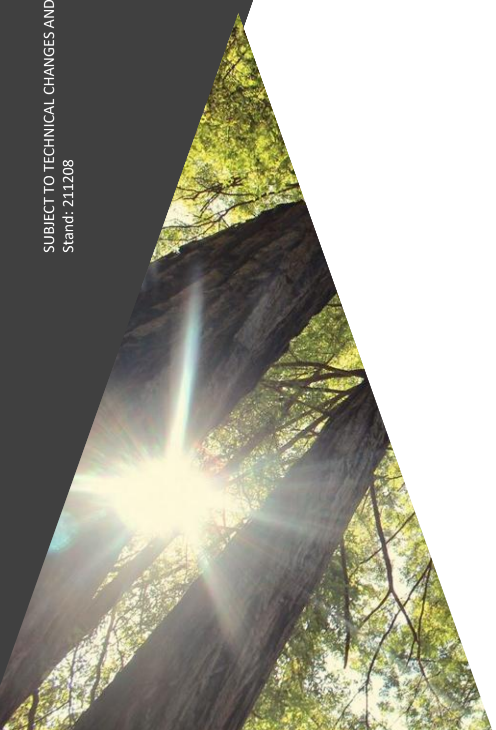



Spanner Re$^{2}$ GmbH
Niederfeldstraße 38
D-84088 Neufahrn i. NB

Phone + 49 (0) 8773 707 98 - 0
Fax + 49 (0) 8773 707 98 - 299
info@holz-kraft.de
www.holz-kraft.com

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