KHD Technologies For The Decarbonization Of The Cement Industry

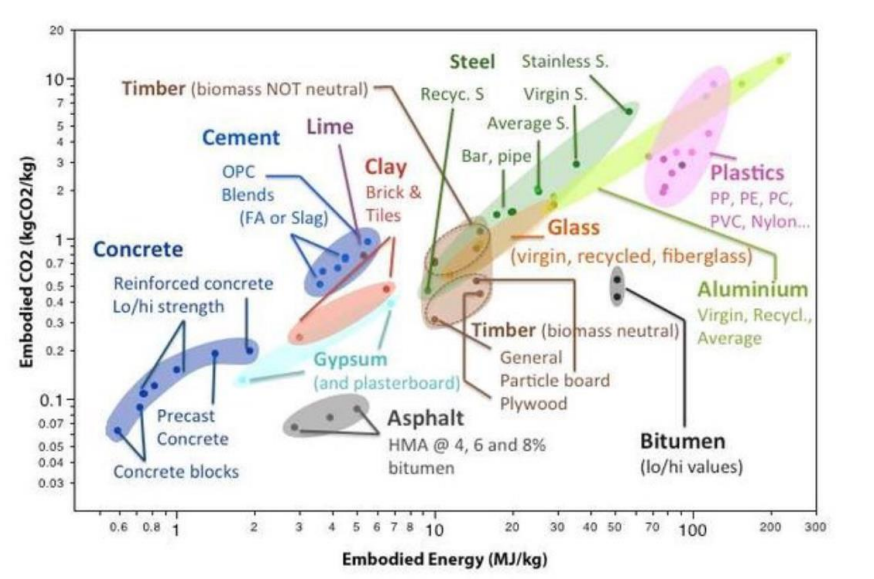
2024-05-13 WCA Annual Conference 2024 | Matthias Mersmann, KHD

WCA Conference 2024

KHD | HUMBOLDT WEDAG

innovation by tradition

Cement And Concrete Are Eco-Friendly And Will Remain Indispensable



Karen Scrivener: LC2 & LC3 Major Mitigation Leavers For The Cement Industry, RMI Webinar 2023

- Cement and concrete have the lowest embodied carbon & energy of many materials
- The total carbon footprint of cement and concrete is only as high because of the big mass produced and utilized
- Alternative building materials are neither lower in CO_2 footprint, nor are they sustainably appropriate to substitute cement at scale

Cement Beyond Carbon

KHD's Vision of a prosperous cement industry of the future:

- There is no future without cement – but also no cement without decarbonization
- The cement industry will transform into a future beyond carbon
- KHD will provide the solutions for a successfull transformation:
  - Less fuel and electricity consumption
  - Use of alternative fuels and raw materials
  - Capture and use the remaining CO2 emissions at low cost

CEMENT BEYOND CARBON

KHD Transformation Roadmap

Step-by-step

CEMENT BEYOND CARBON

Until 2030

The road to 2030 will use existing solutions or those close to commercialization. Things like roller presses for energy-efficient grinding; the Pyrorotor® to maximize alternative fuels; advanced digital solutions that optimize process efficiency, such as our KHD ProMax suite; and clay calcination.

These technologies and approaches are available today to reduce CO_2 emissions.

KHD Transformation Roadmap

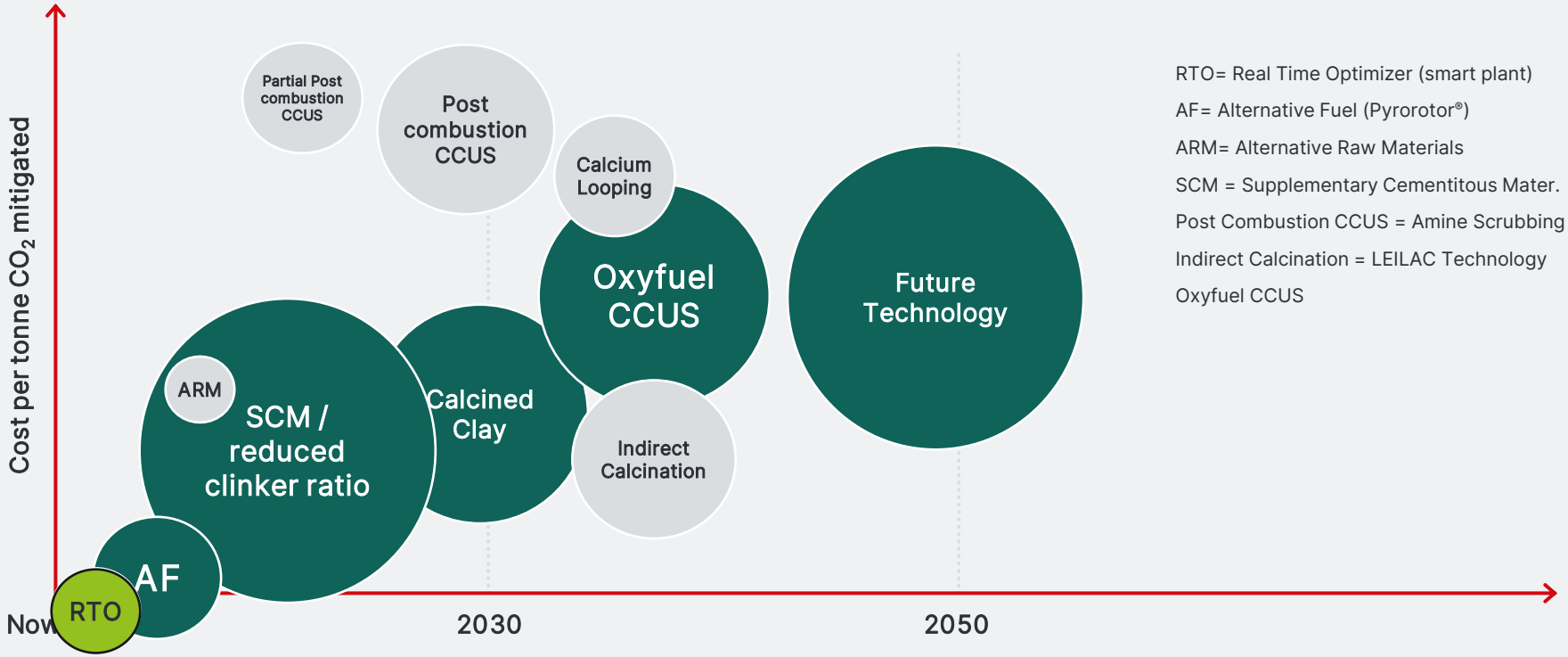
CEMENT BEYOND CARBON

The next chapter

After 2030

The road after 2030 will take use to complete decarbonization of the cement process with the help of future solutions, including carbon capture and storage. Alongside strategic partners in the industry, we are already working hard to develop and bring these important new technologies to commercial viability.

Navigating Through The Transition With KHD Technology



RTO= Real Time Optimizer (smart plant)

AF= Alternative Fuel (Pyrorotor®)

ARM= Alternative Raw Materials

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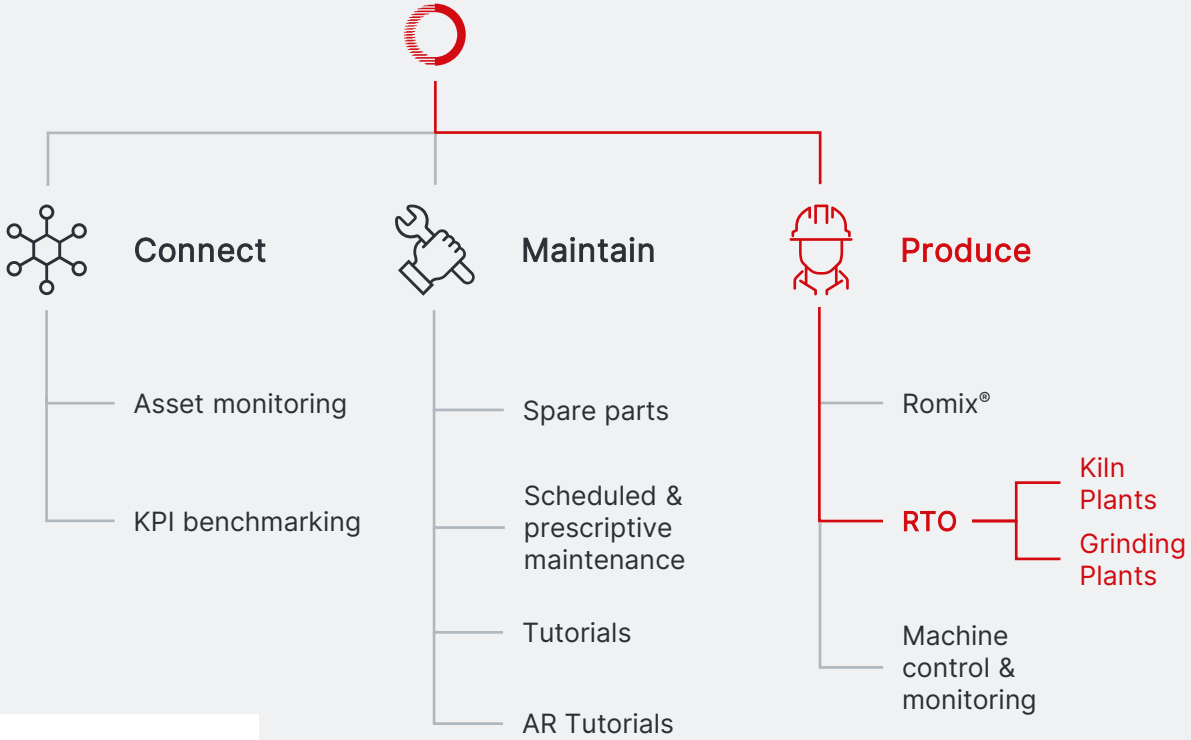
Post Combustion CCUS = Amine Scrubbing

Indirect Calcination = LEILAC Technology

Oxyfuel CCUS

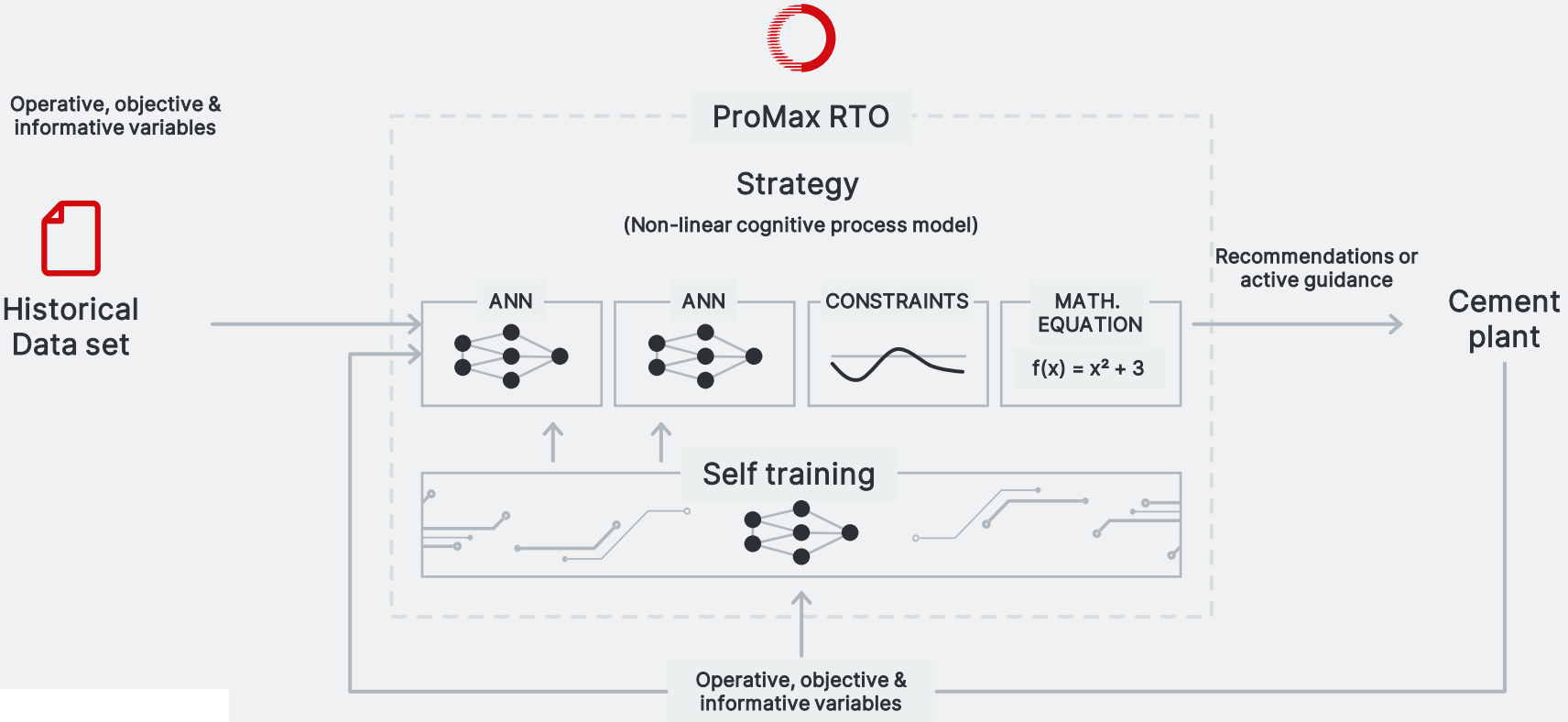
→ Technologies in green are promising and offered by KHD

KHD **ProMax®** – The Digital Twin Suite For Optimized Production



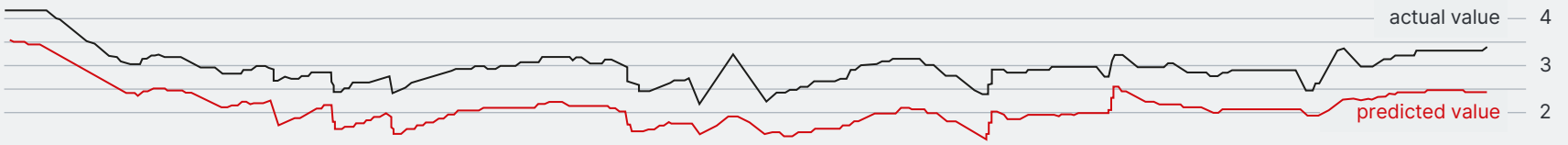
- + Digital Twin Suite for optimized
  - + Asset management
  - + Maintenance
  - + Operation
- + Configuratable functionality
- + Flexible for edge and cloud data
- + Real Time Optimizer powered by:
  - + Double ML online optimization
  - + Process knowledge guidance
  - + Self tuning technology
- + VR/AR tutorials
- + Extended Remote Services

KHD **ProMax**® RTO – Combination of AI AND Human Knowledge

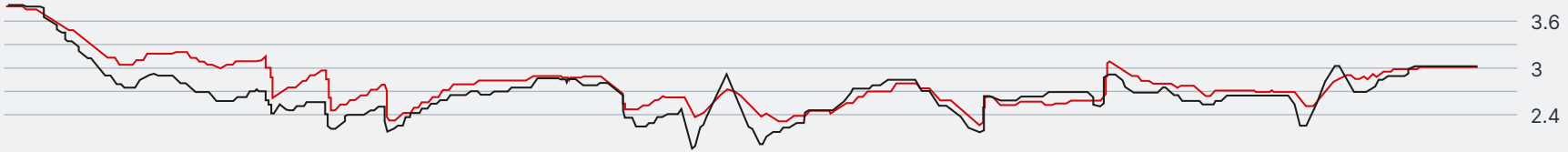


KHD **ProMax**® RTO – Continuous Self Adaptation

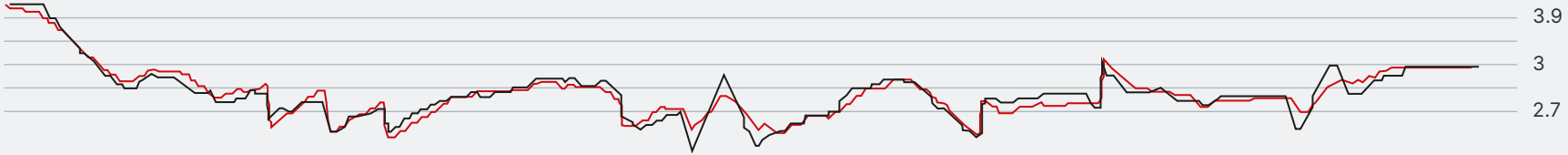
1st run with initial models



2nd run with self-trained models

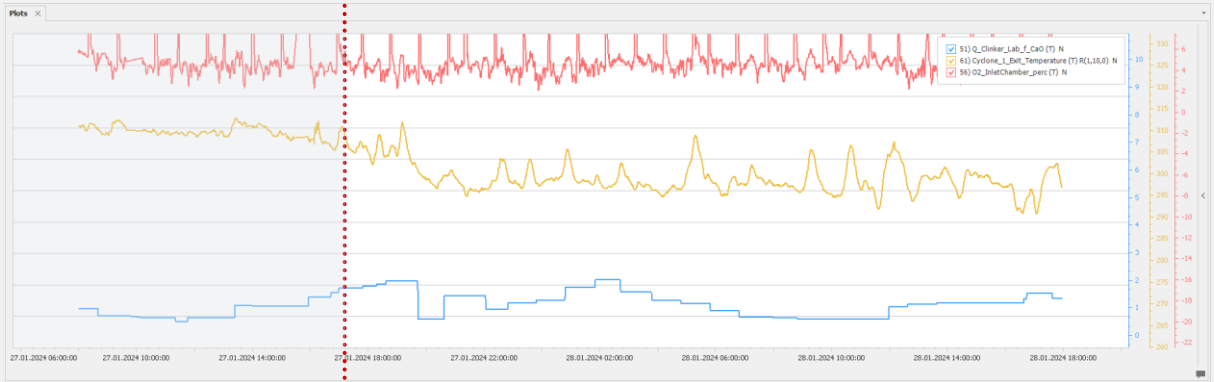


3rd run with self-trained models

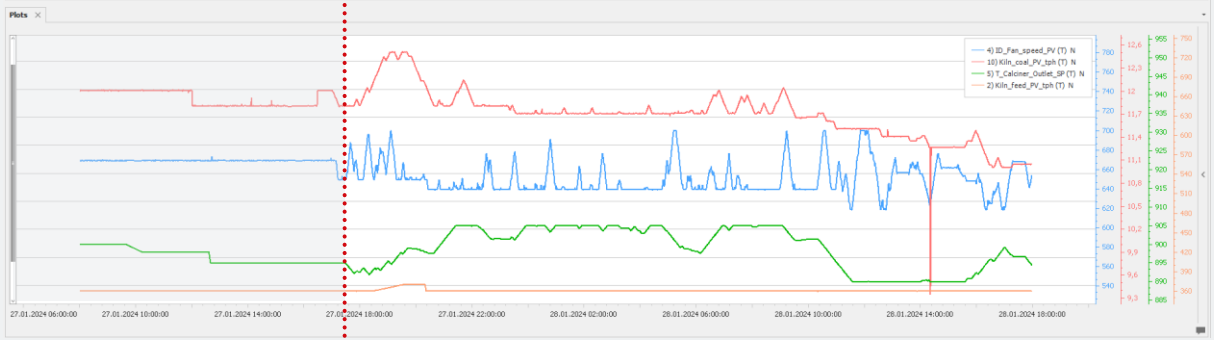


KHD **ProMax**® RTO – Optimization Results: Instant And Sustainable Improvment

- Kiln O2
- Preheater Outlet Temperature
- Clinker Quality fCaO

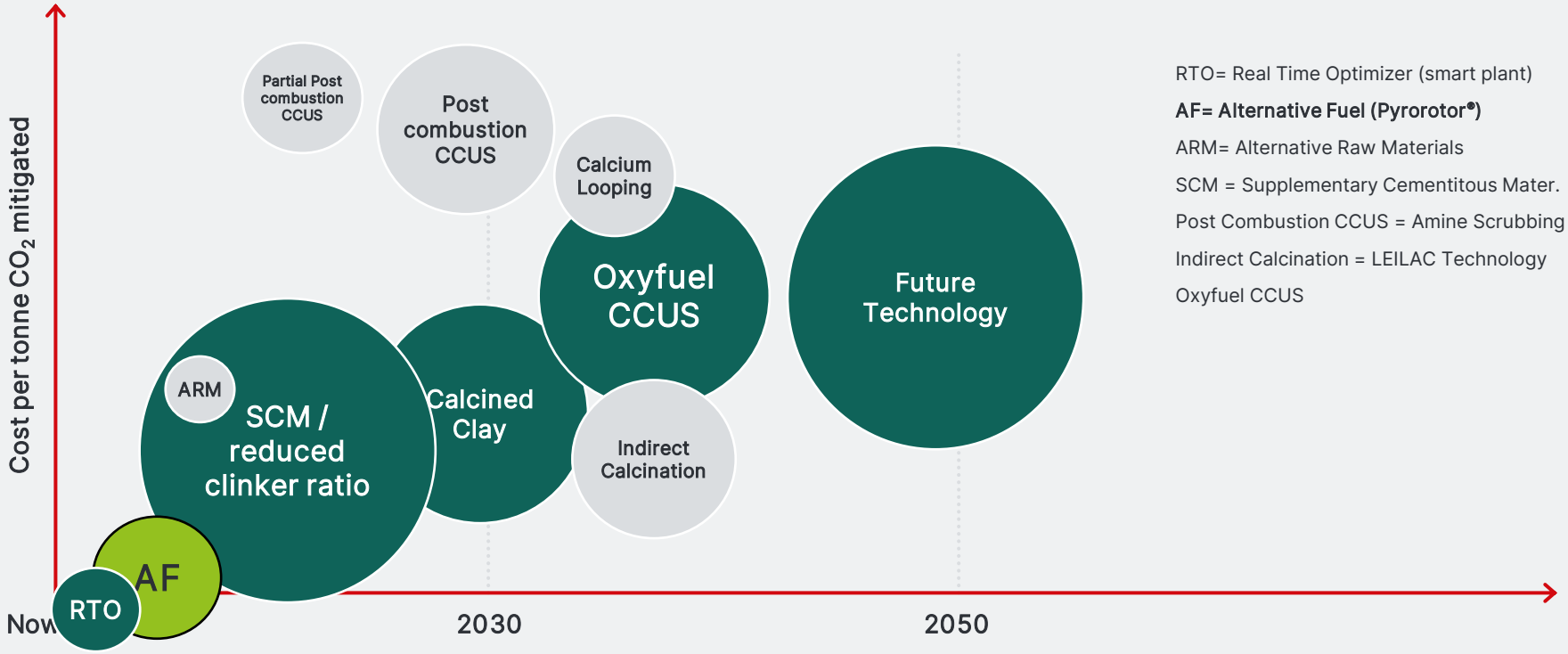


- Coal Main Burner
- Preheater Fan speed
- Calciner Temperature
- Kiln Feed



Manual Operation → RTO Operation

Navigating Through The Transition With KHD Technology



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Oxyfuel CCUS

→ Technologies in green are promising and offered by KHD

Increasing Use of AF is Reducing CO_2 Emissions AND Cost

Ambitious reference scenario

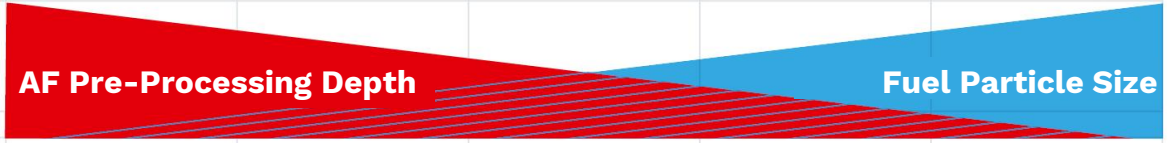
- Thermal efficiency: +13%
- Alternative fuels: 85%
  (of which 35% biomass)
- 15% conventional fuels
- Without CCUS

Climate neutrality scenario

- Thermal efficiency: +13%
- Alternative fuels: 90%
  (of which 35% biomass)
- 10% hydrogen
- Use of CCUS

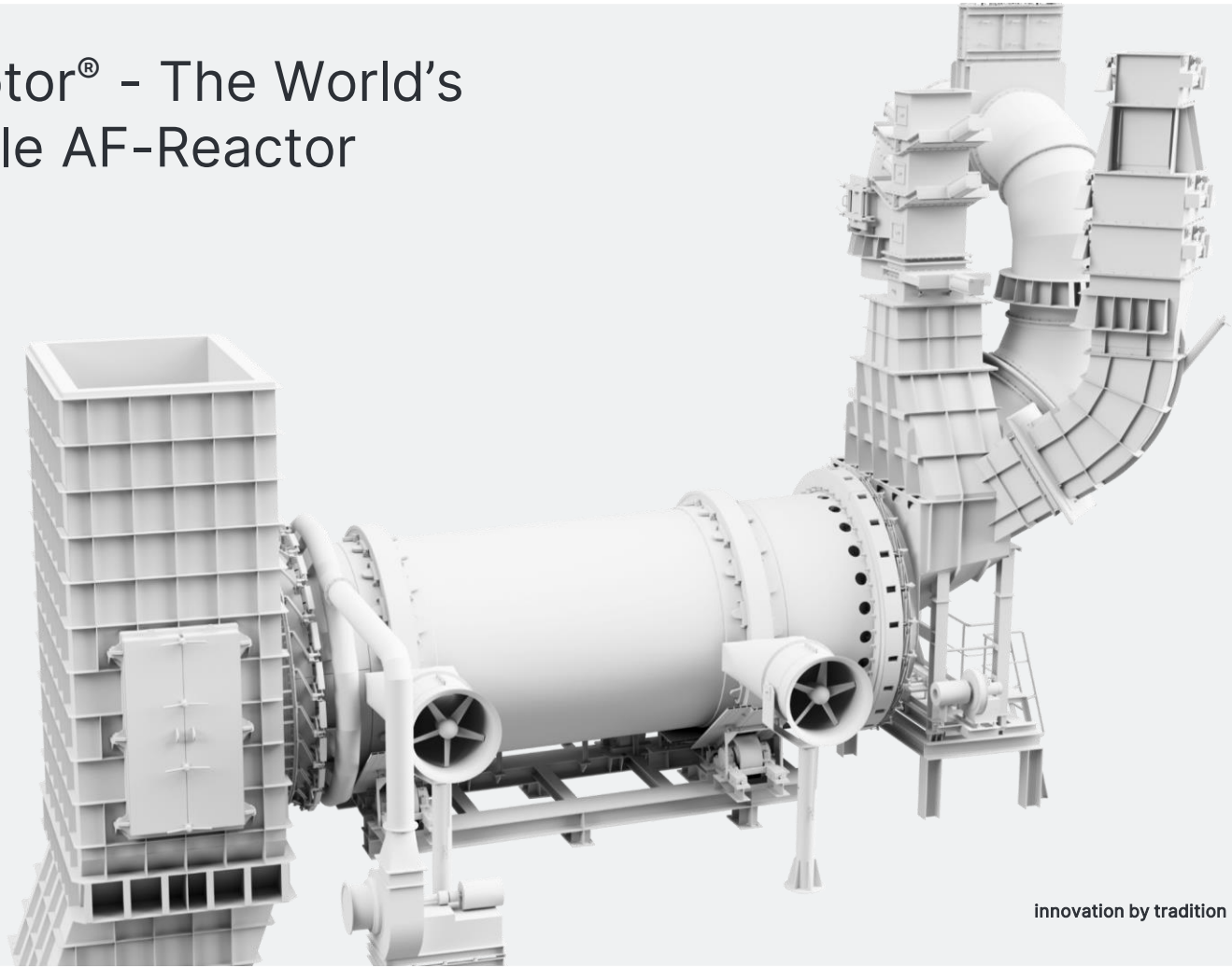
Excerpt from VDZ Roadmap: „Decarbonizaing Cement and Concrete“, VDZ 2020

KHD Equipment For AF Utilization from 0 - 100%



	Pyrojet Kiln Burner	Pyroclon R Calciner	Pyroclon R with Pyroincinerator	Pyroclon R with Combustion Chamber	Pyroclon R with Pyrorotor
Waste Oil / Animal Meal / Sewer Sludge	✓	✓	✓	✓	✓
Biomass	max. 2×1×1 mm (3D)	max. 5×5×2 mm (3D)	max. 20×20×5 mm (3D)	max. 40×40×10 mm (3D)	max. 100×100×15 mm (3D)
Plastics	max. 2×1×1 mm (3D)	max. 5×5×2 mm (3D)	max. 20×20×5 mm (3D)	max. 40×40×10 mm (3D)	max. 300×100×100 mm (3D)
RDF / Fluff	max. 10×10 mm (2D)	max. 30×30 mm (2D)	max. 70×70 mm (2D)	max. 100×100 mm (2D)	max. 300×300 mm (2D)
Tire Chips	×	max. 40×40×25 mm (3D)	max. 50×50×25 mm (3D)	max. 70×70×25 mm (3D)	max. 300×300×25 mm (3D)
Whole Tires	×	×	×	×	✓

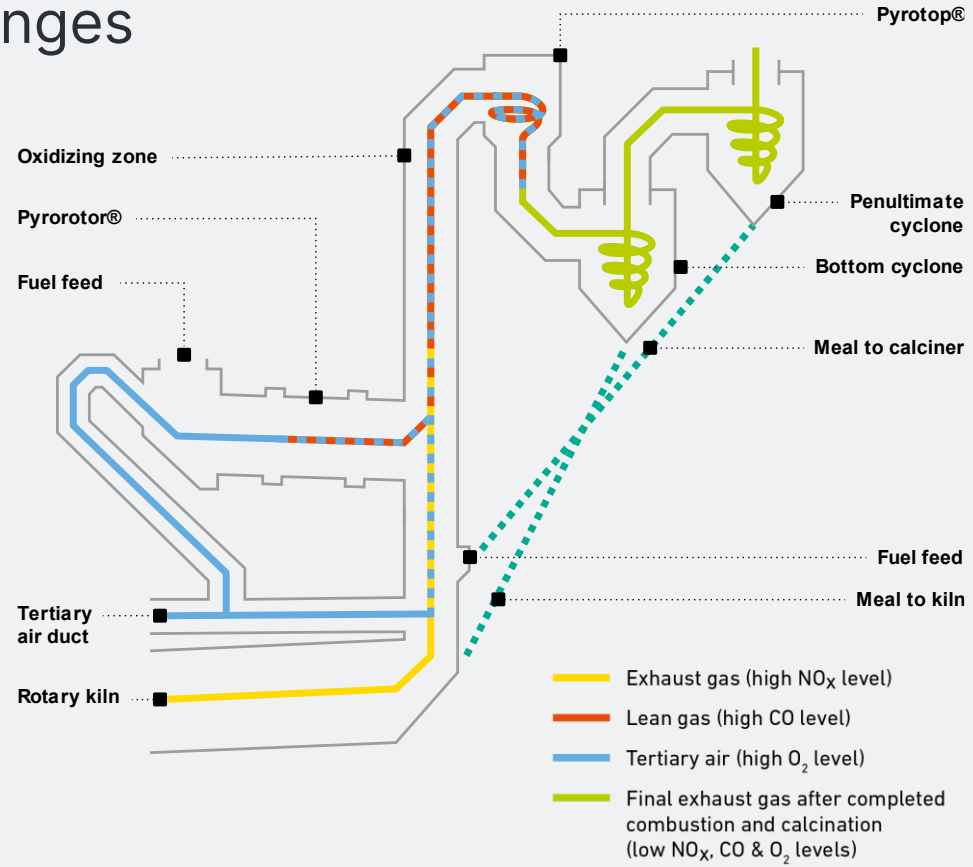
KHD Pyrorotor® - The World's Most Flexible AF-Reactor



Pyrorotor® Solves 3 Challenges

Pyrorotor® enables:

+ AF-burning rate of up to 100%
+ NO_X emission reduction through high volatiles in AF
+ CO_2 emissions reduction thanks to suitability for any kind of alternative fuel, especially humid biogenic wastes
+ Very high thermal substitution rates in general

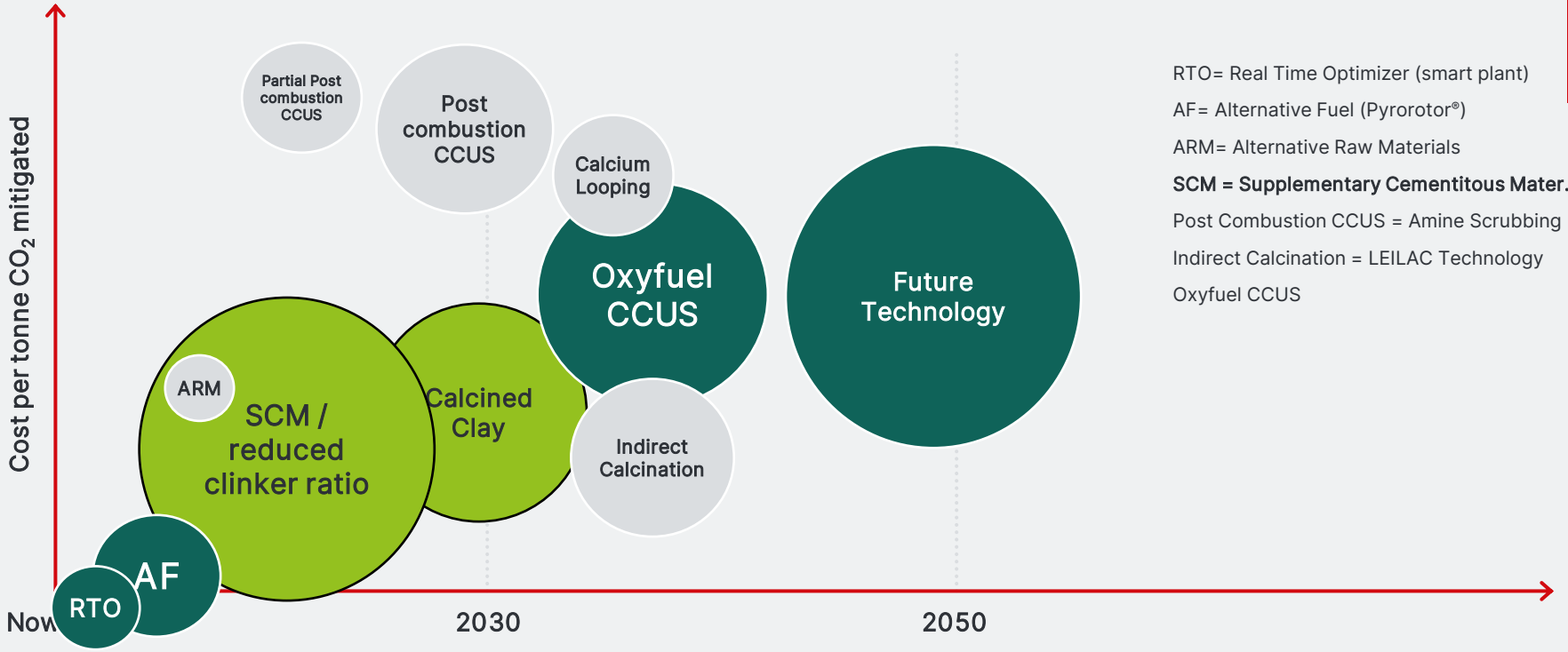


Pyrorotor® - 11 Successful Installations (and counting)

		Reference 1		Reference 2		Reference 3	
		Contract	PG Test	Contract	PG Test	Contract	PG Test
Clinker production	tpd	5000	5058	5000	5096	4060	4133
Heat consumption	kcal/kg	840	760	852	859	825	805
Thermal AF substitution rate at calciner	%	>85	87	>85	85	>85	86
Pyrorotor® fuel amount (PG test average)	tph		18.1		23.5		14.5
Pyrorotor® fuel amount (daily operation)	tph		20-25		20-25		14-17
AF mix heat value	kcal/kg	>3500	5110	>3500	4253	>4060	4708
Clinker free lime	%	1.5	0.83	1.5	1.2	1.5	0.75

No negative effect on the kiln process and product quality – stabilization on high TSR operation

Navigating Through The Transition With KHD Technology



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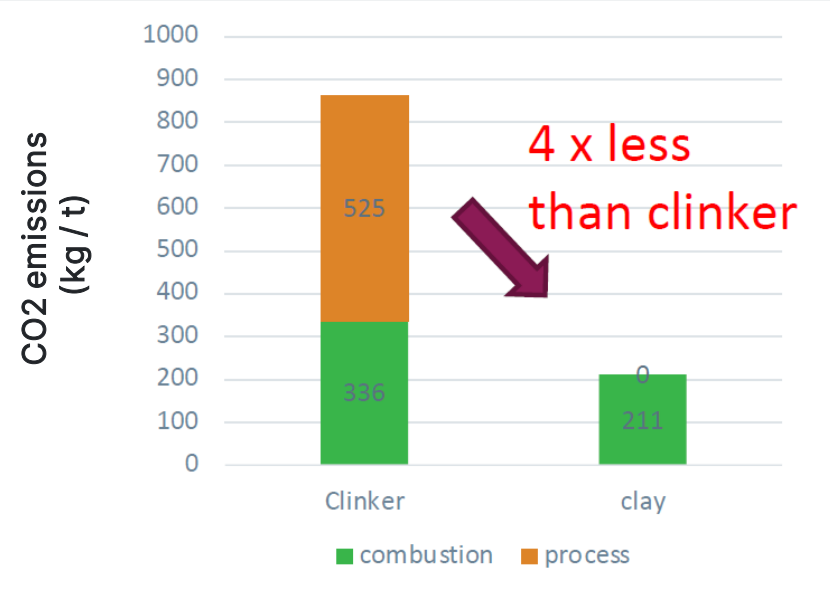
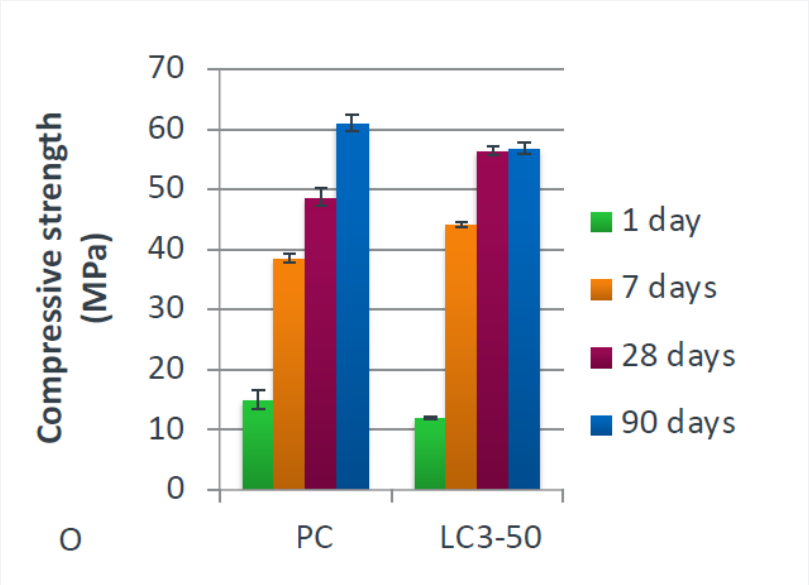
Oxyfuel CCUS

→ Technologies in green are promising and offered by KHD

Calcined Clay in LC3 Reduces CO_2 Footprint Without Reducing Strength





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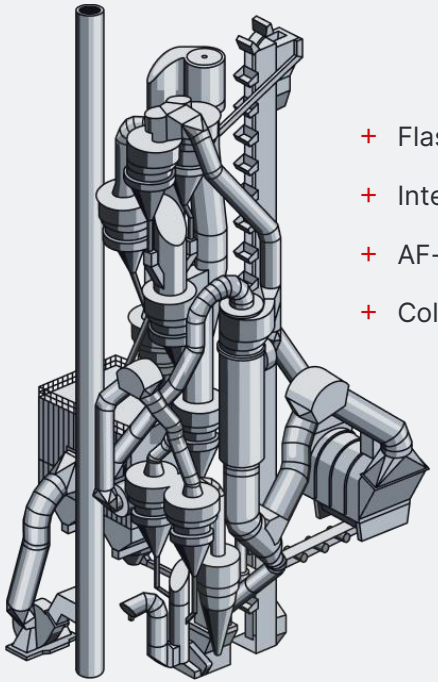
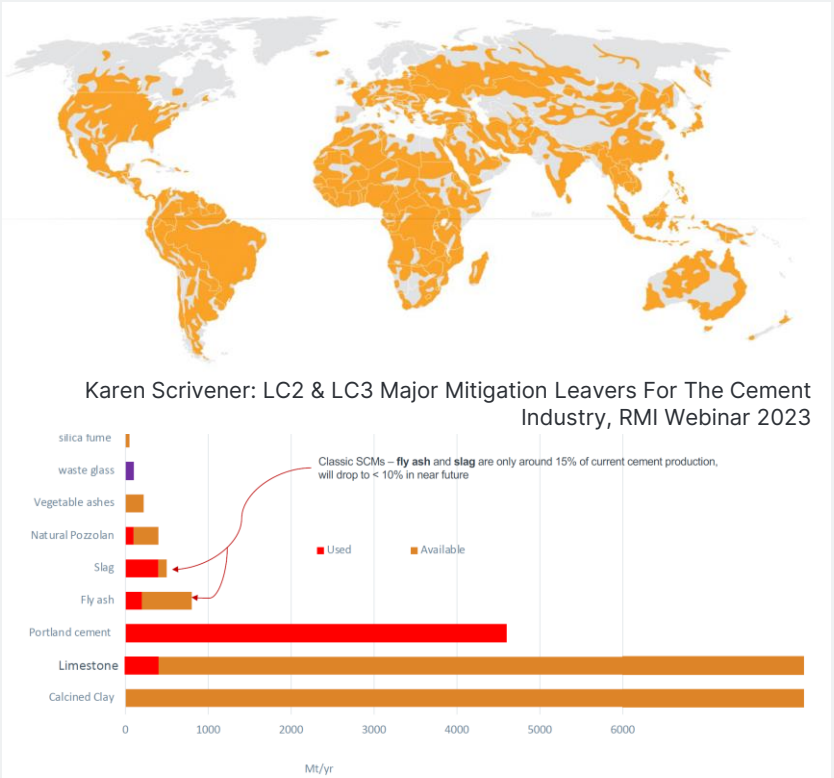
KHD Clay Calcining – Flash Tube or Rotary Kiln



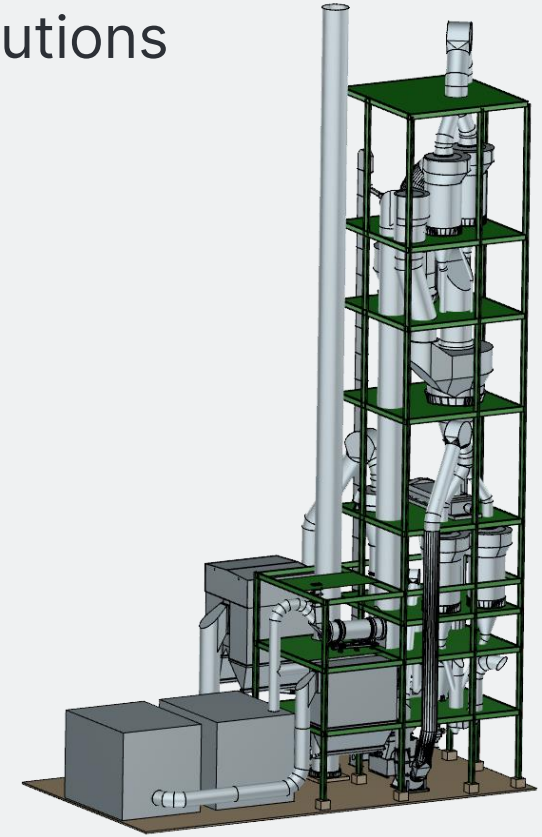
+ Flash tube or rotary kiln
+ Integrated or stand-alone
+ AF-ready
+ Colour control



KHD Clay Calcining – Optimized solutions for all requirements

Flexible concept for:

+ Highest energy efficiency
+ Colour controlled product
+ Fuel fired and electrically heated
+ Alternative fuel utilization



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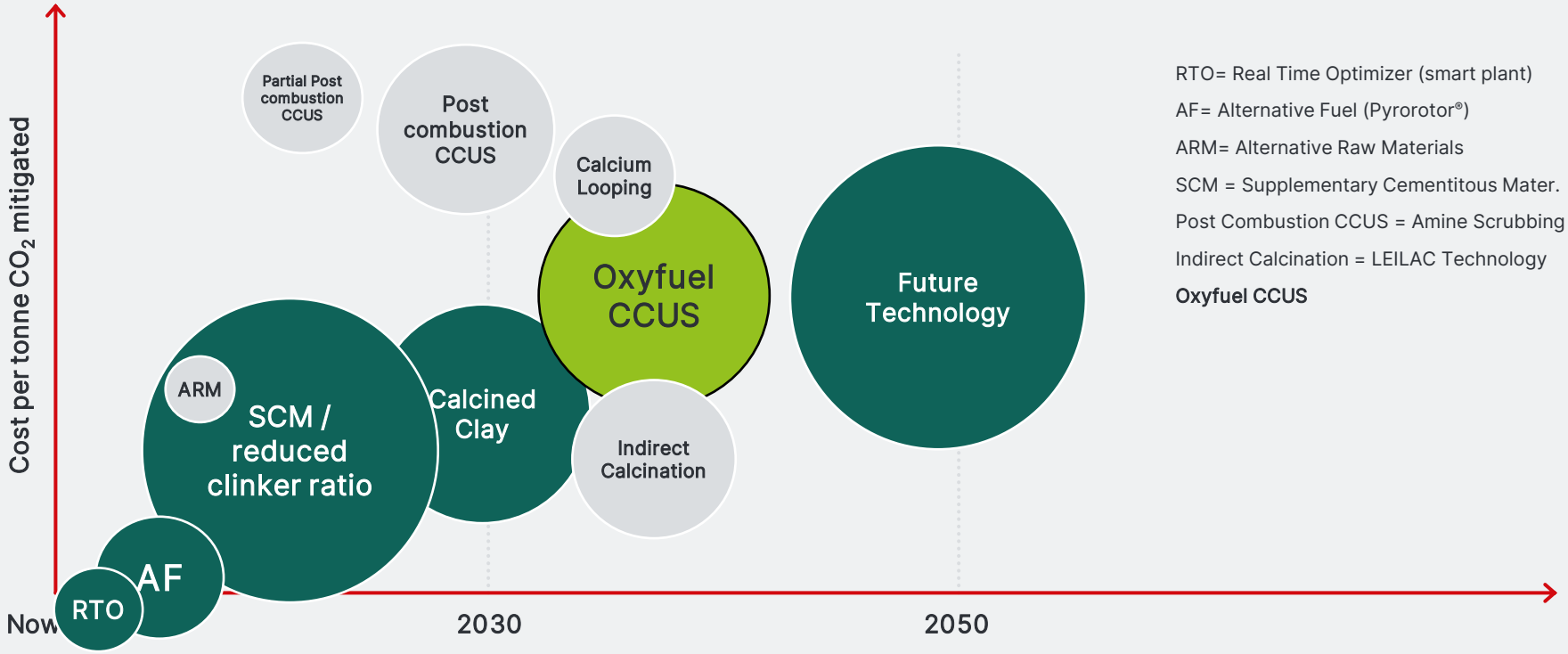

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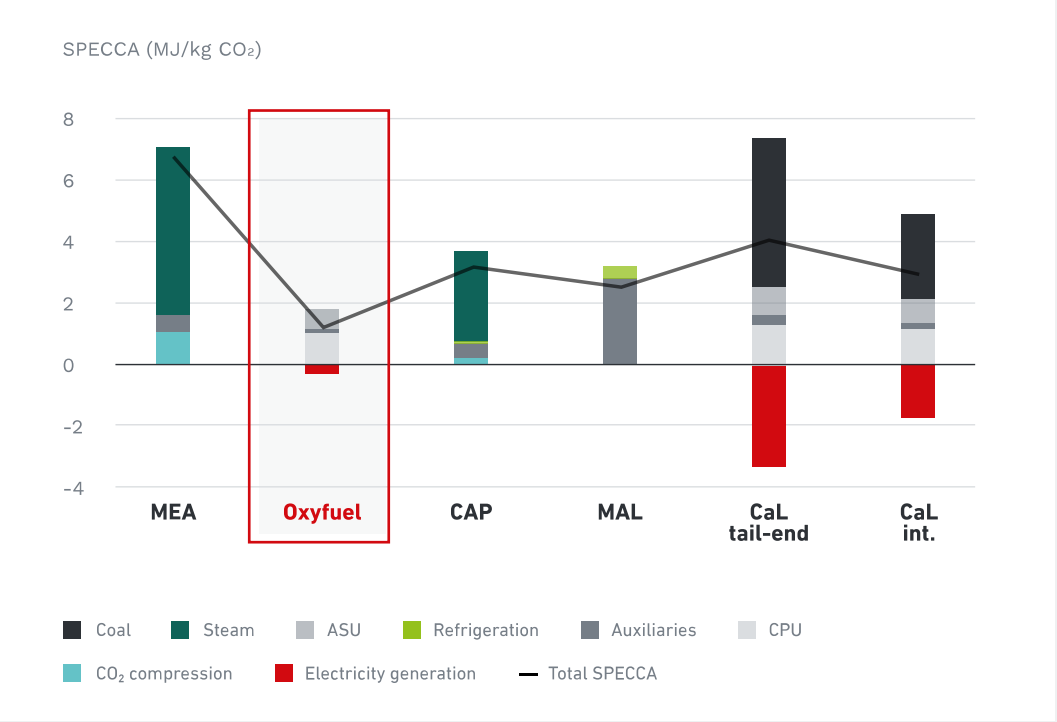
Oxyfuel CCUS

→ Technologies in green are promising and offered by KHD

Without CCUS The Decarbonization of Cement is Impossible

„Decarbonizaing Cement and Concrete“, VDZ 2020

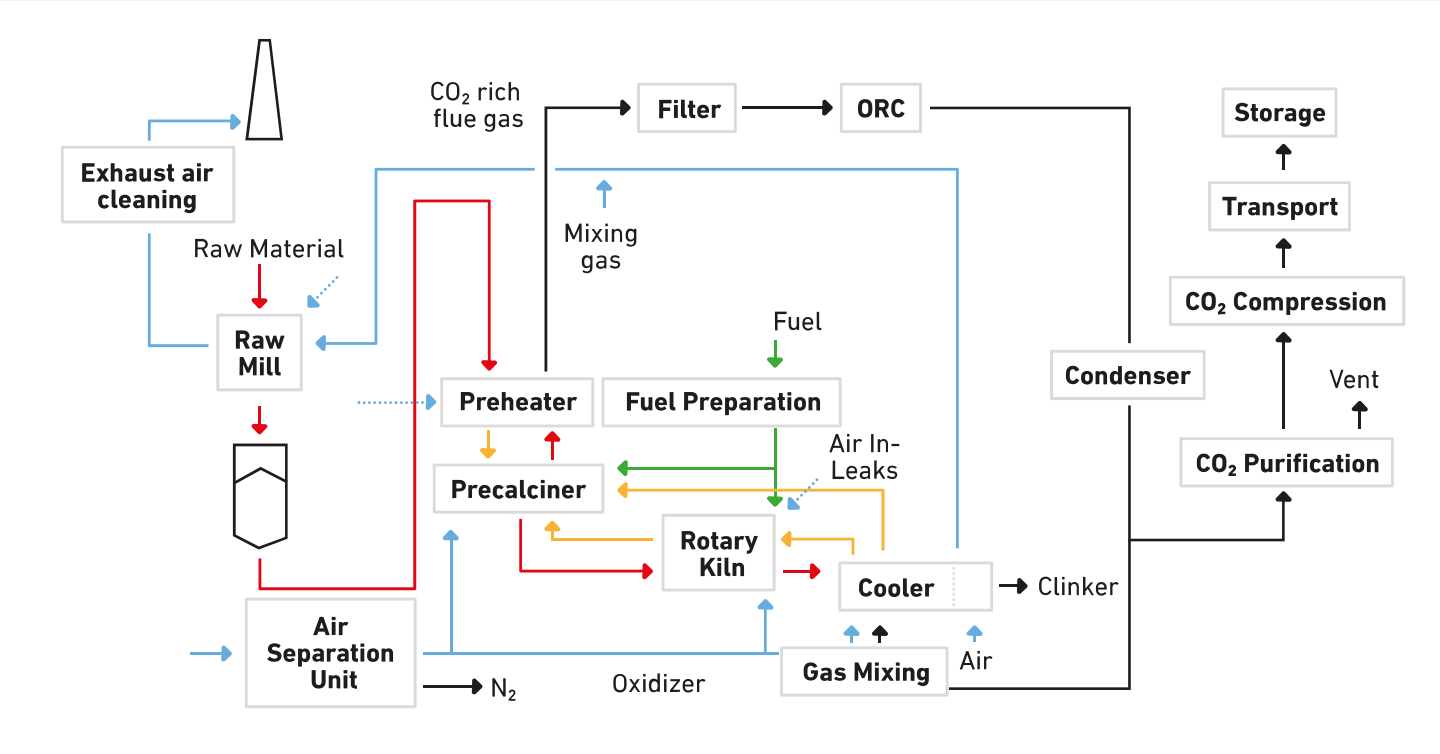
Oxyfuel Is the Most Economic Solution For Carbon Capture



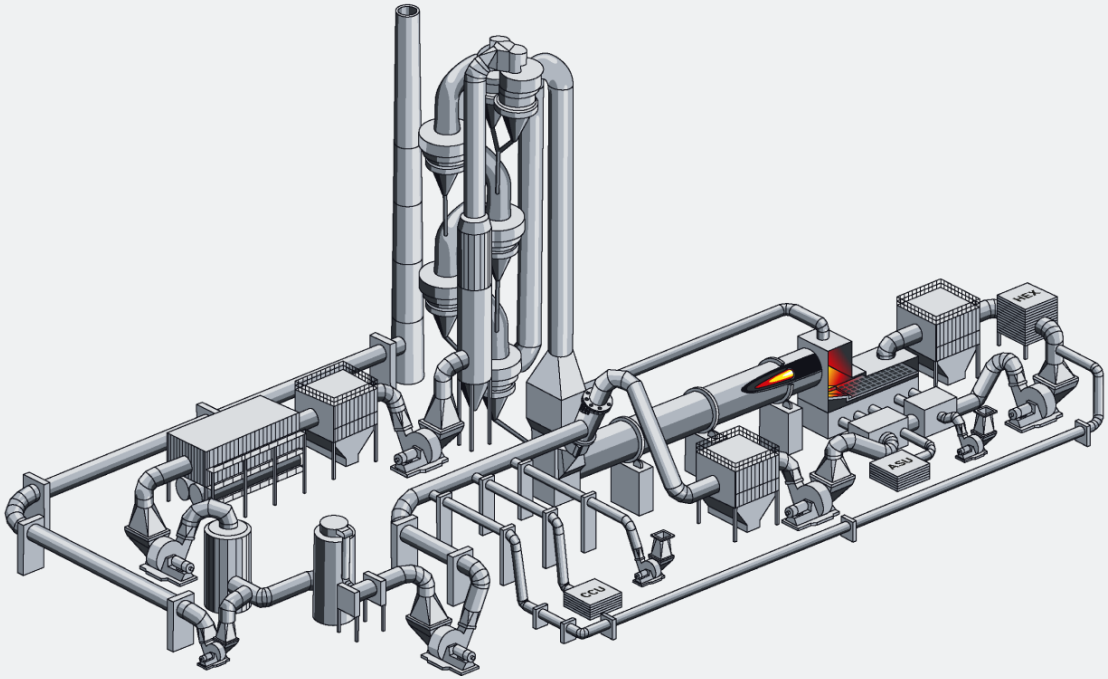
SPECCA= specific primary energy consumption for CO_2 avoided

Volsund, M. et al.: Comparison of technologies for CO2 capture from cement production, Energies 2019

Oxyfuel Flowsheet

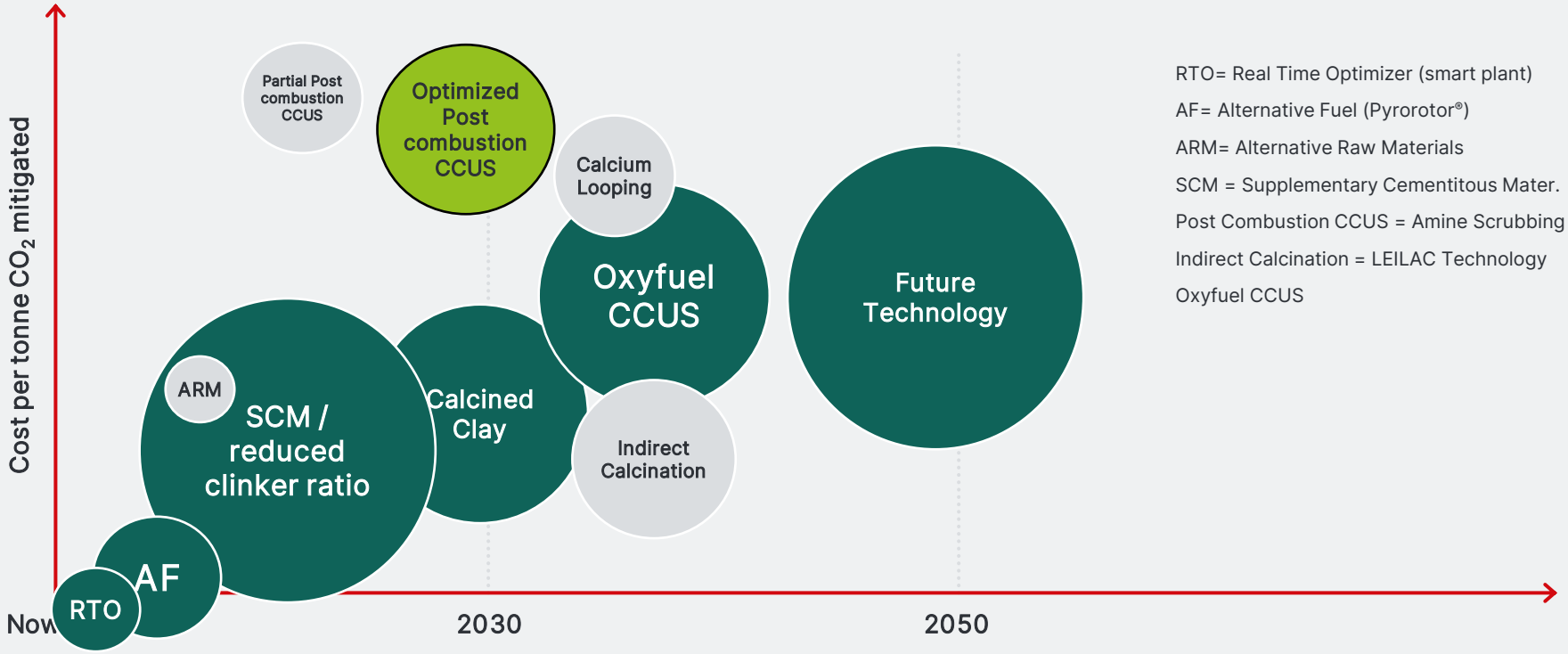


KHD‘s Oxyfuel Technology For Cutting Capture Cost



+ Concentration of CO_2 up to 85%
+ Reduces capture costs largely
+ Flexible operation and
+ switchover
+ Retrofittable to existing plants
+ Innovative sealing solutions
+ Oxyfuel kiln burner
+ Available today

Navigating Through The Transition With KHD Technology



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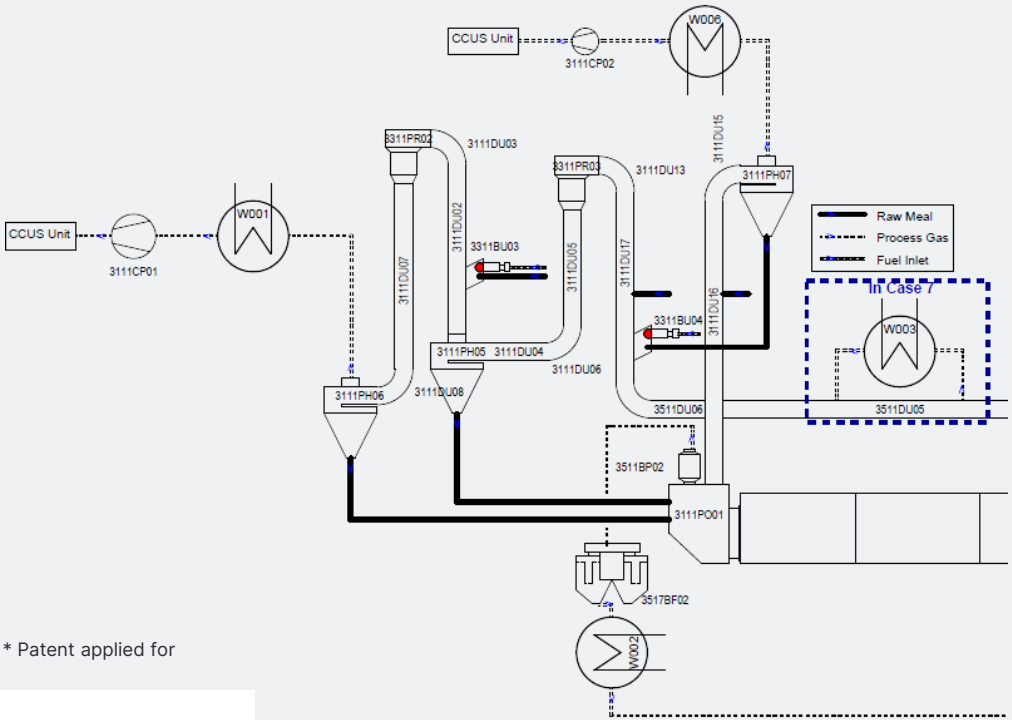
Carbon Capture Behind Cement Plants Adds Conceivably To Cost

+ The operation of a post combustion amine scrubbing carbon capture plant requires ~ 2500 $kJ/kg_{CO2,\ captured}$ for the regeneration of the solvent (almost as much as for clinker production)
+ Additional CAPEX is required to build the CCP plant
+ This significantly increases the production cost per tonne of clinker
  + approx. 107 €/t $CO_{2,\ cap}$ *
  + @ 800 kg_{CO2} / t_{Cli} : 86 € / t_{Cli}

→ **How can those additional cost be reduced?**

* ACCSESS-Project (www.accsessproject.com): techno-commercial evaluation for a Amine-based CCP retrofitted to an existing mid-size cement plant in Germany

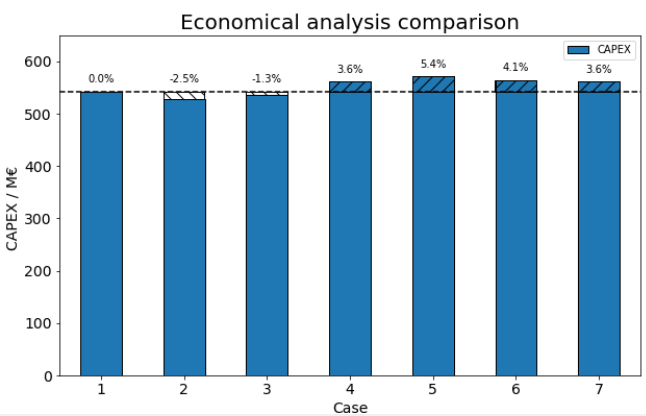
Pyroflex Kiln Plant For Energy Autonomous Amine Scrubbing*

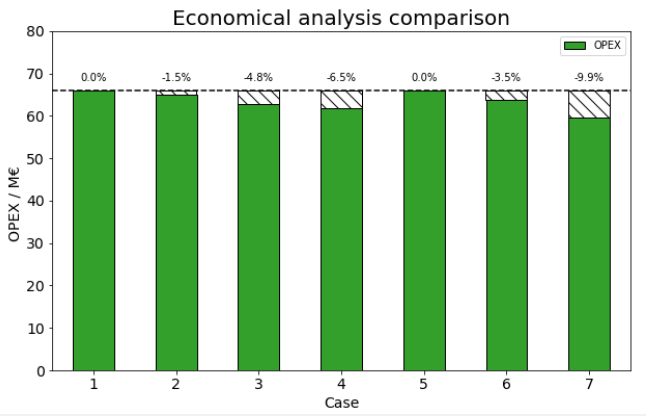


* Patent applied for

- Maximum possible heat extraction from the pyro process
- No more preheater
- Utilization of the hot kiln gases for heating up a portion of meal
- Using the hot meal portion to facilitate ignition of fuel in cold air stream from heat reduced tertiary air
- 2 subsequent calciners for flexible meal and fuel injection
- Supply of sufficient heat to the PCC plant

CAPEX and OPEX For Combined Clinker Production And Amine Scrubbing PCC



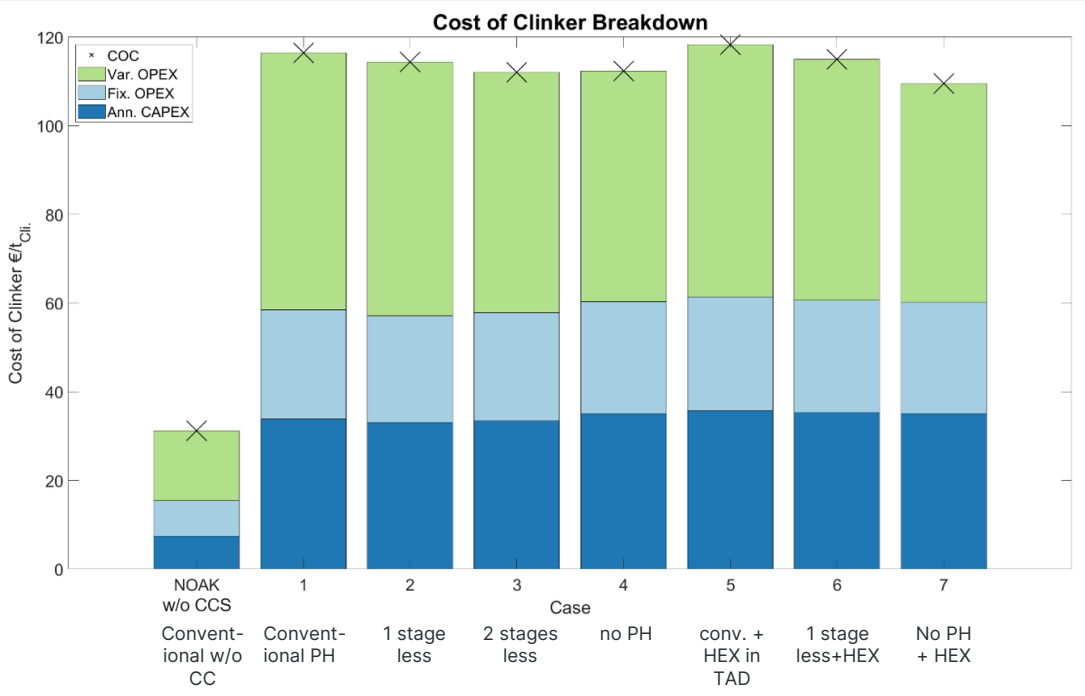


1. conventional kiln plant with CC
2. 1 PH stage less
3. 2 PH stages less
4. no PH
5. 1 PH stage less + HEX in TAD
6. 2 PH stages less + HEX in TAD
7. no PH + HEX in TAD

+ The novel Pyroflex process allows to reduce the OPEX by 10 % *
+ Increasing price differntial between fossil and alternative fuels further increases this cost advantage

*: this novel kiln process has been developed under the ACCSESS-Project (www.accsessproject.com)

CAPEX and OPEX For Combined Clinker Production And Amine Scrubbing PCC



- The total cost per ton of clinker in a combined clinker + capture plant (pyro only) will increase to almost 400%
- The novel Pyroflex process can reduce the total cost per tonne of clinker when fully decarbonized by approx. 5-10 % compared to the conventional kiln line with CC *

* this novel kiln process has been developed under the ACCSESS-Project (www.accsessproject.com)

KHD Will Provide The Solutions For A Successfull Transformation

+ Less fuel and electricity consumption
+ Use of alternative fuels and raw materials
+ Capture and use the remaining CO_2 emissions at low cost

Thank you for your time!