SOLAR CEMENT

Industrial Decarbonization

Renewable Process Heating from Concentrating Solar Thermal

Workshop - September 14 & 15, 2021

Dr. Davide Zampini

Head of CEMEX Global R&D

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Global Building Materials Company

CEMENT | AGGREGATES | READY-MIX | URBANIZATION SOLUTIONS

CEMENT AND GRINDING PLANTS **65**
MILLION TONS PRODUCTION CAPACITY **93**
CEMENT

QUARRIES **262**
MILLION TONS ANNUAL SALES VOLUME **135**
AGGREGATES

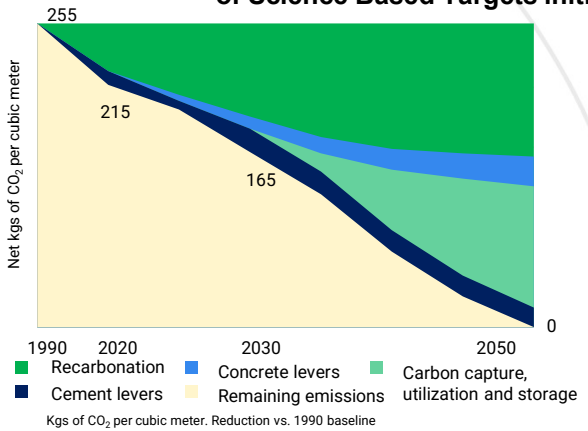
PLANTS **1,427**
MILLION m^3 ANNUAL SALES VOLUME **50**
READY-MIX CONCRETE

LAND DISTRIBUTION CENTERS **279**
MARINE TERMINALS **56**
TERMINALS

THOUSAND EMPLOYEES **+40.6**
PEOPLE

Climate Action Targets

Aligning sustainability targets to Well-Below 2-Degree Scenario of Science Based Targets initiative

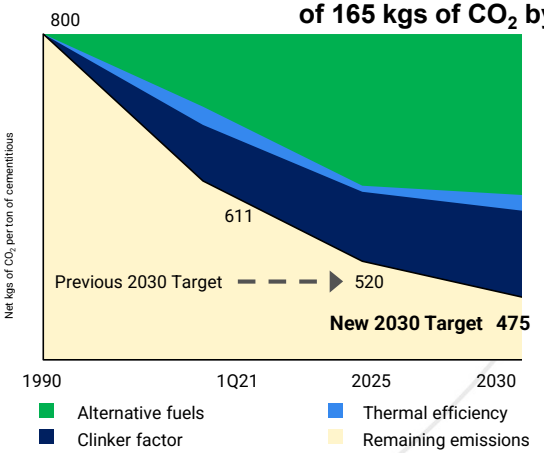


Kgs of CO_2 per cubic meter. Reduction vs. 1990 baseline

<475 kgs by 2030
>40% reduction

520 kgs by 2025
35% reduction

Announcing a medium-term carbon reduction goal in concrete of 165 kgs of CO_2 by 2030



Kgs of CO_2 per ton of cementitious material. Reductions vs. 1990 baseline

165 kgs by 2030
35% reduction

Net zero by 2050

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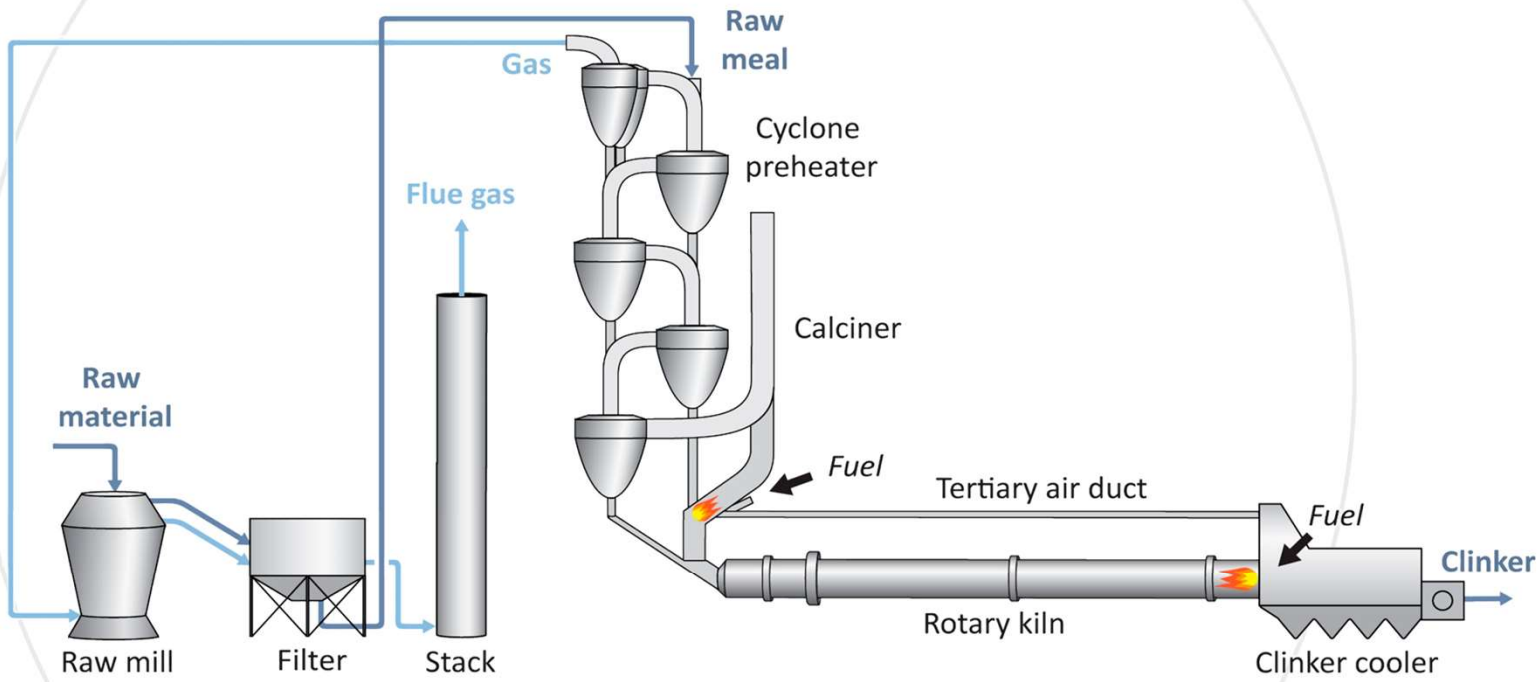
CLINKER MANUFACTURING PROCESS

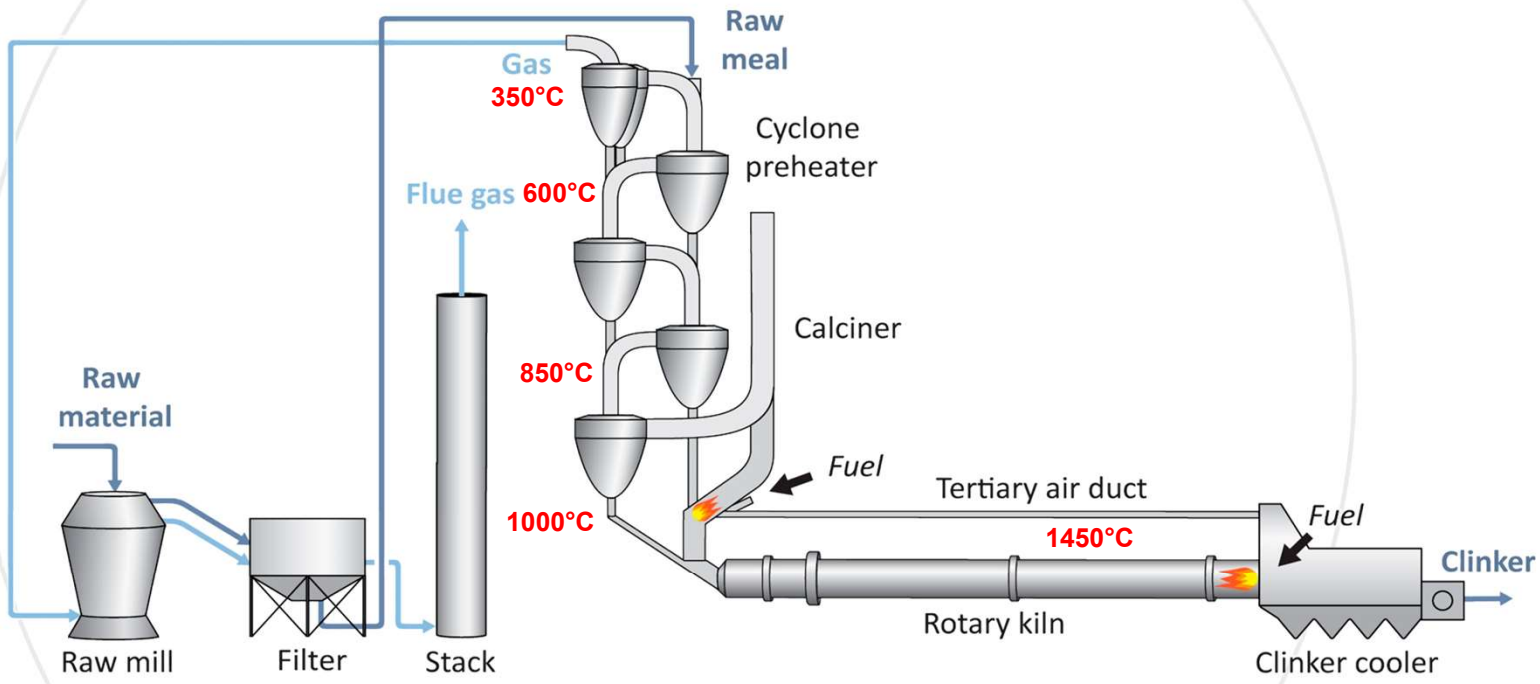
PRODUCTION PROCESS



Cement Manufacture Diagram - Pires, J.. (2019). Carbon Capture and Storage.

CLINKER MANUFACTURING PROCESS

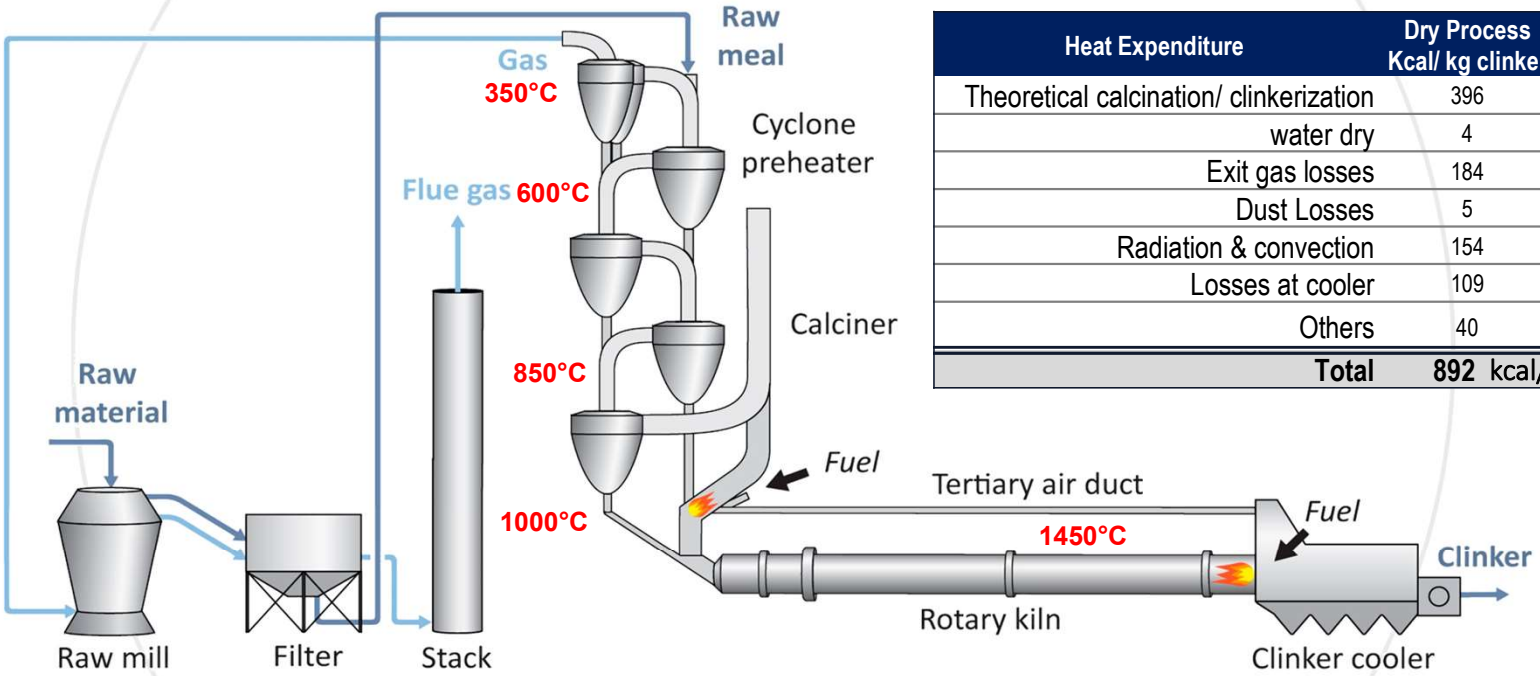
TEMPERATURES



Cement Manufacture Diagram - Pires, J.. (2019). Carbon Capture and Storage.

CLINKER MANUFACTURING PROCESS

ENERGY REQUIREMENTS

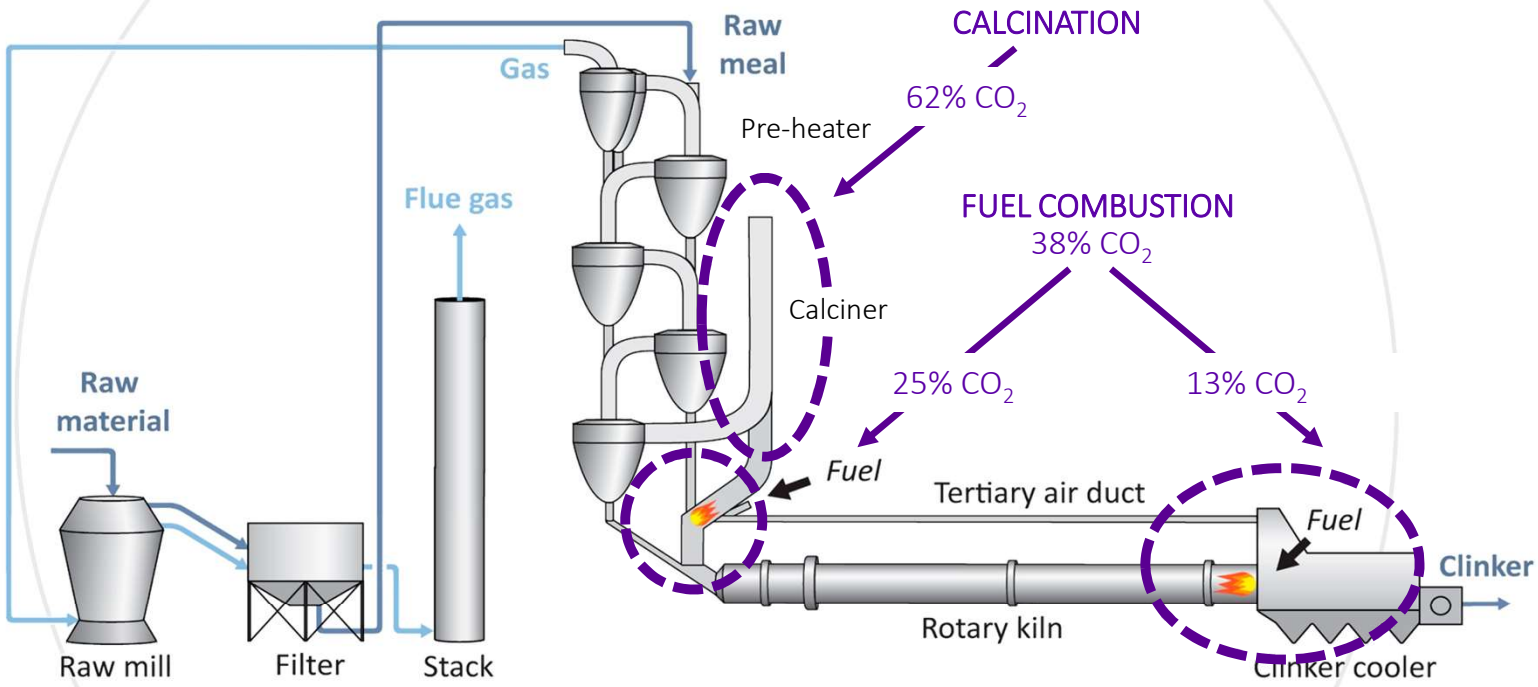


Heat Expenditure	Dry Process Kcal/ kg clinker	Dry Process (%)
Theoretical calcination/ clinkerization	396	44.4
water dry	4	0.4
Exit gas losses	184	20.6
Dust Losses	5	0.6
Radiation & convection	154	17.3
Losses at cooler	109	12.2
Others	40	4.5
Total	**892** kcal/ kg clinker	

Cement Manufacture Diagram - Pires, J.. (2019). Carbon Capture and Storage.

CLINKER MANUFACTURING PROCESS

CO_2 GENERATION



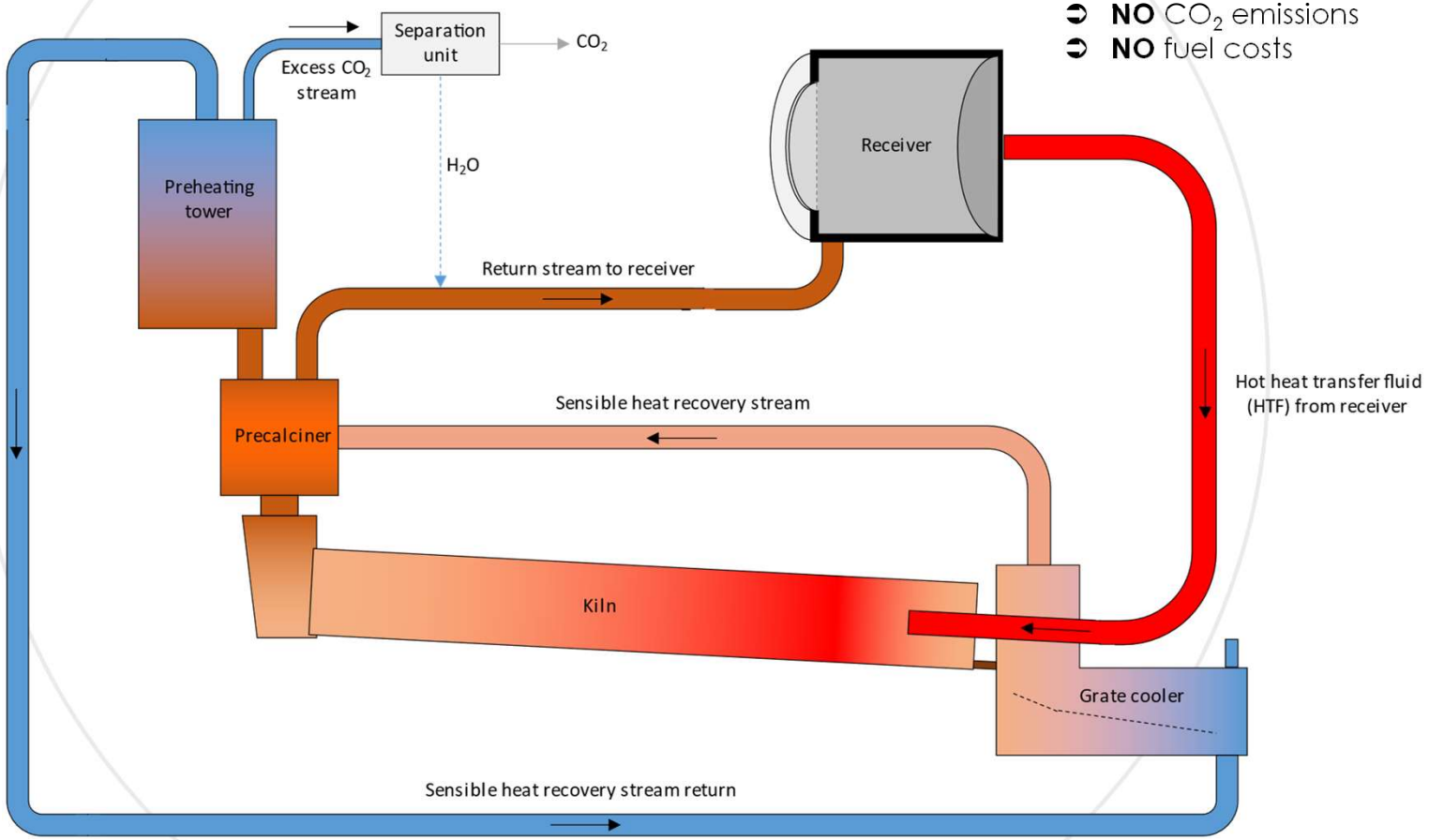
892 kcal/ kg clinker → Total CO_2: 828 kg/ton Clinker

Cement Manufacture Diagram - Pires, J.. (2019). Carbon Capture and Storage.

SOLAR-DRIVEN PYRO-PROCESSING OF CLINKER

High Level Conceptualization – Inspiration of the Aspiration

- **DRIVE FULL PROCESS WITH SOLAR ENERGY** in line with conventional process flow
- **NO** CO_2 emissions
- **NO** fuel costs



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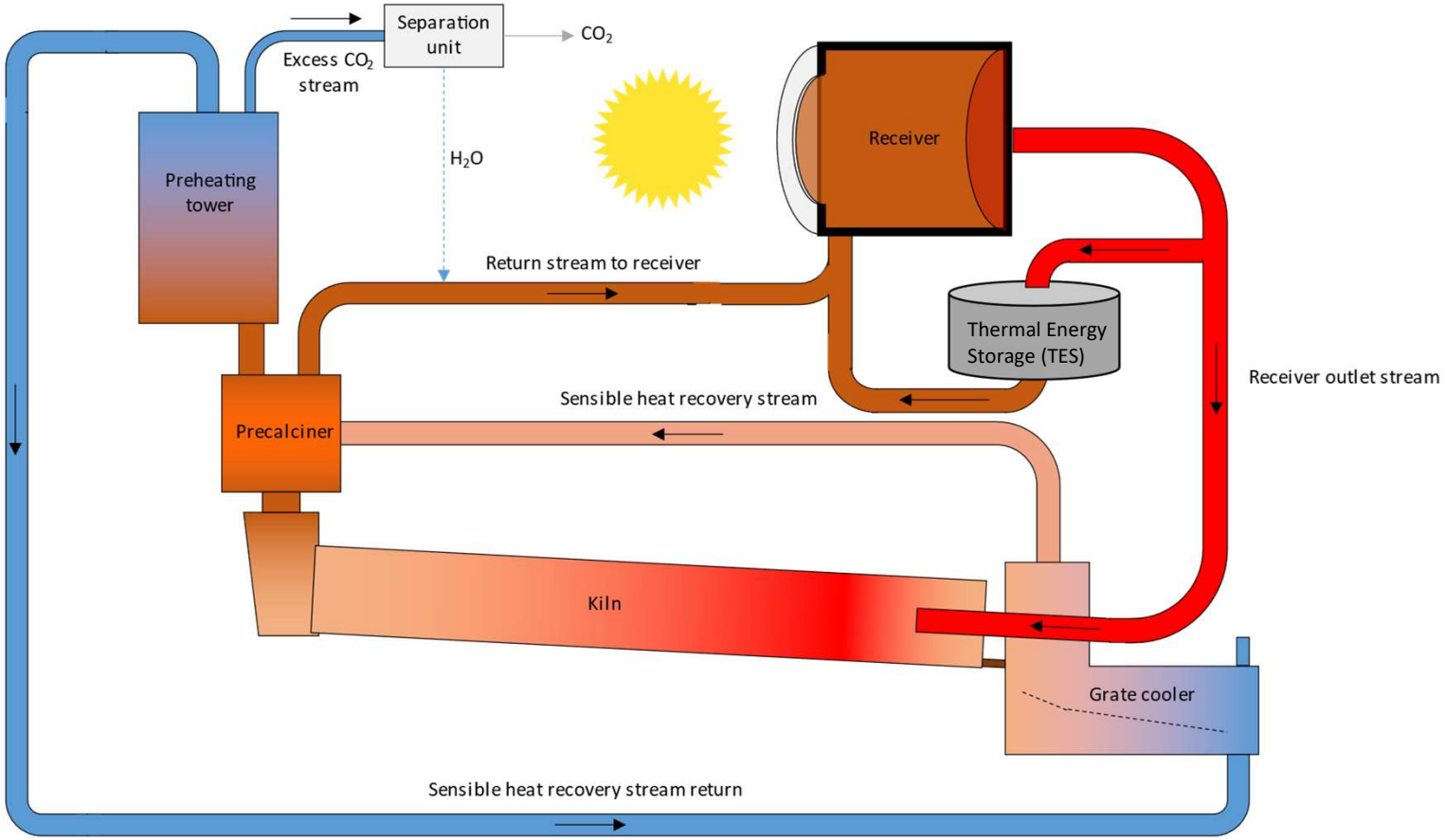
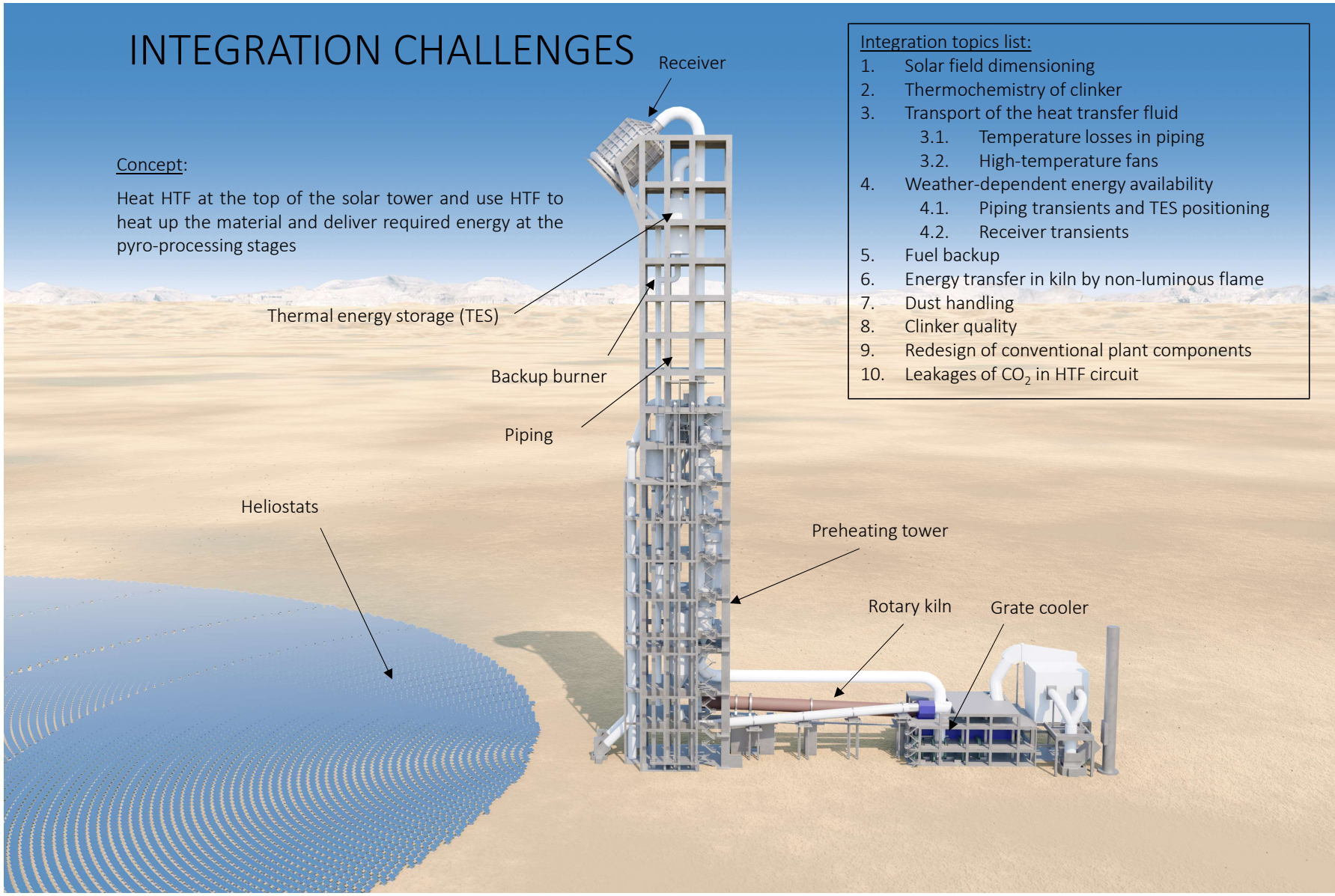
Daytime Operation



INTEGRATION CHALLENGES



Integration topics list:

1. Solar field dimensioning
2. Thermochemistry of clinker
3. Transport of the heat transfer fluid
   - 3.1. Temperature losses in piping
   - 3.2. High-temperature fans
4. Weather-dependent energy availability
   - 4.1. Piping transients and TES positioning
   - 4.2. Receiver transients
5. Fuel backup
6. Energy transfer in kiln by non-luminous flame
7. Dust handling
8. Clinker quality
9. Redesign of conventional plant components
10. Leakages of CO_2 in HTF circuit

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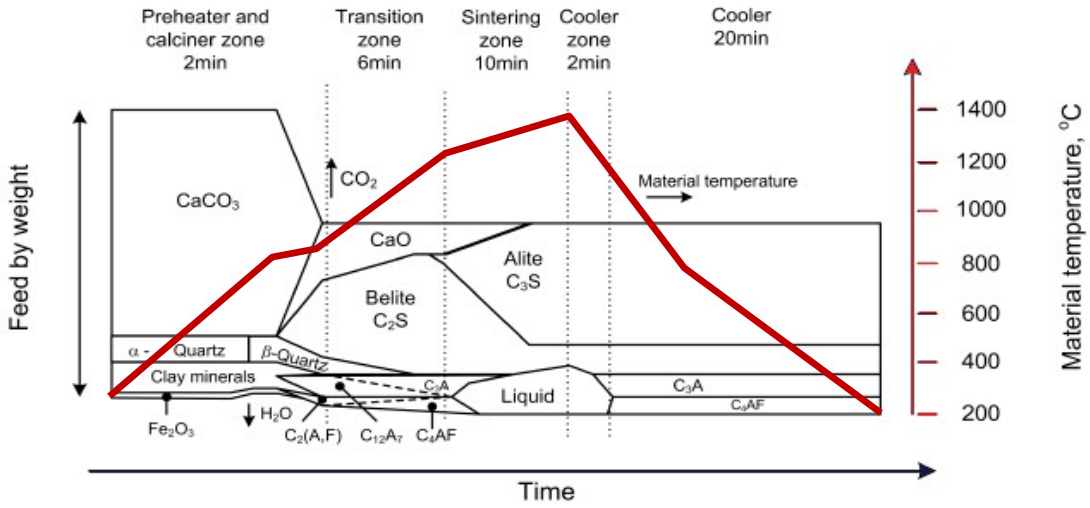
INTEGRATION CHALLENGES

HTF CLINKERIZATION AND CALCINATION



- Impact of the Heat Transfer Fluid (HTF) on the heating zones including residence time
- Heat exchange efficiency between material as a function of CO_2/ H_2O ratios
- Shifts of heating curves and phases formation

* Nørskov, L. K., Dam-Johansen, K., Glarborg, P., Jensen, P. A., & Larsen, M. B. (2012). Combustion of solid alternative fuels in the cement kiln burner. Kgs. Lyngby: Technical University of Denmark (DTU).

INTEGRATION CHALLENGES
MATERIAL QUALITY & PERFERMANCE

Pictures			
Samples		CEMI with 100% air Clinker	CEMI with 100% CO2 Clinker
Compressive strength	2 days (Mpa)	28.77	29.2
	7 days (Mpa)	49.79	50.18
	28 days (Mpa)	63.19	63.58
Mineralogical composition	Alite C3S- Ca3SiO5	59.5	60
	Belite C2S- Ca2SiO4	18.8	18.5
	C3A cubic -Ca3Al2O6	8.2	8.5
	C4AF - Ca2(Al,Fe)2O5	9.3	9.4
	Quartz - SiO2	0.9	0.3
	Periclase - MgO	2.6	2.6
	Lime - CaO	0.8	0.7

Observations

- The cements prepared with both clinkers (100% air and 100%CO2) present the same performance
- High CO2 concentration in the HTF will not affect the clinkerization temperature, nerveless it will displace the calcination of raw meal at higher temperature 50-150°C

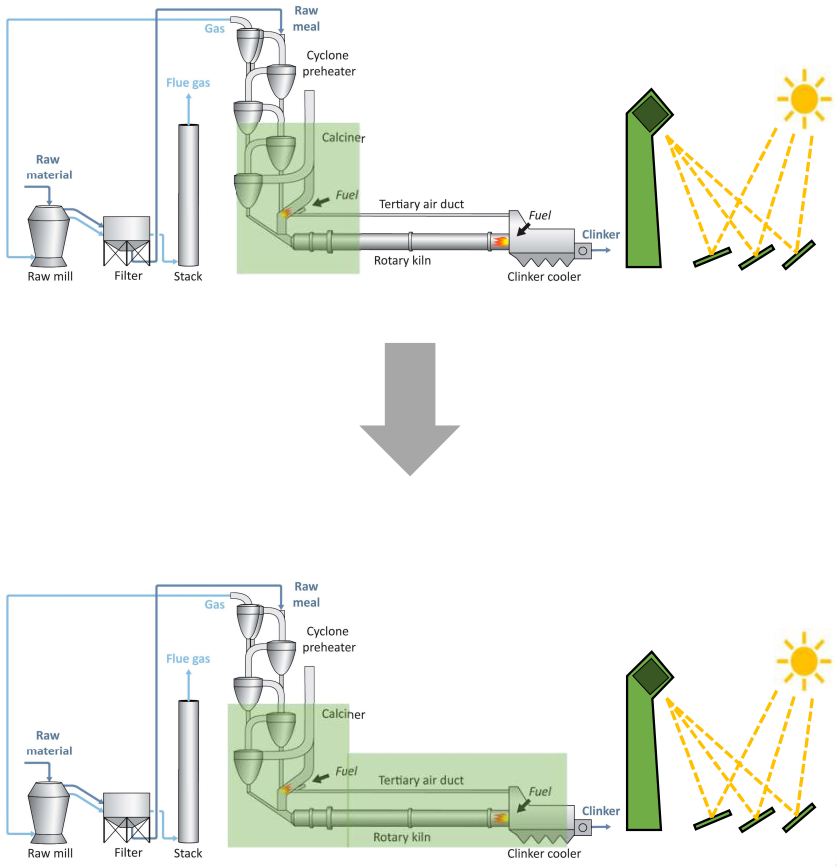
INTEGRATION: STEP-WISE HYBRIDIZATION

CONFIGURATION

Solar Calcination →

Full Solar →

INTERVENTION SCHEME



2021
Calcination "Lab" Pilot
250kW$_{th}$

2023
Calcination Pilot
1 MW$_{th}$

Full Solar
10 MW$_{th}$

2026
Full Scale Integration
100MW$_{th}$

2028
Industrial Scale
150MW$_{th}$
900 tpd

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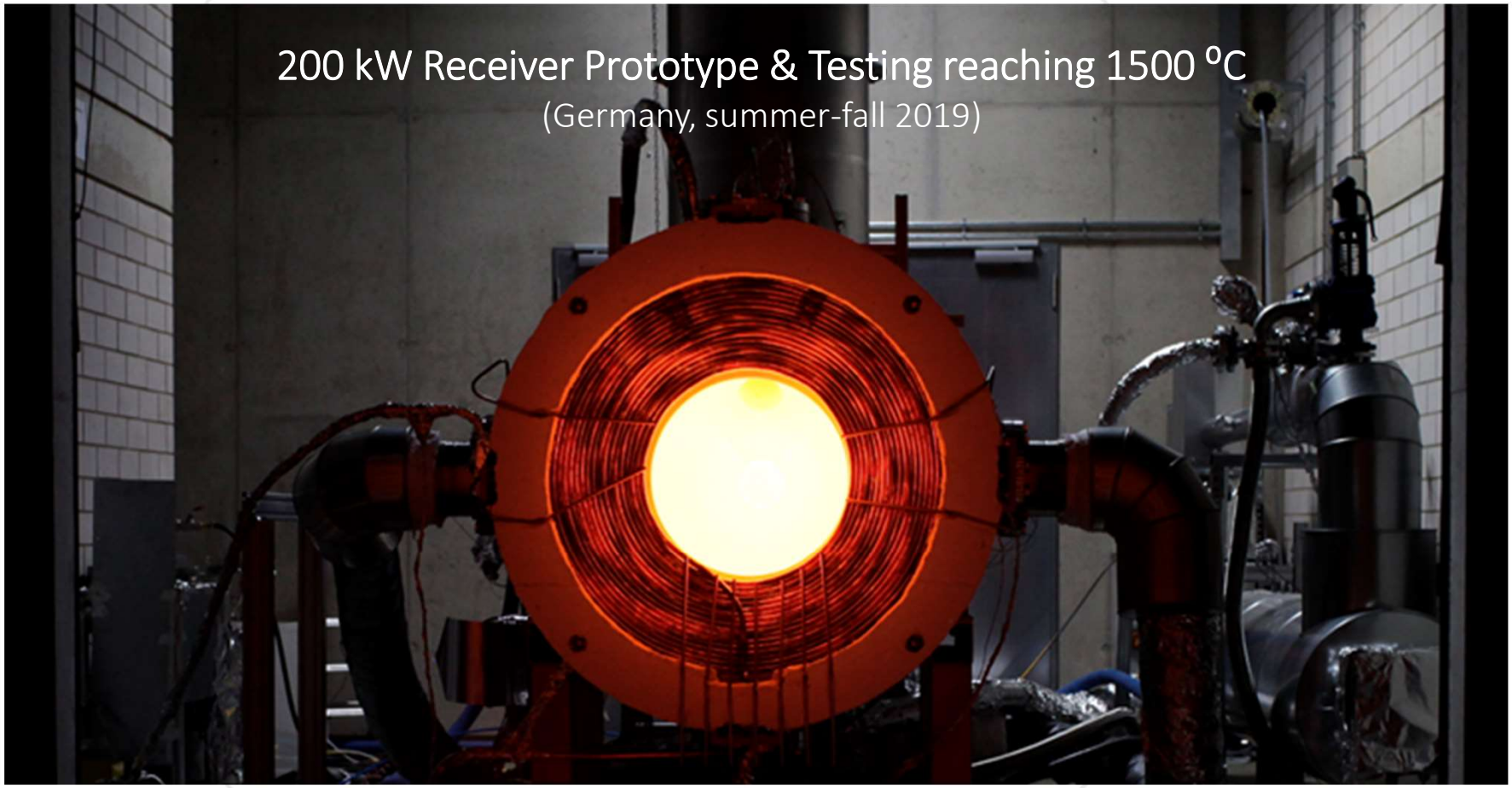
TECHNOLOGICAL VALIDATION – KEY MILESTONES

Synhelion



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