CEMENT PRODUCTION

Energy Storage for Manufacturing and Industrial Decarbonization Workshop “Energy StorM”

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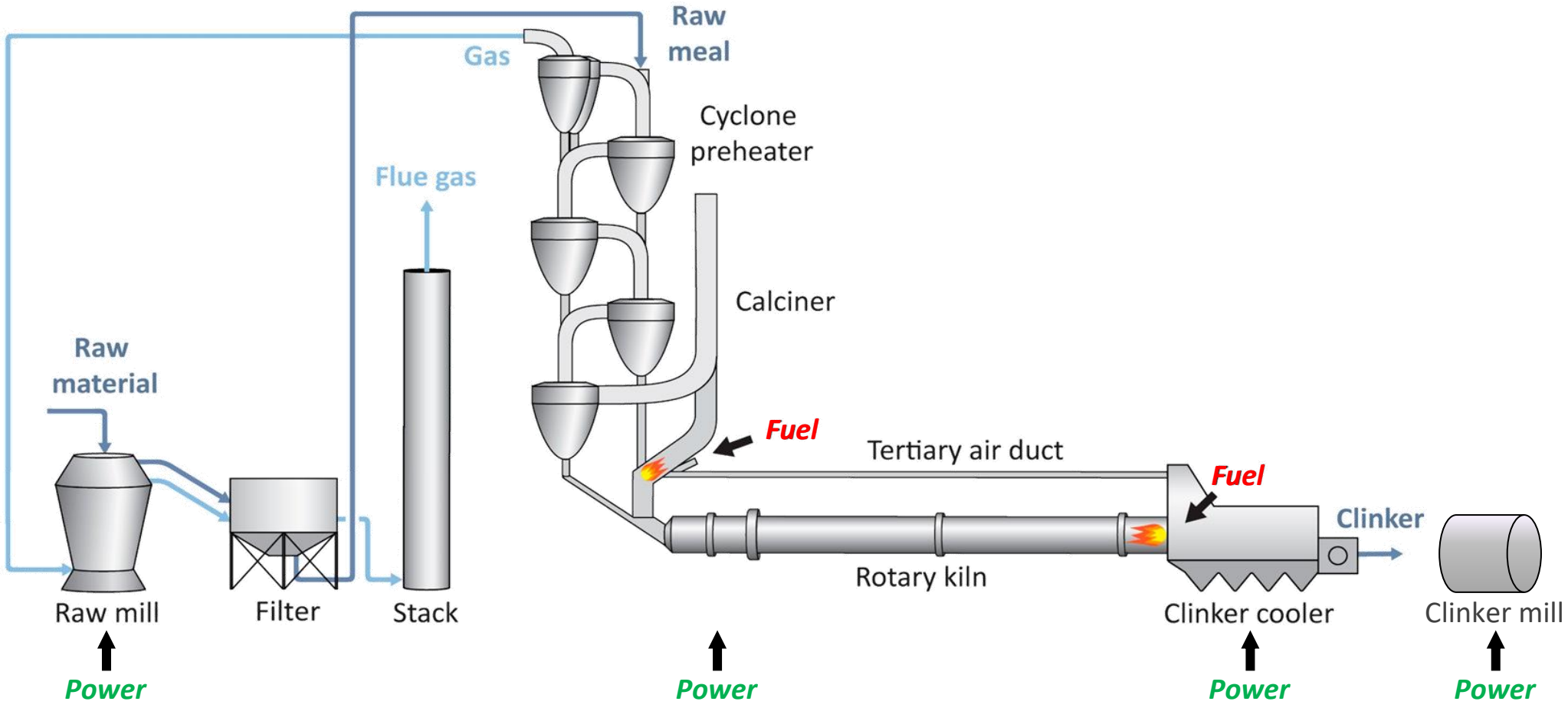
Dr. Gianluca Ambrosetti
CEO, Synhelion SA

Dr. Davide Zampini
Head of CEMEX Global R&D

CLINKER MANUFACTURING PROCESS

PRODUCTION PROCESS



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Cement manufacture diagram from Voldsund et al. Energies 2019, 12, 559

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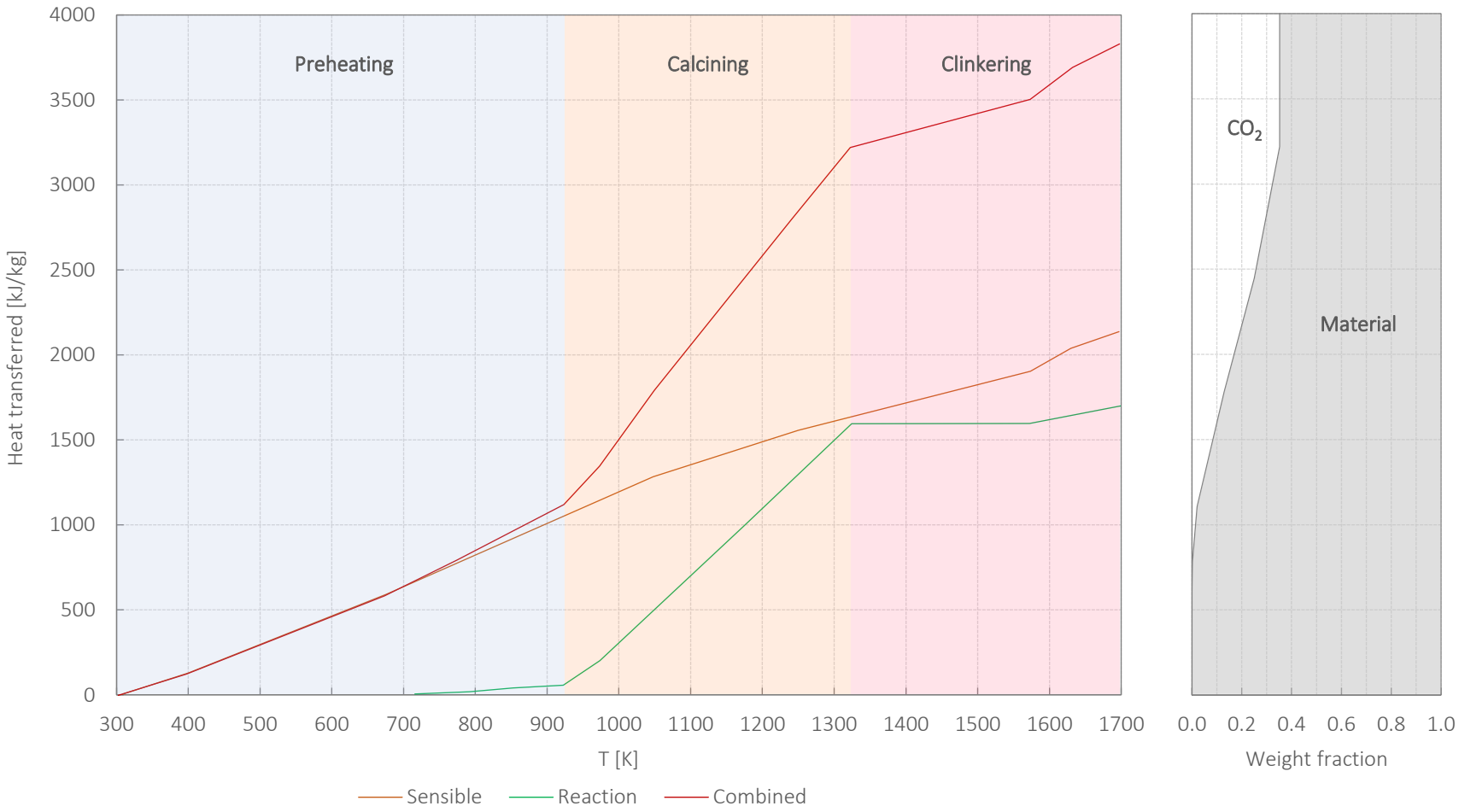
CLINKER THEMROCHEMISTRY

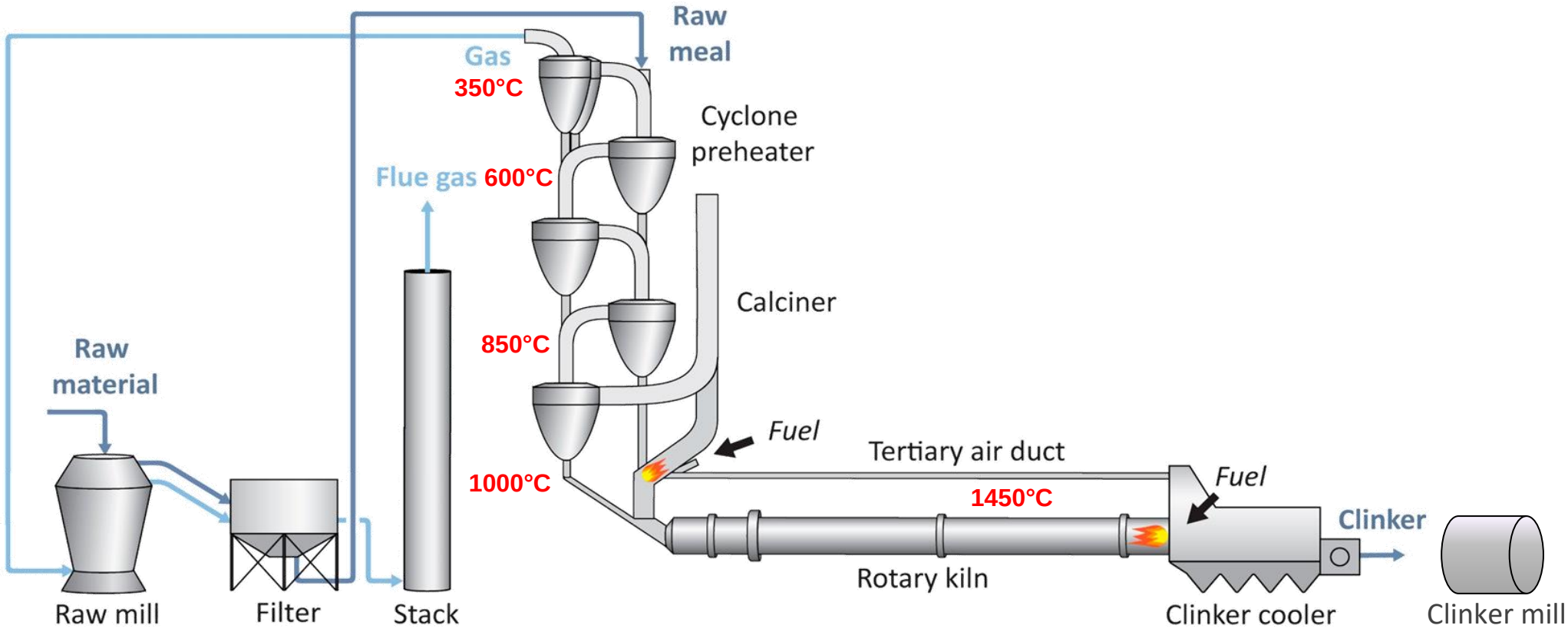
Cumulated reaction and sensible heat as a function of material temperature. **Sensible heat is largely recovered**.



Source: https://www.cementkilns.co.uk/ckr_therm.html

CLINKER MANUFACTURING PROCESS

TEMPERATURES



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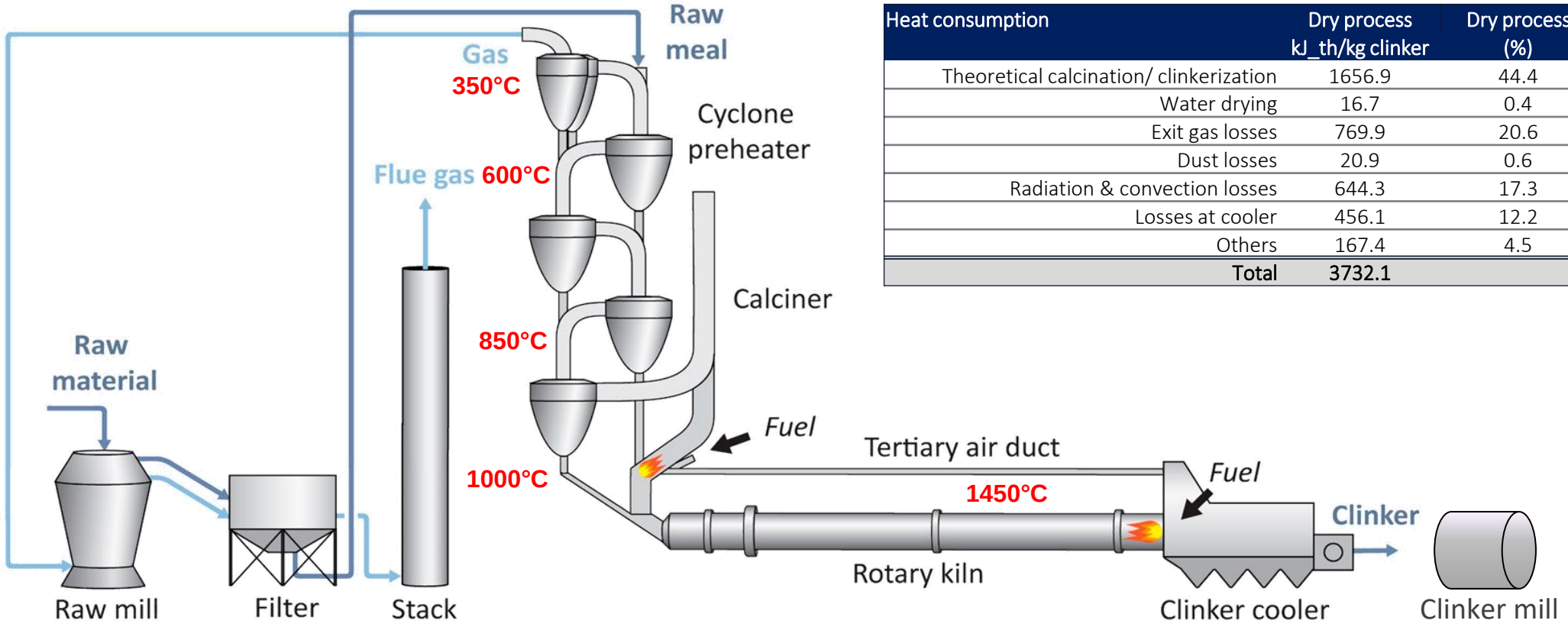
CLINKER MANUFACTURING PROCESS

ENERGY REQUIREMENTS



Heat consumption	Dry process kJ_th/kg clinker	Dry process (%)
Theoretical calcination/ clinkerization	1656.9	44.4
Water drying	16.7	0.4
Exit gas losses	769.9	20.6
Dust losses	20.9	0.6
Radiation & convection losses	644.3	17.3
Losses at cooler	456.1	12.2
Others	167.4	4.5
Total	3732.1	

Power consumption	Dry process kWh_el/t clinker	Dry process kJ_el/kg clinker	Dry process (%)
Clinker grinding	44.0	158.4	40
Raw materials grinding	22.0	79.2	20
Kiln gear	27.5	99.0	25
Quarry- related consumption (crusher etc.)	16.5	59.4	15
Total	110.0	396.0	

Power consumption source: CCS Institute 2013, Deployment of CCS in the cement industry

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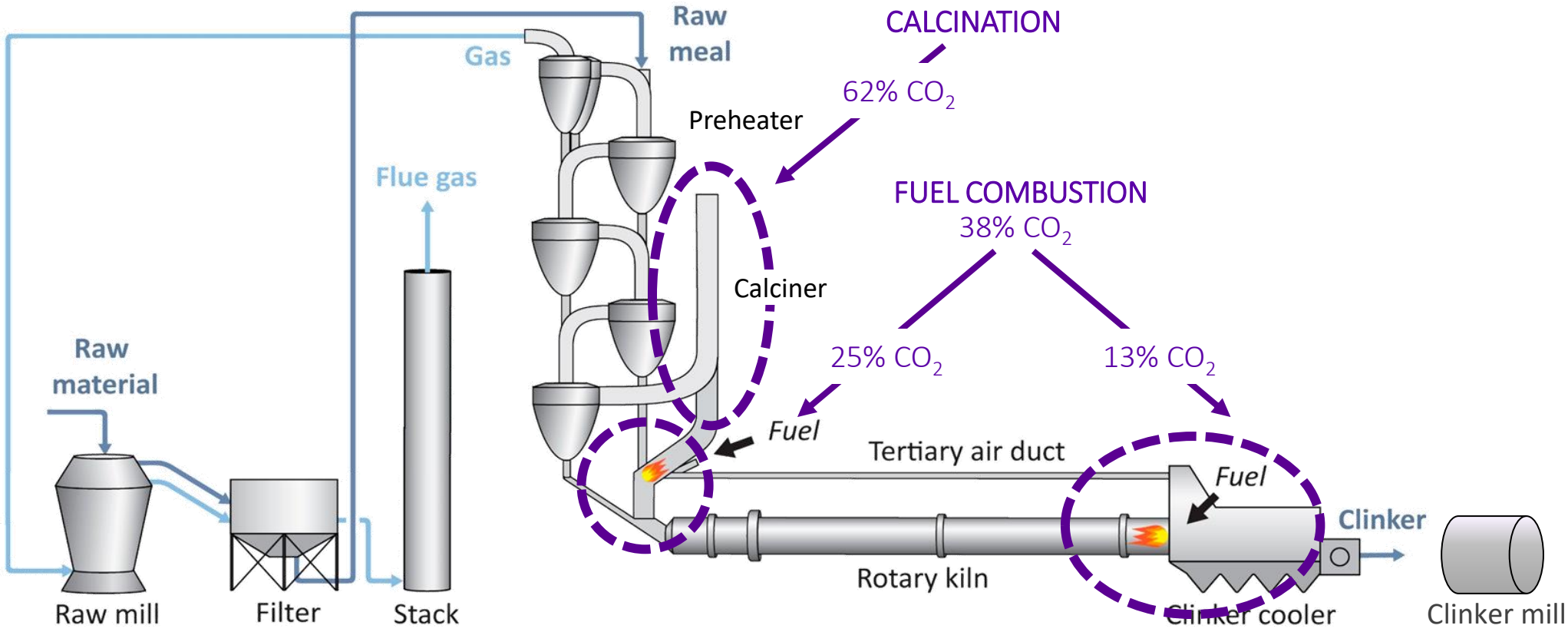
CO_2 GENERATION



3732 kJ/kg clinker → **Total CO_2: 828 kg/t clinker**

62% from calcination

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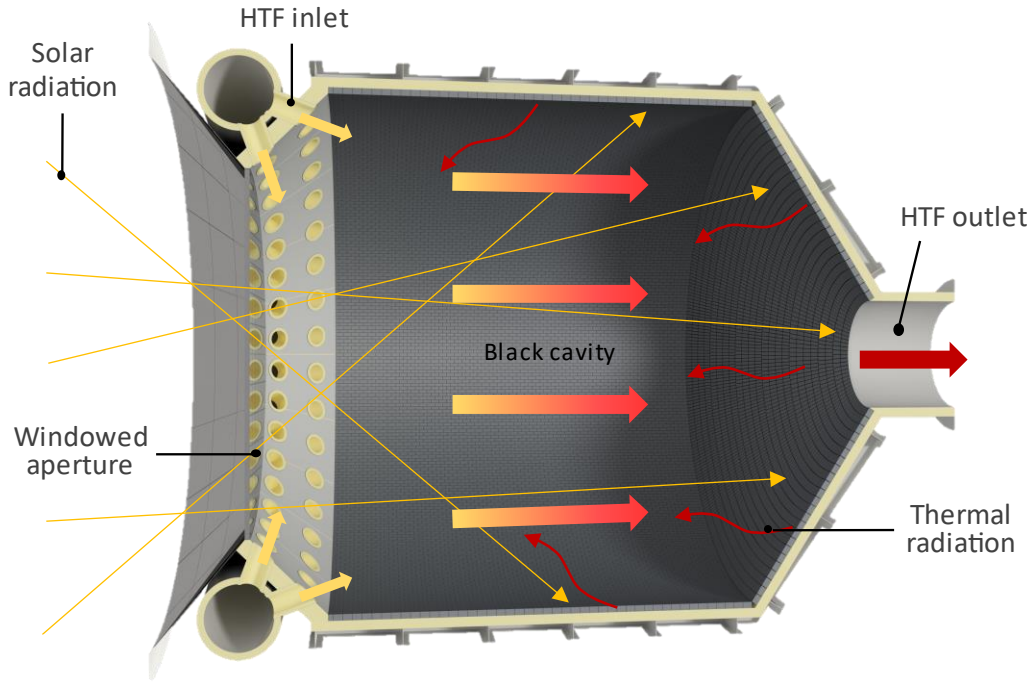
The IR radiation-absorbing (greenhouse) gas is heated by the thermal radiation of the receiver walls and acts as heat transfer fluid (HTF).



- Delivers clean solar process heat at up to 1500°C with receiver efficiency > 80% at moderate solar concentration (~1 MW/m^2)
- HTF: H_2O vapor or mixtures of H_2O and CO_2 (greenhouse gases)

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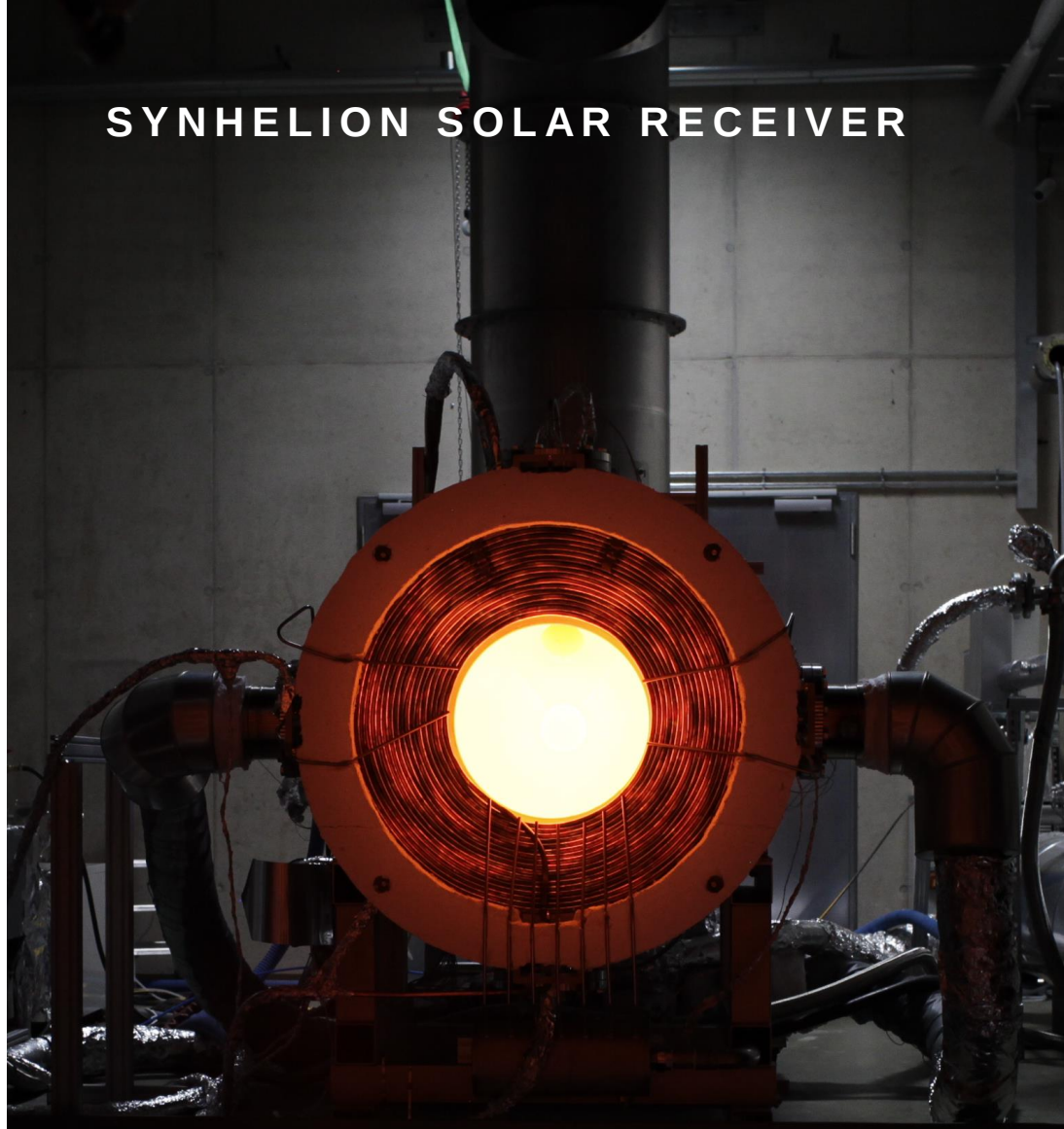
G. Ambrosetti and P. Good, Solar Energy 183, 521–531, 2019

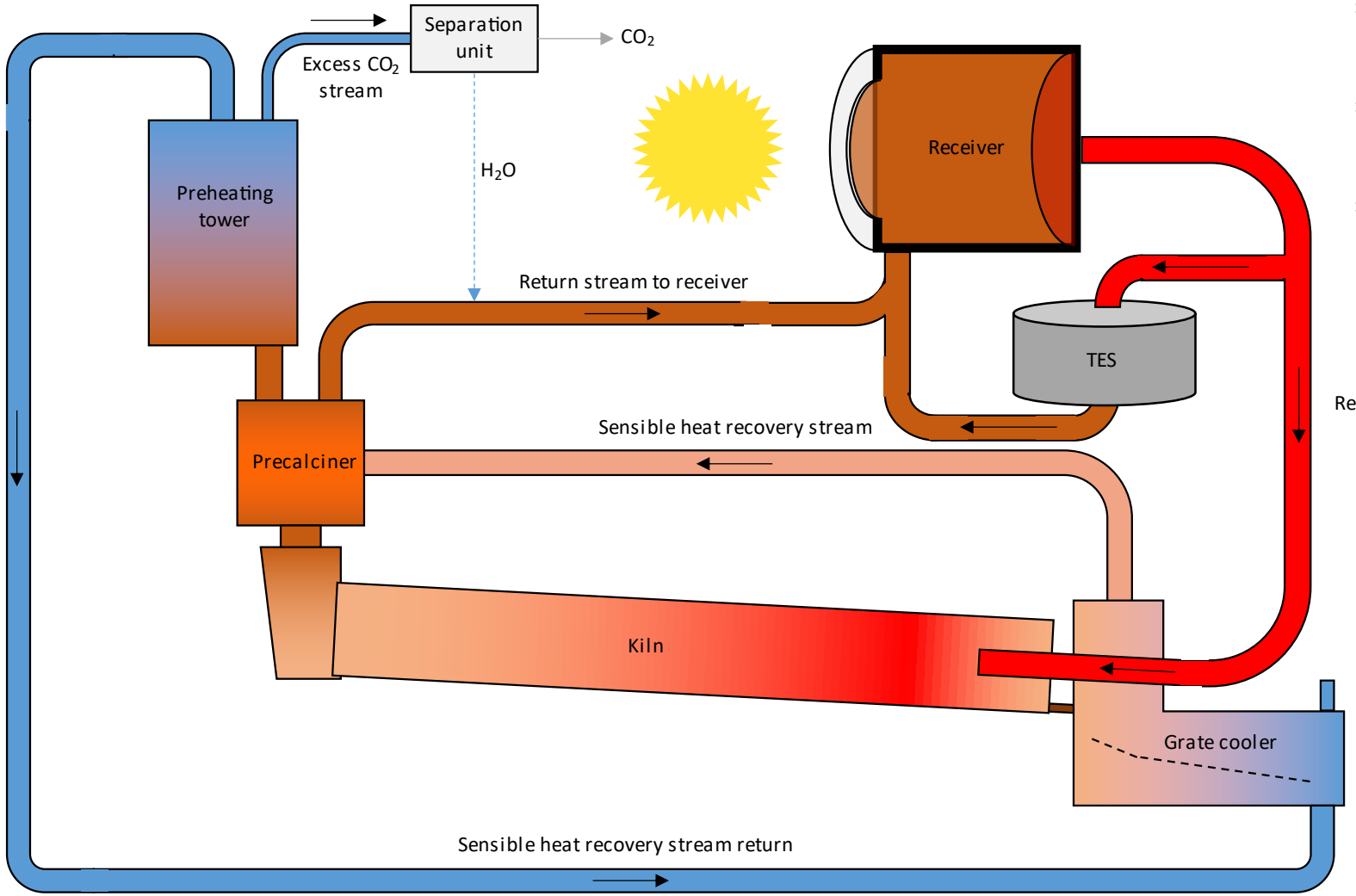
SYNHELION SOLAR RECEIVER



The 250 kW receiver unit glowing after tests at DLR's Synlight (Jülich, Germany)

SOLAR CLINKER

SOLAR-DRIVEN PYRO-PROCESSING OF CLINKER



- HTF is a **mixture of H_2O and CO_2**
- **CO_2 from calcination** gets mixed with HTF and **is easily separated** in concentrated form
- **Radiation-dominated heat transfer** from HTF in kiln (radiative / greenhouse gases)
- **Thermal energy storage (TES)** enables **continuous operation**

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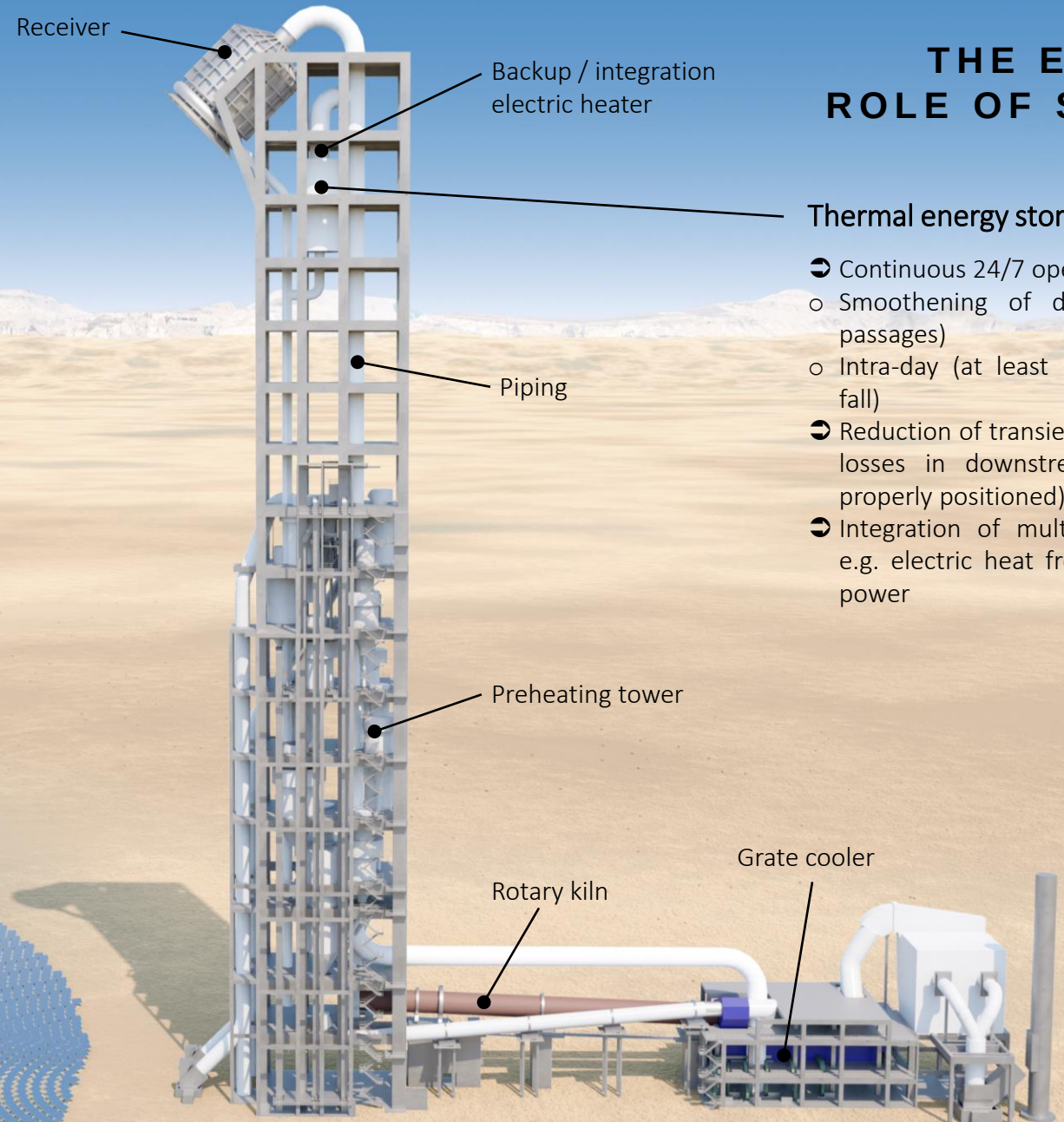
SOLAR CLINKER

THE ENABLING ROLE OF STORAGE



Thermal energy storage (TES)

- Continuous 24/7 operation
  - Smoothening of daily fluctuation (cloud passages)
  - Intra-day (at least in spring, summer, and fall)
- Reduction of transient (thermal inertia) heat losses in downstream piping (if storage properly positioned)
- Integration of multiple stochastic sources e.g. electric heat from curtailed renewable power

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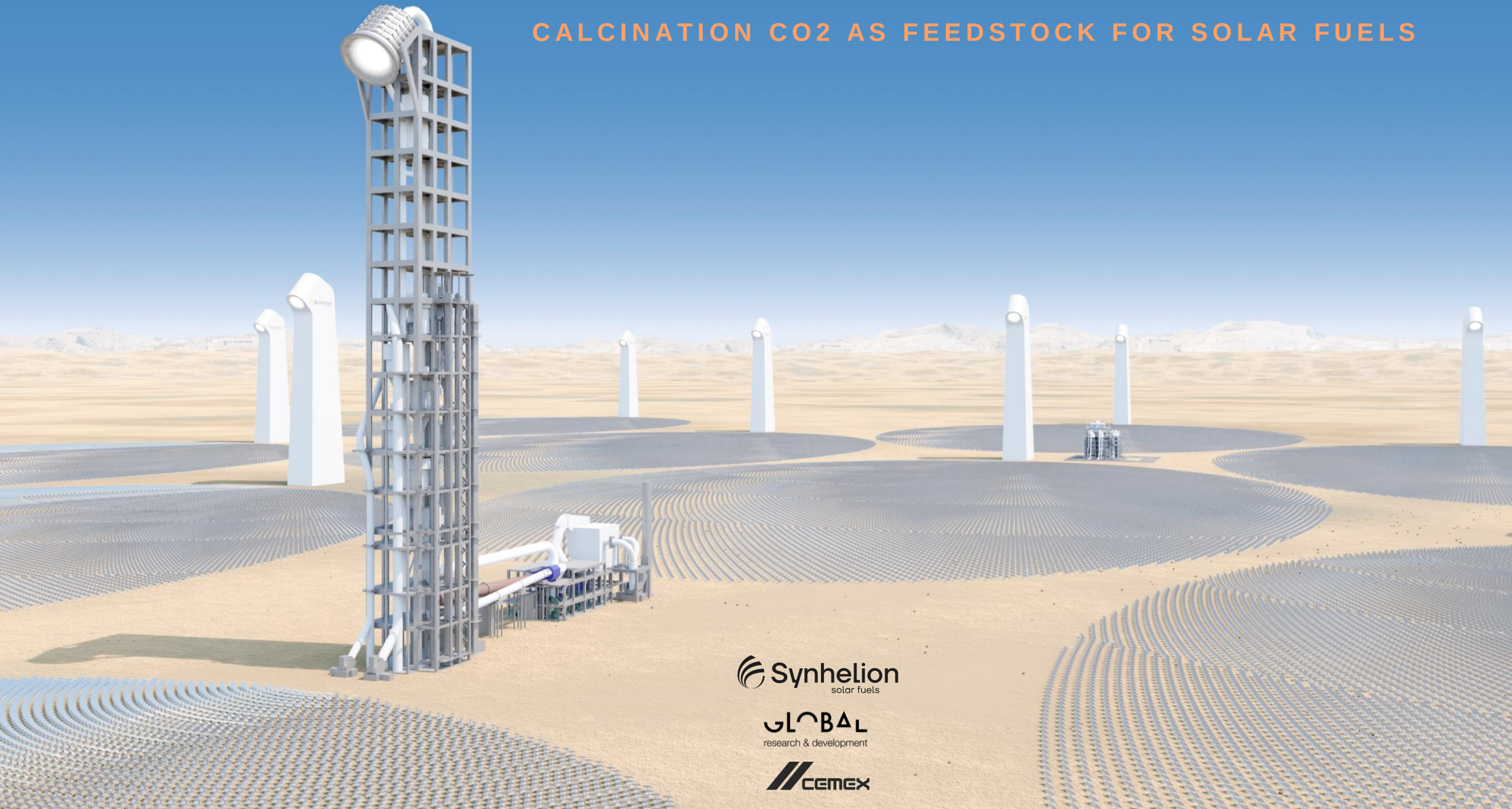
CALCINATION CO2 AS FEEDSTOCK FOR SOLAR FUELS



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