

CLEAN clinker by calcium
looping for low-CO₂ cement

CLEAN KER



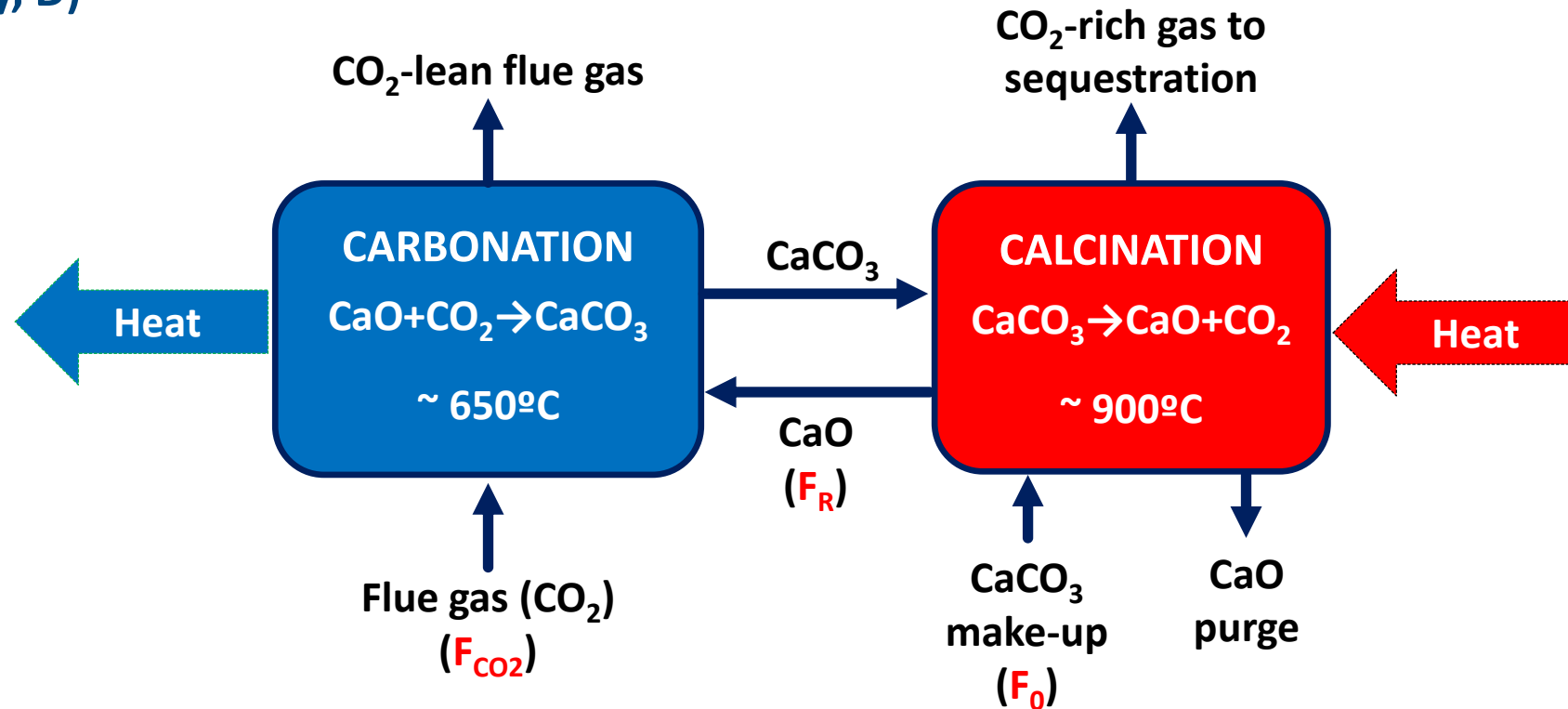
CLEAN KER – Clean clinker by calcium looping process for low-CO₂ cement production – Overview and current stage

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- Originally proposed by Shimizu et al., 1999. A twin fluid-bed reactor for removal of CO₂. Chem. Eng. Res. Des., 77.
- Continuously developed since 1998, mainly for application in power plants
- Several fluidized bed pilot facilities - demonstrated at size > 1 MW (La Pereda, Oviedo, ES; Darmstadt University, D)



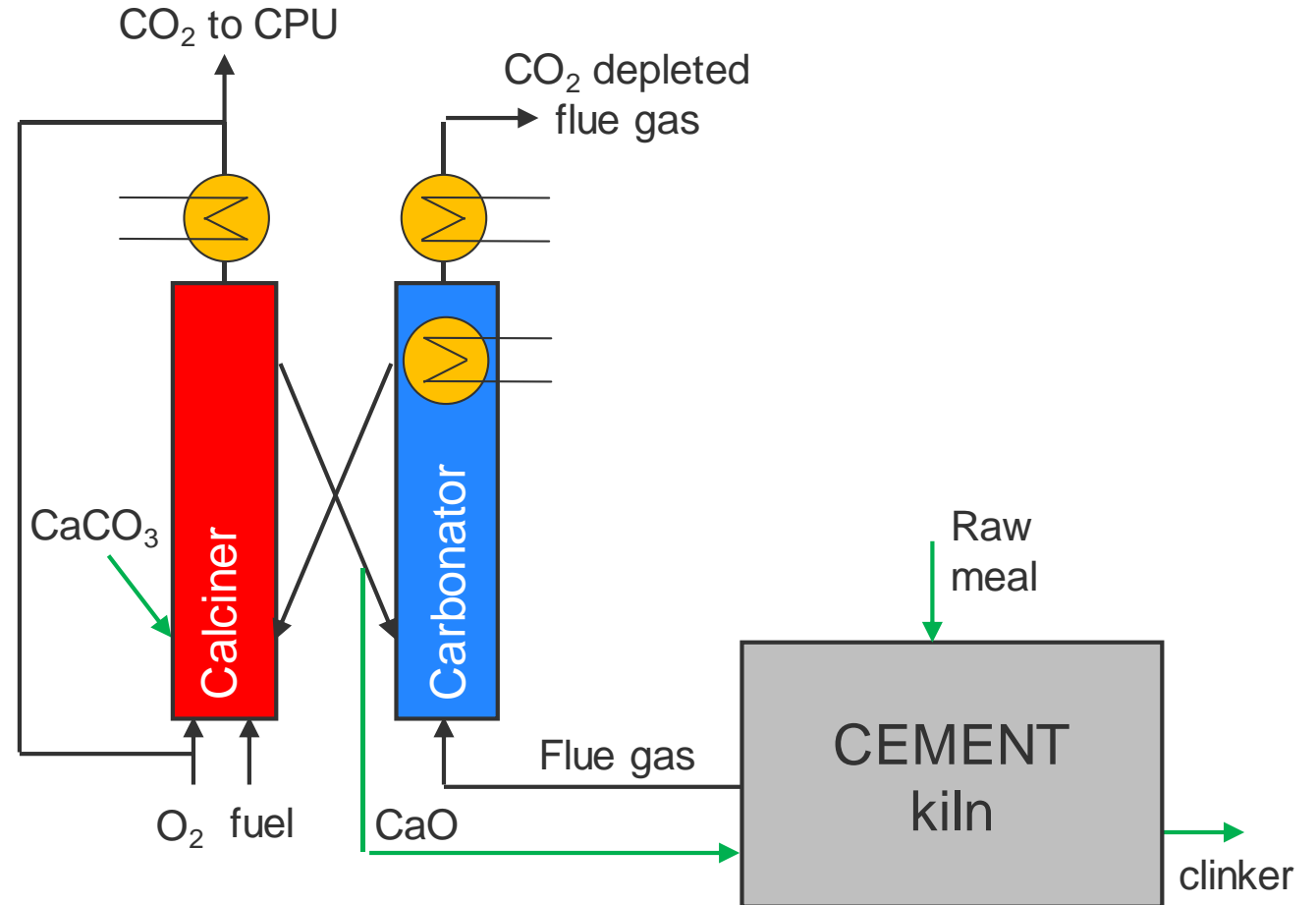
«Tail-end» CaL configuration

- Carbonator removes CO₂ from cement plant flue gas → highly suitable for retrofit
- CaO-rich purge from CaL calciner used as feed for the cement kiln
- High fuel consumption due to double calcination of the mineral CO₂ (air-blown precalciner + oxy-blown CaL calciner)

Arias et al., 2017. CO₂ Capture by CaL at Relevant Conditions for Cement Plants: Experimental Testing in a 30 kW Pilot Plant. *Ind. Eng. Chem. Res.*, 56, 2634–2640.

Hornberger et al., 2017. CaL for CO₂ Capture in Cement Plants – Pilot Scale Test. *Energy Procedia*, 114, 6171–6174.

De Lena et al., 2017. Process integration of tail-end CaL in cement plants. *Int J Greenh Gas Control* 67, 71-92.

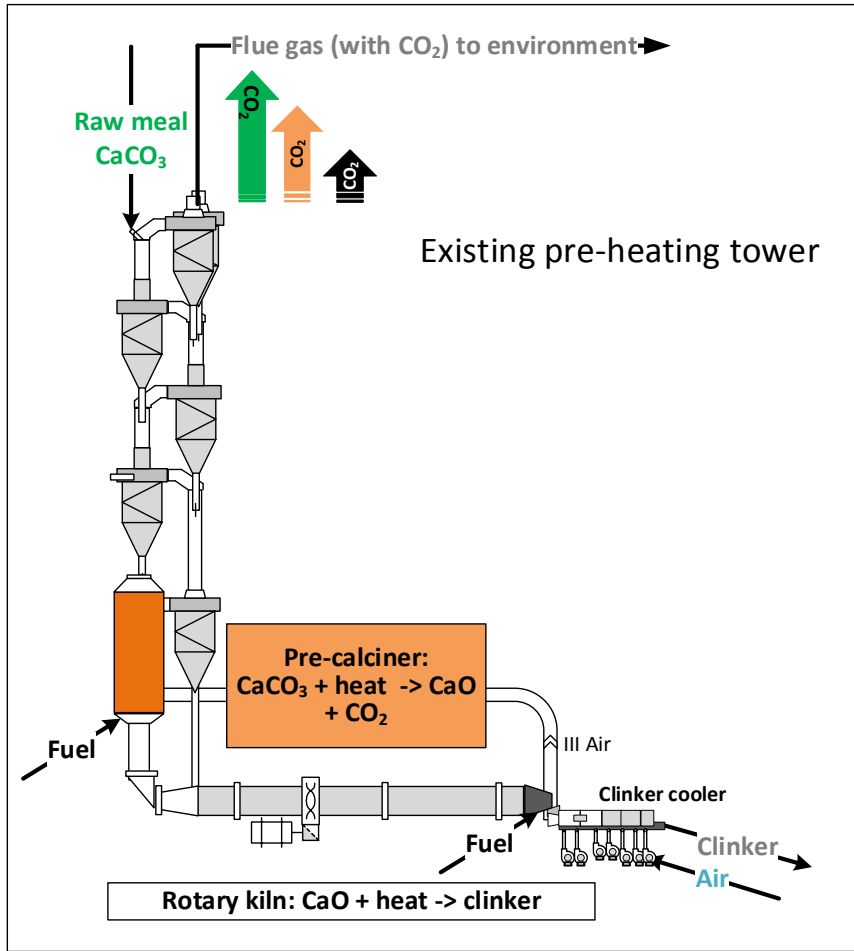


CEMCAP

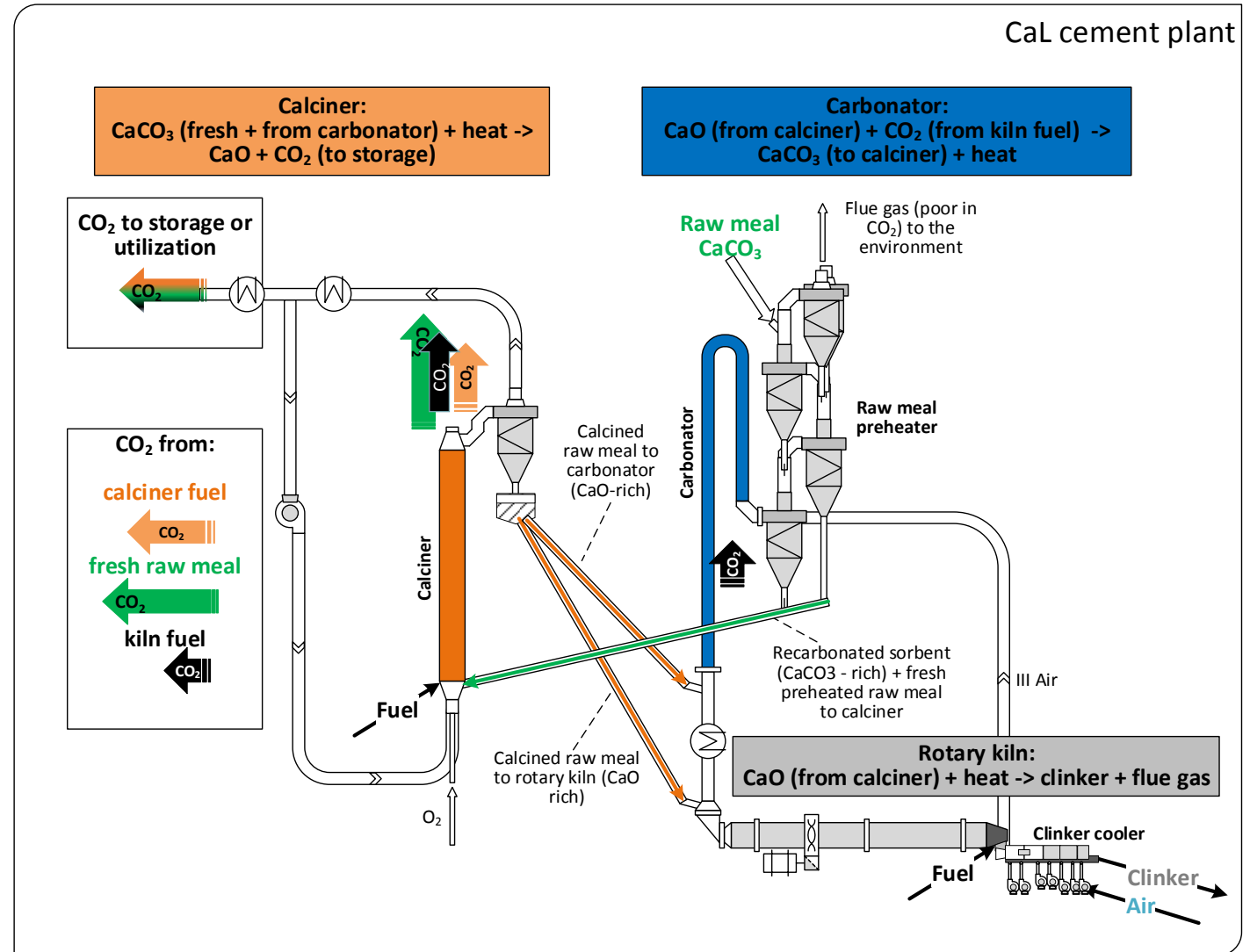


«Integrated» CaL configuration

Conventional cement kiln



Integrated CaL cement kiln

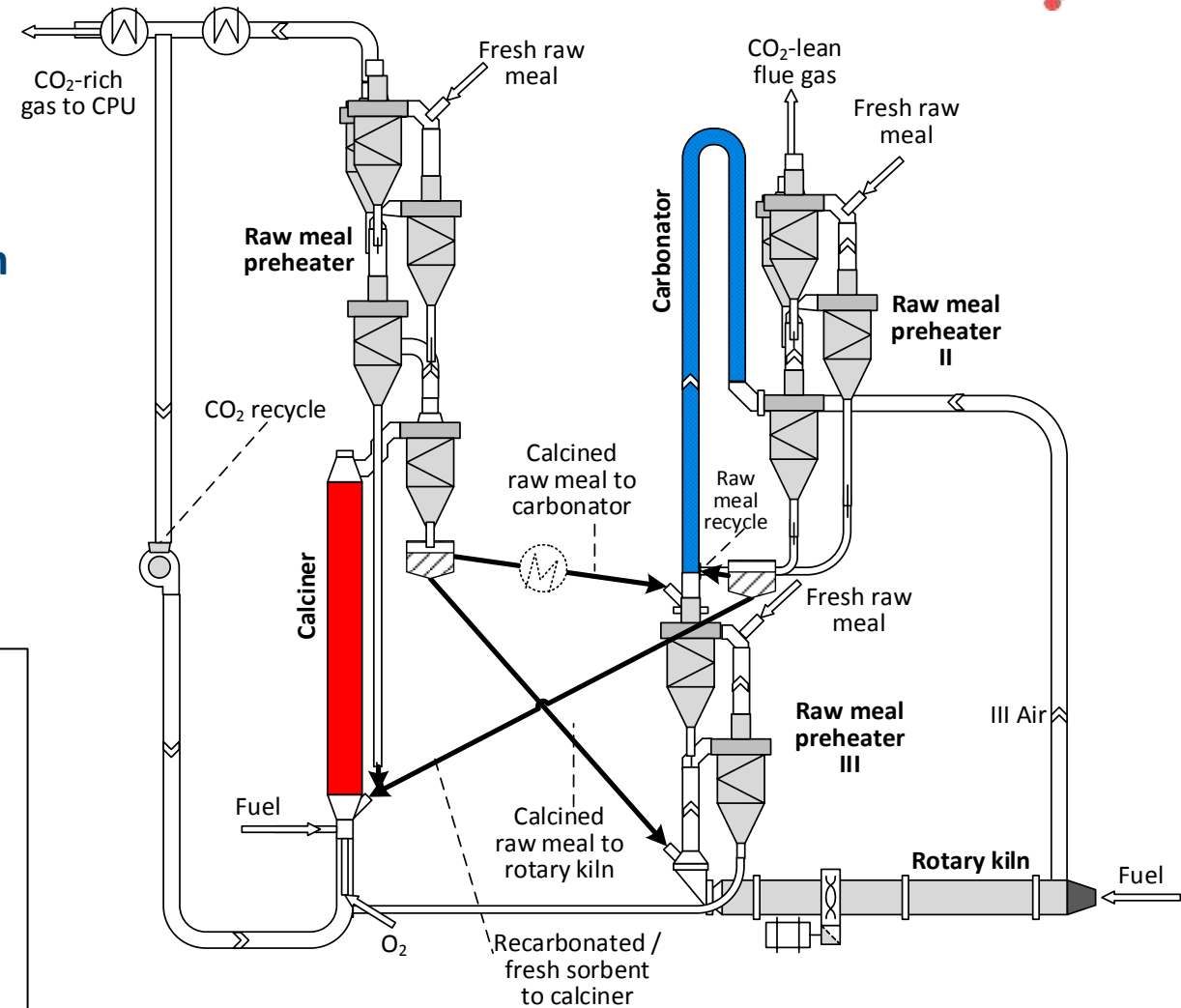


- CaL carbonator integrated in the preheater, treats the rotary kiln gas only
- CaL calciner coincides with the cement kiln pre-calciner → single calcination step and reduced fuel consumption
- Calcined raw meal as CO₂ sorbent in the carbonator
- Sorbent has small particle size ($d_{50}=10-20 \mu\text{m}$) → entrained flow reactors

Alonso et al., 2018. Capacities of Cement Raw Meals in Calcium Looping Systems. *Energy & Fuels*, 31, 13955–13962.

Spinelli et al., 2018. One-dimensional model of entrained-flow carbonator for CO₂ capture in cement kilns by calcium looping process. *Chemical Engineering Science*, 191, 100-114.

De Lena et al., 2019. Techno-economic analysis of Calcium Looping processes for low CO₂ emission cement plants. *Int J Greenh Gas Control*, 82, 244-260.



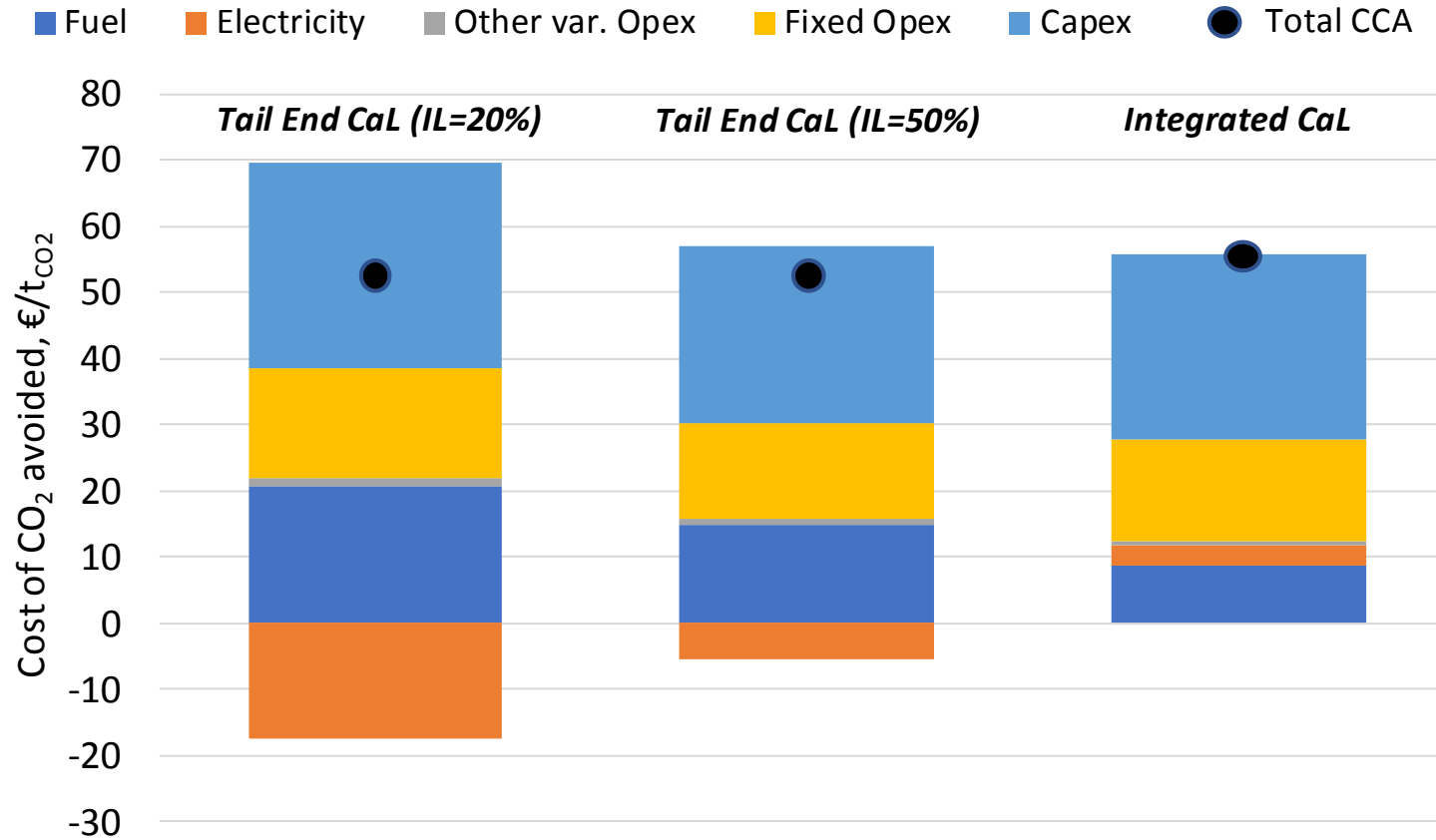
Tail-end vs. Integrated CaL configurations

	Cement plant w/o capture	Tail-end CaL (20% integration)	Tail-end CaL (50% integration)	Integrated CaL
Carbonator CO₂ capture efficiency [%]	--	88.8	90.0	82.0
Total fuel consumption [MJ_{LHV}/t_{clk}]	3240	8720	7100	5440
Rotary kiln fuel consumption [MJ _{LHV} /t _{clk}]	1230	1220	1220	1150
Pre-calciner fuel consumpt. [MJ _{LHV} /t _{clk}]	2010	1550	850	4290
CaL calciner fuel consumpt. [MJ _{LHV} /t _{clk}]	--	5950	5040	
ASU electric consumption [kWh/t _{cem}]	--	85	73	62
CPU electric consumption [kWh/t _{cem}]	--	110	101	89
Steam turbine production [kWh/t _{cem}]	--	413	260	150
Other auxiliaries consumption [kWh/t _{cem}]	97	137	128	116
Net electricity consumpt. [kWh_{el}/t_{cem}]	97	-81	42	117
Direct CO ₂ emissions [kg _{CO2} /t _{clk}]	865	119	79	55
Indirect CO ₂ emissions [kg _{CO2} /t _{clk}]	35	-29	15	46
Equivalent CO ₂ emissions [kg _{CO2} /t _{clk}]	900	90	94	101
Equivalent CO₂ avoided [%]	--	90.0	89.5	88.8
SPECCA [MJ_{LHV}/kg_{CO2}]	--	4.42	4.07	3.16

De Lena et al., 2019. Techno-economic analysis of Calcium Looping processes for low CO₂ emission cement plants. *Int J Greenh Gas Control*, 82, 244-260.



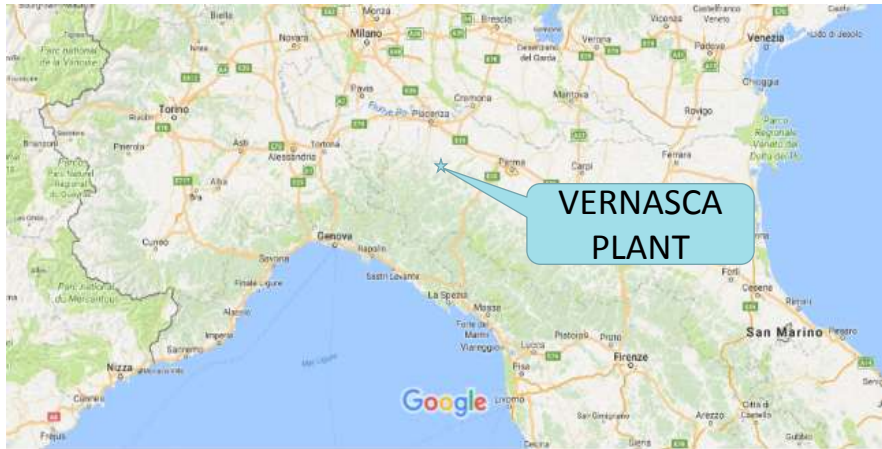
Tail-end vs. Integrated CaL configurations



De Lena et al., 2019. Techno-economic analysis of Calcium Looping processes for low CO₂ emission cement plants. *Int J Greenh Gas Control*, 82, 244-260.



The ultimate objective of CLEANKER is advancing the integrated Calcium-looping process for CO_2 capture in cement plants.



This fundamental objective will be achieved by pursuing the following primary targets:

- Demonstrate the integrated CaL process at TRL 7, in a new demo system connected to the operating cement burning line of the Vernasca 1.300.000 ton/y cement plant, operated by BUZZI in Italy.
- Demonstrate the technical-economic feasibility of the integrated CaL process in retrofitted large scale cement plants through process modelling and scale-up study.
- Demonstrate the storage of the CO_2 captured from the CaL demo system, through mineralization of inorganic material in a pilot reactor of 100 litres to be built in Vernasca, next to the CaL demo system.

The consortium

Starting date: October 1st 2017

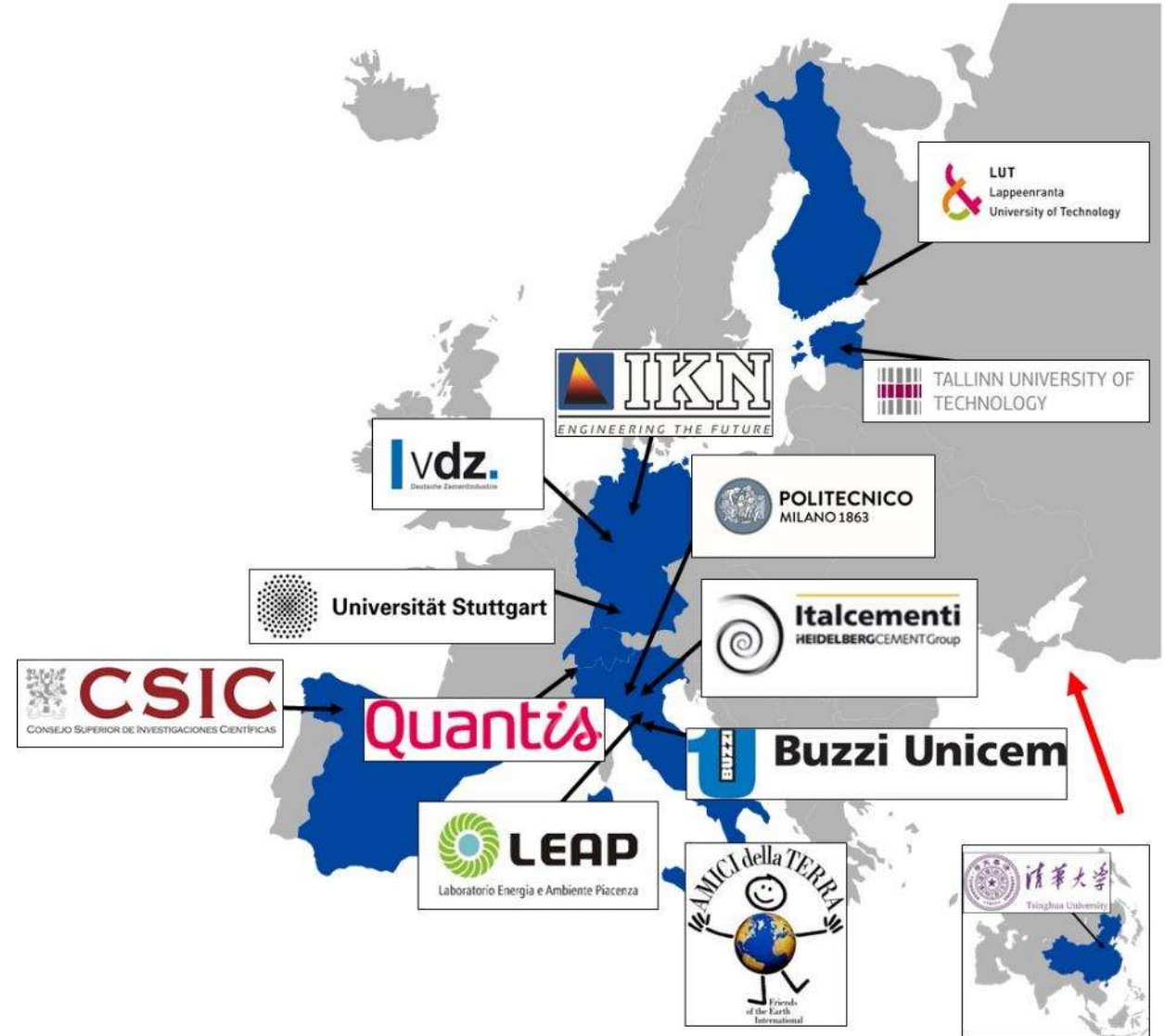
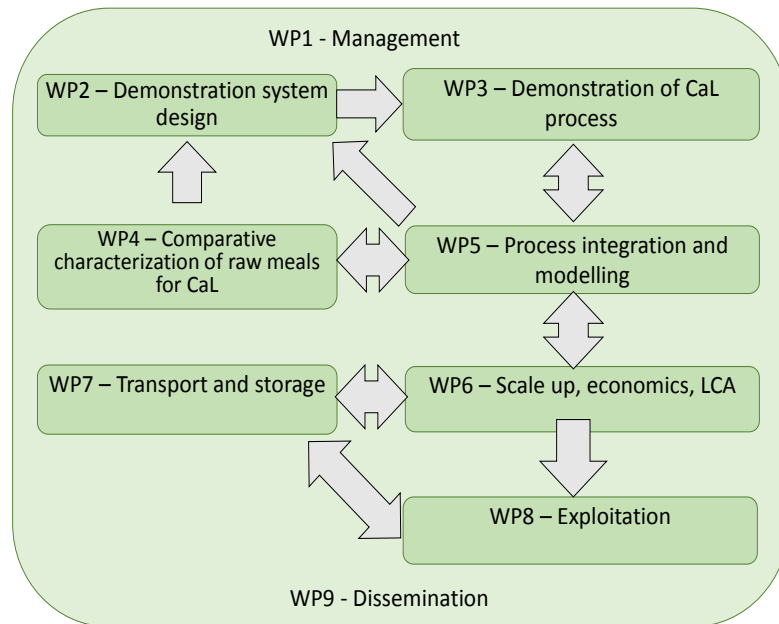
Duration: 4 years

Total budget: € 9.237.851,25

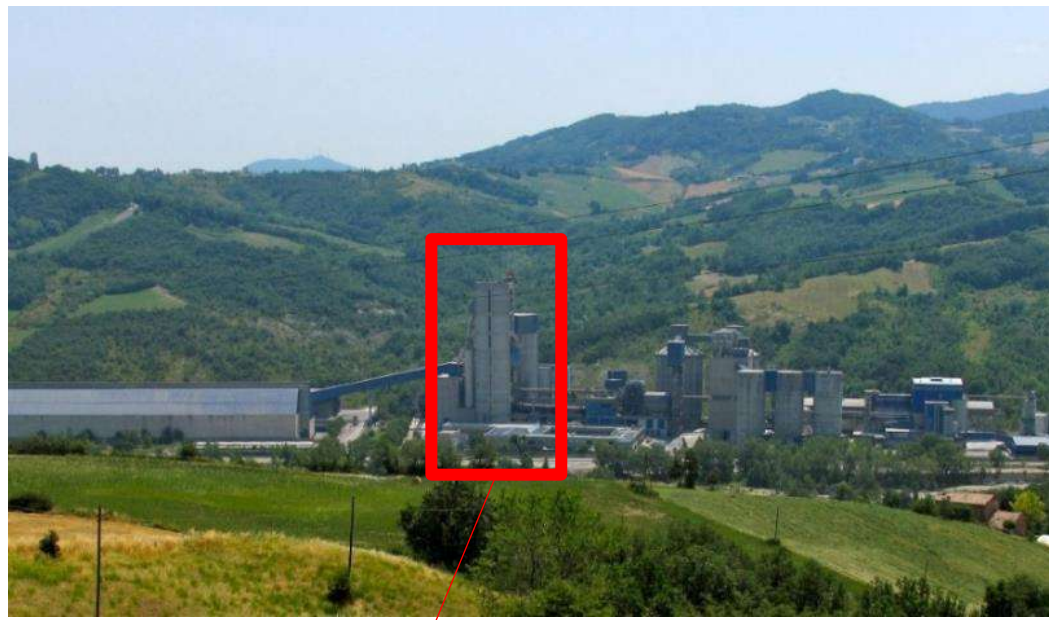
UE co-financing: € 8.972.201,25

Chinese government founding: 265.650 €

Partner: 13 from 5 EU member states +
Switzerland and China



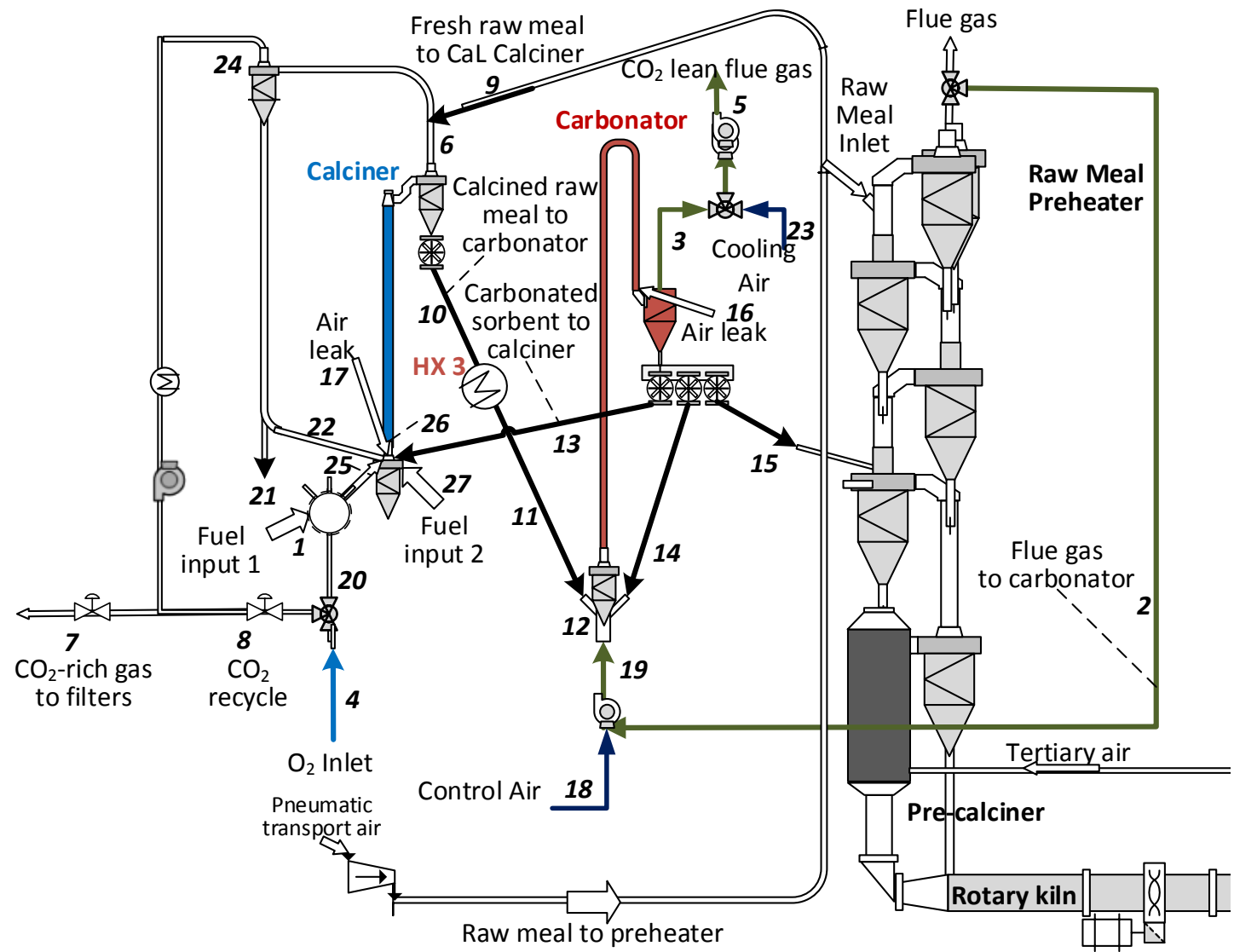
Vernasca kiln preheater and rendering of CaL pilot

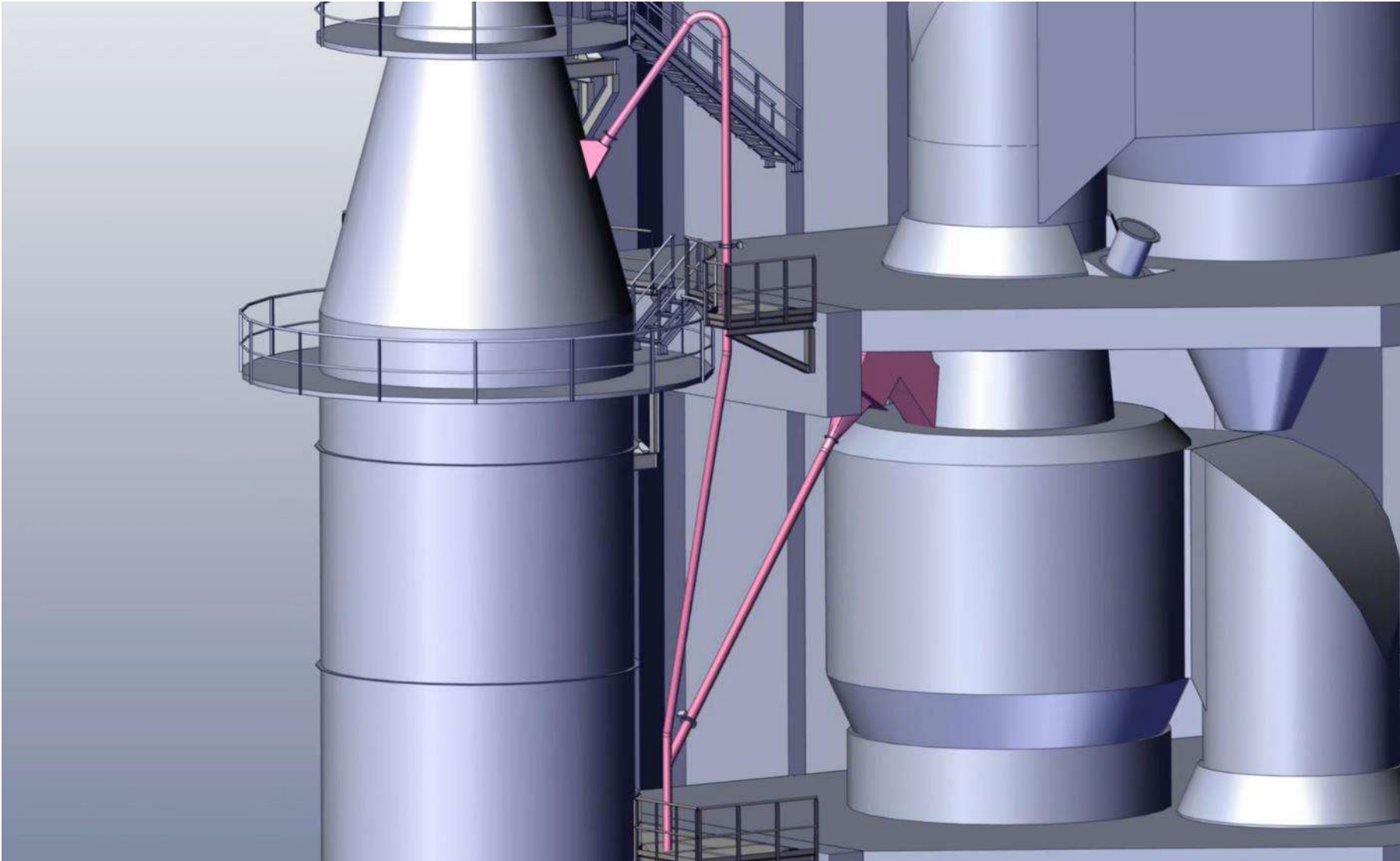


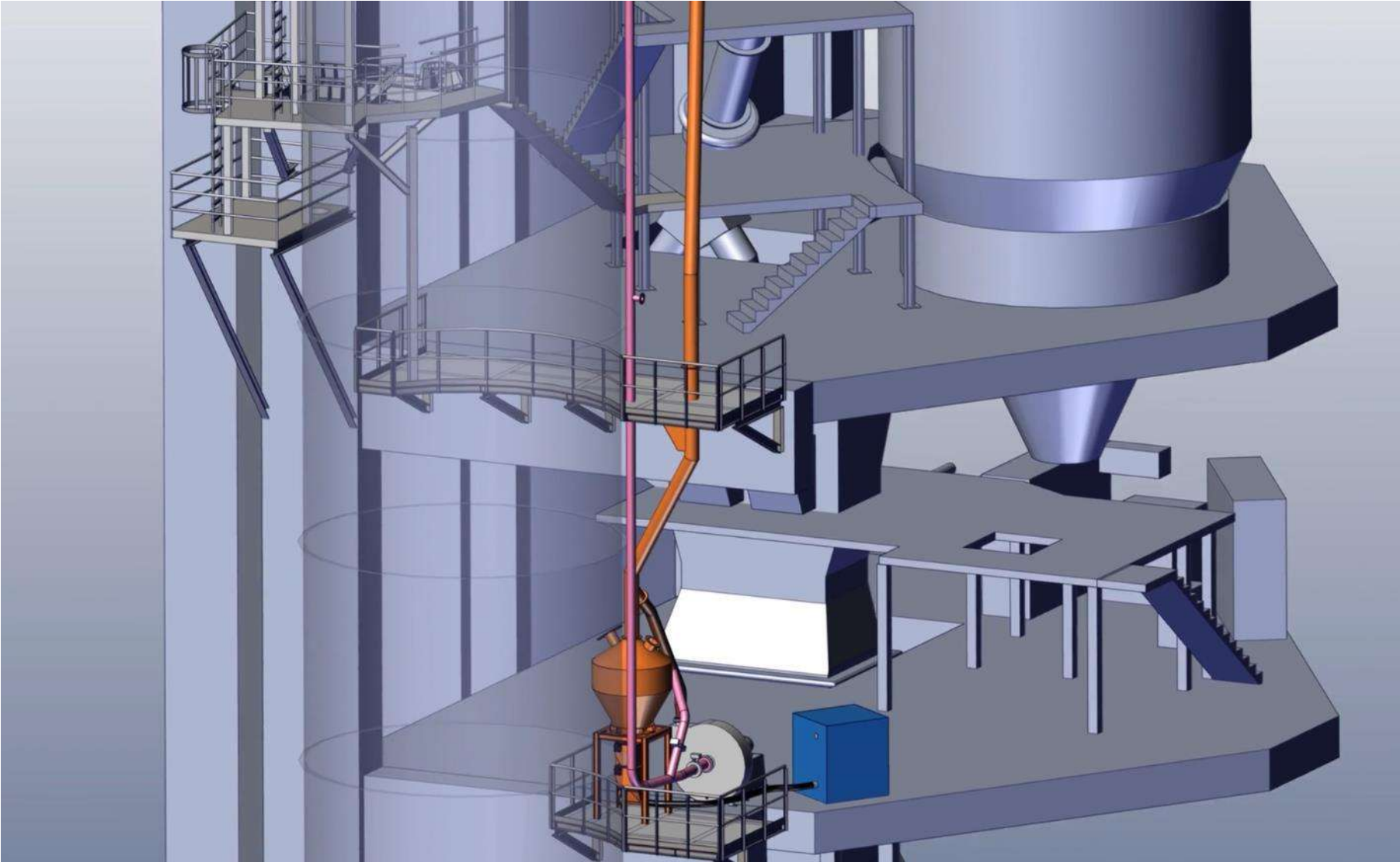
Preheater tower

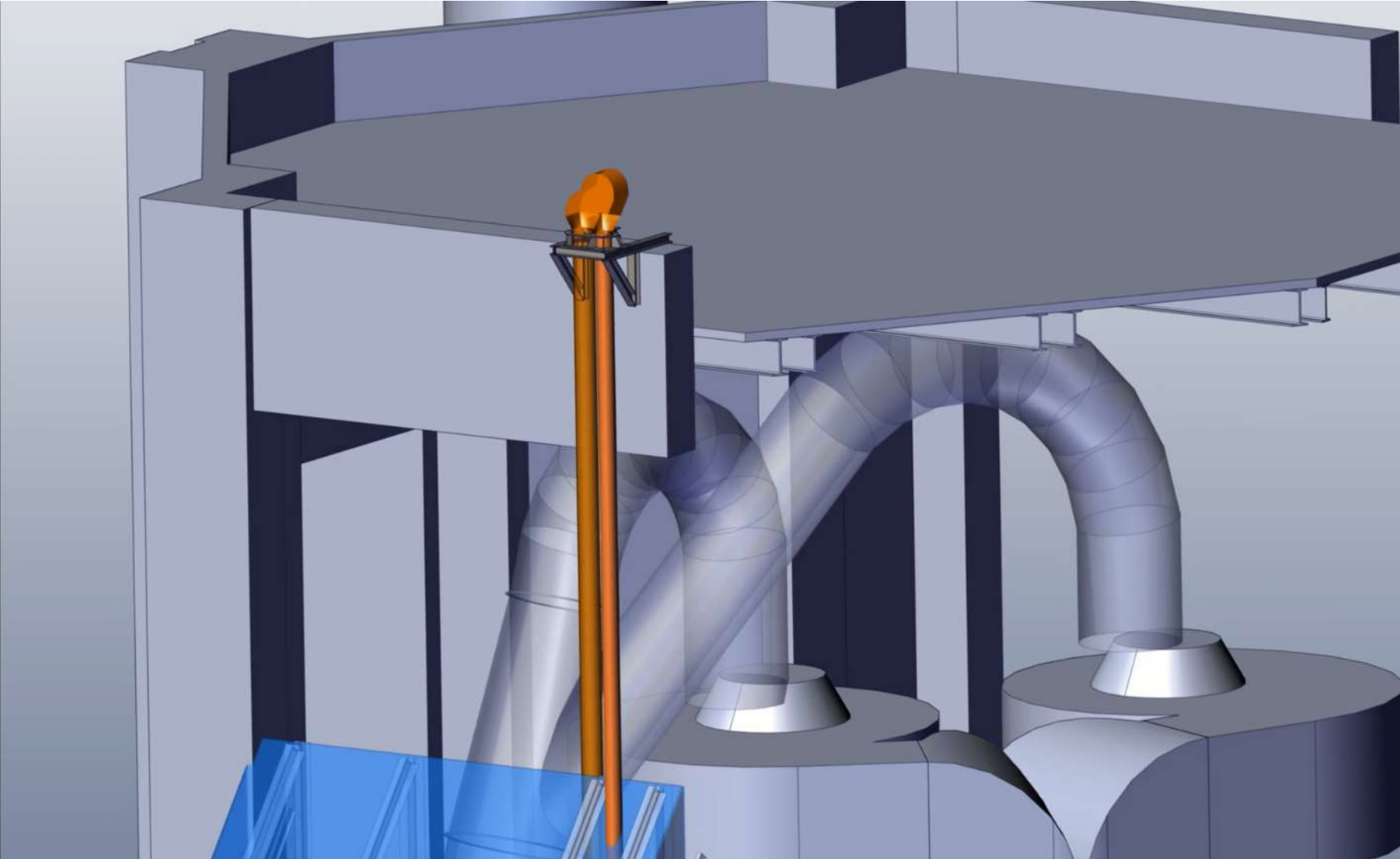


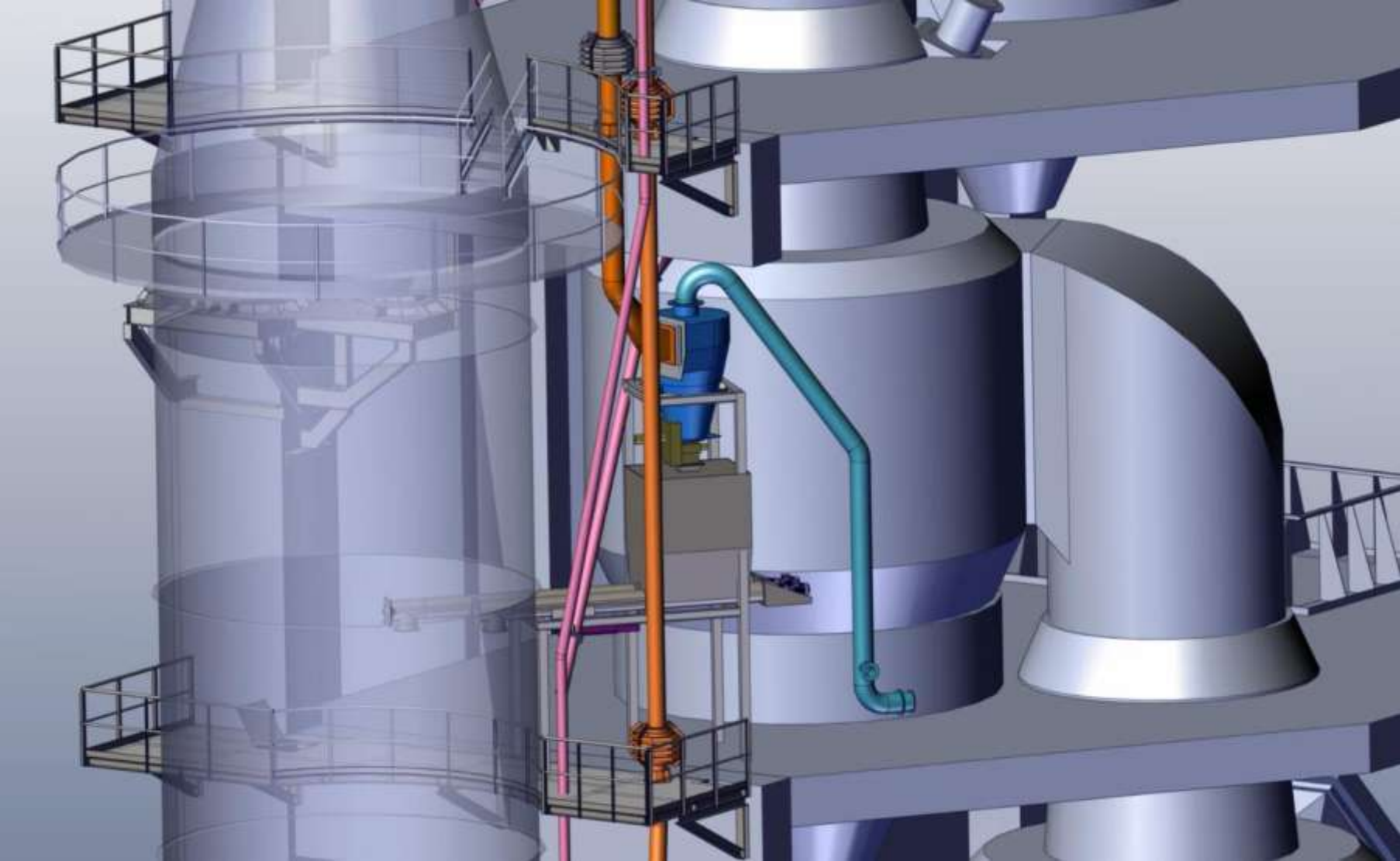
CLEANKER pilot plant configuration

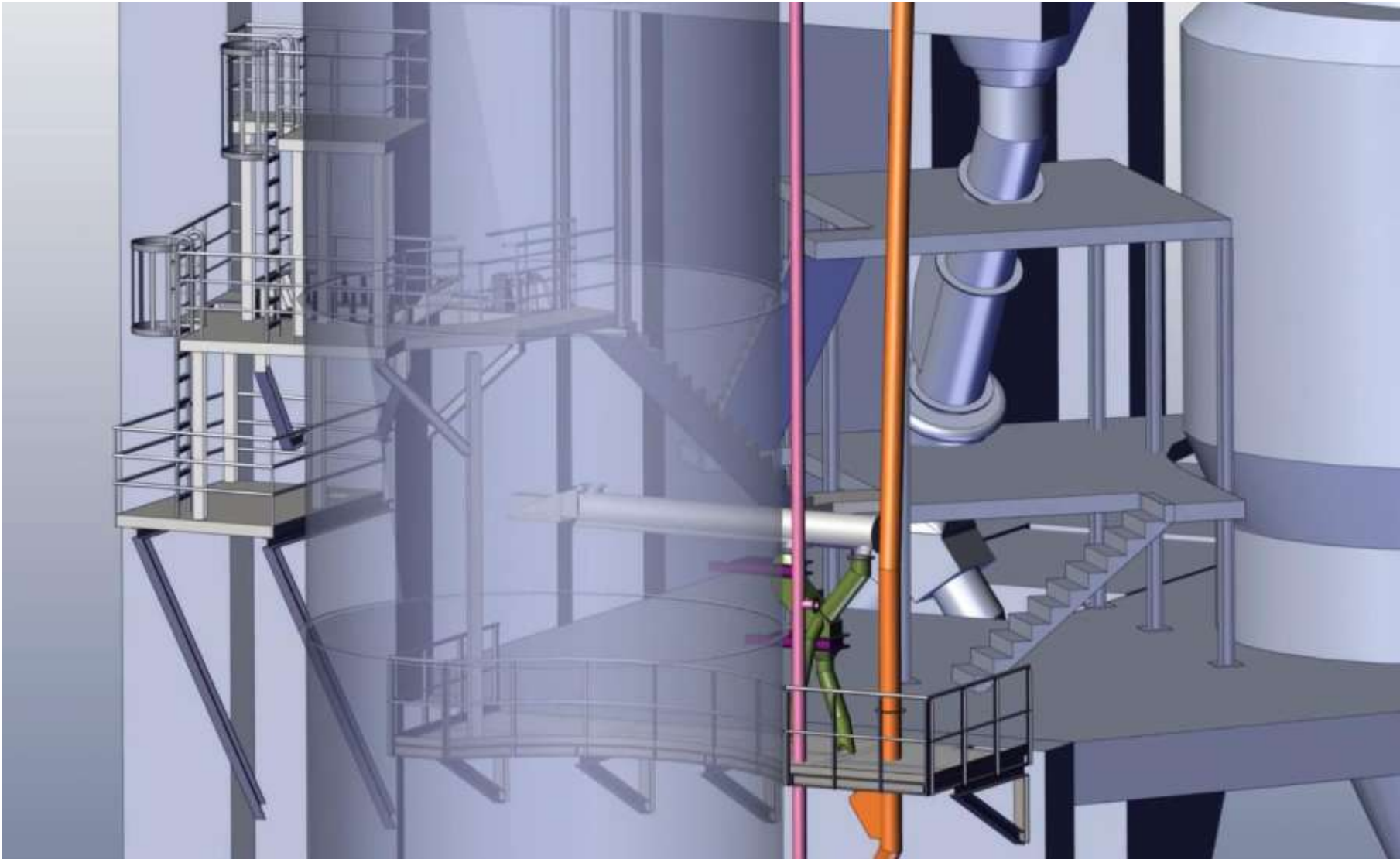




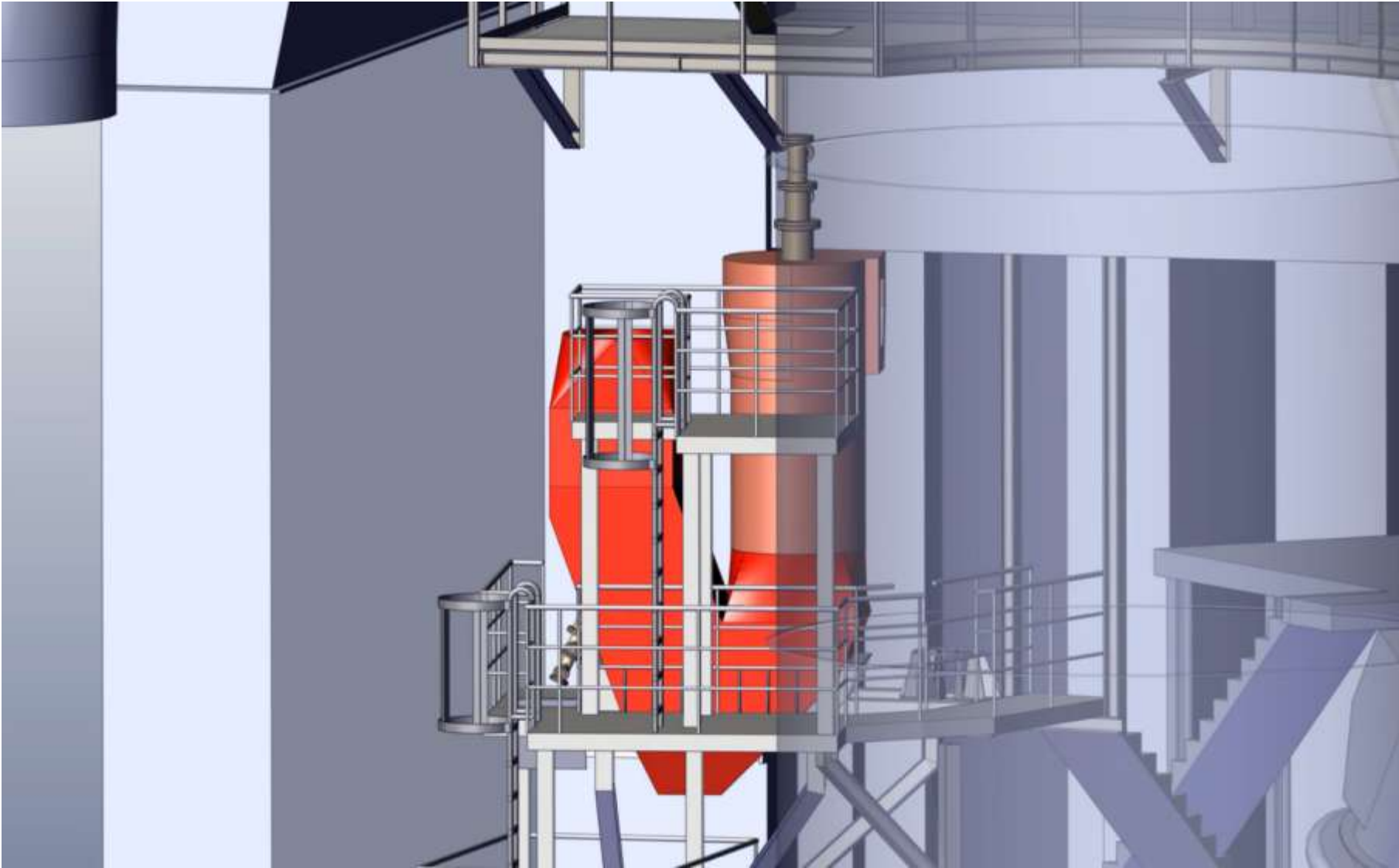


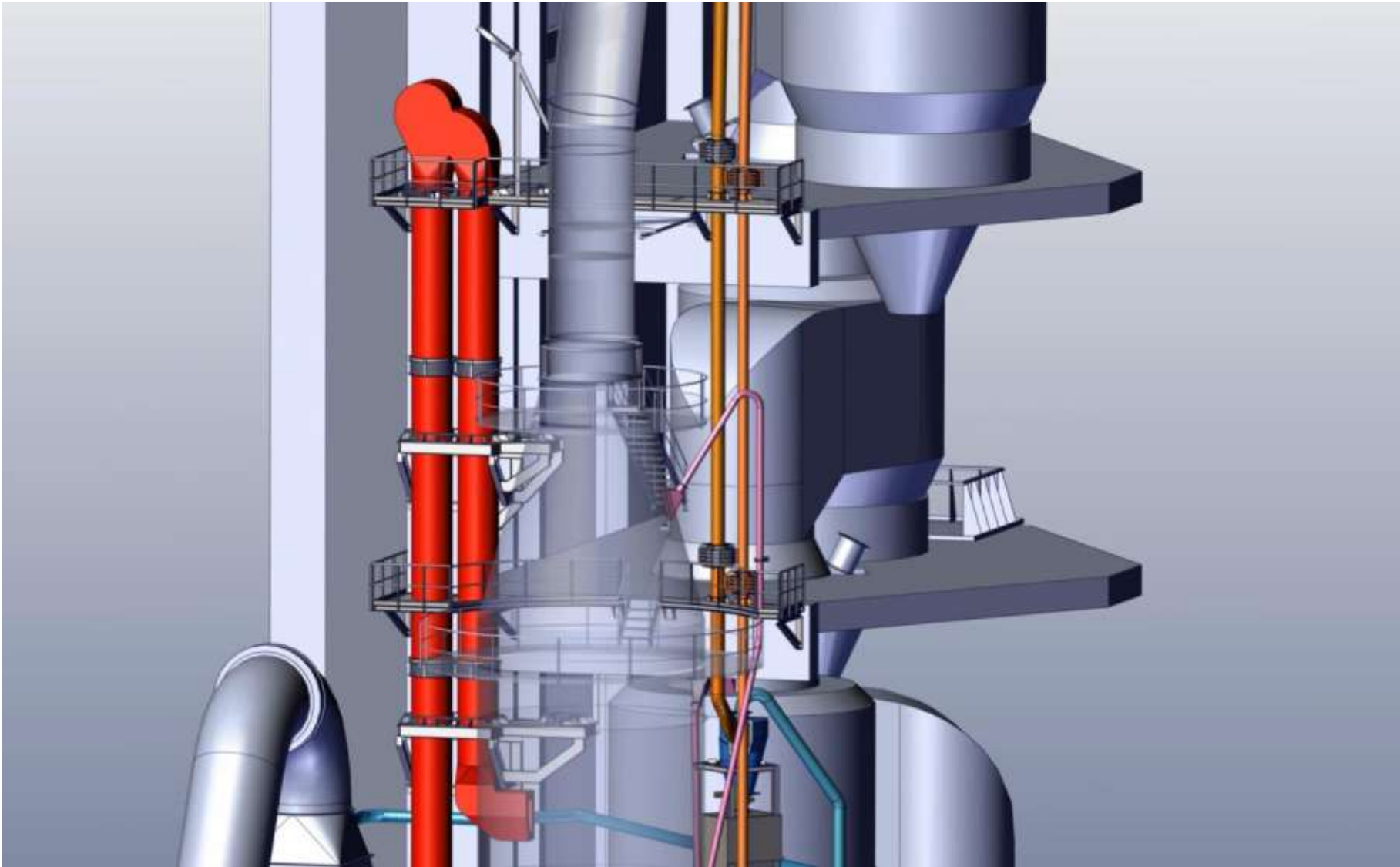


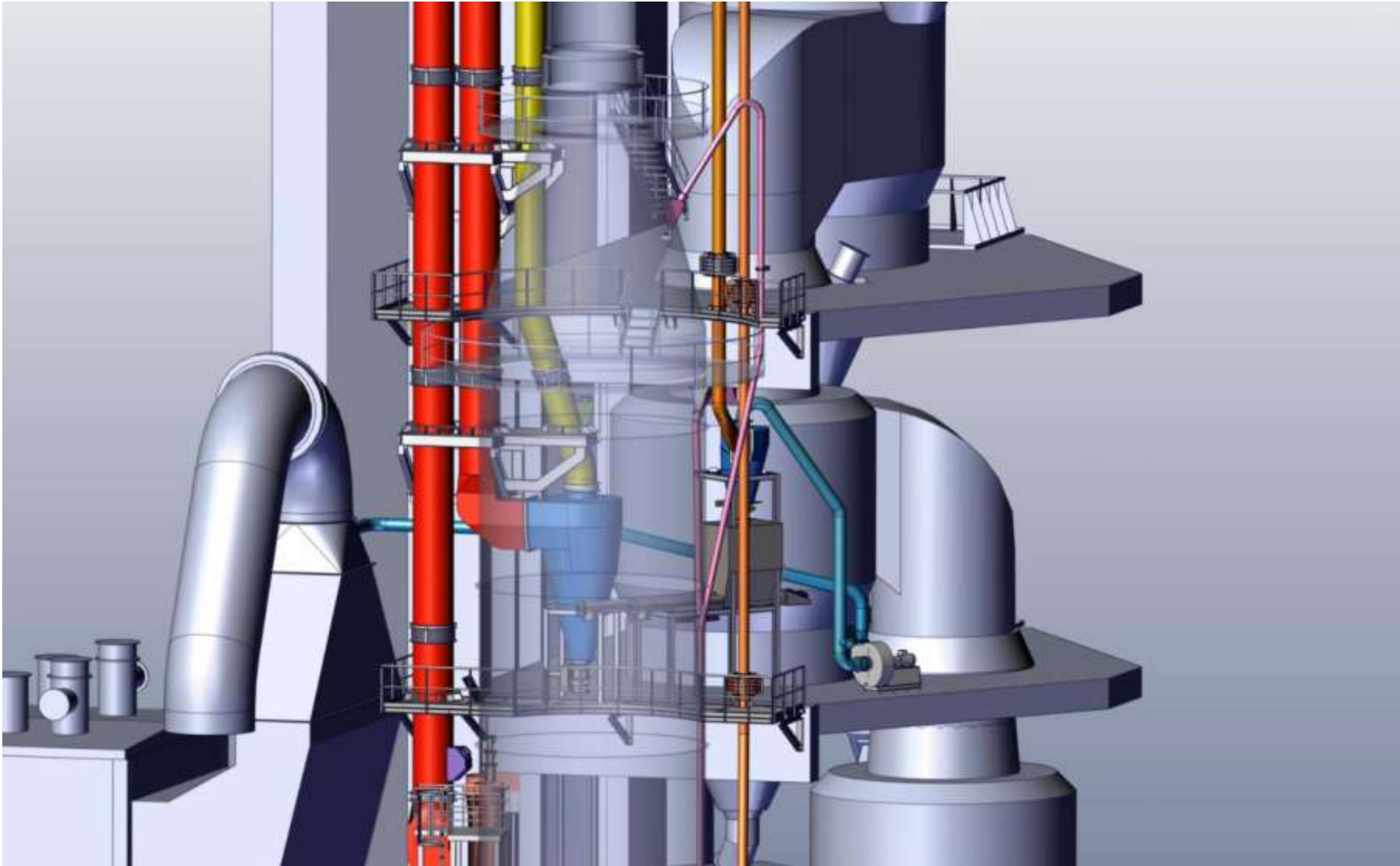


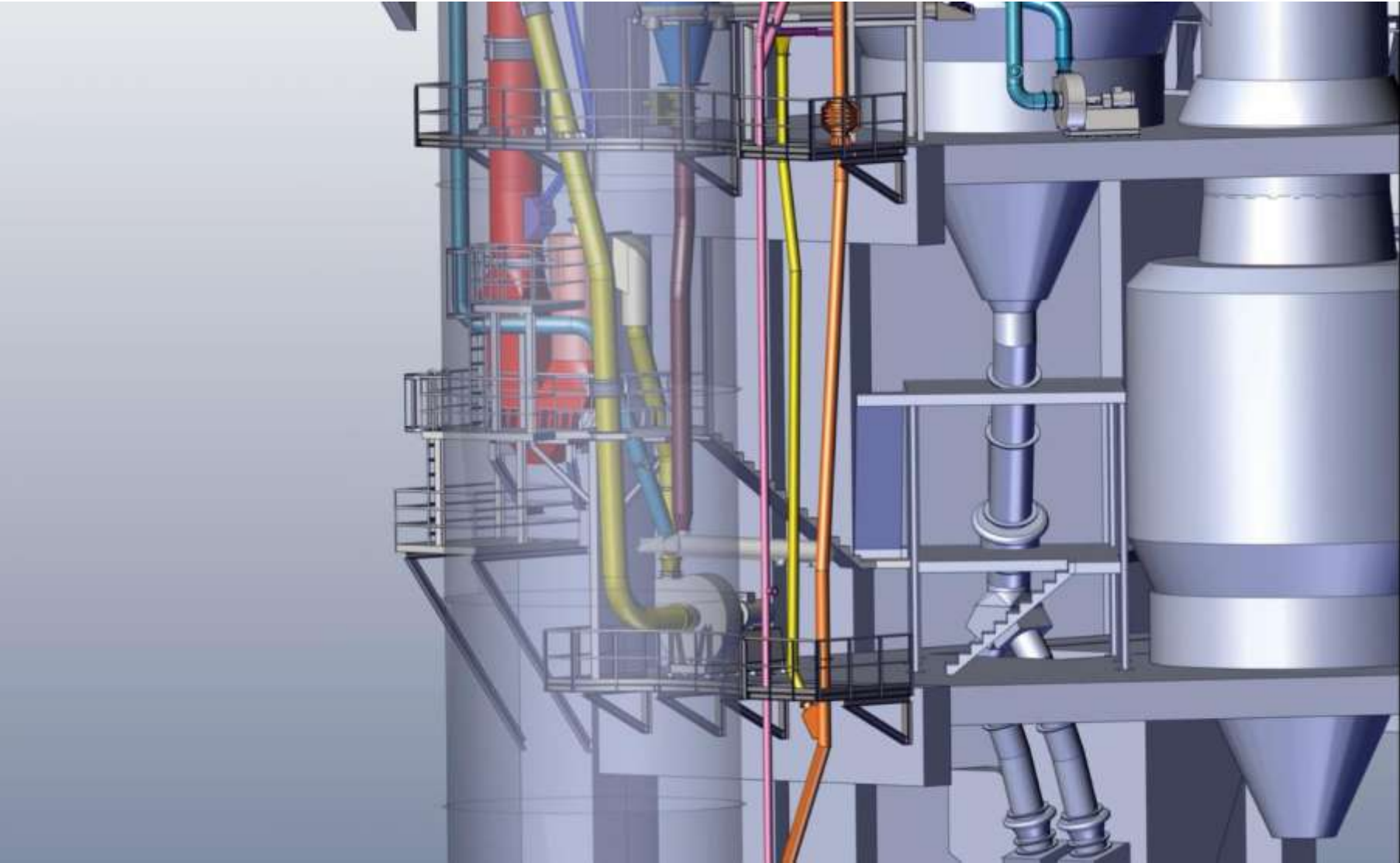


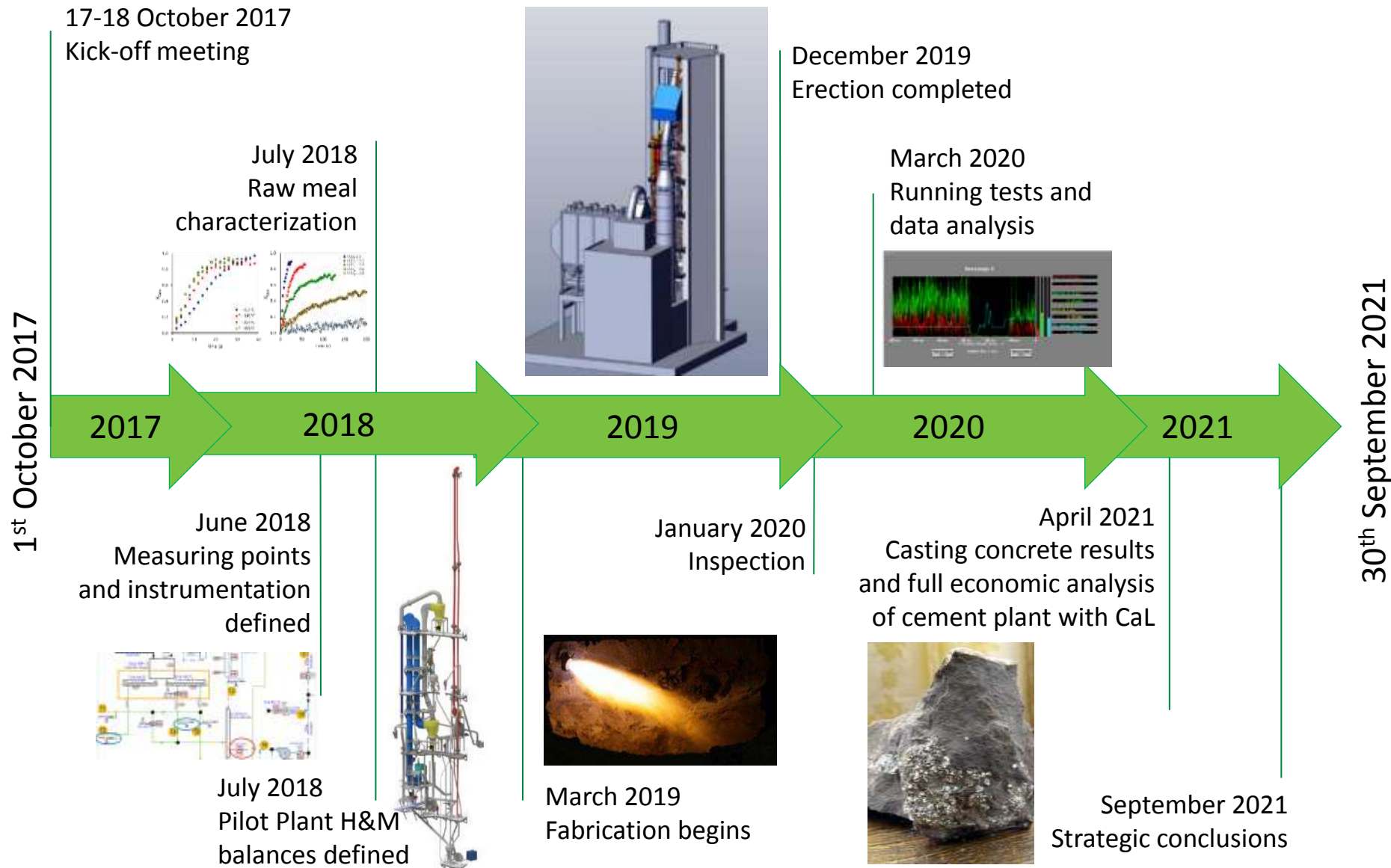
CLEANKER pilot 3D











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