# LC3 Financial Profitability

**LC3 Information Day**

19th November 2019 – Cape Town

**Laurent Grimmeissen**

CEMENTIS

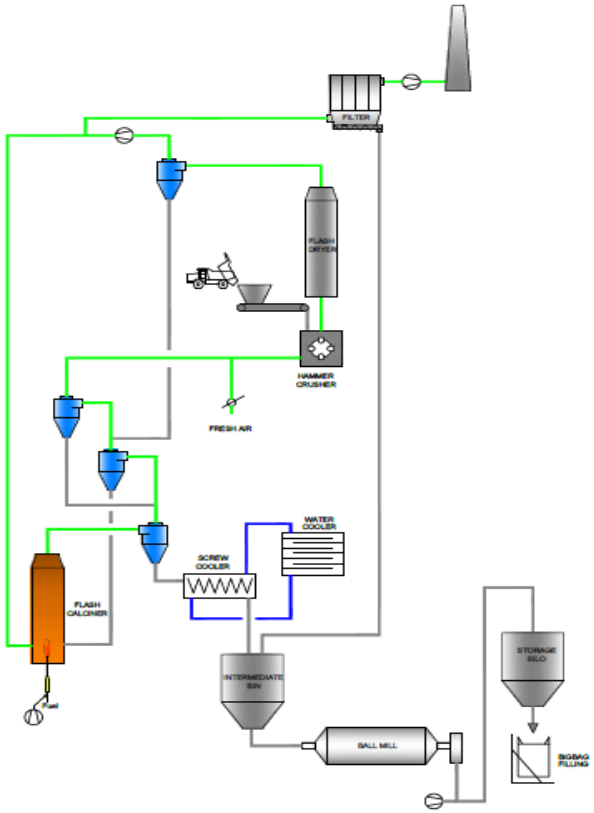
# Key issues on financial feasibility

- Producers of LC3 are private sector: shareholders need returns
- Production of LC3 shall then be more profitable than current cement

→ LC3 sales price minus production cost shall cover investment in clay calcination and generate profit for the company (low CAPEX and OPEX)

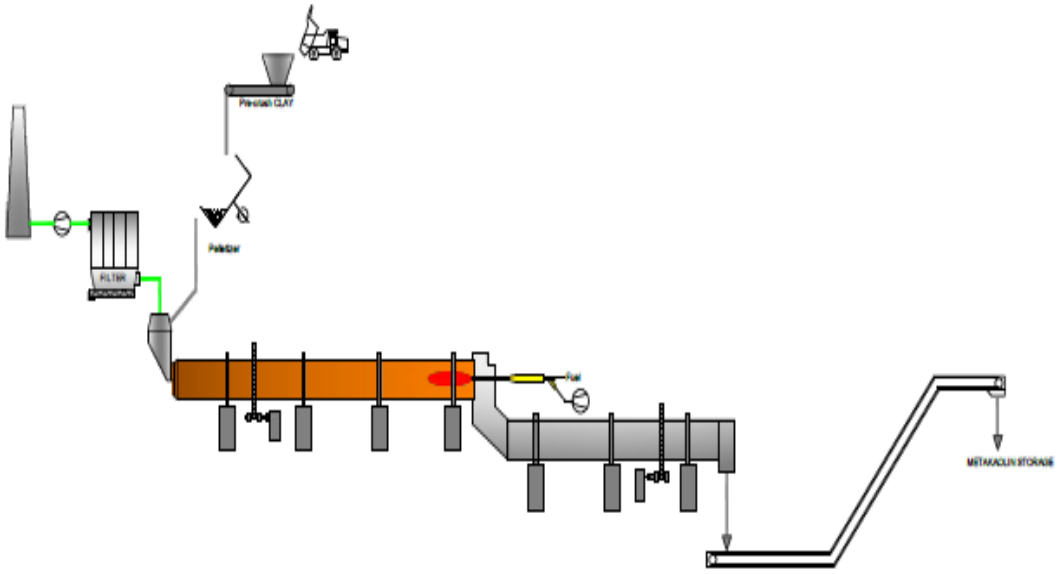
# LC3 CLAY CALCINATION: TWO TECHNOLOGICAL SOLUTIONS – (I) FLASH CALCINER (II) ROTARY KILN

## Flash Calciner




## Rotary Kiln

Existing kilns can be modified but cost shall be compared with new kiln




CEMENTIS

# 3 Scenario's for producing LC3

**Scenario 1:**

- In a cement Plant
- 1 Mio ton LC3
- 300 ktpa of CC
- FC vs. RT
- Clay <10km vs. 200km
- Cash Cost USD 30/t·cem

**Scenario 2:**

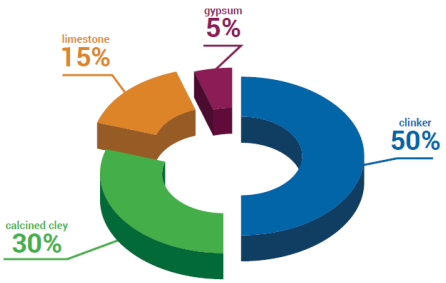
- In a grinding Plant
- 0.4 Mio ton LC3
- 124 ktpa CC
- FC vs. RT
- Clay <10km vs. 200km
- Cash Cost USD 47/t·cem

**Scenario 3:**

- Greenfield grinding unit
- 0.4 Mio ton LC3
- 124 ktpa CC
- FC vs. RT
- Clay <10km vs. 200km
- Cash Cost USD 47/t·cem

# Basic assumptions valid for all 3 scenarios

**LC3 =**




**compare LC3 vs. CEM I.**

**Fuel =**

**Coal @delivered cost of USD 80 per ton coal and a lowest heat value of 26 MJ /kg. (HFO / diesel not economically feasible)**

**Raw materials =**

- **limestone @ USD 2.8 /T (poor quality or reject limestone from existing quarry)**
- **Gypsum cost: USD 20 /T gypsum**

**Cost of clay is assumed at:**

- **USD 4.0 /T clay - when located close to the plant (< 10km)**
- **USD 17.0 /T clay - when 200 km from plant**

CEMENTIS

# CAPEX needed according to scenario

| | Scenario's | Capacity | Flash Calciner scenario | Rotary Kiln scenario |
|---|---|---|---|---|
|  | Scenario 1 | 300 ktpa of Calcined Clay | USD 10.3 million for the flash calciner turn key | USD 6.6 million for the rotary kiln turn key |
|  | Scenario 2 | 125 ktpa of Calcined Clay | USD 8.15 million for the flash calciner turn key & Coal mill | USD 6.1 million for the rotary kiln turn key & Coal mill |
|  | Scenario 3 | 125 ktpa of Calcined Clay | USD 27 million for the flash calciner, coal mill, and grinding plant | USD 26 million for the rotary kiln, coal mill, and grinding plant |

CEMENTIS

# Assumptions for scenario 1

Case of 1 million ton LC3 produced in a cement plant
Volume of calcined clay needed: 300 kT

Investment needed: rotary kiln or flash calciner depending on sub-scenario

Estimated cash production clinker: USD 23.9 /T
Estimated cash production cost CEM I: USD 30.0 /T

# CAPEX & OPEX estimations for 300 t/y CC production a cement plant.

| Flash Calciner | Rotary Kiln |
|---|---|
| CAPEX: USD 10.3 million for the flash calciner turn key | CAPEX: USD 6.6 million for the rotary kiln turn key |
| ▪ Specific thermal energy consumption: 2 MJ/kg<br>▪ Specific fuel cost: USD 6.92 /T clay<br>▪ Specific variable costs for calcined clay production:<br>➢ Fuel for mobile equipment USD 0.5 /T clay<br>➢ Variable electricity costs: USD 1 /T clay<br>➢ Wear parts: USD 0.4 /T clay<br>▪ Specific fix costs for calcined clay production<br>➢ Fix electrical energy: USD 0.2 /T clay<br>➢ Labour expenses: USD 1.0 /T clay<br>➢ Maintenance material: USD 0.2 /T clay | ▪ Specific thermal energy consumption: 2.8 MJ/kg<br>▪ Specific fuel cost: USD 9.69 /T clay<br>▪ Specific variable costs for calcined clay production<br>➢ Fuel for mobile equipment USD 0.5 /T clay<br>➢ Variable electricity costs: USD 0.3 /T clay<br>➢ Wear parts: USD 1.0 /T clay<br>➢ Major kiln repairs: USD 1.0 /T clay<br>▪ Specific fix costs for calcined clay production<br>➢ Fix electrical energy: USD 0.2 /T clay<br>➢ Labour expenses: USD 1.0 /T clay<br>➢ Maintenance material: USD 0.4 /T clay |

CEMENTIS

# SC1: LC3 production within a Cement Plant

Production capacity of calcined clay: 300'000 t/year or 960 tpd or 40t/h

Production capacity of LC3: 1'000'000 t/y

## Flash Calciner

### If Clay is close to the plant (cost 4 USD/t)

| Cost of LC3 | % in LC3 | Cost USD/t |
|---|---|---|
| Cost of clinker | 50% | 11.9 |
| Cost of Gypsum | 5% | 1.0 |
| Cost of Calcined Clay | 30% | 4.3 |
| Cost of Limestone | 15% | 0.4 |
| Cost of Grinding | - | 5.7 |
| **Total Cost of LC3** | **100%** | **23.4** |

### If Clay is at 200 km from the plant (cost 17 USD/t)

| Cost of LC3 | % in LC3 | Cost USD/t |
|---|---|---|
| Cost of clinker | 50% | 11.9 |
| Cost of Gypsum | 5% | 1.0 |
| Cost of Calcined Clay | 30% | 8.2 |
| Cost of Limestone | 15% | 0.4 |
| Cost of Grinding | - | 5.7 |
| **Total Cost of LC3** | **100%** | **27.3** |

## Rotary Kiln

### If Clay is close to the plant (cost 4 USD/t)

| Cost of LC3 | % in LC3 | Cost USD/t |
|---|---|---|
| Cost of clinker | 50% | 11.9 |
| Cost of Gypsum | 5% | 1.0 |
| Cost of Calcined Clay | 30% | 5.1 |
| Cost of Limestone | 15% | 0.4 |
| Cost of Grinding | - | 5.7 |
| **Total Cost of LC3** | **100%** | **24.2** |

### If Clay is at 200 km from the plant (cost 17 USD/t)

| Cost of LC3 | % in LC3 | Cost USD/t |
|---|---|---|
| Cost of clinker | 50% | 11.9 |
| Cost of Gypsum | 5% | 1.0 |
| Cost of Calcined Clay | 30% | 9 |
| Cost of Limestone | 15% | 0.4 |
| Cost of Grinding | - | 5.7 |
| **Total Cost of LC3** | **100%** | **28.1** |

CEMEN

# Assumptions for scenario 2

- Case of 413 kT LC3 produced in a grinding plant plant
- Volume of calcined clay needed: 124 kT

- CEM I is produced with imported clinker
- Calcined clay production requires coal installation

Investment needed:
- rotary kiln or flash calciner depending on sub-scenario,
- coal grinder and storage

- Estimated import cost clinker: USD 40.0 /T delivered
- Estimated cash production cost CEM I with imported clinker: USD 47.0 /T

# CAPEX & OPEX estimations for 124 t/y CC prod in a grinding plant.

| Flash Calciner | | Rotary Kiln |
|---|---|---|
| CAPEX:<br>*SC2*: USD 8.15 million for the flash calciner turn key & Coal mill | > | CAPEX:<br>*SC2:* USD 6.1 million for the rotary kiln turn key & Coal mill |
| ▪ Specific thermal energy consumption: 2.5 MJ/kg | | ▪ Specific thermal energy consumption: 3.0 MJ/kg |
| ▪ Specific fuel cost: USD 8.65 /T clay | < | ▪ Specific fuel cost: USD 10.38 /T clay |
| ▪ Specific variable costs for calcined clay production:<br>➢ Fuel for mobile equipment USD 0.5 /T clay<br>➢ Variable electricity costs: USD 1.2 /T clay<br>➢ Wear parts: USD 0.4 /T clay | < | ▪ Specific variable costs for calcined clay production<br>➢ Fuel for mobile equipment USD 0.5 /T clay<br>➢ Variable electricity costs: USD 0.4 /T clay<br>➢ Wear parts: USD 1.0 /T clay<br>➢ Major kiln repairs: USD 1.0 /T clay |
| ▪ Specific fix costs for calcined clay production<br>➢ Fix electrical energy: USD 0.2 /T clay<br>➢ Labour expenses: USD 1.4 /T clay<br>➢ Maintenance material: USD 0.2 /T clay | | ▪ Specific fix costs for calcined clay production<br>➢ Fix electrical energy: USD 0.2 /T clay<br>➢ Labour expenses: USD 1.4 /T clay<br>➢ Maintenance material: USD 0.4 /T clay |

# SC2: LC3 production within a Grinding Unit

Production capacity of calcined clay: 124'000 t/year or 400 tpd or 16t/h

Production capacity of LC3: 413'000 t/y

## Flash Calciner

### If Clay is close to the plant (cost 4 USD/t)

| Cost of LC3 | % in LC3 | Cost USD/t |
|---|---|---|
| Cost of clinker | 50% | 20.0 |
| Cost of Gypsum | 5% | 1.0 |
| Cost of Calcined Clay | 30% | 5.0 |
| Cost of Limestone | 15% | 0.4 |
| Cost of Grinding | - | 5.7 |
| **Total Cost of LC3** | **100%** | **32.1** |

### If Clay is at 200 km from the plant (cost 17 USD/t)

| Cost of LC3 | % in LC3 | Cost USD/t |
|---|---|---|
| Cost of clinker | 50% | 20.0 |
| Cost of Gypsum | 5% | 1.0 |
| Cost of Calcined Clay | 30% | 8.9 |
| Cost of Limestone | 15% | 0.4 |
| Cost of Grinding | - | 5.7 |
| **Total Cost of LC3** | **100%** | **36.0** |

## Rotary Kiln

### If Clay is close to the plant (cost 4 USD/t)

| Cost of LC3 | % in LC3 | Cost USD/t |
|---|---|---|
| Cost of clinker | 50% | 20.0 |
| Cost of Gypsum | 5% | 1.0 |
| Cost of Calcined Clay | 30% | 5.5 |
| Cost of Limestone | 15% | 0.4 |
| Cost of Grinding | - | 5.7 |
| **Total Cost of LC3** | **100%** | **32.6** |

### If Clay is at 200 km from the plant (cost 17 USD/t)

| Cost of LC3 | % in LC3 | Cost USD/t |
|---|---|---|
| Cost of clinker | 50% | 20.0 |
| Cost of Gypsum | 5% | 1.0 |
| Cost of Calcined Clay | 30% | 9.4 |
| Cost of Limestone | 15% | 0.4 |
| Cost of Grinding | - | 5.7 |
| **Total Cost of LC3** | **100%** | **36.5** |

# Assumptions for scenario 3

- Case of 413 kT LC3 produced in a greenfield plant. Main difference with scenario 2 is that scenario 3 requires investment in a clinker grinding plant
- Volume of calcined clay needed: 124 kT

- CEM I is produced with imported clinker
- Calcined clay production requires coal installation

Investment needed:

- rotary kiln or flash calciner depending on sub-scenario,
- clinker grinder and storage
- coal grinder and storage

- Estimated import cost clinker: USD 40.0 /T delivered
- Estimated cash production cost CEM I with imported clinker: USD 47.0 /T

# CAPEX & OPEX estimations for 124 t/y CC prod in a grinding plant.

| Flash Calciner | | Rotary Kiln |
|---|---|---|
| CAPEX:<br>CAPEX: USD 27 million for the flash calciner, coal mill, and grinding plant | > | CAPEX:<br>CAPEX: USD 26 million for the rotary kiln calciner, coal mill, and grinding plant |
| ▪ Specific thermal energy consumption: 2.5 MJ/kg<br>▪ Specific fuel cost: USD 8.65 /T clay | < | ▪ Specific thermal energy consumption: 3.0 MJ/kg<br>▪ Specific fuel cost: USD 10.38 /T clay |
| ▪ Specific variable costs for calcined clay production:<br>➢ Fuel for mobile equipment USD 0.5 /T clay<br>➢ Variable electricity costs: USD 1.2 /T clay<br>➢ Wear parts: USD 0.4 /T clay | < | ▪ Specific variable costs for calcined clay production<br>➢ Fuel for mobile equipment USD 0.5 /T clay<br>➢ Variable electricity costs: USD 0.4 /T clay<br>➢ Wear parts: USD 1.0 /T clay<br>➢ Major kiln repairs: USD 1.0 /T clay |
| ▪ Specific fix costs for calcined clay production<br>➢ Fix electrical energy: USD 0.2 /T clay<br>➢ Labour expenses: USD 1.4 /T clay<br>➢ Maintenance material: USD 0.2 /T clay | | ▪ Specific fix costs for calcined clay production<br>➢ Fix electrical energy: USD 0.2 /T clay<br>➢ Labour expenses: USD 1.4 /T clay<br>➢ Maintenance material: USD 0.4 /T clay |

# SC3: Greenfield LC3 production

Production capacity of calcined clay: 124'000 t/year or 400 tpd or 16t/h

Production capacity of LC3: 413'000 t/y

## Flash Calciner

### If Clay is close to the plant (cost 4 USD/t)

| Cost of LC3 | % in LC3 | Cost USD/t |
|---|---|---|
| Cost of clinker | 50% | 20.0 |
| Cost of Gypsum | 5% | 1.0 |
| Cost of Calcined Clay | 30% | 5.0 |
| Cost of Limestone | 15% | 0.4 |
| Cost of Grinding | - | 5.7 |
| **Total Cost of LC3** | **100%** | **32.1** |

### If Clay is at 200 km from the plant (cost 17 USD/t)

| Cost of LC3 | % in LC3 | Cost USD/t |
|---|---|---|
| Cost of clinker | 50% | 20.0 |
| Cost of Gypsum | 5% | 1.0 |
| Cost of Calcined Clay | 30% | 8.9 |
| Cost of Limestone | 15% | 0.4 |
| Cost of Grinding | - | 5.7 |
| **Total Cost of LC3** | **100%** | **36.0** |

## Rotary Kiln

### If Clay is close to the plant (cost 4 USD/t)

| Cost of LC3 | % in LC3 | Cost USD/t |
|---|---|---|
| Cost of clinker | 50% | 20.0 |
| Cost of Gypsum | 5% | 1.0 |
| Cost of Calcined Clay | 30% | 5.5 |
| Cost of Limestone | 15% | 0.4 |
| Cost of Grinding | - | 5.7 |
| **Total Cost of LC3** | **100%** | **32.6** |

### If Clay is at 200 km from the plant (cost 17 USD/t)

| Cost of LC3 | % in LC3 | Cost USD/t |
|---|---|---|
| Cost of clinker | 50% | 20.0 |
| Cost of Gypsum | 5% | 1.0 |
| Cost of Calcined Clay | 30% | 9.4 |
| Cost of Limestone | 15% | 0.4 |
| Cost of Grinding | - | 5.7 |
| **Total Cost of LC3** | **100%** | **36.5** |

# LC3 cement – A competitive product versus CEM I

| | | Scenario Description | Capacity | | CAPEX | OPEX | | STEC |
|---|---|---|---|---|---|---|---|---|
| | | | [ktpa clay] | [ktpa cem] | [MUSD] | [USD/t·clay] | [USD/t·cem] | [MJ/kg·clay] |
| **Scenario 1** | 1.1 | Flash Calciner - Clay near facility | 300 | 1000 | ~10.3 | 14.3 | 23.4 | ~2.0 |
| (At existing integrated plant) | | Flash Calciner - Clay at < 200km | 300 | 1000 | ~10.3 | 27.3 | 27.3 | ~2.0 |
| | 1.2 | Rotary Kiln - Clay near facility | 300 | 1000 | ~6.6 | 17.0 | 24.2 | ~2.8 |
| | | Rotary Kiln - Clay at < 200km | 300 | 1000 | ~6.6 | 30.0 | 28.1 | ~2.8 |
| **Scenario 2** | 2.1 | Flash Calciner - Clay near facility | 124 | 413 | ~8.15 | 16.7 | 32.1 | ~2.5 |
| (At existing grinding station ) | | Flash Calciner - Clay at < 200km | 124 | 413 | ~8.15 | 29.7 | 36 | ~2.5 |
| | 2.2 | Rotary Kiln - Clay near facility | 124 | 413 | ~6.1 | 18.3 | 32.6 | ~3.0 |
| | | Rotary Kiln - Clay at < 200km | 124 | 413 | ~6.1 | 31.3 | 36.5 | ~3.0 |
| **Scenario 3** | 3.1 | Flash Calciner - Clay near facility | 124 | 413 | ~27.0 | 16.7 | 32.1 | ~2.5 |
| (Greenfield Grinding Plant) | | Flash Calciner - Clay at < 200km | 124 | 413 | ~27.0 | 29.7 | 36 | ~2.5 |
| | 3.2 | Rotary Kiln - Clay near facility | 124 | 413 | ~26.0 | 18.3 | 32.6 | ~3.0 |
| | | Rotary Kiln - Clay at < 200km | 124 | 413 | ~26.0 | 31.3 | 36.5 | ~3.0 |

**At Existing Integrated Plants**

**Δ 2-7 USD/t benefit - LC3 v. Cem I** (Cash Cost USD 30/t·cem)

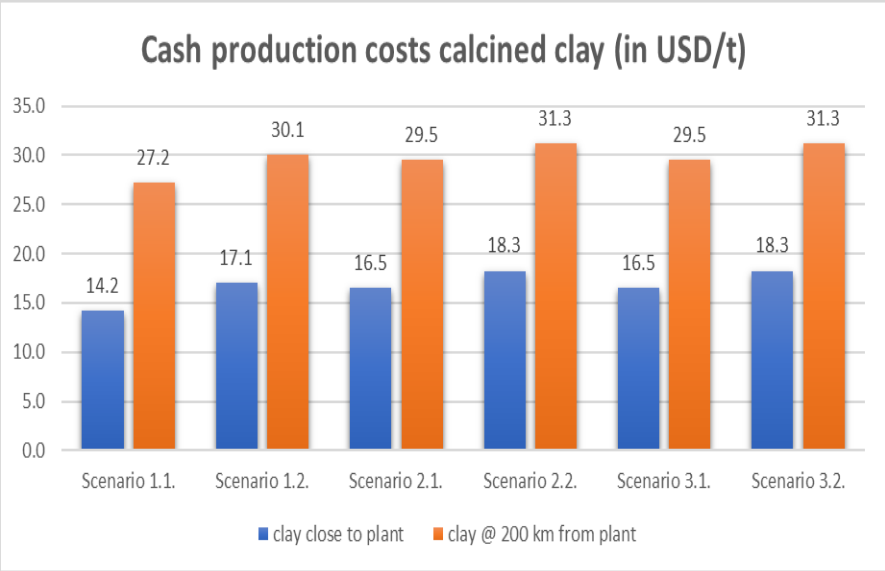
**At Existing and Greenfield Grinding Stations**

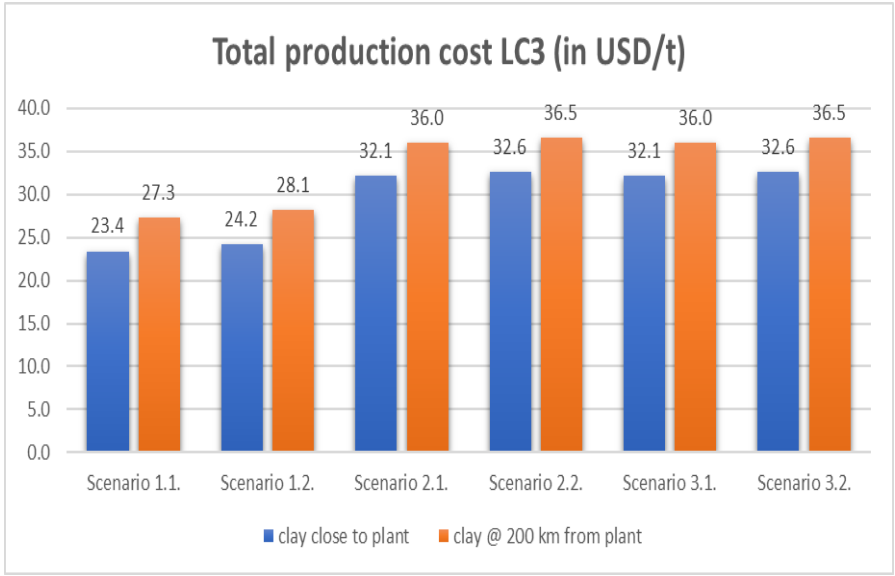
**Δ 10-15 USD/t benefit - LC3 v. Cem I** (Cash Cost USD 47/t·cem)

**OPEX**

CEMENTIS

# Production cost of calcined clay & LC3

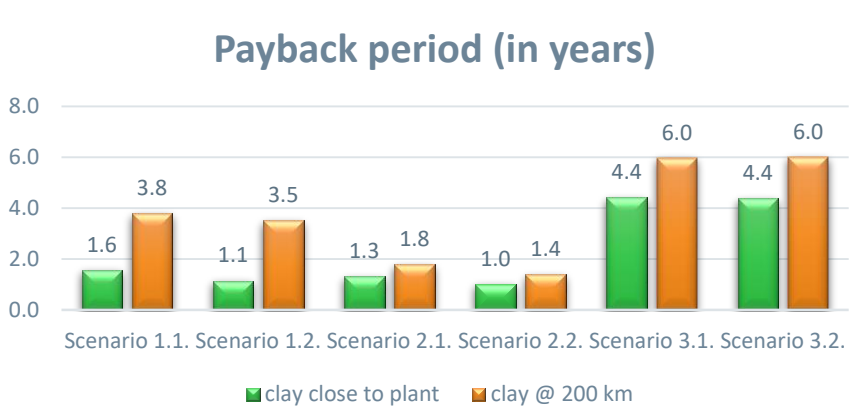


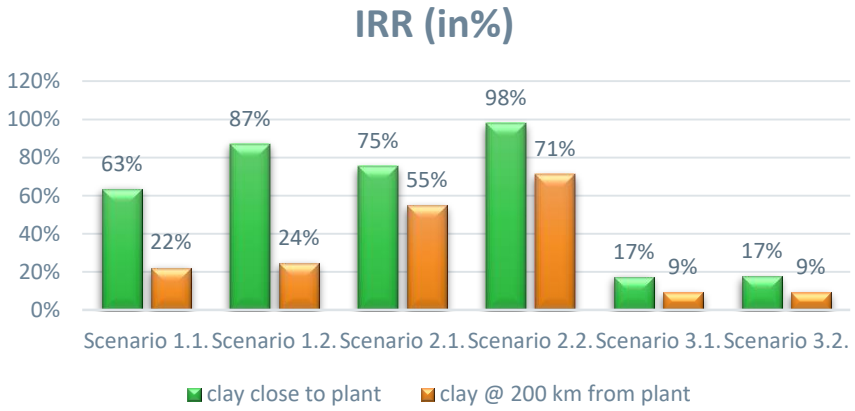




**Logistic is a key component in clay cost**

CEMENTIS

# Financial Profitability (based on simplified DCF)




- Producing LC3 versus CEM I is attractive in case of an existing integrated or grinding plant even if the clay is located as far as 200 km from the plant
- Producing LC3 instead of CEM I out of a greenfield project remains attractive though to a lesser extent due to the high investment costs required for the grinding plant itself. However, clay shall be located close to the plant.
- **Distance of clay to the production facility is a key driver.**

# PRACTICAL CASE

## Variable Cost Comparison of $LC^3$ with PPC and OPC

| Parameters | $LC^3$ | PPC | OPC |
|---|---|---|---|
| | | | |
| **Input Material Ratio (% of Cement)** | | | |
| Clinker | 50.00 | 66.74 | 90.00 |
| Gypsum | 5.00 | 6.94 | 5.00 |
| Fly Ash | 0.00 | 26.32 | 0.00 |
| Calcined clay | 30.00 | 0.00 | 0.00 |
| Sub-grade Limestone | 15.00 | 0.00 | 5.00 |
| **Total Input Material (%)** | **100.00** | **100.00** | **100.00** |

| Parameters | LC$^3$ | PPC | OPC |
|---|---|---|---|
| **Input Material Cost (USD/MT of Specific Material)** | | | |
| Clinker | 23.10 | 23.10 | 23.10 |
| Gypsum | 20.00 | 20.00 | 20.00 |
| Fly Ash | 14.00 | 14.00 | 14.00 |
| Calcined clay | 11.30 | 11.30 | 11.30 |
| Granulated Slag | 18.30 | 18.30 | 18.30 |
| Sub-grade Limestone | 3.60 | 3.60 | 3.60 |
| | | | |
| **Input Material Cost (USD/MT cement)** | | | |
| Clinker Cost | 11.55 | 15.42 | 20.79 |
| Gypsum Cost | 1.00 | 1.39 | 1.00 |
| Fly Ash Cost | 0.00 | 3.68 | 0.00 |
| Calcined clay | 3.39 | 0.00 | 0.00 |
| Granulated Slag | 0.00 | 0.00 | 0.00 |
| Sub-grade Limestone | 0.54 | 0.00 | 0.18 |
| **Total Input Material Cost (USD/MT cement)** | **16.48** | **20.49** | **21.97** |

| Parameters | LC$^3$ | PPC | OPC |
|---|---|---|---|
| | | | |
| **Power Cost in Grinding (USD/MT cement)** | | | |
| Specific Power Consumption (KWh/ MT cement) | 14.50 | 29.00 | 31.00 |
| Power Cost (USD/ KWh) | 0.08 | 0.08 | 0.08 |
| **Total Power cost in grinding (USD/MT cement)** | **1.16** | **2.32** | **2.48** |
| | | | |
| **Total Variable Cost (USD/MT cement)** | | | |
| **Total Variable cost (USD/MT cement)** | **17.64** | **22.81** | **24.45** |
| | | | |
| **Cost Savings Comparison** | | | |
| **Absolute cost savings (USD/MT cement)** | | **5.17** | **6.81** |
| **Percentage cost savings (%)** | | **22.7%** | **27.9%** |

# Overall conclusion on profitability

- Production of LC3 always more profitable than OPC
- With PPC depends on clinker substitute cost vs. calcined clay
- Distance of clay from plant (logistic cost) has strong influence
- Refurbishing of existing kiln technically possible but cost shall be compared with new kiln
- “Jackpot case”: grinders in markets without clinker but with clay
- Options for RMX producers if no LC3 available:
  - Buy clinker + calcined clay+ limestone + gypsum and grind it, or
  - buy OPC + calcined clay + limestone and mix it

# CO2 emissions OPC vs. LC3

| | OPC | LC3 50 | | |
|---|---|---|---|---|
| CO2 emissions from coal | 0.097 | 0.097 | *T CO2 / GJ* | *IPCC default value* |
| Thermal consumption | 3.5 | 2.3 | *GJ / T clinker* | *GNR world 93AG* |
| CO2 emissions from combustion | 0.34 | 0.22 | *T CO2 / T clinlker* | |
| Process emission | 0.507 | 0 | *T CO2 / T clinker* | *IPCC default value* |
| Total CO2 emissions | 0.85 | 0.22 | *T CO2 / T clinker* | |
| Clinker factor | 95% | 50% | *clinker in cement* | |
| Clay content in LC3 | | 30% | | |
| **Total CO2 emissions OPC** | **0.80** | **0.49** | ***T CO2 / T cement*** | |
| | | **-39.1%** | | |

CEMENTIS

# Thank you