Low Emissions Intensity Lime and Cement (LEILAC)

Calix Direct Separation Reactor de-carbonisation

Lixhe, November 10th 2016

Jan Theulen
Director Alternative Resources

HEIDELBERGCEMENT

Leilac

The LEILAC Project Vision is to future-proof the cement and lime industries without significant impact on operability, capital intensity or efficiency…

LEILAC aims to apply Direct Separation technology to the cement and lime industry, enabling CO_2 process emissions to be captured without significant operating issues, energy or capital penalty.

The first objective of LEILAC is to create a pilot that will:

- Have an input feed capacity of 10 tph of cement meal, or 8 tph limestone,
- Demonstrate over 95% of CO_2 process emissions could be captured, and verify its quality.
- Evaluate and mitigate the major technical risks associate when applied at scale, including:
  - That the plant can be safely operated (Safety risk).
  - That the technology can be applied at the expected costs (pilot and full scale). (Finance risk)
  - Scale up the processing temperature (to about 905ºC) for processing limestone in a single tube reactor of 1.86m diameter (Temperature scale up risk)
  - Have a calcination rate of 95% (internal target). (Temperature scale up risk)
  - Investigate optimum diameter/length/feed rate of a single tube, enabling the future doubling of the capacity through an 'Extension Program'. (Future Capacity Scale-Up risk)
- Confirm that the end cement and lime products are not negatively impacted.
- Ensure stakeholders have a good understanding of the project, and address any questions they have.

The second objective is to facilitate the scale up of the technology, by:

- Disseminating data and findings which support the anticipated performance and cost of full-scale application.
- Establish a roadmap for the technology's roll out.

These are the abridged objectives. See the grant for the full list.

Consortium Partners

HEIDELBERGCEMENT

Lhoist

Calix

TARMAC
A CRH COMPANY

CEMEX

ECN

PSE

CARBON TRUST

amec foster wheeler

Quantis
Sustainability counts

Imperial College London

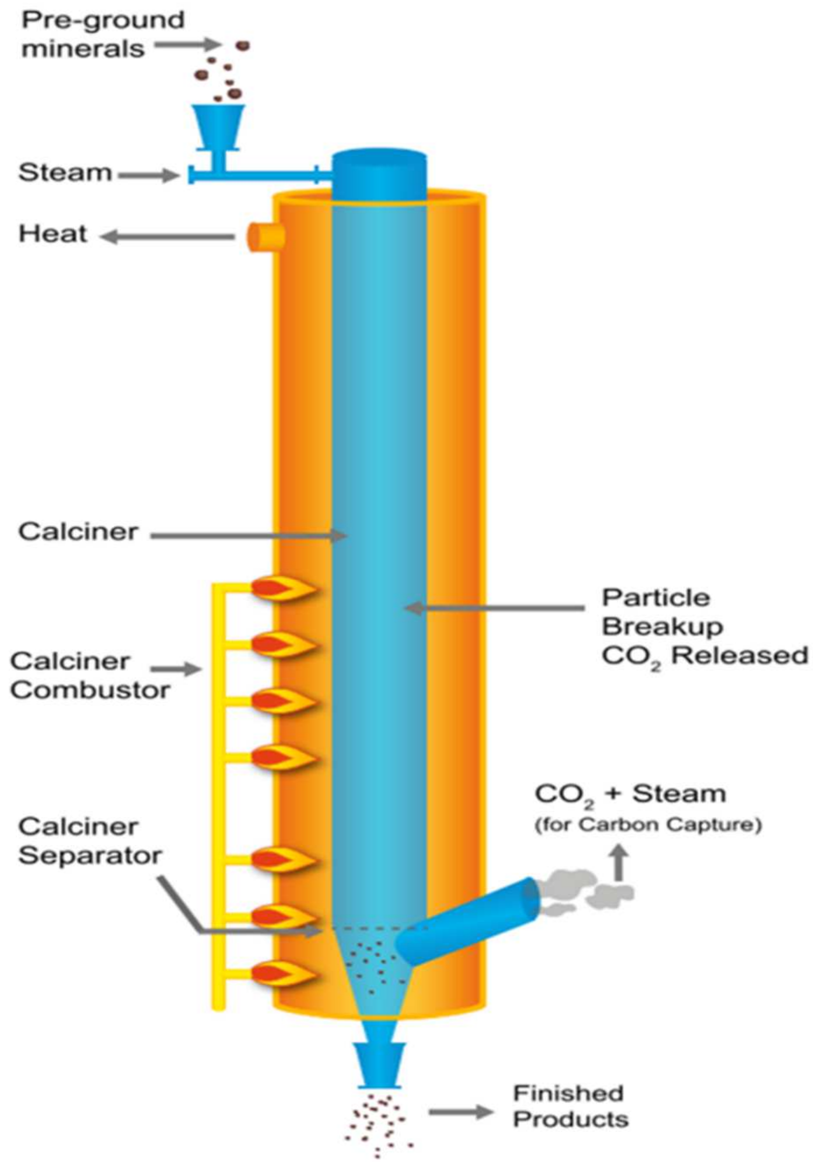
This project has received €12m of funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654465

The Calix company and their Direct Separation Reactor

- **Calix Australia operates a 100 t/d demo-plant for $MgCO_3$ to MgO calcination in Bachus Marsh in Victoria (AUS)**
- **MgO product extra ordinary high surface**
  - gets hydrated to $Mg(OH)_2$ with grades of 10x surface compared to usual
  - sold commercially for aquaculture treatment & agricultural spray for premium price
- **Expanding DSR into “neighboring” industries such as cement and lime**
- **EU is funding the pilot plant at HC’s Lixhe plant**
  - with 12 Mil € within the next 5 years
  - and up to 9 Mil € contribution from partners

Calix Direct Separation Reactor for Cement & Lime

- **$MgCO_3$ and $CaCO_3$ have very similar temperature demands of 750 …. 930°C**
- **The calciner is in-direct fired, which allows to extract a undiluted CO_2 stream**



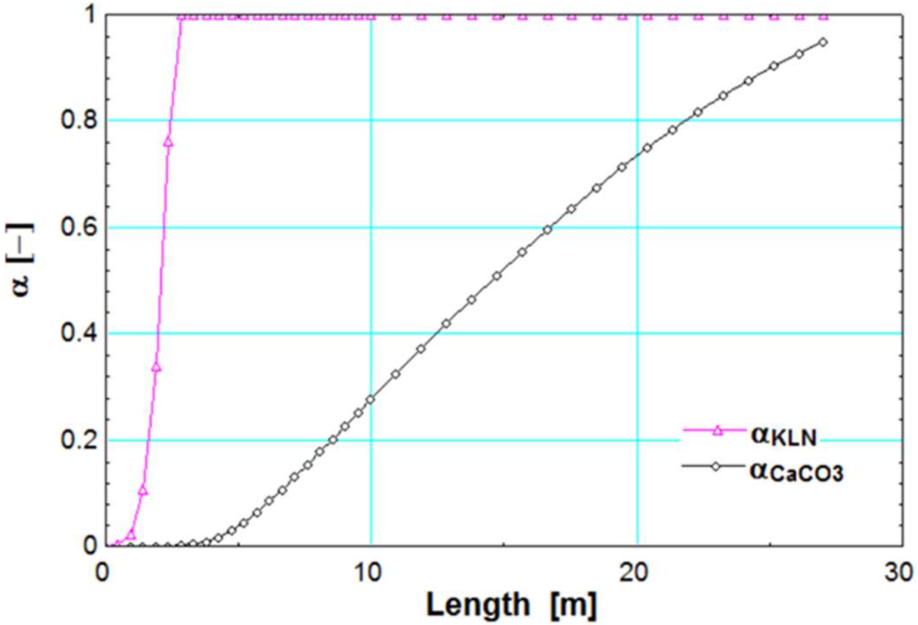
Calix DSR Energy Assumption

- **DSR assumes small increase on power and energy demand**
- **Lixhe test will reveal if the assumptions are fair**
- **In Working group 5 the upscaling will be handled**

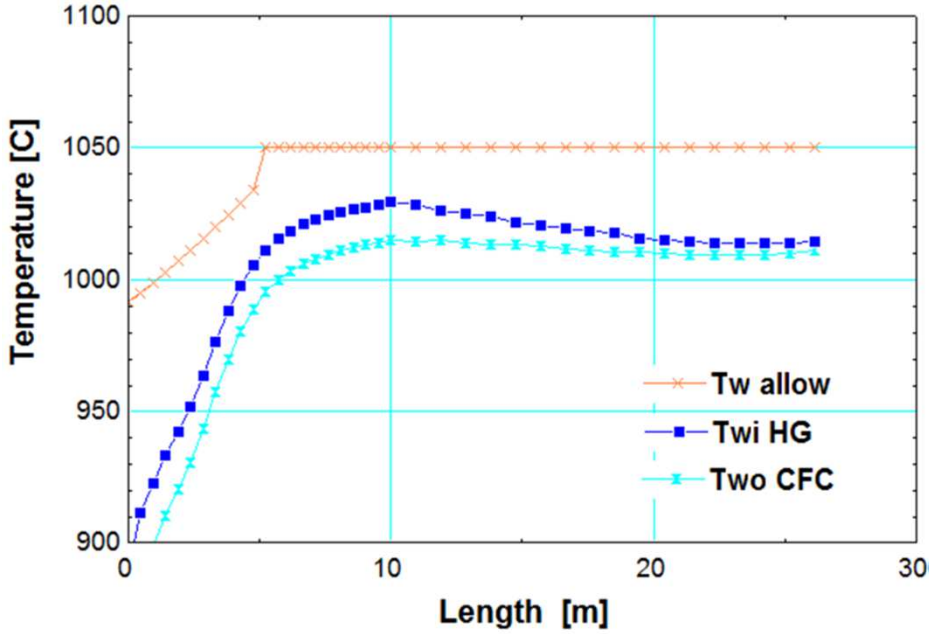
Cement Clinker Production		
Energies in kJ/kg Cement	Direct Separation	Pre-Heater Calciner
Energy - Coal LHV	3,251	3,119
Power – Fans	106	102
Gross Power	3,357	3,221
Clinker Reaction Energy	1,788	1,788
Moisture Removal	217	217
Gross Process Energy	2,005	2,005
Gross Efficiency	60%	62%

Calix DSR Temperature vs Calcination

- **Calcination vs Length**



- **Temperature vs Length**



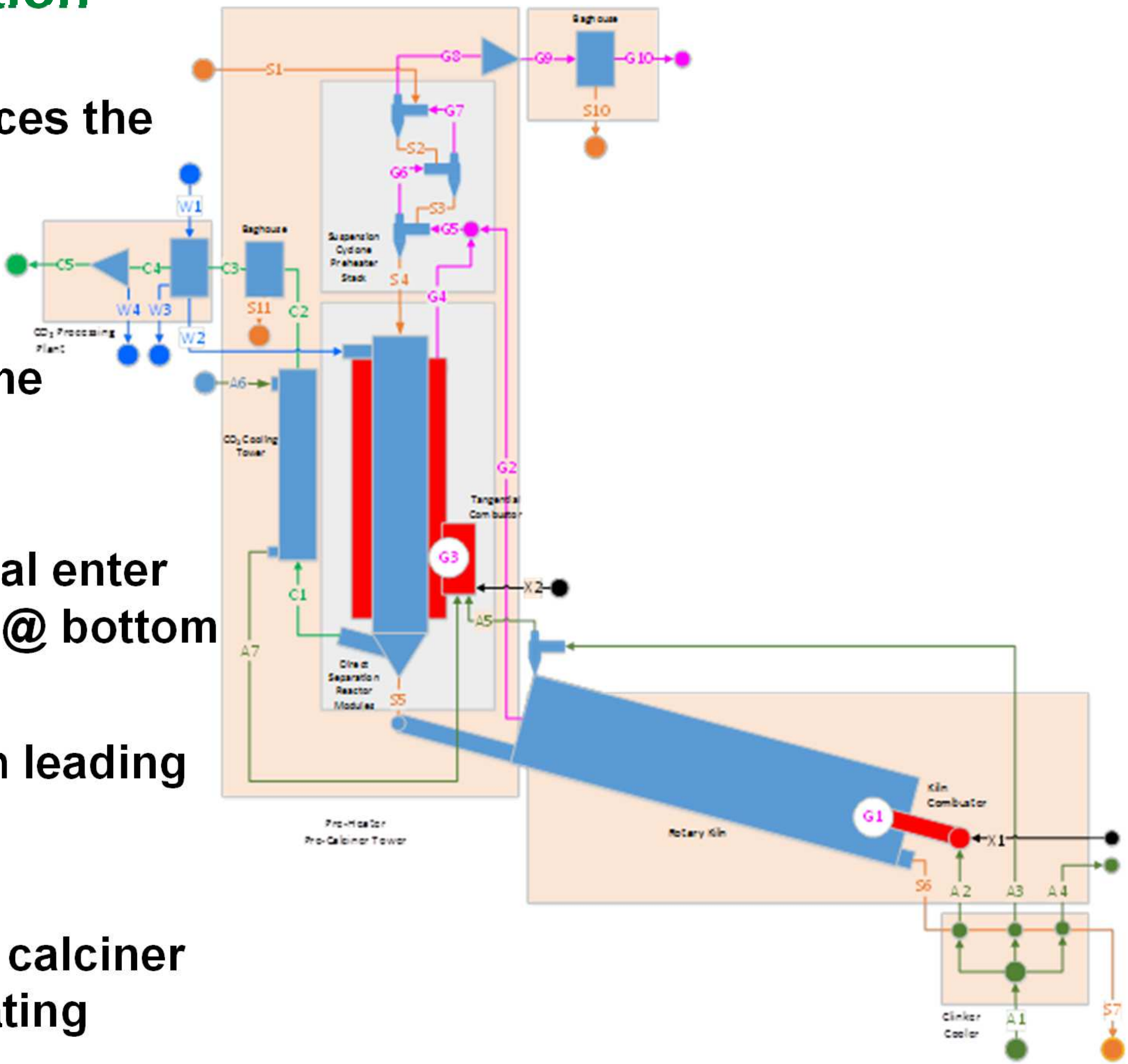
Consortium Partners

HEIDELBERGCEMENT
Lhoist
Calix
TARMAC A CRH COMPANY
CEMEX
ECN
PSE
CARBON TRUST
amec foster wheeler
Quantis Sustainability counts
Imperial College London

This project has received €12m of funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654465

DSR Configuration

- Calix reactor replaces the usual calciner
- Tertiary air feeds the calciner burners
- Pre-heated raw meal enter from top → leaves @ bottom
- Indirect calcination leading to a “pure” CO_2
- Kiln gas & indirect calciner gas join for preheating



Location of the tower

Figure 8 – LEILAC plot view from ground level

Consortium Partners

HEIDELBERGCEMENT
Lhoist
Calix
TARMAC
A CRH COMPANY
CEMEX
ECN
PSE
ARBON
UST
amec
foster
wheeler
Quantis
Sustainability counts
Imperial Colleg
London

This project has received €12m of funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654465

Calix DSR Test Program

- **Main process issue to be clarified at demo Lixhe for scale-up**
  - Rate of scaling within the tube with “cement” feed
  - Degree of calcination with “lime” feed
  - Heat transfer and required temperature to control degree of calcination
  - Usability of the selected Steel group (corrosion, erosion, …) at 1050°C
  - Purity in CO_2 and unwanted gaseous constituent

- **Program raw materials**
  - External delivery of raw materials for “lime”
  - Use of plants material for by splitting raw meal silo (cold)

- **Not in program**
  - Carbon Capture Utilisation
  - Use of fuels other than natural gas (only impurity injection)
  - Use of de-carbonised raw-mix in kiln (back feeding to raw material dryer)

Consortium Partners

HEIDELBERGCEMENT

Lhoist

Calix

TARMAC
A CRH COMPANY

CEMEX

ECN

PSE

CARBON
TRUST

amec
foster
wheeler

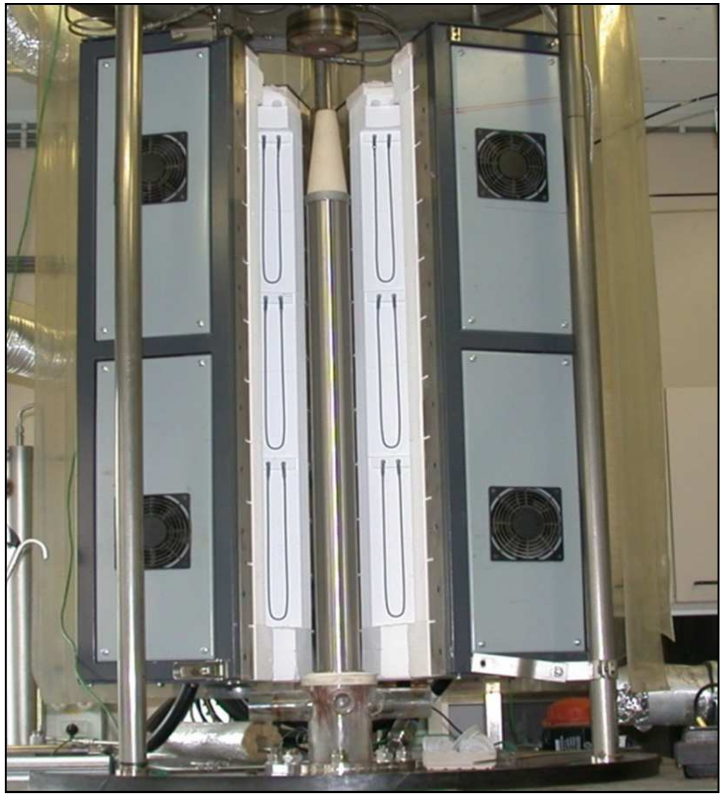
Quantis
Sustainability counts

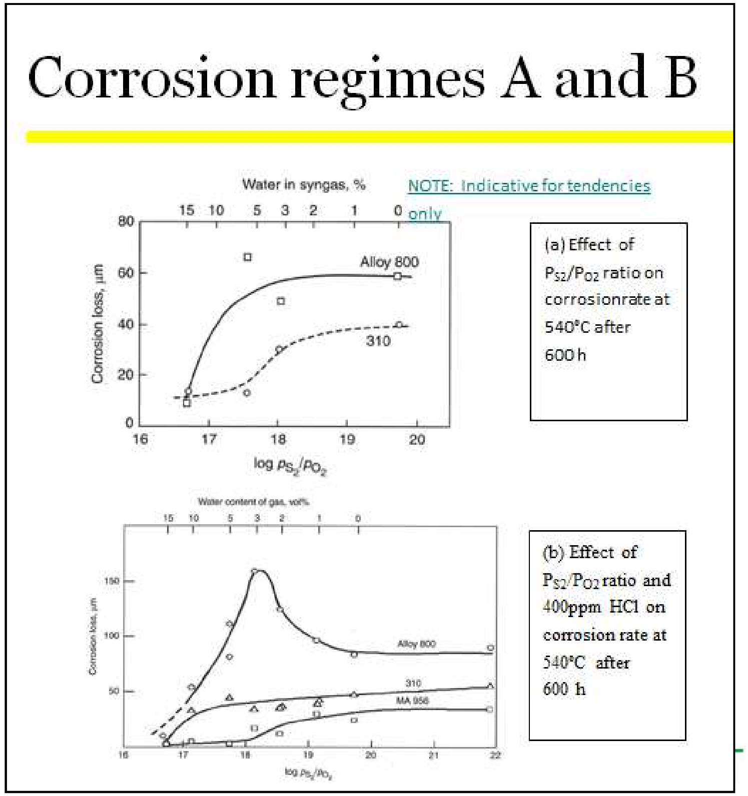
Imperial College
London

This project has received €12m of funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654465

Lab-testing done of high-temp steel tube at ECN-Petten

- **Small scale high temperature reactor simulate operation conditions**
- **Analysis of corrosion regimes and extrapolation of expected lifetime**





Consortium Partners

HEIDELBERGCEMENT

Lhoist

Calix

TARMAC
A CRH COMPANY

CEMEX

ECN

PSE

CARBON TRUST

amec foster wheeler

Quantis
Sustainability counts

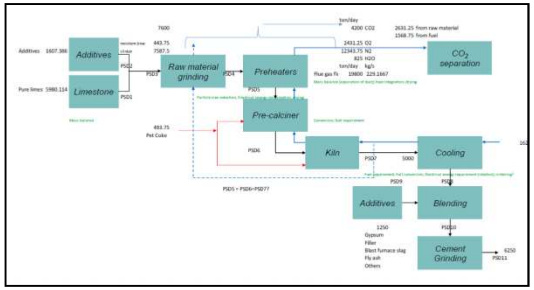
Imperial College London

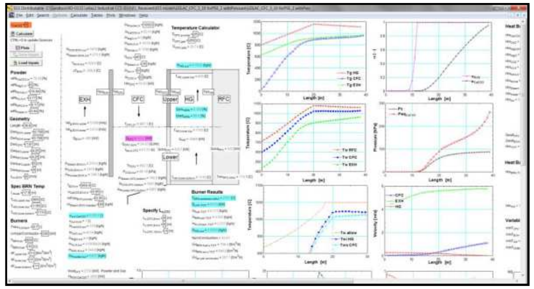
This project has received €12m of funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654465

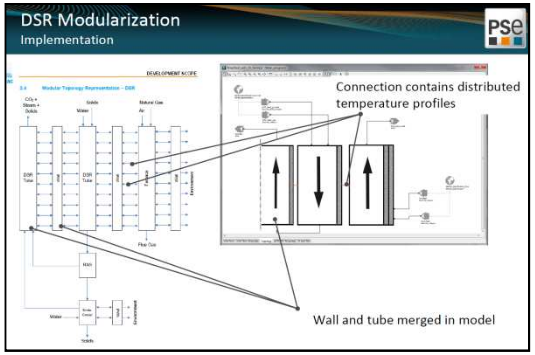
PSE for benchmarking and process models (gPROMS)

Outline

- Task 3a.1 – Reference technologies
  - Cement production
  - Lime production
  - Reference CO_2 capture technologies
- Task 3a.2 - Calculation of mass and energy balances
  - Direct Separation Reactor model in gPROMS
- Task 3a.4 – Definition of performance criteria
  - Reference capture technology model
  - Cement and lime production component models







Consortium Partners

HEIDELBERGCEMENT   Lhoist   Calix

TARMAC A CRH COMPANY   CEMEX   ECN   PSE

CARBON TRUST   amec foster wheeler   Quantis Sustainability counts   Imperial College London

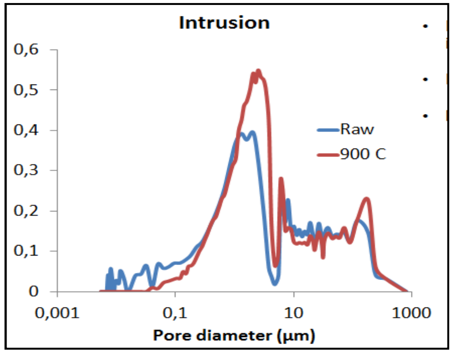
This project has received €12m of funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654465

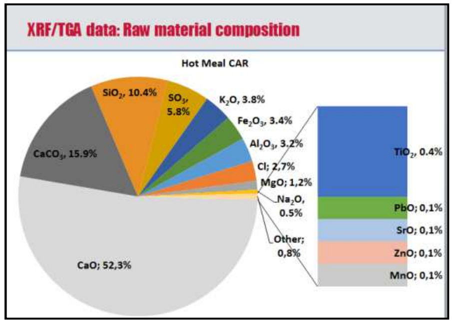
Imperial College - Product evaluations

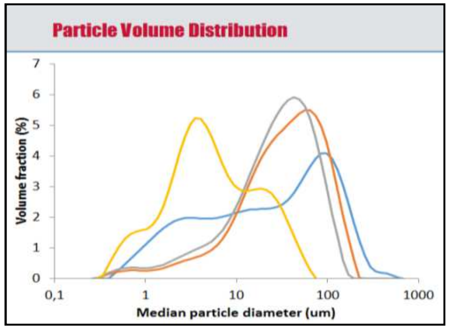
Imperial College
London

Summary

- **WP 2a.1:** Materials characterised
- **WP 2a.1:** Reactor design mostly complete; construction underway
- **WP 2a.2:** Most product testing methods organised
- **WP 3a.1:** Reference documents completed
- **WP 3a.2:** Acquisition of necessary expertise almost completed







HEIDELBERGCEMENT

Consortium Partners

HEIDELBERGCEMENT

Lhoist

Calix

TARMAC
A CRH COMPANY

CEMEX

ECN

PSE

CARBON TRUST

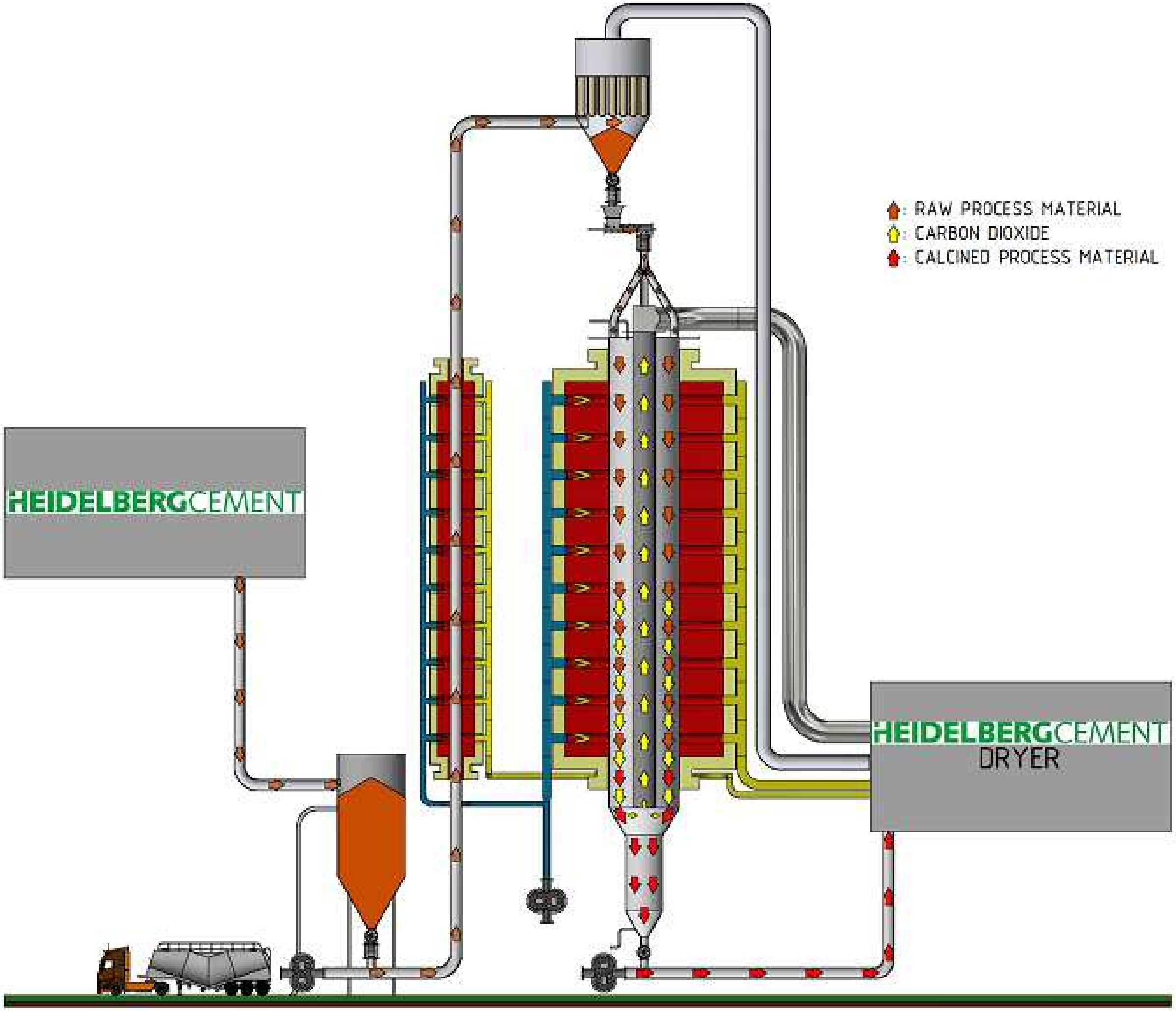
amec foster wheeler

Quantis
Sustainability counts

Imperial College London

This project has received €12m of funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654465

Process flow explained



Front and side view of the tower

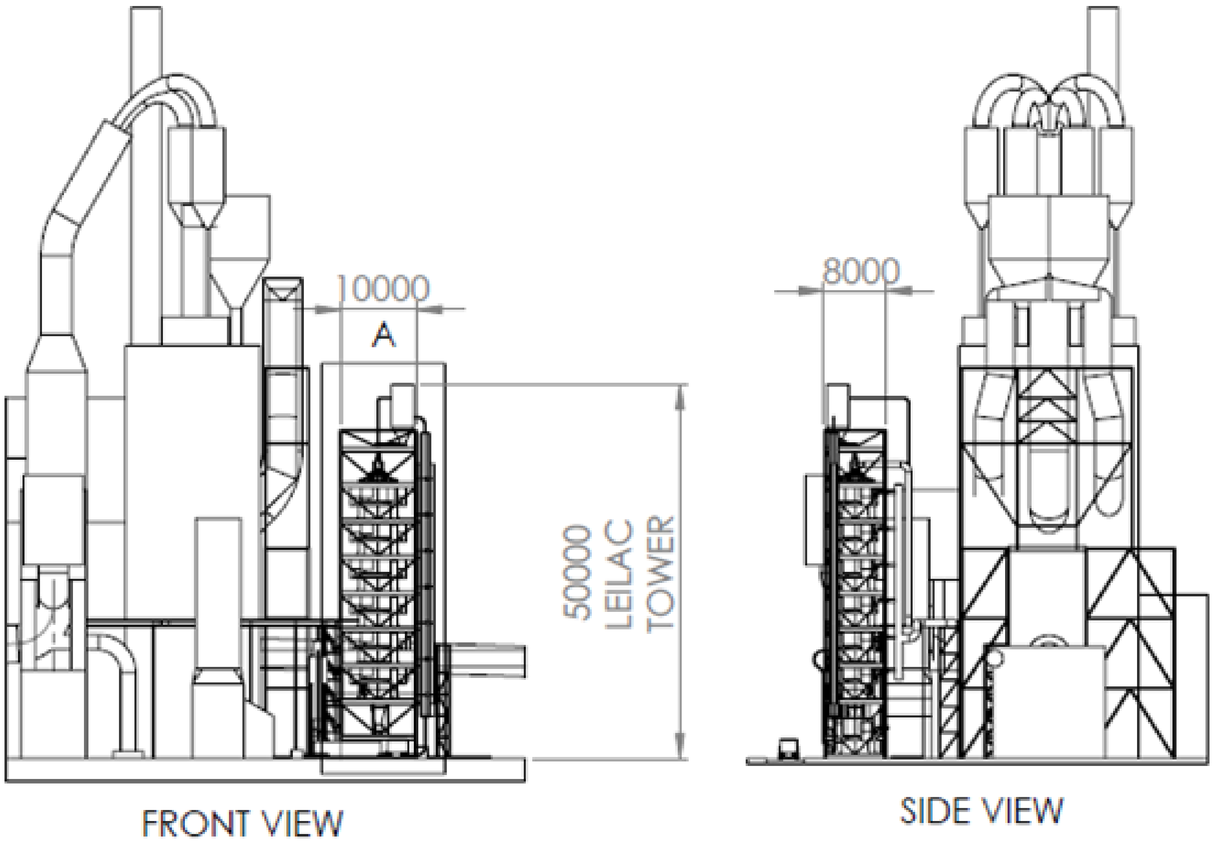
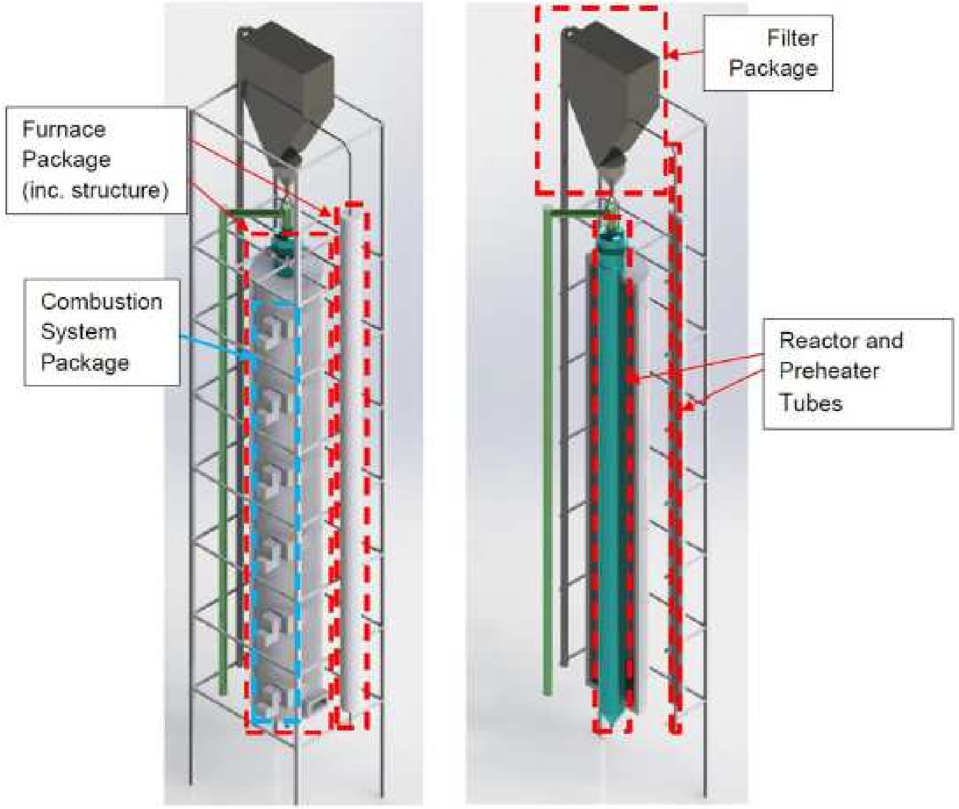


Figure 9 – Tower, shown within existing CBR Lixhe cement plant

Leilac

WP3b project summary – actions through pre-FEED

- Order of Cost (OOC) Estimate produced for the Basis of Design
- Discussions, qualification assessment, and NDAs in place for main suppliers of the four main equipment packages for the pilot
- PFD/HAZID/ENVID Reviews held
- Preliminary Plot Plan Review held
- Preliminary Constructability Review held
- Modularisation Screening Study held
- Design Press/Temp Diagram prepared
- Materials Selection Diagram prepared
- Budget quotations for the major items of equipment have been received and qualified.
- End of pre-FEED Stage Gate Review held (including Cost Gate 1)
- Early FEED activities progressed, e.g. P&IDs, line list, major equipment datasheets.



Cost analysis in order to remain within the budget

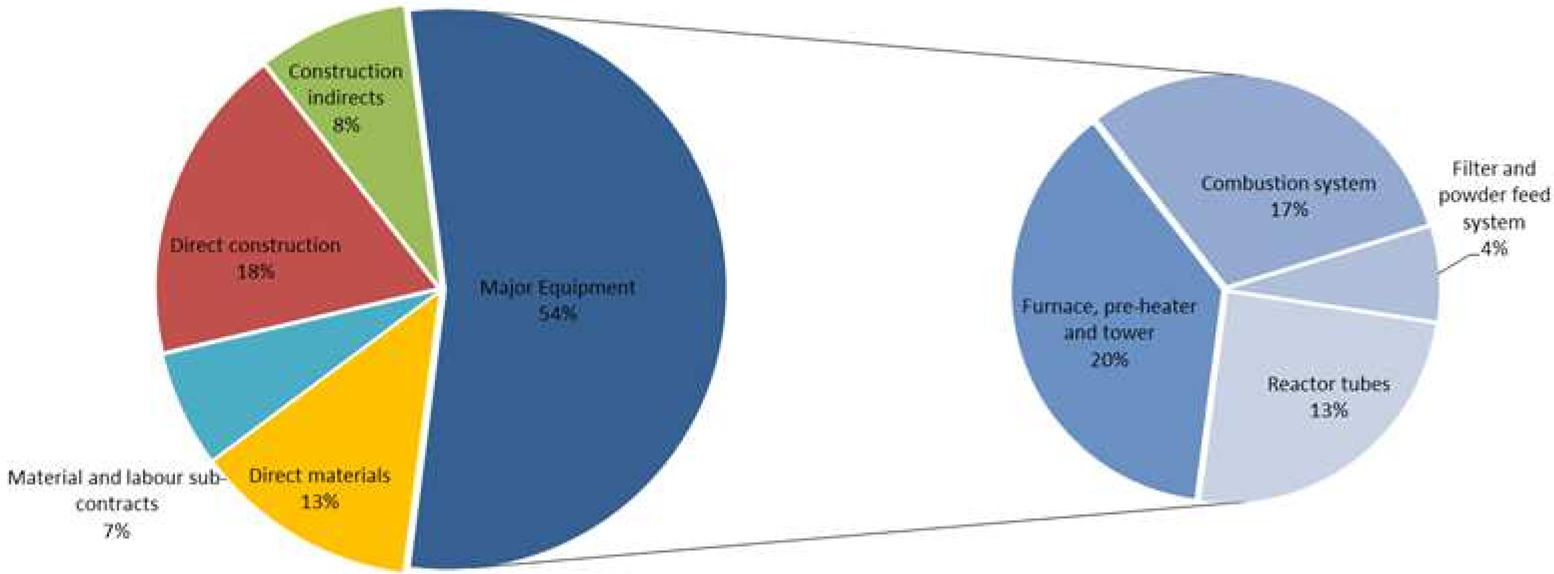


Figure 14 – Pilot's material and construction cost split

Sharp time-schedule – first milestone done !

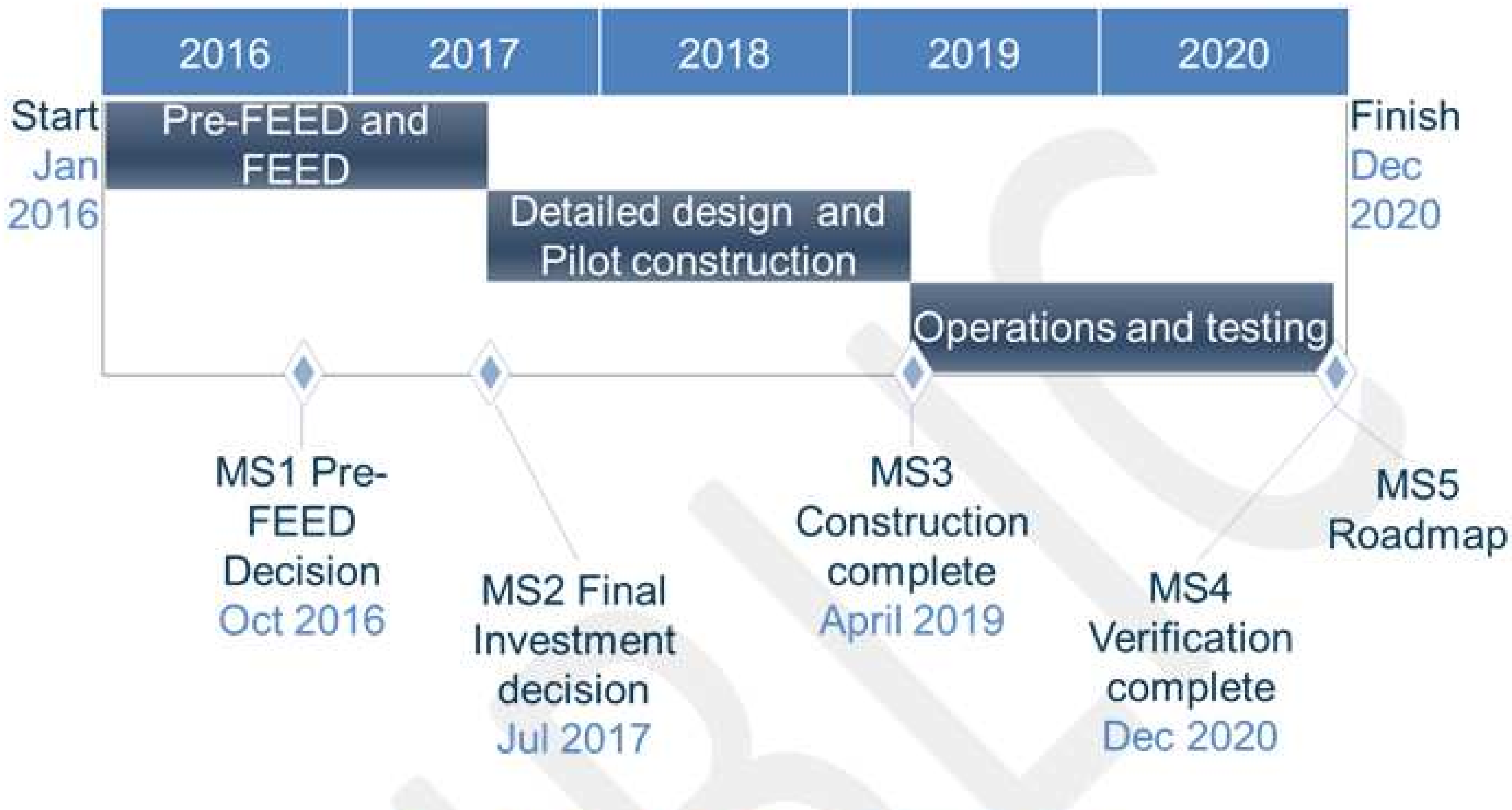


Figure 15 – The LEILAC project's high level timing

Consortium Partners

HEIDELBERGCEMENT

Lhoist

Calix

TARMAC
A CRH COMPANY

CEMEX

ECN

PSE

CARBON TRUST

amec foster wheeler

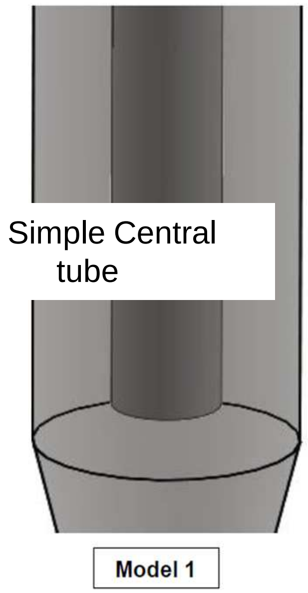
Quantis
Sustainability counts

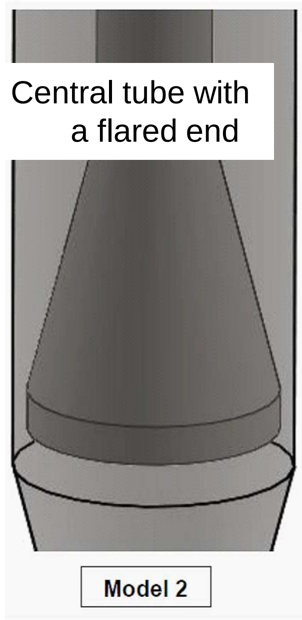
Imperial College London

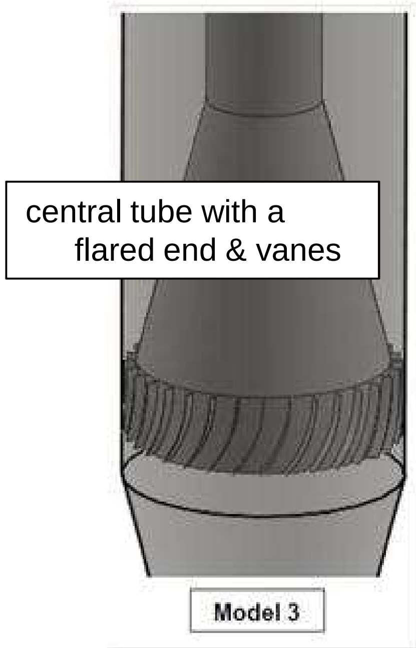
This project has received €12m of funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654465

CFD – analysis in full progress (I)

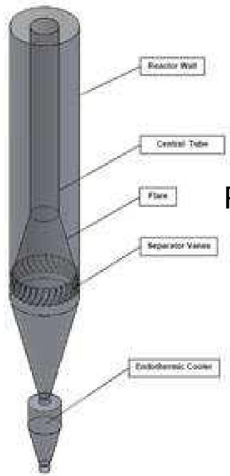
- **3D geometry under development, in order to calculate:**
  - A. Separation efficiency in 10 micron bands.
  - B. Identify areas of accumulation / erosion .
  - C. Suggestions to enhance the separation efficiency
  - D. Magnitude of the torsion on the Central tube caused by the vanes generating a swirl on the gas and particle stream.



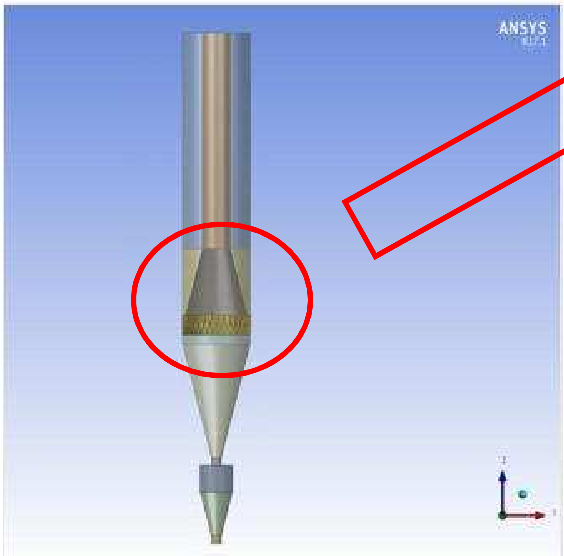


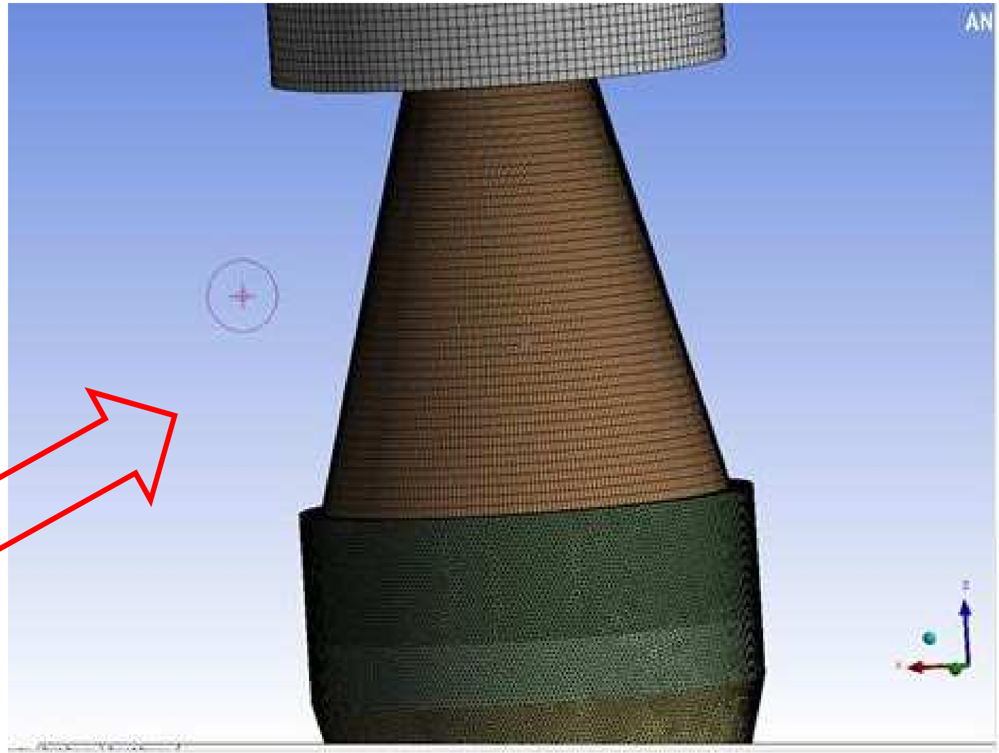


CFD – analysis in full progress (II)



Reference





Consortium Partners

HEIDELBERGCEMENT

Lhoist

Calix

TARMAC
A CRH COMPANY

CEMEX

ECN

PSE

CARBON TRUST

amec foster wheeler

Quantis
Sustainability counts

Imperial College London

This project has received €12m of funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654465

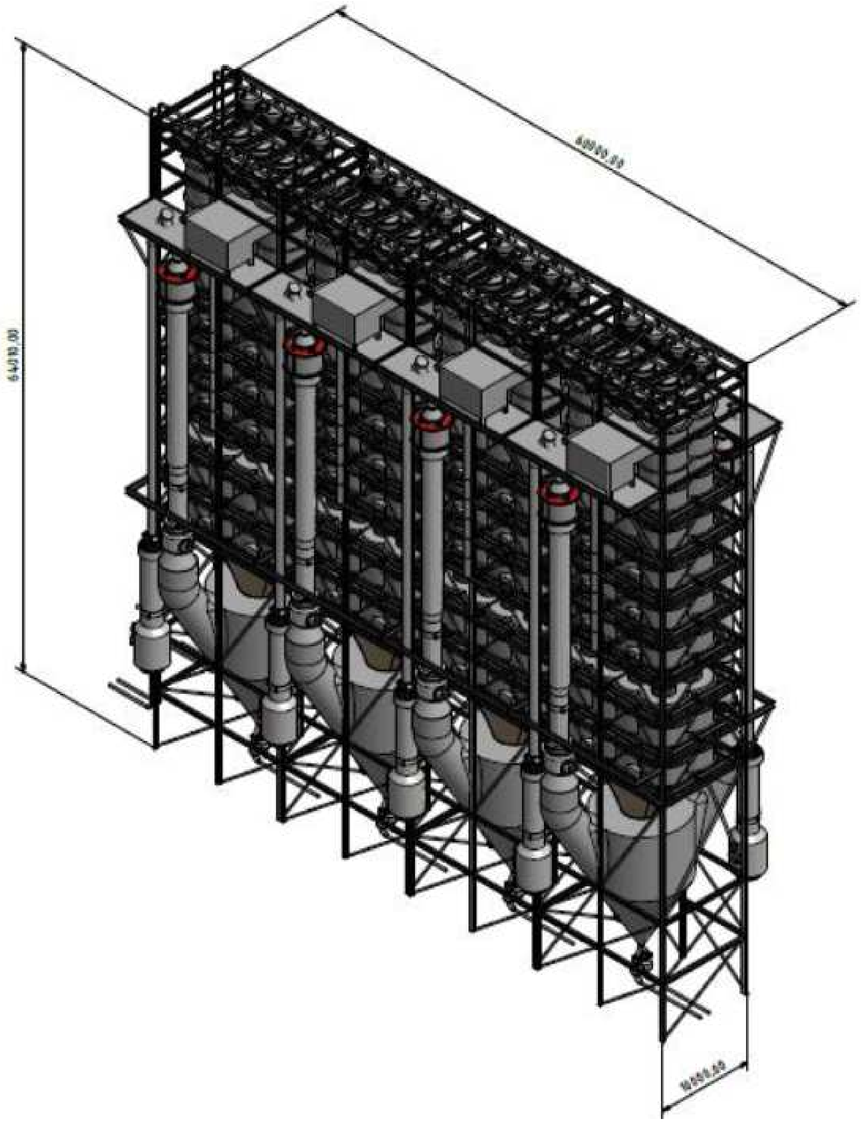
Commercial application (I)

- **Single reactor**
- **Lime – kiln 250 tpd**
  - High surface
  - Added value products
- **CCU for cement kiln 250 tpd**
  - CO_2 separated 30 kton/year
  - Matches with 80 MWe P-t-G facility

HEIDELBERGCEMENT

Commercial application (II)

- **Upscaling for cement industry – full CCS/CCU**
- **Increasing diameter**
- **Multiple reactor**

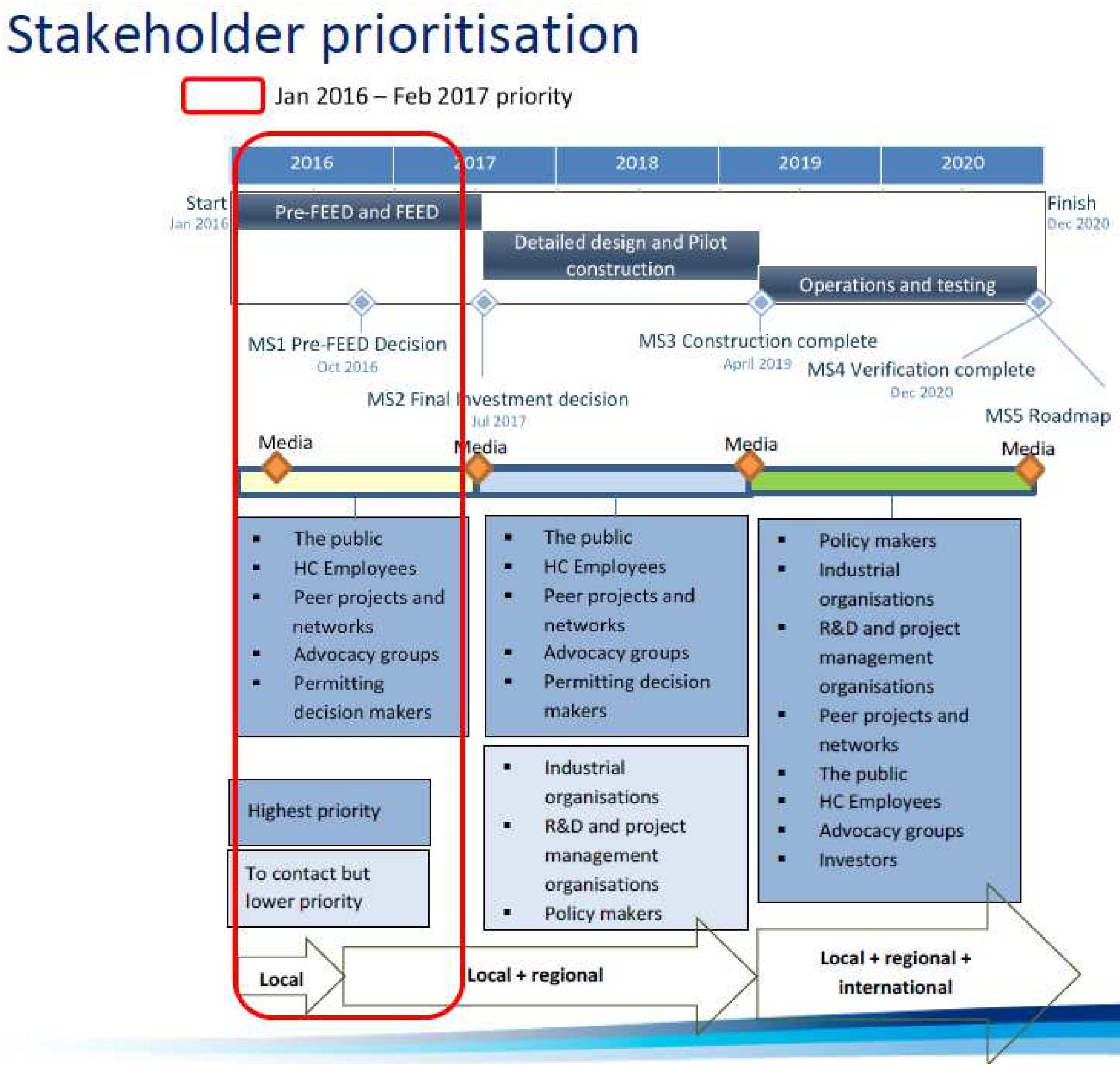


HEIDELBERGCEMENT

Consortium Partners

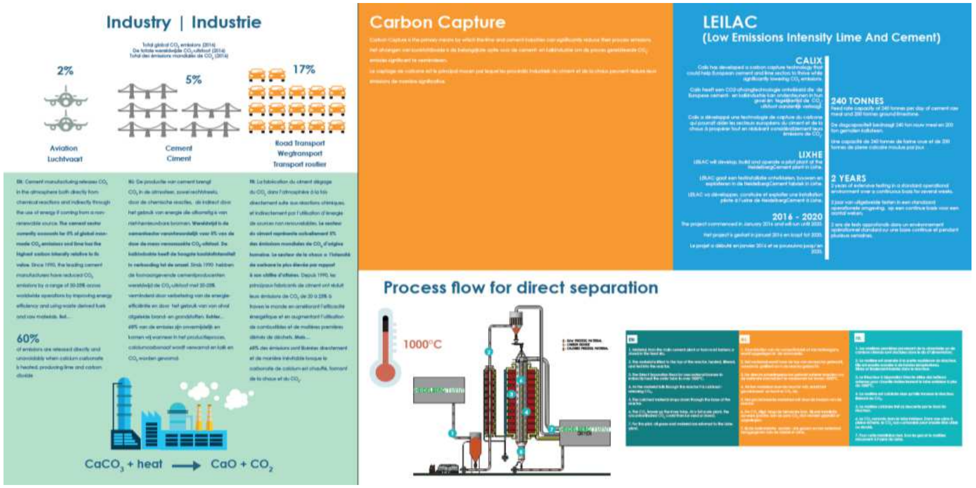
This project has received €12m of funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654465

PR + Communication



Website / articles / visitor centre

- **Website**
  - Hits
  - Seconds/visit
  - Blogs
  - Dutch and French
- **Panels in our visitor center opened today**
- **Press releases in 100 media outlets**
- **Publications:**
  - ICR, CC Journal, Global Cement
  - Wir Heidelberger, HC Group Online etc



42 RESEARCH AND DEVELOPMENT

Carbon capture breakthrough

The EU has awarded a €12m grant to the LEILAC (Low Emissions Intensity Lime And Cement) consortium. The consortium, led by technology provider Calix, aims to apply and demonstrate a breakthrough calciner that can separate the process-related CO_2 without additional energy demand. In combination with conventional carbon capture techniques for the flue gas-related CO_2, this has the potential to give the most economical purification of 100 per cent of a cement or lime kiln's CO_2 emissions. HeidelbergCement, as one of the key consortium partners, is hosting the site for the demonstration at its plant in Lixhe, Belgium.

■ *by* ***Jan Theulen****, HeidelbergCement, Belgium*

In the context of COP21 in Paris, HeidelbergCement signed, together with 17 other cement companies, the Low Carbon Technology Partnership initiative (LCTPi) for cement. This commitment reconfirms the ambitions of the cement industry as stated before in the World Business Council for Sustainable Development's (WBCSD) Global Cement Technology Roadmap. Based on a multi-tiered action plan, the initiative aims to reduce global CO_2 emissions by 20-25 per cent by 2030, compared to "business as usual".

The power sector is accelerating away from fossil fuels. Engie, a multinational power giant, has announced that it will not invest in any new fossil fuel-fired power stations. Meanwhile, large investors such as pension funds are aiming to divert their interest into the renewable energy sector. In some countries, such as The Netherlands, there is an ongoing debate about closing all existing coal-fired power stations.

For the cement sector, however, a large part of CO_2 emissions is process related and cannot be avoided. Therefore, the sector is

Calix's commercial magnesium oxide reactor in Melbourne, Australia

Consortium Partners

HEIDELBERGCEMENT

Lhoist

Calix

TARMAC
A CRH COMPANY

CEMEX

ECN

PSE

CARBON TRUST

amec foster wheeler

Quantis
Sustainability counts

Imperial College London

This project has received €12m of funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654465

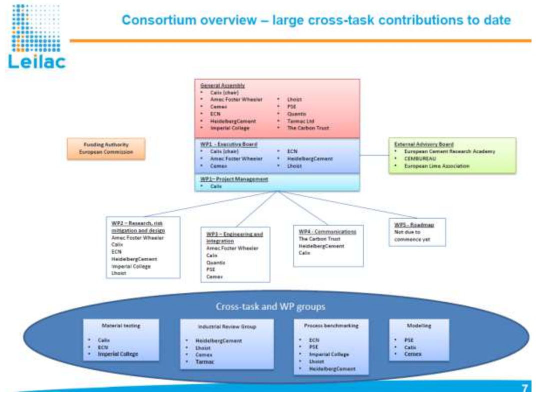
Projectmanagement

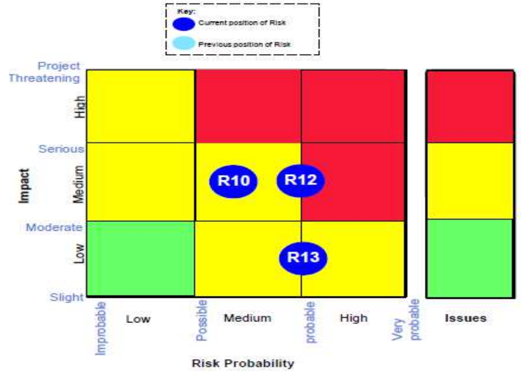
- **Consortium organisation**
  - Workpackages
  - Executive Committee
  - GA, EAB etc

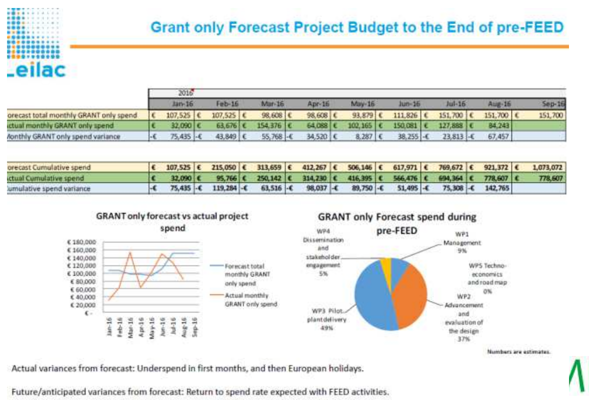
- **Reporting to EU**

- **Risk control**
  - Mitigation management

- **Budget control**
  - Granted money
  - In kind contribution
  - Variations over partners







	2016 Jan-16	Feb-16	Mar-16	Apr-16	May-16	Jun-16	Jul-16	Aug-16	Sep-16
orecast total monthly GRANT only spend	€ 107,525	€ 107,525	€ 98,608	€ 98,608	€ 93,879	€ 111,826	€ 151,700	€ 151,700	€ 151,700
ctual monthly GRANT only spend	€ 32,090	€ 63,676	€ 154,376	€ 64,088	€ 102,165	€ 150,081	€ 127,888	€ 84,243	
Monthly GRANT only spend variance	-€ 75,435	-€ 43,849	€ 55,768	-€ 34,520	€ 8,287	€ 38,255	-€ 23,813	-€ 67,457	
orecast Cumulative spend	€ 107,525	€ 215,050	€ 313,659	€ 412,267	€ 506,146	€ 617,971	€ 769,672	€ 921,372	€ 1,073,072
ctual Cumulative spend	€ 32,090	€ 95,766	€ 250,142	€ 314,230	€ 416,395	€ 566,476	€ 694,364	€ 778,607	€ 778,607
umulative spend variance	-€ 75,435	-€ 119,284	-€ 63,516	-€ 98,037	-€ 89,750	-€ 51,495	-€ 75,308	-€ 142,765	

Consortium Partners

HEIDELBERGCEMENT

Lhoist

Calix

TARMAC
A CRH COMPANY

CEMEX

ECN

PSE

CARBON TRUST

amec foster wheeler

Quantis
Sustainability counts

Imperial College London

This project has received €12m of funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654465

On paper today,
reality in 2019…

HEIDELBERGCEMENT