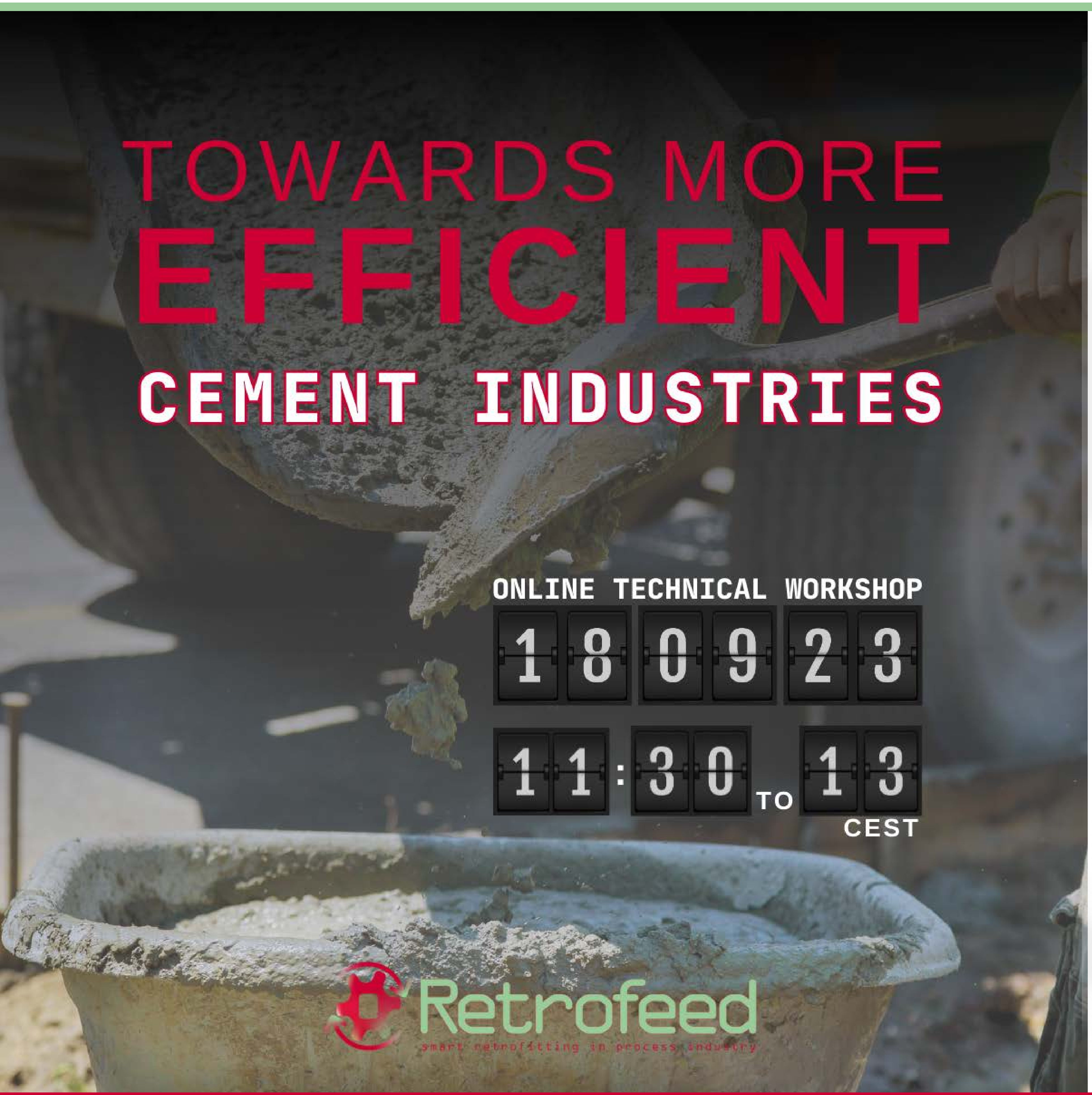


ONLINE TECHNICAL WORKSHOP

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869939.

WELCOME!

For any question, please type it in the chat.

A dedicated Q&A session is scheduled at the end of the event.

This event is recorded and the video will be publicly stored on the website of the project and within the project consortium.

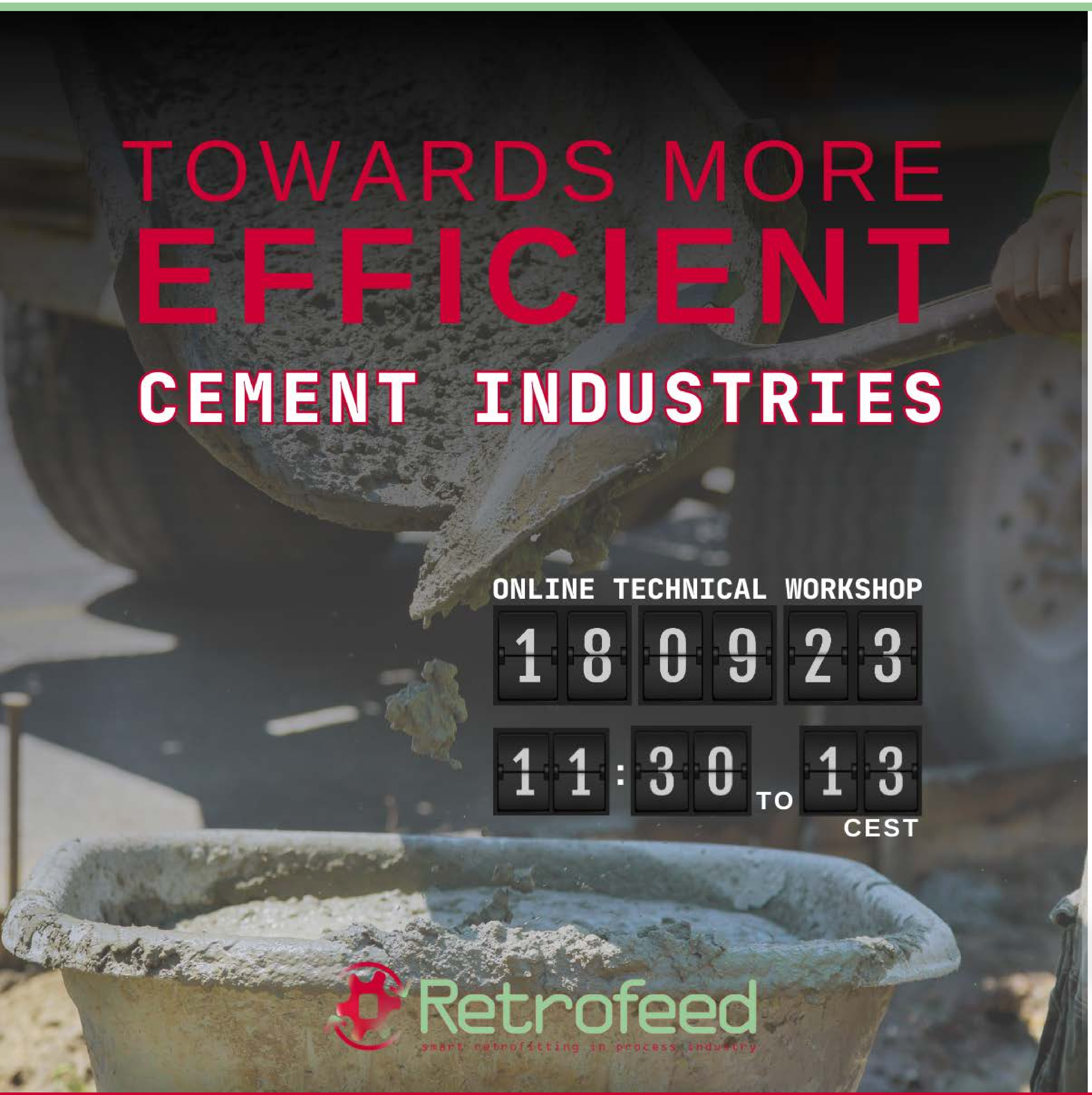
For more info please visit www.retrofeed.eu/privacy/

Retrofeed

smart retrofitting in process industry

Agenda

Monday, 18th September 2023		
SCHEDULE	**AGENDA**	**SPEAKER**
11:15 – 11:30	*Reception on MS TEAMS*	
11:30 – 11:40	**Welcome and RETROFEED introduction**	*Olga Lysenko (IVL)* *Roberto Arevalo (CIRCE)*
11:40 – 11:55	**Digital Twin in cement industry**	*Antonio Alcaide (CIRCE)*
11:55 – 12:10	**Flame visualization monitoring tool**	*Jorge Arroyo (CIRCE)*
12:10 – 12:25	**Quality measurement monitoring system for clinker**	*Francisco Rodriguez (AIMEN)*
12:25 – 12:35	**Main achievements on cement demo site**	*Valter Tavares (SECIL)*
12:35 – 13:00	**Q&A**	*Olga Lysenko (IVL)* *Diego Redondo (CIRCE)*
END OF THE WORKSHOP		



RETROFEED PROJECT

Roberto Arévalo (CIRCE)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869939.

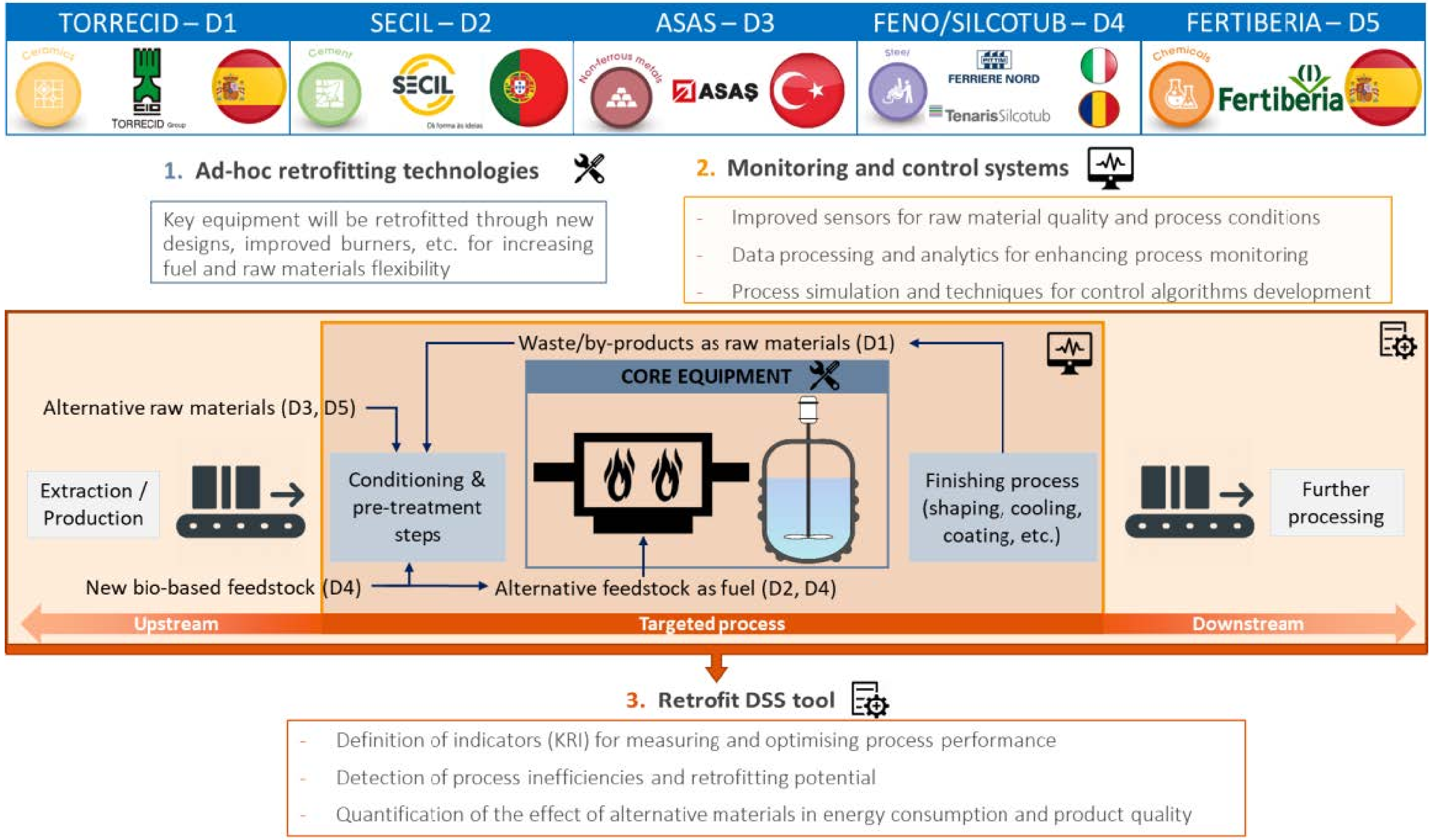
Main objective

RETROFEED main objective is to:

Enable the use of an increasingly variable, bio-based and circular feedstock in process industries through the retrofitting of core equipment, the implementation of an advanced monitoring and control system, and providing support to the plant operators by means of a DSS covering the production chain.

This approach will be demonstrated in **five Resource and Energy Intensive Industries (REIIs (ceramic, cement, aluminium, steel, and agrochemical).**

Overall concept



- ✓ Core equipment retrofitting
- ✓ Improving M&C system
- ✓ Development of new sensors
- ✓ Development of Digital Twins
- ✓ Development of Decision Support Systems
- ✓ TRL 7 solutions

CORE EQUIPMENT – ROTARY KILN

SECIL
Dá forma às ideias

Retrofitting actions

- ✓ Full-scale multi-fuel burner design
- ✓ Image based combustion diagnosis tool
- ✓ Alternative fuels properties determination
- ✓ Real time clinker optical characterization

Goals

- ✓ CO_2 emissions reduction
- ✓ Replacement of fossil fuel close to 100%
- ✓ Increment in energy efficiency
- ✓ M&C improvement

CORE EQUIPMENT – MELTING FURNACE

ASAŞ

Retrofitting actions

- ✓ Delacquering system
- ✓ O_2 injection system
- ✓ New burner head design
- ✓ O_2 and TOC analyzers

Goals

- ✓ 50% increment in the amount of scrap
- ✓ Reduction of the energy consumption 15 times
- ✓ More efficient combustion
- ✓ Reduction of the GHG emissions
- ✓ Improved M&C system

CORE EQUIPMENT – ELECTRICAL ARC FURNACE

Retrofitting actions FENO

- ✓ Burner modification for feeding biochar and plastic grains
- ✓ Injection system

Retrofitting actions SILCOTUB

- ✓ Feeding injection system

Goals

- ✓ Reduction of GHG emissions
- ✓ Use of alternative feedstock
- ✓ M&C system improvement

CORE EQUIPMENT – FRITS FURNACE

TORRECID

Retrofitting actions

- ✓ Feeding system enhancement
- ✓ Redesign of the flue gases recovery system
- ✓ Implementation of new sensors
- ✓ Smart control

Goals

- ✓ Energy and material savings
- ✓ Optimization use of fuel and combustion air
- ✓ Reduction of material waste
- ✓ Improved M&C system

CORE EQUIPMENT – PHOSPHOROUS REACTOR

Fertiberia

Retrofitting actions

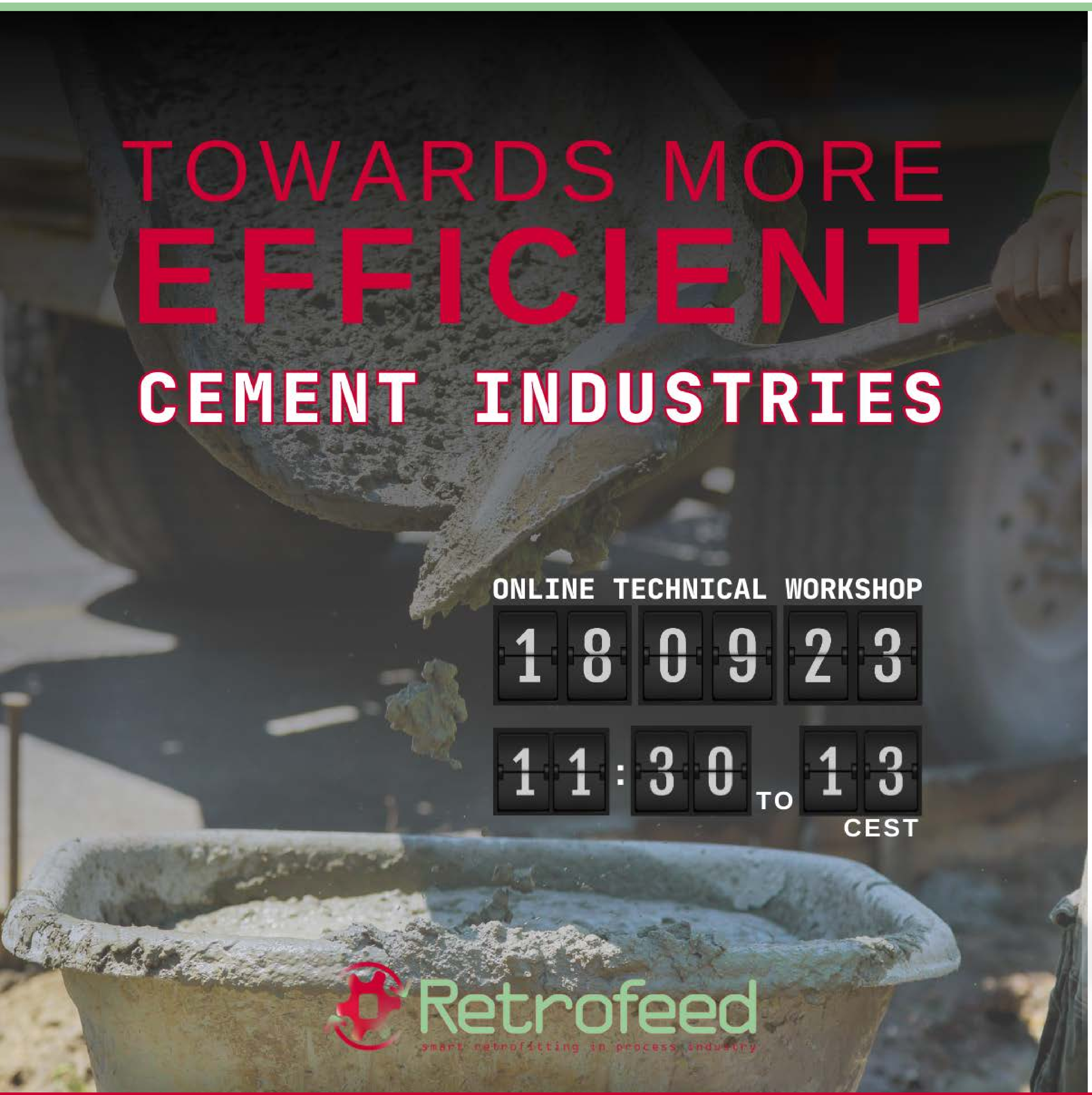
- ✓ New design of a in-line reactor for alternative phosphorus sources

Goals

- ✓ Replace 10% of the currently used phosphorous sources
- ✓ Recover valuable raw materials from wastes
- ✓ Reduction of cost
- ✓ M&C system improvement

Direct impacts

- Increasing the resource and energy efficiency of the targeted processes by 20%;
- Decrease GHG emissions through retrofitting by at least 30%;
- Decreased utilisation of fossil resources in the process industry of at least 20%;
- Reduced OPEX by 30% and increased productivity by 20%;
- Effective dissemination



DIGITAL TWIN IN CEMENT INDUSTRY

Antonio Alcaide (CIRCE)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869939.

Digital twin of a cement rotary kiln

INDEX

1. Context and problem definition

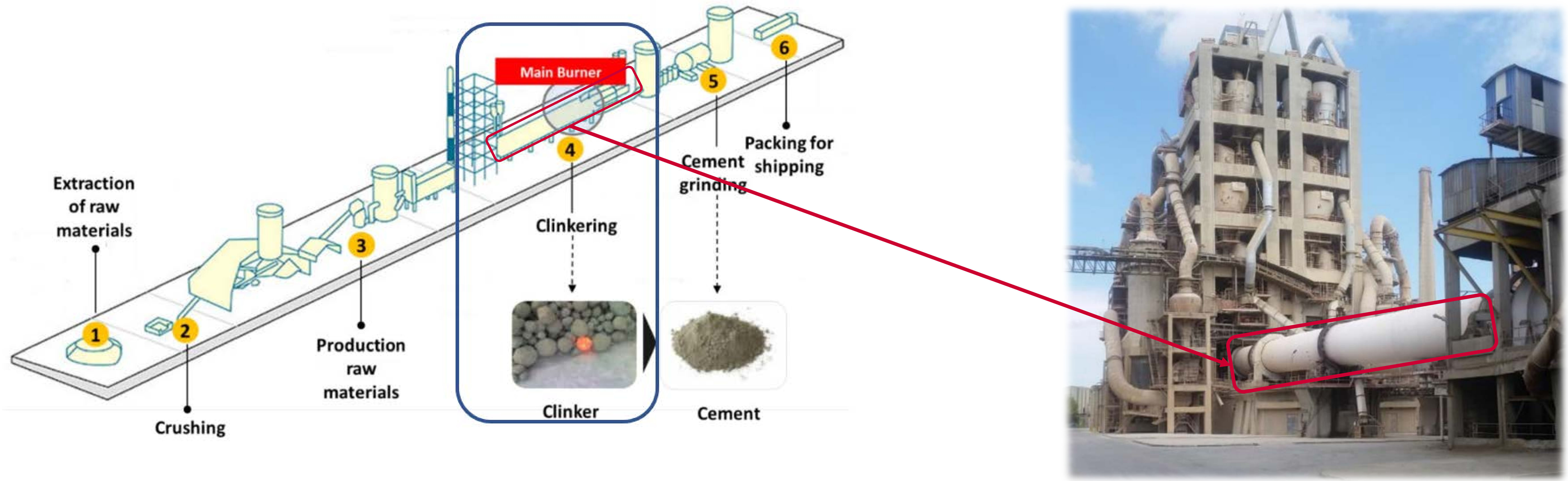
Cement industry pollution → Alternative fuels to reduce impact → Use of **Refuse Derived Fuel (RDF)** and **tyres**

- 5-8 % global CO2 emissio
- Highly energy intensive in
- Fuels usually account for 3
- Alternative fuels allows re solution for avoiding landf
- Alternative fuels of fossil o
- Biobased alternative fuels and bone meal, paper, wo
- Refuse Derived Fuels (RD cardboard, textiles, fluff…
- Moisture can range from ~ ~150 mm
- Heterogeneous mixture of properties, combustion kin

Low quality fuel (moisture, ashes, big size, heterogeneity)

Complex combustion behaviour

1. Context and problem definition



1. Approach and challenges

Clinker production requirements

+

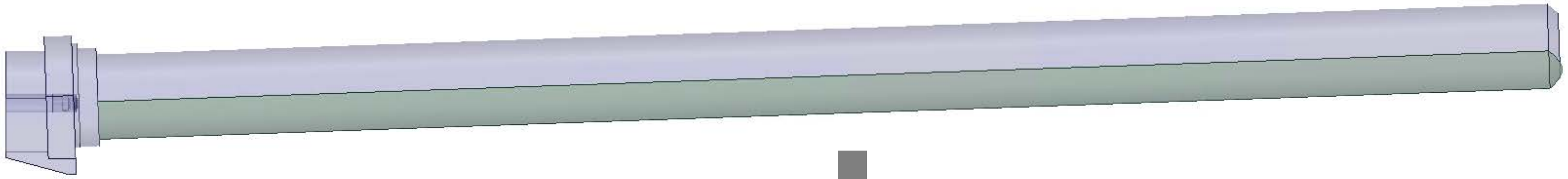
Complex physics inside kiln

+

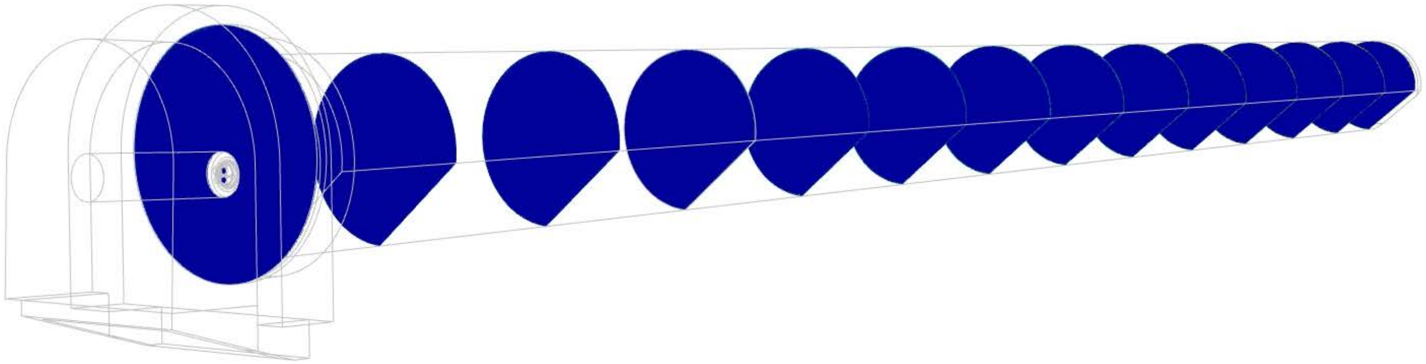
Low quality of RDF

Need of a digital model to assess effect of relevant variables, provide support and test what-if scenarios

CFD model of rotary kiln to solve combustion behaviour of fuels



1D sliced model for solving clinker composition and assessing changes in operational parameters in a computationally cheap way

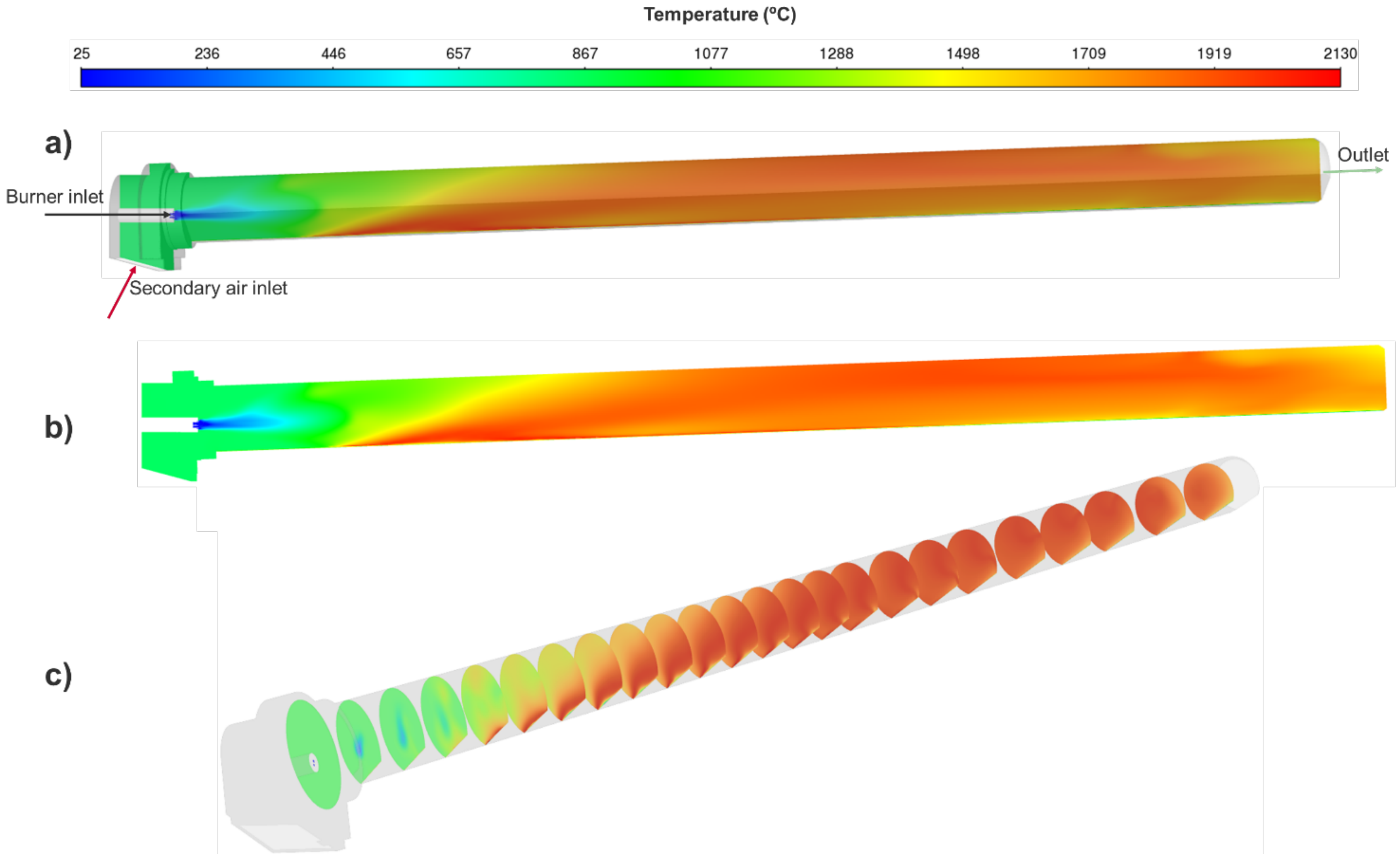


1. Approach and challenges

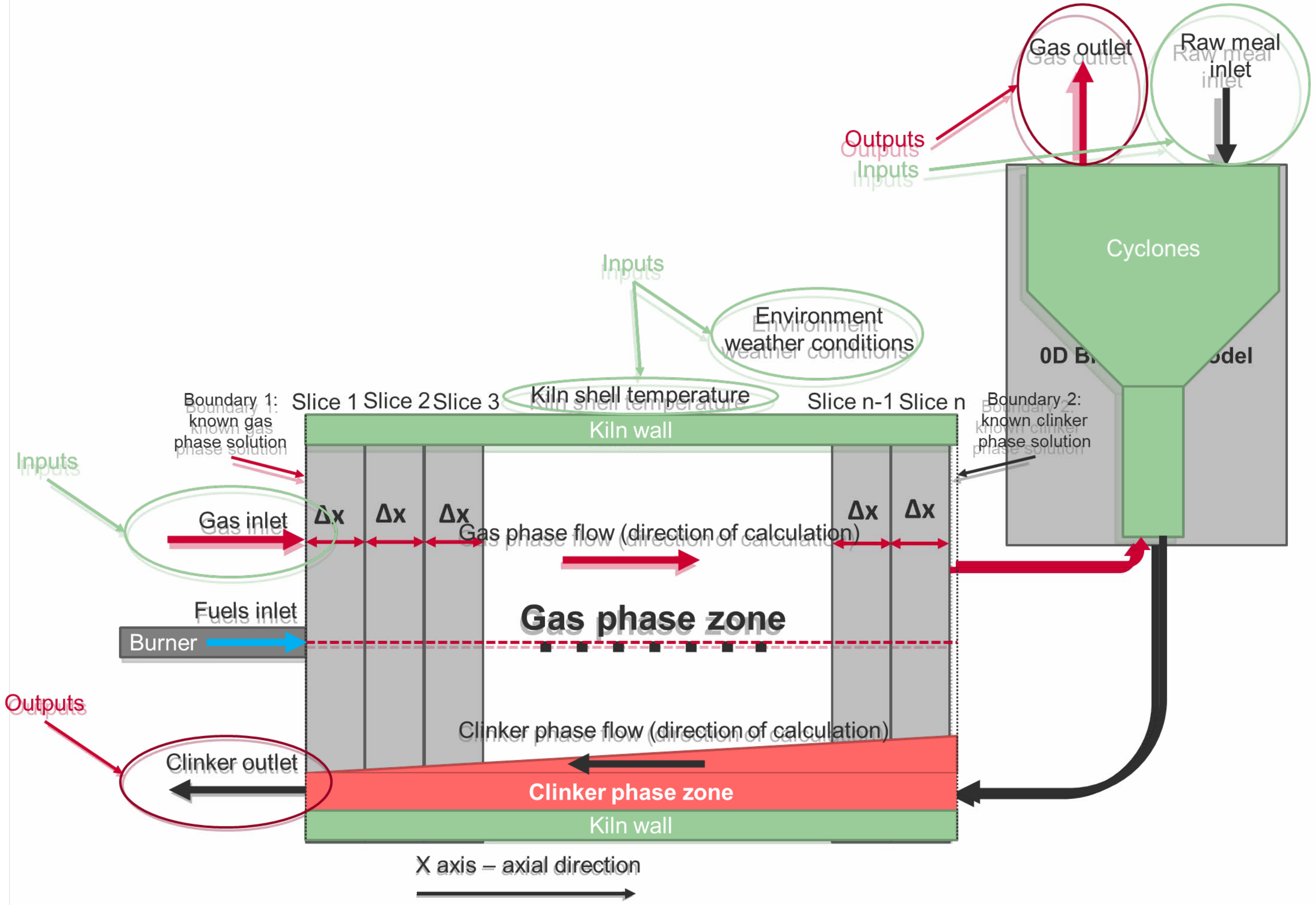
Cause	Problem	Possible solutions	Adopted solution
Local peak values for temperature are not computed	Minor pollutants (NOx, SOx, CO) formation cannot be considered	Search for simplified models to estimate → Very inaccurate	No minor pollutants will be given as outputs, agreed with partners
Local sinks of oxygen are not computed	All oxygen is available for fuel	Break every slice into different zones to compute location of particle and available oxygen in that location → Difficult, gain in accuracy is not guaranteed	Compute some CFD simulations with representative fuels mixture, and use burning fuels information to feed 1D model as fixed burning values
Flight of particles are not computed	Inaccurate burning location of particles	Perform simplified force balances with empirically obtained correlations to calculate falling locations → Tedious, but possible. Not very accurate	Compute some CFD simulations with representative fuels mixture, and use burning fuels information to feed 1D model as fixed burning values
Heat radiation fluxes are not computed	Inaccurate radiation modelling	Apply direct or network method, using view factors → Possible, but very computationally expensive and complex since it also requires coupling with other heat transfer mechanisms	Use very rough heat transfer contribution estimation, from literature review

2. Model development

CFD model of rotary kiln



1D model of rotary kiln and cyclone



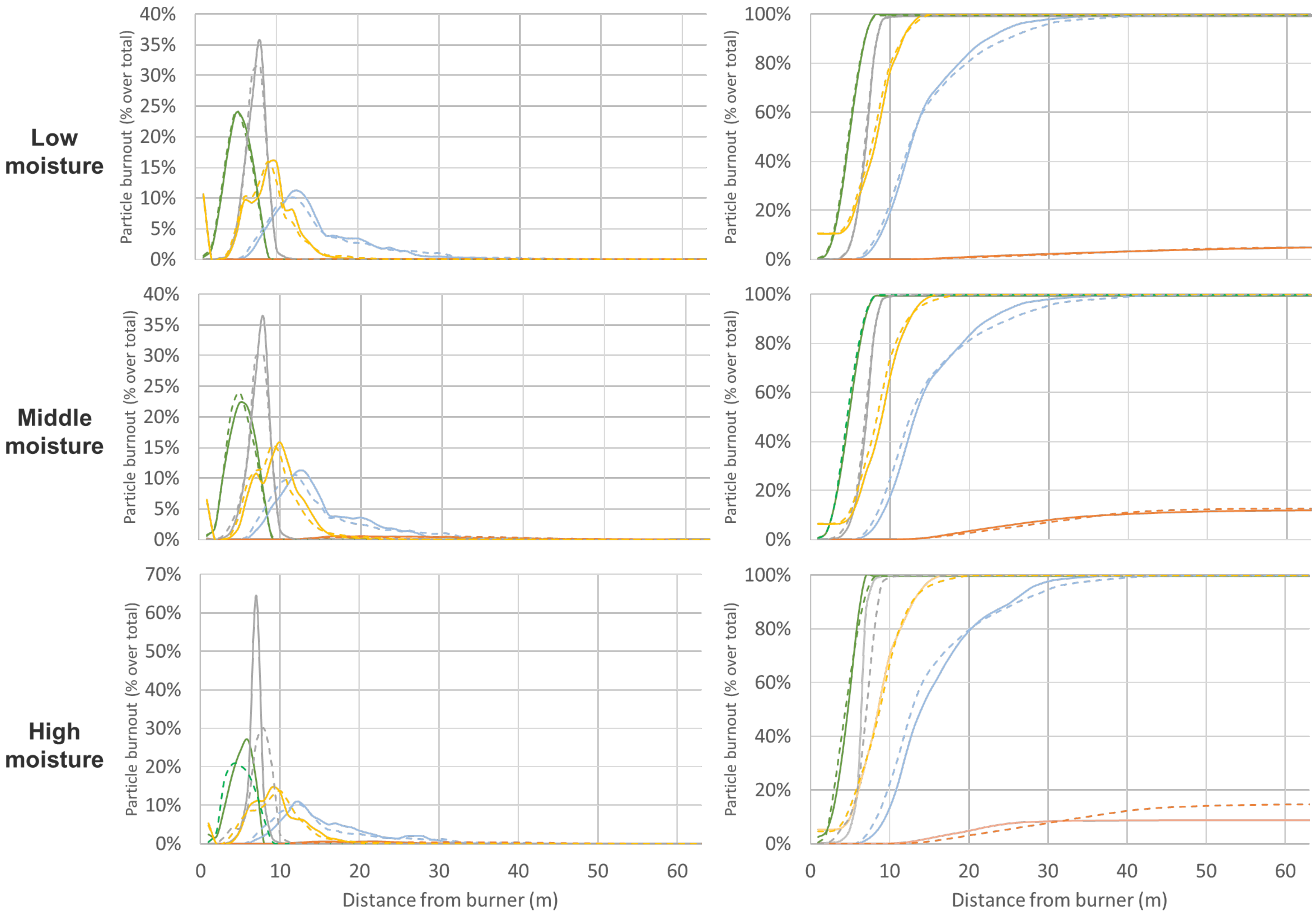
3. Results from validation and fine-tunning

Combustion profiles from CFD simulations

	λ=1.1	λ=1.4
Petcoke volatiles	solid green line	dashed green line
Petcoke char	solid grey line	dashed grey line
RDF volatiles	solid blue line	dashed blue line
RDF char	solid orange line	dashed orange line
Evaporated water	solid yellow line	dashed yellow line

↑ Moisture ↑ RDF burnout length

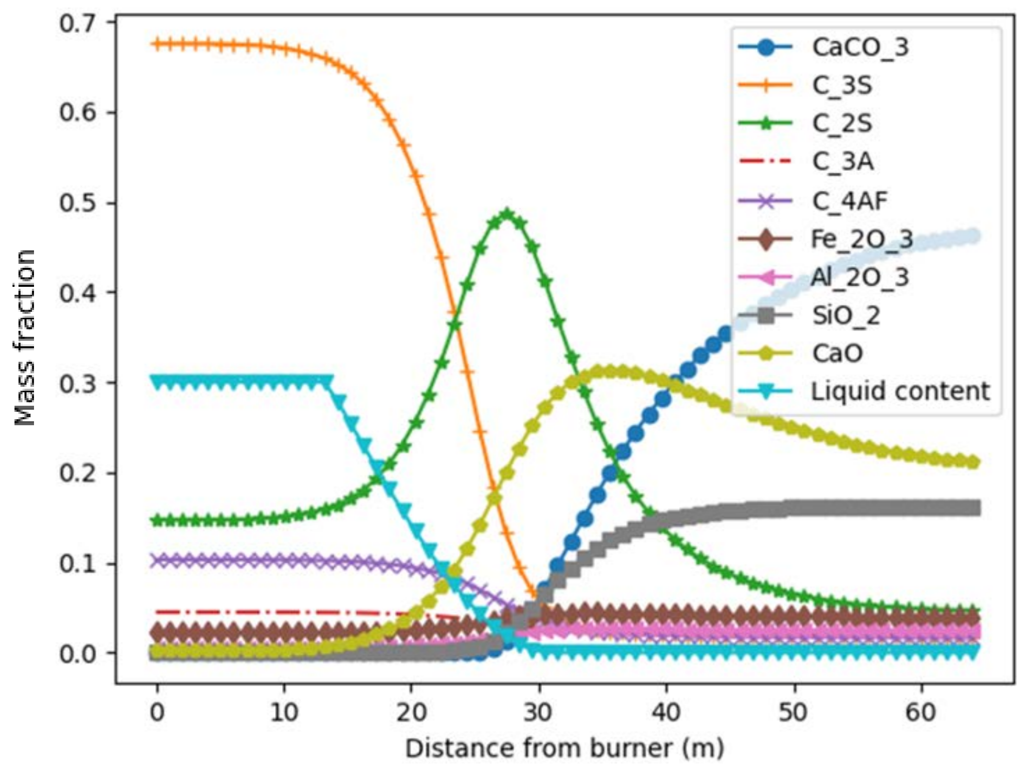
↑ Excess air ↑ RDF burnout fraction



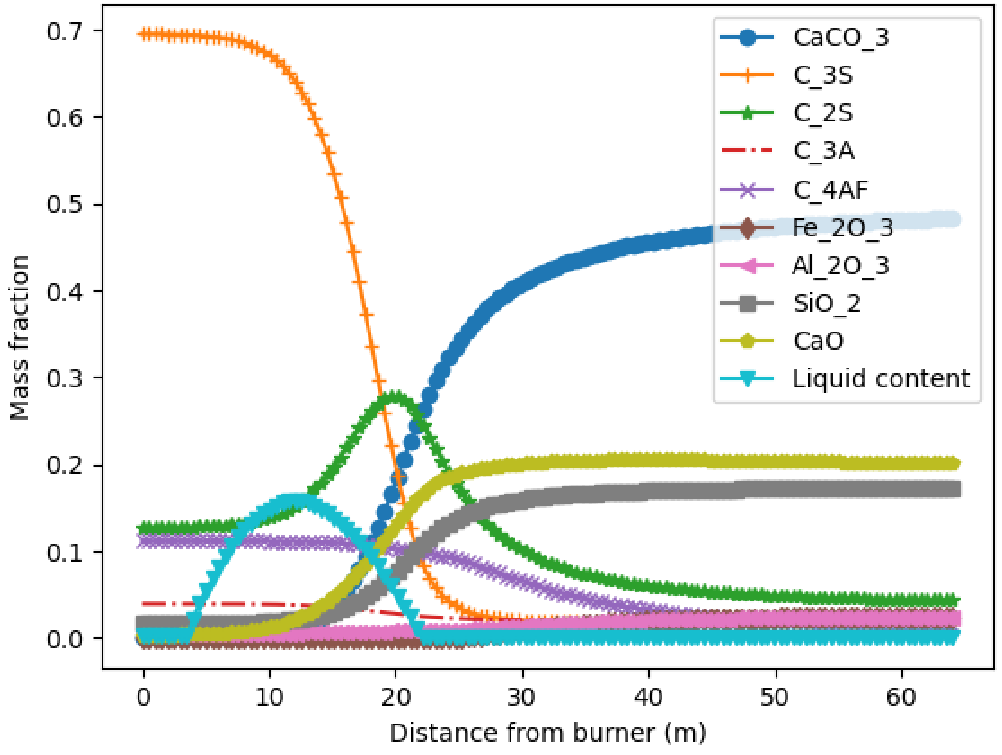
3. Results from validation and fine-tunning

A set of 14 empirical parameters exist in the model and were adjusted to match as good as possible 6 validation points, by using metaheuristic methods (Covariance Matrix Adaptation Evolution Strategy).

1st DT version



2nd DT version



Comparison

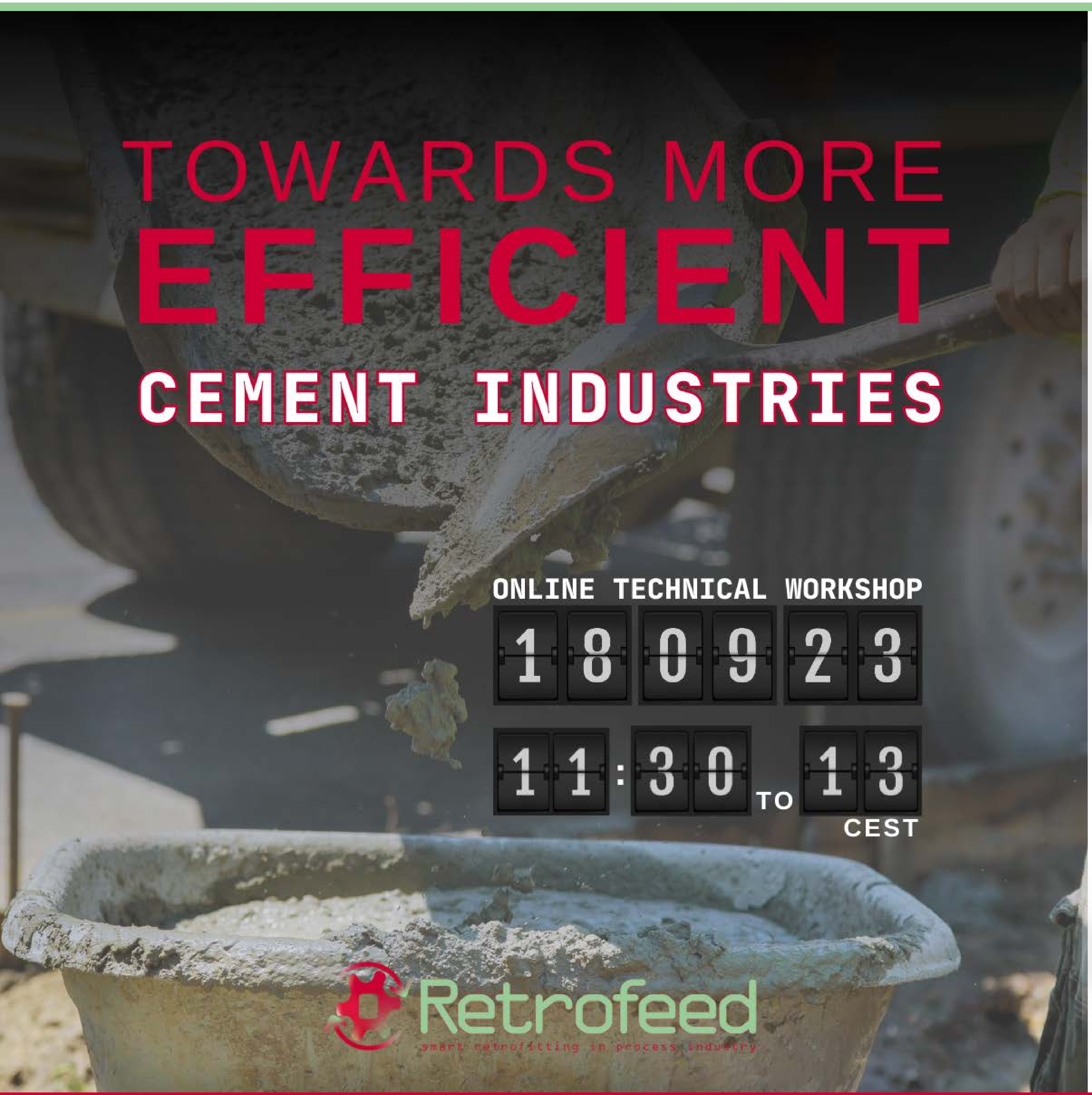
- Doubled sampling of kiln slices
- More accurate empirical parameters
- Better melting computation

Species	Mean relative error (%)		
	1st version	2nd version	Diff.
$CaCO_3$	0	0.00	0
CaO	78.46	81.38	-2.92
SiO_2	0.00	0.00	0
C_4AF	6.14	2.62	3.52
C_2S	36.58	20.74	15.84
C_3S	5.57	2.25	3.32
C_3A	8.82	5.70	3.12
Overall weighted error	10.12	5.35	4.77

Retrofeed
smart retrofitting in process industry

4. Conclusions

- All fuels have been characterised using historical data and taking into account their variability in time and performing size distribution measurements
- RDF is a very heterogeneous mixture of fuels which needs to be simplified to be introduced in numerical models
- CFD model captures the complex behaviour of RDF particles flight and burning, thus providing useful and accurate information to 1D model, thus accomplishing the task 6.1 objective of proper modelling of alternative fuels. Furthermore, it has been seen that the general flight and burning trajectories of the different RDF modelled is similar, which helps to reduce uncertainties when changing RDF supply
- The modelling approach considered here, a hybrid CFD-1D model, seems to be enough to provide realistic outputs estimation avoiding high computation times for the Decision Support System (DSS)

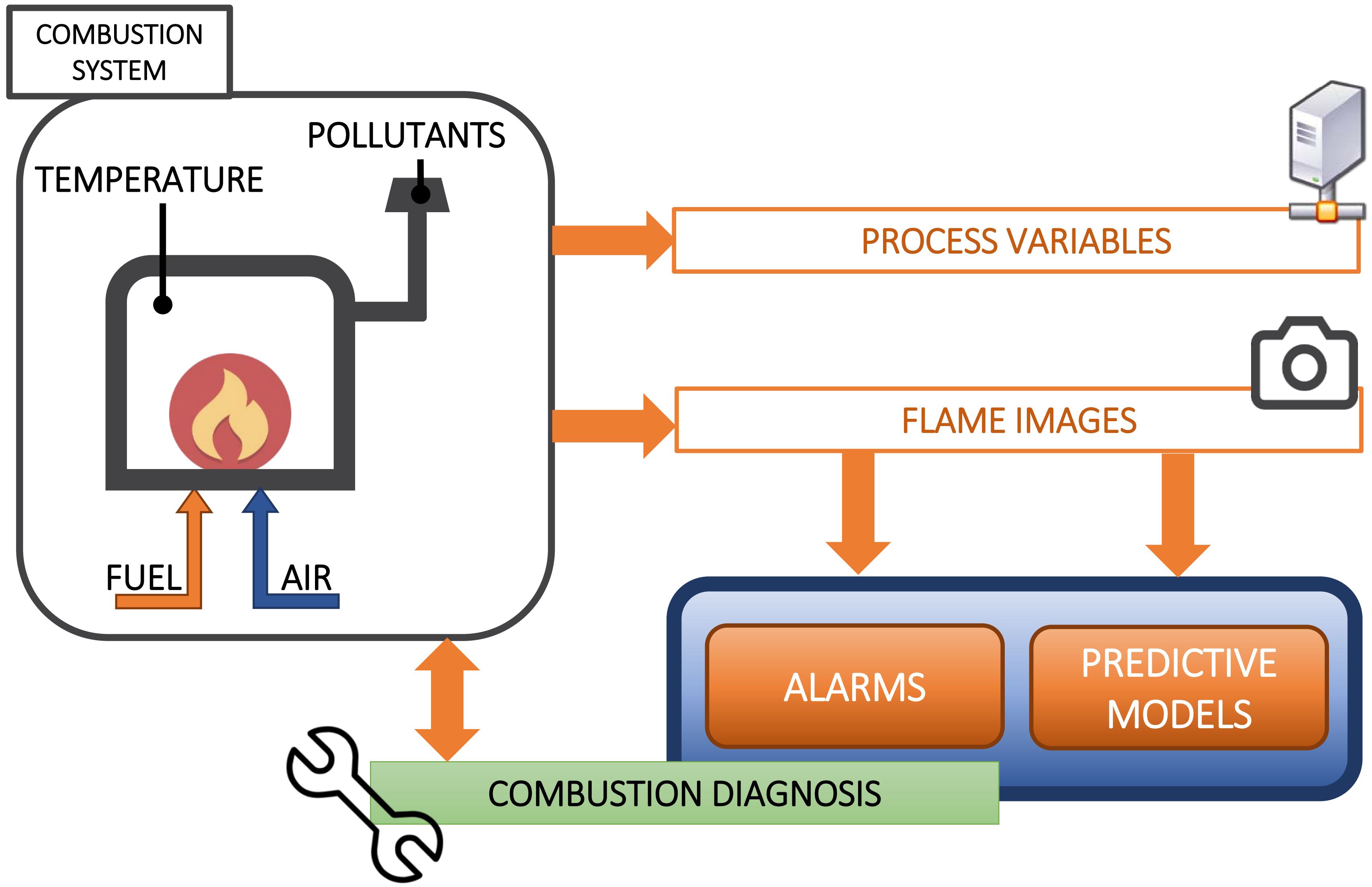


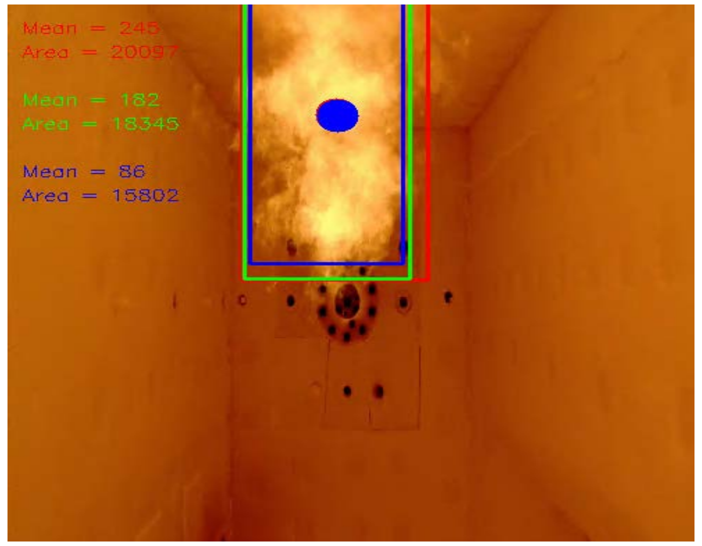
FLAME VISUALIZATION MONITORING TOOL

Jorge Arroyo (CIRCE)

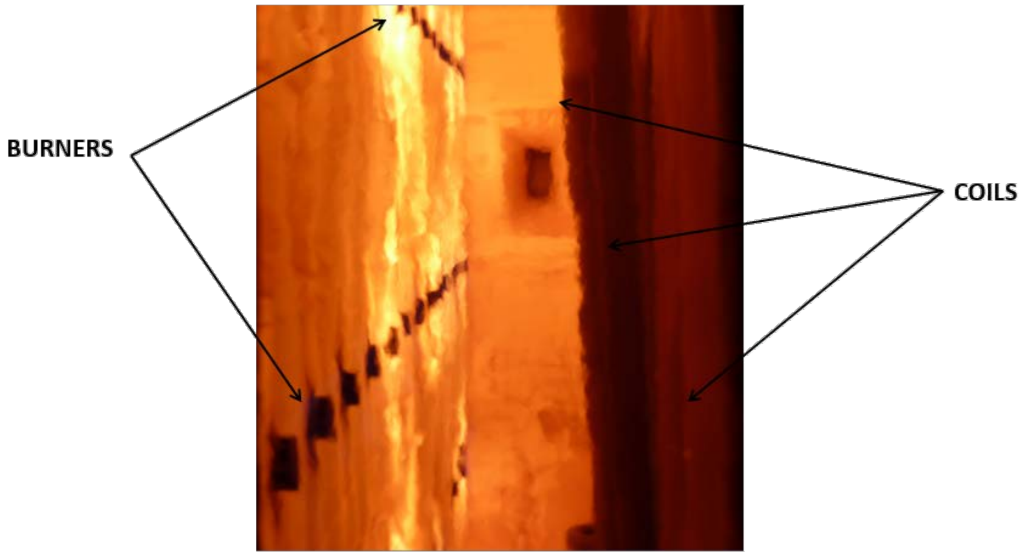
This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 869939.

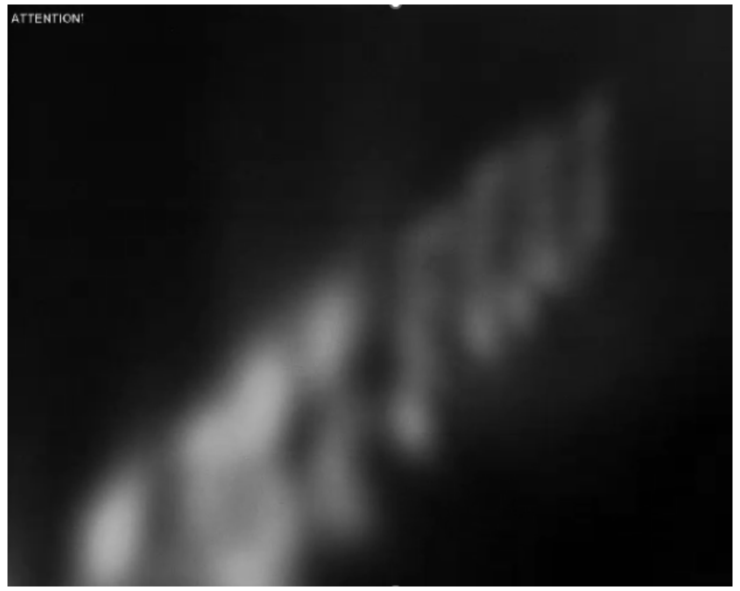
Combustion monitoring in REIIs





Steel Sector

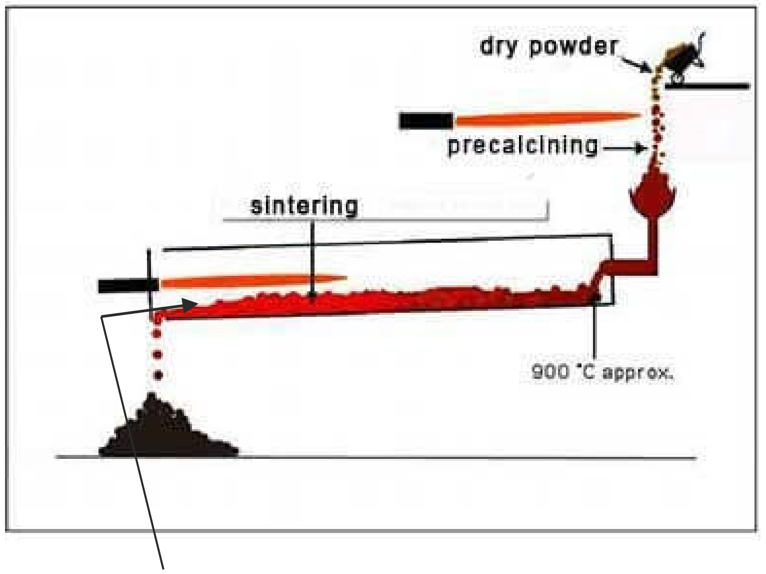




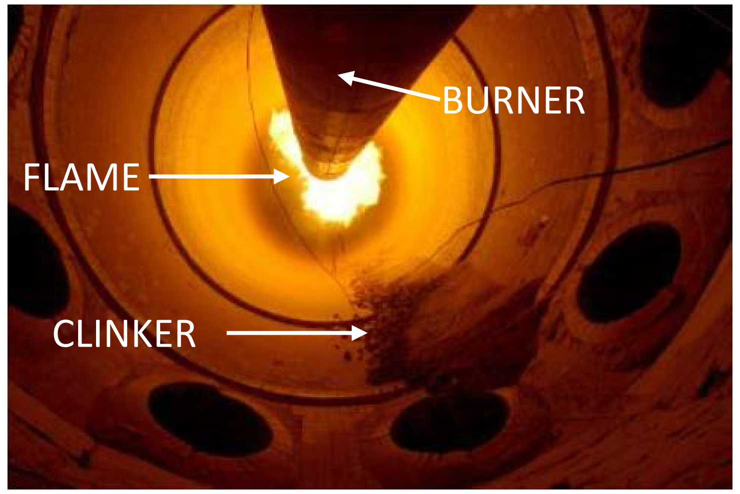
Chemical Sector

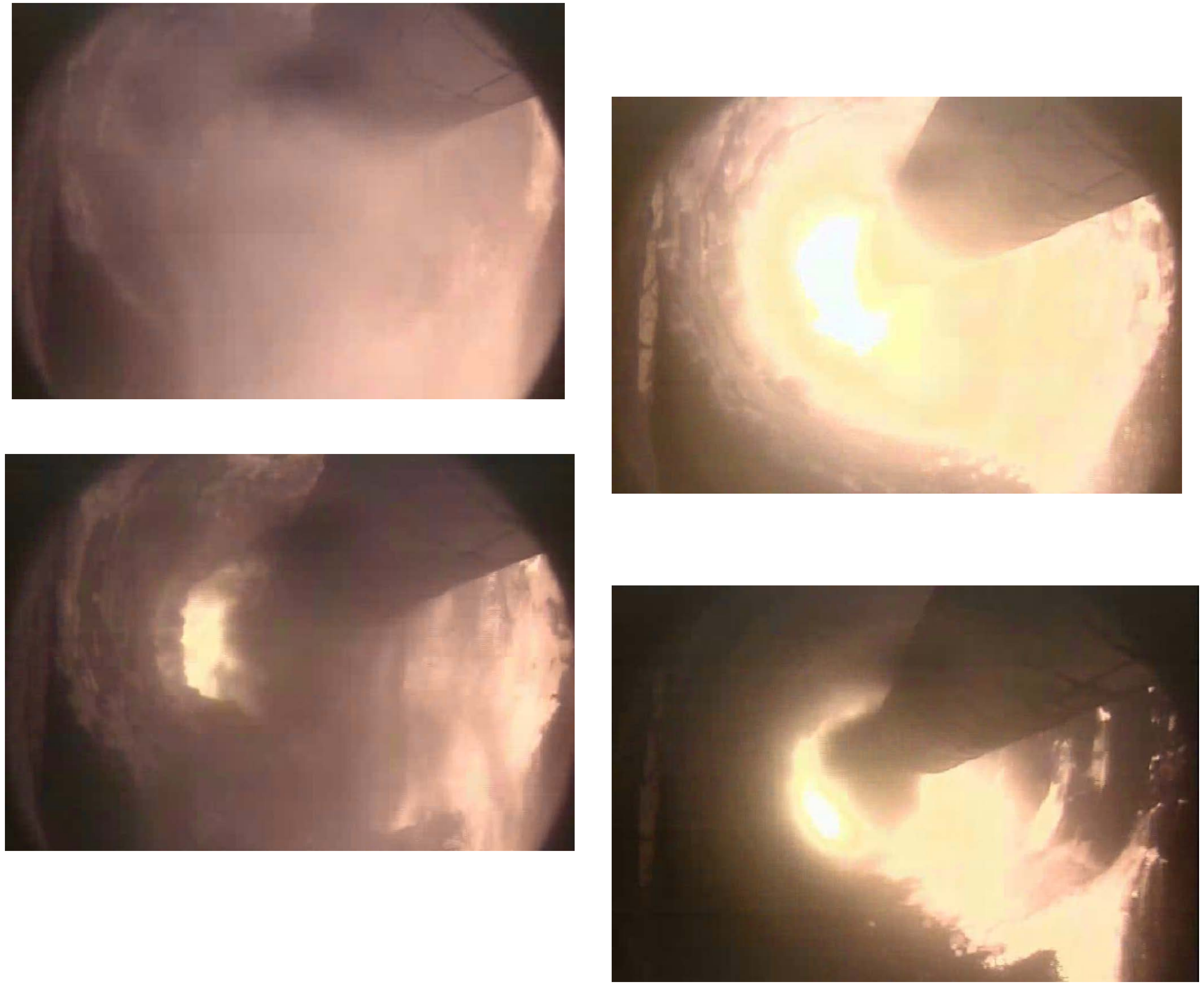
Laboratory Setup

Combustion monitoring in rotary kilns – RETROFEED



CAMERA

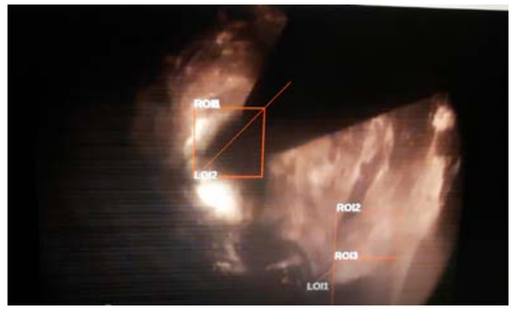


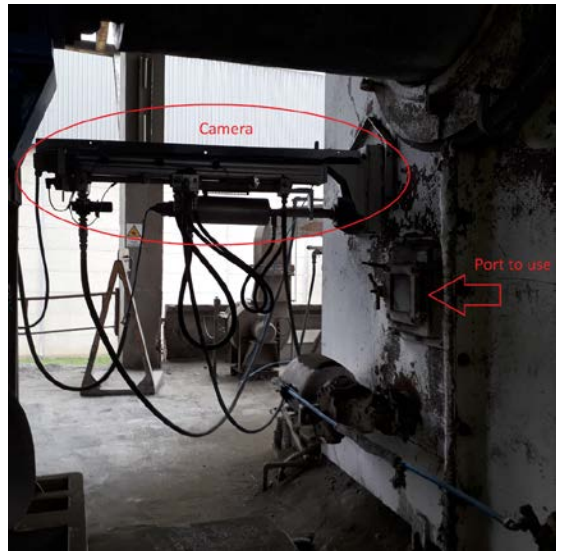


REAL KILN IMAGES

SECIL rotary kiln case

USE OF CURRENT ANALOG VIDEO SYSTEM?

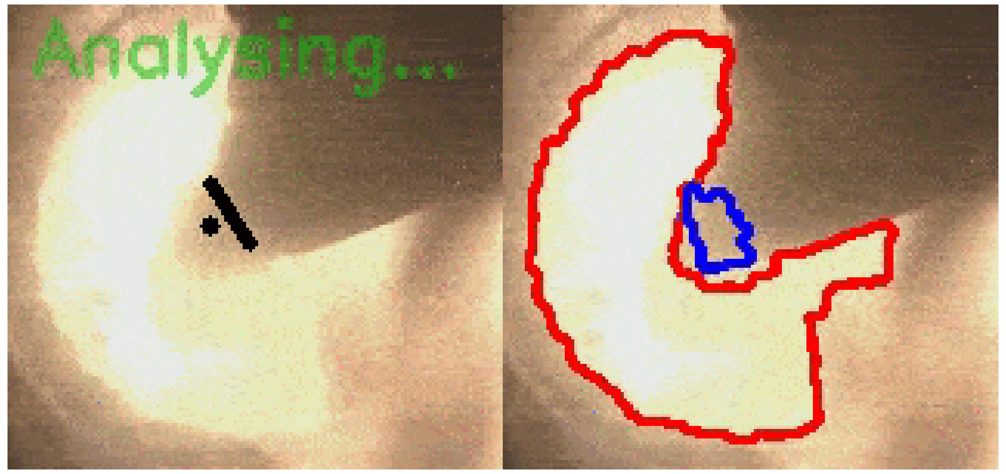




DURAG D-FS 50 FURNACE CAMERA

- ✔ No additional installation needed
- ✔ Low investment needed
- ✔ Easier replication in other kilns with camera systems
- ✔ Current camera has the best location

- ✗ Video conversion difficult
- ✗ Camera parameters fixed



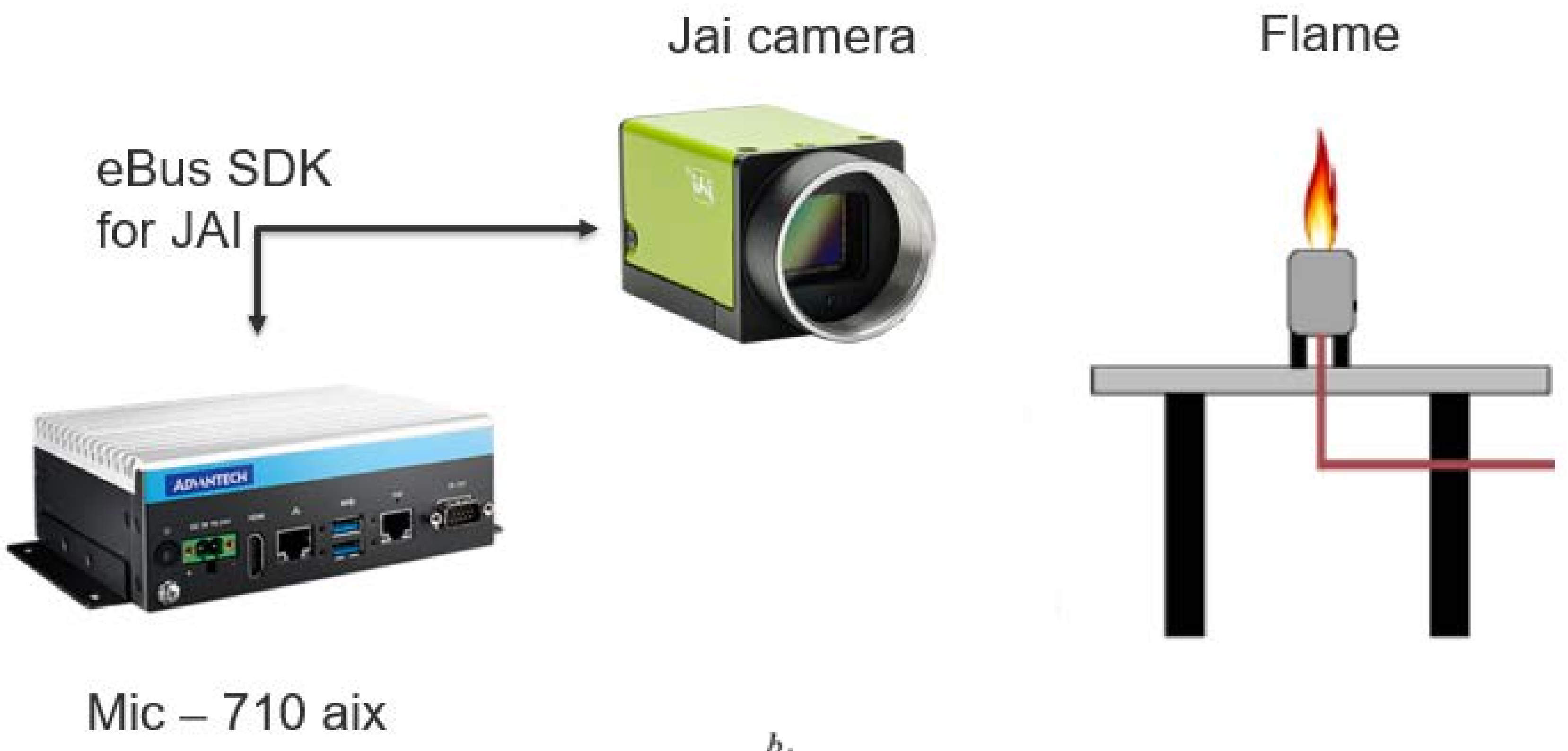
- ✔ Video processing feasible with the current system

- ✗ Low quality video
- ✗ Developing algorithms will Require a lot of videos and the modification of the parameters

USE OF DURAG VIDEO SYSTEM OK

Data acquisition and video processing

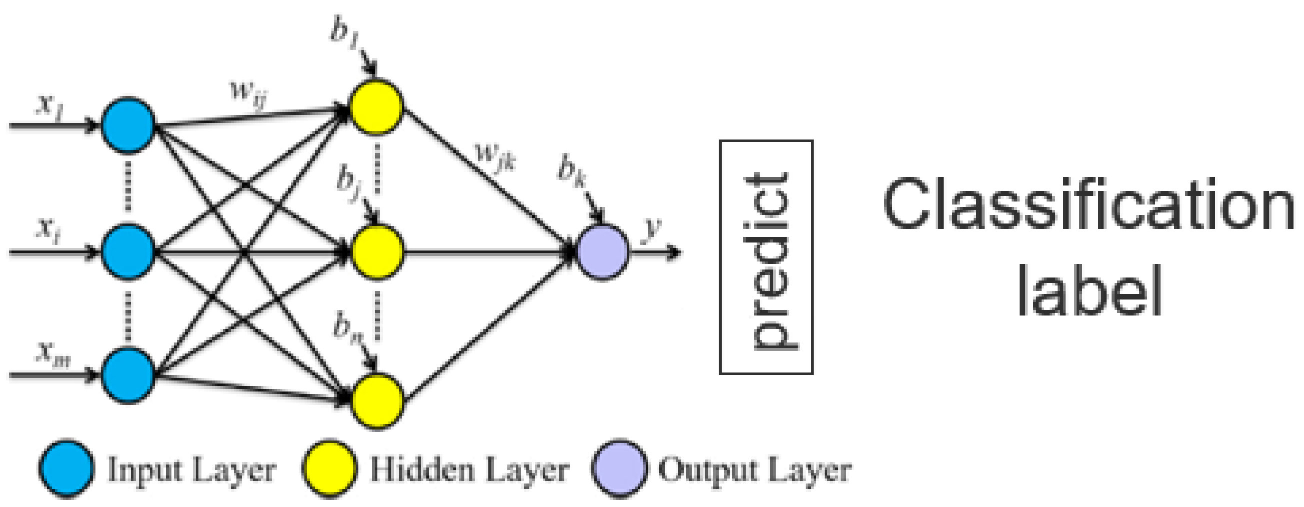
LABORATORY TRIALS -> TEST IA ALGORITHMS UNDER CONTROLLED CONDITIONS



OBJECTIVE

Acquisition system development for real-time

Flame pictures



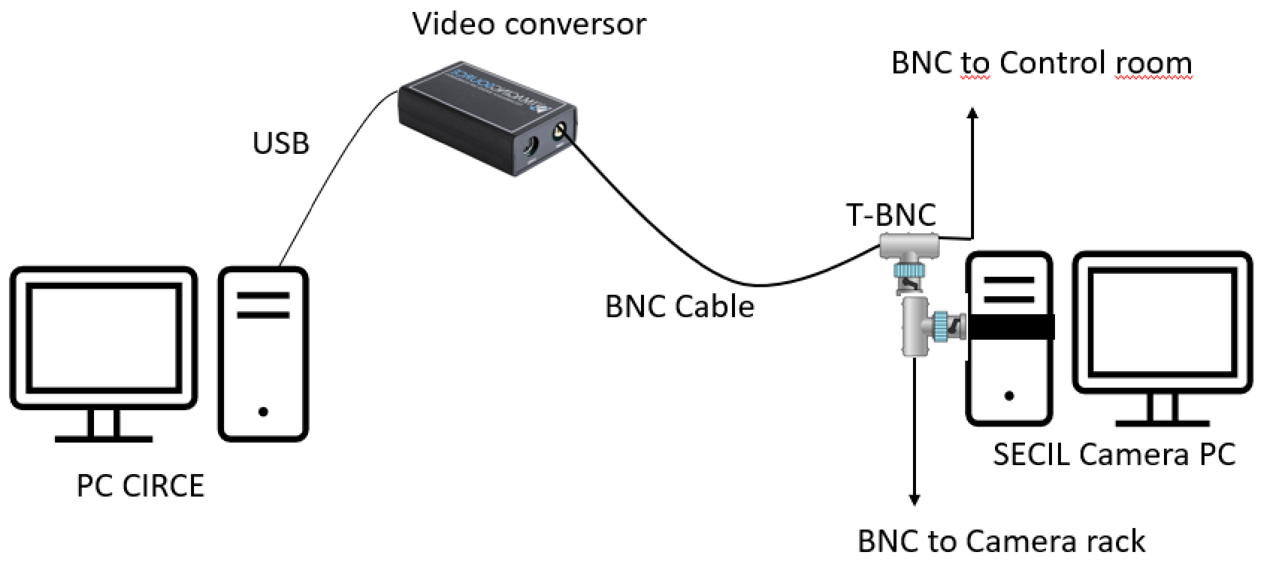
Neuronal network

OBJECTIVE

- Labeling of pictures
- Training neuronal network
- Testing / Validation

Data acquisition and video processing

INDUSTRIAL TRIALS -> OBTAIN REAL SAMPLES UNDER MULTIPLE WORKING CONDITIONS



Date	Video 1	Video 2	Video 3	Video 4
21/02/2022	8:02:44	8:26:49	8:33:52	9:03:15
22/02/2022	8:21:39	17:45:26	17:54:55	18:01:23
23/02/2022	7:47:16	7:55:12	12:51:57	18:13:44
24/02/2022	13:42:32	15:16:39	17:47:57	
25/02/2022	7:49:21	12:11:00	16:59:18	17:16:08
26/02/2022				
27/02/2022				
28/02/2022	7:53:22	14:45:54	17:46:04	17:52:25
01/03/2022	7:54:56	13:26:53	18:03:47	
02/03/2022	8:02:26	12:09:04	17:26:32	17:32:15
03/03/2022	7:51:39	9:52:38	17:19:58	
04/03/2022	12:26:45			
05/03/2022				
06/03/2022				
07/03/2022				
08/03/2022	8:08:20	13:46:12		
09/03/2022	8:01:45	12:30:52	17:30:49	
10/03/2022	8:00:53	9:33:23	17:01:13	17:14:17
11/03/2022	8:00:57	12:59:30		
12/03/2022				
13/03/2022				
14/03/2022	8:02:41	12:07:33	17:07:29	17:45:23
15/03/2022	8:01:20	12:25:58	17:20:42	
16/03/2022	13:00:56	17:52:46		
17/03/2022	8:06:30	12:02:54		
18/03/2022	8:49:46	12:17:45	13:05:30	
19/03/2022				
20/03/2022				
21/03/2022	8:02:42	13:14:18	17:22:29	
22/03/2022	7:47:07	17:37:26		
23/03/2022	8:01:35	12:15:13	17:21:04	17:41:16
24/03/2022	8:02:47			
25/03/2022	11:47:51	12:52:54		
26/03/2022				
27/03/2022				
28/03/2022	8:28:21	10:57:20	17:45:20	
29/03/2022	8:00:50	18:06:41		
30/03/2022	8:06:23	12:29:42		
31/03/2022	8:36:47	12:42:01		
01/04/2022	13:41:16			
02/04/2022				
03/04/2022				
04/04/2022	15:55:58	17:01:20	17:19:15	

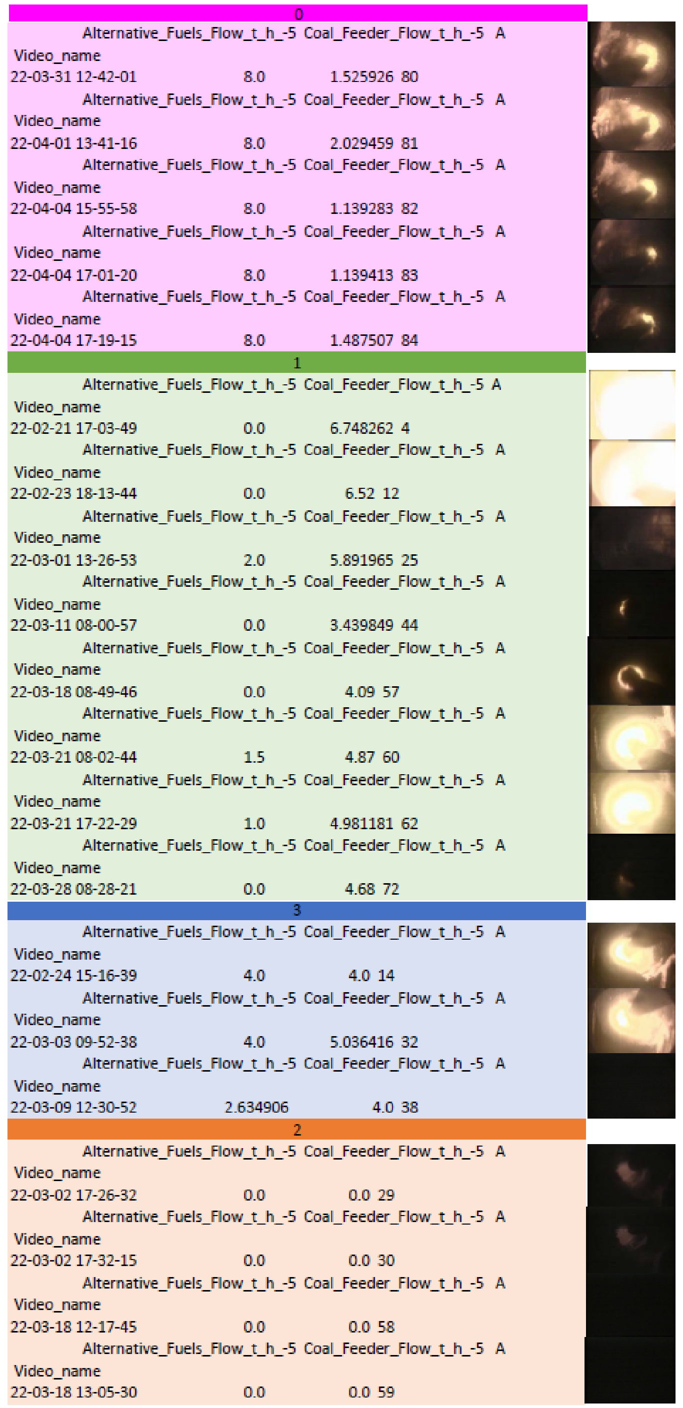
Video Campaign

FO6FT_6087	Raw Meal Flow to Kiln	t/h	
AR6LCC_F	LCC Feed	t/h	
FO6SIC_6101	Kiln Speed	rpm	
FO6II_6101_FILT	Kiln Current	A	
FO6DO6141_F	Coal Feeder Flow	t/h	
FO6PCA414_F	Alternative Fuels Flow	t/h	
FO6DO6500_F	Tyre Feed Rate	t/h	
FO6DOH2_Running	Hidrogen Feed		
FO6DOH2_2_F	Hidrogen Unit 2 Flow	%	
SMQFO6Energy01Pct1	Energy Desired Setpoint	%	Coal
SMQFO6Energy04Pct1	Energy Desired Setpoint	%	RDF
SMQFO6Energy06Pct1	Energy Desired Setpoint	%	Tyres
SMQFO6Fuel01PCI	Burning Value with water	kcal/kg	Coal
SMQFO6Fuel04PCI	Burning Value with water	kcal/kg	RDF
SMQFO6Fuel06PCI	Burning Value with water	kcal/kg	Tyres
PCAFUEL08RECIPEPERC	Parque de Combustiveis Alternativos - Fuel #8 Volumetric Recipe Percentage	%	RDF Very High
PCAFUEL10RECIPEPERC	Parque de Combustiveis Alternativos - Fuel #10 Volumetric Recipe Percentage	%	RDF High
PCAFUEL11RECIPEPERC	Parque de Combustiveis Alternativos - Fuel #11 Volumetric Recipe Percentage	%	RDF Medium
PCAFUEL12RECIPEPERC	Parque de Combustiveis Alternativos - Fuel #12 Volumetric Recipe Percentage	%	RDF Low
SMQFO6MainPCI	Mean PCI in main burner	kcal/kg	
SMQFO6EnergySumPct1Main	Sum of Energy Pct to Main Burner	%	
SMQFO6EnergySumPct1Calc	Sum of Energy Pct to Calciner	%	
SMQFO6EnergySumMWMain	Sum of MW to Main Burner	MW	
SMQFO6EnergySumMWCalc	Sum of MW to Calciner	MW	
SMQFO6EnergySumMWTotal	Sum of MW to Kiln Total	MW	
FO6SIC_6142	Primary Air Fan Speed	rpm	
FO6O2_6461	O2 6th Floor	%	
FO6AI_6461	CO 6th Floor	%	
FO6NO_6461	NO 6th Floor	ppm	
FO6SO2_6461	SO2 6th Floor	ppm	
FO6PT_6385	ExhaustFan 6103 Outlet Pressure	mmca	
FO6SIC_6103	Exhaust Fan 6103 Speed	rpm	
FO6JIAH_6103	Exhaust Fan 6103 Power	kW	
FO6PT_6370	ExhaustFan 6103 Inlet Pressure	mmca	
FO6PT_6371A	Cyclone 1A Outlet Pressure	mmca	
FO6PT_6371B	Cyclone 1B Outlet Pressure	mmca	
FO6PT_6372	Cyclone 2 Outlet Pressure	mmca	
FO6PT_6369	Cyclone 3 Outlet Pressure	mmca	
FO6PT_6368	Cyclone 4 Outlet Pressure	mmca	
FO6PT6387	Kiln Outlet Pressure	mmca	
FO6TT_6320	Exhaust Fan Inlet Temperature	°C	
FO6TT_6321A	Cyclone 1A Temperature	°C	

Process Data

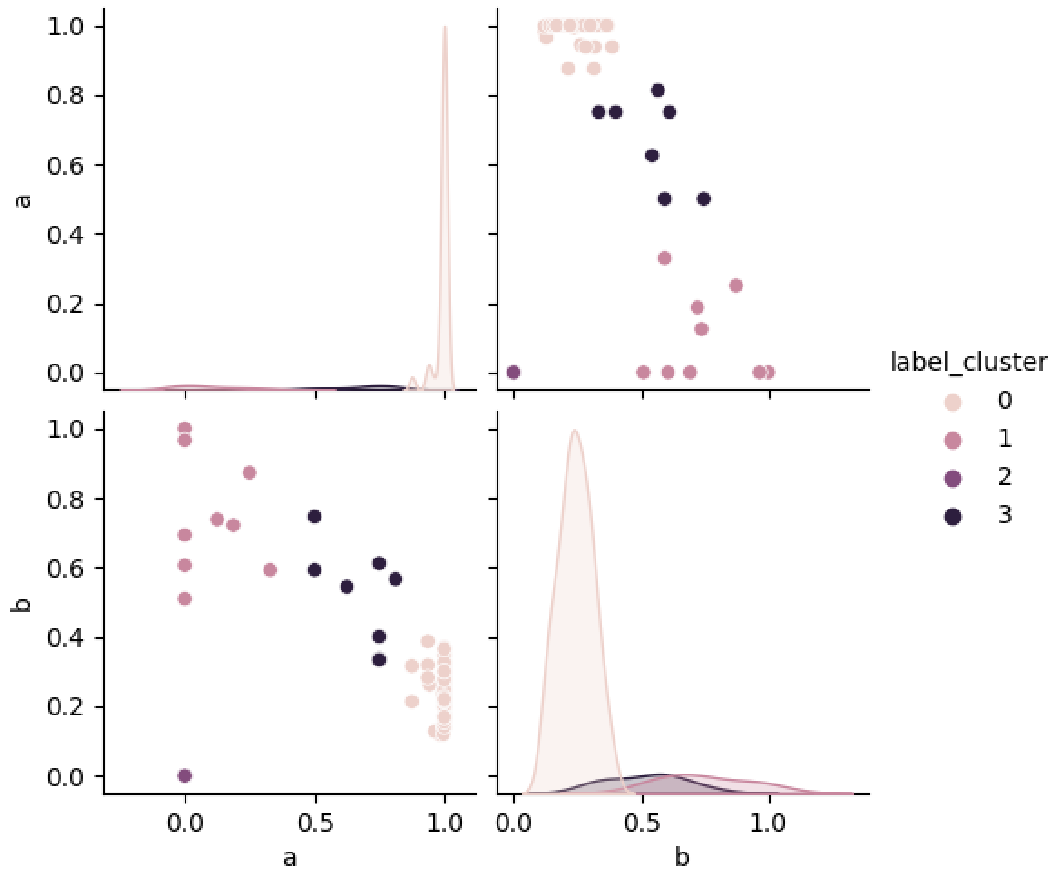
Data processing

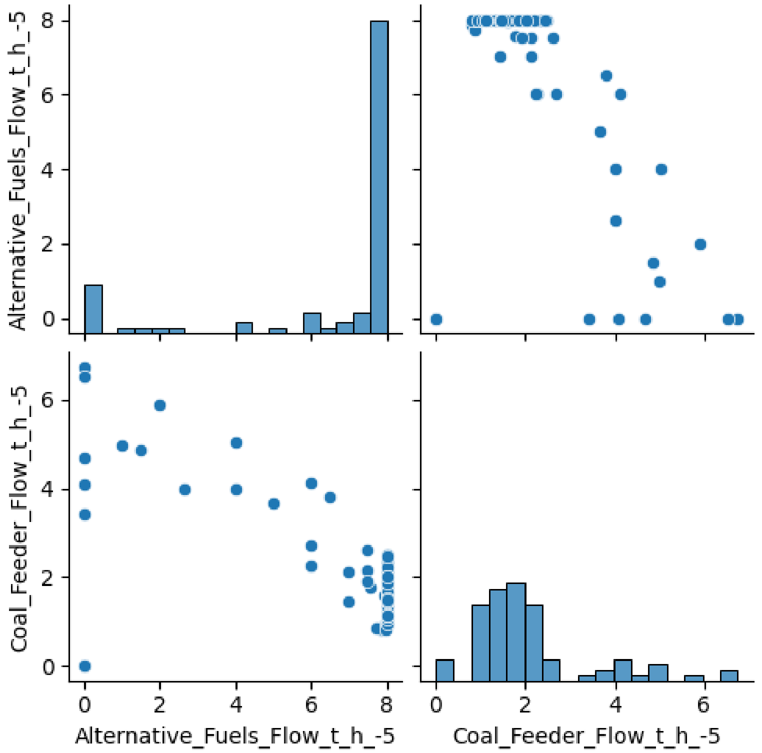
CLUSTERING -> SELECT VIDEOS AND CONDITIONS SUITABLES FOR PROCESSING



Cluster	Video_name	Alternative_Fuels_Flow_t_h_-5	Coal_Feeder_Flow_t_h_-5	A
0	22-03-31 12-42-01	8.0	1.525926	80
0	22-04-01 13-41-16	8.0	2.029459	81
0	22-04-04 15-55-58	8.0	1.139283	82
0	22-04-04 17-01-20	8.0	1.139413	83
0	22-04-04 17-19-15	8.0	1.487507	84
1	22-02-21 17-03-49	0.0	6.748262	4
1	22-02-23 18-13-44	0.0	6.52	12
1	22-03-01 13-26-53	2.0	5.891965	25
1	22-03-11 08-00-57	0.0	3.439849	44
1	22-03-18 08-49-46	0.0	4.09	57
1	22-03-21 08-02-44	1.5	4.87	60
1	22-03-21 17-22-29	1.0	4.981181	62
1	22-03-28 08-28-21	0.0	4.68	72
3	22-02-24 15-16-39	4.0	4.0	14
3	22-03-03 09-52-38	4.0	5.036416	32
3	22-03-09 12-30-52	2.634906	4.0	38
2	22-03-02 17-26-32	0.0	0.0	29
2	22-03-02 17-32-15	0.0	0.0	30
2	22-03-18 12-17-45	0.0	0.0	58
2	22-03-18 13-05-30	0.0	0.0	59

Clustering using two most relevant variables by k-means





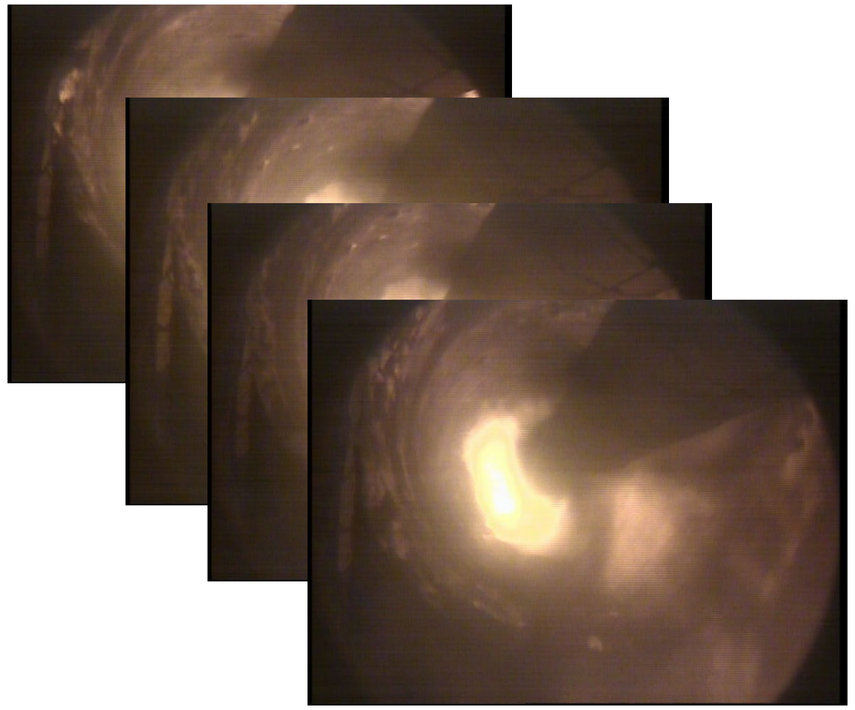

```
a = Alternative_Fuels_Flow_t_h_-5, b = Coal_Feeder_Flow_t_h_-5, c = Kiln_Current_A_+15, d =
Kiln_Speed_rpm
e = Primary_Air_Fan_Speed_rpm , f = Raw_Meal_Flow_to_kiln_t_h_+15, g =
Secondary_Air_Temperature_Celsius_+15'
```

Retrofeed
smart retrofitting in process industry

Flame monitoring development

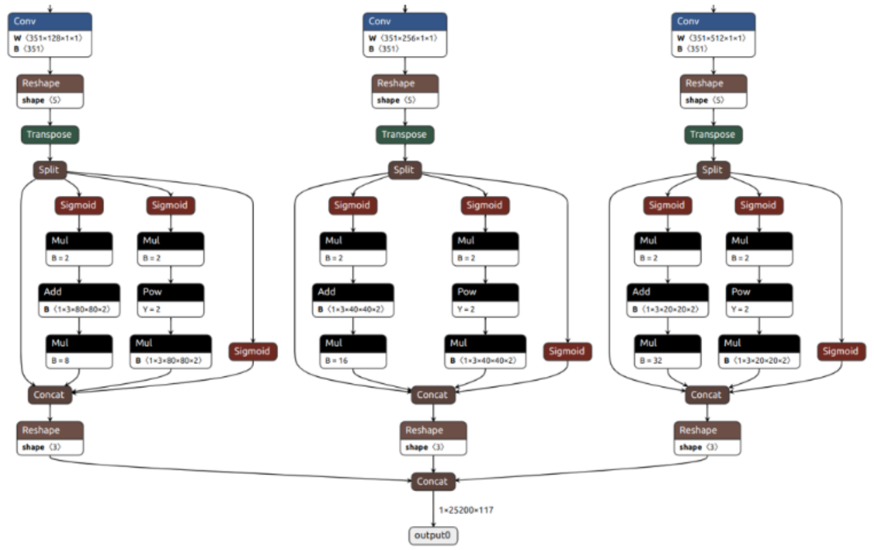
TRAINING PROCESS -> USE OF DEEP LEARNING YOLO V8

Input

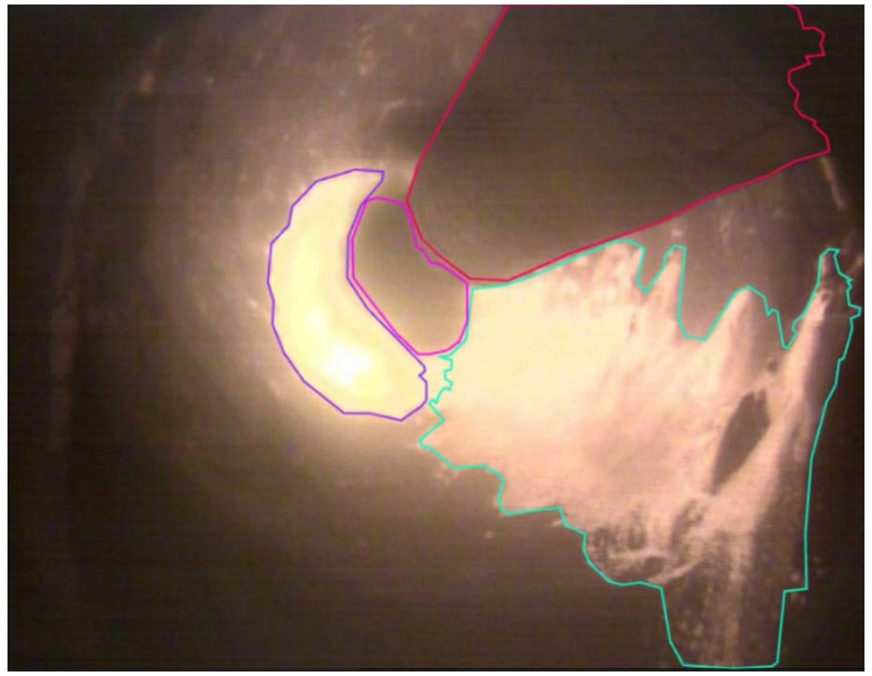


Model for Real Time Instance Segmentation

YOLOv8



Output

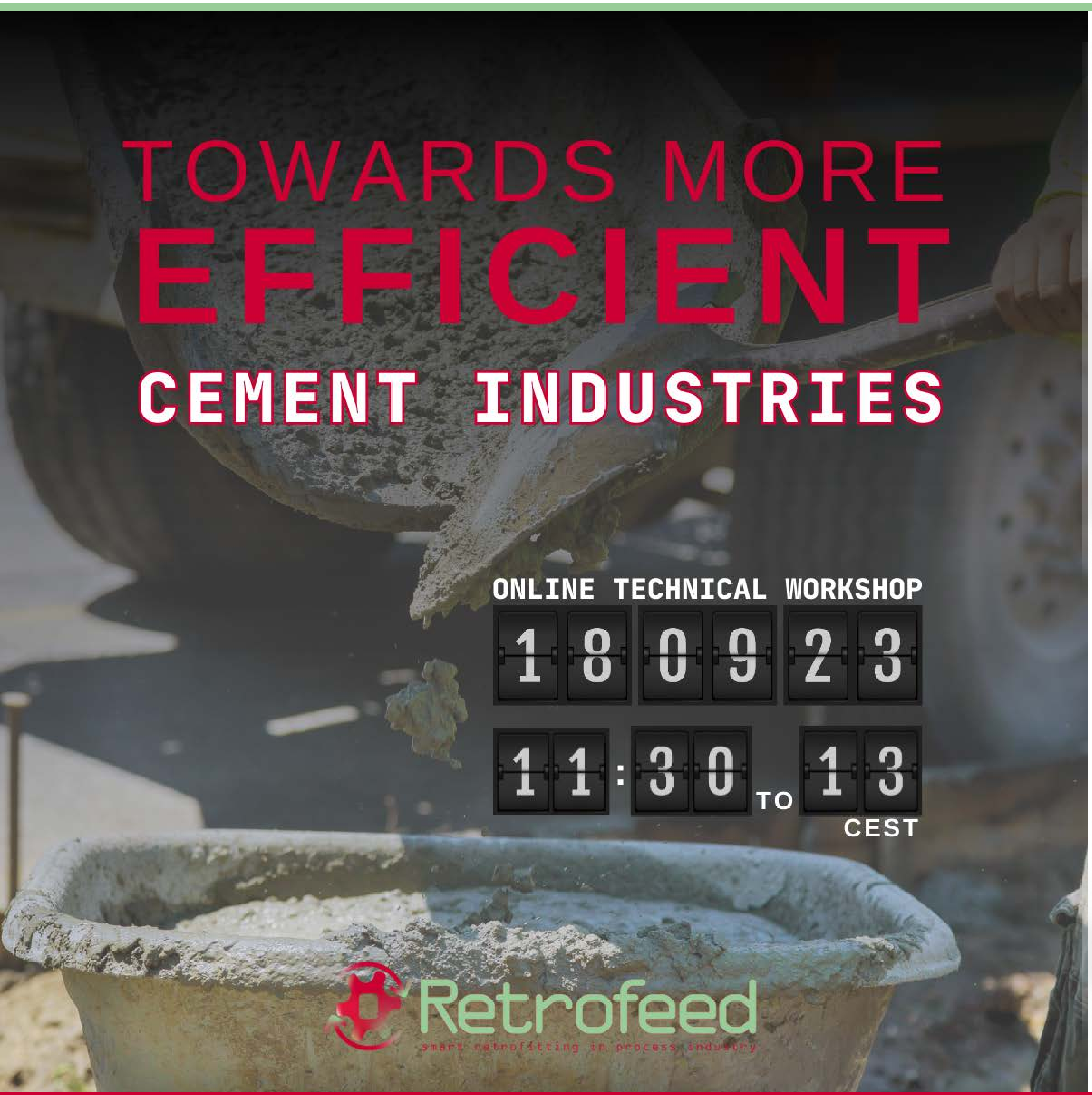


Flame monitoring aplication

- Graphical interface
- Segmentation of elements
- Element identificación
- Area characterization
  - Geometrical features
  - Statistical features
  - Texture features
- Real time updates

Future developments

- Validation under real conditions (long periods of time) -> Feedback from operators
- Correlation with process variables: On a first step offline, on a second step on real time
- Replication in other plants and in other sectors



QUALITY MEASUREMENT MONITORING SYSTEM FOR CLINKER

Francisco Rodriguez (AIMEN)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869939.

Objectives and challenges

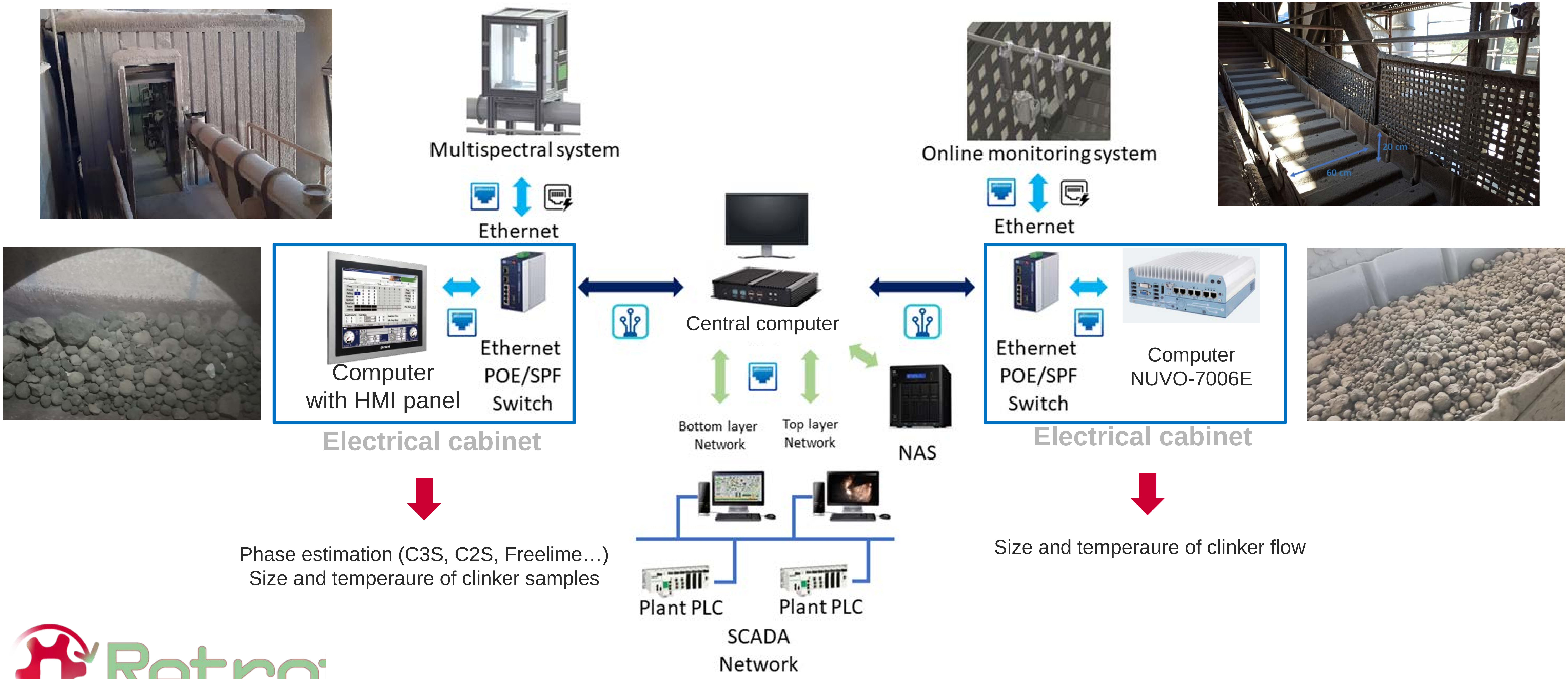
Objectives:

- Measure **temperature and clinker size** at SECIL cement factory
- **Estimate CCN phase** (freelime, C2S, C3S…)

Challenges:

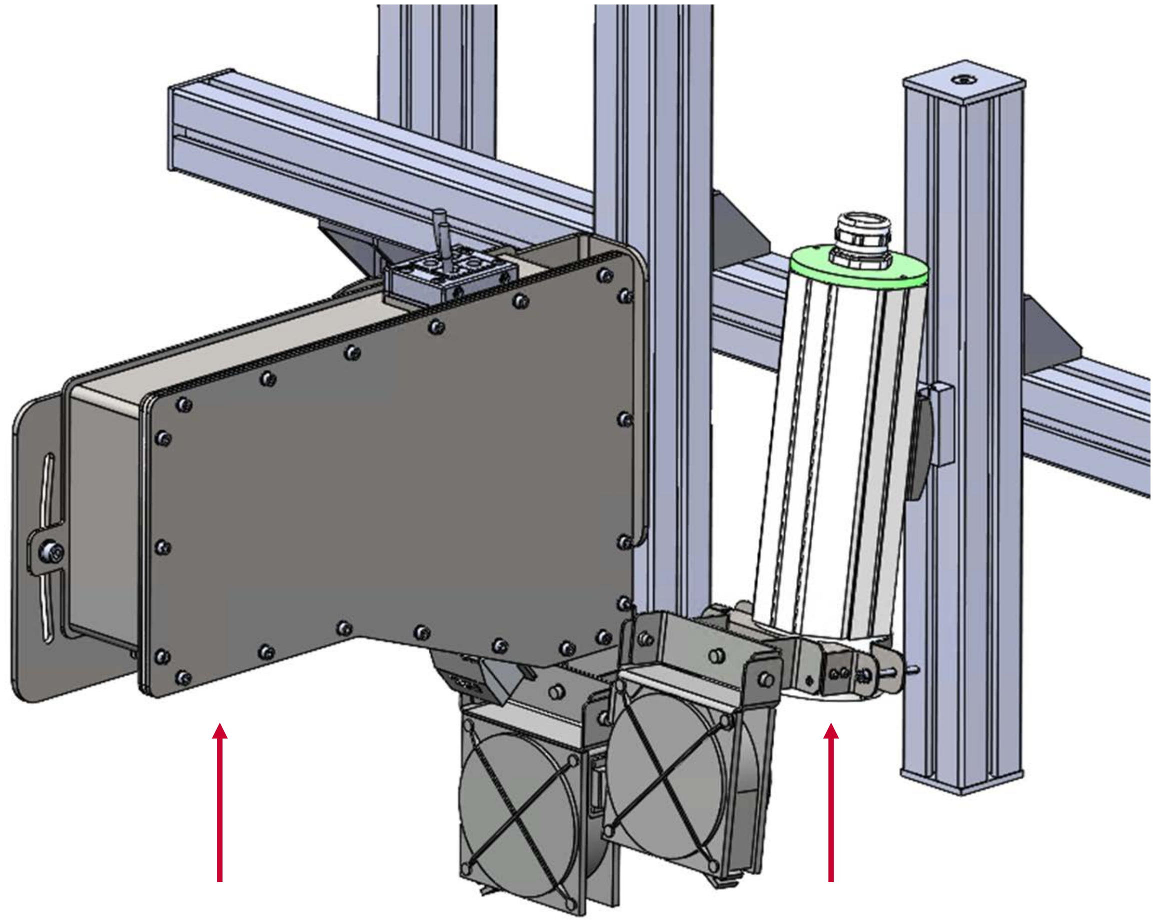
- **Harsh environment** : sensors selection (robustness and accuracy), devices protection
- **Factory integration**: Modular systems, How to simulate factory environment for optimize development and validation? How to integrate without stopping or reducing production?
- **System architecture**: data transmission (long distances), data flow management
- **Data analysis**: processing strategies, results

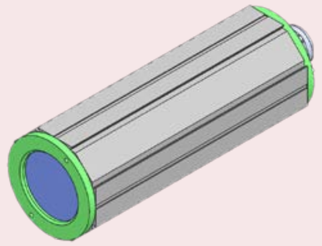
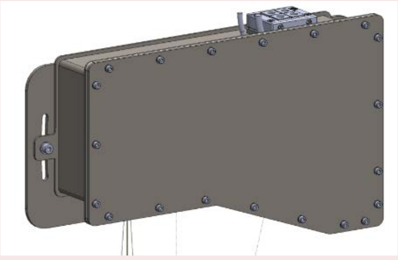
General architecture for monitoring system deployed in factory

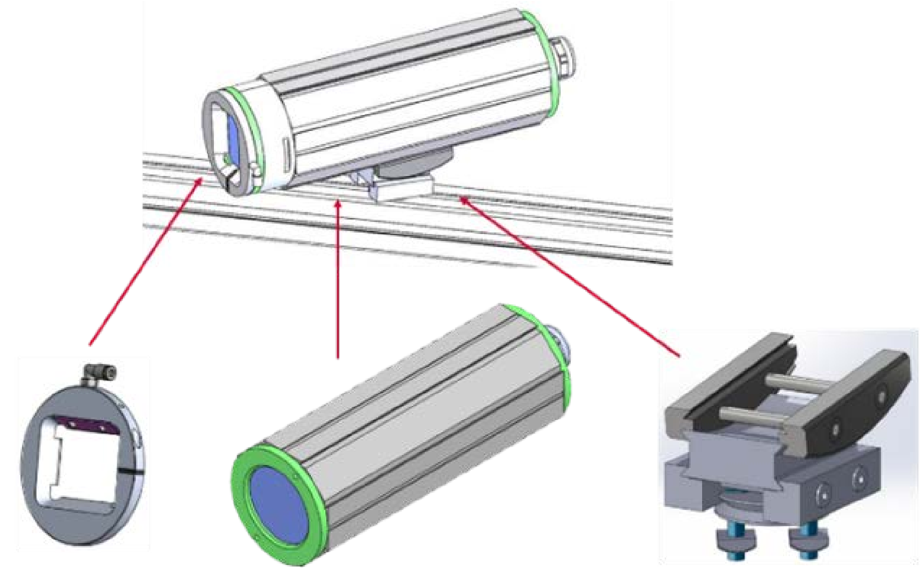


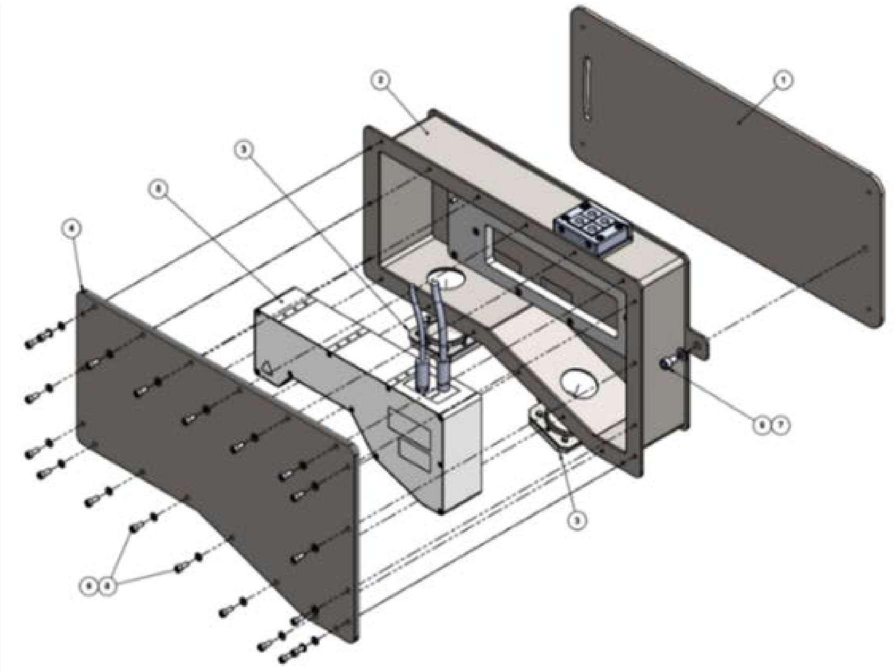
Temperature and size for transportation belt : mechanical system

Clamping and protection system



CAMERA	PROFILOMETER
	
IRSX 640 Compact	Compact Sen. C5-2040CS19-640
AT (Automation Technology)	AT (Automation Technology)
	
ORCA camera enclosure (IP67)	Designed for profilometer (IP65)
Autovimation	AIMEN



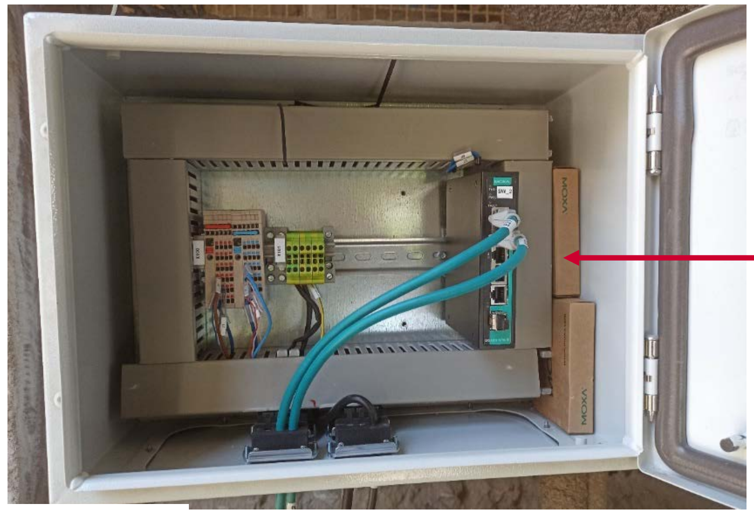


Windows with air curtains are mounted on both systems for ensuring protection aginst dust

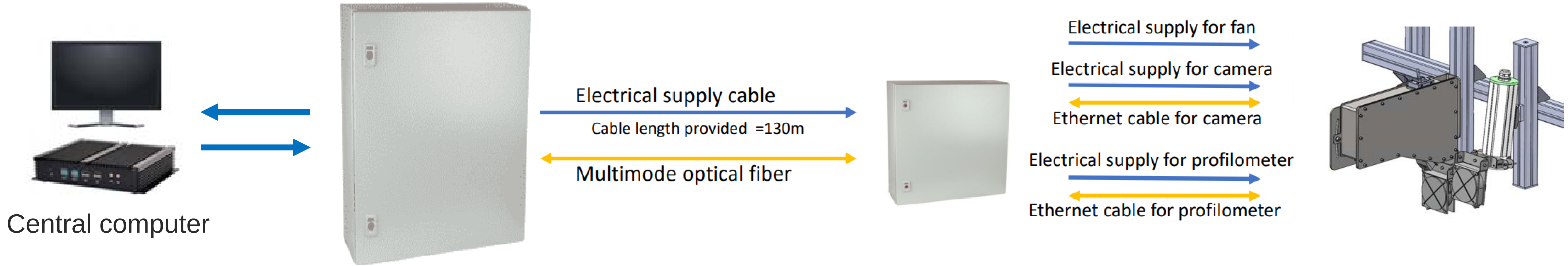
System integrated in transportation belt in SECIL factory

Electrical cabinet

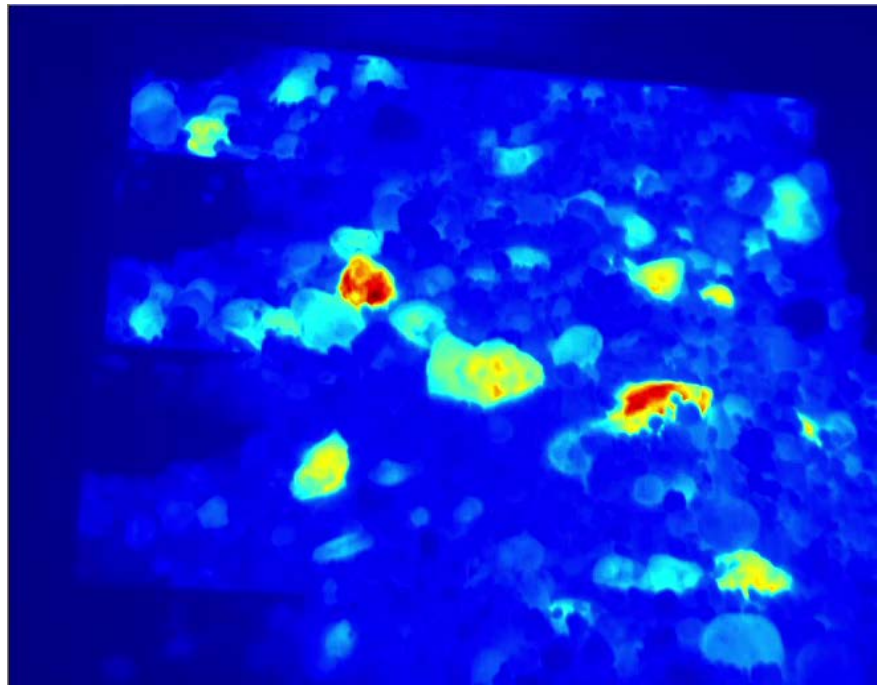
Small cabinet



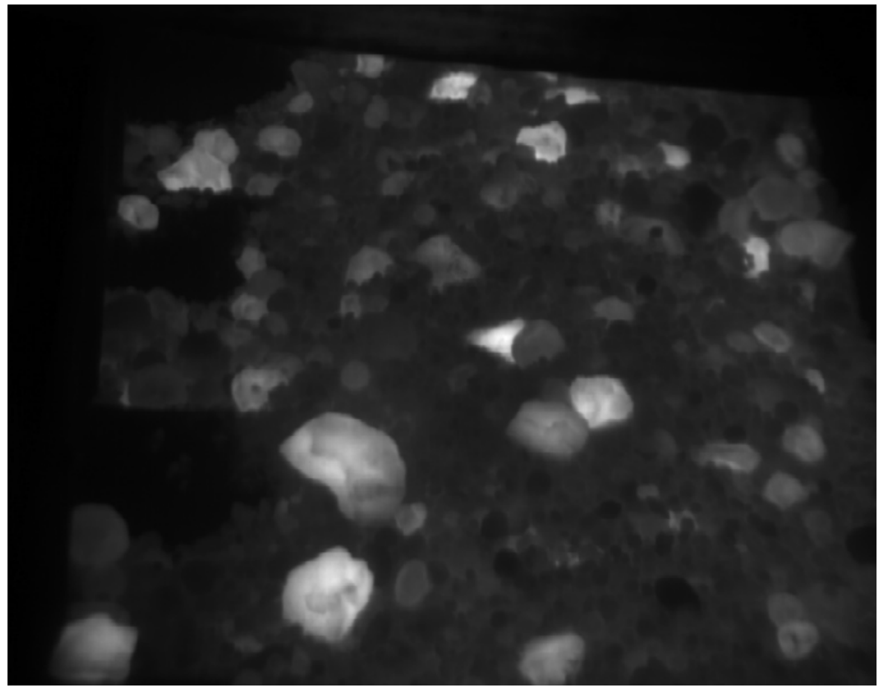
Com system
Optical fiber
router



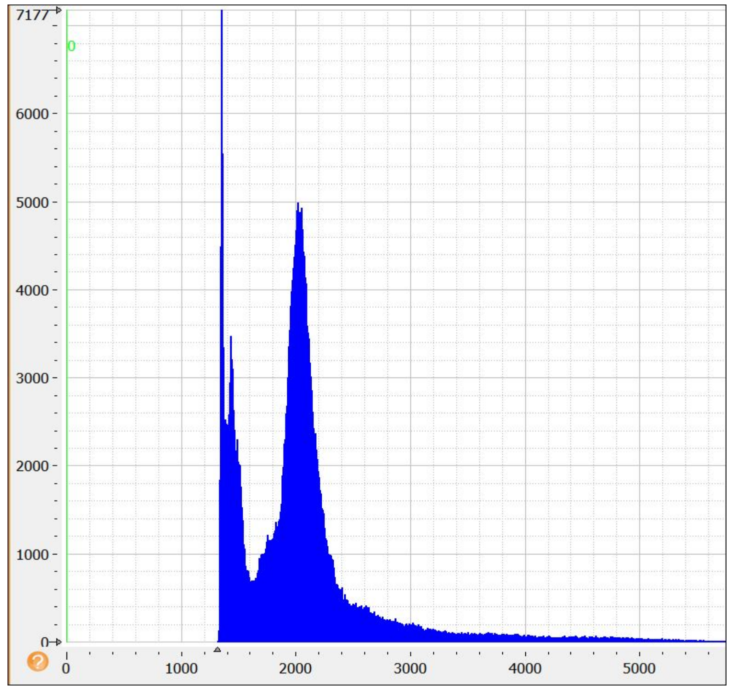
Temperature and size: results from acquisition on transportation belt



Thermal video

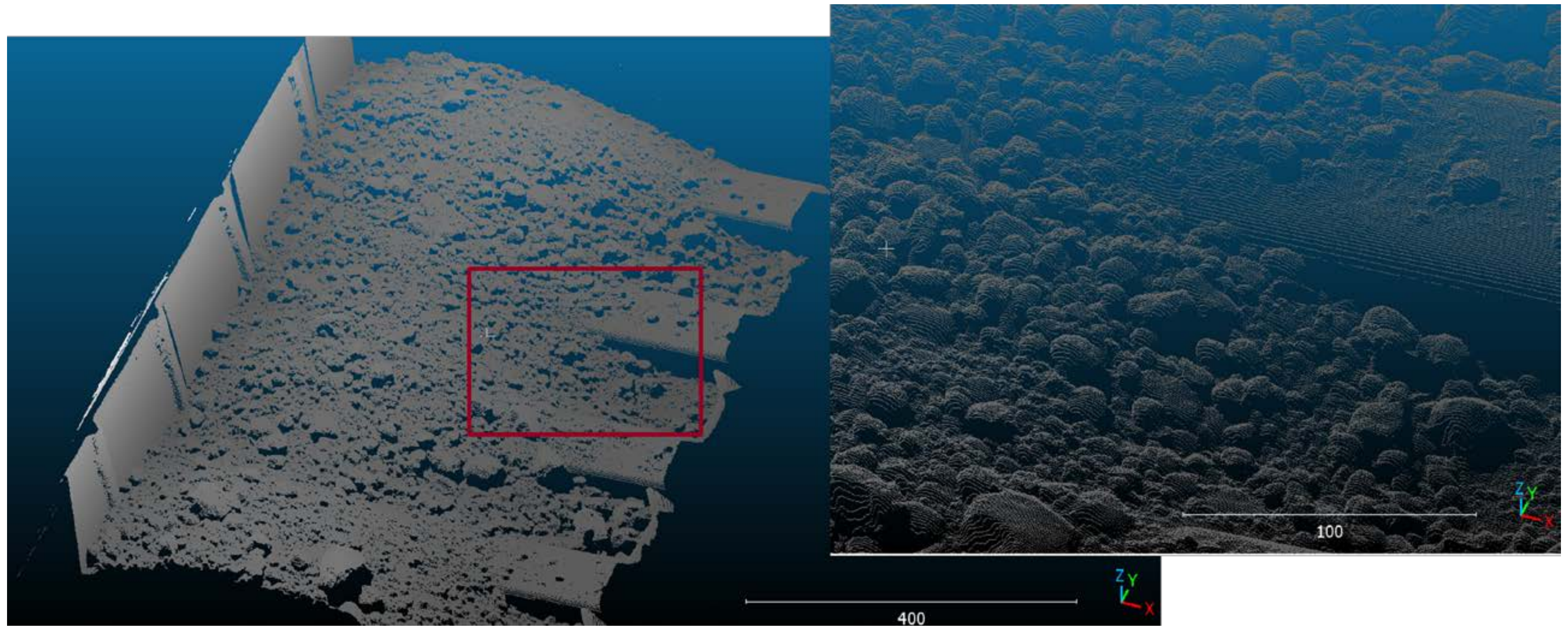


Thermal gray scale image



Temperature Histogram distribution

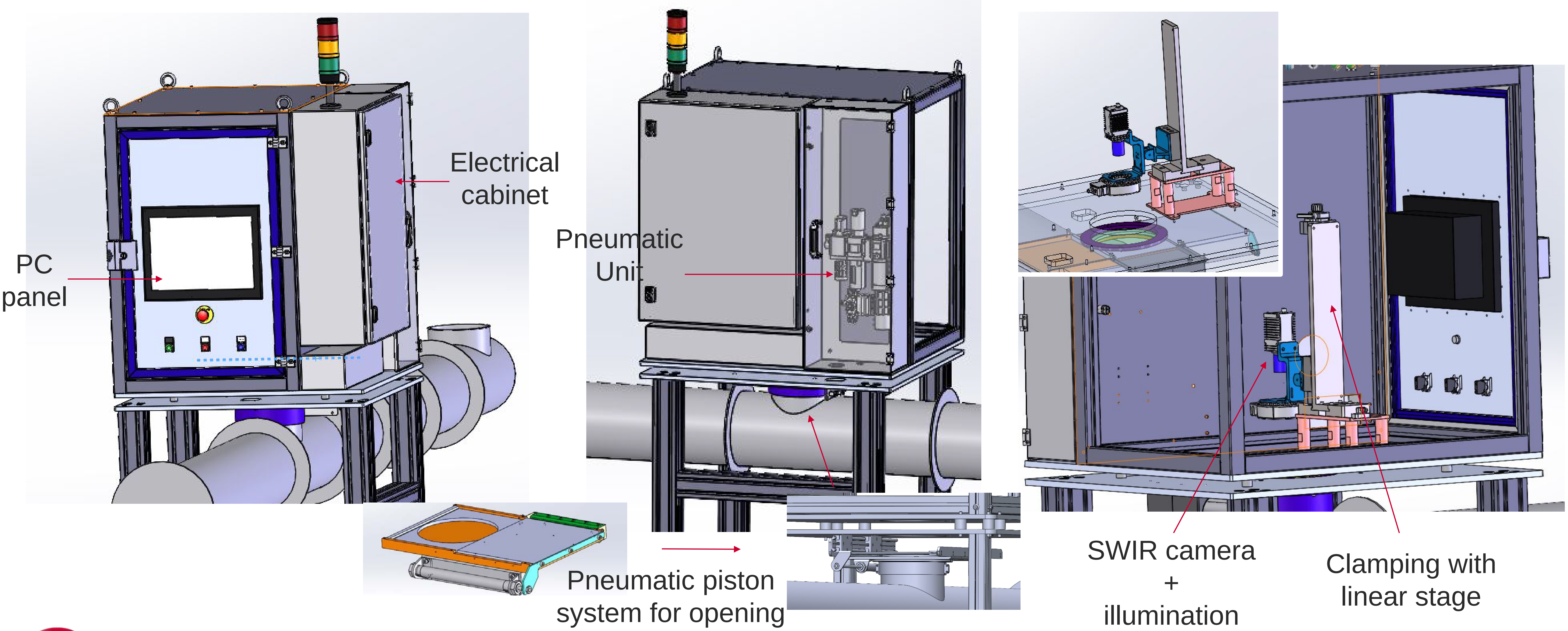
Laser line projected on clinkers flow



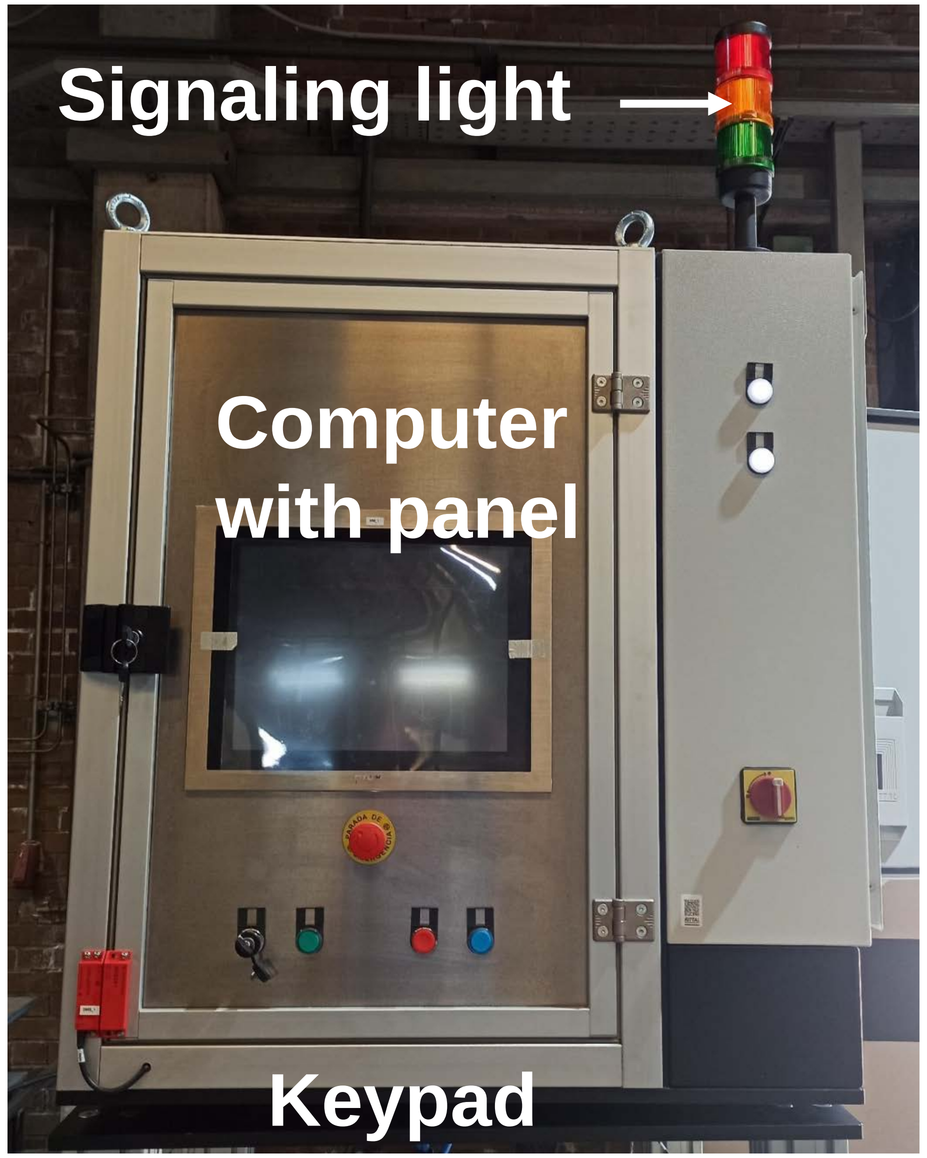
Point cloud obtained from profilometer

→ pcl Pyntcloud → Clinker size

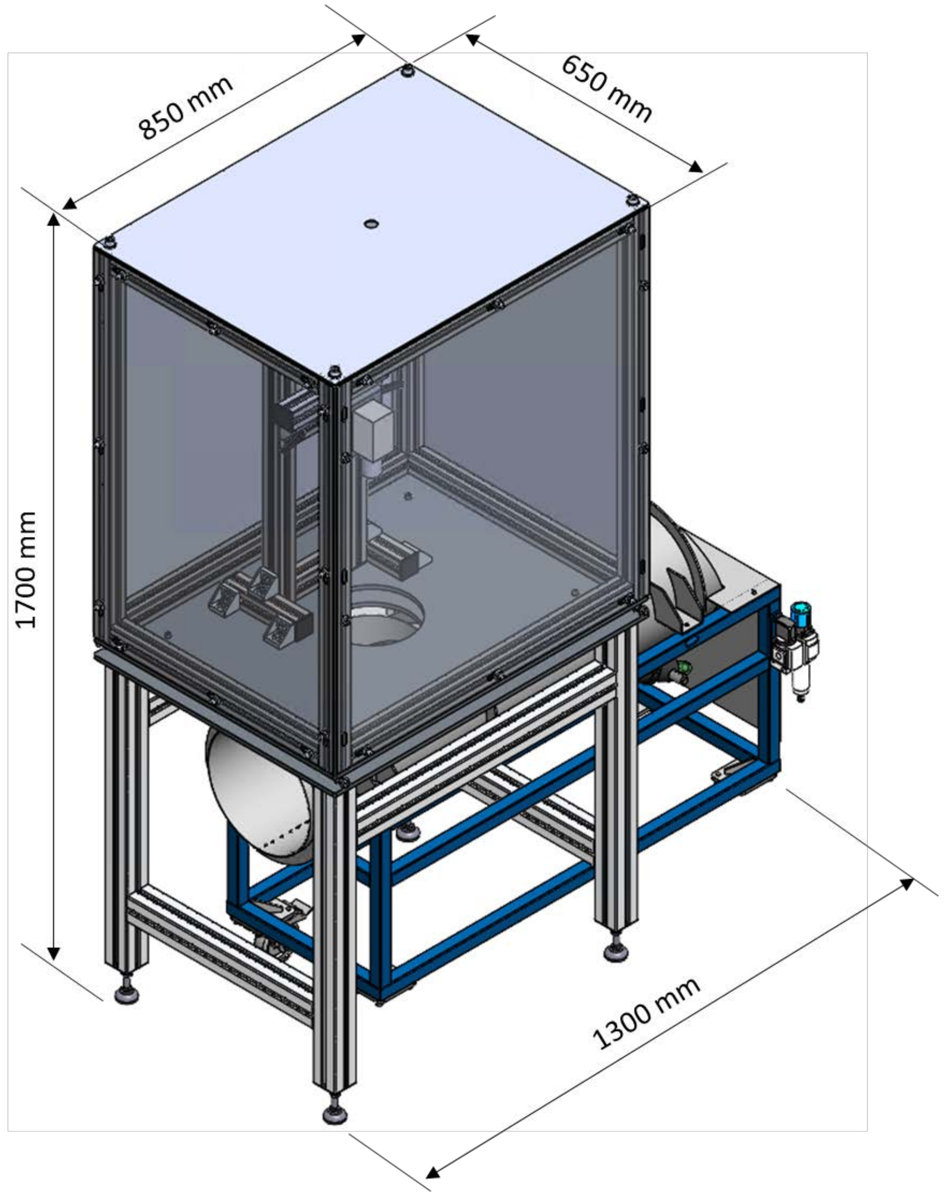
Temperature and size measurement: enclosure system for conveyor pipe

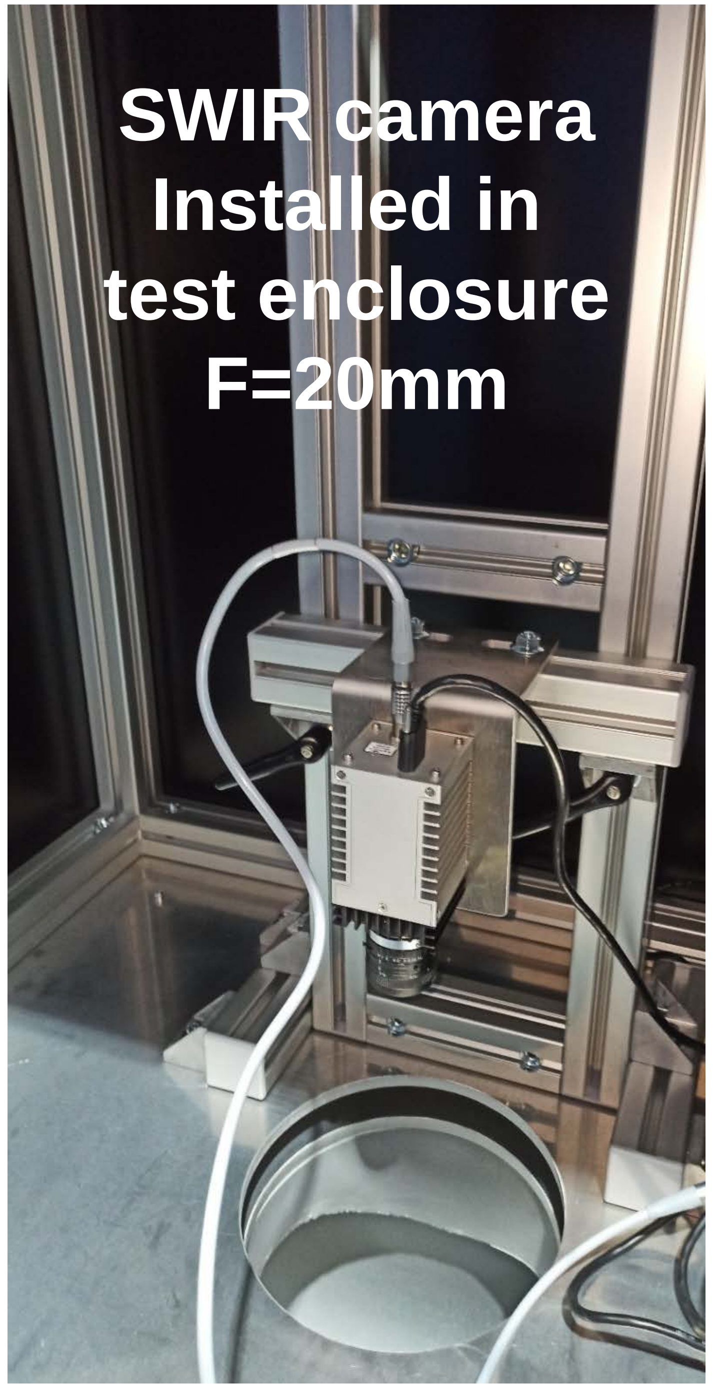


Enclosure system assembly and test at AIMEN facilities

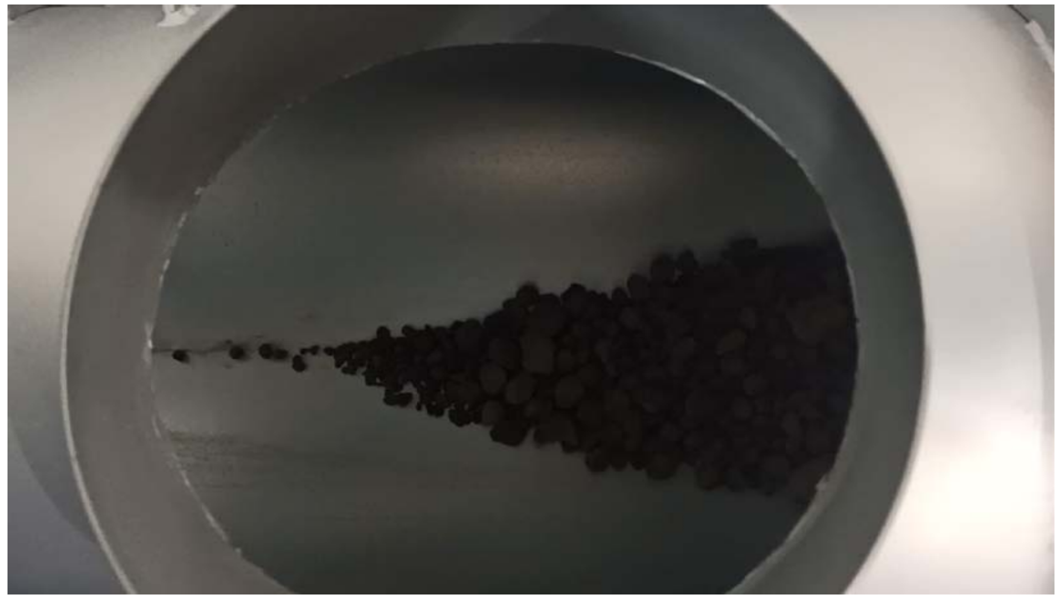


Testing bench developed at AIMEN for simulating clinker on pipe





Conveyor pipe system

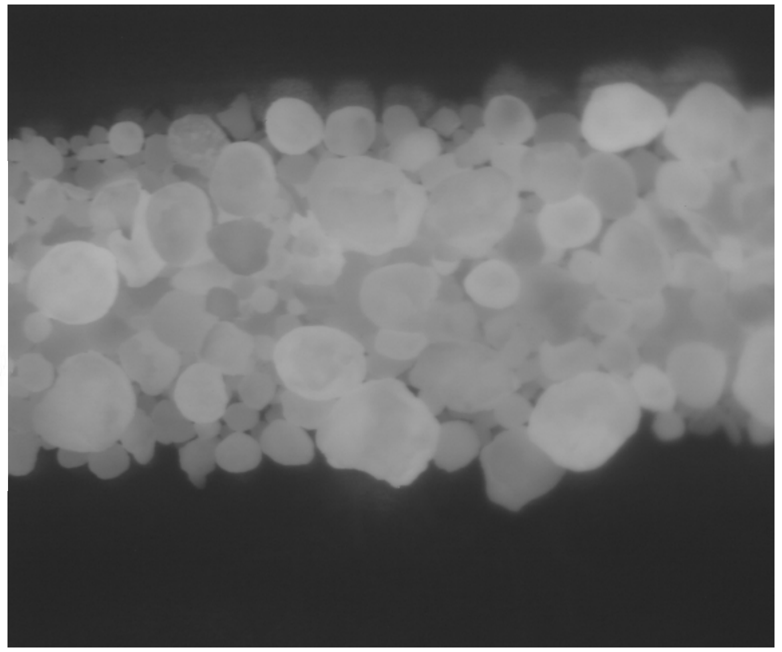


Clinker flow simulated

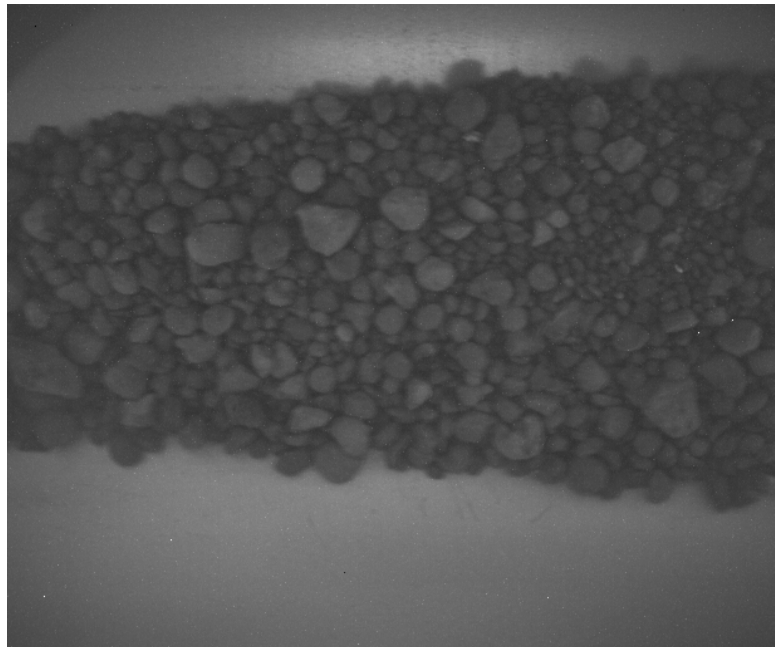
Retrofeed
smart retrofitting in process industry

Infrared and size measurements on conveyor pipe

EO spec.	Gobi GigE Xenics
Image format	640x480 pxs
Pixels pitch	17 µm
Detector type	a-Si microbolometer
Active area	10,88 x 8,16 mm
Spectral range	[8-14] m
Max. FP full	60 Hz
Digital output	GigE



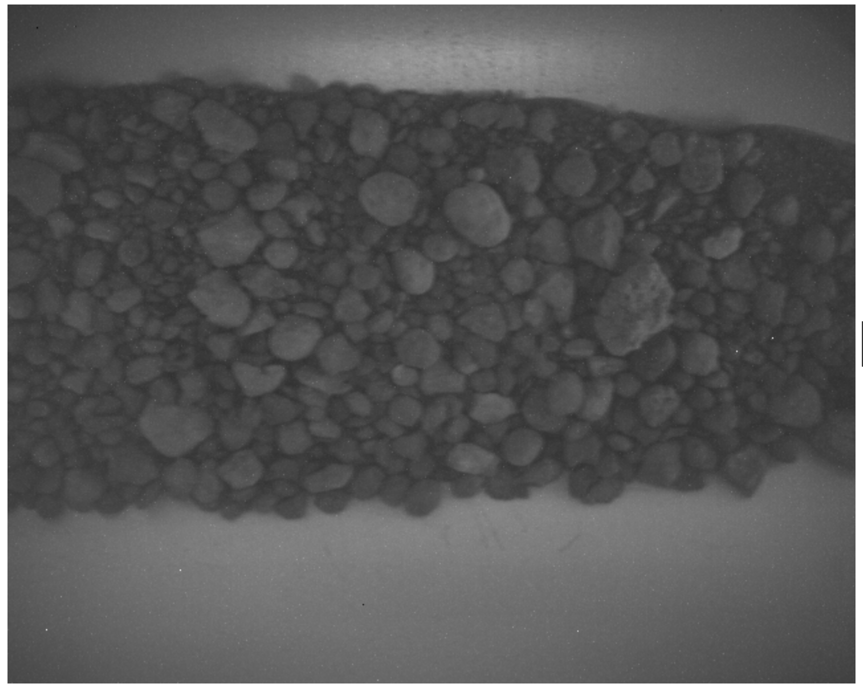
LWIR image



SWIR image

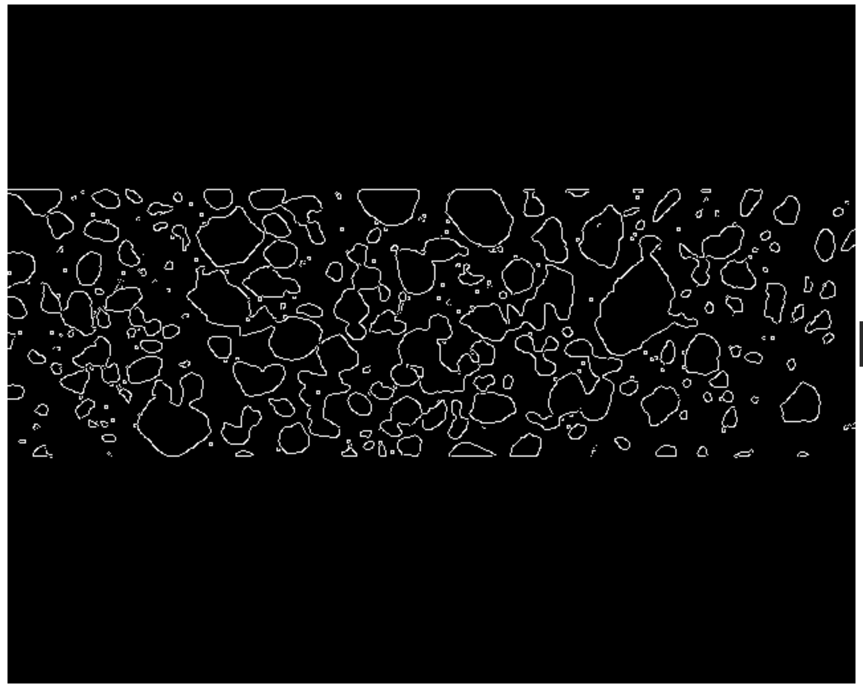
EO spec.	Wildcat UV3100 Xenics
Image format	640x512 pxs
Pixels pitch	20 µm
Detector type	InGaAs
Active area	12,8x10,24 mm
Spectral range	[900-1700] nm
Max. FP full	110 Hz
Digital output	USB3 Vision

Segmentation example for size estimation:



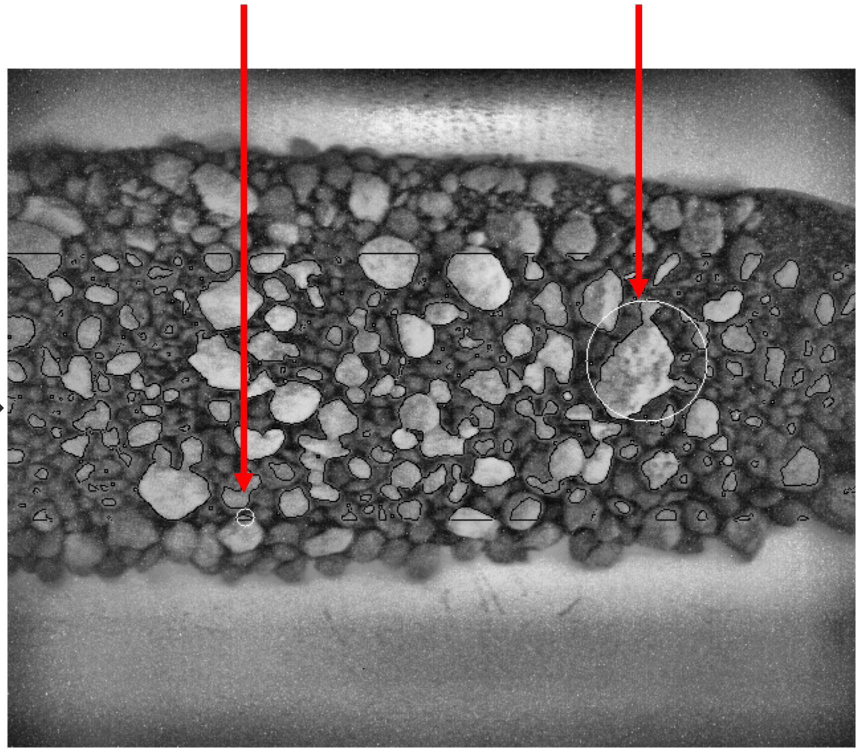
SWIR image

Binarization



Edge detection

Smallest and biggest clincker



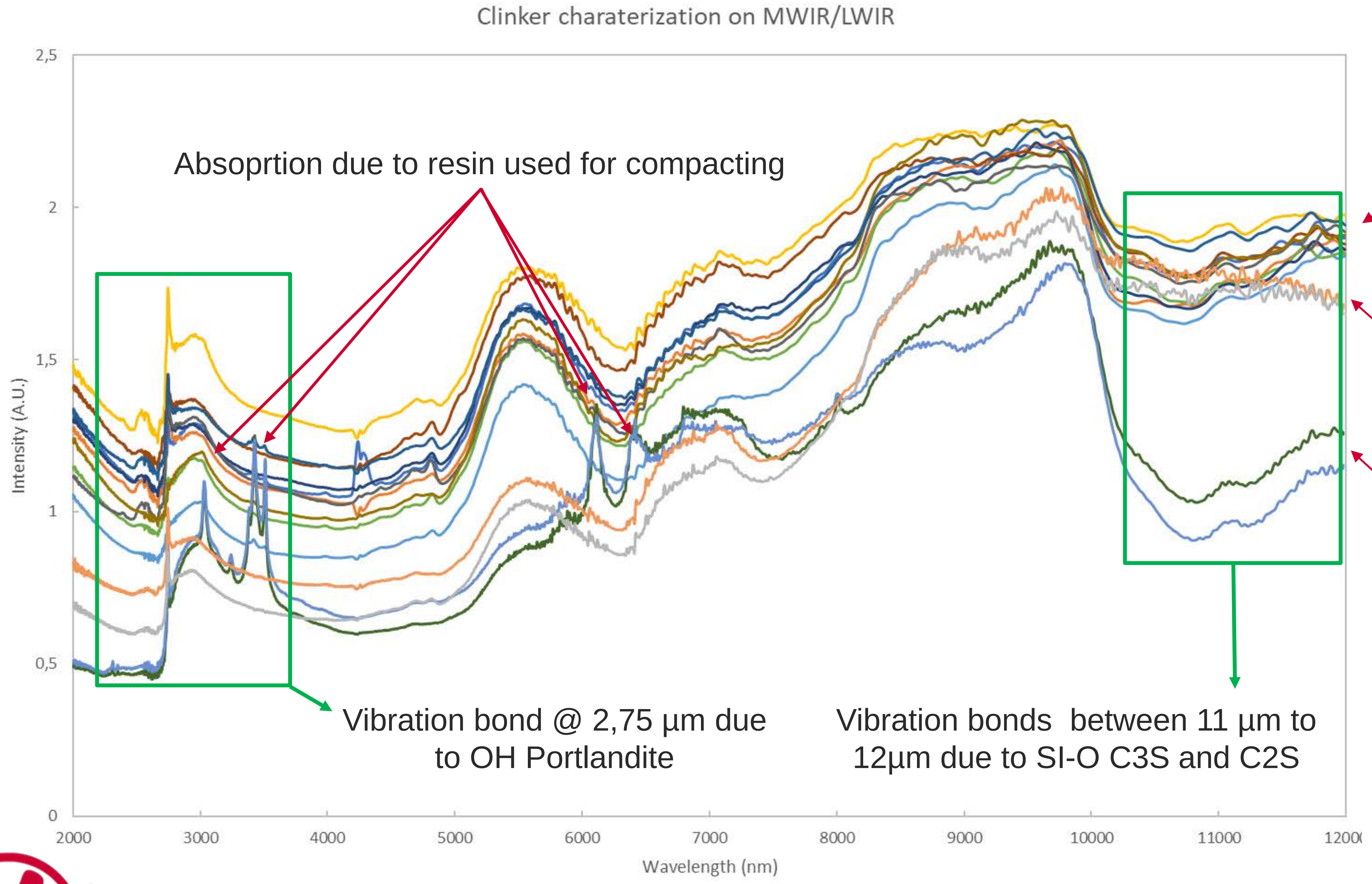
Contours detection

Phase estimation: Infrared measurements

Bonds	Wavenumber (cm^{-1})	Wavelength (nm)	Phase/compound	CCN
Si-O	876	11415.5	Ca_3SiO_5	Alite (C_3S)
Si-O	840 904	11904.7 11061.9	Ca_2SiO_4	Belite (C_2S)
Al-O	700 740	14285.7 13513.5	Ca_3Al2O_6	Celite (C_3A)
O-H	3640	2747.2	$Ca(OH)_2$	Portlandite

Infrared vibration bonds monitored that are characterist of CCN phase

→ Out of range for spectrophotometry technology used



Spectra obtained with clinker

Raw material.
Dispersion due to granularity
Sampling system complex to developp

Spectra obtained with powder

Grinded material.
More homogeneous
Sampling system complex to developp

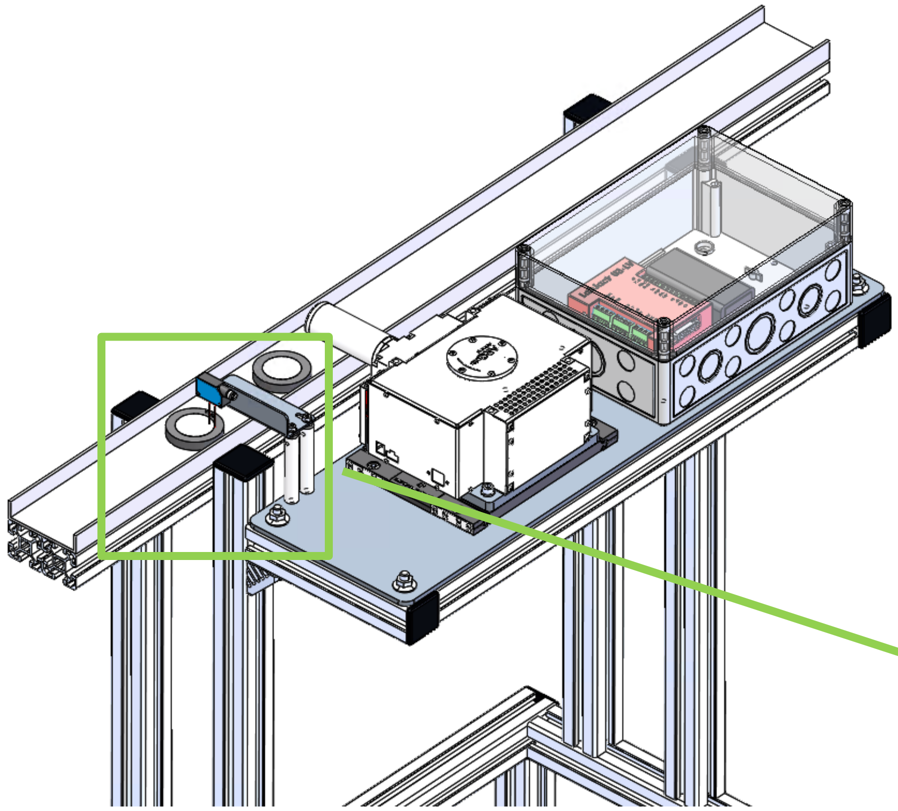
Spectra obtained with tablet

Compacted material.
More homogeneous
Resin interference but sampling system is easier to developp

Correlation established comparing with XRD/XRF measurements

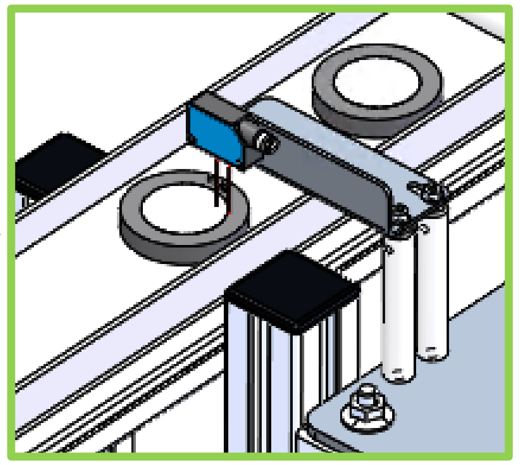
Solution based on infrared spectrophotometry for laboratory

SECIL factory laboratory

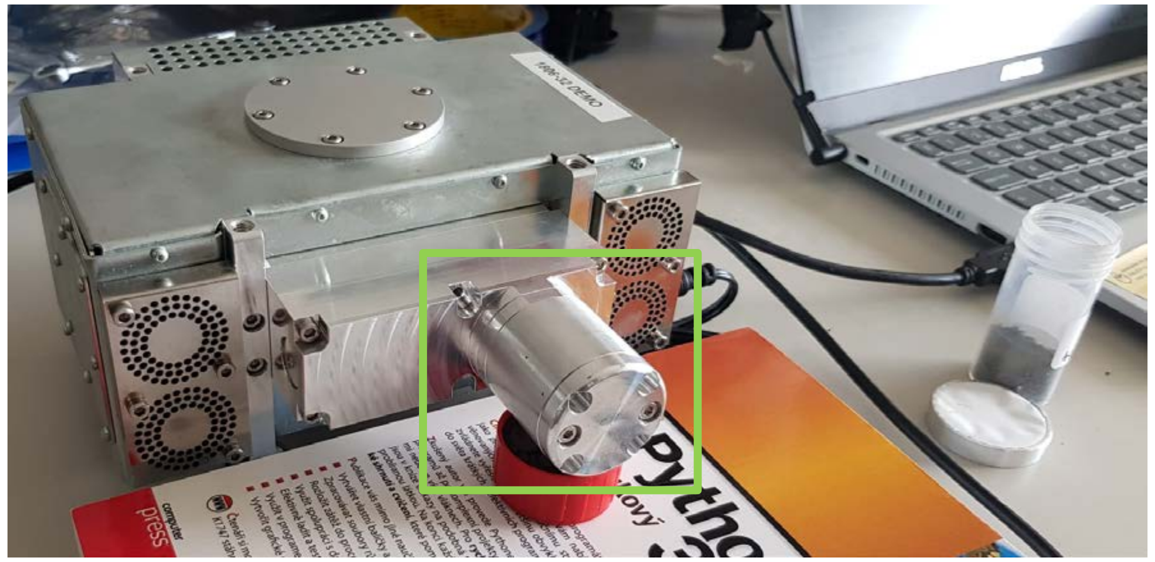


Power supply 24V

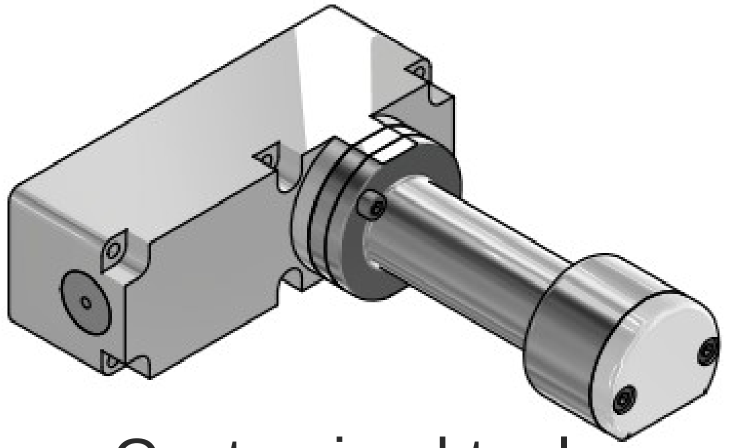
DaQ board



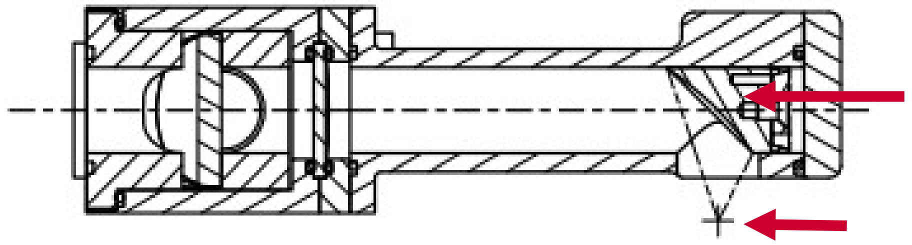
Photoelectric sensor



Comon path spectrophotometer



Customised tool



Optical mirror

Focalisation point on sample

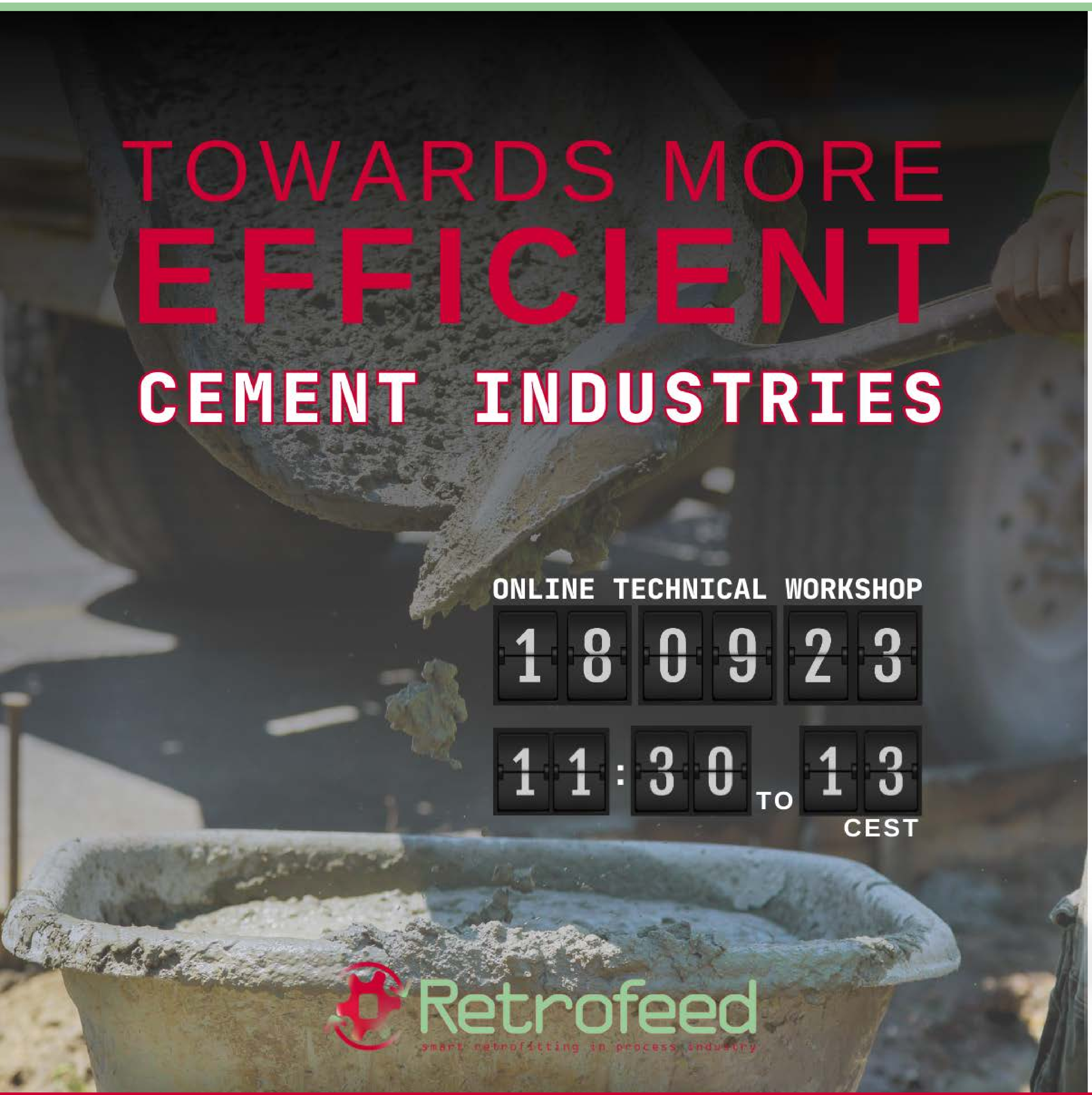
Next steps

Integration:

- Integrate enclosure in conveyor pipe
- Optimize transportation belt system
- Integrate spectrophotometer in laboratory
- Connect to SCADA

Fine tuning and data analysis:

- Collect data to link temperature and size measurement with clinker quality production/control
- Collect data to improve model for phase estimation



MAIN ACHIEVEMENTS ON CEMENT DEMO SITE

Valter Tavares (SECIL)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869939.

SECIL Goals

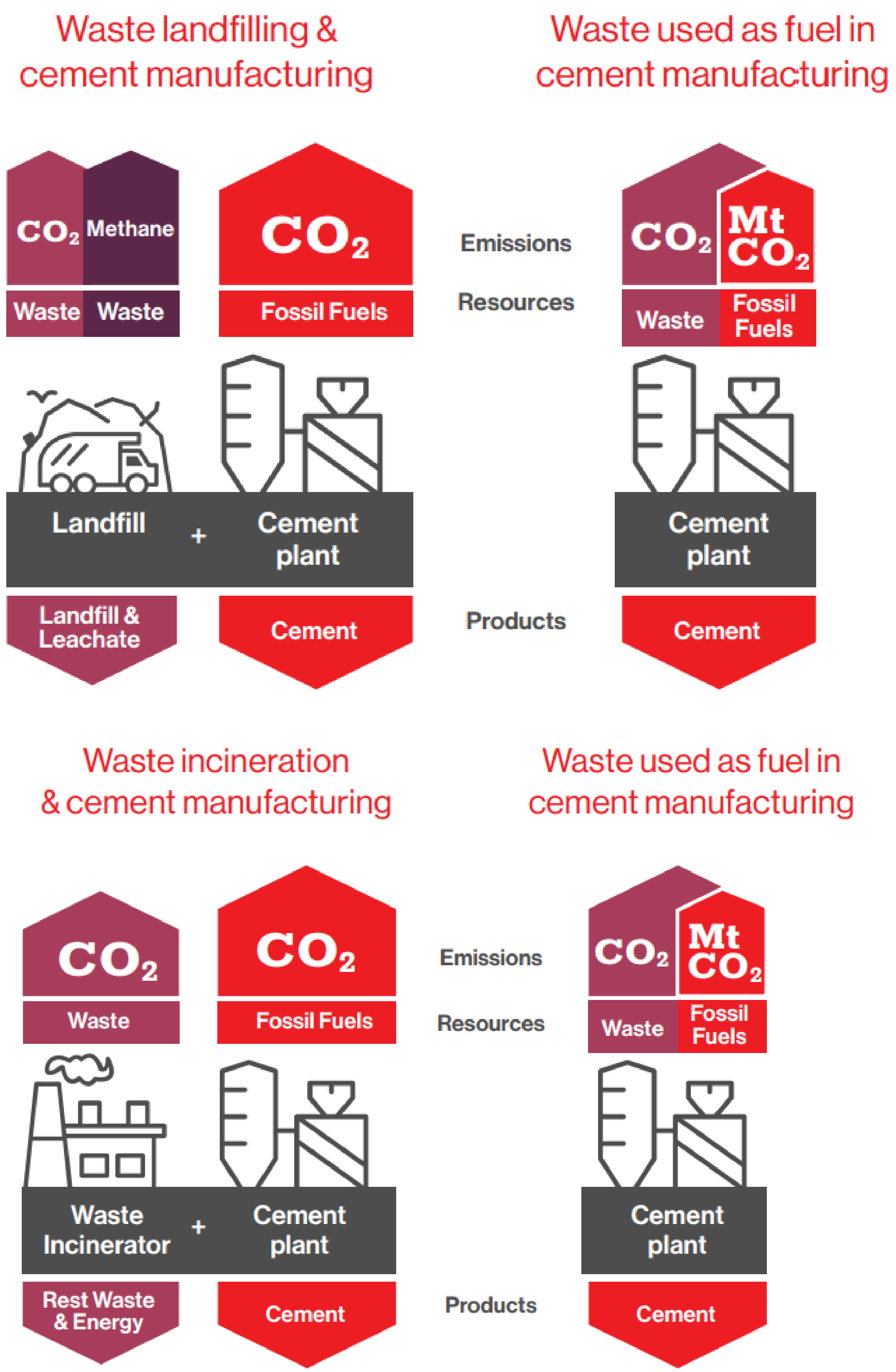
To improve the plant **environmental performance** by replacing fossil fuel for alternative fuels, decreasing CO_2 emissions.

To increase the knowledge about the process conditions and feedstock characteristics, ending up in an **improvement of the plant efficiency** (energy, cost, process yield).

Maceira-Liz

Why use Alternative Fuels (AF)?

- **Fuel emissions** account for approximately **35% to 40% of total CO_2 emissions** from cement manufacturing.
- Alternative fuels are derived from **non-primary materials (waste or by-products)** and can be biomass, fossil or mixed (fossil and biomass) alternative fuels. SECIL uses RDF (Refuse Derived Fuel) whose alternative **disposal option is incineration or landfilling.**
- The extremely high temperatures and residence times of a cement kiln ensure these are managed in a **safe and environmentally sound way**.
- **CO_2 is saved** by replacing fossil fuels with the alternative waste streams and through those emissions not being released by incineration or landfilling.



Source: CEMBUREAU

RDF Challenges

- High heterogeneity (size, material)
- High variation of calorific value
- High variation of moisture content
- Chlorine content
- Flame control
- Product quality

Cement kiln

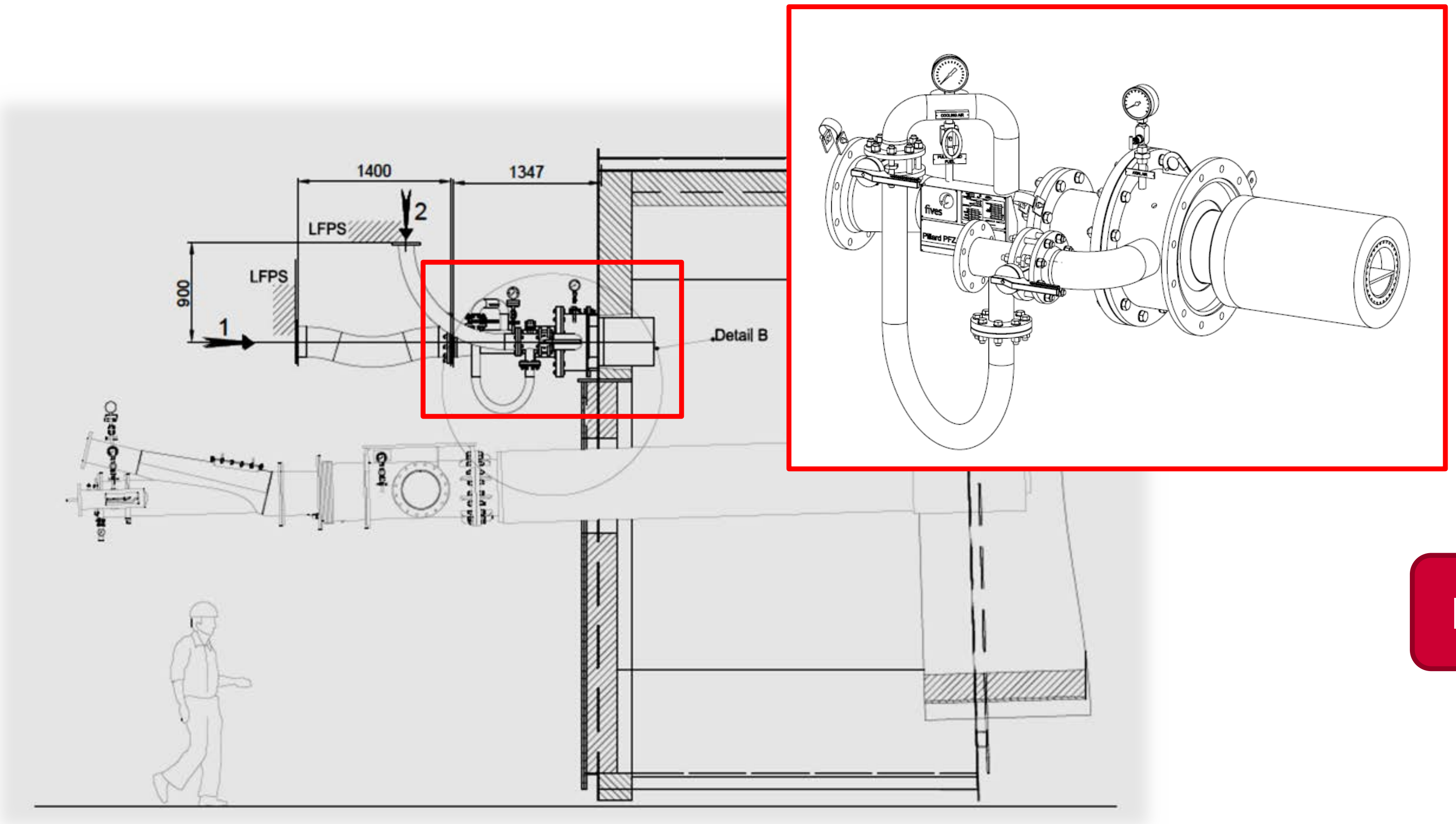
Petroleum coke

RDF (Refuse Derived Fuel)

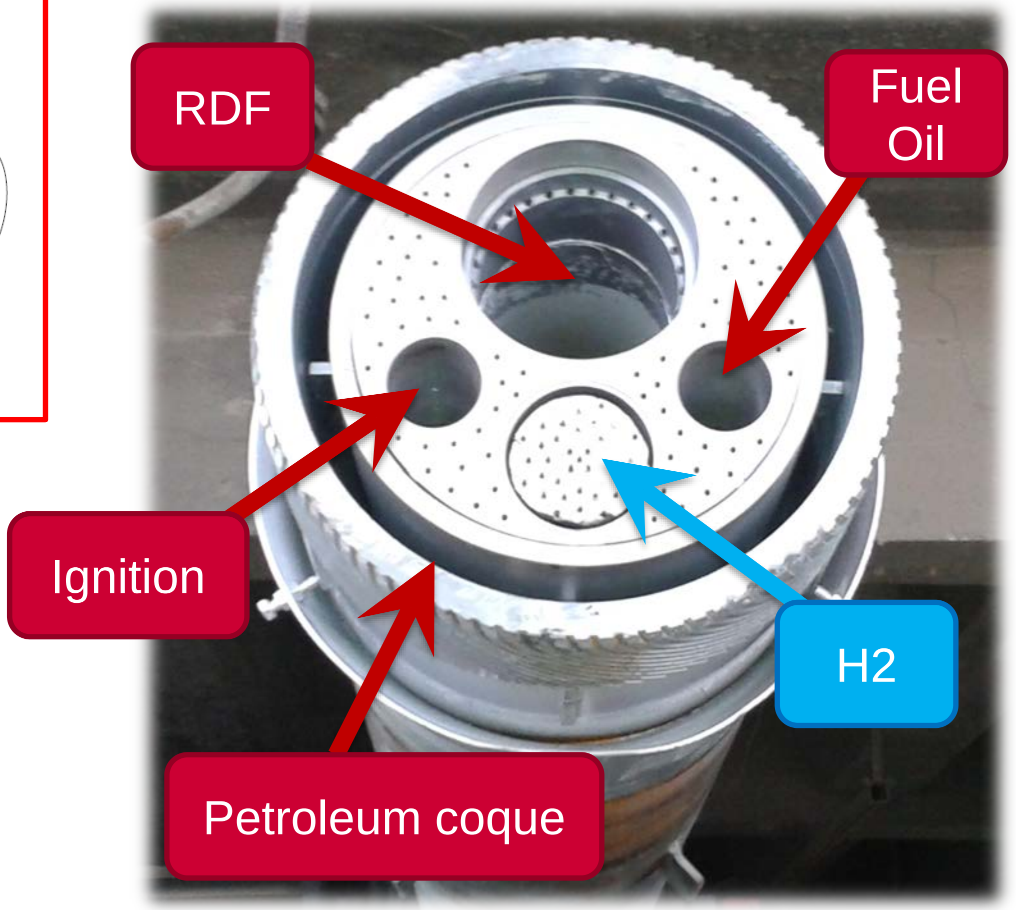
New burner design

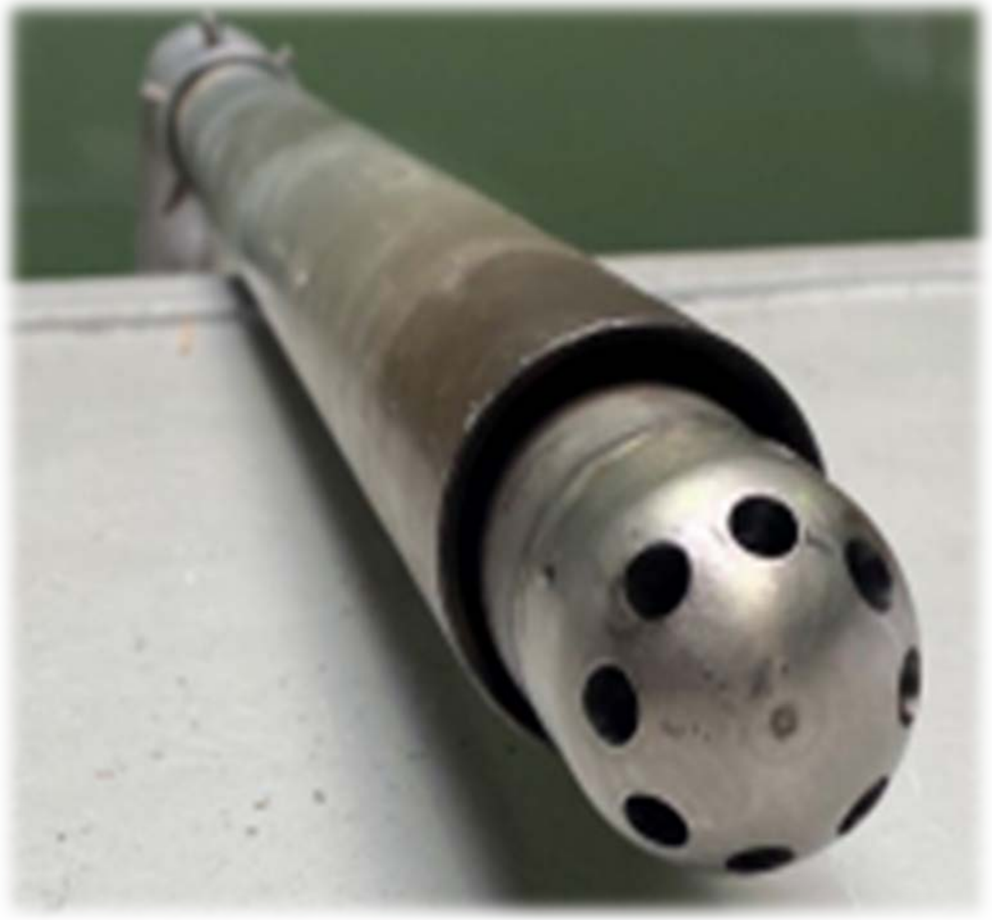
Based on CFD models and trials on a prototype burner, we defined the **new design of the main burner**.

- Conclusion: Use two different RDF streams in the main burner.
- Solution: Satellite burner:



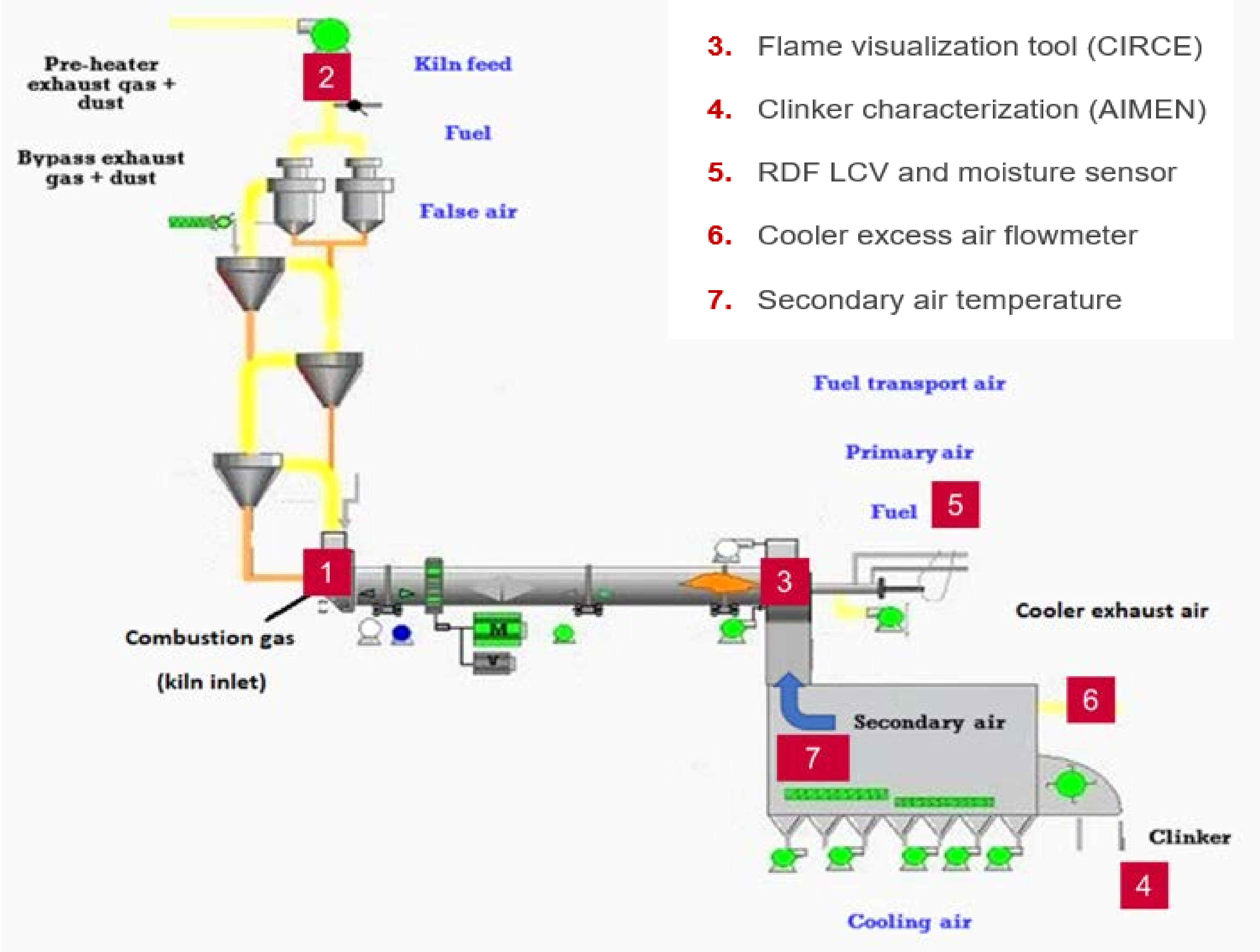
- Conclusion: Use a high calorific fuel to increase RDF rate.
- Solution: Inject H2 in the main burner:

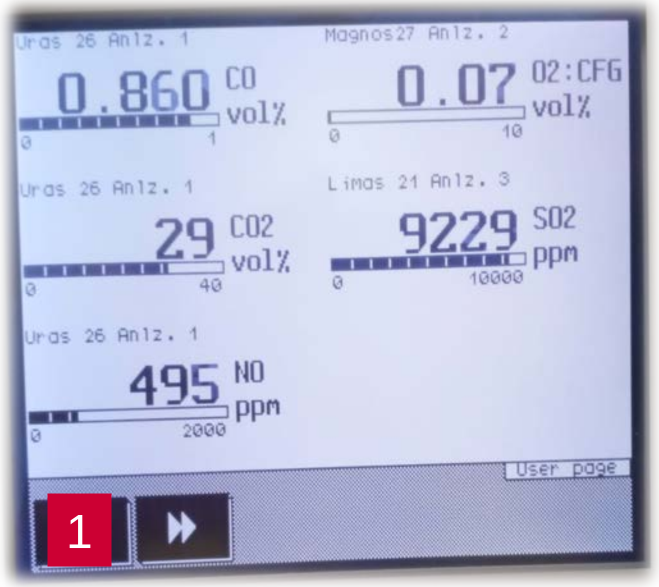


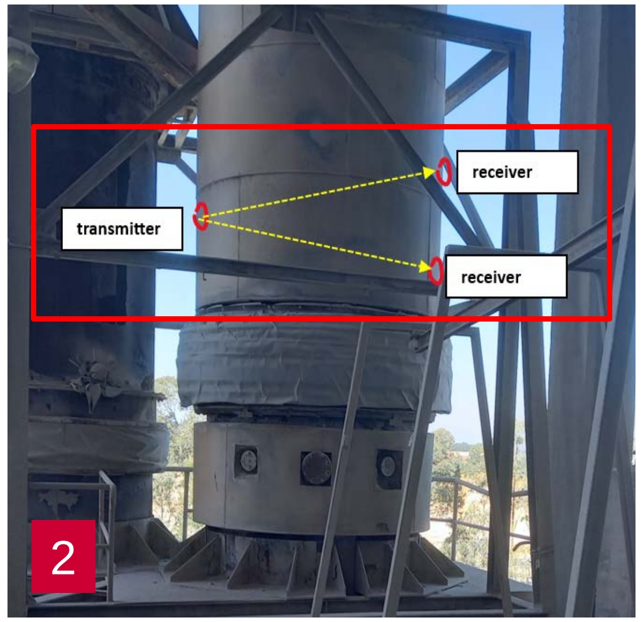


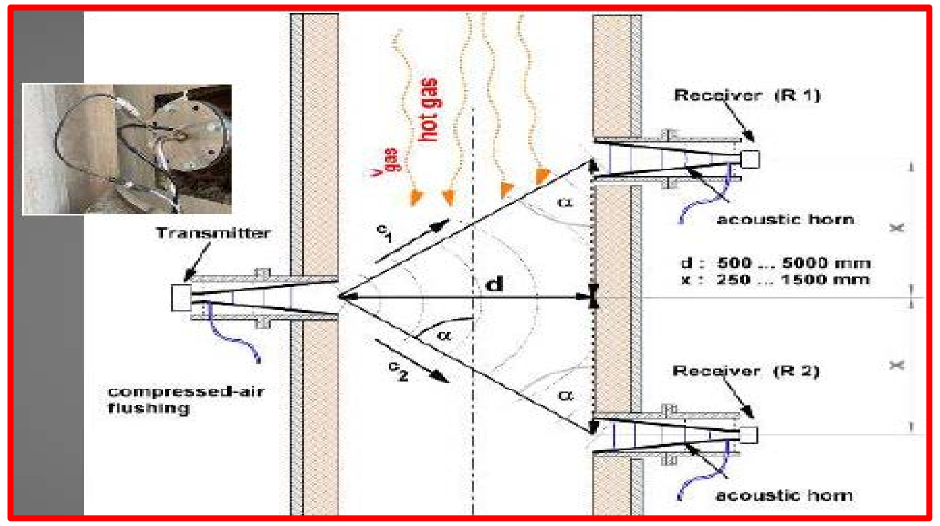
New sensors

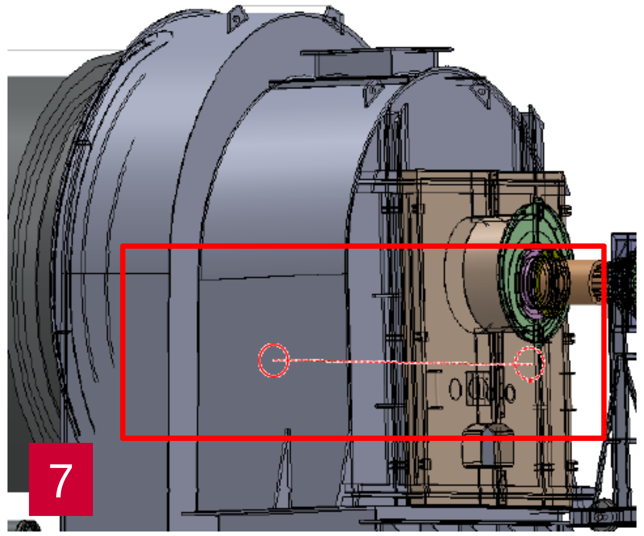
1. Kiln Inlet Gas Analyser
2. Preheater gas flowmeter
3. Flame visualization tool (CIRCE)
4. Clinker characterization (AIMEN)
5. RDF LCV and moisture sensor
6. Cooler excess air flowmeter
7. Secondary air temperature

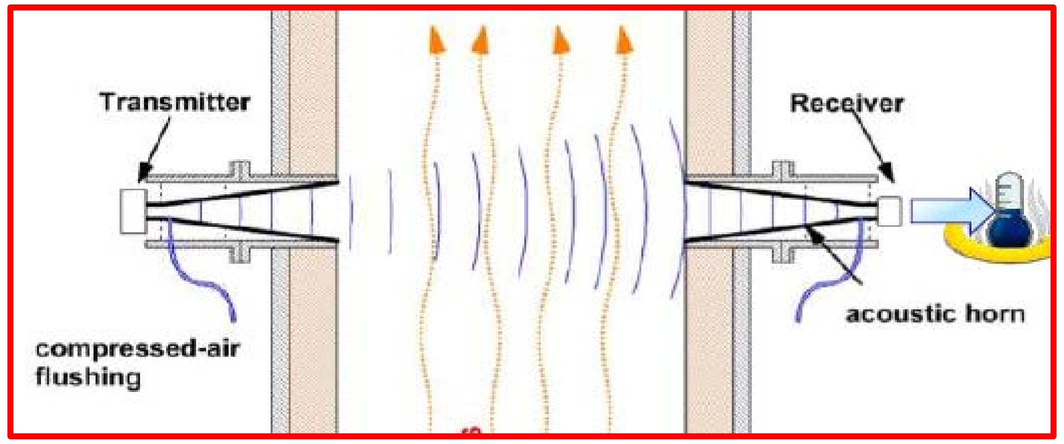












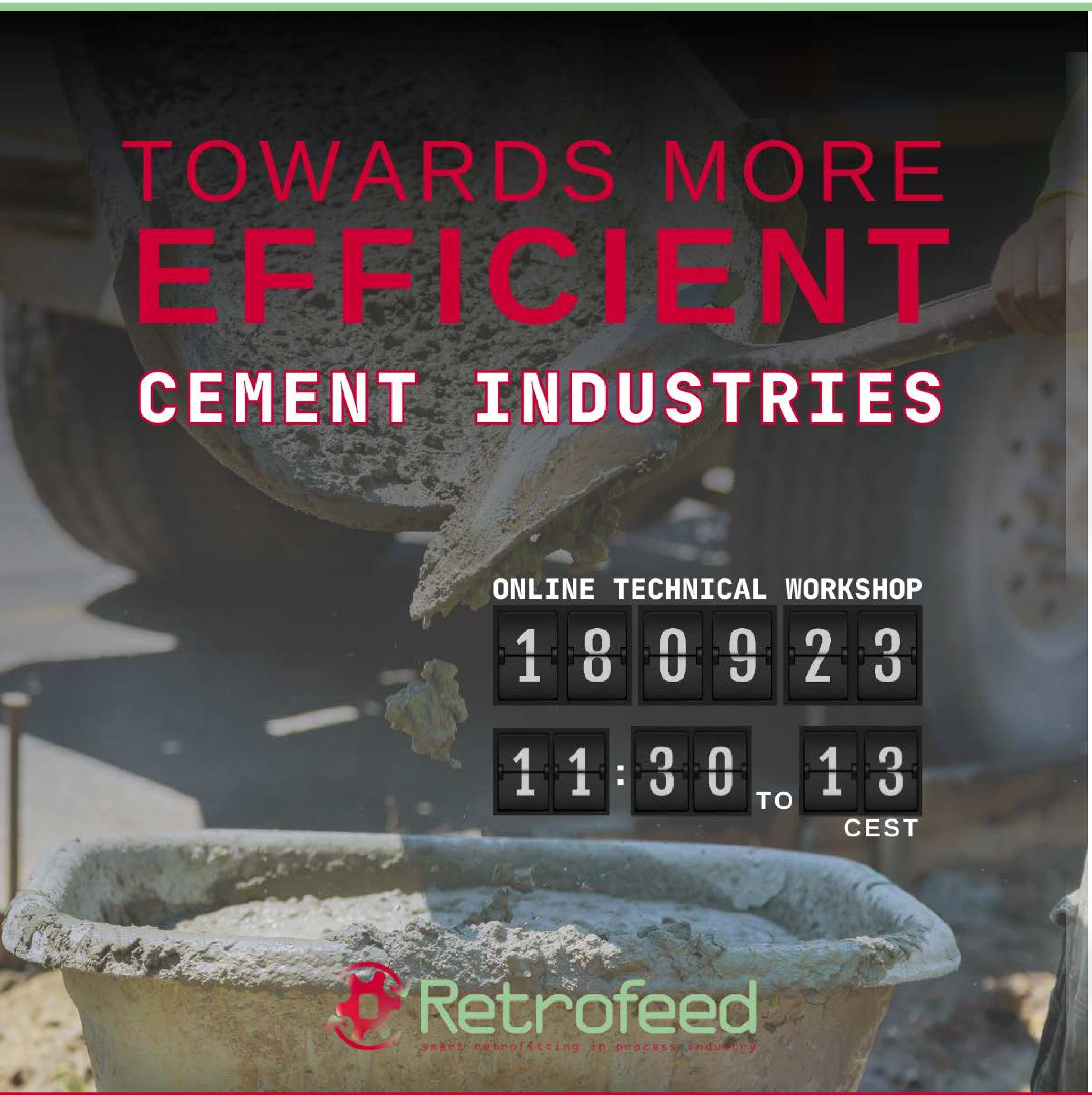
Retrofeed
smart retrofitting in process industry

Next Steps

- **Validation tests:**
  - **New burner**
  - **New sensors**
  - **Kiln digital twin/ Decision Support System (DSS).**
- **Optimization:**
  - **Reduce environmental footprint**
  - **Reduce energy consumption**
  - **Improve productivity**
  - **Improve quality**
- **Test hydrogen in the main burner**
- **Development of machine learning models**
- **Development of the SECIL replication strategy**

Circular economy

Maceira-Liz



Q&A

Olga Lysenko (IVL)

Diego Redondo (CIRCE)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869939.

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