ESTEP SPRING DISSEMINATION EVENT

14 MARCH 2024

BRUSSELS

REA BUILDING IN NORTH LIGHT

AVENUE SIMON BOLIVAR 34

HIYIELD

Highly efficient technologies for increased yields in steelmaking processes and reduced environmental impact

HORIZON-CL4-2021-TWIN-TRANSITION-01-19: Improvement of the yield of the iron and steel making (IA)

This project has received funding from the European Union's Horizon-IA innovative program under grant agreement number 101058694.

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Aim

HIYIELD aims to **promote circular economy** by progressively **increasing the scrap uptake** in three demo cases that represent the current European steelmaking routes, with the ambition to **deliver solutions with relevance to all steelmakers**.

Project duration: 01/07/2022 – 30/06/2025

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Consortium

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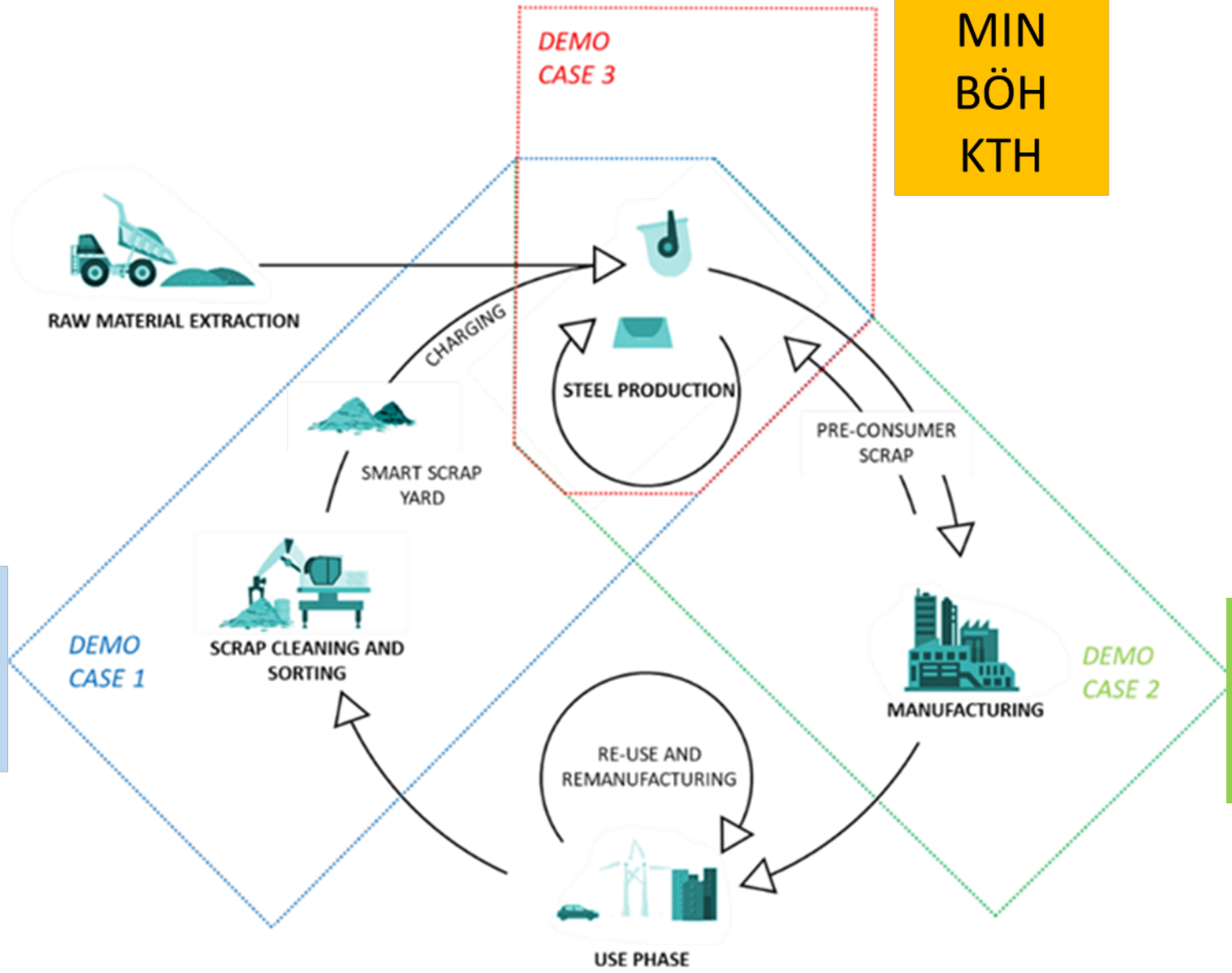
Demo Cases

MIN
BÖH
KTH

AEIF
FENO
KTH

SAG
STE
SHS



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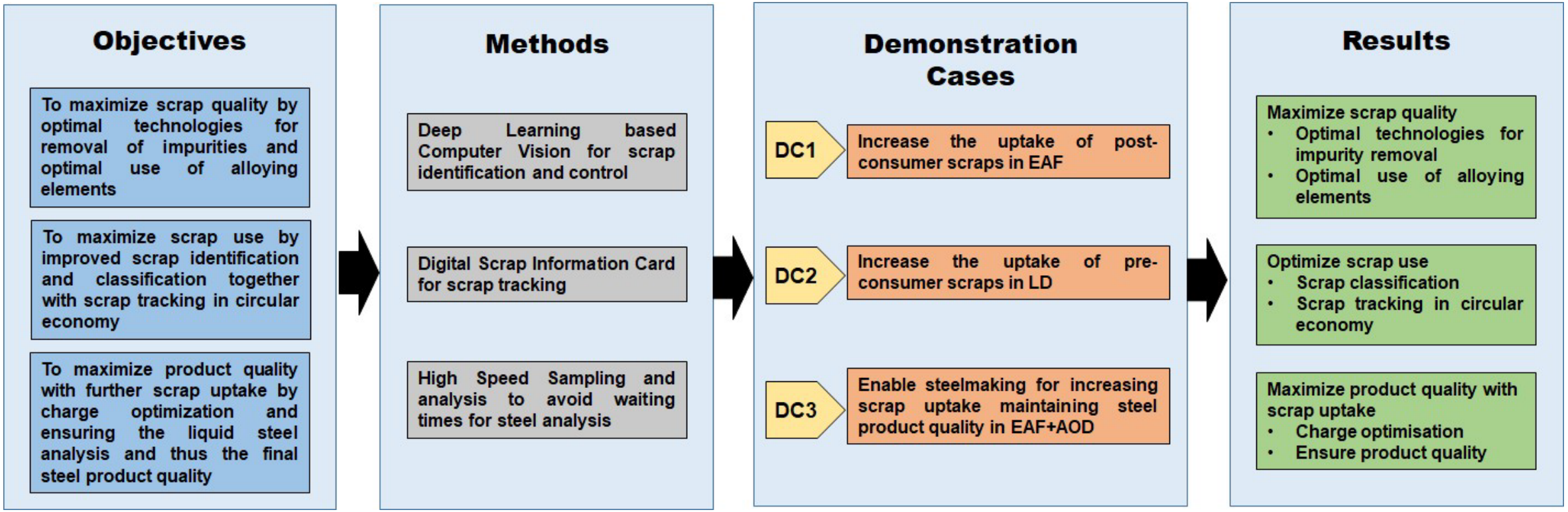
Objectives



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DEMO CASE 1: Upgrading and intelligent use of post-consumer scraps

- ✓ **Definition of components & equipment** for processing of selected scrap types
  - Combination of techniques to upgrade low-grade scraps
  - Dimensioning of all components/equipment
  - Basic engineering data and specifications

- ✓ **Implementation activities**
  - Procurement of new equipment
  - Modification of existing equipment

- ✓ **Industrial scale trials**
  - Combination of mechanical, physical, and sensor-based sorting techniques to efficiently upgrade low-grade scraps
  - Three combinations (Modes) promoted through trials, by utilizing the available equipment

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DEMO CASE 1: Upgrading and intelligent use of post-consumer scraps

Three combination modes promoted through industrial trials

Mode A

1. Pre-sorting (grabs/magnets, stationary grizzly screen)
2. Size sorting in fractions (waste/scrap screen & flip-flow).
3. Magnetic drum separation.
4. Density sorting of Fe stream with air-separator (per size)
5. Hand sorting of Fe stream

Remark:

Very low efficiency due to complexity of consecutive stages and time consuming

Mode B

1. Shredder with grate opening <100mm
2. Magnetic drum separation.
3. Density sorting of Fe stream with air (zig-zag)

Remark:

High efficiency due to out-put size <100mm and air

Mode C

1. Shredder with grate opening 150mm+
2. Magnetic drum separation.
3. 2nd pass of shredding
4. 2nd magnetic drum separation.
5. Density sorting of Fe stream with air (zig-zag)

Remark:

Moderate efficiency due to out-put size.

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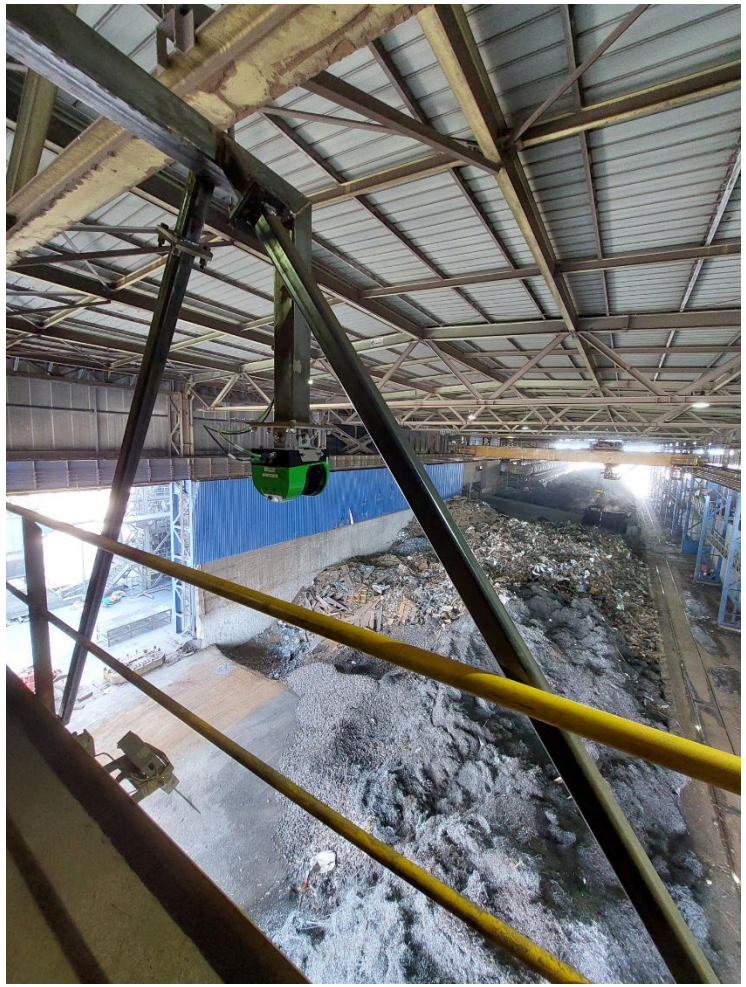
DEMO CASE 1: Upgrading and intelligent use of post-consumer scraps

Laser Scanner installation in scrapyard

- Laser Scanner installed in all scrapyards
- Scrapyard 1 : already working
- Scrapyard 2 and 3: fine tuning needed



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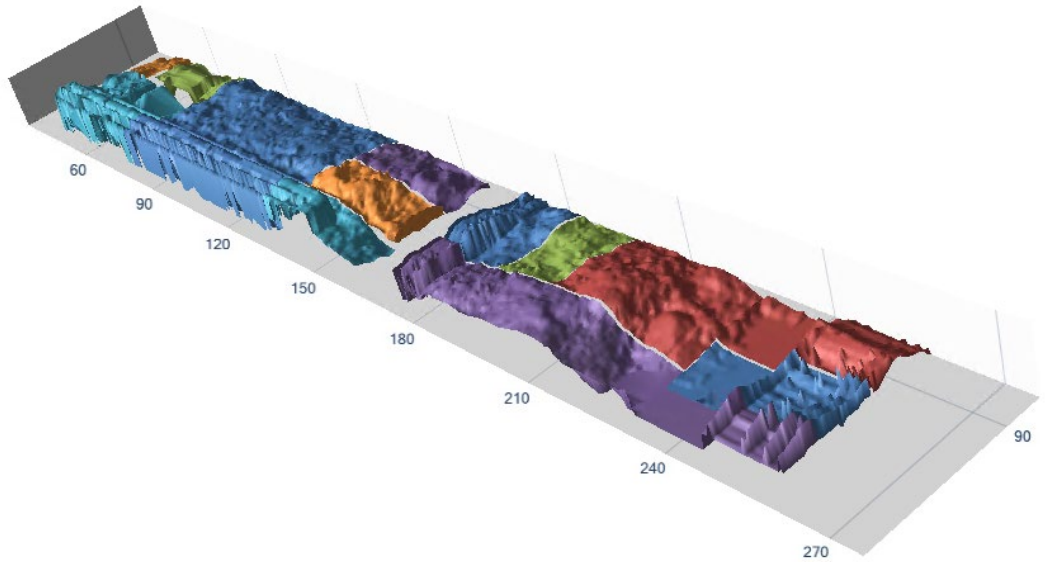
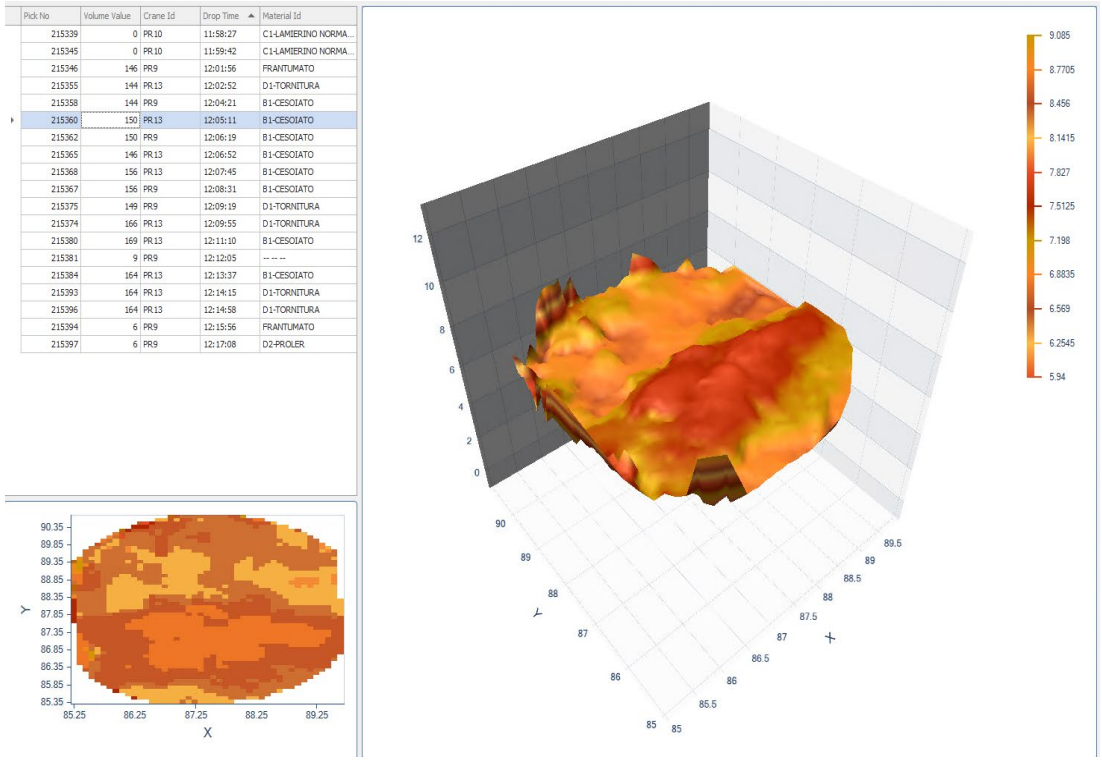
DEMO CASE 1: Upgrading and intelligent use of post-consumer scraps

Laser Scanner installation in scrapyard

- Volume distribution in the scrapyard
- Volume distribution of each layer inside the bucket



3D map of Scrapyard



Pick No	Volume Value	Crane Id	Drop Time	Material Id
215339	0	PR10	11:58:27	C1-LAMIERINO NORMA...
215345	0	PR10	11:59:42	C1-LAMIERINO NORMA...
215346	146	PR9	12:01:56	FRANTUMATO
215355	144	PR13	12:02:52	D1-TORNITURA
215358	144	PR9	12:04:21	B1-CESOIATO
215360	150	PR13	12:05:11	B1-CESOIATO
215362	150	PR9	12:06:19	B1-CESOIATO
215365	146	PR13	12:06:52	B1-CESOIATO
215368	156	PR13	12:07:45	B1-CESOIATO
215367	156	PR9	12:08:31	B1-CESOIATO
215375	149	PR9	12:09:19	D1-TORNITURA
215374	166	PR13	12:09:55	D1-TORNITURA
215380	169	PR13	12:11:10	B1-CESOIATO
215381	9	PR9	12:12:05	-- -- --
215384	164	PR13	12:13:37	B1-CESOIATO
215393	164	PR13	12:14:15	D1-TORNITURA
215396	164	PR13	12:14:58	D1-TORNITURA
215394	6	PR9	12:15:56	FRANTUMATO
215397	6	PR9	12:17:08	D2-PROLER

Bucket layering

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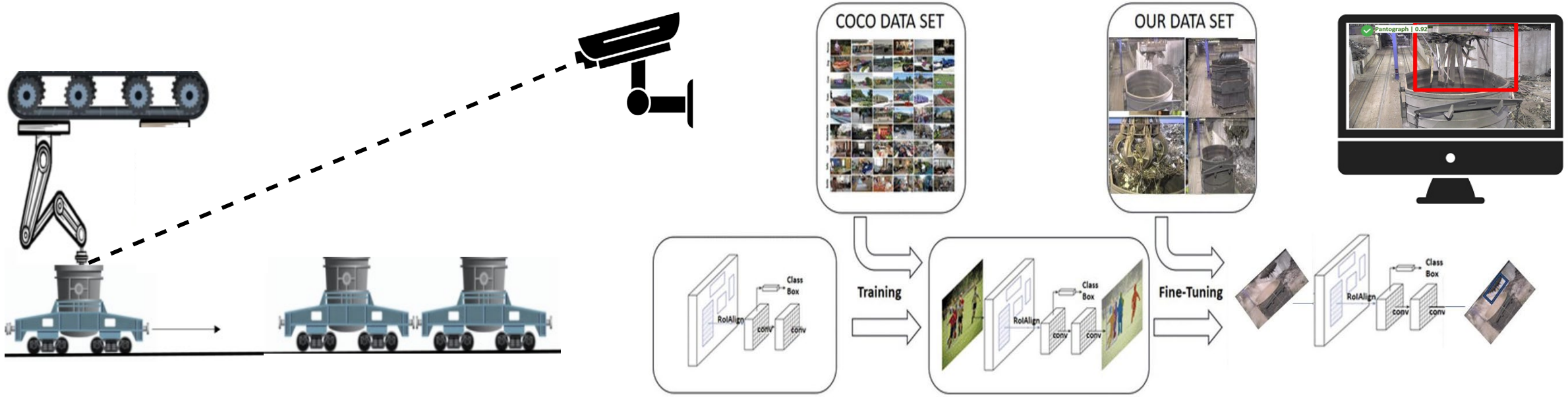
DEMO CASE 1: Upgrading and intelligent use of post-consumer scraps

Deep learning based computer vision for scrap identification

- Transfer learning was used to develop novel scrap identification algorithm
- Computer vision model is trained on ~25000 images to detect post-consumer scrap category



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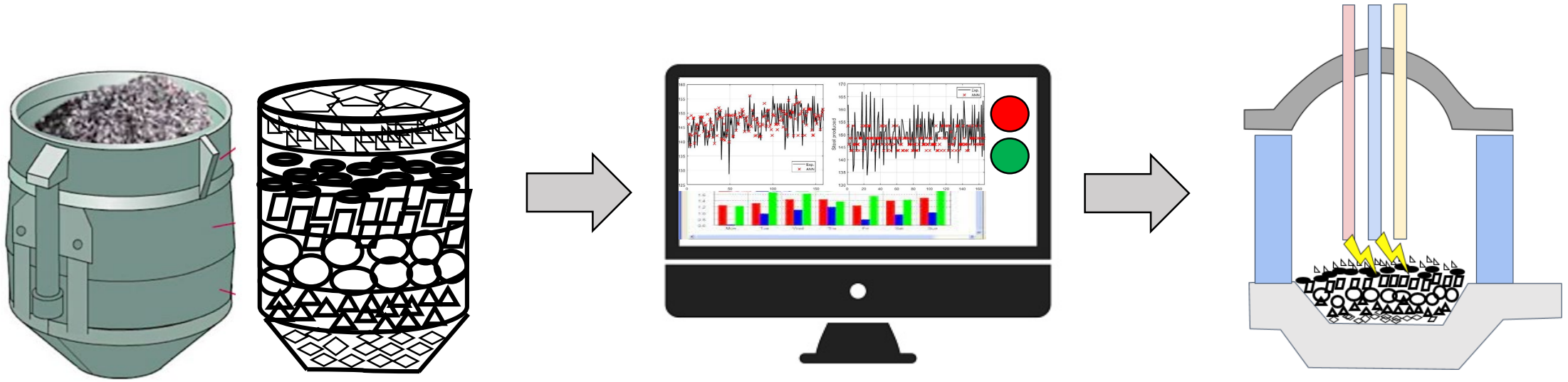
DEMO CASE 1: Upgrading and intelligent use of post-consumer scraps

Online optimizer tool for bucket charge based on scrap availability

- A novel response function was designed based on electrical energy consumption and steel produced in EAF per heat
- An unsupervised Artificial Neural Network is tested on different combinations of bucket layering



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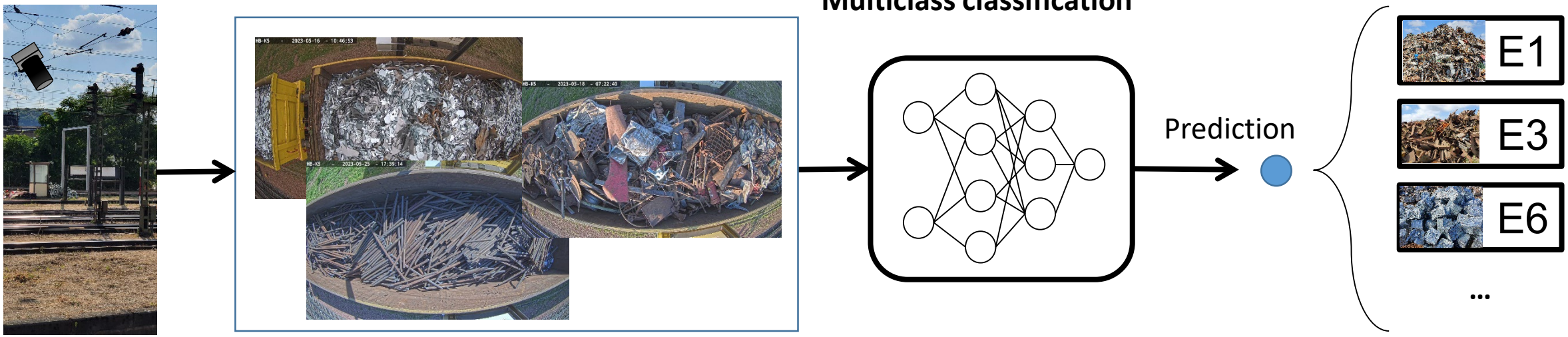
DEMO CASE 2: Identification and tracking of pre-consumer scraps

Deep Learning - based scrap identification



Model recognizes classes with large geometric differences very well


E6


E8

Challenge: Distinguishing between scrap types that differ only by dimension or can be assigned to several categories


E3


E2

```
Test accuracy: 73.46%
```

```
tensor([[   0.,    0.,    0.,    0.,    0.,    0.,    0.,    0.,    0.],
        [   0.,  933.,    6.,  671.,    0.,    0.,    0.,   15.,    3.],
        [   0.,    0.,  471.,  171.,    0.,    0.,    0.,    0.,    0.],
        [   8.,   87.,  137., 1570.,    0.,    0.,    8.,   23.,    0.],
        [   0.,   49.,    0.,   20.,  179.,  340.,   58.,   34.,    0.],
        [  33.,   56.,    3.,   15.,   17.,  397.,   11.,  185.,    0.],
        [   5.,   29.,    0.,    4.,    0.,    0., 1013.,   18.,    0.],
        [   0.,    2.,    7.,   65.,    0.,    0.,    0.,  853.,    0.],
        [   0.,   42.,    0.,   39.,    0.,    0.,    0.,    7.,  547.]])
per-class accuracy:
 ['BACKGROUND', 'E1', 'E2', 'E3', 'E40', 'E5H', 'E6', 'E8', 'EHRB']
tensor([   nan, 0.5731, 0.7336, 0.8565, 0.2632, 0.5537, 0.9476, 0.9202, 0.8614])
```

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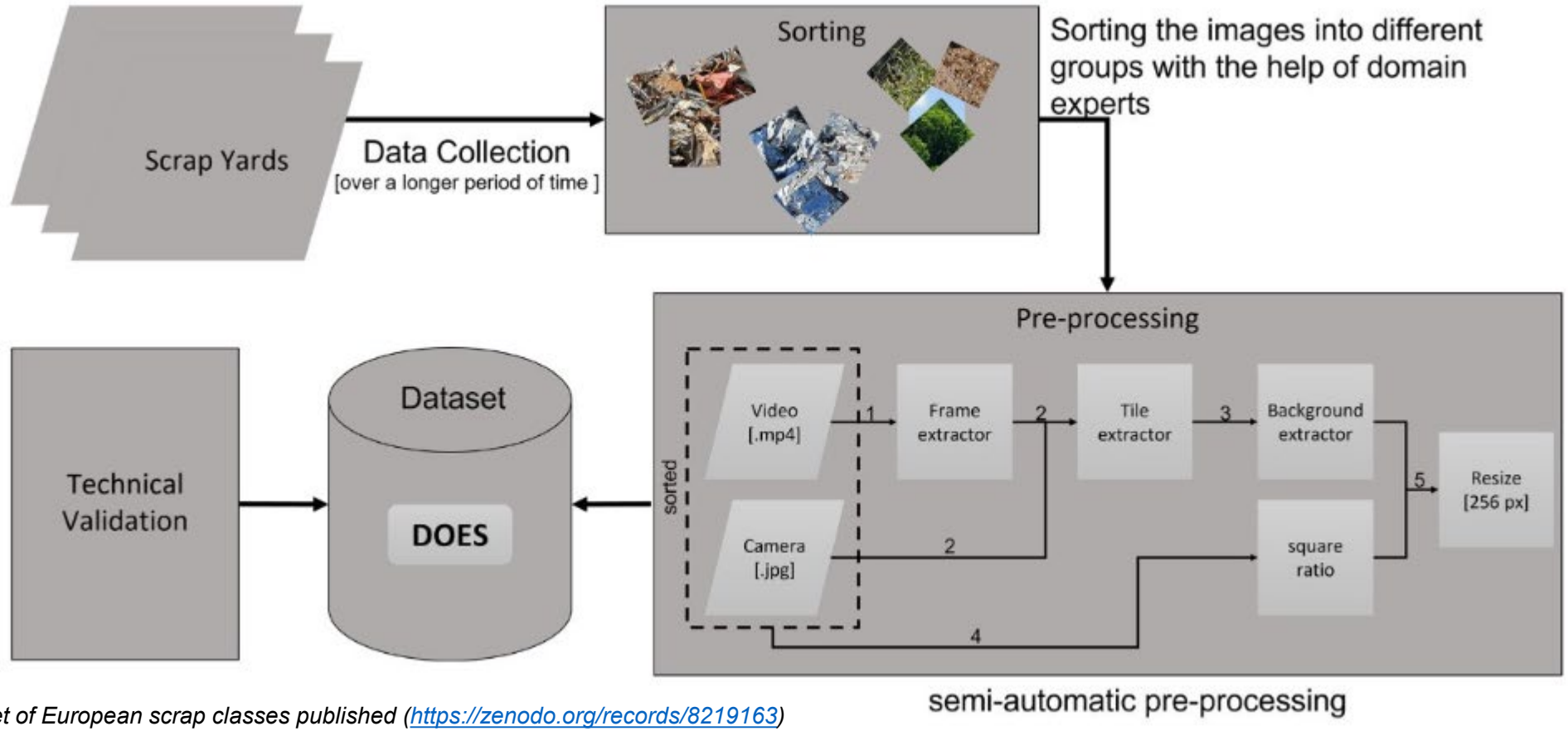
DEMO CASE 2: Identification and tracking of pre-consumer scraps

Schematic overview of approach



DOES – dataset of European scrap classes published (https://zenodo.org/records/8219163)
DL-based algorithmes for scrap identification trained (https://www.nature.com/articles/s41597-023-02662-6)

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DEMO CASE 2: Identification and tracking of pre-consumer scraps

- *A demo unit for combined sorting and analysis was installed and commissioned.*
- *Tests with different material streams were performed and a set up was implemented for further tests.*
- *A first Digital Scrap Information Card was created and sent to partner with the material delivered.*

Demo unit at facility Trier

THEO STEIL Pure Rohstoffe

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DEMO CASE 3: Enabling steelmaking to further increase scrap uptake and improved utilization of alloys by providing high-speed sampling and analysis

High speed sampling and direct OES analysis at steelmaking

- Avoiding liquid steel temperature losses
- Reducing waiting times
- Energy savings of 2% per batch

- Pneumatic setup finished ✓
- Electrical setup finished ✓
- PLC software ✓
- Siemens HMI Panel ✓
- Foiling ✓
- Setup of measuring equipment in laboratory and testing ✓

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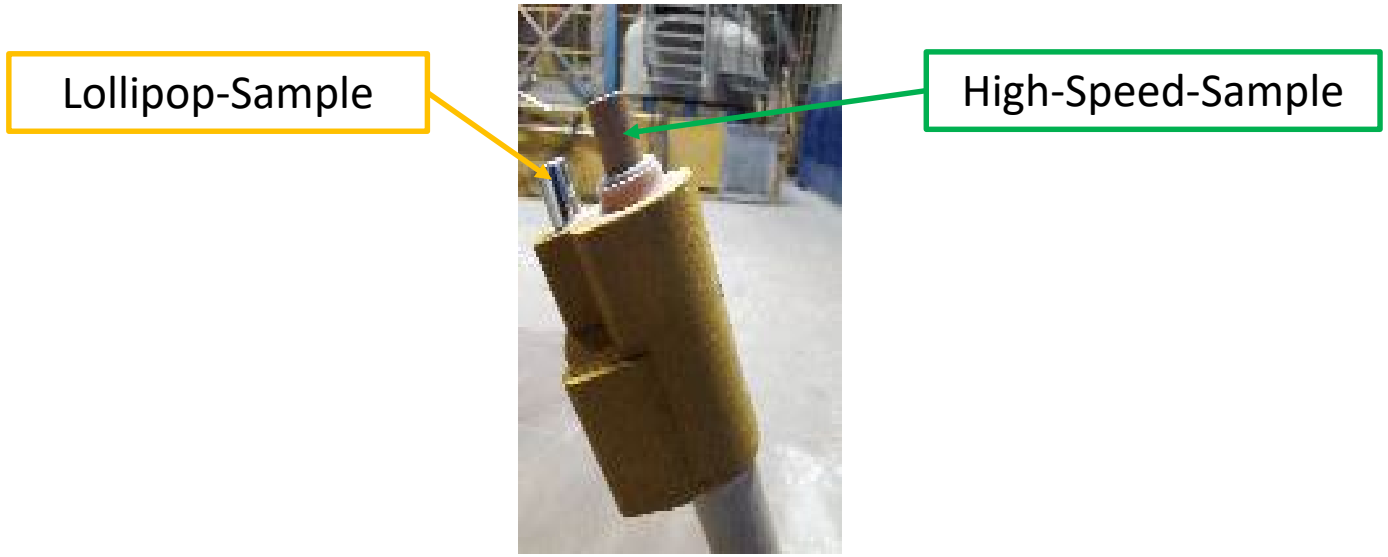
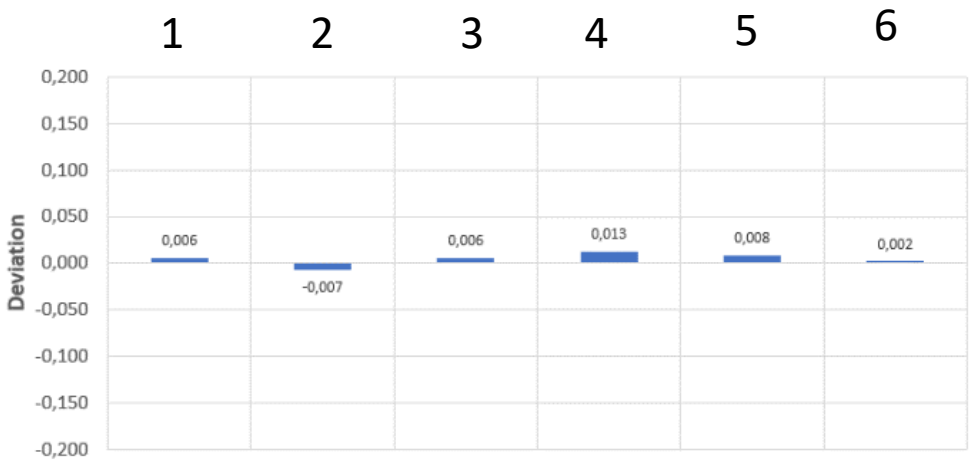
DEMO CASE 3: Enabling steelmaking to further increase scrap uptake and improved utilization of alloys by providing high-speed sampling and analysis

Industrial sampler verification

- A combination sampler of high-speed sampling and conventional Lollipop sampling was developed and successfully tested





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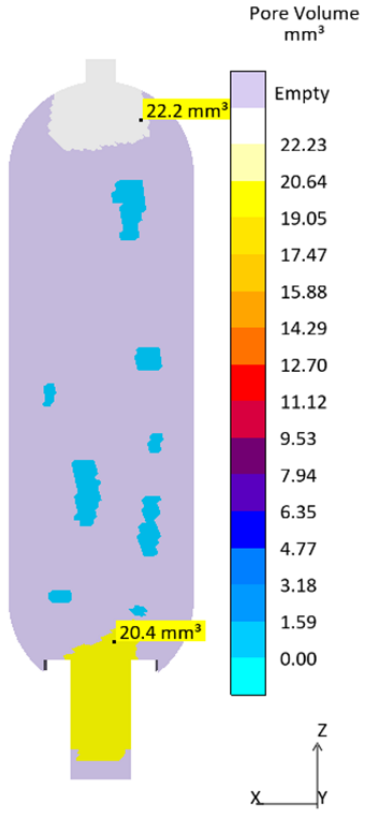
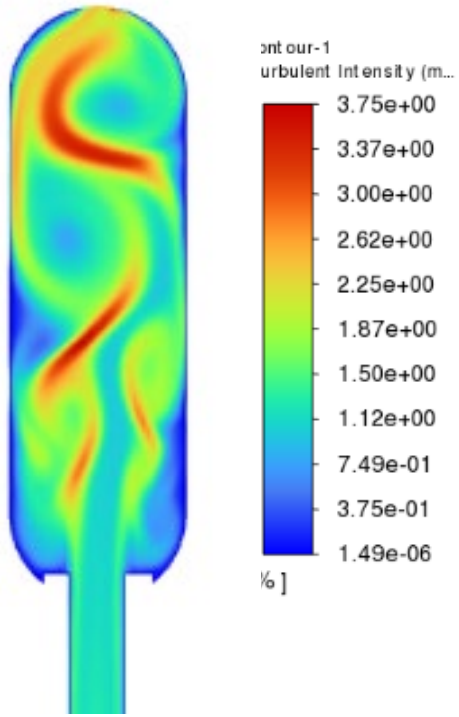
DEMO CASE 3: Enabling steelmaking to further increase scrap uptake and improved utilization of alloys by providing high-speed sampling and analysis

Sampler modelling using MAGMASOFT

- Optimization of sampler geometry
- Pore volume on mould thickness and mould material
- Immersion depth, inlet length and inlet diameter on flow behaviour
- Impact of melt composition and melt temperature on filling and solidification behaviour



Areas of pore formation during solidification



Contour plot for turbulent intensity of fluid during filling

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