Deliverable 6.5

Publishable Report

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G.A. 101112102

Project details

Project Name	**Remote expert virtual system enhancing human management capabilities and favors preservation, transfer and continuous evolution of knowledge for steelmaking operation**		
Project Acronym	iSteel-Expert		
Project No.	101112102	Duration	36 months
Project Start Date	01.07.2023	Project End Date	30.06.2026

Document details

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1.0			
1.1			
1.2			
2.0			
2.1			

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1. Introduction

With a 36-month duration starting on 1st July 2023, the iSteel-Expert RFCS Project targets the modernization of the steel sector through an innovative, integrated approach based on a virtual system. The system monitors operations and proposes improvements derived from data pre-analysis performed by Machine Learning (ML) algorithms.

iSteel-Expert implemented and demonstrated in one industrial environment (at SIDERPOTENZA plant, located in Potenza - IT) a remote expert virtual system able to monitor 24/7 process progress and events, analysis the information to produce relevant KPI and suggest actions to improve and/or correct the steelmaking operations.

iSteel-Expert acts as a human expert in collecting and analyzing information coming from the melting furnace while increasing substantially the quality of the information needed to the operator decision-making process. The system, based on IoT, supports standard and maintenance operations and, enhancing human management capabilities, detects any relevant events and their consequences.

Finally, it prevents the loss of individual knowledge through the implementation of knowledge-based tool that work integrated in a interactive training tools, which favour preservation, transfer and continuous evolution of the industry's wealth of knowledge.

The project was structured into seven distinct Work Packages (WPs), including WP7 Project Management and Coordination, to ensure systematic progress and comprehensive coverage of all activities. Each WP was led by a dedicated partner and included specific deliverables—such as reports and key performance indicators—that marked the successful completion of key tasks.

Alongside deliverables, nine Milestones served as key checkpoints to monitor progress and ensure the successful attainment of all project objectives.

The iSteel-Expert Consortium, comprised six partners:

1) **TENOVA SPA (TENOVA) – Coordinator:** a worldwide supplier of advanced technologies, products and services for metal and mining industries, providing innovative, integrated solutions for complete process areas.
2) **SCUOLA SUPERIORE DI STUDI UNIVERSITARI E DI PERFEZIONAMENTO S. ANNA (SSSA):** an autonomous, special statute public university operating in the field of applied sciences.
3) **SIDERPOTENZA SPA (SIDER):** a steelmaker, based in Potenza (Italy, part of Pittini Group since 2002.
4) **INSTITUT CATHOLIQUE DE LILLE (UNICL):** a major actor of the French higher education system.
5) **UNIVERSIDAD DE LA ROJA (UNIRIO):** a public University, with extensive experience in research.
6) **SIM4FUTURE SRLS (SIM4):** a High-Tech Spin-off of the Genoa University, specialized in Strategic Consulting, Modeling & Simulation (M&S), Artificial Intelligence & Machine Learning, Extended Reality (XR), Data Analytics.

The present document provides an overview of the results and their exploitation and dissemination; it also provides the general conclusions on the project and impact.

The Consortium sought to maximize project impact by sharing results widely within and beyond the European steel industry. This strategic focus is reflected in several deliverables dedicated entirely to Communication, Dissemination, and Exploitation (D&C&E).

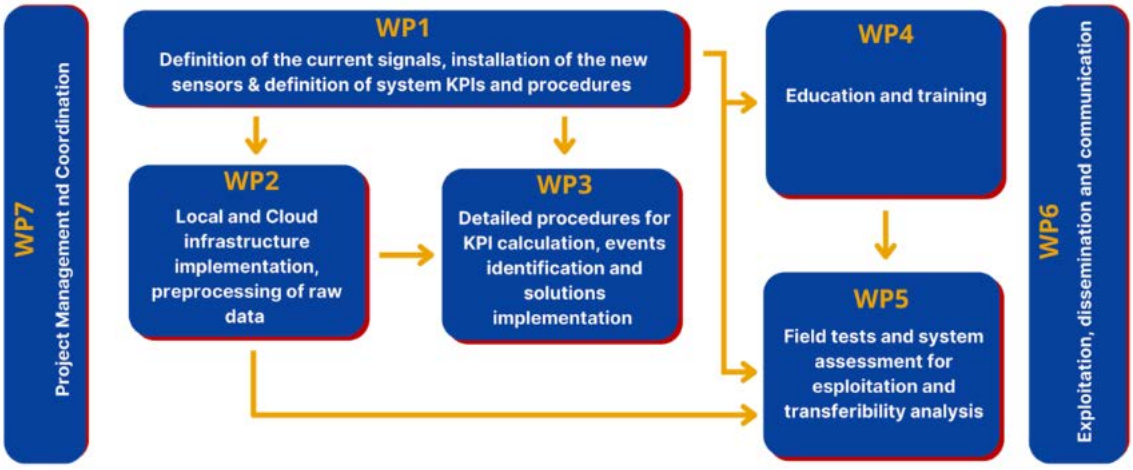
This document, focussing on the results of the project, is divided into 3 main sections:

- Section 1 focuses on activities and findings of the technical WPs of iSteel-Expert project;
- Section 2 summarises the Exploitation activities and Dissemination activities, carried out before the conclusion of the project, that are detailed in the deliverables D6.6; D6.7 and D6.8;
- Section 3 provides some concluding remarks about impacts and other considerations.

2. Summary of actions and results

This section provides a detailed summary of the findings and impacts of the technical WPs within the iSteel-Expert project. The outcomes aligned seamlessly with both the overall project goals and the specific objectives of each individual WP.

iSteel-Expert Workplan



Work Package 1 - Definition of the current signals, installation of the new sensors & definition of system KPIs and procedures

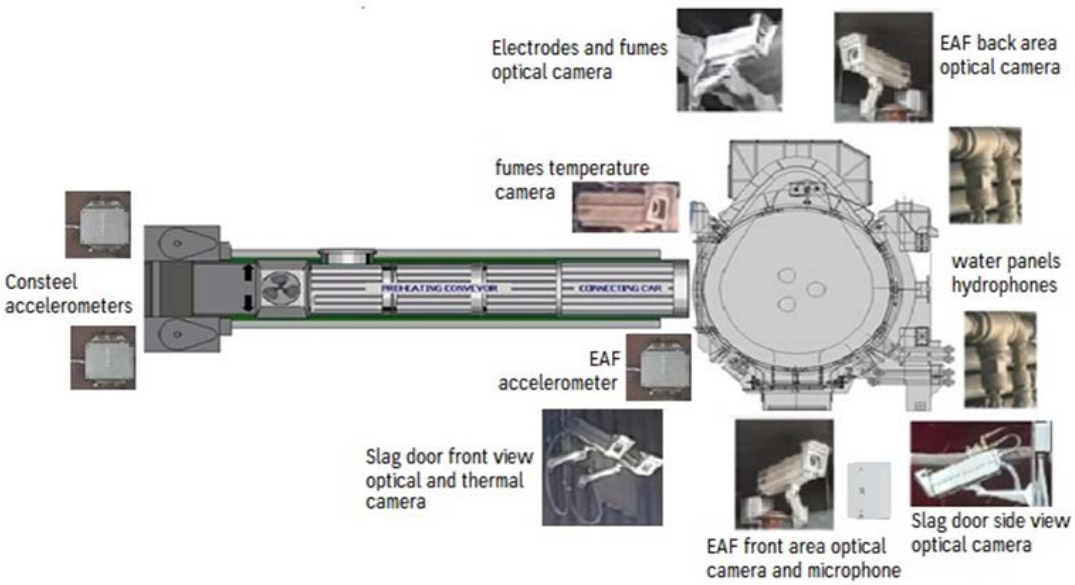
The following actions have been taken:

- **Analyzed** current manual procedures and measured data within the EAF shop in detail;
- **Compiled** a comprehensive list of existing sensors and measurement technologies in the EAF shop, including their technical datasheets;
- **Gathered** historical data, including specific operational details relevant to process and equipment status;
- **Identified** which real-time signals and available data had to be collected for subsequent analysis and integration into the "digital expert system".

Regarding the new sensors, the following actions have been executed:

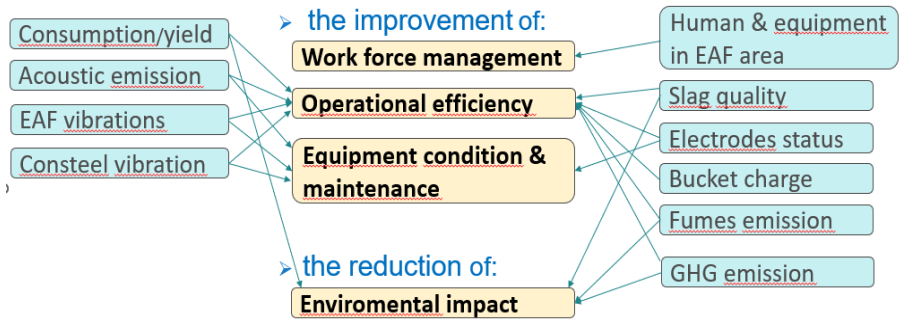
- **Selected** the sensor set and developed the basic engineering documentation for their installation and protection;

- **Procured** and installed with the required protection the new set of sensors.

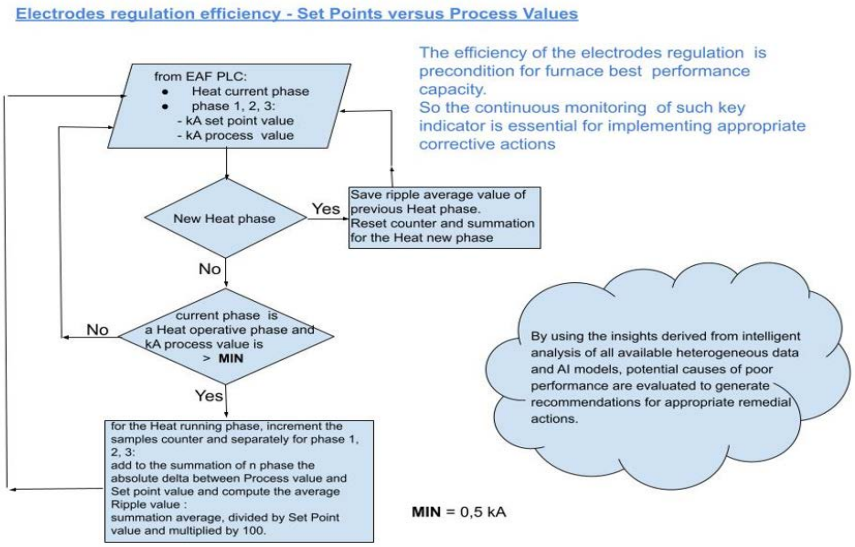


Regarding system KPIs and procedures, the following work has been performed:

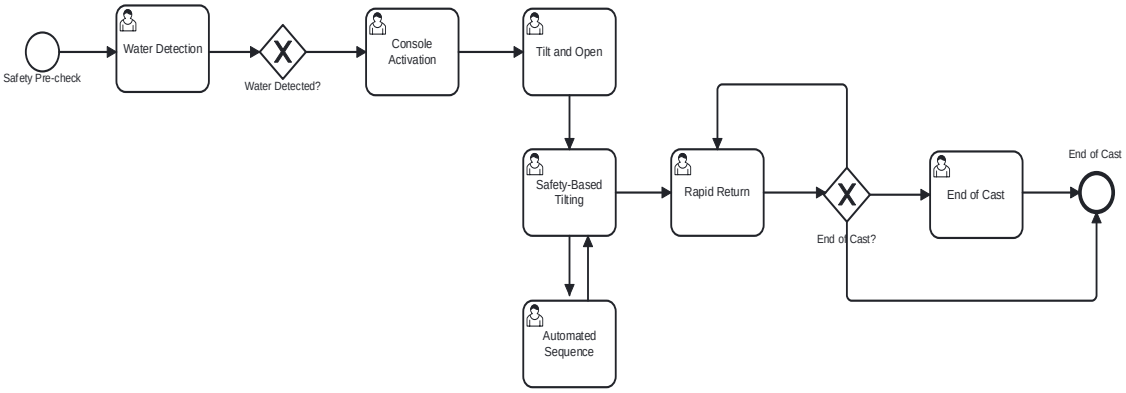
- **Selected** specific KPIs necessary for the proper implementation and assessment of all required system functionalities;



- **Developed** basic computation procedures for KPIs concerning EAF equipment, operations, and processes.



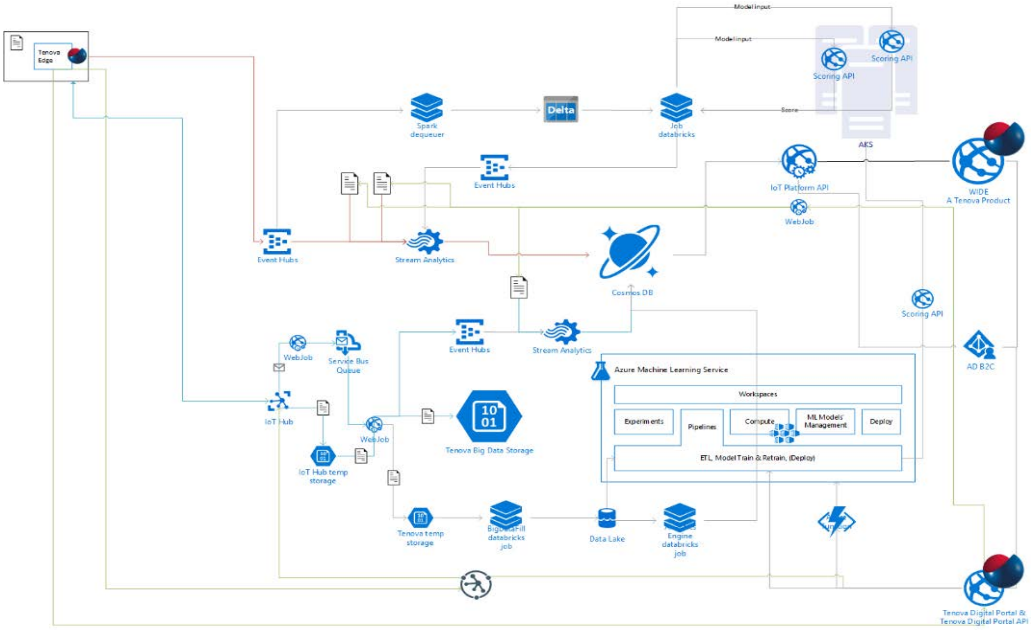
WP1 also included an **analysis of existing training procedures and end-user digital skills**, which were investigated, assessed and documented during onsite plant surveys.



Work Package 2 - Local and Cloud Infrastructure Implementation and Raw Data Preprocessing

The following actions have been taken:

- Implemented and configured the Cloud infrastructure on the Microsoft Azure platform;
- Installed a Tenova proprietary EDGE solution at the plant site to enable real-time data acquisition from PLCs, sensors, databases, and cameras, transferring the preprocessed data directly to the cloud;



The implemented cloud infrastructure ensures controlled access, incorporates state-of-the-art cybersecurity protocols and features user-friendly dashboards that are easy to read and navigate

- Defined the hardware (HW) and software (SW) specifications required for the local preprocessing of the new sensor data;
- Procured and installed the selected hardware (HW) and software (SW) for the plant's local infrastructure.

Regarding the preprocessing of the raw data, the following tasks have been carried out:

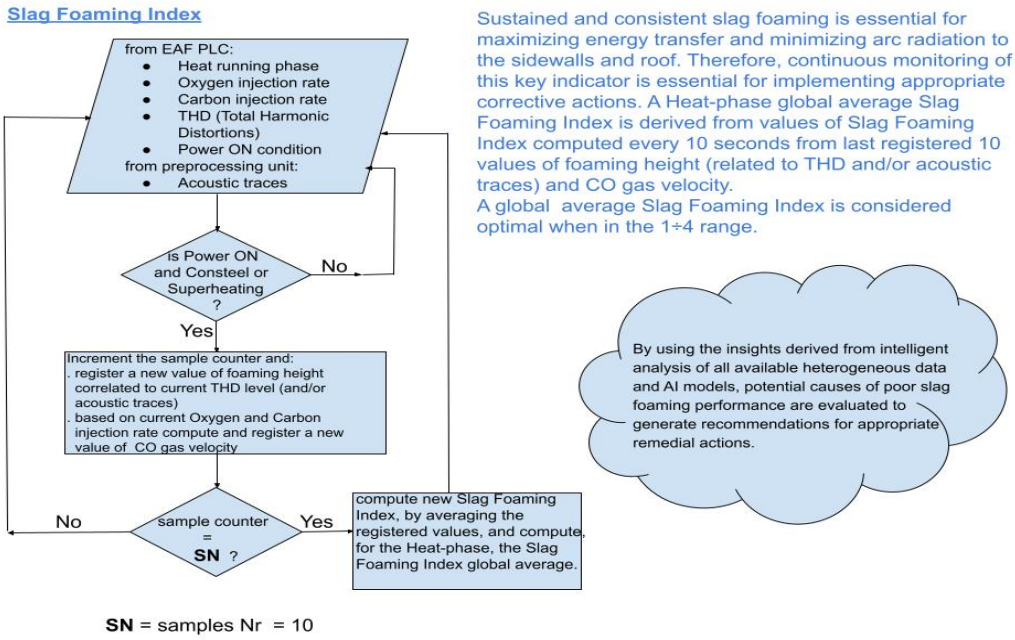
- **Drafted** the technical specifications for processing image, acoustic, and vibration data received from the new sensors;
- **Engineered** computational routines to process collected data against defined baseline indicators, isolating key features for cloud transmission and subsequent KPI calculation.

Work Package 3 – Detailed procedures for KPI calculation, events identification and solutions

The following activities have been carried out:

- **Software implementation of KPI calculations**: the procedures for computing the KPIs defined in the previous task have been developed and deployed, focusing primarily on event detection and classification.

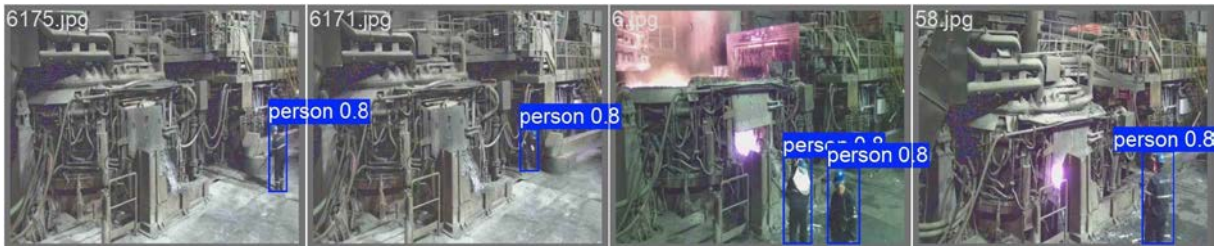
- **Implementation of basic logics** for event detection and implementation /suggestion of corrective actions based on KPIs



- **Implementation of advanced logics** for event detection, implementation /suggestion of corrective actions and further incorporation of personnel know-how: more sophisticated strategies by exploiting artificial intelligence-based approach for overcoming limitations of previously elaborated simplified strategies, more closely reproducing human reasoning, fully exploiting historical data and data collected during the first test campaign for fining of the internal system parameters (e.g. decision thresholds for some crisp logic rules) and for embedding the possibility for end users to incorporate their own knowledge into the system by validating the suggestions of the system or provide alternative solutions.
  - AI- based tools for event detection based on plant data (PLC, videos and acoustic signals) have been developed
  - Fuzzy-inference systems for embedding human knowledge to be tuned with data have been sketched-out

Slag door status - open/closed/unclosed due to slag crust

Human detection in EAF area

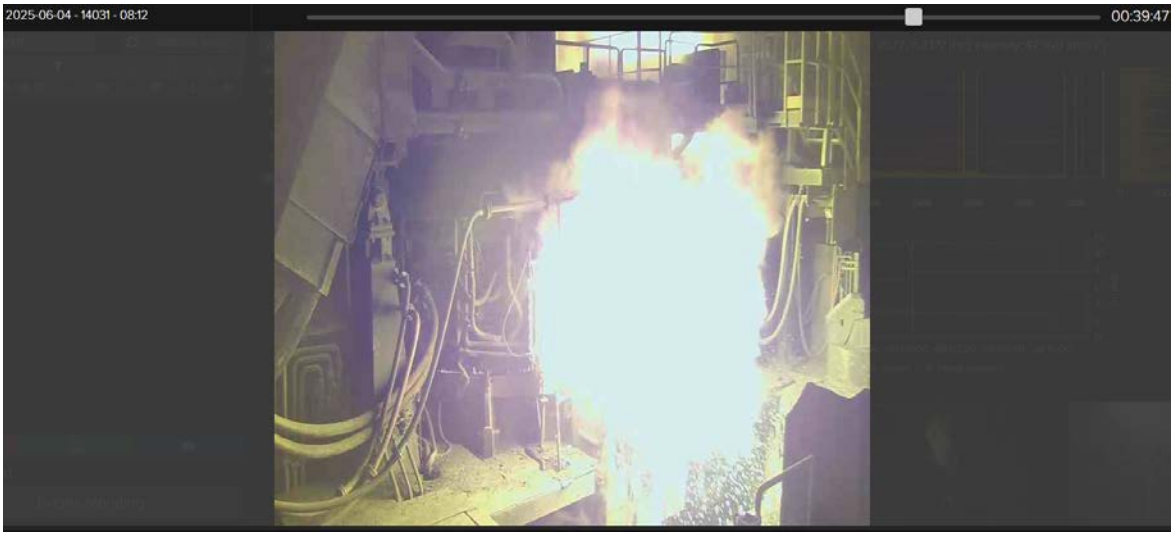


Detection of widespread fumes emission

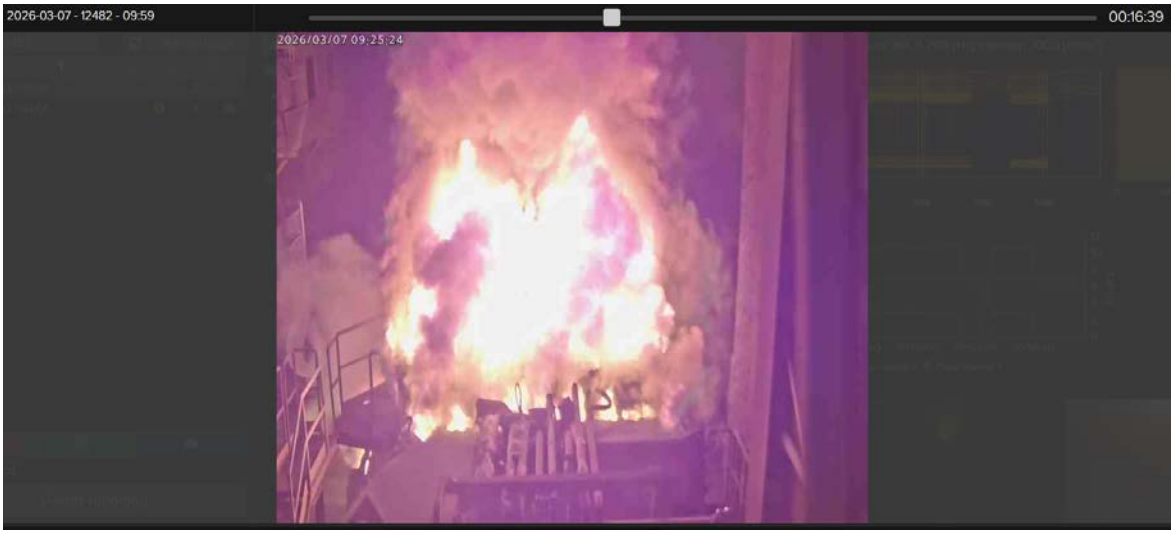
Deriving the electrode up and down speed by detecting the position of its clamp

Detection of electrode breakage

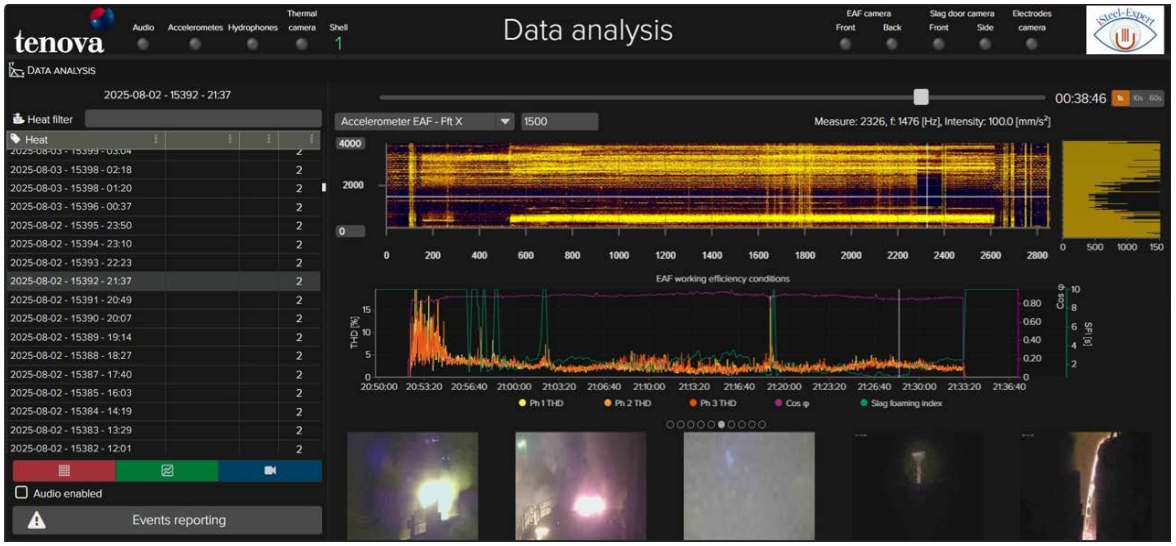
Detection of slag strong rection



Detection of strong reaction inside the furnace

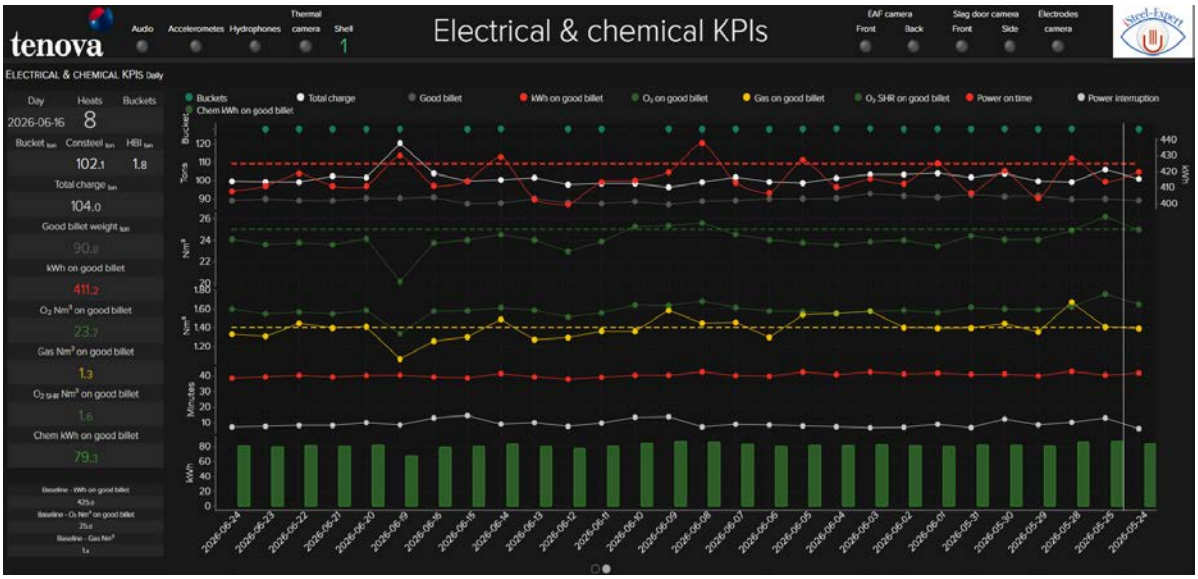


Integration of the system and dashboard creation

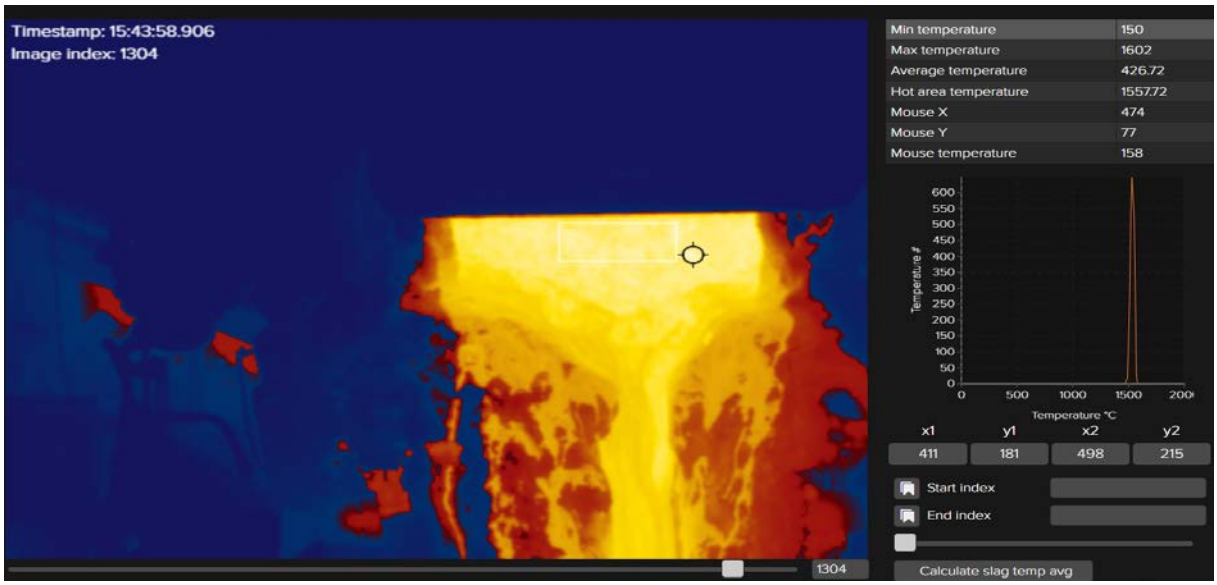


Snapshots of events detected: humans in EAF area, strong reaction, electrode Tip wear classification, widespread fumes emission

KPIs trend values



Slag temperatures map from thermal camera



Electrode tip ware detection and classification

Work Package 4 – Education and Training

Work Package 4 (WP4) focuses on education and training for EAF-based steelmaking. Its purpose is to transform process knowledge, operational procedures and expert experience into structured learning paths supported by simulation, interactive exercises and knowledge verification tools. The training approach is not intended to replace plant-specific instruction or certified operational qualification. Its role is to provide a controlled learning environment where trainees can understand the logic of the EAF heat cycle, the purpose of the main operational phases, the consequences of process decisions, and the safety principles that govern furnace work.

Three-pillar training model is the main result that have been achieved.

The following table illustrates the pillars of the developed training system and their main characteristics.

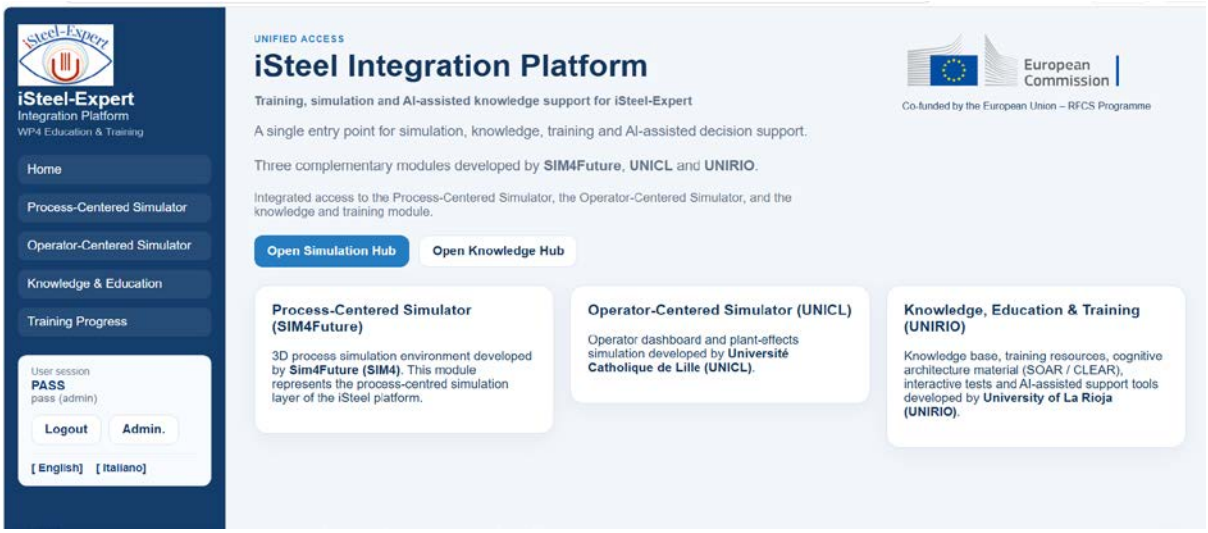
Table 2.1. Main components of the training system

Pillar	Primary contribution	Trainer use	Trainee outcome
Learning Platform - SIM4Future	Conceptual and process-centered training modules with multimedia content and quizzes.	Prepare learners, configure modules, manage users, review statistics and export course versions.	Understand EAF phases, safety principles, decisions and basic abnormal situations.
Operator-centered / immersive simulation - UNICL	Complementary 3D or VR environment for spatial, auditory and operational awareness.	Use after conceptual training; focus on decision context and debrief rather than copying technical architecture.	Experience heat-cycle progression and special cases safely in a virtual setting.
Knowledge, Education and Training Module - UNIRIO	Knowledge structuring, AI-supported consultation, tests and future cognitive support.	Prepare study guides, support learner questions, maintain test banks and connect documentation to scenarios.	Reinforce understanding and retrieve official project knowledge during study.

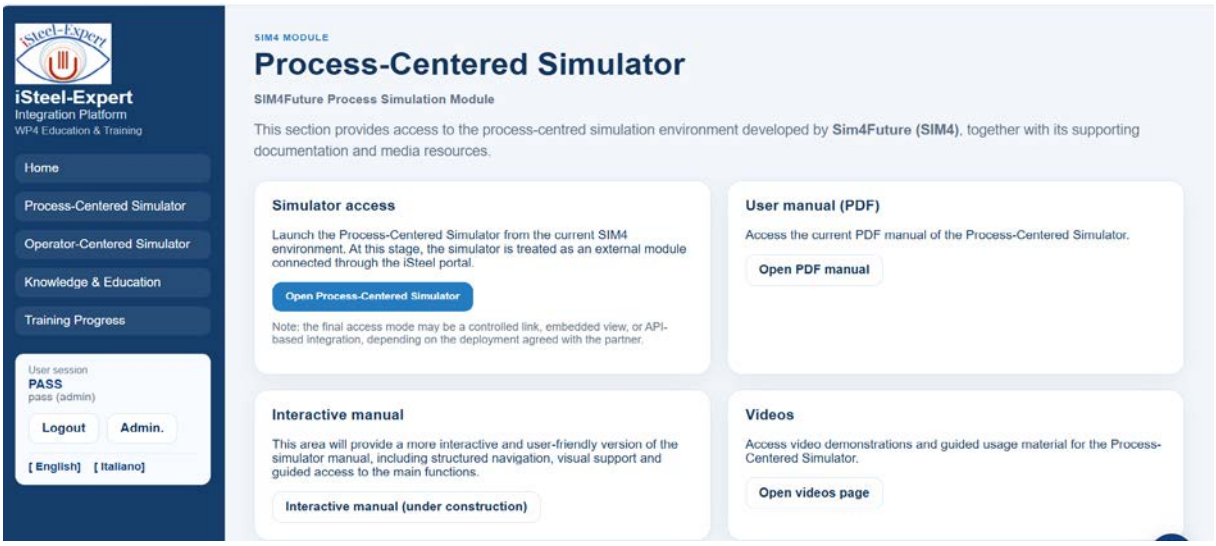
The three components should be understood as complementary parts of a single training ecosystem. Where the centralized iSteel-Expert integration platform is available, it provides a common access point from which users can reach the SIM4Future Learning Platform, the UNICL operator-centered simulation environment, and the UNIRIO Knowledge and Education resources. This integrated access layer does not change the pedagogical role of each component; rather, it simplifies navigation, helps trainees understand the relationship between the tools, and supports trainers in organizing a coherent training session.

Access to the three components is provided through the centralized iSteel-Expert integration platform, which acts as a common entry point for the Learning Platform, the VR/operator-centered simulator, and the Knowledge and Education resources.

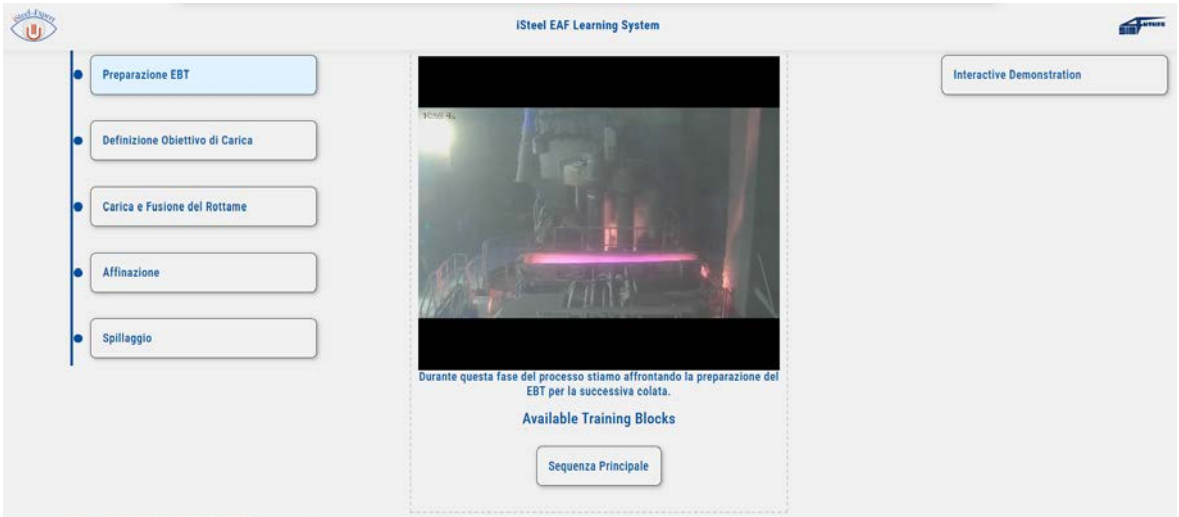
Centralized entry point to access the training components

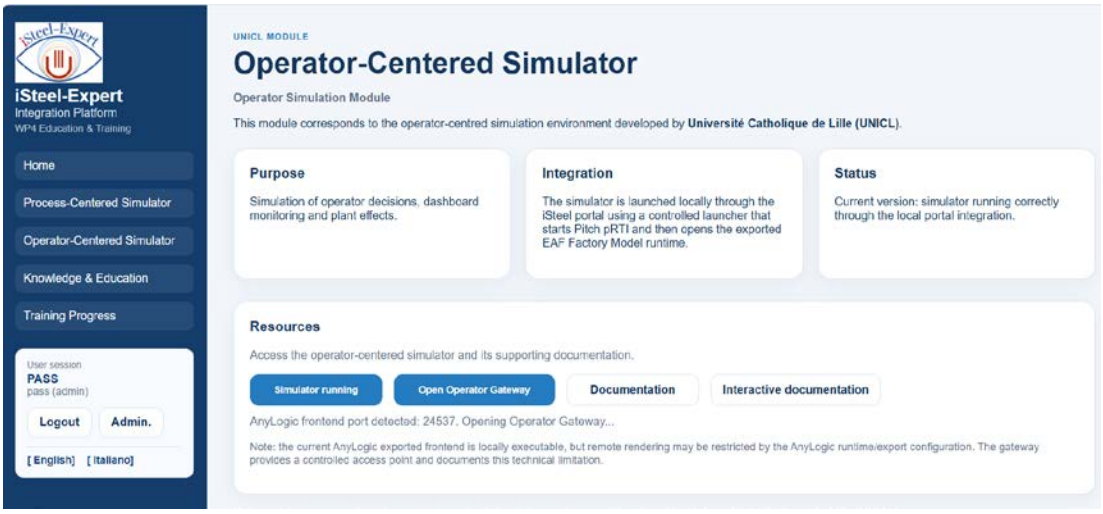


The main output is a structured set of procedures. Trainers receive guidance for planning sessions, configuring modules, managing learners, conducting briefings and debriefings, observing trainee behavior, interpreting results and selecting remediation. Trainees receive clear expectations for preparation, safe use of the simulator, completion of learning modules, quiz behavior, note taking and reflection. The result-analysis chapters explain how to use training time, testing time, scores, attempts, response time by block, score distribution and activity by day without over-interpreting the data.

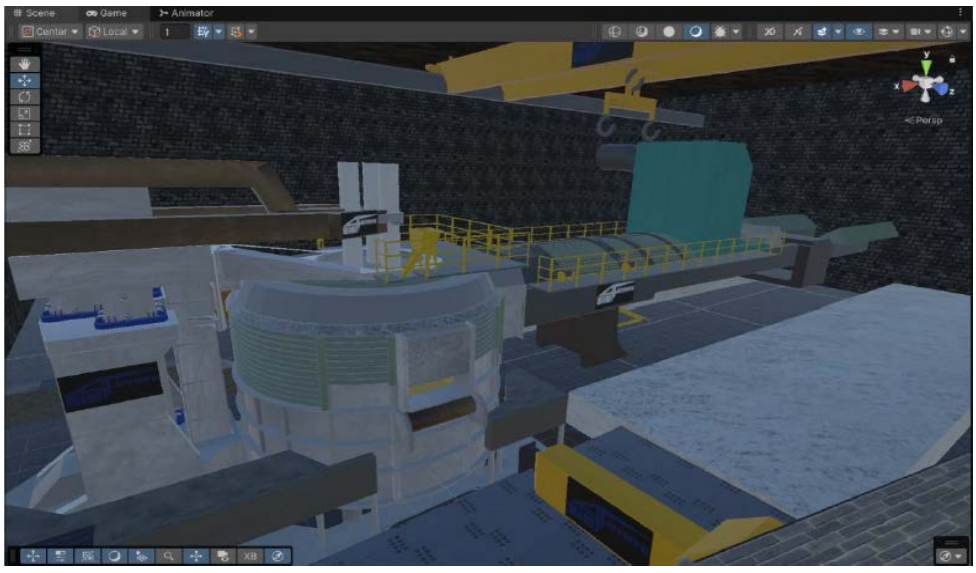

iSteel-Expert
Integration Platform
WP4 Education & Training
Home
Process-Centered Simulator
Operator-Centered Simulator
Knowledge & Education
Training Progress
User session
PASS
pass (admin)
Logout
Admin.
[English] [Italiano]
SIM4 MODULE
Process-Centered Simulator
SIM4Future Process Simulation Module
This section provides access to the process-centred simulation environment developed by Sim4Future (SIM4), together with its supporting documentation and media resources.
Simulator access
Launch the Process-Centered Simulator from the current SIM4 environment. At this stage, the simulator is treated as an external module connected through the iSteel portal.
Open Process-Centered Simulator
Note: the final access mode may be a controlled link, embedded view, or API-based integration, depending on the deployment agreed with the partner.
User manual (PDF)
Access the current PDF manual of the Process-Centered Simulator.
Open PDF manual
Interactive manual
This area will provide a more interactive and user-friendly version of the simulator manual, including structured navigation, visual support and guided access to the main functions.
Interactive manual (under construction)
Videos
Access video demonstrations and guided usage material for the Process-Centered Simulator.
Open videos page

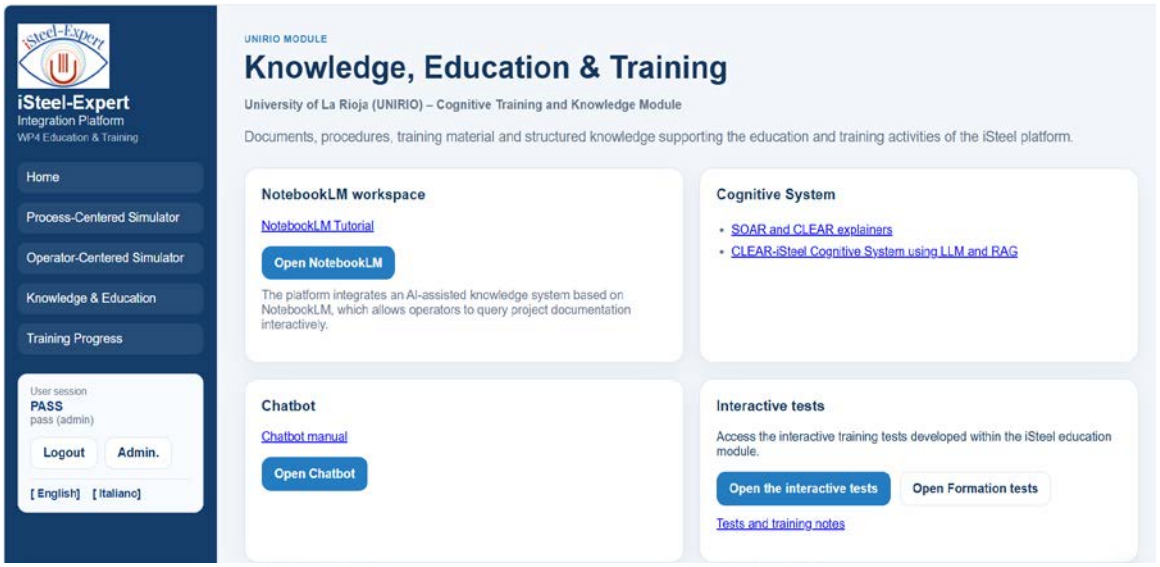

iSteel EAF Learning System
Preparazione EBT
Definizione Obiettivo di Carica
Carica e Fusione del Rottame
Affinazione
Spillaggio
Interactive Demonstration


iSteel EAF Learning System
Preparazione EBT
Definizione Obiettivo di Carica
Carica e Fusione del Rottame
Affinazione
Spillaggio
Interactive Demonstration
Durante questa fase del processo stiamo affrontando la preparazione del EBT per la successiva colata.
Available Training Blocks
Sequenza Principale

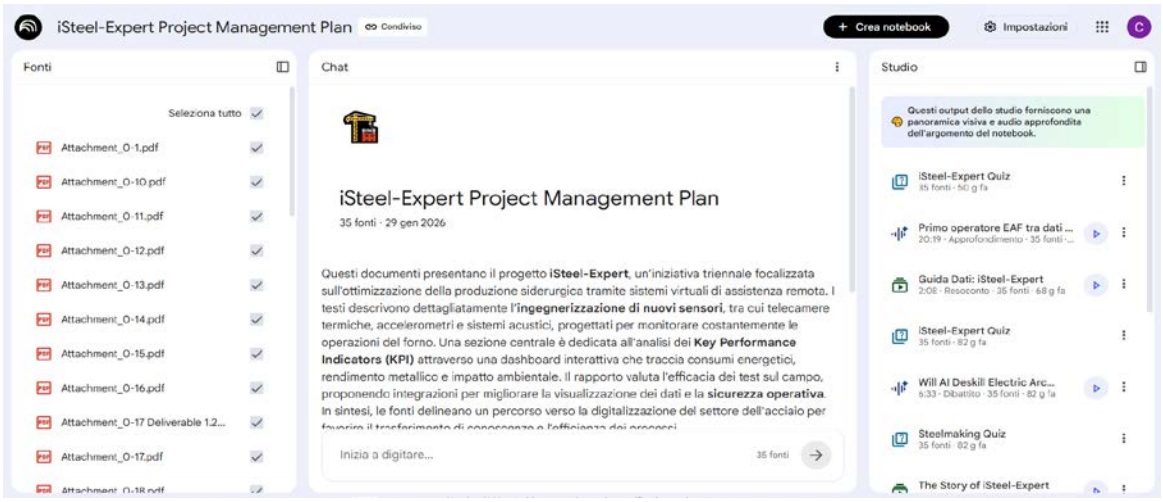

iSteel-Expert
Integration Platform
WP4 Education & Training
Home
Process-Centered Simulator
Operator-Centered Simulator
Knowledge & Education
Training Progress
User session
PASS
pass (admin)
Logout
Admin.
[English] [Italiano]
UNICL MODULE
Operator-Centered Simulator
Operator Simulation Module
This module corresponds to the operator-centred simulation environment developed by Université Catholique de Lille (UNICL).
Purpose
Simulation of operator decisions, dashboard monitoring and plant effects.
Integration
The simulator is launched locally through the iSteel portal using a controlled launcher that starts Pitch pRTI and then opens the exported EAF Factory Model runtime.
Status
Current version: simulator running correctly through the local portal integration.
Resources
Access the operator-centered simulator and its supporting documentation.
Simulator running
Open Operator Gateway
Documentation
Interactive documentation
AnyLogic frontend port detected: 24537. Opening Operator Gateway...
Note: the current AnyLogic exported frontend is locally executable, but remote rendering may be restricted by the AnyLogic runtime/export configuration. The gateway provides a controlled access point and documents this technical limitation.


Phase Name
O2 injected
C injected
Lime injected
Methane injected
N injected
Temperature
Specfic Energy
Weight to Tap
Charge Objective
Metallic Charge
Residue
Charge Rate
Constreel Velocity

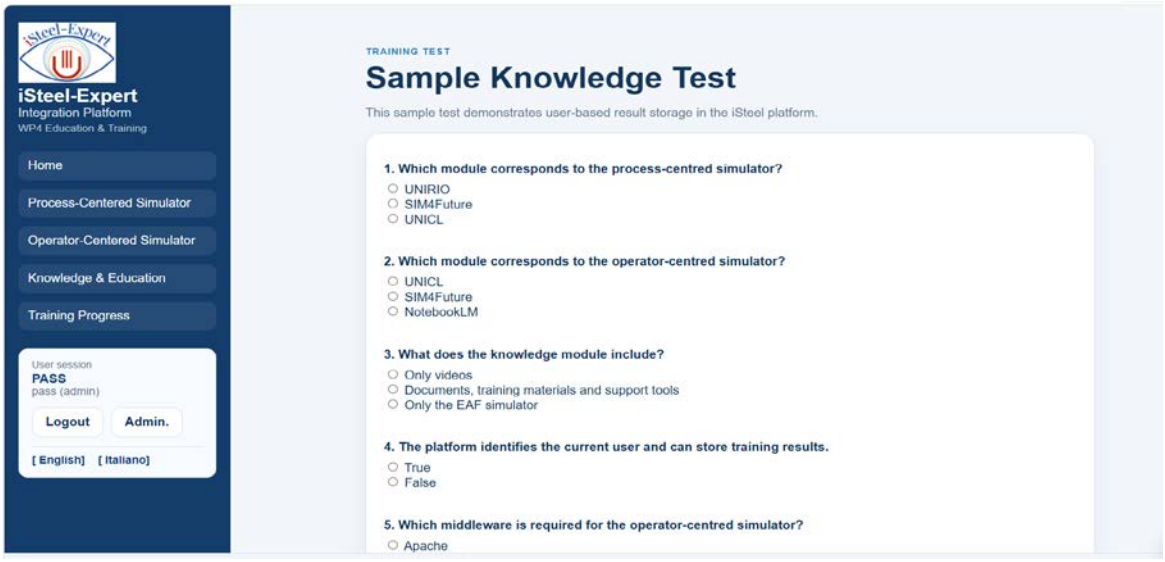




Chatbot



Interactive test



Work Package 5 – Field Tests and system assessment for exploitation and transferability analysis

The following main activities have been carried out:

- Conducting field tests of the system and collecting implementation feedback.
- Evaluating system performance against previously defined KPIs.
- Developing a thorough transferability analysis.

The final release of the iSteel-Expert System has proved to provide a set of useful tools to support the monitoring and analysis of the EAF process, with relevant industrial values that can be summarized in the following points:

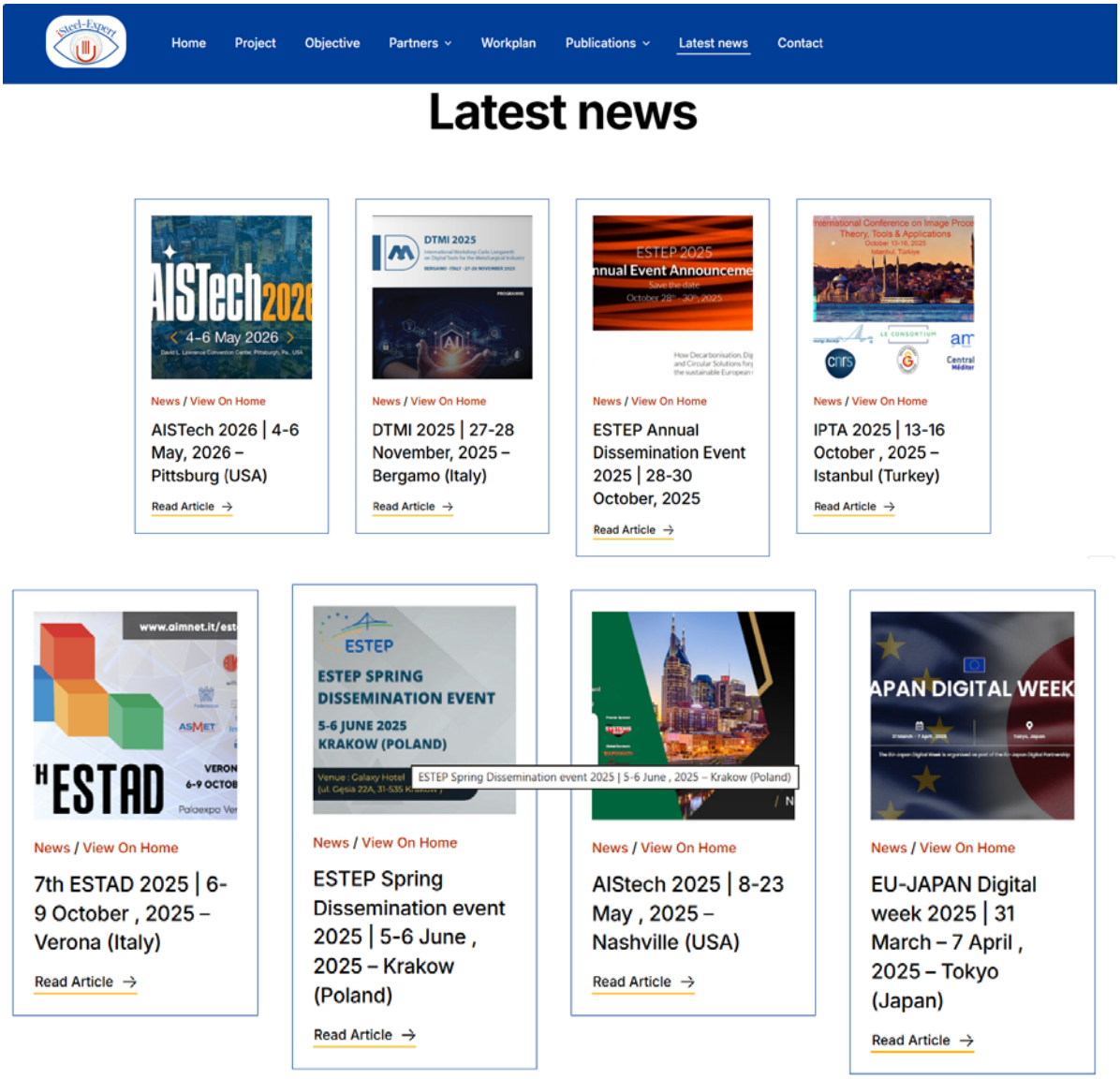
- **Post-production analysis of heats**
  The dashboard allows heats to be reviewed after production by analyzing data, signals, events, and KPIs in an integrated manner.
- **Linking KPIs to events**
  KPIs are not used merely as numerical values, but as tools to identify situations that require further investigation.
- **Troubleshooting support**
  The combination of data analysis and detected events allows the operating context of events to be reconstructed, effectively supporting technical analyses.
- **Continuous improvement**
  Visualizing daily and monthly trends makes it possible to identify process evolution and areas for improvement.
- **Know-how transfer**
  The evidence collected in the dashboard can support technical discussions, internal training, and knowledge transfer between experienced operators and new personnel.
- **Safety support**
  Safety KPIs and human presence indicators provide a quantitative interpretation of exposure in critical areas and safety-relevant events.
- **Sustainability support**
  Environmental indicators link operating performance to Scope 1 and Scope 2 impacts, contributing to a broader interpretation of overall process performance.

Work Package 6 – Exploitation, dissemination and communication

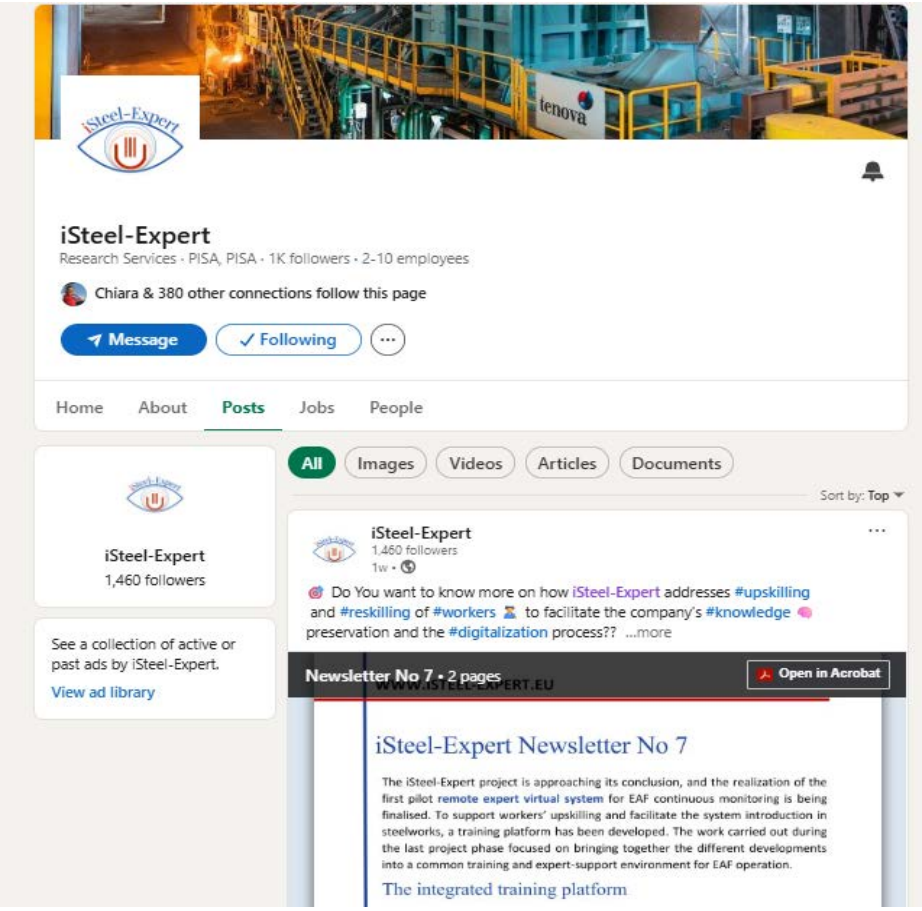
The iSteel-Expert Consortium is committed to exploiting and disseminating the project results across the European steel sector and beyond, thereby maximizing overall impact and fostering industrial interest.

Two public Deliverables are dedicated to exploitation (D6.1; D6.6). Three public Deliverables (D6.6; D6.7; D6.8) describe the dissemination and communication activities implemented by the iSteel-Expert Consortium during a period of 36 months and beyond.

Screenshot of the iSteel-Expert website



Screenshot of iSteel-Expert on Linkedin



3. Exploitation activities

The iSteel-Expert Consortium is keen to get maximum exploitation of the project results at all levels, especially considering the pilot/demonstration nature of the project, which developed a full-scale prototype of a system to improve situation awareness in the EAF area by also implementing advanced training solutions for the operators.

From the technical point of view, the project pursued a modular and integrated approach, which is inherently implementable to any electric steel works as a full system, including the need sensors based on the starting digitalization level of the plant. Therefore, the different modules, developed by the different partners under the leadership of the coordinator TENOVA, were gradually integrated as building blocks of the system.

To the aim of getting maximum benefits from the project results, the Consortium outlined an exploitation strategy that considered the different contribution of the partners in the development of the various modules and was basically organized into two stages:

· The first stage focuses mainly on the areas of highest impact of the system, analysis of market trends and patents, identification of strategic stakeholders to be involved as well as potential adopters, the compilation of detailed description of exploitable results. A first individual exploitation plan is also reported at this stage.

· The second phase addressed the implementation of the exploitation strategy itself, considering the analysis and initial versions of previously mentioned elements. That includes deciding a deployment strategy that fit better on partners' exploitation interests and market around, by defining possible joint exploitation opportunities and the role of each partner in ensuring the sustainability and wide uptake of the iSteel-Expert results especially in the post-project period.

A first version of the exploitation plan (Deliverable D6.1) was developed by M13 as per the plan defined in the DoA, where two main Key Exploitable Results (KER) were identified:

· The iSteel-Expert System: the first integrated cloud-based intelligent digital expert that enables situation awareness in the EAF area and supports preservation, transfer and continuous evolution of industry's wealth of knowledge.

· The Modular sensor suite to monitor the EAF area.

For each KER, a gap analysis was conducted, and the individual exploitation plan of the partners have been identified as an initial step, as the project was still at an early development stage, and thus, the definition of joint exploitation plans cannot be carried out yet (see Deliverables for details).

Indeed, the exploitation actions carried out within iSteel-Expert are in strong interaction with planned and undertaken the dissemination and communication actions to foster and promote future usage of the developments in the steel industry.

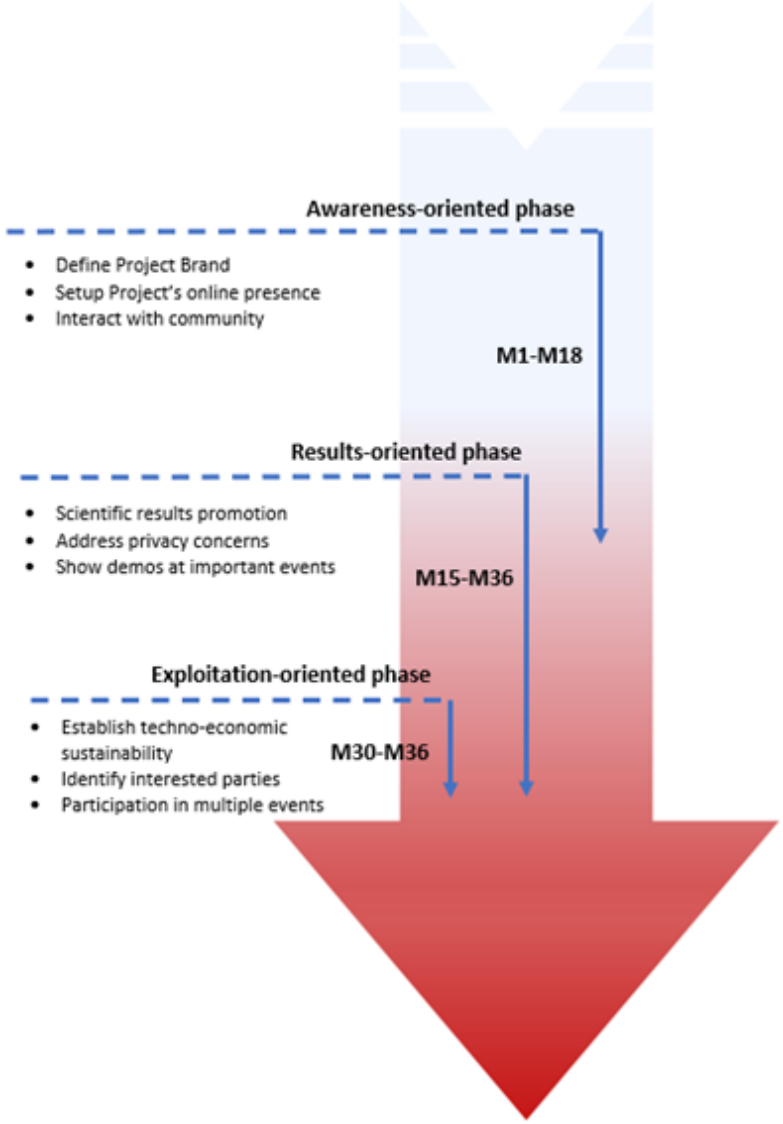
All public Deliverables are made available on the Project website (https://www.isteel-expert.eu), including the first (D6.1) and second (D6.6) versions of the exploitation plan.

4. Dissemination activities

At the beginning of the project a Communication and Dissemination plan (Deliverable D6.2 - submitted on the 27 Sep 2023) was defined, which implements a strategy that is being executed from the initial stages. The goal of such strategy was to ensure adequate dissemination and communication of the project's results to the targeted audiences by leveraging their active participation, involving potential new research, development and innovation actors for fruitful exchanges and future scale-up of the project outcomes as well as potential commercial partners interested in the exploitation of some project results in the medium-long run. Such strategy, which is schematically depicted in the figure below was articulated into 3 main phases:

- an *awareness-oriented phase*, aimed at raising public, industry and research community awareness about the project and the problems it addresses.
- A *results-oriented phase*, which aimed at promoting project intermediate and finale results to targeted stakeholders in the steel industry and research community.
- An *exploitation-oriented* phase, in which specific activities will be carried out to improve awareness related to the project results, by targeting potential users of project results.

Overview of iSteel-Expert Dissemination and Communication strategy



In the Communication and Dissemination Plan (Deliverable D6.2), the main objectives for dissemination and communication activities were established, the target audiences for dissemination and communication actions were identified, some Key Performance Indicators (KPIs) were established for both Communication and Dissemination activities, to be constantly monitored throughout the project duration. This Deliverable is public via the project webpage.

In iSteel-Expert Project, dissemination was focused on the public disclosure of the project results to specific target groups with the following main Dissemination Objectives (DOs):

DO1. to raise awareness and interest of potential users on the project results;

DO2. to foster interaction with stakeholders and potential users (the ecosystem) to obtain key feedback and enhance exploitation opportunities;

DO3. to transfer knowledge of the developed solutions to the scientific community and exchange experiences which can support improvements and refining of the research activities;

DO4. to foster the acceptance of iSteel-Expert outcomes and tools in the EU steel industry;

DO5. to ensure a broad applicability of the project results also beyond the steel sector

Several conference papers were produced and presented. Above the others:

- Innovative Extended Reality and Simulation-based Training for Control Room Operators in Industry, *European Modeling and Simulation Symposium, EMSS*, within *International Multidisciplinary Modeling & Simulation Multiconference (I3M 2024),* Tenerife, (Spain) September 18-20, 2024. https://doi.org/10.46354/i3m.2024.emss.038
- Towards Federating IoT and Simulation Systems: an HLA-Based Approach, Annual Modeling and Simulation Conference (ANNSIM 2025), Madrid (Spain), May 26-29, 2025
- Critical applications of AI in the metals and steel industry, EU-Japan Digital Week, Workshop "Critical Applications of AI in Industry, Healthcare and Other Sectors" 31.03-07.04.2025 Tokyo (Japan).
- Intelligent Steel Expert: Let the Sensors Think, So You Can Thrive!, Annual Iron and Steel technology Conference and Exposition AISTech 2025, Nashville (TN, USA) May 5-8, 2025.
- Eyes on Steel: AI-Powered Monitoring for Enhanced EAF Safety and Efficiency, ESTEP Spring Dissemination Event 2025, Krakow (Poland), June 5-6, 2025.

Further outcomes of the project were presented at:

- XXII International Multidisciplinary Modelling and Simulation Multiconference I3M 2025, Fes, (Morocco) 17-19 September 2025;
- 7th European Steel and Application Days (ESTAD 2025), Verona (Italy) 6-9 October 2025;
- 14th IEEE International Conference on Image Processing Theory, Tools and Applications IPTA2025, Istanbul (Turkey), 13-16 October 2025;
- ESTEP Annual Dissemination Event 2025, Udine (IT), 28-30 October 2025;
- DTMI 2025 - International Workshop Carlo Longaretti on Digital Tools for the Metallurgical Industry, Bergamo (IT), 27-28 November 2025;
- Annual Iron & Steel Technology Conference and Exposition (AISTech 2026), Pittsburgh (USA), 4-6 May 2026;
- 14th European Electric Arc Furnace Conference EEC 2026, Milan (IT), 11-13 May 2026.

At EEC 2026, iSteel-Expert was present with a booth and a special session.

Pictures of EEC 2026 held in Milan: iSteel-Expert booth and special session

Contributions are available on the events' website:

- Development of Intelligent Monitoring Systems for Anomaly Detection in Electric Arc Furnace Steelmaking
  https://submit.m-n.marketing/event/66/contributions/5469/

- Improving Safety in Steelmaking Operations through Advanced Computer Vision and Machine Learning within the iSteel-Expert Project
  https://submit.m-n.marketing/event/66/contributions/5500/

- Simulation Based Training for Industrial Operations: Interactive Learning for Complex Tasks
  https://submit.m-n.marketing/event/66/contributions/5470/

- A Cognitive and AI-Based Training Framework for Electric Arc Furnace Workforce Development
  https://submit.m-n.marketing/event/66/contributions/5471/

A paper, authored by researchers of SSSA and TENOVA, concerning the investigation of exploitation of Artificial Intelligence in the context of the iSteel-Expert project has been published on the May issue Journal "La Metallurgia Italiana" published by Associazione Italiana di Metallurgia.

Dissemination activities will continue even after the end of the project.

5. Impacts

iSteel-Expert has proved to provide improvements in:

- Process efficiency, to reduce environmental impact.
- Equipment condition and maintenance, resulting from equipment monitoring to identify wear, performance degradation and maintenance needs.
- Workforce management, with a specific focus on:
  - Preserving know-how to avoid the rapid loss of expertise caused by an aging workforce.
  - Improving safety by reducing the time required for tasks performed physically within the melt shop.
  - Attracting and rapidly training new talent through innovative methods.

ENVIRONMENTAL IMPACT:

The benefits of iSteel-Expert are connected to the optimization of the EAF melting process allowing the reduction of environmental impact (decreasing CO2 emissions due to energy saving).

INDUSTRIAL AND ECONOMIC IMPACT:

The benefits of iSteel-Expert are connected to the implementation of Industry 4.0 technologies, which allow for the preservation of knowledge and the consequent repeatability of industrial processes. This can limit unplanned stops and delays, leading to improved efficiency, reduced resource and energy consumption, and decreased production costs for steelmaking facilities.

SOCIAL IMPACT:

The benefits of iSteel-Expert are connected to the modernization of the steel industry, enhancing workforce management (safety, knowledge, and expertise), providing continuous training to protect the most vulnerable people and workers, and facilitating the digital and environmental transition (green skills).

Better working conditions decrease avoidable occupational health case. Reducing occupational exposure, to emissions, noise, high temperatures, and electromagnetic fields, contributes to a better perception of the steel industry and attracts new young talent.

6. General conclusions and strategic Impacts

The project successfully achieved its core objectives by validating **a remote expert virtual system that monitors 24/7 the progress of the process, analyses the information and suggests actions to improve and/or correct steelmaking operations within an operational steelmaking environment, pushing the technology readiness level to TRL 7.**

From an industrial perspective, the final system provides a powerful framework which could in future integrate real-time support significantly enhancing process improvement and EAF performance.

In alignment with the EU Climate Law and the Circular Economy Action Plan, the project's environmental impact is highlighted by a near-double-digit percentage reduction in specific electrical energy consumption, with a correspondingly significant mitigation of Scope 1 and Scope 2 CO_2 emissions.

Furthermore, by integrating safety KPIs and reducing physical human presence in critical melt-shop zones, the project directly fosters safer working conditions.

The European steel sector stands to benefit from the high transferability of these results, driving both digital transformation and competitive sustainability across the continent.