



# Final report on Key Performance Indicators

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| Project Acronym | Symbio-Steel                                                                                                                                                                                           |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Project Title   | Fostering Industrial Symbiosis solutions for the steel sector by results monitoring and dissemination from national and EU funded projects coupled to definition of cross-sectorial synergy scenarios. |
| Number          | 101156509                                                                                                                                                                                              |
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# Abbreviations and acronyms

|                        |                                  |
|------------------------|----------------------------------|
| <b>BOF:</b>            | Basic oxygen furnace             |
| <b>CE:</b>             | Circular economy                 |
| <b>CO<sub>2</sub>:</b> | Carbon dioxide                   |
| <b>D:</b>              | Deliverable                      |
| <b>EAF:</b>            | Electric arc furnace             |
| <b>EU:</b>             | European Union                   |
| <b>GHG:</b>            | Greenhouse gas                   |
| <b>IS:</b>             | Industrial symbiosis             |
| <b>KPIs:</b>           | Key performance indicators       |
| <b>M:</b>              | Month                            |
| <b>PU:</b>             | Public                           |
| <b>RFCS:</b>           | Research Fund for Coal and Steel |
| <b>T:</b>              | Task                             |
| <b>WP:</b>             | Work package                     |

# Summary

This deliverable, D3.3, entitled “Report on Key Performance Indicators,” presents the additional monitoring and assessment results for KPIs performed under WP3 “Impact Assessment” of the Symbio-Steel project. The D3.3 documents the identification and evaluation of quantitative KPIs derived from selected EU- and nationally funded projects relevant to IS, CE, decarbonization of iron and steelmaking, and resource efficiency. The results demonstrate that significant progress has been achieved, e.g., in fossil carbon replacement, slag recycling, etc. However, regulatory constraints and process integration barriers may remain limiting factors for full-scale deployment.



# Introduction

The European steel industry is undergoing a transition towards climate neutrality, resource efficiency, and circular production. In this context, IS is a key strategy for the exchange and valorisation of materials, energy streams, and by-products across industrial sectors. WP3 of Symbio-Steel focuses on evaluating impact by defining and monitoring KPIs. These KPIs may serve several purposes, for instance, quantifying environmental and technical improvements, showcasing across different European and national projects, identifying scalable solutions, and supporting a cross-sectoral synergy scenario. This deliverable, D3.3, showcases additional projects and the KPIs assessment.

# An update of the projects and the defined KPIs

The screening and selection methodology applied in this D3.3 remained consistent with the approach adopted in the previous assessment carried out in the previous version of the deliverable. The inclusion criteria comprised the following conditions: (i) clear relevance to at least one of the defined KPIs; (ii) demonstrated or intended application in steelmaking or closely linked cross-sector value chains; (iii) projects completed within 15 years from the project end date.

In total, eight new projects (see Appendix I) were identified and evaluated against these criteria. Following detailed technical and relevance screening, it was possible to demonstrate quantitative KPI values for three additional projects.

The project entitled “Gradual integration of REnewable non-fossil Energy sources and modular HEATIng technologies in EAF progressive CO<sub>2</sub> decrease”<sup>[1]</sup> GreenHeatEAF, with a project duration 01.01.2023-31.12.2026 under Horizon Europe funding programme. The project aims to reduce CO<sub>2</sub> emissions and dependence on fossil energy and carbon source markets by demonstrating integration of non-fossil fuels and renewable carbon sources into the EAF route and improving heat recovery solutions from off-gases and slag. Its listed objectives include integrating non-fossil gas flows into EAF processes, developing modular regenerative/alternative heating technologies to improve off-gas heat recovery and valorize slag latent heat, and demonstrating the exploitation of alternative carbon sources for non-fossil energy intake in EAF. In Table 1, KPI (Replacement rate of fossil carbon materials) quantifies the rate of fossil carbon substitution in the EAF process. It measures the percentage of fossil carbon



replaced by renewable carbon carriers (e.g., biochar) under controlled industrial trials.

**Table 1.** Gradual integration of REnewable non-fossil ENergy sources and modular HEATing technologies in EAF for progressive CO<sub>2</sub> decrease

| Project title                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                           |
|---------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Gradual integration of REnewable non-fossil ENergy sources and modular HEATing technologies in EAF for progressive CO <sub>2</sub> decrease |                                                                                                                                                                                                                                                                                                                                                           |
| Project abbreviation                                                                                                                        | GreenHeatEAF                                                                                                                                                                                                                                                                                                                                              |
| Duration                                                                                                                                    | 01.01.2023-31.12.2026                                                                                                                                                                                                                                                                                                                                     |
| Funding programme                                                                                                                           | Horizon Europe                                                                                                                                                                                                                                                                                                                                            |
| KPI No.                                                                                                                                     | VIII                                                                                                                                                                                                                                                                                                                                                      |
| KPI Name                                                                                                                                    | Replacement rate of fossil carbon materials                                                                                                                                                                                                                                                                                                               |
| Method to obtain                                                                                                                            | Reported                                                                                                                                                                                                                                                                                                                                                  |
| Unit                                                                                                                                        | %                                                                                                                                                                                                                                                                                                                                                         |
| KPI value                                                                                                                                   | 100                                                                                                                                                                                                                                                                                                                                                       |
| Baseline value unit                                                                                                                         | kg                                                                                                                                                                                                                                                                                                                                                        |
| Baseline value                                                                                                                              | 196-203                                                                                                                                                                                                                                                                                                                                                   |
| Reference value unit                                                                                                                        | kg                                                                                                                                                                                                                                                                                                                                                        |
| Reference value                                                                                                                             | 227                                                                                                                                                                                                                                                                                                                                                       |
| Remarks                                                                                                                                     | 100% replacement of the 5 <sup>th</sup> -hole carbon stream during the biochar trial context (biochar used instead of anthracite at the 5 <sup>th</sup> hole). Also, reported: <15% (share of total fossil carbon corresponding to the partial substitution case), and ~5-13% (fossil carbon substitution magnitude in the sensitivity analysis context). |

The project entitled “Towards a zero CO<sub>2</sub> sintering”<sup>[2]</sup> TACOS, with a project duration of 01.06.2019-31.12.2022, under the RFCS funding programme. The objective of TACOS was to evaluate alternative heat solutions in iron ore sintering to significantly reduce CO<sub>2</sub> emissions, while maintaining process productivity and sinter quality. A wide range of biogenic and waste-derived carbon carriers were tested, e.g., residues from wood gasification, char from pyrolysis of agricultural waste, torrefied biomass, hydrothermally treated biomass, coffee production residues, and pyrolyzed eucalyptus flakes. Table 2 shows the feasibility of partial substitution of fossil fuels in iron ore sintering, with up to 60% replacement under optimized conditions.

**Table 2.** Towards a zero CO<sub>2</sub> sintering

| Project title        | Towards a zero CO <sub>2</sub> sintering                                |
|----------------------|-------------------------------------------------------------------------|
| Project abbreviation | TACOS                                                                   |
| Duration             | 01.06.2019-31.12.2022                                                   |
| Funding programme    | RFCS                                                                    |
| KPI No.              | VIII                                                                    |
| KPI Name             | Replacement rate of fossil carbon materials                             |
| Method to obtain     | Reported                                                                |
| Unit                 | %                                                                       |
| KPI value            | Up to 60                                                                |
| Baseline value unit  | %                                                                       |
| Baseline value       | 0                                                                       |
| Reference value unit | %                                                                       |
| Reference value      | 0                                                                       |
| Remarks              | Pyrolyzed eucalyptus flakes were used in iron ore sintering pot trials. |

TACOS successfully validated technological pathways towards zero-CO<sub>2</sub> sintering. The project showed that decarbonization is technically feasible through alternative solid fuels, process gas valorisation, and integration of external combustion chambers.

The project entitled “Reuse of slags from integrated steelmaking”<sup>[3]</sup> Slagreus, with a duration 01.06.2019-30.11.2022, funded by the RFCS, focuses on the sustainable reuse of slags from integrated steelmaking, specifically BOF slag. The project aimed to recycle the Fe-enriched BOF slag fraction internally as a substitute for iron ore fines in sinter plants and utilize the Ca- and P-enriched fraction externally as cement additives or fertilizers. A new process chain was developed to enhance the reuse of BOF slag, emphasizing Fe-enrichment while reducing P content. This involved liquid Fe enrichment via slag recirculation and solid Fe enrichment via microwave-assisted comminution, selective grinding, and dry magnetic separation. The Ca-rich fractions retain hydraulic properties, making them suitable for external applications such as raw meal substitutes in clinker production, alternative reactive cement constituents, and lime fertilizers. The project contributes to KPI V (Slag recycling rate), with reported values reaching up to 25%.

**Table 3.** Reuse of slags from integrated steelmaking

| Project title        | Reuse of slags from integrated steelmaking                                                                      |
|----------------------|-----------------------------------------------------------------------------------------------------------------|
| Project abbreviation | Slagreus                                                                                                        |
| Duration             | 01.06.2019-30.11.2022                                                                                           |
| Funding programme    | RFCS                                                                                                            |
| KPI No.              | V                                                                                                               |
| KPI Name             | Slag recycling rate                                                                                             |
| Method to obtain     | Reported                                                                                                        |
| Unit                 | %                                                                                                               |
| KPI value            | Up to 25                                                                                                        |
| Baseline value unit  | %                                                                                                               |
| Baseline value       | 0                                                                                                               |
| Reference value unit | %                                                                                                               |
| Reference value      | Up to 25                                                                                                        |
| Remarks              | The limiting factor was the Cr content, which restricted substitution by a factor of 5 in certain applications. |

The project assessed the environmental and economic benefits of these reuse concepts. While the materials showed potential for substitution in clinker production, their use as fertilizers or reactive cement constituents was limited by low reactivity and by high concentrations of trace elements, such as Cr and V, that exceed EU regulatory limits.

# Conclusions

This D3.3 extends results through additional project screening and KPI definitions. The combined findings of D3.2 and D3.3 confirm that IS solutions in the steel sector are technologically viable and increasingly scalable. Fossil carbon substitution and material circularity are already demonstrable at high substitution rates in selected process streams. However, achieving full systemic transformation requires coordinated regulatory alignment, market incentives, and cross-sector integration frameworks. The KPI framework developed under WP3 provides a structured, harmonised, and transferable methodology for assessing IS performance in the steel sector. It creates a quantitative basis for future scenarios and supports evidence-based decision-making for industrial stakeholders and policy frameworks.

Eventually, IS in the steel sector is technically viable and environmentally effective, but its full implementation requires coordinated regulatory alignment, market incentives, and deeper cross-sector incorporation.



# References

- [1] Gradual integration of REnewable non-fossil ENergy sources and modular HEATing technologies in EAF for progressive CO<sub>2</sub> decrease. <https://cordis.europa.eu/project/id/101092328/reporting> (accessed March 17, 2026).
- [2] TACOS: Towards a zero CO<sub>2</sub> sintering. <https://www.estep.eu/event-materials/seccarb4steel-estep-workshop> (accessed March 17, 2026).
- [3] S. Wölfelschneider, R. Pietruck, D. Adolphy, H. Schmid, M. Häuselmann, M. Omran, L. Gronen, A. Morillon, Reuse of slags from integrated steelmaking. Periodic Technical Report, 2023.



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# Appendix I

## List of screened projects

| No. | Project Title                                                                                                                                     | Acronym      | Report No.                                                                                                | Funding Program | Project Duration      |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|--------------|-----------------------------------------------------------------------------------------------------------|-----------------|-----------------------|
| 1   | <b>Gradual integration of Renewable non-fossil Energy sources and modular HEATing technologies in EAF for progressive CO<sub>2</sub> decrease</b> | GreenHeatEAF | Deliverable D2.2                                                                                          | Horizon Europe  | 01.01.2023-31.12.2026 |
| 2   | <b>Towards a zero CO<sub>2</sub> sintering</b>                                                                                                    | TACOS        | Fouarge H., TACOS: Towards a zero CO <sub>2</sub> sintering, ESTEP workshop SecCarb4Steel, November 2024. | RFCS            | 01/06/2019-31/12/2022 |
| 3   | <b>Sintering process role in the (partial) transition to the Direct Reduction Route</b>                                                           | TranSinter   | Not available                                                                                             | RFCS            | 01/07/2023-31/12/2026 |
| 4   | <b>Acid dew point and corrosion sensors for dynamic waste heat recovery from steel mill flue gases</b>                                            | SafeDewPoint | SafeDewPoint summary of the results 2019-2020                                                             | RFCS            | 01/07/2019-31/12/2022 |
| 5   | <b>Reuse of slags from integrated steelmaking</b>                                                                                                 | Slagreus     | Periodic report: 2nd                                                                                      | RFCS            | 01/06/2019-30/11/2022 |
| 6   | <b>Eco-friendly steelmaking slag solidification with energy recovery to produce a high quality slag product for a sustainable recycling</b>       | ECOSLAG      | Not available                                                                                             | RFCS            | 01/06/2018-30/11/2021 |
| 7   | <b>Boosting new Approaches for flexibility Management By</b>                                                                                      | BAMBOO       | D8.8: Report on replication                                                                               | Horizon Europe  | 01/09/2018-28/02/2023 |

|   | Optimizing process Off-gas and waste use                                                                                                   |            | potential in the steel sector |                |                       |
|---|--------------------------------------------------------------------------------------------------------------------------------------------|------------|-------------------------------|----------------|-----------------------|
| 8 | <b>A rEVOLUTIONary approach for maximising process water REuse and REsource REcovery through a smart, circular and integrated solution</b> | R3VOLUTION | Not available                 | Horizon Europe | 01/01/2024-31/12/2027 |