AID4GREENEST

FINAL NEWSLETTER

AI-powered characterisation and modelling for green steel technology.

EDITION 6 | NOVEMBER 2026



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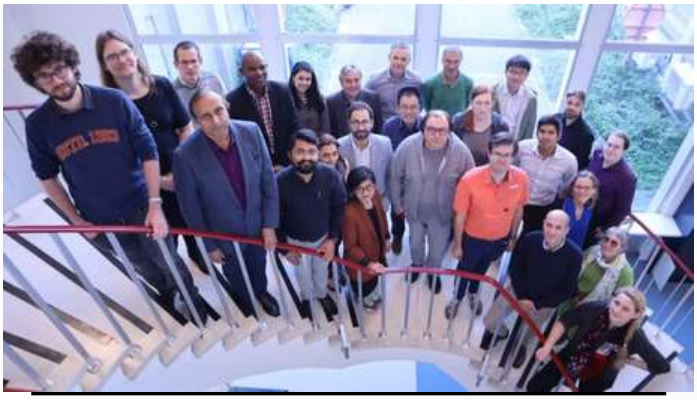
Welcome to the final AID4GREENEST project newsletter!

After three exciting and productive years, AID4GREENEST has successfully reached the end of its journey! What started in September, 2023, as an ambitious idea has grown into a successful European collaboration, bringing together researchers, engineers and industrial experts working towards a common goal.



2023

This is, making the European steel industry more sustainable through innovative AI-powered tools. Over these three years, we have achieved significant scientific and technological progress, developed innovative solutions and demonstrated their potential to address real industrial challenges.



2024

It is the wonderful team we have built, the strong collaborations we have established, and the experiences we have shared. As Project Coordinator, I would like to sincerely thank all our partners for their dedication, enthusiasm and excellent team spirit. It has been a real pleasure and privilege to work with such an outstanding team!



2025

Although AID4GREENEST has come to an end, new journeys lie ahead, promising even more exciting challenges, opportunities and achievements. Thank you all for being part of this remarkable journey, and looking forward to our next adventures together!



2026

Dr. Ilchat Sabirov

AID4GREENEST Project Coordinator
IMDEA Materials Institute

AID4GREENEST

IN NUMBERS

9
Work packages complete

38
Deliverables submitted

8
Milestones met

10+
Publications

1.500+
Social media followers

30+
Scientific conferences attended

6
CHADA MODA templates developed

1
Microstructure data platform developed

AID4GREENEST Concludes Final Consortium Meeting and Completes European Commission Review

AID4GREENEST reached a major milestone with the successful completion of its final Consortium Meeting and European Commission Review last month, marking the culmination of several years of collaborative research and innovation in support of the green and digital transformation of European industry.

On October 13, project partners gathered online for the project's Final Consortium Meeting to review the progress achieved across all work packages and prepare for the project's final evaluation. Representatives from all partners: ePotentia, EurA AG, Fraunhofer IWM, IMDEA Materials, Łukasiewicz GIT, OCAS NV, Reinosa Forgings & Castings, the Spanish Association for Standardisation (UNE), the University of Liège and the University of Oulu discussed the main activities carried out throughout the project, highlighting key scientific and technical achievements, completed deliverables, and the impact of the project's results.



Project members attended the final European Commission Review in person and online.

The meeting provided an opportunity to reflect on the advances made in developing and applying artificial intelligence-driven solutions for more sustainable and efficient industrial processes. Partners also discussed lessons learned, future exploitation opportunities, and the project's broader contribution to strengthening the competitiveness and sustainability of European manufacturing.

Building on this preparation, the consortium successfully participated in its European Commission Review on October 27, 2026. During the review, partners presented the project's achievements, demonstrated the progress made towards its objectives, and highlighted the value of the developed technologies and methodologies for supporting the twin green and digital transition.

The successful completion of both the Final Consortium Meeting and the European Commission Review represents a significant achievement for the entire consortium. It reflects the commitment, expertise, and close collaboration of all project partners throughout the project's lifetime.

Throughout AID4GREENEST, the project's consortium remained committed to maximising the impact of its results and ensuring that the knowledge, tools, and innovations developed during the project will continue to support a more sustainable and resilient industrial future in Europe. You can find more details on the advances and achievements made throughout AID4GREENEST in the Partner Contributions section of this newsletter, pages 10-27.

New Framework Could Cut Creep Testing Time by More Than 75%

- Researchers from the University of Liège, Fraunhofer IWM and IMDEA Materials have developed a modelling framework that may dramatically accelerate the characterisation of creep behaviour in high-temperature materials

The European research team behind AID4GREENEST has developed a mathematical framework that could significantly reduce the time required to assess how materials deform under prolonged mechanical loads and elevated temperatures.

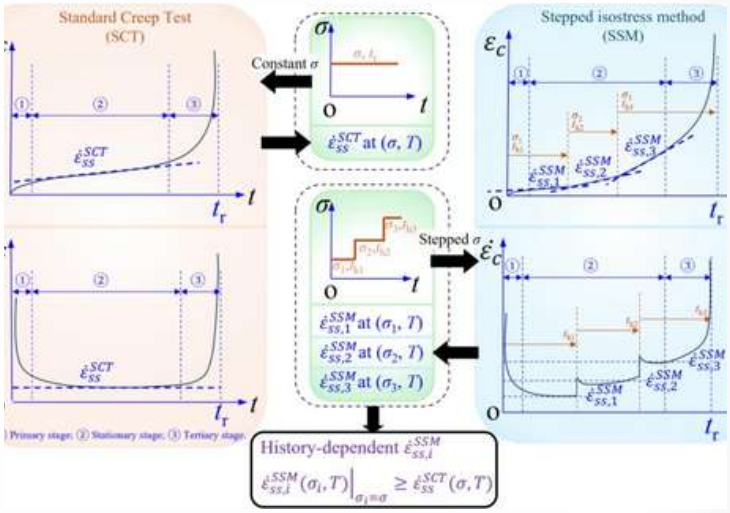
Published in the International Journal of Solids and Structures, the new approach enables researchers to reconstruct the intrinsic long-term creep behaviour of materials from accelerated testing methods, reducing total testing time by up to 76.7%.

The breakthrough addresses one of the major challenges associated with creep testing, which is used to understand how materials gradually and permanently deform when subjected to sustained stresses over long periods.

Accurate creep characterisation is essential for materials used in demanding applications such as power generation turbines, where components must operate safely under high temperatures and mechanical loads for years.

However, conventional creep testing is notoriously time-consuming. Establishing a material's long-term performance typically requires multiple samples to be tested independently under different stress levels, where experiments can last months or even years.

One of the most promising characterisation methods for accelerating this process is the Stepped Isostress Method (SSM). Instead of performing separate tests at each stress level, SSM progressively increases the stress applied to a single specimen, allowing creep behaviour under multiple loading conditions to be investigated within a single experiment. Due to their previous loading conditions, however, experiments have consistently shown that creep strain rates measured during stepped testing are systematically higher



Schematic comparison between the standard creep test (SCT) and the stepped isostress method (SSM), illustrating the history-dependent evolution of the stationary creep strain rate under stepped loading at constant temperature.

than those obtained from conventional constant-stress tests under otherwise identical conditions. This loading-history effect alters the internal state of the material, meaning SSM data cannot be directly interpreted as representing the material's intrinsic creep behaviour...***Read more***.

AID4GREENEST Research Showcased at AIMET 2026

AID4GREENEST research was featured at AIMET 2026 (Conference on AI in Metallurgy) in Mechelen, Belgium, where project partners presented innovative work on the use of generative artificial intelligence for materials science and steel development.

The presentation highlighted research by Dr. Daria M. Tomecka from ePotentia, carried out within the AID4GREENEST project, exploring how generative AI can be used to create realistic synthetic microstructures to supplement experimental materials datasets. By generating data in areas where experimental information is limited, these models can help overcome one of the major challenges in materials development: data scarcity.



Dr. Michael Sluydts from ePotentia presents at AIMET 2026.

Beyond filling gaps in existing datasets, the technology opens the door to virtual experimentation, enabling researchers to predict the microstructures and properties resulting from specific processing routes before a steel is ever manufactured...***Read more***.

AID4GREENEST Roadmap for a Sustainable Steel Industry Presented at SDEWES Conference

Mary Osorio Baena (EurA AG) presented two complementary AID4GREENEST contributions at this year's SDEWES Conference, showcasing both the project's sustainability findings and its long-term vision for the future of the European steel industry.



A key focus of the presentation was the AID4GREENEST roadmap for the European steel sector towards 2050, developed by EurA AG as part of the project. Building on existing European steel-transition strategies, the roadmap identifies critical gaps and integrates lessons learned throughout AID4GREENEST into six strategic pathways for action.

AID4GREENEST's Mary Osorio Baena at SDEWES 2026.

These pathways connect advances in materials characterisation, modelling, environmental assessment and data-driven technologies with practical priorities for future industrial implementation...***Read more***.

AID4GREENEST Researchers Showcase Advanced Materials Research at DSL 2026

Researchers from the AID4GREENEST project shared their latest findings at the International Conference on Diffusion in Solids and Liquids (DSL 2026), held in Rhodes, Greece, highlighting cutting-edge work in the characterisation and development of advanced engineering materials.

Paula Alejandra Chonillo Vera, an AID4GREENEST researcher at IMDEA Materials Institute, presented her project-related research on EBSD-based microstructural characterisation and prior austenite grain reconstruction in 30CrMoNiV5-11 bainitic heat-resistant steel.

This high-strength, low-alloy bainitic steel is widely used in critical industrial applications where reliability and durability are essential. Combining high strength, toughness, fatigue resistance and excellent performance at elevated temperatures...***Read more***.

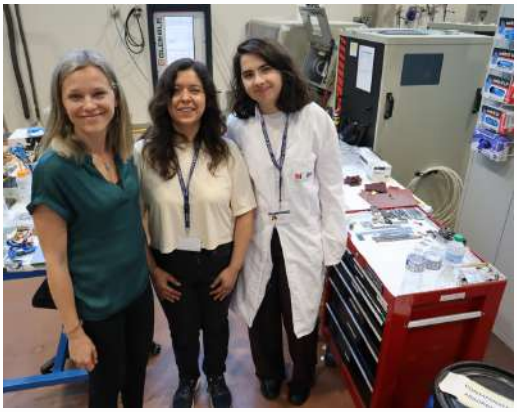


Paula Chonillo (right) with IMDEA Materials researcher Archani Ravi at DSL 2026.

Celebrating the Women Driving Innovation in AID4GREENEST

On June 23, the global engineering community marked International Women in Engineering Day (INWED) 2026, an annual celebration of the achievements of women engineers and their contributions to shaping a better future through innovation.

Organised by the Women's Engineering Society, this year's theme, "Engineering Intelligence", resonated strongly with the mission of AID4GREENEST.



IMDEA Materials researchers Dr. Christina Schenk (left), Paula Chonillo and Emma García.

Behind these advances stands a diverse and talented team of women whose expertise spans engineering, materials science, computer science, artificial intelligence, project management and ethics.

Together, these researchers and professionals represent the multidisciplinary expertise that lies at the heart of AID4GREENEST. ***Read more***.

AID4GREENEST Study Explores How Circular Strategies can Improve Sustainability and Resilience in Steel Production

A new study developed within the AID4GREENEST explores how Electric Arc Furnace (EAF) steelmaking can contribute to a more sustainable, circular and resilient steel industry.

The research, led by project partners EurA AG and Reinosa Forgings & Castings, analyses the environmental impact of steel production using a cradle-to-gate Life Cycle Assessment (LCA) methodology based on real industrial data.

The study examines how circular economy strategies and process optimisation can help reduce environmental impact while improving resource efficiency across the steel value chain.

Particular attention is given to the role of EAF steelmaking, which is increasingly recognised as an important route towards lower-emission steel production.

One of the key findings of the study is the importance of distinguishing between process-level and product-level environmental assessments.

While EAF steelmaking often performs favourably from a process perspective, the research shows that downstream manufacturing operations can become significant environmental contributors when the complete product system is considered.

The work also investigates the role of Critical Raw Materials (CRMs) in steel production. Using a simplified screening indicator, the researchers identified relevant CRM-related inputs such as nickel, vanadium and manganese, helping to make material dependencies and recovery opportunities more visible throughout the production chain.

According to EurA AG Life Cycle Assessment Consultant Mary Osorio, “studying circular approaches could play an important role in strengthening Europe’s industrial resilience by improving material efficiency and increasing the recovery of valuable secondary materials from industrial waste streams”.

The research also highlights how certain optimisation and recovery strategies could reduce environmental impacts by up to 15%, demonstrating the potential of circular solutions to support a more sustainable steel sector.



EurA AG’s Mary Osorio Baena presenting on scrap-based steelmaking at the 14th European Electric Steelmaking Conference (EEC 2026).

Industry leaders Explore AI-Powered Materials Characterisation at AID4GREENEST Workshop

Researchers, technology developers and representatives from the European steel industry gathered in Freiburg, Germany in June for the AID4GREENEST workshop "Materials Characterisation for Industrial R&D: From Fragmented Data Towards AI-powered Workflows."

Hosted by Fraunhofer IWM and co-organised by AID4GREENEST project partners ePotentia, Ghent University and Fraunhofer, along with the European Materials Modelling Council (EMMC), the two-day event showcased how digitalisation, artificial intelligence and FAIR data principles are transforming materials characterisation for greener steel production.



As advanced characterisation techniques generate ever-increasing volumes of experimental data, one of the greatest challenges facing industry is ensuring that this information is organised, accessible and reusable.

The workshop focused on practical solutions for overcoming fragmented data workflows by introducing standardised approaches that enable more efficient research, improved traceability and AI-driven analysis.

The first day explored the foundations of digital materials data management, highlighting the importance of FAIR (Findable, Accessible, Interoperable and Reusable) principles and the CHADA (Characterisation Data) framework for standardising experimental workflows.



Participants learned how structured data can support machine learning models capable of predicting long-term material behaviour, reducing testing times and accelerating alloy development for industrial applications.

A guided tour of the Fraunhofer IWM laboratories provided attendees with the opportunity to see the complete digital workflow in practice, from mechanical testing and microstructural characterisation through to the creation of AI-ready datasets. Interactive afternoon sessions enabled participants to work directly with standardised test data, apply digital documentation frameworks and explore how Large Language Models (LLMs) can be used to query materials databases using natural language.

The second day shifted the focus towards practical AI tools for microstructural analysis. Participants were introduced to ePotentia's MicrostructureDB platform, an AI-enhanced environment designed to organise, analyse and share microstructural datasets in a standardised and interoperable format. Through a series of guided demonstrations, attendees explored how artificial intelligence can assist with organising microscopy data, automatically enriching metadata and accelerating the interpretation of complex materials datasets.

Hands-on sessions highlighted the growing role of conversational AI in materials science, enabling natural-language database queries and rapid access to microstructural data. Workshops also demonstrated explainable AI techniques for analysing microscopy, SEM and EBSD data, showing how machine learning can accelerate and improve materials characterisation.

Discussions stressed that digitalisation is not just about handling more data, but about creating connected workflows that support faster decisions, stronger research-industry collaboration, and more sustainable steel technologies.







A selection of photos from the Materials Characterisation for Industrial R&D Workshop organised by AID4GREENEST project partners Fraunhofer IWM, ePotentia and Ghent University, alongside the European Materials Modelling Council (EMMC).

Partner Contributions

ePotentia: Building the AI Infrastructure for Data-Driven Microstructure Analysis

Dr. Michael Sluydts, ePotentia

As a key technology partner in AID4GREENEST, **ePotentia** developed MicrostructureDB, an open platform designed to make advanced microstructural data analysis more accessible to researchers and industry alike. The platform serves as a central hub for storing, processing and exploring microstructural datasets, while integrating the artificial intelligence tools developed throughout the project.

One of ePotentia's major achievements has been the automation of EBSD (Electron Backscatter Diffraction) analysis. Traditionally, processing EBSD scans required extensive manual work using specialist software. Through MicrostructureDB, uploaded scans can now be analysed automatically within minutes, generating orientation and deformation maps without user intervention.

Working closely with Ghent University and OCAS, ePotentia also developed AI models capable of estimating key microstructural properties, including grain-size distributions and phase fractions, directly from conventional SEM images. This approach enables rapid screening of samples and helps identify which specimens require more detailed EBSD characterisation, significantly reducing analysis time and resources.

> The project has also demonstrated the potential of generative and conversational AI for materials science.

ePotentia created an AI research assistant capable of searching, interpreting and discussing microstructure datasets, allowing researchers to interact with complex data in a more intuitive way. In parallel, generative AI models developed with project partners were able to produce realistic steel microstructures based on processing conditions, with results that experts found difficult to distinguish from real micrographs.

A lasting outcome of this work is the continued growth of MicrostructureDB itself. The platform now contains nearly 12,000 consistently processed micrographs and EBSD scans, providing researchers with access to sophisticated analysis tools through a single, user-friendly interface, without requiring programming expertise.

Looking beyond AID4GREENEST, ePotentia plans to further develop AI-assisted data exploration, enabling researchers to analyse large experimental datasets through natural interactions rather than laborious manual workflows. The company also aims to expand the platform's applicability to additional industrial datasets, new materials systems and future collaborative initiatives, helping to accelerate the adoption of AI across materials research and development.

EurA AG: Assessing Environmental Impact and Shaping the Future of Sustainable Steel

Mary Osorio, EurA AG

EurA AG has played a central role in evaluating the environmental performance of the technologies and processes developed within AID4GREENEST project. Through life cycle assessment (LCA), benchmarking activities and strategic roadmap development, EurA helped translate technical results into practical insights for the future of the European steel industry.

> *One of EurA's main contributions was the development of the environmental modelling framework used to assess the project's industrial validation case.*

This included a comprehensive life cycle assessment of the steam turbine shaft produced within AID4GREENEST, comparing different production and testing configurations to better understand their environmental implications.

The analysis demonstrated that environmental performance depends on far more than the steelmaking process alone. Factors such as heat-treatment configuration, energy consumption, electricity sourcing and transport logistics all proved to have a significant influence on the final environmental footprint. These findings provide valuable guidance for manufacturers seeking to reduce emissions and improve sustainability across their production chains. Beyond the industrial case study, EurA developed a benchmarking approach that combines both product-level and process-level perspectives. This methodology enables decision-makers to identify environmental hotspots and understand where improvement efforts can deliver the greatest impact.



Mary Osorio Baena (EurA AG) presenting the AID4GREENEST roadmap, translating project findings into six strategic pathways towards a sustainable, circular, resilient and competitive European steel industry by 2050.

By integrating project findings with existing European steel-transition strategies, EurA also helped identify opportunities and priorities related to environmental performance, circularity, resource efficiency and industrial competitiveness.

A particularly important outcome of EurA's work was the identification of material resilience and Critical Raw Materials (CRMs) as emerging priorities for the steel transition. By linking environmental performance with circularity, alloying requirements, traceability and supply-chain exposure, EurA helped establish a more comprehensive framework for evaluating future steel technologies and transition pathways. This LCA model, benchmarking framework and roadmap approach provide practical tools for supporting industrial decision-making, assessing transition readiness and accelerating the development of more sustainable, resilient and competitive manufacturing systems.

Fraunhofer IWM: Driving Digital Innovation for Greener Steel Manufacturing

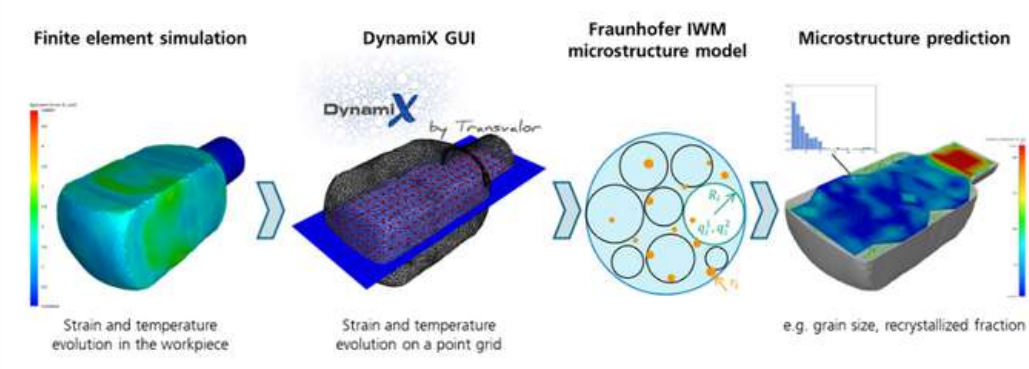
Dr. Maxim Zapara, Fraunhofer IWM

Throughout the AID4GREENEST project, **Fraunhofer IWM** has advanced the digital tools and methodologies needed to accelerate the development of more sustainable steel manufacturing processes. By combining expertise in materials modelling, thermomechanical testing, machine learning and knowledge transfer, the team helped bridge the gap between experimental research and industrial application.

One of Fraunhofer's key contributions focused on developing advanced models capable of predicting how the microstructure of steel evolves during large-scale forging operations.

Understanding these changes is critical, as the internal microstructure of a material ultimately determines its performance, durability and long-term reliability in demanding industrial environments. To support this work, Fraunhofer developed and calibrated a physics-based material model that was integrated into a finite-element simulation framework, enabling researchers and industrial partners to track microstructure evolution throughout entire forged components.

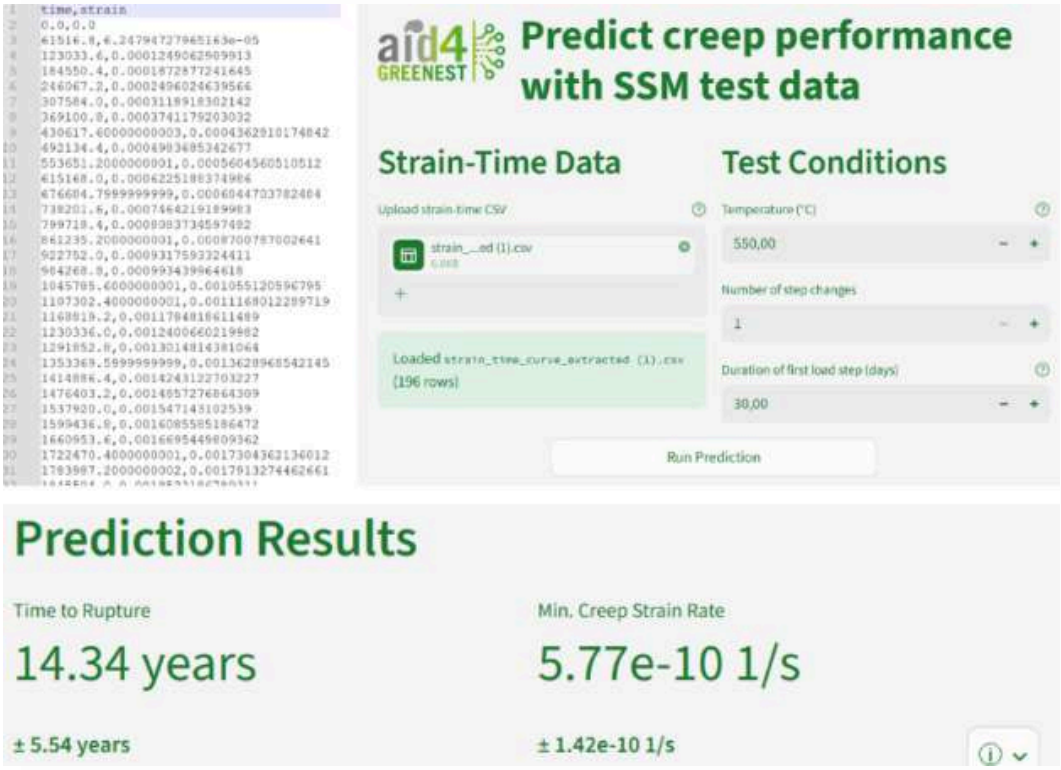
This approach represented a major step forward because it allowed complex industrial forging processes to be simulated efficiently without relying on computationally intensive fully coupled models. By linking manufacturing parameters directly to microstructure development, the framework provides valuable insights for process optimisation while reducing the need for costly and time-consuming physical trials.



Microstructure simulation framework.

Alongside its modelling activities, Fraunhofer made significant contributions to one of AID4GREENEST's core objectives: improving the assessment of creep performance in heat-resistant steels. The team supported accelerated creep-testing activities and led the development of a machine-learning-based approach to predict the long-term creep behaviour of materials. These tools offer the potential to significantly shorten evaluation times while maintaining confidence in performance predictions, helping industry accelerate the introduction of new high-temperature materials.

The project also benefited from Fraunhofer's expertise in data management and standardisation. The team coordinated efforts to harmonise modelling workflows and experimental data using methodologies such as CHADA and MODA, helping ensure that information generated across the consortium could be shared, understood and reused efficiently. These activities contributed to one of the broader goals of AID4GREENEST: creating more interoperable, data-driven approaches to materials development.



Web app predicting creep life of heat-resistant steels.

Beyond the technical work, Fraunhofer led the project's communication, dissemination and networking activities. Through stakeholder engagement, scientific dissemination and collaboration-building initiatives, the organisation helped maximise the visibility and impact of AID4GREENEST's achievements while strengthening connections between researchers, industry and the wider materials community.

The achievements made by Fraunhofer IWM throughout the AID4GREENEST project demonstrate how advanced digital tools can support more reliable manufacturing process design, reduce the need for extensive experimental testing and contribute to more resource-efficient production routes for steel components.

Looking beyond the project's conclusion, Fraunhofer plans to build upon these results by further developing the modelling, machine-learning and data-standardisation approaches established during AID4GREENEST. The organisation will also continue leveraging the networks and collaborations created through the project to promote model-based materials development, interoperable materials data and the faster transfer of research innovations into industrial practice.

Ghent University: AI-Driven Microstructural Understanding for More Sustainable Steel Development

Dr. Tuan Nguyen Minh, UGENT

Throughout AID4GREENEST, **Ghent University (UGENT)** has contributed its internationally recognised expertise in microstructural characterisation and materials science to support the development of AI-assisted tools for advanced steel design and manufacturing. By combining state-of-the-art electron microscopy techniques with decades of accumulated materials data, UGENT has played a key role in strengthening the link between physical metallurgical knowledge and data-driven approaches.

Understanding Complex Steel Microstructures

One of UGENT's principal contributions has been the generation and analysis of high-quality microstructural data using advanced scanning electron microscopy (SEM) techniques, including Secondary Electron (SE), Backscattered Electron (BSE) and Electron Backscatter Diffraction (EBSD). In parallel, the team made available a unique historical database of microstructural information collected over more than two decades of research, providing an important resource for training and validating AI and machine learning models developed within the project.

A particular focus of UGENT's work was the characterisation of complex martensitic steel microstructures in collaboration with OCAS and ePotentia. These materials present significant challenges for both conventional analysis and AI-based classification because their characteristics depend not only on their morphology and crystallographic features, but also on chemical composition and thermomechanical processing history.

The research demonstrated that reliable microstructural characterisation requires consideration of the broader composition-processing-structure relationship. Without this contextual understanding, automated approaches risk generating inaccurate classifications or predictions.

Bringing Physical Understanding to Artificial Intelligence

Beyond generating experimental data, UGENT emphasised the importance of understanding the physical mechanisms that govern microstructure evolution. Rather than focusing solely on identifying features in microscopy images, the team worked to establish meaningful relationships between processing conditions, alloy chemistry and the resulting microstructures.

This contribution highlights one of the central lessons of AID4GREENEST: while AI can significantly accelerate quantitative analysis, scientific interpretation remains essential. Machine learning tools can efficiently handle large datasets and uncover patterns, but expert knowledge is still required to understand why those patterns emerge and how they influence material performance.

The Value of Collaboration

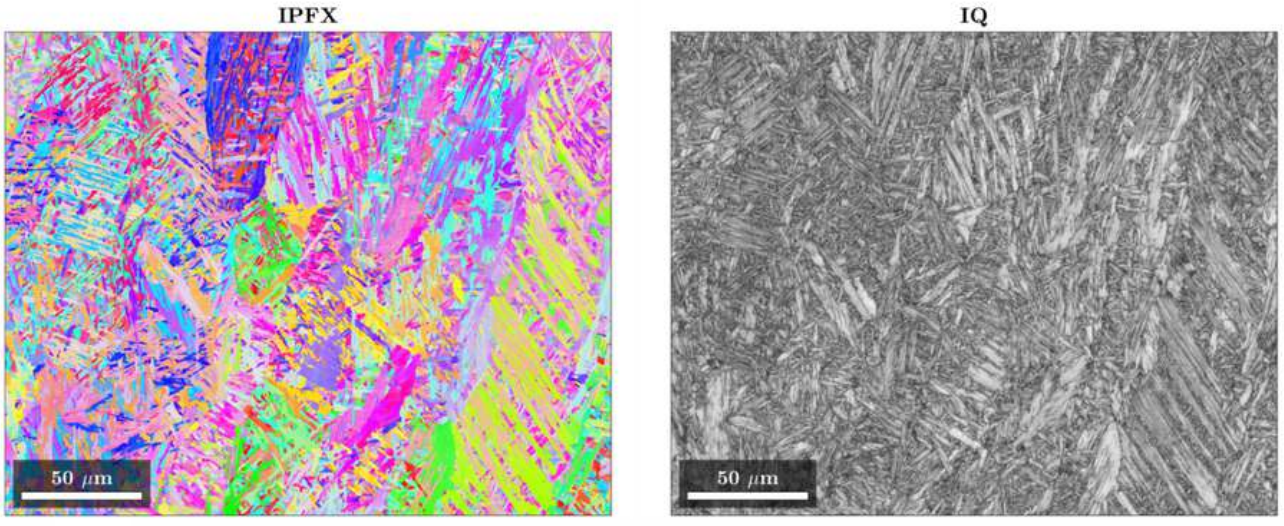
For UGENT, one of the most significant outcomes of AID4GREENEST has been the opportunity to collaborate closely with partners across the consortium. The project has demonstrated both the strengths and limitations of AI-based microstructural characterisation while reinforcing the continuing importance of scientific expertise.

In particular, UGENT highlights its collaborations with OCAS, ePotentia and the University of Liège. Although the partners approached microstructural characterisation from different perspectives, their research activities proved highly complementary. By combining experimental characterisation, metallurgical expertise and advanced data analytics, the consortium achieved a more comprehensive understanding of the relationships between composition, processing, microstructure and material properties.

Looking Beyond AID4GREENEST

Building on the knowledge generated during the project, UGENT will continue advancing microstructural research through advanced characterisation techniques and mean-field modelling approaches. The team remains committed to fostering scientific collaboration with researchers and industrial partners interested in understanding and optimising complex material systems.

The expertise, datasets and collaborative networks developed through AID4GREENEST will continue to support future research efforts aimed at accelerating materials discovery while ensuring that AI-driven approaches remain grounded in sound physical understanding.



EBSD characterisation of a martensitic steel microstructure. The inverse pole figure (IPF) map reveals the crystallographic orientation distribution within the material, while the image quality (IQ) map highlights crystallographic disorder, lattice distortions and microstructural boundaries. Together, these analyses provide valuable insight into the complexity of martensitic microstructures and support the development of physically informed AI models for microstructural characterization.

IMDEA Materials Institute: Coordinating Innovation for Sustainable Steel Assessment

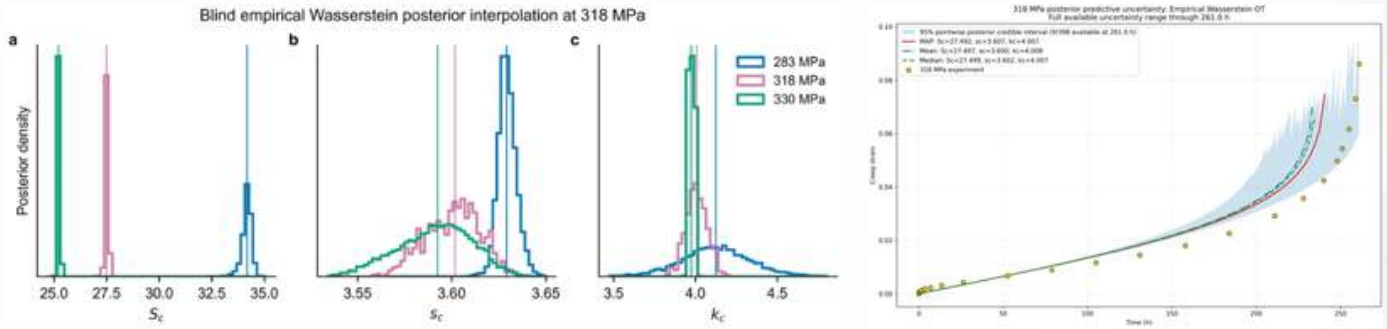
Dr. Ilchat Sabirov, Dr. Christina Schenk, Estela Izquierdo and Andrew Johnston, IMDEA Materials Institute

As coordinator of the AID4GREENEST project, IMDEA Materials Institute played a central role in guiding the scientific, technical, and administrative activities of the consortium. Over three years, IMDEA Materials ensured effective collaboration among partners and the successful delivery of the project's objectives, while contributing expertise in physical simulation of metallurgical processes, advanced materials characterisation, mechanical testing, and machine learning (ML).

A major focus of IMDEA Materials' research was the development of innovative methodologies to accelerate the assessment of creep performance in heat-resistant steels. By combining high-temperature low-cycle fatigue testing with machine-learning techniques, the team demonstrated a promising approach for estimating long-term creep behaviour using experiments that require only a fraction of the time of traditional creep tests. This work highlights the potential of data-driven methods to significantly reduce testing times while supporting reliable materials qualification.

IMDEA Materials also developed ACBICI, an open-source Bayesian calibration and inference tool that enables material model calibration and uncertainty quantification. The tool was successfully applied to improve creep-performance predictions while providing valuable information about prediction reliability. In parallel, IMDEA Materials contributed to new accelerated creep-characterisation methodologies based on stepped isostress testing and developed advanced phase-identification approaches for heat-resistant steels, supporting more accurate microstructural characterisation and interpretation of material behaviour.

One of the most important outcomes of IMDEA's work was demonstrating how accelerated testing, advanced characterisation, computational modelling, and AI can be combined to create more efficient and data-driven approaches to materials assessment. These advances have the potential to reduce experimental effort, support more informed engineering decisions, and accelerate the development and qualification of high-performance materials for industrial applications.



Creep prediction with uncertainty quantification using ACBICI. Bayesian calibration of an existing creep-damage model using experimental data at two stress levels (283 and 330 MPa), enabling prediction of creep behaviour at an intermediate stress level (318 MPa) with quantified uncertainties.

Beyond its scientific contributions, IMDEA successfully coordinated a multidisciplinary European consortium that brought together expertise in materials science, artificial intelligence, computational modelling, and industrial steel manufacturing to address real-world challenges facing the energy sector. The institute also led the project's communication and dissemination activities, ensuring a notable societal impact among industry and the wider public.

Looking ahead, IMDEA Materials Institute will continue advancing the integration of machine learning, physical simulation, and microstructural analysis to accelerate materials development and qualification. The knowledge generated and collaborations established through AID4GREENEST provide a strong foundation for future European research initiatives and industrial partnerships aimed at enabling more efficient and sustainable materials innovation.





Under IMDEA Materials' coordination, the AID4GREENEST consortium successfully brought together expertise in materials science, AI, computational modelling and industrial steel manufacturing to address key challenges and develop more sustainable steel technologies. Above, inaugural project meeting in 2023 and below, final project review meeting in 2026.

Łukasiewicz-GIT: Advancing Surface Engineering and Lifetime Prediction for Green Steel Manufacturing

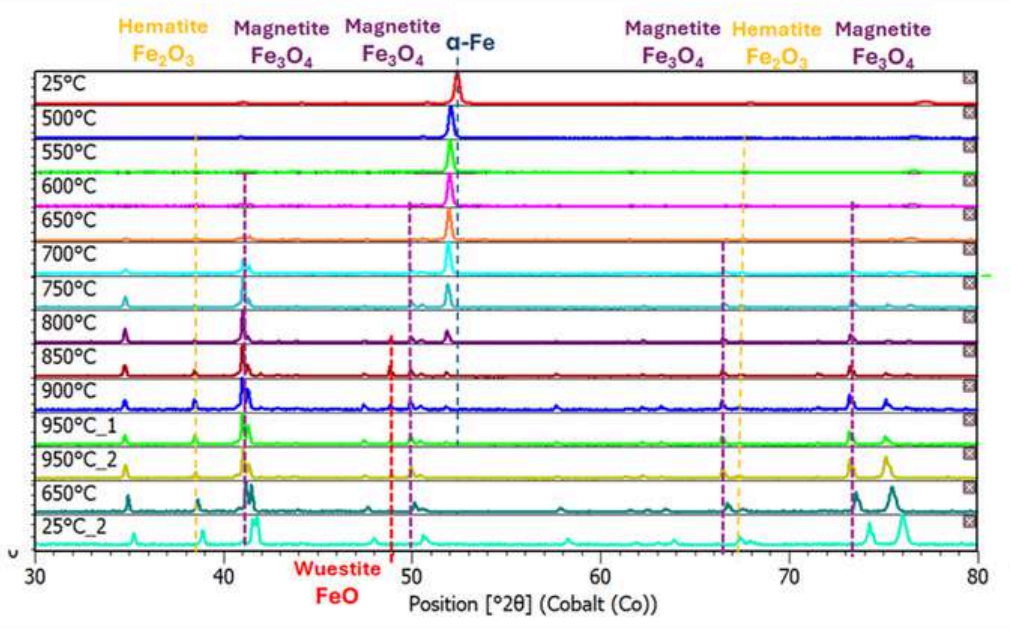
Dr. Łukasz Poloczek, Łukasiewicz – GIT

As a partner in the AID4GREENEST project through the Horizon Europe Hop-On programme, the **Łukasiewicz Research Network - Upper Silesian Institute of Technology (Łukasiewicz-GIT)** led research into two critical aspects of sustainable steel manufacturing: the influence of oxidation on processing and the role of surface condition in creep and creep-fatigue behaviour.

Leveraging its expertise in high-temperature testing, advanced materials characterisation, and numerical simulation, the institute investigated how surface phenomena affect both manufacturing processes and the long-term performance of large steel components.

Working closely with project partners, Łukasiewicz-GIT developed predictive models describing oxide-scale growth, decarburisation, heat transfer during quenching, oxide-scale damage, and material degradation under creep and creep-fatigue loading.

Among the project's key achievements was a comprehensive study of oxidation and decarburisation in 30CrMoNiV5-11 steel. Through in-situ high-temperature X-ray diffraction and advanced microstructural analysis, researchers identified the formation and evolution of oxide phases during heating and developed mathematical models capable of predicting oxide-scale thickness and decarburisation depth under different processing conditions.



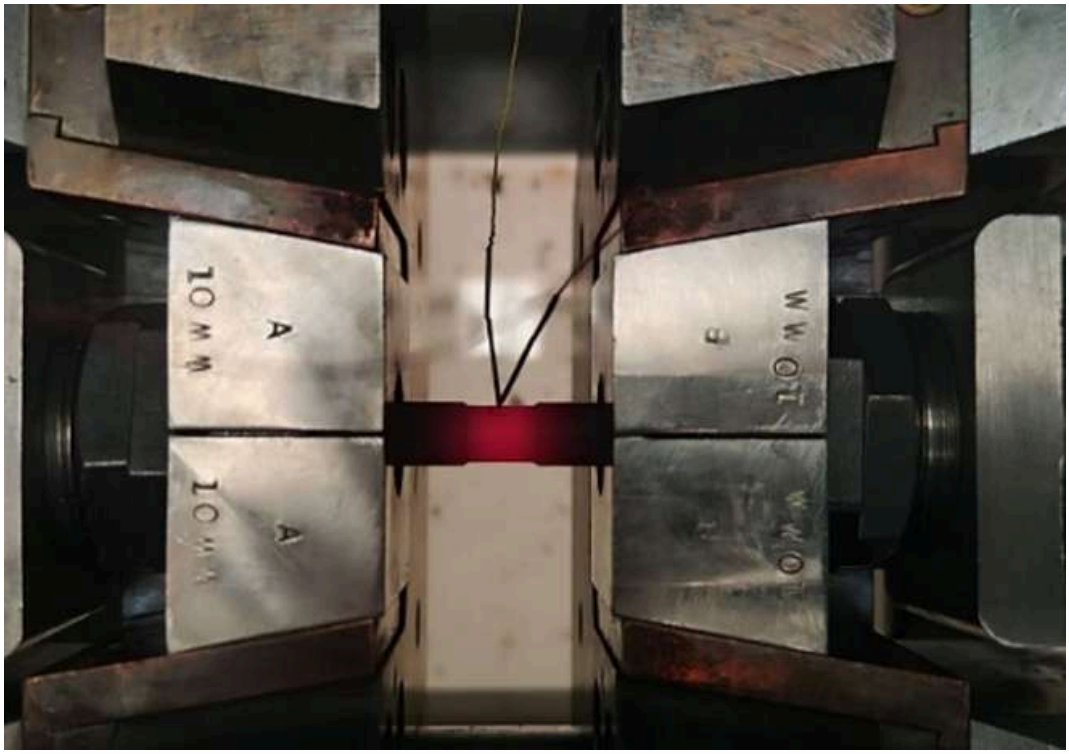
High-temperature investigations at Łukasiewicz-GIT enabled the formation and evolution of oxide phases during steel heat treatment to be characterised.

The team also demonstrated the significant impact of oxide-scale thickness on heat transfer during quenching, providing new insights that improve the accuracy of simulations used for large steel forgings. Further investigations explored oxide-scale cracking and spallation mechanisms using controlled cooling experiments and thermomechanical simulation. These findings supported the development of physically based models for predicting oxide-scale detachment.

In parallel, accelerated creep and creep-fatigue testing provided a deeper understanding of how environmental conditions and surface state influence material degradation and lifetime, leading to the development of a preliminary methodology for predicting service life under combined fatigue and creep loading.

One of Łukasiewicz-GIT's most important contributions to AID4GREENEST has been the creation of an integrated modelling framework linking surface degradation phenomena with heat-treatment performance. By combining oxidation, decarburisation and heat-transfer models, the approach enables more realistic process simulations, helping manufacturers optimise heat-treatment parameters, improve surface quality, reduce material waste and minimise manufacturing defects.

Looking beyond the project, Łukasiewicz-GIT plans to further develop its high-temperature characterisation techniques and predictive modelling capabilities, extending validation to a wider range of materials, geometries and industrial operating conditions. The institute also aims to strengthen collaboration with AID4GREENEST partners through future research initiatives, scientific publications and innovation projects supporting more efficient and sustainable steel production.



Testing performed using the Gleeble 3800 thermomechanical simulator provided insights into the creep and creep-fatigue behaviour of 30CrMoNiV5-11 steel.

OCAS NV: Bridging Artificial Intelligence and Industrial Steel Innovation

Dr. Kurt Lejaeghere, OCAS NV

As an industrial end-user and validation partner in the AID4GREENEST project, **OCAS NV** played an important role in ensuring that the project's research and technology developments remained closely aligned with the real-world needs of the steel industry. By contributing industrial expertise and practical perspectives, OCAS helped guide the development and assessment of AI-based tools designed to support advanced steel characterisation and process optimisation for more sustainable manufacturing.

AID4GREENEST provided a unique environment for collaboration between industrial and research organisations across Europe.

Within this multidisciplinary consortium, OCAS contributed its extensive experience in steel innovation and the challenges associated with the transition towards a more sustainable and competitive European steel sector. This input helped shape and evaluate emerging artificial intelligence methodologies, ensuring that the developed solutions addressed genuine industrial requirements and implementation pathways.

Throughout the project, OCAS actively participated in technical discussions, workshops, reviews and collaborative activities, helping to connect cutting-edge research with practical industrial applications. Beyond the project's technical achievements, these interactions enabled valuable exchanges of knowledge between experts in materials science, characterisation, modelling, data management and artificial intelligence. As a result, the consortium strengthened professional networks, shared best practices and expanded understanding of the opportunities offered by digital technologies within the steel industry.

One of the most significant outcomes for OCAS has been the demonstration that advanced AI methodologies can effectively complement traditional materials development workflows. The project showed how data-driven tools can accelerate materials characterisation, support process optimisation and improve access to complex metallurgical knowledge, helping researchers and engineers make more informed decisions more efficiently. Equally important was the opportunity to gain first-hand experience of emerging AI technologies and their potential role in future steel innovation activities.

Looking ahead, OCAS intends to build on the expertise gained through AID4GREENEST by further exploring the integration of artificial intelligence and data-driven methodologies into industrial research and development activities. The knowledge, methodologies and partnerships established during the project provide a strong foundation for future initiatives focused on more efficient, sustainable and knowledge-driven steel development. OCAS also remains committed to strengthening collaboration between industry and research organisations to accelerate the adoption of trustworthy AI solutions across the materials sector.

Reinosa Forgings & Castings: Bringing AID4GREENEST Innovations to an Industrial Scale

Francisco Tomas Ibañez Gutierrez, RFC

Reinosa Forgings & Castings (RFC) has been central to AID4GREENEST as the project's industrial manufacturing partner. RFC was responsible for producing and validating the full-scale demonstrator: a large steam turbine shaft manufactured through an industrial production route that included casting, forging, heat treatment and machining.

As the consortium's real-world test case, RFC provided the material samples, process data and industrial expertise needed to validate the project's modelling, characterisation and sustainability assessment activities. Detailed information on chemical composition, process parameters and material behaviour at every stage of production enabled project partners to refine and validate their forging, quenching and microstructure models, while also supporting the environmental assessment of the manufacturing route.

"A major achievement of the project was the successful manufacture and qualification of a steam turbine shaft capable of meeting demanding industrial performance requirements."

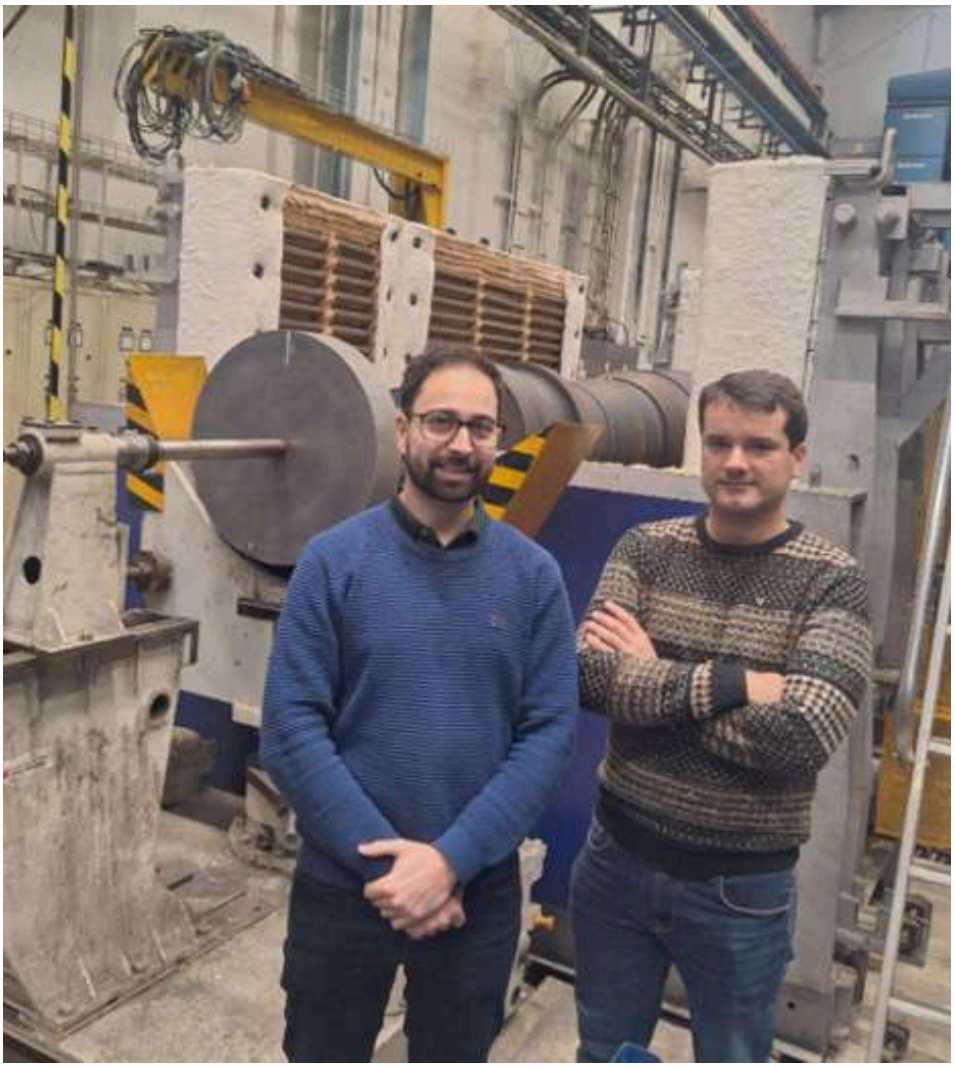
The demonstrator provided an industrial-scale platform for validating the advanced modelling and characterisation tools developed throughout AID4GREENEST, demonstrating their applicability under real manufacturing conditions.

Through close collaboration with the project's research partners, RFC gained deeper insight into the complex relationships between processing conditions, microstructure evolution and final component performance. This knowledge extends beyond conventional product qualification and provides a more detailed understanding of how manufacturing decisions influence the properties of large forged components. The project also provided RFC with a comprehensive cradle-to-gate environmental assessment of its manufacturing route. Based on real production data collected during the manufacturing of the demonstrator, the analysis compared different production configurations and showed how decisions related to process integration, energy use and logistics can significantly influence the environmental footprint of the final component.

"For RFC, one of the most valuable outcomes of AID4GREENEST has been the combination of advanced simulation, experimental characterisation and industrial validation on a real product."

By understanding not only whether a component meets specifications, but also why it meets them, RFC is better equipped to anticipate production challenges, reduce trial-and-error approaches and minimise waste throughout the manufacturing process.

Looking beyond the project, RFC plans to build on these results in the development of future high-performance components for the energy sector. Further analysis of the demonstrator shaft will continue to generate valuable metallurgical data, helping to refine the models developed within AID4GREENEST. The partnerships established during the project, including collaborations with research organisations and industrial stakeholders, also provide a strong foundation for future initiatives focused on smarter, greener and more competitive manufacturing.



Heat stability test: successful validation of the manufacturing route. Carlos Llovo (left) and Francisco Tomas Ibañez Gutierrez.

UNE: Driving Standardisation for Long-Term Impact

Javier López-Quiles Pastor, UNE

A key objective of AID4GREENEST was to ensure that its innovations can be effectively adopted, replicated and built upon beyond the project's lifetime. The **Spanish Association for Standardisation (UNE)** has played a pivotal role by leading standardisation activities and helping connect research outcomes with the wider standards community.

As Spain's national standardisation body and a member of both the European and international standardisation systems, UNE worked throughout the project to identify the standards, technical committees and standardisation initiatives most relevant to AID4GREENEST's activities. This provided consortium partners with valuable insight into the regulatory and standardisation landscape.

UNE also served as an important bridge between the project and the standardisation community, ensuring that AID4GREENEST achievements were shared with relevant stakeholders and helping partners understand how standards can strengthen the market uptake of research results. Among its notable contributions was participation in the revision of CWA 17815:2025 "*Materials Characterisation – Terminology and Structured Documentation*", where UNE provided both technical and standardisation expertise.

To further build awareness and capacity within the consortium and beyond, UNE organised a European Standardisation webinar focused on the opportunities that standardisation offers to research and innovation projects.

The event highlighted how standards can improve the comparability, compatibility and interoperability of project outcomes while supporting dissemination, adoption and future exploitation. Perhaps UNE's most valuable contribution has been empowering project partners and sister initiatives to engage more effectively with standardisation processes.



The online Seminar "European standardisation to support R+I": counted on the participation of 42 attendees, among them representatives of several EU projects including, ACCORDs, CHARISMA, DiMAT, DigiCell, Instruct, D-STANDART, DOMMINIO, HySolChem, MatCHMaker, METAFACTURING, and more.

By promoting understanding of how standards are developed and how researchers can contribute to them, UNE has helped ensure that project results can influence future standardisation activities and ultimately contribute to higher-quality, safer and more sustainable products and services.

UNE will continue applying the knowledge and experience gained through the project to support future research and innovation initiatives, and is already preparing to participate in new projects related to the steelmaking industry. This will carry forward the lessons learned and reinforce standardisation as a key enabler of industrial innovation and sustainable growth.

University of Oulu: Multiscale Modelling for Steel Microstructure Design

Dr. Aarne Pohjonen, UOulu

The **University of Oulu (UOulu)** contributed to AID4GREENEST through advanced numerical modelling and experimental investigations of microstructure formation during quenching. By combining simulations at multiple length scales with detailed experimental characterisation, the team developed a comprehensive understanding of how processing conditions influence the final microstructure of large forged steel components. Using a multiscale modelling approach, researchers simulated the thermal and metallurgical processes occurring during quenching, from heat transfer throughout metre-scale turbine shafts to the evolution of individual microstructural features at the micrometre scale. Experimental studies conducted throughout the project provided the data needed to calibrate and validate these models, ensuring that the simulations accurately reflected real industrial conditions.

Understanding steel from the macro to the microscale

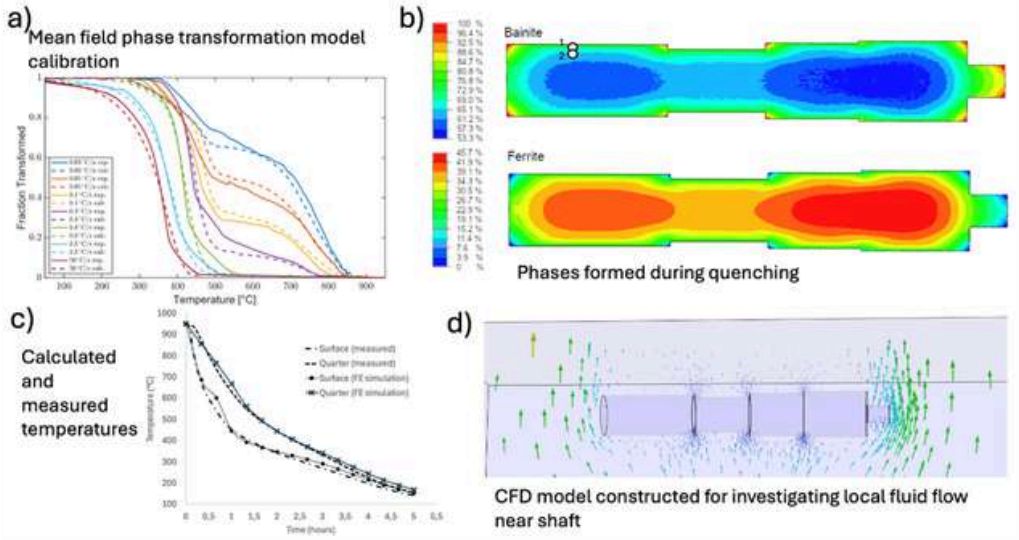
A major achievement of the project was the further development and validation of a modelling framework capable of predicting microstructure evolution across multiple length scales. The University of Oulu combined mean-field modelling, cellular automata simulations and phase-field methods to capture the complex physical processes that govern phase transformations during cooling. This work provided both predictive and mechanistic understanding of microstructure development. Researchers were able to simulate how different ferritic phases form throughout the component under varying cooling conditions, while also gaining insight into the underlying mechanisms that determine their morphology and distribution. The resulting models help explain why different microstructures emerge in different regions of a large steel shaft and how these features ultimately influence material performance.

The validated multiscale modelling framework enables virtual experimentation, allowing researchers and industry to explore cooling strategies and predict microstructure evolution before carrying out costly industrial trials.

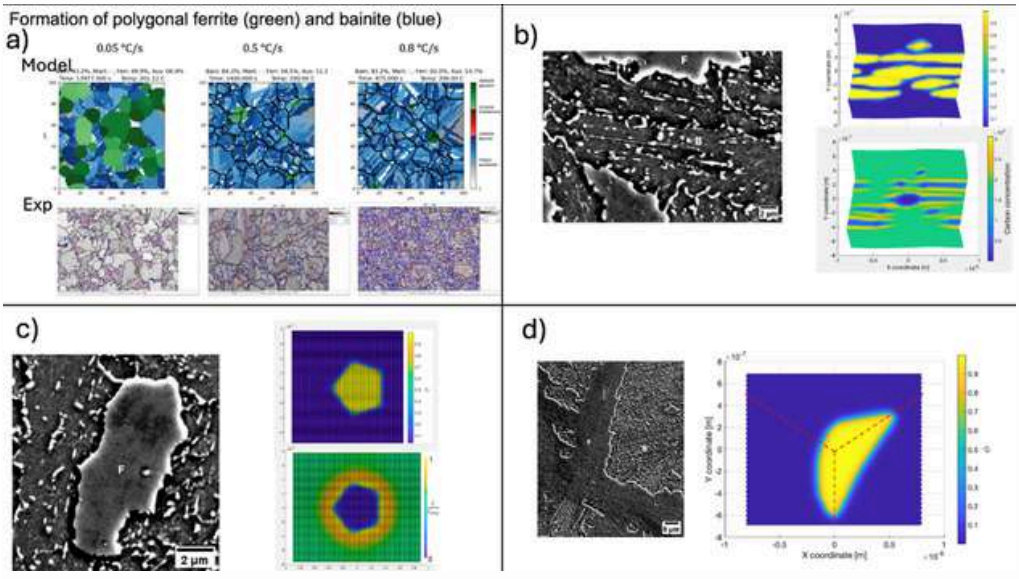
Beyond the development of modelling tools, AID4GREENEST strengthened collaborations between the University of Oulu and other project partners. These partnerships enabled new connections between solidification, forging, microstructure evolution and machine-learning-assisted model calibration, creating a more integrated understanding of steel manufacturing processes.

the University of Oulu sees significant potential for applying the developed tools to the design of future steel processing routes. By linking processing conditions to microstructure development and, ultimately, material properties, the modelling framework could support the intelligent design of cooling schedules and manufacturing practices for next-generation steel products.

Building on the expertise and networks established through AID4GREENEST, the team intends to continue working towards comprehensive processing-microstructure-property models capable of accelerating innovation in sustainable steel manufacturing.



Coupled heat transfer, conduction and mean field modelling of oil quenching of large shaft: a) calibrated mean field phase transformation model (model result in dashed lines and experiment in solid lines), b) calculated bainite and ferrite fractions in the shaft resulting from the quenching c) calculated versus measured temperatures in the positions 1 and 2 indicated in b) and d) computational fluid dynamics simulation of oil flow near the shaft.



Full field microstructure models and characterisation: a) cellular automata model of polygonal ferrite and bainite compared to experimental microscopy images, b) phase field model and partitioned carbon compared to bainite (B) in microscopy image, c) phase field model of polygonal ferrite showing grain interface effects and carbon partitioning and diffusion, d) phase field model showing ferrite growing along prior austenite grain boundaries and microscopy observation.

University of Liège: Accelerating Creep Prediction Through Modelling and Artificial Intelligence

Prof. Anne Marie Habraken, ULiège

Within AID4GREENEST, the **University of Liège (ULiège)** coordinated Work Package 3, focused on accelerated creep testing (ACT) and the development of machine learning-based tools for creep prediction. The team performed standard creep tests (SCT), developed methodologies to translate accelerated testing results into conventional creep behaviour, generated virtual creep datasets to support AI model development, and carried out detailed microstructural characterisation of specimens tested under both standard and accelerated conditions.

> A major contribution from ULiège was the development of a multiscale modelling framework combining advanced finite element simulations with physically based creep models.

Using an elasto-visco-plastic constitutive approach, the team reproduced creep behaviour through numerical simulations validated against experimental data. These validated models provided a powerful source of virtual creep-test data, enabling project partners to generate large datasets needed for training and improving machine learning algorithms.

ULiège also played a central role in assessing the Stepped Isostress Method (SSM) as an accelerated alternative to conventional creep testing. While the research demonstrated that SSM cannot directly replace standard creep tests, the team showed that, when combined with an appropriately calibrated modelling approach, SSM results can be used to reliably recover standard creep behaviour. This achievement formed the basis for the development of the project's "SSM-SCT Prediction App", a machine learning tool capable of estimating key creep properties from a single accelerated test, significantly reducing experimental time and resources.

> Another important achievement was the application of the Mean Field Creep (MFC) model to the steel grade 30CrMoNiV5-11.

Unlike empirical approaches, the MFC methodology incorporates the underlying physical mechanisms governing creep deformation, including dislocation kinetics, subgrain evolution and precipitate behaviour. This allows the generation of highly accurate virtual creep data requiring only a limited experimental dataset. The approach is valuable for low-stress conditions where conventional creep tests can last for several years. The project demonstrated how physically based modelling can complement machine learning by supplying reliable virtual data for training and validation purposes.

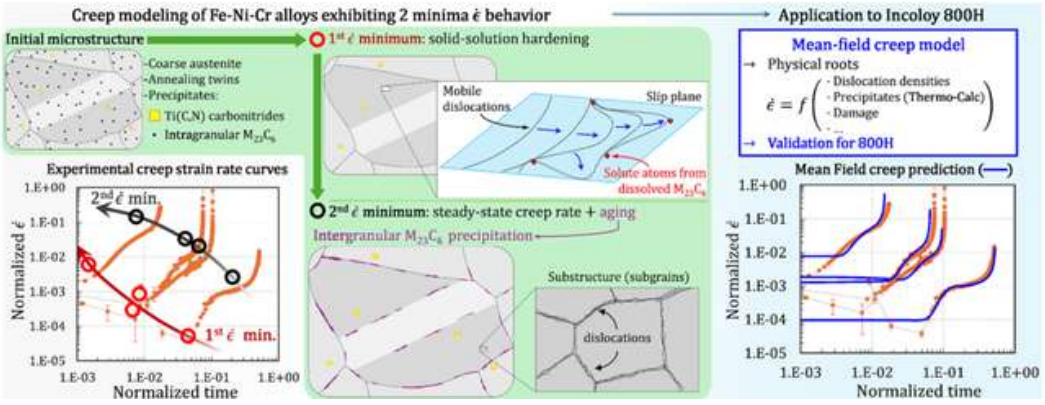


Image extracted from J Mater Sci (2026) 61:23113–23136 showing that MFC not only works for 30CrMoNiV5-11 but also for 800H that exhibits a specific creep behaviour.

For ULiège, one of the most significant outcomes of AID4GREENEST has been the demonstration that accelerated testing methods can dramatically reduce the duration of creep-characterisation campaigns while maintaining predictive accuracy. By combining experimental testing, finite element modelling, physically based creep simulations and artificial intelligence, the team established a pathway towards faster, more efficient and more cost-effective assessment of material performance. These advances have the potential to reduce testing times by up to 70%, while supporting more accurate lifetime predictions for high-temperature components.

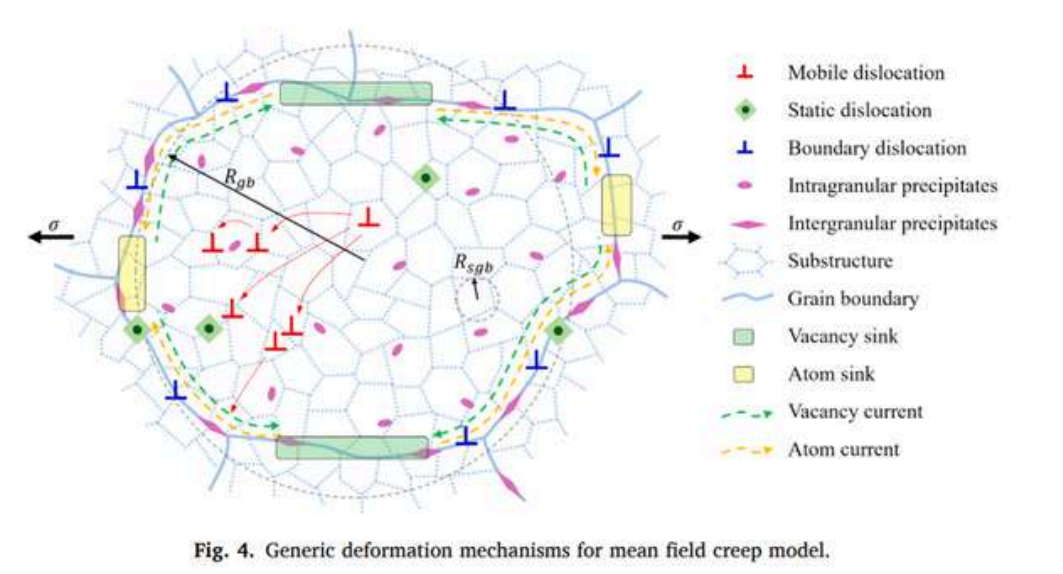


Fig. 4. Generic deformation mechanisms for mean field creep model.

*Image from **Materials & Design 266 (2026) 116152**: what creep does from a microstructure point of view at the level of a grain presenting sub-grains, precipitates and dislocations for a stress σ and medium to high temperature loading.*

ULiège will continue building on the results generated through AID4GREENEST, including development of the Mean Field Creep modelling framework, additional scientific publications, and new research applying these methodologies to advanced alloys produced through additive manufacturing. The team is also pursuing new collaborative research opportunities with project partners, including work combining phase-field modelling, mean field creep approaches and finite element simulations. Through these efforts, ULiège aims to further strengthen predictive materials engineering and support the development of faster, more sustainable approaches to materials qualification and industrial component design.

Collaboration and cluster activities

Building a European Ecosystem for Advanced Materials Modelling

Throughout the project, AID4GREENEST actively engaged in collaboration, clustering, standardisation and networking activities, building strong links with sister projects, industry, standardisation bodies and European materials communities to maximise the impact of its research.

Strong Collaboration with Horizon Europe Sister Projects

AID4GREENEST developed close working relationships with eight Horizon Europe projects operating in complementary fields of advanced materials modelling, characterisation, and digitalisation, including AddMorePower, CHARISMA, CoBRAIN, DiMAT, D-STANDART, KNOWSKITE-X, MatCHMaker and NanoMECommons. These collaborations enabled knowledge exchange, joint dissemination activities, and coordinated efforts on topics of common interest.

Sister and partner projects

A particular focus was placed on supporting European standardisation and interoperability initiatives, including activities related to CHADA and MODA standards and the adoption of EMMO ontologies. Project partners also participated in numerous joint events, workshops, webinars, and networking activities, helping to strengthen connections across the European materials community and maximise the impact of project results.

Launch of the AiMPACT Cluster

A major achievement of the project was the creation of the Advanced Materials Modelling and Characterisation Cluster (AiMPACT). Bringing together six Horizon Europe projects, the cluster was established to promote long-term cooperation in digital materials technologies, facilitate knowledge exchange, and coordinate dissemination activities beyond the lifetime of individual projects.

Through AiMPACT, partners contributed to a series of collaborative workshops and training activities addressing topics such as data life cycles in materials research, FAIR documentation practices, and data-driven collaboration. The cluster has become an important platform for connecting researchers working across the modelling and characterisation domains and for strengthening the European materials innovation ecosystem.

Engagement with European Industrial and Policy Initiatives

AID4GREENEST partners actively participated in a range of high-level European initiatives linked to the digital and green transition of industry. Project partners contributed to the activities of the European Steel Technology Platform (ESTEP) and the Clean Steel Partnership, participating in annual events and supporting discussions on the future of sustainable steel production in Europe.

The project also engaged with broader European Commission initiatives related to digital technologies, Web 4.0, virtual worlds, and artificial intelligence. These activities helped ensure that AID4GREENEST remained connected to emerging policy developments and contributed to discussions on the future deployment of AI technologies in European industry. In parallel, project partners participated in standardisation activities involving the German standardisation body DIN, supporting efforts to improve harmonisation and data interoperability across the materials research community.

Collaboration with EMMC and EMCC



Dr. Alexandra Simperler (EMMC) presented at the AID4GREENEST Workshop in Freiburg.

AID4GREENEST established particularly strong ties with the European Materials Modelling Council (EMMC) and the European Materials Characterisation Council (EMCC), two leading organisations driving collaboration within the European materials community. The project became formally visible within both networks, being recognised as an EMMC-related initiative and joining the wider EMCC community. These connections significantly increased the visibility of AID4GREENEST among stakeholders working in materials modelling and characterisation.

Collaboration extended beyond networking. AID4GREENEST researchers participated in the EMMC Annual Event in Vienna in 2025, while EMMC representatives contributed to the AID4GREENEST Symposium held during EUROMAT 2025 in Granada. The collaboration culminated in the co-organisation of the AID4GREENEST workshop hosted at Fraunhofer IWM in Freiburg in 2026, where experts from both communities exchanged experiences on FAIR data, data life cycles, and barriers to technology adoption.



Dr. Michael Sluydts (ePotentia) presented a poster at an EMMC event in Vienna.

Project publications

Here you can find a complete repository of all publications released to date related to the AID4GREENEST project.

1. R. Bharadwaj; A. Pohjonen; J. Kömi; I. Sabirov; M. Somani. *Effect of cooling rate on phase transformation and microstructure evolution in a heat-resistant medium-carbon bainitic steel*. **Materials & Design**. 271. 117073. 2026

2. C. Schenk; I. Romero. *A framework for the Bayesian calibration of complex and data-scarce models in applied Sciences*. **Archives of Computational Methods in Engineering**. 33 (10667-10693). 2026

3. F. Chen; C. Rojas Ulloa; A. Kott; L. Morand; C. Schenk; M. Zapara; D. Laurent; A.M. Habraken. *A history-dependent creep framework for stepped isostress test and inverse determination of minimum creep rate*. **International Journal of Solids and Structures**. 340. 114264. 2026

4. R. Shoghi; L. Morand; D. Helm; A. Hartmaier. *Diversity-aware batch-mode active learning for efficient sampling in data-driven constitutive modeling*. **Computational Materials Science**. 274. 114979. 2026

5. F. Chen; C. Rojas Ulloa; J. Tchoufang Tchuindjang; O. Dedry; R. Bharadwaj; M. Somani; A. Mertens; A.M. Habraken. *Microstructure-informed creep model for 30CrMoNiV11-5 steel*. **Materials & Design**. 266. 116152. 2026

6. C. Rojas Ulloa; F. Chen; J. Tchoufang Tchuindjang; O. Dedry; T. Nguyen-Minh; L. Kestens; A. Mertens; V. Tuninetti; L. Duchêne; A.M. Habraken. *Mean-field prediction of transient solid solution hardening creep deformation response in Fe-Ni-Cr alloy*. **Journal of Materials Science**. 61 (23113-23136). 2026

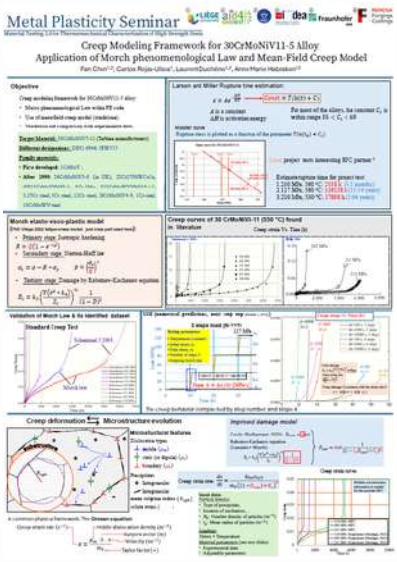
7. D. Geoffrey; J. Ludovic; A. Ouzia; A. Clausner; C. Jaeken; A. Laukkanen; J.A. Pascoe; M. Sebastiani; G. Bolelli; A. Simperler. *Advances in characterisation methods and computational modelling*. **EU Open Research Repository**. 2025

8. A. Pohjonen; O. Seppälä; O. Väinölä; J. Larkiola. *Cellular automata model for austenite formation and grain growth during heating and holding above austenization temperature*. **The 65th SIMS Conference on Simulation and Modelling (SIMS 2024)**. 2024.

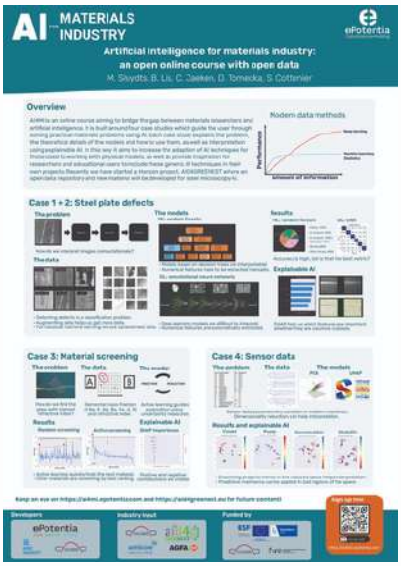
9. T. Puro; A. Pohjonen. *GPU acceleration of average gradient method for solving partial differential equations*. **The 65th SIMS Conference on Simulation and Modelling (SIMS 2024)**. 2024.

10. A. Pohjonen; T. Puro; A. Aravindh Sasikala Devi. *Non-interacting lattice random walks for calculating diffusion controlled growth in solid state for dilute concentrations*. **The 65th SIMS Conference on Simulation and Modelling (SIMS 2024).** 2024.

Poster Gallery



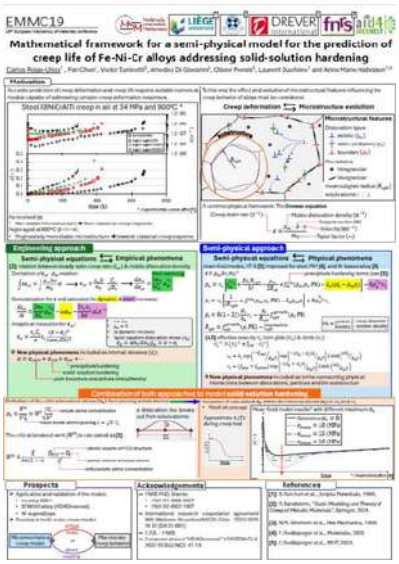
Creep modeling framework for 30CrMoNiV11-5 alloy application of Morch phenomenological law and mean-field creep model.



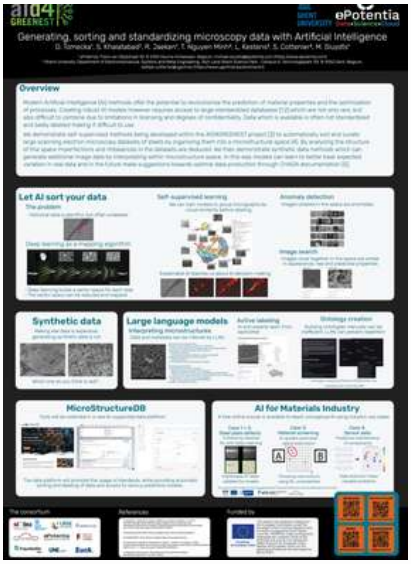
Artificial intelligence for materials industry: an open online course with open data.



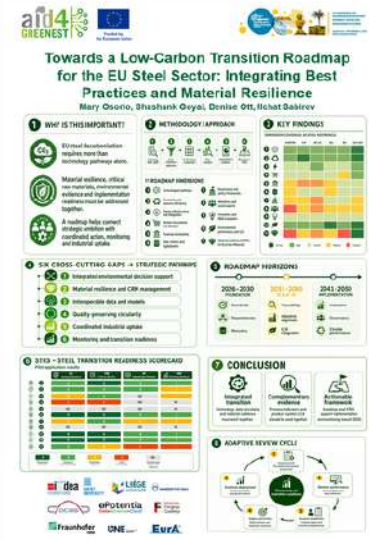
Transforming forging industry practices with advanced material simulation.



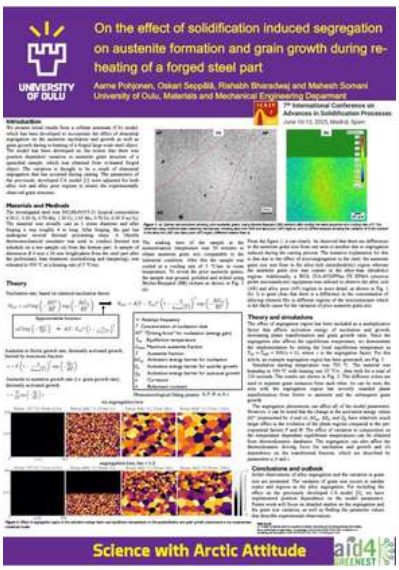
Mathematical framework for a semi-physical model for the prediction of creep life of Fe-Ni-Cr alloys addressing solid-solution hardening.



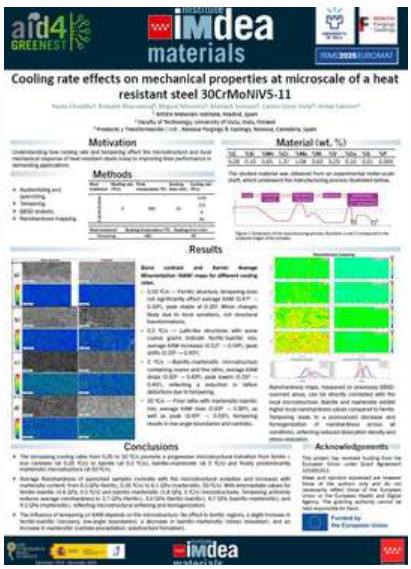
Generating, sorting and standardising microscopy data with Artificial Intelligence.



Towards a low-carbon transition roadmap for the EU steel sector: integrating best practices and material resilience.



On the effect of solidification induced segregation on austenite formation and grain growth during re-heating of a forged steel part.



Cooling rate effects on mechanical properties at microscale of a heat resistant steel 30CrMoNiV5-11.

Thank you for signing up for the AID4GREENEST newsletter. You can also follow the project at our website: www.aid4greenest.eu

And don't forget to follow us on our social media channels:

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