ISSN 2599-8293

European Commission

CORDIS Results Pack on

energy-intensive industries

A thematic collection of innovative EU-funded research results

June 2024

Decarbonisation, energy efficiency and circularity for a climate-neutral and sustainable EU

Research and Innovation

Contents

Editorial

Energy-intensive industries, while being fundamental to the economy, are both major energy users and major greenhouse gas emitters. The EU is addressing this challenge by funding research and innovation in climate-neutral and circular industries.

Energy-intensive industry (EII) sectors need to reduce their carbon footprint and accelerate the transition to climate neutrality by providing affordable and effective clean technology solutions. These efforts will support the EU's long-term environmental goals, while contributing to energy independence and security as well as resource autonomy for Europe.

Process industries such as chemicals, cement, steel, aluminium, glass or ceramics require large amounts of energy to turn raw materials into useful products, all the while generating carbon emissions and waste. The European Green Deal commits the EU to becoming the first climate-neutral continent by 2050 and stresses the need to develop breakthrough technologies in key industrial sectors by 2030. The European Industrial Strategy underpins the important role of industry in the transition to a green and digital economy.

EIIs are a key component of the EU's economy. The materials produced by these industries are used to construct buildings and infrastructure as well as making consumer goods and many other products that are integral to our daily lives.

However, they represent the second largest global source of CO_2 emissions. Although these industries have substantially reduced their emissions in recent decades, they still represent 17 % of total CO_2 emissions within the EU. The major carbon footprints of EIIs mean their decarbonisation is indispensable to reaching climate neutrality.

In addition, increasing the circularity of the industrial processes and reducing waste generation in these sectors will have a broad impact on EU sustainability, leading to the efficient use of natural resources and secondary materials.

Process industries are also of strategic importance for the resilience of our society and therefore they need to maintain and ideally improve their global competitiveness.

The goals of climate neutrality and circularity are achievable with the aid of the right instruments and strategies. The EU's efforts in research and innovation include two public-private partnerships under Horizon Europe, Processes4Planet and Clean Steel, which support the development of net-zero and circular value chains across Europe. These partnerships build from the outcomes of the Horizon 2020 partnership Sustainable Process Industry through Resource and Energy Efficiency (SPIRE).

This new CORDIS Results Pack focuses on 12 Horizon 2020 research projects, funded within the SPIRE partnership, that demonstrate technological pathways for decarbonisation, efficiency and circularity in EIIs. They include a range of technologies that can reduce the CO_2 emissions of current processes, replace the need for fossil fuels, reduce the energy and resource consumption and create new production routes with a lower environmental impact.

Materials artificial intelligence tool poised to advance energy-intensive industries

Using artificial intelligence, EU-funded researchers have engineered new materials and protective coatings tailored to withstand the extreme and fluctuating conditions typical in energy-intensive industries.

One of the biggest challenges in energy-intensive sectors is finding materials that can withstand extreme conditions, such as high temperatures, corrosive environments and physical stress. Artificial intelligence (AI) toolkits can analyse vast amounts of data to propose materials with the most suitable properties. By predicting material properties, such toolkits reduce the need for time-consuming and costly physical testing.

© ACHIEF project

Driving innovative materials to market success

The EU-funded ACHIEF project has created an innovative AI platform that aids in selecting high-performance materials and protective coatings tailored to specific industry needs.

Project members have developed four types of novel materials. These include polymer-derived ceramic coatings with improved resistance to high-temperature corrosion and erosion, and advanced chromium-steel grades with 15 % improved resistance to creep and high-temperature corrosion. Furthermore, breakthroughs have been made in the development of high-temperature and creep-resistant materials inspired by high-entropy superalloy models. High-performance coatings have also been produced using high-entropy alloy nanocomposites.

"We sought to take emerging technologies from technology readiness level (TRL) 3-4 to TRL5, demonstrating their potential in real-world industrial conditions," notes Raquel Aleman, a member of the ACHIEF team. "These technologies are being tested in aluminium, petrochemical and steel production processes. Beyond our AI-aided material design toolbox, advanced temperature and corrosion sensors have been instrumental to our endeavours."

The results from lab-scale experiments have been promising. The next step is to outline the industrial process that should allow production and application of these materials and coatings on a larger scale and over bigger surfaces, considering the additional constraints that come with scaling up.

Pioneering methodologies in material evaluation and design

ACHIEF is at the forefront of a revolution in material design, leveraging innovative computational modelling and experimental techniques.

"ACHIEF is at the forefront of a revolution in material design, leveraging innovative computational modelling and experimental techniques. It advances beyond the current state of the art by merging sophisticated computational models with cutting-edge experimental methods to tackle complex material design challenges," highlights Aleman.

ACHIEF's innovative approaches include fusing deep learning architectures to optimise structural designs and integrating data-driven and physics-based models to quickly evaluate how a process impacts the structure, properties and performance of materials. In addition to these, it is developing new materials boasting superior properties. "ACHIEF's approach to advancing material design processes, making materials more resistant and adding real-time monitoring systems represents a significant leap in material science and engineering. This means we can create groundbreaking materials for use in energy-intensive industries," remarks Aleman.

Promising benefits

The prospective advantages of ACHIEF developments are multifold. The newly developed materials have been designed with the objective of enhancing energy efficiency and reducing operational costs in energy-intensive sectors. They also promise to improve material performance under extreme conditions, leading to a significant reduction in environmental impact. The project impact on industry standards and practices is expected to be profound: particularly, it aims to enhance energy efficiency by 20 %, cut down CO_2 emissions by 20 % and extend the lifespan of equipment by 20 % or more.

"ACHIEF is poised to usher in significant changes in energy-intensive industries. Collaborations with esteemed partners such as Constellium, Tüpraş and ArcelorMittal mark just the beginning. With significant advancements in coatings, especially those providing corrosion protection under high temperatures, the future looks promising. Moving forward, ACHIEF is set to leave an indelible mark, reshaping how industries operate – enhancing efficiency, sustainability, and global competitiveness," concludes Aleman.

PROJECT
ACHIEF - Innovative high-performance Alloys and Coatings for HIghly EFficient intensive energy processes

COORDINATED BY
French Alternative Energies and Atomic Energy Commission (CEA) in France

FUNDED UNDER
Horizon 2020-LEIT-ADVMANU

CORDIS FACTSHEET
cordis.europa.eu/project/id/958374

PROJECT WEBSITE
achief.eu/

Transforming the process industry with four levels of automation

A modular cognitive automation platform is helping diverse industries reduce energy consumption and materials waste while enhancing product quality.

Digitisation can enhance the sustainability of process industries by enabling the processes to produce more with less – less energy and materials, the latter by minimising waste. This translates into a smaller carbon footprint.

We developed sensors for measuring the properties of raw materials, intermediates and final products like dust flow or scale in steel. Cognitive planning tools enabled efficient allocation of resources. Advanced control algorithms were designed to save energy or maintain the quality of a key parameter of an active pharmaceutical ingredient.

Nowhere is this more important than in energy-intensive industries (EIIs). The EU-funded CAPRI project delivered a cognitive automation platform that accomplishes this while improving quality, flexibility and performance. The solutions were demonstrated in three diverse applications comprising asphalt, steel and pharmaceuticals.

Digital transformation enabled by cognitive solutions

According to project coordinator Cristina Vega of CARTIF Technology Centre: "We developed sensors for measuring the properties of raw materials, intermediates and final products like dust flow or scale in steel. Cognitive planning tools enabled efficient allocation of resources. Advanced control algorithms were designed to save energy or maintain the quality of a key parameter of an active pharmaceutical ingredient."

CAPRI's cognitive automation platform integrated all of the technical solutions. It was built on a reference architecture leveraging machine learning and cognitive human-machine interaction consisting of Internet-of-Things connections, AI-based decision support, smart events processing and knowledge data models. These tools coordinate cognitive automation on four levels: planning, sensors, control and operation.

Modular, scalable, open-source platform expands impact

The platform and tools are modular and scalable, enabling a tailor-made cognitive automation platform for various use cases. Vega stresses "the importance of developing solutions the factory workers need, including the flexibility to adapt the solutions to real environments. This guarantees that they will use them."

In addition, the cognitive automation platform was developed with the open-source FIWARE framework to achieve the FAIR principles of findability, accessibility, interoperability and reusability. This will facilitate use with other software and in webinars and training programmes beyond CAPRI's end, to nurture a mindset of cognitive and smart technologies implementation in researchers and practitioners.

Demonstrable success in diverse industries

Overall, eight cognitive sensors were developed for the three use cases along with cognitive planning, control and operations solutions. The tailored implementations enabled all three EIIs to reduce energy consumption and related emissions.

For example, in the asphalt use case, the manufacturer was able to determine the composition of the mixture in real time – critical data that enabled it to eliminate the heating of materials it could not use in the end. In pharma and steel, the manufacturers were able to detect problems with the product early in the process rather than at the end, reducing materials waste and energy consumption. In all three use cases, product quality was improved. The impact was particularly significant in the asphalt and pharma cases with the end users stating: "We can no longer imagine working without the solutions implemented in the project."

CAPRI's modular, scalable, open-source platform for cognitive automation will support EIIs in their digital transformation. Easily modified for application in a plethora of industries, its adoption promises to significantly reduce industry's carbon footprint while enhancing product quality – supporting both European energy and climate goals and the EU economy.

PROJECT

CAPRI – Cognitive Automation Platform for European PRocess Industry digital transformation

COORDINATED BY

CARTIF Technology Center in Spain

FUNDED UNDER

Horizon 2020-LEIT-ADVMANU

CORDIS FACTSHEET

cordis.europa.eu/project/id/870062

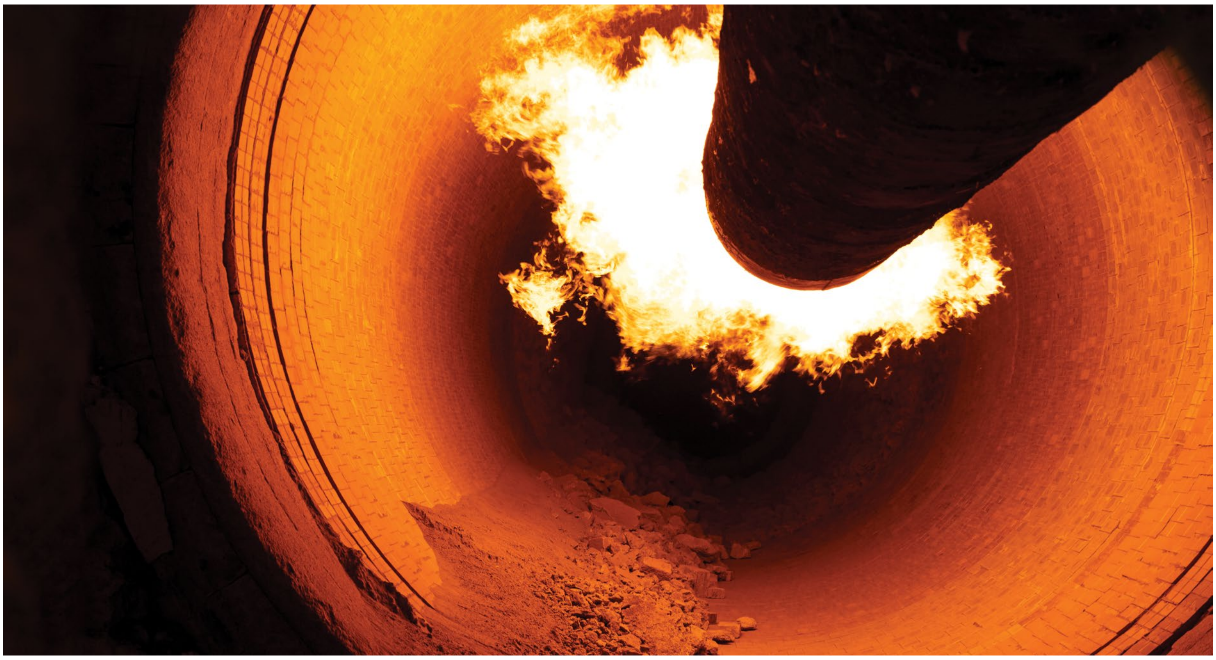
PROJECT WEBSITE

capri-project.com

Accelerating the digitisation and decarbonisation of energy-intensive industries

A cloud-based platform for data collection and predictive modelling has facilitated process control and slashed materials use, energy consumption and emissions in process industries.

Digitisation and improved process control can have significant impact on the environmental footprint of industrial processes, but process industries are lagging in the digital transition. The EU-funded COGNIPLANT project has enabled energy-intensive industries (EIIs) to harness big data via a flexible cloud architecture, advanced data analytics and machine learning. Predictive models and digital twins enhanced sustainability in four use cases: chemicals, concrete, aluminium and metals.



Big data handling, machine learning models and digital twins

COGNIPLANT's common cloud infrastructure can flexibly collect, store, process and display data and analytics from any EII's workflows. Within this same infrastructure, a predictive modelling system using data mining and machine learning was deployed. The integration of the predictive modelling in the cloud-based architecture enabled efficient management of model training via the big data as well as model deployment, execution and maintenance.

According to project coordinator Pedro Maria De la Peña Tejada of Ibermática (now an Ayesa company): "Multiple machine learning models simulate different aspects of industrial processes. For example, they can predict the amount of energy required to reach a certain temperature in a steel casting or the steam required in a Bayer process for the production of aluminium."

Two types of digital twins were also developed. One focused on providing feedback to the operator regarding the optimal process parameters required to achieve a target variable, and the other was designed to adjust production process parameters dynamically in real time.

The hierarchical monitoring and supervisory control providing users with information on performance, energy consumption and resource use enabled the process industry pilots to significantly decrease their environmental impact. The energy consumption of some processes was reduced by about 10 %. One of the partners reduced CO_2 emissions by up to 8 100 tonnes, while others reduced CO_2 emissions from 19-30 %. Some partners also reduced scrap by up to 15 %.

"The reduction in raw materials use, energy consumption and CO_2 emissions achieved with COGNIPLANT has taught us that increased digitisation of production processes and data-driven approaches can have a very significant impact on the environmental footprint of EIIs," De la Peña concludes. Once lagging in digitisation, these process industries now have a tremendous opportunity for a step change in the way they do business with outsized benefits for industries and the planet.

The reduction in raw materials use, energy consumption and CO_2 emissions achieved with COGNIPLANT has taught us that increased digitisation of production processes and data-driven approaches can have a very significant impact on the environmental footprint of [energy-intensive industries].

Accelerating digitisation – and decarbonisation – of process industries

"Many of the developments were the first step toward digitisation and data utilisation for process control for the process industries involved. This made the project's initial phase complex in terms of having a common language and unified expectations," notes De la Peña. Once this was overcome, progress accelerated quickly. For each use case, an on-site training session for each of the pilots was organised for the employees. The training materials for each of the use cases are available on the project website, to inspire and support others in reducing the resource and energy inefficiency and environmental impact of process industries.

PROJECT
COGNIPLANT - COGNITIVE PLATFORM TO ENHANCE 360° PERFORMANCE AND SUSTAINABILITY OF THE EUROPEAN PROCESS INDUSTRY

COORDINATED BY
Ibermática (now an Ayesa company) in Spain

FUNDED UNDER
Horizon 2020-LEIT-ADVMANU

CORDIS FACTSHEET
cordis.europa.eu/project/id/869931

PROJECT WEBSITE
cogniplant-h2020.eu/

Advanced engineering materials and components lasting longer in industrial applications under extreme conditions

EU-funded researchers are redefining the production of material and components for industrial furnaces in process industry. Advanced strategies and tools facilitate the development of novel alloys and components that can extend their in-service life in high temperatures and corrosive environments.

Developing longer-lasting materials and components that can withstand high temperatures or thermal cycling – repeated heating and cooling that cause materials to expand and contract – is challenging. The use of less resource-intensive manufacturing technologies offers the opportunity to conserve energy and mineral resources, while also offering a new standard of efficiently producing components for engineering equipment which are resistant to high temperatures and corrosion.

Challenges hindering sustainability in hot stamping

The EU-funded HIPERMAT project focused on a use case involving a rolling beam furnace, which is used in the hot stamping process. This manufacturing process, used by the automotive industry among others, produces high volumes of lightweight components for the body-in-white structures. Yet, the furnace represents the most energy- and resource-consuming equipment in this manufacturing process.

The furnace operates under challenging conditions: temperatures come close to 1 000 degrees Celsius, there are heavy loads owing to the weight of its beams, steel plates in process, and the high temperature and continuous heat inside the furnace creates a corrosive environment. These tough working conditions result in various failure modes.

The frequent maintenance and component replacements for these furnaces cause significant productivity losses. They also escalate energy and resource use owing to the critical materials needed for manufacturing the furnace components.

Material innovations to address challenges in hot stamping

Seeking to make hot stamping more sustainable, HIPERMAT leveraged advanced design tools to optimise material selection and component durability. The initiative led to the development and validation of alloys resistant to high temperatures and corrosion, including variants of refractory stainless steel and other alloys applied in protective layers.

"Standard refractory stainless steels encompass a wide range of standard chemical elements like carbon, nickel and chrome. By restricting the ratio of these elements in the alloy and intelligently combining others like niobium, tungsten and molybdenum, the alloy microstructure is altered, enhancing their wear and high-temperature properties," explains project coordinator Fernando Santos of AZTERPLAN.

Advanced manufacturing techniques for higher-performance components

To manufacture end components from these high-performance alloys, the project team used advanced additive manufacturing techniques like laser metal deposition (LMD), ceramic coatings and ablation technology.

"Component manufacturing of high-temperature equipment typically involves tweaking bulk materials. However, the introduction of LMD and high-velocity oxy-fuel ceramic coatings allows for the use of high-cost alloys only on the surface, with the basic alloy forming just the core of the part," outlines Santos. "This method of repairing and restoring the external layer, rather than replacing the entire part, marks a significant advancement in resource utilisation."

Ablation technology, when used in bulk material manufacturing, modifies the heterogeneous microstructure created by traditional steel casting processes. Therefore, the resulting alloys have tinier, more evenly distributed carbides, promoting higher resistance to creep and doubling current values.

Following thorough destructive and non-destructive testing evaluations, these components were integrated into a real hot stamping furnace, where their performance has been continually monitored via an advanced network of embedded sensors and data processing tools.

"Conventionally, sensors are placed in the furnace walls, ceiling and floors but not near the parts being processed. The ability to print sensors via LMD and embed them in functional parts close to those being processed facilitates tighter process control and improves the quality of the final part.

"HIPERMAT distinguishes itself by favouring data-driven analysis over traditional physics-based simulations. This approach generates algorithms that identify critical variables, facilitating a quicker development of new materials with advanced properties to endure harsh environments," concludes Santos.

HIPERMAT distinguishes itself by favouring data-driven analysis over traditional physics-based simulations. This approach generates algorithms that identify critical variables, facilitating a quicker development of new materials with advanced properties to endure harsh environments.

By focusing on optimising material selection and improving manufacturing techniques, HIPERMAT advanced the development of enhanced materials with potential for substantial reductions in energy and resource consumption in industrial processes.

PROJECT
HIPERMAT – Advanced design, monitoring, development and validation of novel HIgh PERformance MATerials and components

COORDINATED BY
Fundación AZTERLAN in Spain

FUNDED UNDER
Horizon 2020-LEIT-ADVMANU

CORDIS FACTSHEET
cordis.europa.eu/project/id/958196

PROJECT WEBSITE
aspire2050.eu/hipermat

Advanced chemical technology transforms non-recyclable plastic waste into valuable chemicals

EU-funded researchers leveraged advanced chemical methods to transform plastic waste into high-value chemicals. The products can be repurposed for creating new high-grade materials or serve as valuable feedstock across diverse industrial sectors.

Every year, around 18.5 million tonnes of plastic waste are generated in Europe, and about 70 % of this is not recycled owing to technical and economic reasons. Instead, a substantial portion ends up either in landfill (27 %) or is incinerated (42 %). This negatively impacts the environment and undermines societal views on waste management, consumer products industry and policy-making efforts.

The EU-funded iCAREPLAST project sought to tackle these pressing plastic waste management issues in Europe, providing a cost-effective and energy-efficient solution for the chemical recycling and recovery of this waste. By combining pyrolysis, catalytic treatment and membrane technologies, iCAREPLAST helped transform non-recycled plastic waste into valuable chemicals such as aromatics, which are key in producing virgin-quality polymers.

Our innovative approach reduces the environmental impact of plastic waste by diverting it from landfills and incinerators. It also contributes to economic sustainability, creating an opportunity to generate income from the sale of by-products, including charcoal, CO_2 and various hydrocarbons.

"Our innovative approach reduces the environmental impact of plastic waste by diverting it from landfills and incinerators. It also contributes to economic sustainability, creating an opportunity to generate income from the sale of by-products, including charcoal, CO_2 and various hydrocarbons," highlights project coordinator José M. Serra from the Spanish National Research Council (CSIC).

Innovative recycling technology nearing commercial stage

At the heart of project activities was validating critical technologies across various stages: from waste plastic pre-treatment to pyrolysis, catalytic treatment and membrane molecular separation. A significant part of activities was dedicated to crafting advanced AI control systems for each processing unit and the overall plant operation.

© Urbaser

"A notable milestone was achieved with manufacturing, installing and testing in an industrial environment specific process units at Urbaser facilities, using actual plastic waste," notes Laura Almar, a member of the CSIC team. These real-world tests were crucial to validate the scalability and feasibility of the developed technologies.

Another important achievement has been the development of an oxy-combustion system. This novel fuel cell stack based on solid-oxide cells not only produces pure oxygen for oxidising pyrolysis gases but also generates electricity and a high-purity CO_2 stream.

A thorough techno-economic analysis and a life cycle assessment analysis were conducted, providing valuable information on market acceptance and the economic and environmental sustainability of the iCAREPLAST process. Furthermore, project members developed a tool to integrate life cycle engineering indicators into real-time process control, enabling more accurate monitoring and optimisation of sustainability and productivity indicators.

Marking a shift from existing plastic recycling methods

Almar points out that, "unlike traditional mechanical recycling that grapples with contamination and economic challenges, iCAREPLAST pioneers by leveraging innovative thermochemical techniques like pyrolysis and catalytic transformation." This approach helps convert non-recycled plastic waste into high-value chemicals, while keeping the carbon footprint at minimal levels.

iCAREPLAST sought to close the material loop by efficiently transforming waste into valuable products. Its integration of carbon capture technologies further enhances its environmental sustainability, marking a notable departure from existing energy recovery processes.

The project forecasts a promising increase of 12 % in its pyrolysis liquid yield and a 45 % reduction in energy requirements. The initiative is expected to significantly reduce plastic residue production by 95 %, potentially boosting economic yields by up to 200 %. Furthermore, it promises a substantial decrease in greenhouse gas emissions of between 58 % and 76 %, even achieving below net-zero levels when factoring in secondary product substitution.

Serra states: "iCAREPLAST not only enhances the economic viability of plastic recycling but also reduces reliance on primary fossil resources and supports European targets for waste recycling. Through its educational activities, it also contributes to spreading knowledge and nurturing talent."

PROJECT
iCAREPLAST – Integrated Catalytic Recycling of Plastic Residues Into Added-Value Chemicals

COORDINATED BY
Consejo Superior de Investigaciones Científicas in Spain

FUNDED UNDER
Horizon 2020-LEIT-ADVMANU

CORDIS FACTSHEET
cordis.europa.eu/project/id/820770

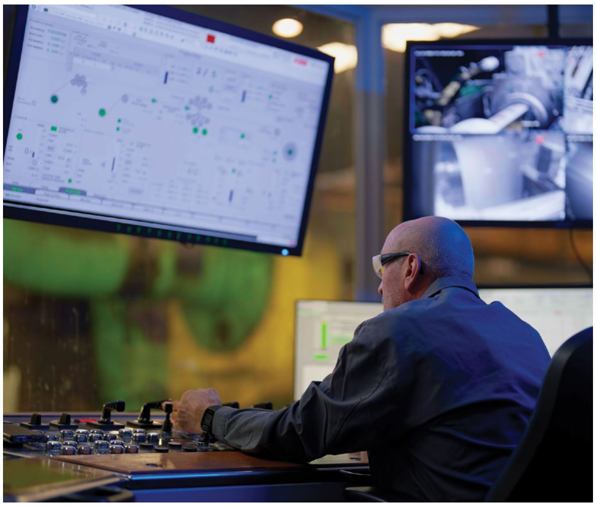
PROJECT WEBSITE
icareplast.eu/

Transitioning to smart automation benefits the metal industry and the environment

Digital technologies for process control in the energy-intensive metal industry have improved process efficiency and product quality while reducing raw materials and energy consumption.

Primary and secondary steelmaking and investment casting of nonferrous metal alloys are highly energy-intensive processes due to the extremely high temperatures, complex chemical reactions and multiple processing stages. Heat losses, scrap recycling and the complexity of maintaining the temperature further increase the energy used.

Manual sampling and measurements lag far behind digitised monitoring and control systems when it comes to optimising manufacturing processes. The EU-funded INEVITABLE project delivered such digital tools leveraging embedded cognitive reasoning to support autonomous process operation.



An evolutionary leap in the digital transition

"The metal industry, known for its conservative approach and limited digitisation, offers many opportunities for improvement. For example, predictive maintenance capabilities can detect potential equipment failures before they occur, minimising downtime and ensuring optimal energy efficiency. Using data analytics and machine learning, predictive modelling can identify patterns and trends to further optimise production efficiency and/or energy consumption," explains Dejan Gradišar of the Jožef Stefan Institute and INEVITABLE project coordinator.

INEVITABLE unlocked this potential with a suite of digital tools based on cognitive approaches. They led to demonstrated improvements in process efficiency, raw materials consumption, product quality and energy consumption in selected use cases covering several metallurgical processes.

Sensor technologies, data analytics and process control

The project delivered six innovative digital tools and a flexible digital infrastructure supporting them. The electric arc furnace (EAF)-refining monitor continuously estimates crucial EAF

Our project contributed to the formalisation of skilled workers' knowledge encapsulated in digital data-backed tools. The tools enable faster decision making and improved energy management. They also reduce dependency on critical measurements through data-driven models, supporting more efficient and cost-effective operations.

process values, improving EAF control and reducing energy consumption by up to 10 kilowatt-hours/tonne. The cold-rolling mill assistant improved quality and equipment performance, leading to a decrease in scrap and unplanned downtime (up to 25 %) and an increase in rolling speed by up to 45 %. The advisory tool for predicting nozzle clogging reduced production losses and quality degradation in continuous casting, reducing clogging by more than the predicted 20 % in one use case.

"INEVITABLE's aided stirring control in refining and continuous casting used real-time data to adjust stirring intensity during steel production. Camera-based stirring monitoring improved process monitoring and anomaly detection. Taken together, they ensured high productivity, reduced energy consumption and improved quality – the latter by more than 75 % based on quality indicators," notes Gradišar. Finally, a smart lean management system implemented in a non-ferrous investment casting process improved traceability and optimised production resource utilisation, resulting in greater process efficiency (the rejection rate was decreased from 12 % to 8 %) and improved product quality.

Finally, "INEVITABLE's systematic methodology for selecting digital infrastructure tailored to a company's needs ensures alignment with process and organisational requirements, which is crucial for seamless integration into existing workflows," Gradišar adds.

Flexible tools that support industry and the environment

"Our project contributed to the formalisation of skilled workers' knowledge encapsulated in digital data-backed tools. The tools enable faster decision making and improved energy management. They also reduce dependency on critical measurements through data-driven models, supporting more efficient and cost-effective operations," notes Gradišar.

Finally, "by focusing on reducing energy consumption, increasing production efficiency and improving product quality, our project will not only benefit the metal industry but reduce its environmental impact through sustainable production practices and environmental management," concludes Gradišar. INEVITABLE's innovative tools and training materials will energise the nascent digital transition of energy-intensive industries with minimal 'energy input' on the part of adopters.

PROJECT
INEVITABLE - Optimization and performance improving in metal industry by digital technologies

COORDINATED BY
Jožef Stefan Institute in Slovenia

FUNDED UNDER
Horizon 2020-LEIT-ADVMANU

CORDIS FACTSHEET
cordis.europa.eu/project/id/869815

PROJECT WEBSITE
inevitable-project.eu/

Novel and smart industry solutions for water waste prevention

Multiple technological advances in water preservation are demonstrated in three case studies involving energy production, mining and electroplating.

Water use has been rising globally at a rate of 1 % a year for several decades, and this trend is not likely to change. In Europe, industry is one of the biggest users, responsible for more than 30 % of water consumption. Fresh water is needed to support many industrial practices, and often the wastewater generated is contaminated, posing a threat to the environment. With case studies in Germany, Greece and Spain, the EU-funded intelWATT project addresses both high consumption levels and water pollution concerns with a suite of technological advances applicable to diverse industries.

The aim is to recover up to 85+ % of chromium and copper and 50 % of nickel while preserving 95+ % of fresh water in a TRL 8 pilot unit..

Targeting energy production, mining and electroplating

The project targets three industries with significant water demands. Energy production, with a reliance on cooling towers, uses copious amounts of fresh water. Industrial brines generated from mining have untapped resource potential. And while electroplating has a more modest water usage than some industries, the metal-laden wastewaters present an environmental hazard. According to project coordinator Andreas Sapalidis from the National Centre for Scientific Research 'Demokritos' (Greece): "The main objective of the intelWATT project is to validate, at TRL 8, innovative and intelligent water treatment technologies combining freshwater preservation, resource recovery and energy conversion based on the circular economy concept."

The evaporating water in power plant cooling towers leaves behind minerals. Fresh water is used to remove the accretions in a process called cooling tower blow down (CTBD). By recycling CTBD water in the first case study, intelWATT aims to reduce water consumption by 99 %. In the second case study, which is focused on industrial mines, the project aims to recover water and valorise the brine stream. The pilot demonstrates harvesting salinity gradient power and recovering deionised water through membrane distillation. The third case demonstrates the recovery of valuable electrolytes and water preservation in an electroplating facility. The aim is to recover up to 85+ % of chromium and copper and 50 % of nickel while preserving 95+ % of fresh water in a TRL 8 pilot unit.

Smart water separation technologies

At the heart of intelWATT solutions are novel wastewater treatment processes and the application of AI mechanisms, Sapalidis says: "The intelWATT project has achieved considerable advances in a broad range of disciplines, specifically regarding materials, smart sensors, modelling, processes and pilot units."

Among the materials designed by intelWATT are several types of membranes used for filtration, distillation, reverse osmosis and electrodialysis. This collection of materials includes graphene-based membranes, an emerging tool in separation processes. The development of smart sensors supports communication and secure data transmission. Other smart technologies include machine learning algorithms that improve predictive modelling and smart monitoring that is expected to yield a 30 % reduction in energy demands. The project's advances in water treatment

processes, such as reverse osmosis, reverse electrodialysis and membrane crystallisation enable energy harvesting and material recovery in wastewater treatment.

The creation of AI-based pilot studies enabled intelWATT to develop multiple tools and processes for water management. The fact that the case studies are at a high technological readiness level is encouraging, as it indicates the possibility of rapid adoption by industry stakeholders and the advancement of a Europe-wide circular economy. The project's contributions to water preservation and resource recovery are significant and will help Europe safeguard water – one of society's most precious resources.

PROJECT
intelWATT - intelligent Water Treatment Technologies for water preservation combined with simultaneous energy production and material recovery in energy intensive industries

COORDINATED BY
National Centre for Scientific Research "Demokritos" in Greece

FUNDED UNDER
Horizon 2020-LEIT-ADVMANU

CORDIS FACTSHEET
cordis.europa.eu/project/id/958454

PROJECT WEBSITE
intelwatt.eu/

Turning an industrial byproduct into bio-sustainable chemicals

The EU-funded LIBERATE project has developed, demonstrated and validated a number of electrochemical-based processes for converting lignin into value-added products.

As one of the most abundant and renewable organic polymers found on Earth, lignin has the potential to be converted into a range of environmentally friendly, value-added products – including chemicals. A byproduct of the papermaking process, it is also a readily available polymer, with as much as 40 million tonnes being produced every year.

Unfortunately, instead of being used as the basis for creating sustainable chemicals, the vast majority of this lignin – up to 95 % – is incinerated as a low-value, high-polluting fuel.

The EU-funded LIBERATE project aims to change this by diverting lignin from incineration and, via selective electrochemistry, converting it into value-added products.

"The main objective of the project was to develop an electrochemical plant to demonstrate the commercial opportunities of converting low-cost lignin feedstock into high-value bio-sustainable chemicals," says Francisco Julia, project manager at the Leitat Technology Centre, the project's coordinating partner.

"In doing so, we will help the energy industry become less dependent on imported fuel and reduce its environmental footprint – all while promoting the circular economy."

From vanillin to chemicals

One of the project's key achievements was the development of an electrochemical pilot plant capable of converting lignin into vanillin and phenolic mixtures.

"Vanillin is the main chemical compound of the extract from the vanilla bean," explains Julia. "While most people know it as a flavouring agent, vanillin can also serve as a building block for producing chemicals."

With a focus on the building block aspect, researchers were able to obtain vanillin using an electrochemical and thermal depolymerisation process that oxidises and breaks lignin into small molecules. "Not only has this process achieved an impressive 8 % yield, it has also produced a phenolic mixture that can serve as an antioxidant and as a phenol substitution in phenol formaldehyde resins," adds Sonia Matencio Lloberas, senior researcher at Leitat.

The main objective of the project was to develop an electrochemical plant to demonstrate the commercial opportunities of converting low-cost lignin feedstock into high-value bio-sustainable chemicals.

All products validated by industrial end users

Project researchers also developed a process to electrochemically convert biogenic cyclohexanols, obtained from natural and sustainable sources, into a monomer called 3-propyladipic acid.

"This monomer opens a new window of sustainable precursors for polyamide and polyesters and will offer an attractive drop-in replacement for petrochemical monomers," notes Matencio Lloberas.

Last but not least, the project created a process to electrochemically convert organosolv lignin into a phenolic mixture. Products from all three processes have been fully validated by various industrial end users.

Mission accomplished, but more work ahead

The LIBERATE project did exactly what it set out to do: demonstrate the possibility of converting lignin feedstock into high-value bio-sustainable chemicals with significant commercial potential.

"Our success is the direct result of the strong cooperation of all the project partners who, together, were able to assess and overcome the main technical challenges when working with bio-based materials," remarks Matencio Lloberas.

While the project achieved most of its technical objectives, Matencio Lloberas says there's still more work to be done: "Further optimisation of the processes is required to improve their technoeconomic and resource efficiency."

PROJECT
LIBERATE – Lignin Biorefinery Approach using Electrochemical Flow

COORDINATED BY
Acondicionamiento Tarrasense Association in Spain

FUNDED UNDER
Horizon 2020-LEIT-ADVMANU

CORDIS FACTSHEET
cordis.europa.eu/project/id/820735

PROJECT WEBSITE
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New technologies make the production of manganese alloys more energy efficient

Units that preheat manganese ore with alternative energy sources lower the energy consumption of alloy production and reduce greenhouse gas emissions.

Manganese (Mn) is a common metal used in combination with other materials to make a variety of products, mainly as an addition to steel, a metal crucial for our modern life, but also batteries and ceramics. To produce Mn-alloys, oxygen in the ore must be removed. This requires a tremendous amount of energy. Mn-alloy is produced in a submerged arc furnace (SAF). Electrodes buried deep in the charge supply energy to melt and heat the ore to 1 500 oC and convert it to metal. The EU-funded PreMa project introduced a suite of technologies to reduce the environmental impact of Mn-alloy production.

Impact of the ore preheating

The project's goal was to reduce the amount of energy used to produce Mn-alloys while still using the existing furnace technology. By heating Mn ore to temperatures of between 800 and 900 oC prior to smelting and utilising off-gas to remove some of the oxygen, PreMa demonstrated up to 15 % reduction in energy consumption and up to 33 % drop in CO_2 emissions.

The PreMa consortium included Mn-alloy producers, researchers and academic institutions from Europe and South Africa, the world's leader in Mn ore extraction. By developing technologies that can be readily integrated with existing production facilities, PreMa increased the chance for rapid industrialisation. According to project coordinator Eli Ringdalen, SINTEF AS: "The preheating units can be built at the existing plants without a stop in production and for a lower cost than if a greenfield plant was needed."

New kiln and furnace design

Project partners designed a rotary kiln and a shaft furnace to preheat ore to the target temperatures. These technologies were identified as having the highest potential for industrialisation. A pilot rotary kiln was built and tested at two pilot sites. Due to challenges along the way, PreMa was able to design a suitable shaft furnace but was unable to build a pilot in the scope of the project.

Instead, PreMa changed its approach. Ringdalen says: "We demonstrated the behaviour of pre-treated ore through a series of kg-scale experiments in one set-up and heating and drying of Mn-ore in industrial sizes by warm gas in a shaft in another set-up and combined the results from these to evaluate pre-reduction of Mn-ore in shaft furnaces."

Alternative energy sources to fuel the new units

A key feature of PreMa's approach was using alternative forms of energy to power the rotary kilns and shaft furnaces. Mn-alloy production from ore that was already heated reduced the energy consumption of SAFs, and fuelling the pre-reduction units with renewable thermal solar or off-gases, an industrial by-product, further reduced the CO_2 emissions of Mn-alloy plants.

The investigated energy sources have the advantage that they are renewable and can be produced locally at the industrial plant. Both thermal solar and CO-rich industrial off-gas can be used for pre-treatment in separate units that can be built in existing Mn-alloy plants and coupled to existing Mn-alloy furnaces for final Mn-alloy production.

Designing units that can run on different fuel sources builds in flexibility. As Ringdalen notes: "The investigated energy sources have the advantage that they are renewable and can be produced locally at the industrial plant. Both thermal solar and CO-rich industrial off-gas can be used for pre-treatment in separate units that can be built in existing Mn-alloy plants and coupled to existing Mn-alloy furnaces for final Mn-alloy production."

Consortium partners included all the western European Mn-alloy producers as well as global leaders in Mn-alloy research. With the testing of rotary kilns, thermal solar power sources and the performance of off-gases for preheating ores, PreMa has set the stage for the rapid uptake of the energy-saving technologies it designed. Mn-alloys are an essential material of modern life, and PreMa's solutions contribute to decarbonising the steel industry value chain.

PROJECT

PreMa - Energy efficient, primary production of manganese ferroalloys through the application of novel energy systems in the drying and pre-heating of furnace feed materials.

COORDINATED BY

SINTEF in Norway

FUNDED UNDER

Horizon 2020-LEIT-ADVMANU

CORDIS FACTSHEET

cordis.europa.eu/project/id/820561

PROJECT WEBSITE

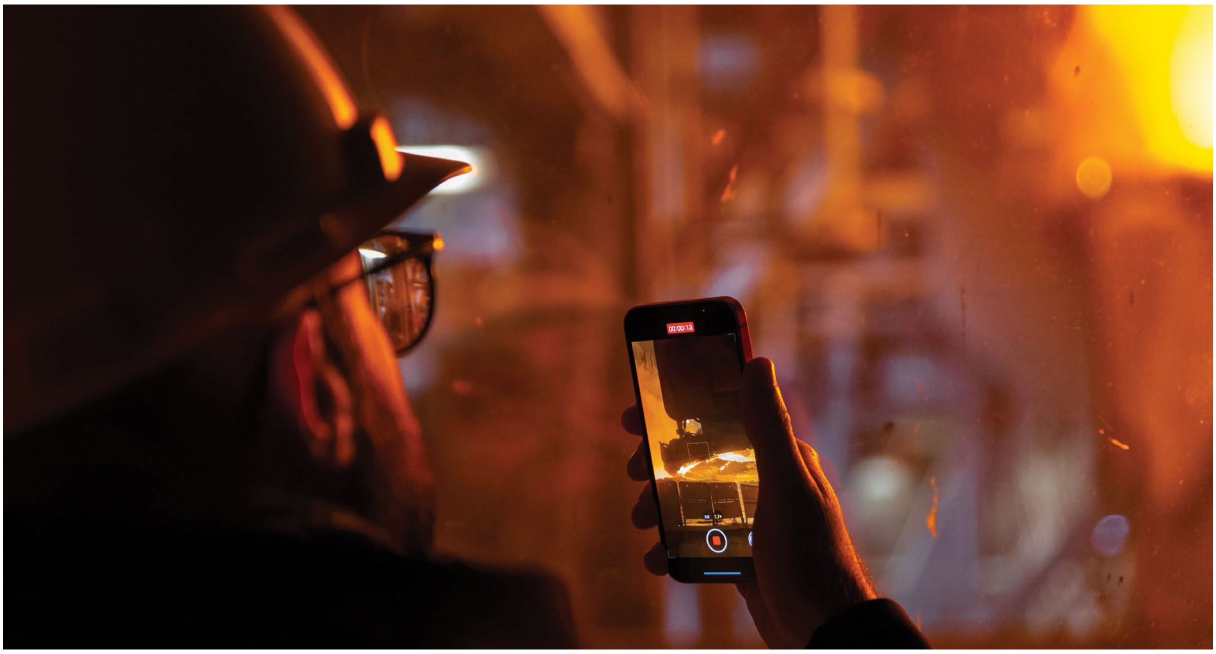
aspire2050.eu/prema

Tailor-made solutions for retrofitting of processes improve sustainability in diverse process industries

A decision support system and novel technologies have helped several energy-intensive industrial sectors reduce emissions and implement new circular economy solutions.

Energy-intensive industries (EIIs) require transformational changes to increase their sustainability. Aside from the technical challenges associated with these changes, industry can be faced with significant investment costs in implementing new technologies and methods.

The EU-funded RETROFEED project helped six EIIs in five key sectors – agrochemicals, aluminium, cement, ceramics and steel – reduce their environmental footprint with minimal investment. Their toolbox of tailor-made technological and digital solutions supported these industries in improving their use of energy and resources, even sourcing some materials from by-products and waste streams in a circular economy approach. And all of this was made possible by retrofitting core equipment, which lowered capital investment costs.



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Decision support for retrofitting options

RETROFEED deployed advanced models to enhance understanding of retrofit energy-intensive processes and leveraged them to develop a decision support system (DSS). The DSS not only helped users determine the best retrofit options for their case but also enabled improved operational efficiency and supply chain optimisation.

According to Roberto Arévalo of [CIRCE Technology Centre] and the project's technical coordinator: "The DSS was tailor-made for each industry and simulates the core processes." For example, many industries use carbon-rich petroleum coke (petcoke) as fuel. A cement company can assess the impact of replacing petcoke with an alternative renewable fuel such as biomass or refuse-derived fuel that is made from solid industrial waste. The tool tells them how much new fuel is required, its characteristics, how the processes are affected and the change in emissions.

Biobased fuels and a circular economy

Replacing petcoke with alternative resources, increasing efficiency and reducing fuel consumption enabled the EIIs to reduce emissions. For example, RETROFEED achieved a tremendous 59 % reduction in fossil resources use in the steel sector, overcoming challenges in finding biogenic carbon sources that fulfilled quality and safety requirements. They increased energy efficiency by 19 % in the aluminium sector.

On the materials side, highlights included the development and patenting of equipment to reuse scrap aluminium. Furthermore, the retrofit solutions reduced the amount of wasted product due to process inefficiencies in the ceramic industry. "Overall, resource efficiency was improved by 40 % in the steel sector, 33 % in the aluminium sector, about 20 % in the ceramic and cement sectors and 10 % in the agrochemical sector," notes Arévalo.

Importantly, productivity was improved in all cases: 37 % and 27 % in the aluminum and ceramic sectors respectively; about 10 % in the agrochemical and steel sectors; and 6 % in the cement sector. Operating expenses were reduced in all cases as well.

EIIs: modest relative changes have absolute long-term impact

"It is encouraging to see that even EIIs can reduce their CO_2 emissions with novel technologies. The circular economy concept applied in RETROFEED is no less important – there is no transformation process without a by-product so we must always search for valorisation of these," Arévalo concludes. And in EIIs, even modest percentage reductions in CO_2 emissions will have a significant impact on climate change mitigation. RETROFEED has provided decision support, digital control and optimisation tools, and other technologies to help diverse EIIs retrofit their processes for a greener future.

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PROJECT

RETROFEED - Implementation of a smart RETROfitting framework in the process industry towards its operation with variable, biobased and circular FEEDstock

COORDINATED BY

CIRCE Technology Centre in Spain

FUNDED UNDER

Horizon 2020-LEIT-ADVMANU

CORDIS FACTSHEET

cordis.europa.eu/project/id/869939

PROJECT WEBSITE

retrofeed.eu/

Retrofit sensors and advanced process control enable reuse of low-quality metal scrap

High-tech sensors for metal scrap characterisation together with decision support and process control tools are helping energy-intensive metal manufacturers reduce their environmental footprint.

European process industries, particularly energy-intensive industries (EIIs), consume tremendous amounts of energy and raw materials. In the metal making industry, recycling and reusing scrap metal can reduce both significantly. However, the industry faces challenges in processing increasingly variable metal scrap while ensuring an efficient use of energy and resources.

The EU-funded REVaMP project set out to address these issues with sensor technologies, decision support systems, and process monitoring and control tools. They helped the metal industry characterise their scrap – in bulk form for the first time – and process it accordingly to achieve high quality products with less materials and energy.

High-tech sensors enable metal scrap analysis in bulk form

Reforging metal is likely the world's oldest recycling practice – in use for more than 2 000 years. Today's metal processing plants use metal scrap as a secondary raw material in their melting processes. It is highly variable in composition, so manufacturers favour more expensive scrap types with known properties or even primary raw materials to ensure the quality of their final recycling products.

According to project coordinator Bernd Kleimt of BFI: "REVaMP developed in-line sensors based on prompt gamma neutron activation analysis (PGNAA) and on laser-induced breakdown spectroscopy (LIBS). PGNAA and LIBS were used for bulk analysis of metal scrap in large containers, for example trucks – something that had never been tried before." Together with statistical methods developed by the project partners, the sensors allowed a comprehensive characterisation of the scrap types in use. This will enable industries to use more of the cheaper, low-quality scrap while maintaining product quality.

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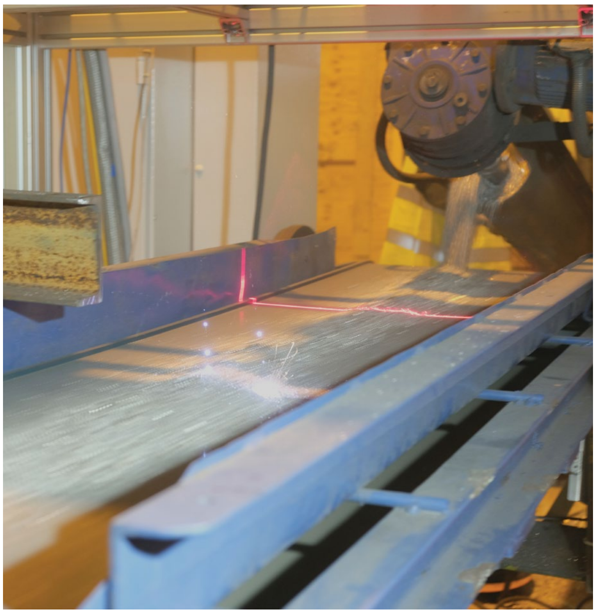
Sensors and ICT tools save energy and materials

"REVaMP's decision support systems determine the charge mix (material input to the furnace) with minimum costs for a given desired product quality using the actual characteristics of the scrap materials used. Our model-based control systems enable dynamic adaptation of energy and material inputs to meet the needs of each individual melt. This reduces the energy and resources used by the scrap melting furnaces," explains Kleimt.



In all three use cases – scrap-based electric steelmaking, aluminium refining and lead recycling – the use of the optimal charge mix tool and the model-based control system reduced energy consumption, emissions, materials' use, and the cost related to the materials. For example, in the aluminium refining sector, the melting furnace's natural gas consumption was reduced by about 15 % and CO_2 emissions by about 5 %. In addition, the costs related to pure alloy consumption were reduced by 3-18 %. Optimised selection of lead bullion in the lead recycling sector led to savings in alloy materials of about one tonne per year.

Easy replication in other EIIs

Most of the developed retrofitting technologies can be applied in other EIIs that use secondary raw materials as feedstock, either directly or with small adaptations.

Kleimt concludes: "REVaMP's outcomes strengthen the circularity of the metal making industry by enhancing the use of metal scrap and other metallic residues. The savings in primary raw materials and energy as well as production-related CO_2 emissions will help the EU fulfil its commitments in the context of the European Green Deal."

PROJECT

REVaMP - Retrofitting equipment for efficient use of variable feedstock in metal making processes

COORDINATED BY

BFI in Germany

FUNDED UNDER

Horizon 2020-LEIT-ADVMANU

CORDIS FACTSHEET

cordis.europa.eu/project/id/869882

PROJECT WEBSITE

revamp-project.eu/

Steel made with electricity offers great potential for large carbon emission reductions

EU-funded researchers have developed an R&D pilot for making steel without CO_2 emissions, leveraging electricity from renewable energy. This system marks a significant effort to transform a traditionally energy-intensive industry into a more environmentally sustainable sector.

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Producing iron is an energy-intensive operation because it involves separating iron from oxygen, which are tightly bound in naturally occurring minerals. At the same time, steel – an alloy of iron and carbon – plays a vital role in building the backbone of our energy infrastructure, from tools and engines to large-sized equipment. This cycle of producing steel and leveraging it into energy infrastructure feeds into itself, leading to both an increase in energy availability and the continuous growth of steel-based infrastructure.

Towards carbon-neutral steel manufacturing

Historically, the process of making steel from ores has relied entirely on energy from burning coal, a method that releases CO_2 into the atmosphere – and a practice that the EU-funded SIDERWIN project sought to change. To this end, it developed an R&D pilot at ArcelorMittal R&D campus' site in Maizières-lès-Metz (France)to validate the technology at TRL 6.

SIDERWIN's approach differed from traditional iron production methods in the step where iron oxide is reduced to metallic iron. In traditional steelmaking, this reduction occurs in a blast furnace through a process that involves high temperatures and carbon (usually in the form of coke). This process generates a significant amount of CO_2 as a by-product.

SIDERWIN eliminated the need for coke and the production of CO_2 associated with the chemical reduction in a blast furnace. "Our approach entails the use of an electrochemical process for the reduction step. This process involves passing an electric current through iron oxide in the presence of an electrolyte to directly convert it into metallic iron and oxygen gas, without involving high temperatures or carbon," notes project coordinator Valentine Weber.

What's more, given that SIDERWIN's process is powered by electricity, it offered the flexibility to use renewable energy sources, such as wind or solar power. This shift from a thermal and carbon-intensive process to an electrochemical one, potentially powered by clean energy, made it possible to produce iron with an even smaller environmental impact. "Our goal was to achieve carbon-neutral steel production by utilising electricity that is nearly 100 % free from carbon," highlights Weber.

SIDERWIN also explored how iron oxides generated as by-products from other industrial processes, such as the waste from the aluminium industry's Bayer process, could serve as raw materials.

Drastic emission reductions and significant cost savings

"By using electricity, it is possible to cut the carbon footprint of steel coil by 60 % in the near term and up to 74 % with a fully decarbonised electricity supply," states Weber. "Moreover, SIDERWIN technology could provide exceptional flexibility capacity to the European power grid, of up to 39 GW."

SIDERWIN technology could provide exceptional flexibility capacity to the European power grid, of up to 39 GW.

This adaptability not only helped balance the power system but also reduced the need for peak-load energy sources. "The flexibility of the SIDERWIN system can prevent around 6 million tonnes of direct CO_2 emissions annually at European level by replacing peak-load energy sources," notes Weber.

PROJECT

SIDERWIN - Development of new methodologies for industrial CO_2-free steel production by electrowinning

COORDINATED BY

Arcelormittal Maizières Research in France

FUNDED UNDER

Horizon 2020-LEIT-ADVMANU

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PROJECT WEBSITE

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Available online in six language versions: cordis.europa.eu/article/id/450530

Published
on behalf of the European Commission by CORDIS at the
Publications Office of the European Union
L-2985 Luxembourg
LUXEMBOURG

cordis@publications.europa.eu

This Results Pack is a collaboration between CORDIS and the European Health and Digital Executive Agency (HaDEA).

Print	ISBN 978-92-78-44148-7	ISSN 2599-8285	doi:10.2830/500055	ZZ-AK-24-013-EN-C
HTML	ISBN 978-92-78-44142-5	ISSN 2599-8293	doi:10.2830/110	ZZ-AK-24-013-EN-Q
PDF	ISBN 978-92-78-44146-3	ISSN 2599-8293	doi:10.2830/948726	ZZ-AK-24-013-EN-N

Luxembourg: Publications Office of the European Union, 2024

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