HI4S

CIRCULARITY IN ENERGY INTENSIVE INDUSTRIES

HEAT IT YOURSELF FOR SUSTAINABILITY

CIRCULARITY IN ENERGY INTENSIVE INDUSTRIES

LAYMAN'S REPORT

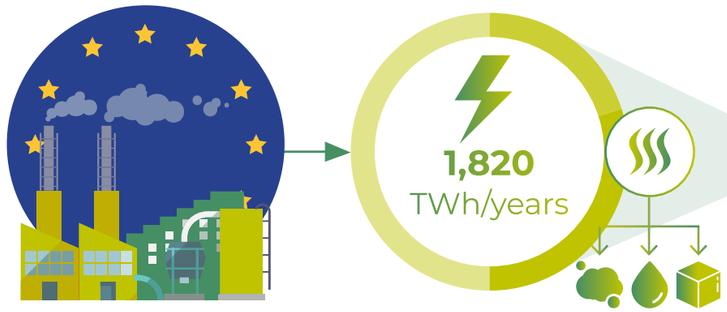
With the contribution of the LIFE Programme of the European Union
LIFE20 CCM/ES/001733

INDEX

LAYMAN'S REPORT

1. CONTEXT

The European Green Deal aims for a climate-neutral Europe by 2050, focusing on full economic decarbonization through advanced technologies that boost energy efficiency, especially in energy-intensive industries with significant waste heat.



Industrial processes in the EU consume **around 1,820 TWh of energy annually** (Eurostat 2015), **with 20–50% of this energy lost as waste heat through gases, liquids, or solids,** often requiring extra resources to cool before release.

While low-to-mid temperature waste heat recovery is mature, high-temperature or "dirty" streams (e.g. with pollutants or particles) remain challenging due to technical and cost barriers, requiring further innovation.

Energy-intensive industries (EIIs) like steel, cement, and foundries have high untapped recovery potential. **Studies suggest up to 15% of energy losses could be saved**.

The steel sector alone uses nearly 30% of EU industrial heat.

Electric arc furnaces (EAFs), which produce steel from scrap, are increasingly used - **making up 42% of EU steel production.**

A typical EAF consumes 704 kWh per tonne of steel, with 260 kWh lost as hot exhaust gases. Globally, **28% of steel (1,816 Mt in 2018) is made via EAFs**, highlighting major potential for heat recovery and efficiency improvements.

In addition, iron and steel industries are highly intensive not only in energy but also in materials consumption, which leads to a great amount of solid waste (e.g. steel slag). The landfilling of slags is a significant source of pollution of air, water and soil, since it may release heavy metals for a long time.

2. WHAT IS LIFE HI4S PROJECT?

51 MONTHS

2021 07/01 START DATE

2025 09/30 END DATE

2 COUNTRIES INVOLVED

2.7M BUDGET

1.5M EU LIFE PROGRAMME CONTRIBUTION

LIFE20 CCM/ES/001733 PROJECT CODE

8 PARTNERS

COORDINATOR: CIC energiGUNE (MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE) · ArcelorMittal · AZTERLAN (MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE) · enerbasque · Grupo Amper Fivemasa · SIDEA ENGINEERING SOLUTIONS · LCE

The LIFE HI4S project focused on the design, construction and validation of innovative, cost-effective plant that produces both heat and electricity by using waste heat from an Electric Arc Furnace (EAF) steelmaking, and steel slag as thermal energy storage (TES) material and energy balance optimization to reduce energy use. The goals is to achieve several impacts:

REDUCE **STEEL SLAG WASTAGE**

REDUCE **CO_2 EMISSIONS**

REDUCE **ENERGY CONSUMPTION**

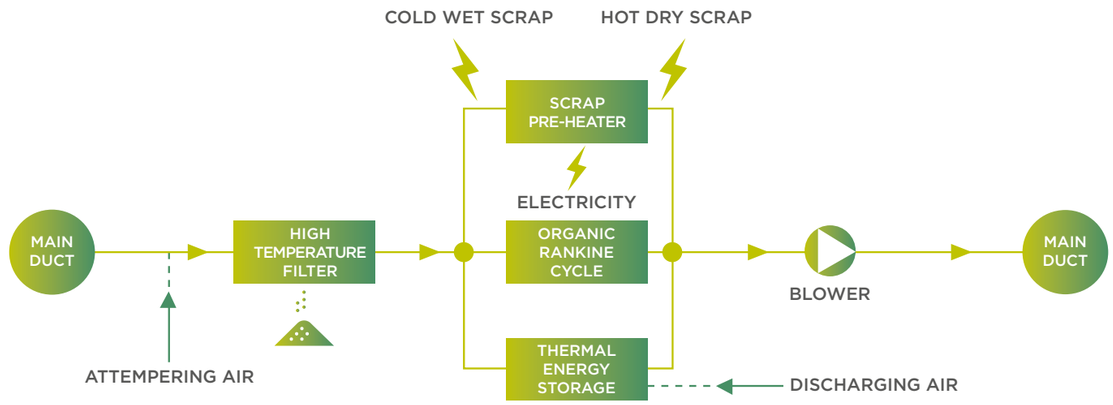
The designed LIFE HI4S system integrates several key technologies:

HIGH-TEMPERATURE CERAMIC FILTERING SYSTEM — to which the dirty waste heat stream is re-directed to remove solid particles and obtain a hot clean stream;

THERMAL ENERGY STORAGE SYSTEM (TES) — Inspired by the H2020 Reslag project, it uses steel slag as a thermal storage material to turn the variable nature of off-gas heat into homogeneous source of energy;

SCRAP DRYER — a container where steel scrap humidity is reduced using hot off-gas before it enters the furnace. This reduces the natural gas consumption associated with the conventional preheating of the scrap;

ORGANIC RANKINE CYCLE (ORC) — which is the equipment that converts the recovered thermal energy into electricity using a low-impact working fluid, supplying power to the steelmaking plant itself.



3. RESULTS

BIG MILESTONE FOR THE LIFE HI4S PILOT PLANT

The LIFE HI4S project has hit an exciting milestone, the successful start-up of the pilot plant at ArcelorMittal Sestao. This commissioning phase included both **cold tests** (to make sure all systems and components worked properly) and **hot tests** (to confirm the technology performs well under real operating conditions).

These first test runs proved that **the plant can capture and use the energy from Electric Arc Furnace (EAF) off-gases**, something that's never been done this directly or efficiently before, either in research or in industry.

During the first trials, the team was able to recover the heat from EAF exhaust gases and put it to good use in downstream processes. For the first time ever, **heat that used to go to waste has been successfully directly captured and transformed into valuable resource.**

The pilot plant also dried three tonnes of scrap metal — removing all moisture and heating it up to around 140 °C before it went into the furnace. This not only saves a lot of energy in the melting stage but also helps the furnace run more smoothly and efficiently.

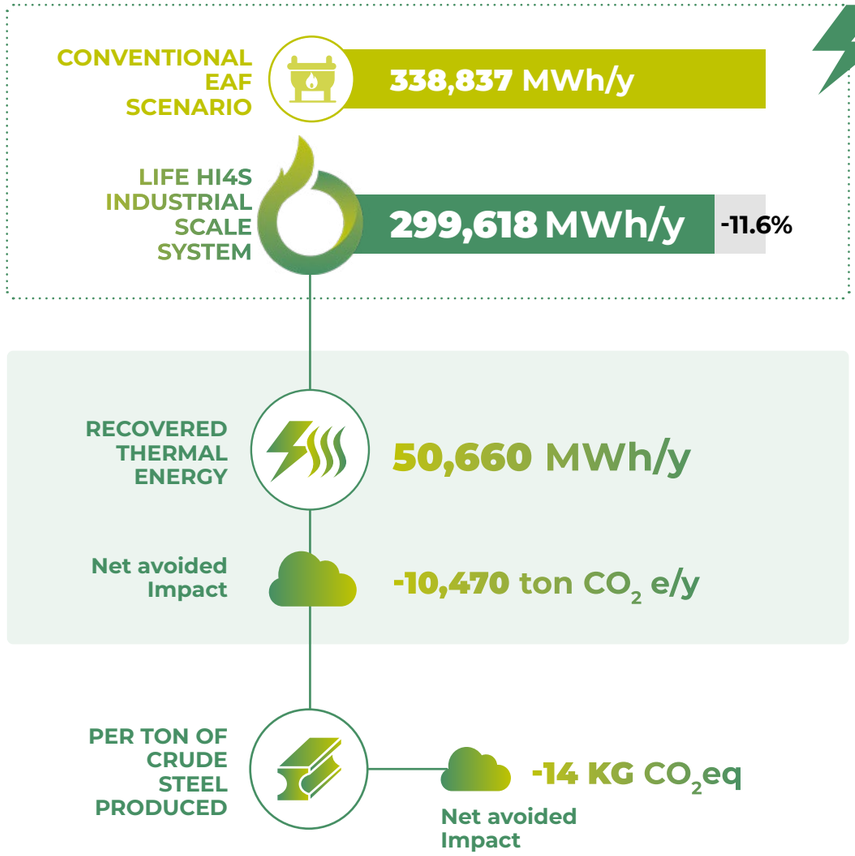
> After the LIFE HI4S project, **partners will continue to operate and monitor the pilot plant** while exploring replication opportunities within ArcelorMittal's European sites and other energy-intensive industries, with the major challengue being the upscaling of the technology.

3.1 ENVIRONMENTAL RESULTS

A Life Cycle Assessment (LCA) has been performed in order to analyse the energy and environmental benefits of using LIFE HI4S technology, by evaluating the environmental impacts associated with the project along its production, integration and operational stages, forming, together with the LCC and s-LCA, a comprehensive life cycle sustainability assessment framework.

The analysis compared two scenarios

- **A conventional steelmaking process using an Electric Arc Furnace (EAF)**;
- **A steelmaking process fully integrated with the LIFE HI4S technology**, considering both a small scale pilot plant, and an industrial-scale system.



Energy consumed for crude steel production of 750.000 ton/year considering 100% of the scrap is pre-heated

Energy reused in the LIFE HI4S system

3.2 ECONOMIC RESULTS

PAYBACK PERIOD OF THE LIFE HI4S INDUSTRIAL-SCALE SYSTEM

4.1 years

1.6 M€

YEARLY SAVING BY USING THE LIFE HI4S SYSTEM INSTEAD OF CONVENTIONAL EAF STEELMAKING PROCESS

VALUE OF LIFE HI4S SYSTEM INVESTMENTS THROUGHOUT ITS LIFETIME (25 YEARS)

17.5 M€

3.3 SOCIAL RESULTS

The Social Life Cycle Assessment (S-LCA) aims to evaluate the social implications of the LIFE HI4S pilot system, both by highlighting its potential benefits and drawbacks for stakeholders directly or indirectly affected by the innovation, and by providing an overview of the risks and opportunities along the value chain involved in the development, implementation, and operation of the technology.

The system under analysis includes not only the production and use of the pilot plant, but also the broader industrial and organizational context represented by the consortium.

In conclusion, the LIFE HI4S innovation demonstrates limited but relevant social impacts. While it does not significantly alter working conditions or offer direct benefits in terms of workplace environment, it enables **local employment opportunities** and **maintains safety standard levels** through appropriate risk mitigation.

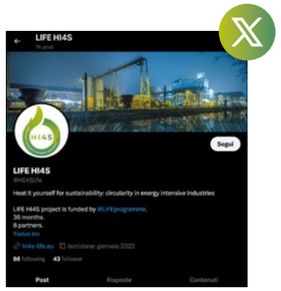
The achievement of TRL 8 without patent restrictions supports broad industrial uptake, fostering innovation dissemination across the European steel sector.

4. DISSEMINATION

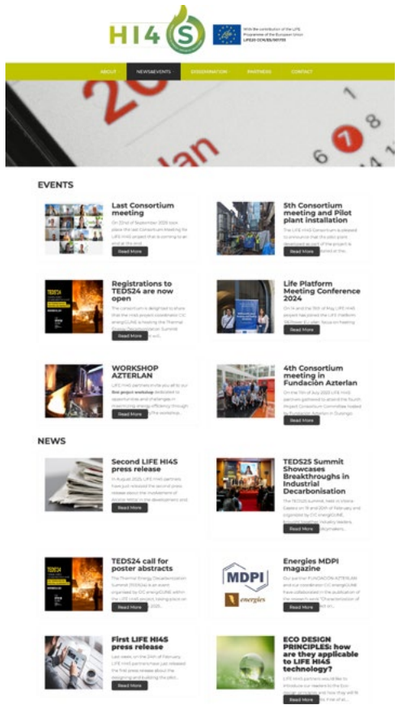
4.1 GENERAL AUDIENCE

During LIFE HI4S partners have been actively involved in communication and dissemination activities. **News, posters, newsletters, press releases, technical articles and social media posts** have been produced and published in order to reach general audience, stakeholders and targets. Through its activities the partners have reached **more than 6,000 visits on LIFE HI4S website** (https://www.hi4s-life.eu), 2,076 active users and more than 8,000 impression per year on LIFE HI4S LinkedIn profile.

SOCIAL MEDIA

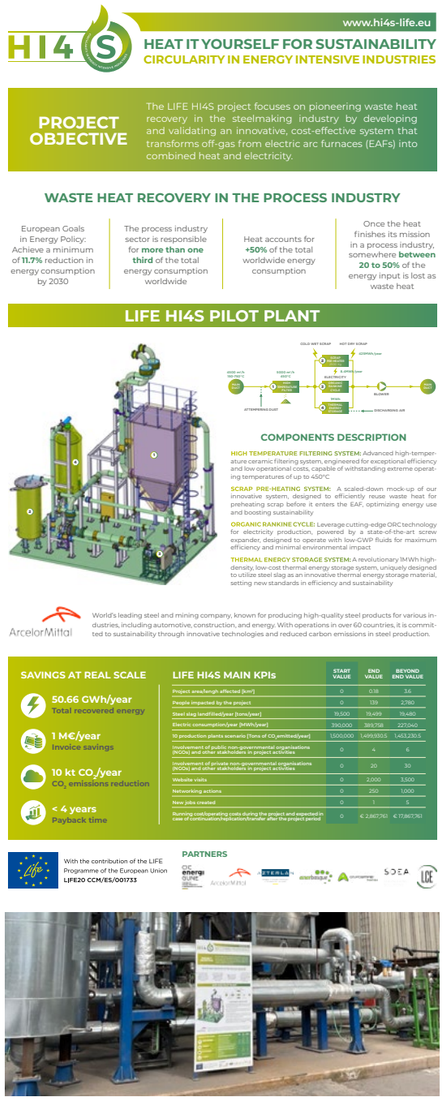


NEWS FROM WEBSITE



NEWSLETTERS

NOTICEBOARD



4.2 POTENTIAL USERS AND STAKEHOLDERS

LIFE HI4S dissemination activities have also been targeted to potential users to spread project results to grow partners' business. More than 1,500 experts from industry, research centers, and academia were reached through congresses participation and workshops organized by LIFE HI4S partners.

WORKSHOPS

WHEN 9th November 2023
WHERE Durango at Azterlan facilities
AUDIENCE 51 attendees

WORKSHOPS

WHEN 19th-20th February 2025
WHERE Alava Technology Park Central Building, in Vitoria-Gasteiz
AUDIENCE 91 attendees

CONGRESS

WHEN 12th-16th June 2023
WHERE Dusseldorf
EVENT 1st CONGRESS – **METEC ESTAD** attended by Erika Garitaonandia from Azterlan

WHEN 17th-21st July 2023
WHERE Muğla University (Convention Center), Akyaka, Muğla, Turkey
EVENT 2nd CONGRESS – **INESS** attended by Jaime Lozano from CIC energiGUNE

CONGRESS

WHEN 9th-11th August 2023
WHERE Brunel University in London
EVENT 3rd CONGRESS – **ICERT'23** attended by Daniel Bielsa from CIC energiGUNE

WHEN 23rd-26th September 2025
WHERE Almeria in Spain
EVENT 4th CONGRESS – **SolarPACES** attended by Ivan Torrano from CIC energiGUNE

4.3 PUBLICATIONS

Energies MDPI magazine

22nd March 2024

energies

MDPI

Article

Characterization of the Ratcheting Effect on the Filler Material of a Steel Slag-Based Thermal Energy Storage

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[2] Centre for Cooperative Research on Alternative Energies (CIC energiGUNE), Basque Research and Technology Alliance (BRTA), Albert Einstein 48, 01510 Vitoria-Gasteiz, Spain; parribalzaga@cicenergigune.com
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Abstract: Thermocline thermal energy storage systems play a crucial role in enhancing energy efficiency in energy-intensive industries. Among available technologies, air-based packed bed systems are promising due to their ability to utilize cost-effective materials. Recently, one of the most intriguing filler materials under study is steel slag, a byproduct of the steel industry. Steel slag offers affordability, ample availability without conflicting usage, stability at temperatures up to 1000 °C, compatibility with heat transfer fluids, and non-toxicity. Previous research demonstrated favorable thermophysical and mechanical properties. Nonetheless, a frequently overlooked aspect is the endurance of the slag particles, when exposed to both mechanical and thermal stresses across numerous charging and discharging cycles. Throughout the thermal cyclic process, the slag within the tank experiences substantial loads at elevated temperatures, undergoing thermal expansion and contraction. This phenomenon can result in the deterioration of individual particles and potential damage to the tank structure. However, assessing the extended performance of these systems is challenging due to the considerable time required for thermal cycles at a relevant scale. To address this issue, this paper introduces a specially designed fast testing apparatus, providing the corresponding testing results of a real-scale system over 15 years of operation.

Keywords: electric arc furnace; packed bed; steel slag; thermal endurance tests; thermal energy storage

check for updates

Citation: Garitaonandia, E.; Arribalzaga, P.; Miguel, I.; Bielsa, D. Characterization of the Ratcheting Effect on the Filler Material of a Steel Slag-Based Thermal Energy Storage. *Energies* **2024**, *17*, 1515. https://doi.org/10.3390/en17071515

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1. Introduction

The energy transition represents a strategic shift in the global energy sector, aiming to shift away from fossil fuels and achieve a carbon-neutral state by the latter half of this century. Its primary objective is the reduction of CO_2 emissions associated with energy production to combat climate change and advance toward a decarbonized economy [1]. In this transformation, the responsible utilization of various renewable energy sources (including bioenergy, geothermal, hydropower, ocean, solar, and wind energy) and the adoption of energy storage technologies are of paramount importance. These measures are essential to ensure a clean, reliable, cost-competitive energy supply, as well as the sustainable management of the energy market. Furthermore, in accordance with projections for societal and industrial development, the Energy Information Administration (EIA) has forecasted a 25% increase in energy demand for Organization for Economic Cooperation and Development (OECD) countries and an 88% increase for non-OECD countries by 2040 [2].

Solar thermal electricity, often referred to as Concentrated Solar Power (CSP), was one of the pioneers in the integration of high temperature Thermal Energy Storage (TES) systems, resulting in exceptional dispatchability, enhanced operational flexibility, and overall plant efficiency [3]. From here on, TES systems introduce an innovative concept

Interpresas – Energías

23rd June 2023

TECNOLOGÍA

CIC EnergiGUNE coordina el proyecto LIFE HI4S

Modelos digitales y reutilización de energía térmica: hacia una industria del metal sostenible

Jaime Lozano, ingeniero del grupo Ingeniería de sistemas y transferencia de tecnología, del área de almacenamiento y conversión de energía térmica de CIC EnergiGUNE 23/06/2023

1323

El proyecto LIFE HI4S se postula como una solución para mejorar la eficiencia de uno de los sectores que más contribuye a las emisiones de gases de efecto invernadero, como es la industria del metal, desarrollando una tecnología de tratamiento, recuperación y reutilización de la energía residual de este proceso industrial.

La industria del metal es reconocida por ser altamente intensiva, tanto en términos de energía como en consumo de materiales, lo que resulta en una gran cantidad de energía residual y residuos sólidos, como la escoria de acero. Esta situación plantea desafíos significativos en términos de sostenibilidad y eficiencia.

De ahí que, en respuesta a esta problemática, se hayan propuesto diversas tecnologías de recuperación de calor y reutilización de materiales para transformar este sector hacia un modelo más sostenible y económicamente viable.

Una de estas tecnologías, es la que propone el proyecto europeo LIFE Heat It Yourself For Sustainability (LIFE HI4S), el cual utiliza un gemelo digital para optimizar y escalar la tecnología ad hoc. Gracias al trabajo realizado hasta el momento, utilizando datos de precio de electricidad de Eurostat (0.2525 €/kWh), podemos considerar que, gracias a este trabajo de modelización y a una primera aproximación hacia la optimización de la operación de la planta, se han podido cuantificar ahorros superiores a 200.000 euros procesando solamente entre el 1-2% de los gases de escape; siendo, además, recuperados alrededor de 1,000 MWh de energía térmica y produciendo unos 20 MWh de electricidad neta.

Industria del metal

La industria del metal contribuye significativamente a las emisiones globales de efecto invernadero. Por ejemplo, en el año 2020, aproximadamente el 7% de las emisiones y el 11% del dióxido de carbono (CO_2), 3,6 gigatoneladas (36 seguido de 11 ceros), pertenecen a esta industria. Además, estos números, lejos de disminuir, continúan aumentando año tras año, impulsados por la creciente demanda mundial de acero.

Es importante destacar que el proceso de obtención de acero no es eficiente en términos de emisiones de CO_2 y energía por tonelada de acero producido. De hecho, se estima que se emiten 1.91 tCO_2/tacero y se consumen 21.31 GJ/tacero de media. Esta energía consumida representa entre un 20 y un 40% del precio total del acero producido, por lo que mejoras en la eficiencia repercutiría de manera significativa en el coste del producto final.

El proyecto europeo LIFE HI4S

El proyecto LIFE HI4S aborda esta situación desarrollando una tecnología de tratamiento, recuperación y reutilización de la energía residual de este proceso industrial. Esta energía recuperada se emplea en el precalentamiento de la chatarra que se usa como materia prima, y en la producción eléctrica mediante un ciclo Rankine orgánico (ORC por sus siglas en inglés). Además, estos elementos se complementan con un almacenamiento de energía térmica (TES — Thermal Energy Storage) basado en la tecnología packed bed, empleando escoria metálica tratada para el almacenamiento del calor, que hace frente a la intermitencia de la fuente de energía, funcionando como buffer y almacenamiento de bajo coste.

CIC energiGUNE es el coordinador de este proyecto europeo, contribuyendo también en varios objetivos técnicos parciales. Por un lado, el grupo de ingeniería de sistemas y transferencia tecnológica aporta su amplia experiencia con almacenamientos térmicos y transferencia de calor para el diseño de la planta piloto que se instalará en Arcelor Mittal en Sestao (Vizcaya, España). Además, se encarga del dimensionamiento y diseño del sistema de precalentamiento y caracterización del TES.

Steelx2

6th September 2025

Industry
~~data~~

ArcelorMittal Spain to boost steelmaking performance

September 6, 2025, 4:23 PM Source: Xiben Information

Summary: ArcelorMittal Spain is about to complete the commissioning of a pilot plant under the framework of the LIFE HI4S project funded by the European Commission, according to a company press release.

ArcelorMittal Spain is nearing commissioning of a pilot plant within the framework of the LIFE HI4S project, funded by the European Commission, that will recover heat from steel mill exhaust gases. The technology involves a ferrous slag-based regenerator that utilizes the energy after it is generated, thereby mitigating the cyclical nature of heat release from the steelmaking furnaces (the source of the exhaust gases).

The pilot plant was developed in collaboration with eight companies in the LIFE HI4S project, including ArcelorMittal Cestao and ArcelorMittal R&D. "Using the energy contained in the heat of steelmaking waste gases is an attractive approach in exploring strategies to reduce the carbon footprint of the steel industry," the source stated. "Approximately 25% of global energy consumption is used for industrial heating processes, of which 48% is used for high-temperature heating (over 400°C)." The four-year development project culminates in the commissioning of the pilot plant, which will allow part of the energy to be used for drying and/or preheating scrap before charging into electric arc furnaces.

Scheduled to start operations in September, the plant will be connected to the purification system at ArcelorMittal's Cestao plant, from which it will draw a portion of its gas flow. Impurities and particulates carried in the steel mill's exhaust gases require pre-filtration to protect the equipment through which the subsequent gas flows. Given the uneven temperature distribution of the exhaust gases from the furnace, the pilot plant is equipped with a Thermal Energy Storage (TES) to act as a buffer, providing a constant supply of heat.

El Canal Maritimo y Logistico

21st February 2025

Consorcio LIFE HI4S

Por primera vez, se ha puesto en marcha en una acería una innovadora planta piloto que combina la producción de calor y electricidad mediante un sistema de recuperación directa de calor. Esta instalación, única en su tipo, permite, en ambientes retadores de alta temperatura y alto contenido de polvo en humos, reducir significativamente el consumo energético al reutilizar el calor residual generado por los hornos de arco eléctrico. Con este avance, se abre una nueva vía hacia una mayor eficiencia energética y sostenibilidad en el sector siderúrgico.

Cabe recordar que el consorcio LIFE HI4S, coordinado por CIC energiGUNE, cuenta con la participación de otros seis socios: ArcelorMittal, Fivemasa, Enerbasque, Life Cycle Engineering-LCE, SDEA Solutions y Azterlan. En su conjunto, el proyecto prevé la consecución de sustanciales impactos ambientales, tales como la reducción de las emisiones de CO_2 de las acerías en 10.000 toneladas al año, lo que supondría el 6% de las emisiones totales de la siderurgia, o un ahorro de 1 M€ al año en el consumo energético.

Este fue el motivo por el que el representante de puerto de Baiona, Joxan Madinabeitia, participó de manera activa en las jornadas. Según explicó a El Canal, en las instalaciones portuarias vascofrancesas se encuentra la Chane Terminal Bayonne, antigua Alkion, dedicada al almacenamiento y manipulación de productos químicos, petrolíferos y betunes, además de dos plantas siderúrgicas: Laminoir des Landes (LDL) y Celsa, los mayores clientes en el puerto, sumando la mitad de los tráficos .

La experiencia de ArcelorMittal podría ser aplicable a estas dos empresas que, junto a otras instaladas en el puerto y dedicadas a los productos químicos y los fertilizantes, consumen tanta energía como el resto de la ciudad.

Madinabeitia señaló que "la experiencia ha sido muy positiva" en lo referido a las aplicaciones de nuevos desarrollos tecnológicos a las empresas implantadas en el puerto de Baiona. Para el futuro queda una visita de responsables técnicos del centro de investigación, de SDEA y de Kraftblock para valorar posibles intervenciones en la dársena vascofrancesa.

Retema – Energías
18nd June 2021

MENÚ

RETEMA
REVISTA TÉCNICA DE MEDIO AMBIENTE

La siderurgia podrá reutilizar el calor residual de los hornos

CIC energiGUNE construirá un prototipo de planta de regeneración de calor y producción de electricidad

3190 lecturas

La siderurgia podrá reutilizar el calor residual de los hornos

ENTIDAD
CIC ENERGIGUNE

18-06-2021

ETIQUETAS
CIC ENERGIGUNE

CIC energiGUNE, centro de investigación vasco referente en almacenamiento en baterías, soluciones de energía térmica e hidrógeno, y miembro de Basque Research & Technology Alliance-BRTA, coordinará la construcción de una **innovadora planta de producción combinada de calor y electricidad que permitirá a la siderurgia reutilizar el calor residual contenido en los humos de un horno de arco eléctrico**. La iniciativa se enmarca en el proyecto HI4S (Heat It yourself For Sustainability) que lidera el centro vasco, y será financiada con 1,5 millones de euros por la Unión Europea a través de su programa LIFE, dedicado al Medio Ambiente.

"La posibilidad de construir e instalar un prototipo a escala real en una planta siderúrgica a pleno rendimiento nos pone ante el mejor escenario posible para la validación del proyecto", ha manifestado Iñigo Ortega, Ingeniero asociado en CIC energiGUNE e Investigador principal del proyecto. "Además, estamos convencidos de que **no solo vamos a poder mejorar la gestión energética de la industria siderúrgica, sino de que les vamos a ayudar en otros campos,** como en la valorización de un subproducto sólido como es la escoria negra", ha añadido Daniel Bielsa, Coordinador de Tecnología de CIC energiGUNE.

Coordinado por CIC energiGUNE, el consorcio HI4S cuenta con la participación de otros seis socios: ArcelorMittal, Fivemasa, Enerbasque, Life Cycle Engineering-LCE, SDEA Solutions y Azterlan. Precisamente, **las instalaciones de ArcelorMittal en Sestao (Bizkaia) acogerán el prototipo de planta de recuperación**, con el objetivo de analizar sobre el terreno los beneficios medioambientales perseguidos y estudiar su replicabilidad en otras Industrias de Gran Consumo de Energía.

With the contribution of the LIFE
Programme of the European Union
LIFE20 CCM/ES/001733

www.hi4s-life.eu