ISSN 2599-8293

European Commission

CORDIS Results Pack on

waste heat valorisation

A thematic collection of innovative EU-funded research results

February 2022

Improving energy efficiency in process industries

Research and Innovation

SECOND EDITION

Contents

Editorial

Clean technologies developed by Horizon 2020-funded projects for reducing the impact of energy intensive industrial processes are helping Europe to transform into a sustainable, competitive economy and address environmental and climate-related challenges. This Results Pack highlights nine cutting-edge EU projects that are supporting this transition.

Energy represents up to 20 % of the total production costs for energy intensive industries in Europe, and even more for some industrial sectors. However, despite considerable technical progress in reducing energy consumption, a significant amount of the input energy is still lost in the form of waste heat.

Excess heat from certain processes can be a valuable resource for other processes within the industry and even for other industries or users, directly or after intermediate transformation steps.

Industrial waste heat recovery potential is still untapped due to a number of technical and non-technical barriers. Among them, the need for efficient and cost-effective technologies to recover heat losses and to re-use, upgrade or transform this heat for its valorisation.

Improved energy efficiency in industrial processes can lead to substantial primary energy savings, decarbonisation of the energy supply and subsequent reduction of CO_2 emissions. The reduction in energy cost will also enable greater competitiveness.

A more sustainable future

The projects presented below have developed and demonstrated innovative methods, solutions, technologies and operational practices to improve energy efficiency in industry, with a focus on the recovery and valorisation of waste heat from industrial processes.

These include heat recovery and storage, heat upgrading and heat to power conversion in different sectors. Many of the potential solutions for recovering unused heat are adaptable to various types of processes and can be replicated across several industrial sectors.

These initiatives support The European Strategic Energy Technology Plan (SET Plan), a key stepping-stone towards a climate neutral energy system through the development of low-carbon technologies, as well as the SPIRE public-private partnership roadmap and its follow-up Processes4Planet Partnership research agenda.

EU research highlighted

In this CORDIS Results Pack we focus on the innovative results developed by Horizon 2020-funded projects working to re-use waste heat from process industry. For example, TASIO created a new generation of direct heat exchange technology for commercial heat-to-power ORC systems in the cement, glass, steelmaking and petrochemical industries.

SUSPIRE developed novel highly efficient heat exchangers and thermal energy storage technology for reuse or commercialisation of waste heat, while VULKANO focused on thermal energy storage technology based on phase change materials that can recover and store high-temperature heat.

I-ThERM designed innovative plug-and-play heat recovery and conversion to power solutions with potential across a wide temperature spectrum, including the novel supercritical CO_2 cycle.

In some processes however, waste energy is of low quality and it is not practical or economical to recover it with current technologies. Indus3Es developed an innovative Absorption Heat Transformer that focused on low temperature heat recovery, and LOWUP demonstrated innovative heat pump technology that captures and upgrades heat energy.

DREAM pioneered the design of heat pipe heat exchangers to recapture the energy lost from kilns and transfer it to another point in the production chain. In a similar vein, ETEKINA designed novel heat pipe heat exchanger technology for recovery and management of heat from exhaust streams.

Finally, DryFiciency developed and successfully demonstrated two different industrial heat pump technologies that recover and reuse waste heat in industrial drying processes.

A novel direct heat exchange concept helps energy-intensive industries reuse waste heat

Industrial waste heat can be used to generate electricity or compressed air to support industry activities or be sold. EU-funded research has made harnessing the waste heat simpler, more efficient and more cost-effective.

Energy-intensive industries are important emitters of greenhouse gases in Europe, with the cement, chemical and steel sectors dominating industrial emissions. Finding solutions to drive down energy consumption and emissions is a top priority.

Exploiting waste heat fosters a circular economy and lower fossil fuel-derived-energy consumption and emissions. The EU-funded TASIO project set out to support that effort with a new generation of waste heat recovery technology targeting

energy-intensive industrial applications in the cement, glass, steelmaking and petrochemical industries, but equally useful elsewhere.

Eliminating the go-between

Waste heat recovery systems transfer the heat to a gas or liquid whose thermal energy can then be converted to electrical or mechanical energy. The generated energy can be consumed directly by the industrial plant where it is generated or connected to the grid.

The organic Rankine cycle (ORC) is ideal for waste heat recovery and reuse. Instead of water as in the ordinary Rankine cycle, it uses an organic fluid that has a much lower boiling point. The vapour powers a turbine that can be directly coupled to a generator to produce electricity or to a compressor to compress air for mechanical work.

TASIO was the first application of direct heat exchange-based ORC technology to energy-intensive industries. Compared to conventional ORC technology, it eliminates the intermediate heat transfer fluid, makes the process simpler, enhances heat transfer efficiency and reduces maintenance costs.

The ORC is typically implemented with indirect exchange of heat to the organic fluid via a heat transfer fluid. Direct heat exchange is the subject of intensive research within the automotive and transport sectors for exploitation of exhaust heat. However, as project coordinator Pedro Egizabal of TECNALIA explains, "TASIO was the first application of direct heat exchange-based ORC technology to energy-intensive industries. Compared to conventional ORC technology, it eliminates the intermediate heat transfer fluid, makes the process simpler, enhances heat transfer efficiency and reduces maintenance costs."

Powering a revolution in sustainability

Egizabal continues: "We successfully demonstrated the technical and economic feasibility of the direct heat exchange ORC technology to produce up to 2 megawatts of electric capacity in an operating cement plant. The system also reduced water consumption; lower operating temperature eliminates the need for a conditioning tower (with a high-pressure pump providing water to cool the waste gas)." Furthermore, the team validated a small-scale demonstrator of a 15 kW ORC module to generate compressed air.

Fundamental to project success was the development of new coating/steel substrate combinations for production of components for the higher-temperature conditions relative to a conventional ORC. Finally, researchers conducted feasibility and cost analyses associated with applying ORC technology to a pilot plant for the treatment of petrochemical sludge.

Incentivising a sustainability transition

Although energy-intensive industries account for more than half of the energy consumption of EU industry, they produce goods and materials that enable reduction of emissions in other sectors like transport, construction and power generation. They are also critical to many strategic value chains. Egizabal concludes: "TASIO has successfully used 'dirty' industrial processes and waste gases to produce electricity through sustainable ORC technology. Public policies and incentives that increase the use of such technologies will enhance the competitiveness and sustainability of these energy-intensive industries that have direct and indirect impact on job creation and the economy."

PROJECT
TASIO – Waste Heat Recovery for Power Valorisation with Organic Rankine Cycle Technology in Energy Intensive Industries

COORDINATED BY
TECNALIA, Spain

FUNDED UNDER
H2020

CORDIS FACTSHEET
cordis.europa.eu/project/id/637189

Waste not, gain big: Reusing industrial heat energy or selling it for a profit

Novel materials and methods help energy-intensive industries capture and reuse waste heat. Not only do they reduce energy consumption and emissions, but the excess can be sold, creating a win-win for industry and society.

© Jordi Hernando, ITPAERO

The industrial sector accounted for 37 % of total global final energy use and 24 % of global emissions in 2018. Between 20 % and 50 % of the energy used in industrial processes is lost as hot exhaust gases, cooling water, and heat losses from equipment and products. The EU-funded SUSPIRE project has exploited this significant opportunity for waste heat recovery and use, reducing overall energy consumption and emissions while providing the opportunity to sell excess energy.

Blazing a trail

Heat transfer fluids (HTFs) and phase change materials (PCMs) are integral to many heat management systems. HTFs transfer heat between materials and processes via heat exchangers. PCMs act as reversible heat storage systems, absorbing or releasing heat during phase changes like an ice cube melting or water freezing.

The use of residual energy recovery can break barriers between process industries and society, making their coexistence an opportunity rather than a threat.

According to Fernando Santos of Azterlan, technical project coordinator of SUSPIRE: “Although HTFs and PCMs have played an important role in solar power generating plants, they had not been exploited for capturing, transferring, and accumulating residual energy in process industrial plants prior to SUSPIRE.”

An energy efficiency cascade

SUSPIRE developed novel highly efficient heat exchangers combined with innovative PCMs and integrated those with a system for longer term storage and reuse or commercialisation. A silicon-based (inorganic) PCM stores heat from exhaust gases at temperatures higher that 500 ºC to be used for other energy-intensive processes in the same plant. An organic PCM in the heat exchanger through which the steam from a high-temperature industrial autoclave (Boilerclave®) passes allows the heat to be recycled back into the Boilerclave® for more steam generation.

SUSPIRE also exploited borehole thermal energy storage (BTES), taking advantage of the ground itself as the storage material. According to Santos, “SUSPIRE harnessed BTES to seasonally accumulate heat from equipment refrigeration systems and excess heat from SUSPIRE energy recovery systems. This heat can be used for room conditioning and office heating as required. It can also be commercialised and sold to third parties for heating purposes.” Finally, SUSPIRE developed tailor-made software to identify critical variables and adjust process parameters to reduce energy consumption due to scrap generation.

Everyone is a winner

The solutions were piloted at an investment casting company; process stages included wax mould making, shell building, dewaxing, firing, melting and pouring. Heating and cooling of office space was also included. The total energy savings achieved were approximately 16 %, a combination of reduced energy consumption and excess available for sale to third parties. A life-cycle assessment predicted a 22 % reduction in CO_2 emissions with the cascade of these technologies. Partner TELUR (site in Spanish) is currently negotiating sale of excess thermal energy to supply a local sports centre, which could slash its natural gas requirements in half. Several developments have far exceeded the planned technology readiness level and the SMEs are in various phases of negotiations and installation of their technologies with customers.

Many of the developments can be applied individually and are not limited to the process industry. The business model enables energy providers to invest in energy recovery and accumulation technologies in industrial plants and benefit by selling it to third parties like companies, sports arenas, or apartment complexes. This encourages investment, reduces emissions, and benefits the community. Santos concludes: “The use of residual energy recovery can break barriers between process industries and society, making their coexistence an opportunity rather than a threat.”

PROJECT
SUSPIRE – Sustainable Production of Industrial Recovered Energy using energy dissipative and storage technologies

COORDINATED BY
Precicast Bilbao SA, Spain

FUNDED UNDER
H2020

CORDIS FACTSHEET
cordis.europa.eu/project/id/680169

Whether warm like a summer day or hot as lava, industrial waste heat will be wasted no more

Industrial waste heat comes from many different sources, resulting in a huge operating temperature range to be accommodated by waste heat recovery and use technology. EU-funded innovation has something for everyone, and this solution's high market potential is making headlines.

Energy regulations are increasing in stringency with the goals of driving down emissions and enhancing sustainability and energy security. Waste heat recovery systems can offset the energy required by industries for their processes and, if not needed, can also be exported to electrical or heat distribution networks.

The EU-funded I-ThERM project set out to develop innovative plug-and-play waste heat recovery and conversion solutions with energy recovery potential across the temperature spectrum from 70 °C to 1 000 °C. The technologies will help Europe reduce its industrial energy consumption and emissions while also increasing its competitive position in numerous industries and in the large global waste heat recovery market.

A portfolio of plug-and-play products

Savvas Tassou, project coordinator and Director of the Institute of Energy Futures, Brunel University London, explains: "I-ThERM designed two heat recovery technologies for operating temperatures between 200 °C and 1 350 °C, and developed two heat-to-power technologies with operating temperatures between 70 °C and 1 000 °C. All four technologies are supported with continuous monitoring of key performance parameters and real-time automatic adjustment." The project also updated the EINSTEIN toolkit that enables quick assessment of the feasibility and economics of waste heat recovery and utilisation to include I-ThERM technologies.

I-ThERM developed two heat recovery technologies for operating temperatures between 200 °C and 1 350 °C, and two heat-to-power technologies with operating temperatures between 70 °C and 1 000 °C. All four technologies are supported with continuous monitoring of key performance parameters and real-time automatic adjustment.

I-ThERM's heat pipe condensing economiser (200-500 °C) is designed to increase the efficiency of heat recovery from boilers and other combustion exhausts. It can recover 10-25 % more energy than non-condensing economisers and is particularly well-suited to "dirty" and acidic exhausts in the petrochemical, cement, glass, steel and food industries. The iron and steel industry could benefit tremendously from the flat heat pipe system (FHPS) designed to recover radiant heat from products cooling on a conveyor from a temperature of 1 350 °C down to 300 °C.

The trilateral flash cycle (TFC) system is suitable for heat-to-power conversion from low-temperature waste heat streams (70-200 °C), particularly in the food and drink, pulp and paper, petrochemical and metal industries. The TFC system enables higher heat recovery potential and higher power output per unit heat input than conventional organic Rankine cycle systems. Finally, Tassou states, "the supercritical CO_2 (sCO_2) waste heat-to-power cycle is a unique technology and the first complete system to be operational in Europe. This technology targets high-temperature waste heat (400-1 000 °C) in the steel, cement, glass and petrochemical industries." Electrical power output of the TFC and sCO_2 technologies are 100 kilowatt-electric (kWe) and 50 kWe, respectively.


© Brunel University London, I-ThERM project

Innovation that gets noticed

Three of the four technologies were picked up by the European Commission's Innovation Radar, which identifies the most promising innovations and the innovators behind them and provides expert advice on reaching the market. Its goal is "creating a steady flow of promising tech companies that can scale up into future industrial champions," and I-ThERM's consortium is among them. Savvas summarises: "The FHPS, TFC and sCO_2 technologies are completely new, currently without direct competition and have been recognised by the Innovation Radar as having high market potential. The project has already led to significant interest in the TFC and sCO_2 technologies in Europe." For numerous industries in Europe and beyond, 'waste' heat may soon be a misnomer.

PROJECT
I-ThERM – Industrial Thermal Energy Recovery Conversion and Management

COORDINATED BY
Brunel University, United Kingdom

FUNDED UNDER
H2020

CORDIS FACTSHEET
cordis.europa.eu/project/id/680599

Once overlooked industrial energy recycling heats up

EU-funded researchers have developed a novel economically competitive technology that recovers low-temperature heat normally lost in industrial processes.

Heat makes up approximately two-thirds of the total energy use in industrial processes. Around one third of industrial energy demand is dissipated into the environment. Despite these impressive figures, there is insufficient investment in waste-heat recovery technologies. The reason is that most of this wasted energy is of low quality. Capturing low-grade heat for reuse elsewhere on an industrial plant is usually not practical or economically viable with current established technologies.

The EU-funded Indus3Es project has developed a low-cost system that rises to these challenges. Absorption heat transformers (AHT) maximise heat recovery at temperatures below 150 °C.

The system was installed and demonstrated in a real industrial environment, in Turkey-based petrochemical company Tüpraş. This is one of the first AHT deployments in Europe in recent years.

Waste heat recovery now viable for low temperatures

The key to making waste heat recovery technically and economically feasible is understanding the nature of the energy involved. The temperature distribution of waste heat depends on the type of industry. Overall, a large portion of waste heat has a temperature below 200 °C in most industries. Yet, economically viable heat recovery and revalorisation technologies have been limited primarily to medium-to-high-temperature waste-heat sources.

"The AHT developed within Indus3Es effectively recovers and revalues low-temperature waste heat at competitive costs. Using a waste steam of around 100 °C, it produces a higher-temperature stream, becoming reusable in refinery operations. Overall, it leverages about 50 % of low-temperature heat that would otherwise be discharged to the atmosphere," notes project researcher Asier Martinez-Urrutia.

General working principles

AHT have operation cycles opposite to those of absorption chillers, which use heat to generate cooling. Both consist of a condenser, an evaporator, an absorber and a generator. The difference is that the absorber and evaporator now operate at a high pressure and the condenser and generator at a low pressure.

The Indus3Es system can produce a high-temperature reusable heat source, with a temperature higher than that of the low-grade waste heat, lifting the temperature of the process stream from 65 ºC to 135 ºC.

Drawing on knowledge of absorption chiller operation, project researchers demonstrated several innovations in the developed system. These include the implementation of two adiabatic absorption operation modes, motor-less purge system for undesirable non-condensable gases and novel automatic control based on characteristic equation.

Getting the technology to the commercial stage

"Tapping industrial waste heat could reduce fossil fuel demands and improve efficiency of countless processes," notes Martinez-Urrutia. "Our AHT enables large energy efficiency increases in energy-intensive industries – especially in the chemical and pharmaceutical, pulp and paper, food and beverage, and refinery sectors."

Absorption heat transformer developed during Indus3Es effectively recovers and revalues low-temperature waste heat at competitive costs.

The first monitoring of the system operation showed promising results besides primary energy savings and CO_2 emissions reduction. "The payback period of the 200 kW system proved to be concretely less than 10 years, which is a very positive value for a first 200 kW capacity level prototype. According to our estimations, a ready-to-market equipment investment would be recovered in about 6 years," adds Martinez-Urrutia.

Researchers have now the objective of developing systems able to work at even bigger scales. Martinez-Urrutia concludes that "the payback period would be reduced to 2 years with an AHT of 1 MW". Achieving higher capacities would lead to a tremendous upsurge in the use of such an AHT in energy-intensive industries.

© Indus3Es Project

PROJECT
Indus3Es - High Temperature Solar-Heated Reactors for Industrial Production of Reactive Particulates

COORDINATED BY
TECNALIA, Spain

FUNDED UNDER
H2020

CORDIS FACTSHEET
cordis.europa.eu/project/id/680738

Cool ways of using low-grade energy from sewage and industrial wastewater

Lukewarm wastewater discharged by industries and higher-temperature effluent from underground sewer networks are excellent energy sources for space heating and cooling and countless industrial processes. An EU-funded project demonstrated technologies that capture the heat wastewater retains.

Sewage systems contain wastewater whose temperatures vary between 10 °C and 25 °C. This temperature permits economical operation of heat pumps for the heating (or cooling) of tertiary buildings, such as hospitals, hotels, swimming pools and malls.

Heating and cooling in buildings and industry account for half of the EU's energy consumption. According to 2019 figures from Eurostat, approximately 75 % of heating and cooling is still generated from fossil fuels. Gathering 13 partners from 7 European countries, the EU-funded LOWUP project has demonstrated innovative technologies that capture and reuse low-grade energy. Waste heat is an untapped resource that offers a step forward towards significantly reducing primary energy consumption and CO_2 emissions.

Flushing valuable heat out of sewers

As surprising as it may seem, beneath our feet is a hidden source of energy that has remained virtually unnoticed: domestic sewage. According to studies conducted in Germany and Switzerland, 3 % of all buildings could be supplied with heat (or cold) by harnessing heat from wastewater.

"Sewage systems contain wastewater whose temperatures vary between 10 °C and 25 °C. This temperature permits economical operation of heat pumps for the heating (or cooling) of tertiary buildings, such as hospitals, hotels, swimming pools and malls," notes Rafael Socorro, project coordinator.

Compared to other traditional energy sources for heat pumps (groundwater, geothermal heat, outdoor air), wastewater from residential drainage systems offers an ideal basis for heat recovery as it exhibits higher temperatures. The challenge is to combine a high-performance heat exchanger (which extracts heat from sewage) with a heat pump.

The innovative HEAT-LowUP solution relies on a hybrid heat exchanger developed by project partner Wasenco. The system recovers around 20–30 % heat from the wastewater going down the drain to heat water used in the kitchen and for laundry. It does so by consuming virtually no electricity thanks to a passive solution implemented.

Recovering heat from industrial wastewater

Project partners have also unveiled HP-LowUP – a solution that recovers heat from lukewarm wastewater produced by industrial processes. Key to the success has been a rotating heat exchanger developed by project partner Pozzi Leopoldo Srl.

© ACCIONA

"This type of heat exchanger is specifically designed to work with dirty effluents containing mechanical particulate, without losing efficiency. By holding a constant rotation of the exchanging surfaces (the discs), it can keep itself clean, requiring little-to-no maintenance," explains Socorro.

"Normally, heat exchangers tend to clog or foul when processing dirty fluids, which can impair the efficiency of wastewater energy recovery installations to a high degree. In the worst case, they can decrease the heat transmission performance of the heat exchanger by a factor of 2.5," adds Socorro.

Apart from the new heat exchanger design, researchers improved the expansion valve control which now has a higher heat transfer coefficient. They also introduced a new control system that offers more accurate feedback on the heat pump state.

HP-LowUP has not been put into practice yet, but first results in a tannery have shown great promise for its widespread use in an industrial environment. Low-temperature discharges (29 °C) were converted into usable pre-heated water (40 °C). "The largest part of the thermal power needed by the heat recovery plant (around 500 kW) was supplied by only consuming around 50 kW (stemming from the system's auxiliary instruments and the heat pump), resulting in an outstanding overall coefficient of performance. Assuming that the system is working 168 h/week for 48 weeks/year, it can recover 3 792 MW/year and avoid the emission of 1 250 tonnes/year of CO_2," concludes Socorro.

PROJECT
LOWUP – LOW valued energy sources UPgrading for buildings and industry uses

COORDINATED BY
ACCIONA CONSTRUCCION SA, Spain

FUNDED UNDER
H2020

CORDIS FACTSHEET
cordis.europa.eu/project/id/723930

PROJECT WEBSITE
lowup-h2020.eu/

Making ceramic production greener with waste heat recovery and new materials

Thanks to an EU-funded project, the EU ceramics industry will soon witness a series of technological innovations that could improve energy efficiency and lower its operating costs.

The ceramics industry plays a substantial role in the EU economy, driven by 17 000 companies, employing over 240 000 people, and producing nearly EUR 30 billion in revenue. However, the industry is also a big user of energy. In fact, producing just one tonne of ceramic tiles requires 1.67 MWh of energy.

Recovering waste heat from the kiln cooling zone to warm air for tile drying eliminates the need to burn natural gas.

"The ceramic tile production processes are very energy intensive. Nearly EUR 1 500 million are spent each year just for natural gas needs in the Italian ceramic sector. If we could increase the energy efficiency for producing a square metre of tiles by 2-3 %, we could witness a huge reduction on the annual costs of natural gas consumption," notes Gabriele Frignani, coordinator of the EU-funded DREAM project.

How heat pipes could slash natural gas costs

Project partners pioneered the design of heat pipe as heat exchangers to recapture the energy lost from kilns and transfer it to another point in the production chain. "Heat pipes recover waste heat from the cooling zone (160-200 °C) of roller kilns to supply air to driers or other thermal machinery, increasing also the process efficiency," explains Frignani.

"Recovering waste heat from the cooling zone to warm air for tile drying eliminates the need to burn natural gas. Overall, heat pipes contribute to reducing natural gas consumption of a drier by 4-5 %. This might sound a tiny amount, but translates to huge savings in terms of energy and costs," adds Frignani.

Another major advantage of using heat pipe technology is that the hot air that moves to the dryer is clean because there is no mixing between the air stemming from the heat exchanger and the potentially contaminated or corrosive exhaust air streams released by the kiln cooling chimney.

Innovative refractory and coating materials

Another interesting output from DREAM is the development of innovative refractory and insulation materials for ceramic kilns. Project partners tested innovative material shapes and compositions that reduce heat transmission through the kiln walls. The result was a reduction of the superficial temperature of kilns by an average of 10 °C.

"Heat transmission losses in kilns account for about 15 % of the thermal energy spent to fire each kilogramme of tile. This heat accounts more or less to 75 kcal/kg above a specific consumption of 500 kcal/kg of product. By reducing the superficial temperature of kilns through the new refractory and coating materials, we reduced heat losses by an average of 1.4 %," explains Frignani.

© Vershinin89, Shutterstock

Powering thermal machines through microturbines

For the first time, project partners investigated how the thermal energy (hot fumes) generated by microturbines could be directed to power the kiln or the drier. Use of microturbines makes sense in countries such as Italy, where the cost of electricity is significantly higher than that of natural gas.

Microturbines eliminate the need to burn significant amounts of natural gas for restarting the kiln after a shutdown because the kiln purging cycle is not needed (fans are also electrically supplied by the microturbine during shutdown). "Another plus is that the microturbine can be sized on the electrical needs of a single thermal machine so, from a fiscal point of view, an industry does not need to upload electricity on the public network, thus avoiding the energy taxation," concludes Frignani.

PROJECT
DREAM – Design for Resource and Energy efficiency in cerAMic kilns

COORDINATED BY
Sacmi Forni, Italy

FUNDED UNDER
H2020

CORDIS FACTSHEET
cordis.europa.eu/project/id/723641

PROJECT WEBSITE
spire2030.eu/dream

Eco-efficient industrial furnaces recover and store waste heat for when they need it

EU-funded researchers demonstrated advanced thermal energy storage technology for industrial furnaces that involves phase change materials that absorb heat as they melt and release it as they solidify. Recovering waste heat and using it to preheat furnaces can increase efficiency of industrial processes by 10 %.

Energy-intensive industries consume vast amounts of energy to power chemical, physical or mechanical processes. Massive amounts of all the energy used are squandered into the environment as waste heat – only a relatively small fraction of it is actually used for direct heating purposes or electricity generation. If the energy is there, then why not use it to further increase the efficiency of industrial processes?

How heat recovery could help save 300 TWh per year

Nowhere could waste heat recovery be more relevant than in the fossil fuel-fired heating and melting furnaces used in industries, particularly in applications involving metallurgy, glass and ceramics.

The largest amounts of heat loss are from the furnace exhaust – temperatures can even reach 1 600 °C. Although this is the most practical heat to recover and reuse, energy-intensive industries barely use this high-temperature heat to their benefit mainly due to technological or economic barriers.

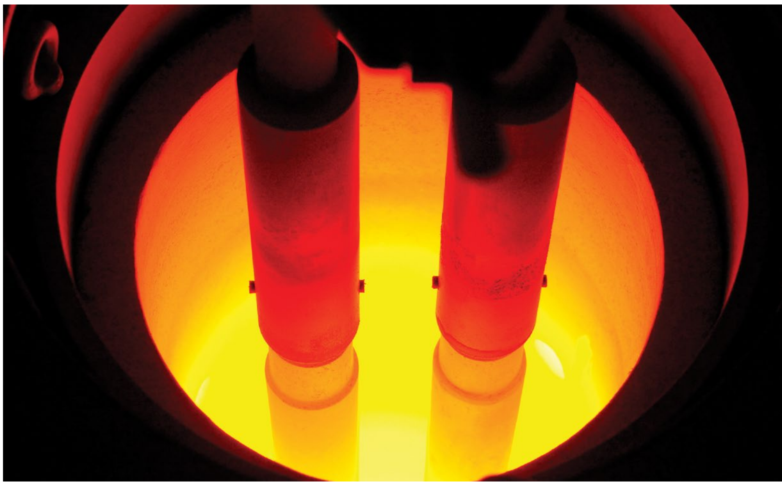
"Industrial plants in Europe could save around 300 TWh of waste heat per year," notes Patricia Royo, project manager at CIRCE Foundation. This translates to more than 250 million tonnes of CO_2 emission savings every year. Together with project partners from Germany, Spain, France, Italy, Poland, Slovenia, United Kingdom and Turkey, the Spain-based technology centre led the EU-funded VULKANO project.

Most of the promising work focused on thermal energy storage technology based on phase change materials that can recover and store high-temperature heat from sources above 1 000 °C. Their retrofitting thermal energy storage solution could help energy-intensive European industries increase the energy efficiency of their heating and melting furnaces by 10 %.

It is all in the phase

"The integration of thermal energy storage with phase change materials allows recovery and storage of waste heat from combustion gases or other surplus heat sources to preheat the air entering the furnace," explains Royo.

When a phase change material melts or solidifies, a great amount of energy is absorbed or released. This latent heat can be used when needed. "Compared to systems that rely on sensible heat, phase change materials have a high energy storage density, which makes them a more compact design option. Furthermore, they help maintain a nearly isothermal storage and increase the system flexibility. The heat storage could serve many purposes, such as preheating the combustion air going to the furnace inlet or increasing the load temperature.



© hramovnick, Shutterstock

Project partners tested their technology in a steel plant in Slovenia and reported exciting results. The system alone can save 351 MWh of thermal energy per year. Reusing the recovered thermal energy resulted in an increase in the combustion air of 200-300 °C in the project demos. Phase change materials could lead to an increase of the furnace energy efficiency by 5-12 % during the discharge phase.

Waste heat storage and recovery technology was only a part of VULKANO's advanced retrofitting integrated solution for eco-efficient and competitive furnaces. Other innovations include refractory materials, co-firing burners, monitoring and control systems and a holistic in-house predictive tool. "VULKANO's integrated retrofitting solutions offer a way to upgrade existing industrial furnaces," concludes Royo. "Annual energy savings could amount to EUR 100 000."

VULKANO's integrated retrofitting solutions offer a way to upgrade existing industrial furnaces. Annual energy savings could amount to EUR 100 000.

PROJECT
VULKANO - Novel integrated refurbishment solution as a key path towards creating eco-efficient and competitive furnaces

COORDINATED BY
Fundación CIRCE, Spain

FUNDED UNDER
H2020

CORDIS FACTSHEET
cordis.europa.eu/project/id/723803

PROJECT WEBSITE
vulkano-h2020.eu

Recycled factory heat benefits industries and the environment

Industrial processes account for more than a fourth of Europe's primary energy consumption and produce a tremendous amount of heat. EU funded research is closing the circle with novel systems that recover waste heat and return it for reuse in industrial process lines.

Most process heat is lost to the environment as exhaust or discharge streams. Recovering and reusing this heat reduces energy consumption, emissions and pollutants. It enables industries to reduce costs, meet regulations and improve their corporate images with broader impacts on competitiveness.

One of the greatest challenges is dealing with the immense variety of exhaust temperatures and constituents, which makes it difficult to use off-the-shelf heat exchangers. The EU-funded ETEKINA project has developed novel tailor-made heat pipe heat exchangers (HPHEs) successfully piloted in the ceramics, steel and aluminium industries.

© ETEKINA

A broad design space meets the needs of complex exhaust streams

Heat pipes are tubes sealed at both ends and containing a working fluid at saturation, meaning any increase in temperature will cause it to vaporise. They are used for heat management in applications from computers to satellites and spacecraft.

In an HPHE, the heat pipes are installed in bundles attached to a plate and placed in a casement. A heat source such as exhaust gas flows into the lower section. The working fluid vaporises and rises in the pipes, where a heat sink such as cool air flows into the top part of the shell and absorbs the heat. The enclosed structure minimises loss while the plate minimises cross-contamination between the exhaust gas and the air.

We have exceeded the project's target of a minimum of 40 % waste heat recovery from exhaust streams. Our Heat Pipe Heat Exchangers HPHEs are also much more compact than conventional heat exchangers, saving valuable factory space. In addition to their efficiency, which lowers costs and emission, they also have a short return on investment.

HPHEs require smaller surface areas for greater heat transfer relative to conventional approaches. This makes them very efficient and mitigates fouling. The challenge is choosing the parameters such that the greatest possible heat is recovered from complex waste streams. There are so many parameters, including the number, diameter, length and material of the heat pipes; their assembled configuration; and the working fluid.

From models to factories

Given the immense parameter space, computational fluid dynamics and transient system simulation (TRNSYS) modelling were developed to help scientists design bespoke HPHEs for three industrial applications.

For example, the crossflow, finned, fouling resistant HPHE (the fins increase surface area to augment heat transfer) designed to recover waste heat from a ceramics roller hearth kiln was the first ever in this configuration applied in the ceramics industry. The heat pipe shells were made of carbon steel and water was the working fluid.

"We have exceeded the project's target of a minimum of 40 % waste heat recovery from exhaust streams. Our HPHEs are also much more compact than conventional heat exchangers, saving valuable factory space. In addition to their efficiency, which lowers costs and emission, they also have a short return on investment," says Hussam Jouhara of Brunel University London and technical and scientific coordinator of the ETEKINA project. The systems successfully recovered heat with no cross-contamination and funnelled it back to the factory to be used in other processes.

The HPHE concept developed in the context of ETEKINA is highly scalable and can be adapted to any type of industrial exhaust over a large temperature range and for a variety of heat sinks, including air, water, and oil. A novel replicability tool will help quickly assess the waste heat recovery potential of future customers.

PROJECT
ETEKINA – HEAT PIPE TECHNOLOGY FOR THERMAL ENERGY RECOVERY IN INDUSTRIAL APPLICATIONS

COORDINATED BY
Ikerlan S. Coop, Spain

FUNDED UNDER
H2020

CORDIS FACTSHEET
cordis.europa.eu/project/id/768772

PROJECT WEBSITE
etekina.eu/

Cutting-edge heat pumps for more efficient energy use and fewer carbon emissions in manufacturing

In the EU, drying methods account for 10 % to 25 % of industrial energy consumption. Using heat pumps to recover and reuse waste heat in drying processes has enormous potential for the manufacturing industry's energy-intensive sectors.

Most of the energy currently utilised for drying is based on the use of fossil fuels. Natural gas burners are one notable example. Several industries are looking to switch from gas burners to industrial heat pumps.

Heat pumps increase both energy efficiency and renewable heat in the process industry. "Heat pumps are widely used in residential buildings," comments Veronika Wilk, thematic coordinator at the AIT Austrian Institute of Technology's Center for Energy, responsible for coordinating the EU-funded DryFiciency project. "However, this is not the case with industrial applications."

Efficient heat recovery technology

The DryFiciency project team developed and successfully demonstrated two different industrial heat pump technologies that turn waste heat into useable heat at temperatures reaching 160 °C. Waste heat is the energy that is not used. Consequently, it is lost, wasted or dumped on the environment. The heat pumps reuse this heat. The elevated temperature makes the technology applicable to a variety of industrial procedures. The

heat pump solutions can be used in the food and beverage, ceramic, pulp and paper, textile and chemical industries, to name a few.

By the end of August 2021, each of the project's two closed loop heat pump systems had already been in operation for around 4 000 hours. Compared to conventional natural gas burners, the heat pump demonstrators led to energy savings of up to 80 % and a decrease in carbon emissions of about 80 %. In addition to these benefits, electric drying with heat pumps can reduce industrial end users' production costs by as much as 20 %.

The heat pumps' technical possibilities were unknown to many industrial end users but also relevant intermediaries, such as energy consultants, plant designers and engineers, or dryer manufacturers, aiming to increase efficiency of their processes.

With the use of a third heat pump system, more than 100 tonnes of biomass have been dried. This resulted in improvements of over 75 % in the dryer's efficiency and capacity while reducing energy consumption by 70 %.

Paving the way for market uptake

Before DryFiciency, there was little awareness of industrial heat pumps in general and high temperature heat pumps in particular. Understanding waste heat's potential and incorporating high temperature heat pumps was limited. "Their technical possibilities were unknown to many industrial end users, but also relevant intermediaries such as energy consultants, plant designers and engineers, or dryer manufacturers aiming to increase efficiency of their processes," explains Wilk.

Thanks to DryFiciency, heat pumps are now present in many potential industrial clients' plans. Furthermore, dryer manufacturers are very interested in improving the efficiency of their drying systems by integrating heat pumps. Sander Geelen, a member of the project's External Experts Advisory Board and CEO of Geelen Counterflow, intensified collaboration with the DryFiciency partners. As of October 2021, the Dutch company had sold three fully electric dryers to China, Norway and South Korea.

Interestingly, project partners have calculated the impact if half of all industrial drying processes in the EU used heat pumps. The contributions to 2030 climate targets in line with the EU Green Deal objectives would be considerable. Lowering energy consumption by 107 to 268 terawatt hours represents 7 % to 18 % of the final energy consumption reduction still needed to comply with EU climate targets. The heat pumps would also lower carbon emissions by 27 to 66 million tonnes per year, contributing 3 % to 7 % of the emission reduction required by 2030 in the EU.

PROJECT
DryFiciency – Waste Heat Recovery in Industrial Drying Processes

COORDINATED BY
AIT Austrian Institute of Technology GmbH, Austria

FUNDED UNDER
H2020

CORDIS FACTSHEET
cordis.europa.eu/project/id/723576

PROJECT WEBSITE
dryficiency.eu/

CORDIS Results Pack

Available online in 6 language versions: cordis.europa.eu/article/id/422033

Published
on behalf of the European Commission by CORDIS at the
Publications Office of the European Union
2, rue Mercier
2985 Luxembourg
LUXEMBOURG

cordis@publications.europa.eu

Editorial coordination
Birgit BEN YEDDER, Silvia FEKETOVÁ

This Results Pack is a collaboration between CORDIS and the European Climate, Infrastructure and Environment Executive Agency (CINEA).

Print	ISBN 978-92-78-42676-7	ISSN 2599-8285	doi:10.2830/632510	ZZ-AK-21-013-EN-C
HTML	ISBN 978-92-78-42710-8	ISSN 2599-8293	doi:10.2830/64923	ZZ-AK-21-013-EN-Q
PDF	ISBN 978-92-78-42677-4	ISSN 2599-8293	doi:10.2830/380172	ZZ-AK-21-013-EN-N

Luxembourg: Publications Office of the European Union, 2022

RESULTS PACK ON CONSTRUCTION SKILLS

Europe's building stock is a major source of carbon emissions and energy expenditure. Transforming it can contribute significantly to the goals of the European Green Deal, but this can only happen if Europe has the skilled and qualified professionals to do so. This CORDIS Results Pack highlights six EU-funded projects working within the BUILD UP Skills initiative, a programme which provides innovative training and new skills to the construction industry.

Check out the Pack at:
cordis.europa.eu/article/id/430447

Publications Office
of the European Union

Follow us on social media too!
facebook.com/EUresearchResults
twitter.com/CORDIS_EU
youtube.com/CORDISdotEU
instagram.com/cordis_eu

EN