LIFE HEAT – R

Waste heat valorization by modular thermoelectric recovery system for resource efficiency in energy intensive industries

HEAT – R
AEinnova
LIFE project

AEInnova
Alternative
Energy Innovations

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THE PROJECT

Project location	Project duration	Project budget	EU contribution
Catalonia, Spain	From 01.01.2018 to 31.12.2021	1.061.019€	636.611€

Data beneficiary

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THE CHALLENGE

Historically, **energy** has been predominantly used among the industrial sector for diverse purposes, including machinery powering and process heating. In fact, as much as **27%** of the European Union's aggregated energy consumption is deployed to the big industries, which are currently facing a broad array of challenges including increasing energy dependency, limited supplies, as well as high and volatile energy prices. Under these circumstances, while researchers argue that energy is one of the most important inputs driving economic development and the globe undergoes strong population growth translating into higher demand levels, the need for industrial energy consumption continues to rise in line with greenhouse gas emissions (GHG).

As a result, **energy efficiency** in the industrial sector remains an important factor to be addressed, considering that the sector loses up to **65%** of its energy consumption in the form of heat. According to research, at least **20%** of such lost heat could be recovered through the implementation of energy harvesting techniques. Bearing in mind the particular focus on global measures to fight against climate change, the big industry plays a crucial role in the decarbonization of the economy through the reduction of energy demand (and thus, carbon emissions) via the increase of energy efficiency, which shall become the main pillar on which industries build their green energy transition strategies as a means to achieve sustainability in the sector.

The average EU industry energy consumption is 3200 EU TW/year

Source: Eurostat, 2019

27%

The industrial sector accounted for 27% of the European Union's total energy consumption

Source: Eurostat, 2020

The average EU industrial heat consumption is 1820 EU TW/year

Source: Eurostat, 2019

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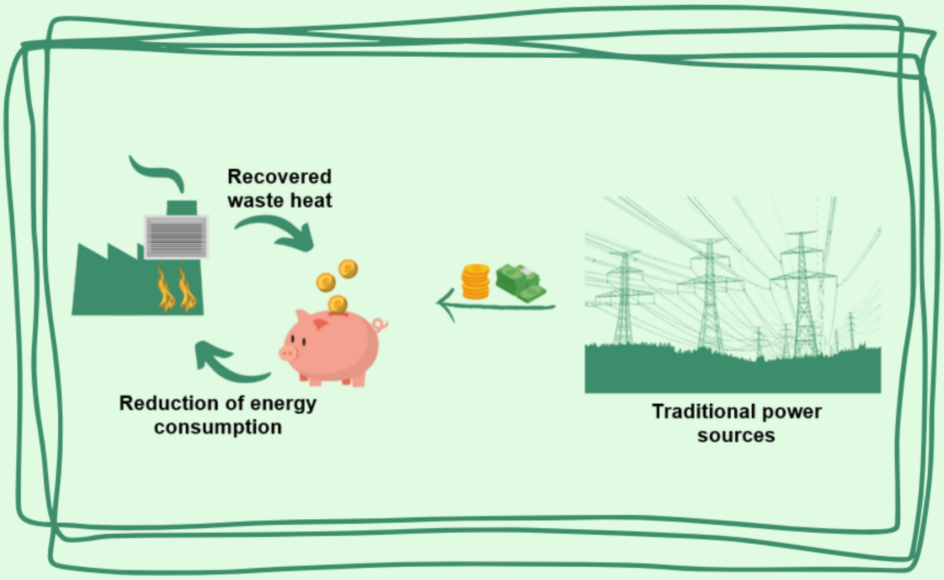
OUR SOLUTION

By assessing the availability of waste heat in industrial surroundings and the potential to recover it, the moment to turn the switch has arrived – and AEInnova has developed the solution to tackle the challenge: the *Waste Heat Recovery Unit* (WHRU). The device is composed of a set of thermoelectric batteries and controlled with our awarded patented microelectronic system which together are able to harvest residual heat from hot surfaces in the industry and convert it into clean electricity for new deployment through the Seebeck effect.



The system is based on **energy harvesting** as an alternative sustainable power resource replacing traditional ones. The presence of waste heat as a byproduct of most industrial processes promotes the opportunity of implementing environmentally friendly technologies that will save energy, CO_2 emissions and economic costs for the industry.

Operating principle

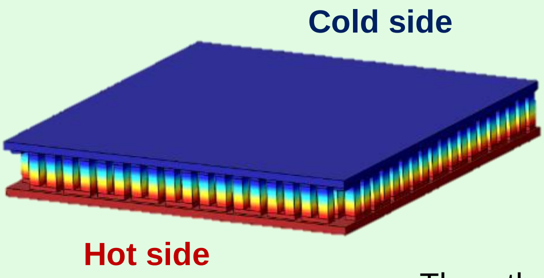


Figure 1: Peltier cell

AEInnova's WHRU is based on three thermoelectric principles called the Seebeck effect, the Peltier effect and the Thomson effect that together result in the thermoelectric effect.

The thermoelectric effect consists of the generation of electricity by creating a **temperature difference** between the two different sides of the Peltier cell. For this reason, the WHRU device incorporates a thermoelectric generator (TEG) composed of several Peltier cells responsible for capturing residual heat from potential heat sources and cooling it down to generate the necessary temperature difference for electricity generation.

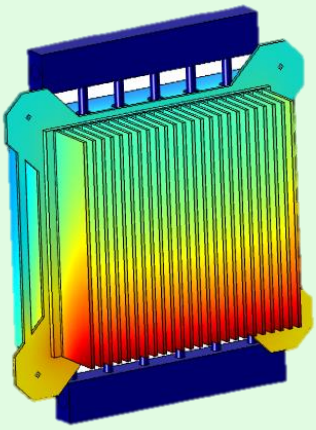


Figure 2: Peltier cell

The application of this principle is pictured in figure 2, where a representation of the functioning of the WHRU solution is presented, with a hot side capturing heat through a heat sink and a cold side refrigerated by water.

The acquired technological knowledge since its foundation and the important development steps that the company has taken have allowed AEInnova to patent its thermoelectric power generating system in Europe, the United States and Canada, with publication number WO/2016/174002 respectively.

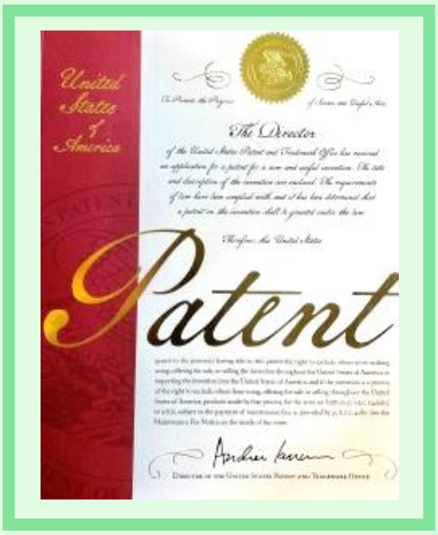


Figure 3: United States patent

The electronics of the device have similarly played a fundamental role in maximizing its performance. Thanks to AEInnova's R&D activities, two electronic features of our patented system shall be highlighted:

Figure 4: WHRU electronics

(1) The functioning of Peltier cells individually (or in small groups) to optimize their performance and avoid power losses that occur when cells are joined.

(2) The simplification of the associated electronics allowing us to calculate the power before the converter (input power) and the power after the converter (output power), yielding as a result the supply of useful constant voltage.

Device features

Figure 5: installed WHRUs

- Clean and sustainable energy
- No maintenance
- Ease of installation (Plug&Play)
- Fully scalable and monitored
- ATEX and CE compliant

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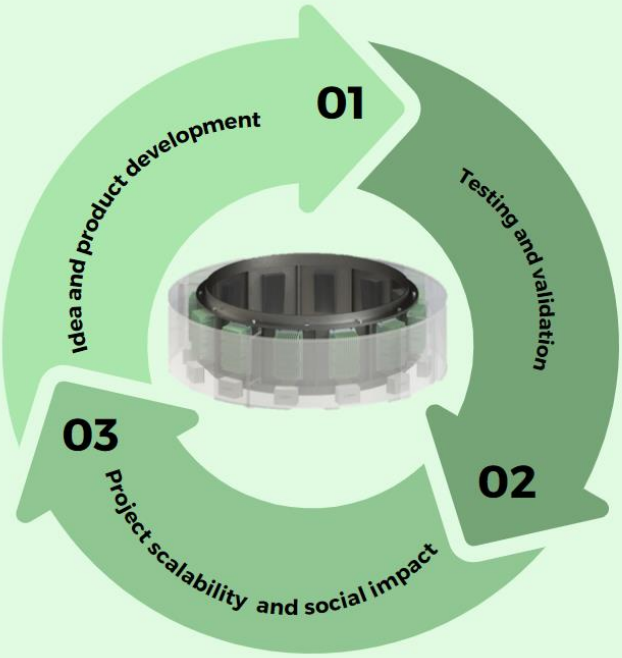
OBJECTIVES

HEAT-R mainly aims at providing a breakthrough in Energy Harvesting (EH) solutions, particularly gearing towards heat recovery in heat-intensive industries, by applying an innovative solution for the efficient management of energy overcoming current technological limitations.

The project is based on the demonstration, at industrial level, of the performance of the device across several industries operating under different temperature ranges. This is going to allow AEInnova to get the full product validation according to customers' needs and market demand, which will certainly become the starting point of our go-to-market strategy supporting the scale-up of the technology at a wider scope through economies of scale.

On the other hand, AEInnova intends to influence behaviour in resource efficiency and generating sustainability awareness in industrial operations. Amidst the unquestionable disruption triggered by Industry 4.0, AEInnova's approach to the challenge is focused on shifting the global mindset from exploiting scarce energy resources to exploring abundant alternative resources such as waste heat.



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IMPLEMENTATION

Even though the initial objective of the HEAT-R project was to apply the developed technology in three industry sectors through the installation of three pilot projects, AEInnova's ambition in the project led to the final installation of five pilot projects tested in five different industries, which was possible thanks to the engagement of five companies – CELSA GROUP, Distiller S.A., Familia Torres, Cementos Molins and Gomà-Camps.

Collaborative companies

The greater quantity of pilot projects has been beneficial for the company to dispose of a larger amount of business cases and information regarding device performance across a wider range of industries, as well as obtaining client feedback and gaining further knowledge about each sector's requirements.

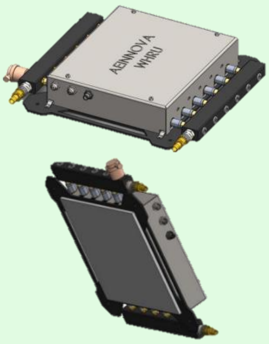
CELSA GROUP

Iron and Steel industry

CELSA group is a Catalan family company and one of the leading European multinationals in long steel products, particularly focused on the production of low-emission circular steel.

The installation of the WHRU in CELSA's manufacturing plant was designed to capture residual heat from the beam blanks in their cooling process.

After understanding CELSA's unwillingness to install the technology right above the beam blanks for greater heat capturing, it was necessary to come up with an alternative solution. Hence, AEInnova designed a metal plate, supported by a metal pillar, intended to catch the radiation emitted by the hot beams in the nearby area (with an approximate distance of 50cm from the ejection zone).



Due to the technical complexity of CELSA's pilot installation and the delay in its implementation as a consequence of the COVID-19 pandemic, AEInnova was not able to obtain conclusive data about the performance of the device.

Figure 6: location of the metal plate

Figures 7 and 8: Metal plate with WHRU system

Figure 9: WHRU

DISTILLER S.A.

Waste management industry

Distiller S.A. is a leading company in the treatment and management of industrial waste, as well as in solvent valorization and water treatment.

Given that thermal oil is used to supply the necessary heat to perform the distillation processes, the factory has thermal oil boilers to heat and recirculate oil. Due to its temperature, AEInnova identified the thermal oil boiler chimney as the optimal installation place for the WHRU system in Distiller S.A.

Working temperature: 130 – 220ºC

Energy generated: 479,30 kWh/year

Power density: 565,80 W/m^2

Figure 10: WHRU

Figure 11: WHRU installation

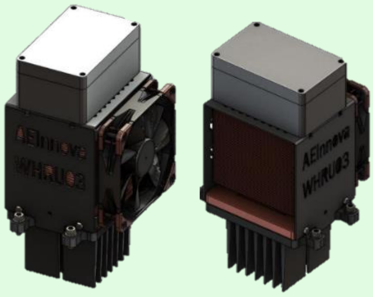
Figure 12: chimney for WHRU installation

FAMILIA TORRES

Wine industry

Since its origins as a family business, Familia Torres has combined tradition and innovation to become a differentiated benchmark in the wine sector operating globally in more than 150 countries.

In the framework of sustainability and as one of their core values, Bodegas Torres is committed to guaranteeing a sustainable production model through the use of biomass boilers to eliminate waste and generate eco-friendly fuel. Therefore, the purpose of the WHRU installed in Torres' facilities is to recover part of the residual heat generated in the combustion process of the biomass boiler located at La Bodega Waltraud.



Working temperature: 150 – 300ºC

Energy generated: 75,56 kWh/year

Power density: 102,33 W/m^2

Figure 13: WHRU device

Figure 14: Heat sink inside the boiler

Figure 15: Boiler for WHRU installation

CEMENTOS MOLINS S.A.

Cement industry

Cementos Molins is another Catalan company focused on exploiting the quarries and producing limestone and natural cement.

Ranked as one of the industries with highest operating temperatures, the cement sector requires huge amounts of heat for the clinker transformation process, which eventually reaches temperatures of 1.540ºC. Part of this heat is later transferred to the outside of the wall, where the temperature is around 200ºC. Because of this, AEInnova's heat collector of the WHRU was installed in the wall of the rotary kiln close to the burner, where heat is obtained by conduction.

Working temperature: 191 – 213ºC

Energy generated: 47,6 kWh/year

Power density: 31,82 W/m^2

Figure 16: WHRU system

Figure 17: installed WHRU system

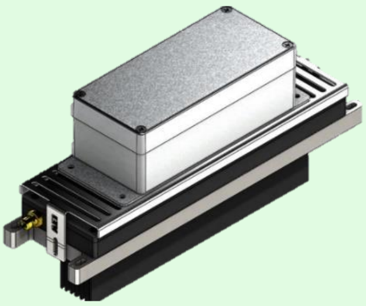
Figure 18: Wall of the rotatory kiln

GOMÀ-CAMPS

Paper and Pulp industry

Gomà-Camps is a Catalan company specialized in the manufacturing of high-quality tissue paper and other related solutions while embracing high sustainability standards.

Pulp and paper production is a water-intensive manufacturing process, causing the later need to dry the products by using vast amounts of hot air from both a drying cylinder and a hood. For this reason, the optimal installation area of the WHRU in Gomà-Camps was found to be the chimney dryer so as to recover part of the residual heat generated in the paper dryer.



Working temperature: 130 – 220ºC

Energy generated: 153,30 kWh/year

Power density: 329,40 W/m^2

Figure 19: Chimney dryer

Figure 20: decagonal WHRU system

Figure 21: installed WHRU device

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CONCLUSION

The HEAT-R project has been a relevant strategic tool to validate the Thermoelectric Waste Heat Recovery technology through business cases, focusing on pilot projects located in energy and heat - intensive sectors. Likewise, the project also allowed us to test different technological approaches to find the best market approach to implement and disseminate the HEAT-R solution while gaining a better understanding of the needs of industrial companies regarding energy efficiency and what drives them to invest in energy efficiency technologies. In this sense, we have identified as main future motivators a payback lower than five years, high energy consumption yet low energy efficiency levels and tight energy regulations towards environmental protection.

The more realistic approach from the technological point of view is a Water-Cooled device in direct contact with the waste heat source. We find this combination in the Distiller pilot (WOGA BOILER), reaching a power density of 565,80 W/m^2 and an efficiency of 4,24%. On the opposite, the pilots where the waste heat was not in direct contact with our device (such as the one in CELSA) did not reach the minimum efficiency to make the product commercially viable due to inefficiencies in the heat transfer process. Therefore, after analyzing the different scenarios overseen through the project, we can define four use-cases where the technology can clearly fit in: Steam Boilers, Woga Boilers, Yankee Dryers, and clinker Kilns.

Even though feedback from adopters has been positive regarding the technology itself and its performance, there is still no willingness to pay for the device since there is no clear motivation to acquire such technological solutions for energy efficiency.

We conclude that the technology is not yet ready for commercialization. There are two main issues to be solved; the need for new, more powerful thermoelectric generating elements (which will probably be available in 2 to 5 years) and an overall cost reduction of the device that can be achieved by scaling up the production. However, the current complex situation of energy markets with rising energy prices is definitely going to change the technology adoption rate – on the one hand, the reduction in payback is evident as we have raised the different scenarios with an average cost of the energy between 25€ MWh and 40€ MWh. On the other hand, new regulations to accelerate the green energy transition and increase energy efficiency to reduce the impact of GHG's will help motivate the industry to put more effort into installing new technologies through their sustainability journey.