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H-REII Heat Recovery in Energy Intensive Industries
PROJECT CO-FINANCED BY THE LIFE+ PROGRAMME OF THE EUROPEAN COMMISSION

Summary

In 2009 a group of actors make awarded that a lot of waste heat from the energy intensive industries processes is wasted in the atmosphere. In parallel a lot of renewable energy investments are rapidly growing thanks to a hard policy commitment by EU-27 member states and to dedicated policies and incentives.

Waste heat recovery is not considered as "renewable" (as happen in some US countries) and there is a lack of policies and incentives to promote this "energy efficiency" field. Furthermore other barriers as lack of knowledge and of a stable legal framework, financial issues, and lack of best practices contribute to reinforce this situation. Technology is not a barrier, because it's available and ready for the market.

So in 2009 the partnership promoted a LIFE+ project with a bottom-up approach, kicked-off after the approval in 2010. The efficient collaboration among the partners led to the **achievement** of all the expected results – both from the technical and the dissemination point of view. From some aspects the HREII partnership arrived even further the original scope.

Starting from an existing industrial technology affirmed in the biomass sector, the ORC - Organic Rankine Cycle, the partners develop a pilot model to estimate the waste heat recovery potential in energy intensive sectors (steel, cement, glass, …), give a national potential dimension, promote specific policies, disseminate Best references and case study (more than 60 events during the project) and make conditions ready for an hard industrial investment plan. The positive expected longer term results are:

- more sustainability of energy intensive industries (less CO2, less energy consumption…);
- more competitiveness;
- the promotion of new industrial filed of excellence, for the EU-27 market and the foreign one.

Demonstration Activities

HREII is the first EU project that has mapped the waste heat recovery potential in Energy Intensive Industries.

In a first phase, preliminary analyses have been carried out for Iron and Steel, Glass and Cement Industries. This evaluation allowed understanding of the high potential of heat recovery in these three energy intensive sectors. These analyses consist of the elaboration of the collected data in some industries of these sectors, by the means of "energy audit model", trough specific software, aimed to estimate the potential of the installable ORC based heat recovery system. After that, the elaborated data was matched with the National Plan of CO_2 assigned in order to estimate the total sector potential.

These preliminary analyses have been carried out to individuate the more interesting industries in these three sectors for developing a detailed monitoring analysis; concerning the other sectors a similar analysis have been developed, but just considering the bigger industries of the different sectors. In fact,

considering the higher consumption of glass, cement and steel industries, the more interesting industries in which developing the monitoring analyses are included in these three sectors.

The collection of detailed data for studying the real heat recovery potential has been executed in different energy intensive industries.

To collect the detailed data of the industrial processes, the instruments already installed in the energy intensive industries for the exhaust treatment and monitoring have been exploited. As foreseen, the data collection has been developed for 10 companies:

- non-ferrous – pig iron (analysis of the flow rate and temperature of the heat source, thermal oil, used for cooling down the exhaust gas, through a flux-meter). A dedicated study, carried out by a company specialized in measurement, has been developed, because the instruments installed by the plant owner are not reliable.
- cement

2 different plants of the same company in the north of Italy (three different operating conditions has been analyzed).

- iron and steel

Brescia (survey of the methane consumption of the oven and also of the temperature of the exhaust gas in three point of the oven – survey developed each 10' for 10 days).

- iron and steel

Lonato (survey of the exhaust gas flow rate and temperature – survey developed each minute for 14 days);

Calvisano (survey of the exhaust gas flow rate and temperature – survey developed in each minute for 12 hours. Also historical data was collected).

- cement (different operating conditions have been analyzed. For better covering as more cases as possible; the limits operating conditions, positive and negative, have been considered).
- non-ferrous – copper (different operating conditions have been analyzed).
- non-ferrous – copper (three different operating condition, based on the different load of the plant, during one year has been considered).
- non-ferrous – aluminum (three different heat sources – dry ovens, rotator ovens, salt waste - have been evaluated for permitting to define the best solution as possible combining these sources).
- petrochemical (different operating conditions of the plant have been considered).
- non-ferrous – aluminum (a detailed report of each furnace exhaust characteristics has been carried out by the furnace supplier).

During the considered period we took contacts with a major copper tubes manufacturer in order to check heat recovery possibilities from furnaces: audit analysis shows no effective opportunity, due to the limited quantity of wasted heat.

A "kit" presenting the project to potential investigable industries has been set up. This “kit” is composed by three key-documents which explain the H-REII project and the energy efficiency solution under investigation:

- a presentation letter to explain in a few words the H-REII project and the aim of the energy audit.
- a short description of the heat recovery technology.
- a data collection sheet to collect the data of the exploitable heat sources.

Usually the energy audits have been realized in different steps. The "kit" is used for establish a first contact with the energy intensive industry and for collecting the main data of the available heat source, after that, an examination of these preliminary data must be carried out to establish the potential of the project. Done this preliminary evaluation, a detailed energy audit must be realized, to define the heat source characteristics and elaborate the study of the potential of the ORC based heat recovery system.
50 companies have been contacted during the H-REII project: 4 companies have shown no interest in developing the energy audit; 46 have shown their availability and interest to develop the energy audit and 46 energy audits have been completed (29 preliminary analysis and 17 detailed studies). The realized audits are recorded in a dedicated schedule, which evolved during the implementation of the project.

The audit results permit to acquire a lot of information about the applicability of the heat recovery solution in the different industrial processes analyzed, having a more detailed picture about the compatibility between heat recovery and the industrial sectors. The information and the data acquired with the audit has permitted to support the definition of the compatibility index attributed to the sector with real data, giving to this number a more concrete value.
To define the potential of the heat recovery system, the collected data have been elaborated trough a technical tool, edited by Turboden with undisclosed technical specifications, which simulates the ORC based heat recovery system giving as output the potential of the system. The tool requires in input the data of the heat source (collected through the energy audit) and with them it simulates the thermodynamic cycle at the base of the ORC system; this simulation elaborates the parameters of the thermodynamic cycle and give as output the potential of the ORC system.
Additionally for complete the evaluation of the system two others tools have been implemented:

- a preliminary technical-economic tool has been developed; this instrument allows analyzing the preliminary feasibility and the cost-efficiency of the plants;
- an interactive diagram of the ORC potential has been developed; this tool permits to represent in a graphic view (Cartesian diagram input data/ORC system potential) the potential of the ORC system.

Finally, to present the results obtained to the industry investigated others two tools have been developed, one for the positive cases (positive case means that the heat recovery plant based on ORC technology is

employable in the company examined) and the other for the negative cases. These tools are two interactive templates filled by the input and output data of the previous described tools; therefore we have verified and validated these tools applying them to the audit realized.

Several tools for the preliminary feasibility survey have been carried out for both positive and negative result of the analysis (positive result means that the heat recovery plant based on ORC technology is employable in the company examined). Through these tools, 50 companies have been contacted: 46 have shown their availability and interest to develop the energy audit and 46 energy audits have been completed (29 preliminary analysis and 17 detailed studies).

This pilot model has been also tested and implemented in Austria, according to the project proposal, with the aim to test the pilot model in another country and to disseminate at EU level the potential of heat recovery applications and emphasize the relevant impact that these energy efficiency solutions could have on energy savings and CO2 emissions.

In order to achieve these important results, as foreseen in the project proposal, collaboration with a specialized Austrian engineering company has been signed, thanks to its local knowledge/presence.

To replicate the pilot model developed in Italy, the specialized Austrian engineering company has followed the same approach, which can be divided in two phases:

1. in the first phase it has carried out a preliminary analysis of the interesting Austrian energy intensive industries, selecting the industries in which there is a higher potential for employing an ORC based heat recovery system. Thanks to the data collected during this preliminary analysis it has selected about 10 companies with a higher potential for employing an ORC based heat recovery system;
2. in the second phase, it has developed a detailed analysis in the 10 companies identified, carrying out technical/economic reports.

Additionally, in order to define the real potential of these energy efficiency solutions in Austria, it has analyzed the Austrian policy in term of policy actions and incentives (considering the complexity of the policy structure in the different EU member states, the role of the specialized Austrian engineering company has been really important for carrying out a good policy analysis in Austria).

We also underline the strategic opportunity to involve an Austrian actor in the project: Austria represents today one of the most important hubs for the gas distribution in Europe, with a strong presence of gas compressor stations and devices. It's an opportunity to investigate the Oil&Gas sector, with great EU's potential waste heat recovery.

This can be considered a sort of "standard result" of the pilot analysis model we have developed with the H-REII project, therefore it could be considered as result format in case the model will be replicated in other countries.

HREII instrument: compatibility coefficient.

The compatibility coefficient has been inserted in the Energy Intensive Industries List (EII List) as a qualitative indication to define a priority between the different sectors identified as interesting for heat recovery applications.

Due to the fact that the compatibility coefficient has been inserted in the EII List during the project it has been defined in two different ways depending on the availability of one or more audits in the industrial sector under analysis:

- If one (or more) of the factories belong to the industrial sector under analysis had been investigated, the compatibility coefficient has been defined based on the audit(s) result;
- If no one factory of the industrial sector had been investigated, the compatibility coefficient has been defined considering the information collected about the sector during the definition of the Energy Intensive Industries list.

The considered elements in the compatibility coefficient are:

- Presence or absence of heat recovery in internal process; where 1 indicates the total absence of heat recovery systems for the process and 3 the presence of heat recovery systems internal to the process that highly reduce the availability of thermal power.
- Access to heat source without invasive procedures for the process; where 1 is referred to the case with one discharge point for all the exhaust with an easier access (for instance, a single chimney where it is easy to install a heat exchanger) and 3 is referred to a case with multiple discharge points for the exhaust gases.
- Hours of operation per year; where 1 is referred to an amount of hours per year which ranges between 6.000 and 8.500 h/y and 3 for an amount between 1.000 and 4.000 h/y.
- Technical parameters of heat source: temperature and flow rate. Concerning temperature, 1 is referred to a temperature higher than 300°C and 3 to a temperature lower than 230°C. Regarding flow rate, the value between 1 and 3 is defined considering the temperature, in order to attribute a 1 to flow rates that permit to achieve a high thermal power (> 3 MWt) and 3 to flow rates that lead to a low thermal power available (< 2MWt).
- The quality of the heat source; where 1 indicates clean gas without presence of dust and 3 indicates dirty gas with presence of dust or other negative characteristics (presence of ash, critical dew-point, …)

The availability of data varies depending on the sector study level.

An example:

Elements	Value 1-3	NOTE
ATECO Sector: Melting of other non-ferrous materials – Secondary refinery		
heat recovery in internal process	3	Usually presence of pre-heating of the raw material (billets)
source temperature	1	Very high temperature of the exhaust
source flow rate	2	Usually it is not so high, due to the use of electric induction furnaces for the melting process
source quality	1	In the most cases the raw material is submitted in quite pure billets and the melting is done with induction furnaces, so the exhaust gases are quite clean and without dust
availability heat source	2	Usually there are several little furnaces, but sometimes the exhaust are piped to a single chimney
h/y operation	2	Usually these companies work only during the weekdays and on two shifts per day
COMPATIBILITY COEFFICIENT	**2**	**Interesting sector, but only for few cases**

Table 1 Example of definition of the compatibility index

Strategy and Process: from demonstration activities to policy proposal.

1) the results obtained with elaborating the tools developed during the 50 audits allow to have an exhaustive number of examined cases in order to support policy/incentives proposals with some values of potentiality, necessary to give credibility to a proposal.

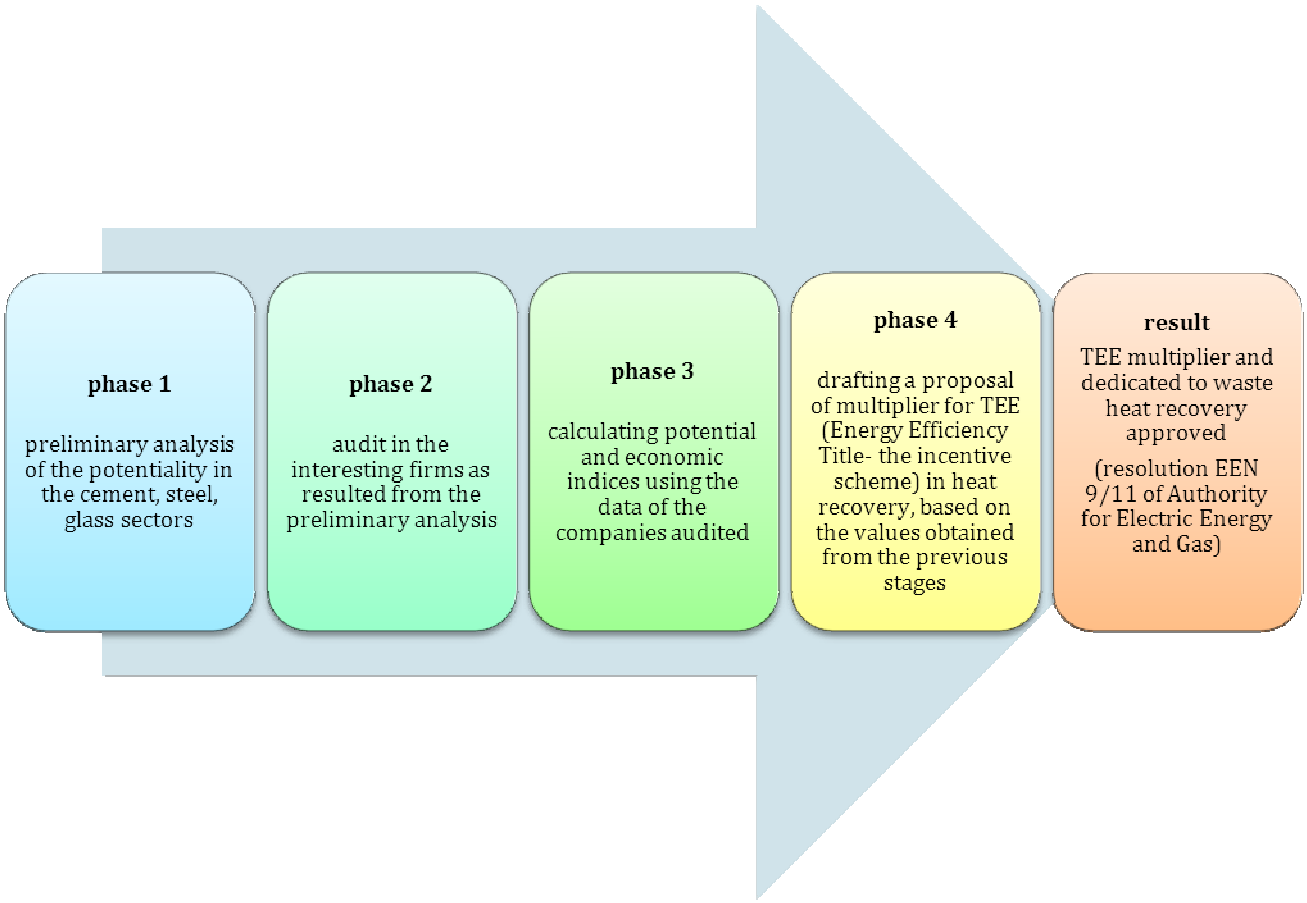
↓

2) interfacing with the audited firms allowed to highlight the economic and "cultural" barriers on which focus policy actions (this aspect has also influenced the dissemination/action 5)

↓

3) Monitoring 10 companies - the most illustrative of the potentiality for heat recovery - has allowed the development of a detailed analysis in order to further support the results obtained with the audit

Example: new Energy Efficiency Incentive for waste heat recovery– the White Certificate:



Conclusion: lesson learnt from the demonstration activities.

The HREII project has developed an instrument – the pilot model – that can be utilized in all the EU member states to quantify the heat recovery potential and the energy generated from it. The preliminary audit can be positively utilized by the EU institutions too, as a tool to support energy efficiency measure.

The HREII partners appreciate the LIFE contribution to develop the project because it has permitted to test an instrument useful for the whole Europe.

The possibility to test the preliminary audit not only in the pilot area – identified by the project as the province of Brescia, one of the most industrialized Italian provinces – but also in another European country (Austria) has validated the project assumptions and replicability. Firstly, the Austrian audits have underlined that the most promising industrial sectors for heat recovery are the same in Austria and in Italy. Secondly, each European country has its proper industrial processes characteristics and the consequently internal improvements. Thirdly, ah huge potential has been calculated in a particular sector, the oil&gas: Austria is a strategic European country for the gas transportation. Along natural gas transport infrastructures, almost every 150-200 km gas compressor stations are placed, in order to

maintain gas pressure at a value of almost 70 bar. These stations take a part of the gas transported and burn it in at least two gas turbines, one of those plays a backup role. Gas compressor stations can be divided in base load stations, which work continuously, approximately 8,000 hours per year, and seasonal stations, located in warm regions, which works less than 4,000 hours per year. The oil&gas is not included in the ETS system because it's not an industrial sector, as a service and transportation sector there aren't energy efficiency measures directly addressed to it but specific "offset" programs could be promoted. (The detailed study of the oil&gas sector and the policy proposal to the EU for valorizing this potential will be developed during the HREII DEMO project – LIFE10 ENV/IT/000397).

Europe is a global leader in developing low carbon and energy efficiency solutions in a wide range of sectors (e.g. energy efficiency technologies and services, energy management system) but the diffusion of such technological solutions is limited for different reasons: technological and not-technological barriers have adversely affected the introduction of more sustainable and more energy efficient systems that permit to recover heat for power generation in the energy intensive industries.

At current trend, EU target of 20% reduction of final energy consumption compared to projections for 2020 with energy efficiency practices will not be met, thus heat recovery represents an opportunity in industry to recover energy. Among heat recovery technologies, ORC systems are increasing its possibilities to be adopted in different industries.

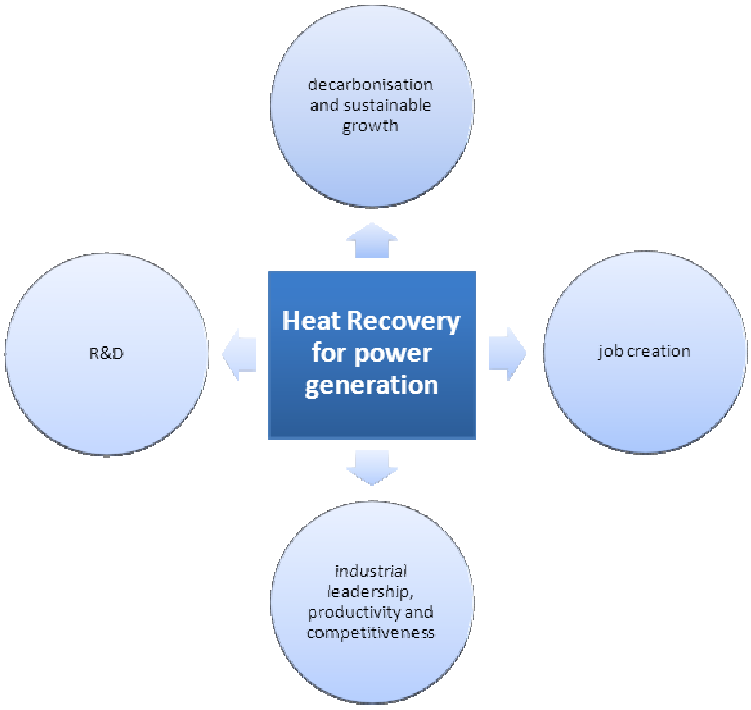


Figure: Heat recovery benefits.

The European Union is invited to introduce new policies to promote and incentive heat recovery in the energy efficiency framework for an over-all benefit:

- decarbonisation and sustainable growth: heat recovery can increase the environmental, economic feasibility and energy sustainability of the industrial processes, and also contribute to reduce GHG emissions; power is generated through the waste heat recovery without any fuel;
- job creation: (i) jobs in the manufacture of waste energy recovery equipment: these employers range from large multinational corporations to small, specialized firms; (ii) jobs in creating on-site "energy islands" in host facilities including welders, pipefitters, design engineers and construction workers; (iii) jobs in operating on-site energy islands; (iv) jobs resulting from increased competitiveness.
- industrial leadership, productivity and competitiveness: heat recovery as an instrument of industrial policy to boost competitiveness and investments in the manufacture sectors, able to collect different industrial actors; it's possible to foreseen a potential investment of 8 billion € in the new sector of heat recovery [source: HREII DEMO project].
- R&D: Important results would be reached with the introduction of innovation policies in order to increase and coordinate European R&D spending to support promising technologies in energy intensive industries.

To put into effect the above mentioned benefits, some measures are to be implemented by European institutions and national authorities.

Firstly, the lack of certain and long-term EU regulatory framework and binding targets for energy efficiency could hinder the development of a European energy efficient market. **The new energy efficiency directive is a step towards the good direction but it's necessary that member states during the implementation phase consider the potential of heat recovery applications, especially referring to article 8.7[1] and article 14[2] : compulsory energy audits and mandatory waste heat recovery for power generation system, when it's technically and economically workable, could catalyze investment in the energy efficiency market, helping to reach the objective of 20% reduction in energy consumption.**

Secondly, the economic obstacle is an important issue: investment payback time for the implementation of technologies related to WHR to electricity generation are usually too long for the industrial sector, for this reason **the creation of ad hoc incentives mechanism or the inclusion in existing supporting schemes (e.g. white certificates or CHP) could help in overtaking this barrier. The European Union is also invited to include in the energy efficiency fund a specific provision for industry, considering the role played by the energy intensive industries in the overall energy consumption.**

[1] Directive 2012/27/UE, article 8.7: "Energy audits may stand alone or be part of a broader environmental audit. Member States may require that an assessment of the technical and economic feasibility of connection to an existing or planned district heating or cooling network shall be part of the energy audit. Without prejudice to Union State aid law, Member States may implement incentive and support schemes for the implementation of recommendations from energy audits and similar measures".

[2] Directive 2012/27/UE, article 14.5 lett. c: "an industrial installation with a total thermal input exceeding 20 MW generating waste heat at a useful temperature level is planned or substantially refurbished, in order to assess the cost and benefits of utilising the waste heat to satisfy economically justified demand, including through cogeneration, and of the connection of that installation to a district heating and cooling network".

Last but not least, **it's necessary to increase in the awareness - through an intensive dissemination campaign and a proper education and training path - of the energy efficiency potential in the industrialists' mind as a solution to raise investments, to create job and to boost sustainability.**
ORC systems are widespread and proved reliable in the biomass applications but they are still uncommon in the industry. The above mentioned proposals could foster this technology as an energy efficiency measure, repeating the positive results obtained with the biomass.