Waste Heat Recovery technologies: Recommendations on how to overcome barriers to their adoption

Paul Christodoulides[1], Lazaros Aresti[1], Vassilios Messaritis[1], Gregoris Panayiotou[1], Giuseppe Bianchi[2], Georgios Florides[1]

[1] Faculty of Engineering and Technology, Cyprus University of Technology, Limassol, Cyprus
[2] Centre for Sustainable Energy Use in Food Chains (CSEF), Brunel University London, U.K.

The I-ThERM project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 680599.

INTRODUCTION

- European primary energy consumptions (in the order of a few GWh/yr) are mostly due to industrial processes that are characterized by a multitude of energy losses.

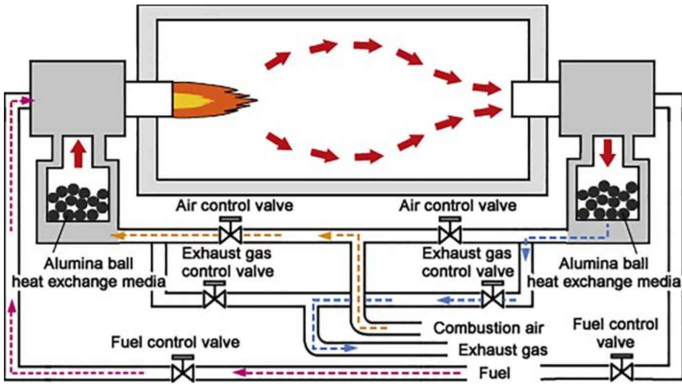
- The ones taking place as waste heat streams in the form of exhausts or effluents occur at different temperature levels: Lower (LT), Medium (MT) and High (HT). The waste heat potential can be estimated using statistical data concerning the energy consumption of the EU industrial sectors.

- It turns out that the overall EU thermal energy waste can be quantified to about 1 GWh/yr. The fact is, hence, that about 30% of EU industry final energy is wasted through losses.

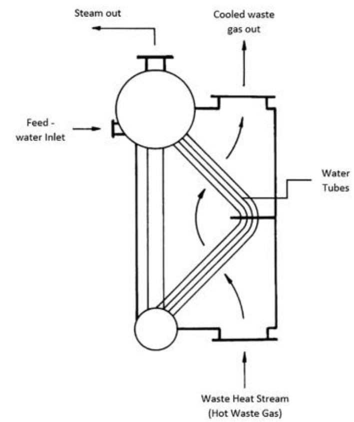
- This has led to the wide adoption of WHR technologies. WHR technologies can be classified into (i) recovery as hot air or steam, (ii) conversion to chemical energy as fuel, (iii) thermoelectric power generation.

The I-ThERM project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 680599.

WHR TECHNOLOGIES



Regenerative burner



Waste heat boiler

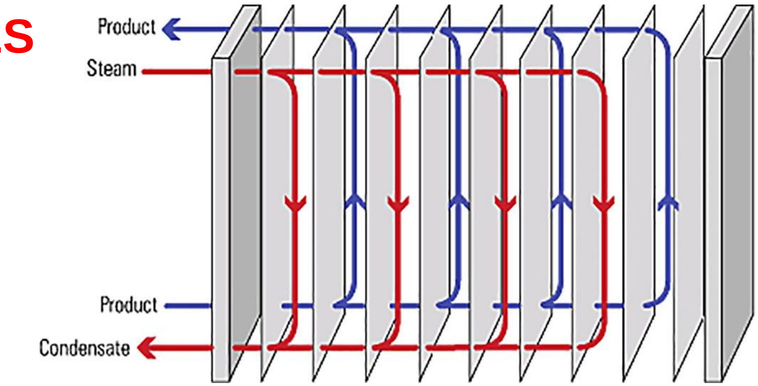
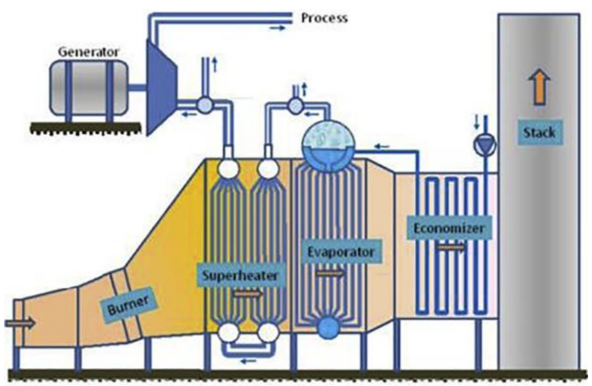
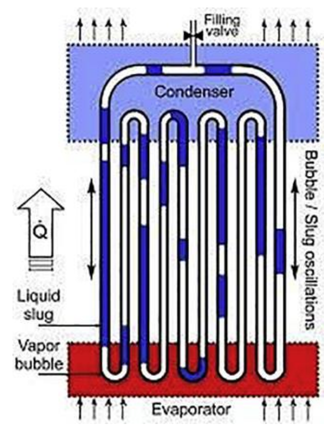


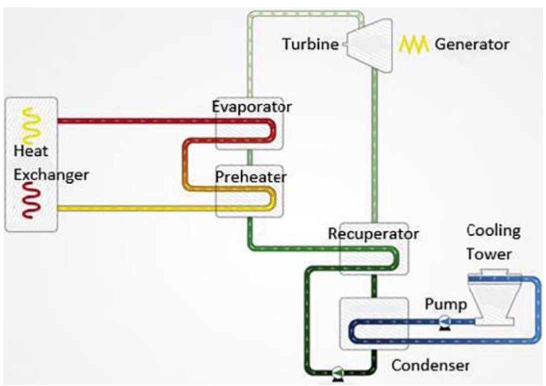
Plate heat exchanger



Steam Generator



Pulsating heat pipe



Organic Rankine cycle

Juhara et al., Waste heat recovery technologies and applications, 2018

The I-ThERM project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 680599.

MOTIVATION/ RATIONALE/ PLAN

- Although there are many different WHR technologies available used for capturing and recovering the waste heat, their adoption is still hindered by specific technical and non-technical “barriers”.
- The goal here was to determine such barriers and make recommendations on how to address them.
- The first step was to perform a thorough literature review and have discussions with people from related industry sectors
- The second step was to prepare a structured questionnaire on barriers to the adoption of WHR technologies and have it completed by a number of industries across the EU.
- Based on the results of the questionnaire several recommendations were derived.

The I-ThERM project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 680599.

QUESTIONNAIRE

- The respondents (46) are categorized with regard to country as follows:
  - *2 from Belgium, 4 from Cyprus, 3 from Greece, 4 from France, 7 from Germany, 6 from Italy, 3 from the Netherlands, 2 from Portugal, 2 from Romania, 6 from Spain and 7 from the UK.*
- With regard to type of industry, they can be categorized as follows:
  - *5 from Iron and Steel, 5 from Chemical/Petrochemical, 4 from Non-ferrous metal, 5 from Non-metallic minerals, 7 from Food and Tobacco, 4 from Paper Pulp and Print, 5 from Wood / Wood Products, 5 from Textile and Leather, 4 from Thermal energy engineering and 2 fromTurbomachinery.*
  - *The size of the companies varied from medium to large (40 to 800 employees).*

The I-ThERM project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 680599.

QUESTIONNAIRE/ RESULTS-1

- (1) Annual energy use at the company: Type:

Biofuel	Fossil fuels	Electricity	District heating	Other
12	42	46	21	4

Regarding total consumption, it varies from about 1 to about 50 GWh/year

- (2) Do you produce excess heat?

Yes	No	Do not know
30	7	9

- (3) Have you examined the possibility of using the excess heat internally/externally?

Yes	No	Do not know
28/8	18/23	-/15

Projecting the outcome here to the large number of EU companies that produce excess heat, it can be thought that there is a considerable number of companies that they either do not know that they produce considerable amounts of excess heat or did not have the time to consider its utilization.

The I-ThERM project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 680599.

QUESTIONNAIRE/ RESULTS-2

- (4) If you answered "yes" to question 3, what was (is) the method used (to be used) and the temperature ranges?

Method	Number	Temperature Range (°C)
Economizers	13/0	70-500
Plate heat exchangers	7/0	50-400
Regenerative and recuperative burners	3/0	800-1500
Waste heat boilers	10/0	70-400
Air preheaters	19/2	50-400
Heat pipe systems	4/6	500-1000
Steam generator	13/2	100-650
Thermodynamic cycles	3/0	100-500
Heat Pumps	5/4	40-70
Flat heat pipes	2/0	500-1000
Condensing economizers	3/0	70-500
Trilateral Flash Cycle	0/0	
Supercritical Carbon Dioxide Cycle	0/0	

The I-ThERM project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 680599.

QUESTIONNAIRE/ RESULTS-3

- (5) If you answered “yes” to question 3, what was the outcome?

Not profitable	Profitable, but not yet implemented	Implemented
12/1	7/5	9/2

The replies to question 3 verify the knowledge and the use by companies of almost all well-known methods for using the excess heat either internally (easier to apply) or externally (needs specific conditions to be applied), within all temperature ranges (low, medium, high).

Regarding the implementation of the use of the excess heat and its profitability, it seems that many companies find this non-profitable.

The I-ThERM project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 680599.

QUESTIONNAIRE/ RESULTS-4

- (6) If you haven't considered installing a WHR system at all, what is(are) the reason(s)?

Reason	Number
Lack of information (i) / technology knowledge (ii)	20
Technology risk (iii)	10
No requirement for using the recovered heat (x)	12
High initial cost (iv)	18
Running and maintenance costs (iv)	13
Lack of financial support / governmental incentives (v)	18
Size / available space limitations (vi)	10
Lack of available infrastructure (vii)	15
Production constraints (viii)	12
Risk of production disruptions (viii)	13
Risk of the system negative impact on the company operations (ix)	7
Policy/regulations restrictions (x)	2
Other	0

The I-ThERM project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 680599.

QUESTIONNAIRE/ RESULTS-5

The replies to question 6 sufficiently cover nearly all ten barriers to the wide adoption of heat recovery technologies, except the “policy/regulation restrictions”.

The most “common” barriers seem to be “the lack of information / technology knowledge”, the “high initial cost” and “the lack of financial support / government incentives”.

- (7) What are the technological barriers for non-installing a WHR system? Please choose 1 or more answers.

Barrier	Number
High capital cost per KW generated (low system efficiency)	17
Low quality and not constant heat stream	10
High cost material to withstand the heat	7
Stream with high chemical activity	7
Transportability (long distance transport of low grade heat)	9
Disturbance within the existing plant operations	7
Other	2

The usual technological barriers, as found in the literature, are confirmed by the replies to question 7. The “Other” technological barriers mentioned were restricted use of low grate heat in the plant and expensive installations without any real effect on the price of product.

The I-ThERM project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 680599.

QUESTIONNAIRE/ RESULTS-6

- (8) In your opinion, what is the most important driver for installing a WHR system?

Energy saving	Environmental benefits	Fuel cost reduction
29	6	11

"Energy saving" was the "winning" option, where obviously all three options are essentially equivalent.

- (9) In your opinion, how can the barriers related to WHR systems be overcome?

Suggestions offered by the respondents:

(i) research and testing,
(ii) technological innovation to reduce capital cost,
(iii) demonstrated case studies,
(iv) availability of information,
(v) increasing the installation incentives.

The I-ThERM project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 680599.

STRATEGIES/ RECOMMENDATIONS-1

- Strategies and Recommendations depend on the type and size of company and on the price of produced goods on energy expenses. The questionnaire verified the barriers to the wide adoption of heat recovery technologies.

- Lack of information; lack of technology knowledge for implementation (i; ii): *To overcome the information barrier, it is suggested to establish an information exchange platform that will establish a research and development group, collect and analyze data from relative scale projects, search and define the best available technology, define pay-back time through a cost benefit analysis and define policy goals and parameters.*

- Technology risks (iii): *An investigation into the matter has shown that the causes of project failures are due to ineffective leadership and failures in communication as well as because of poor technical methods. Issues of organizational fitness (conflicts of people, time and project scope or poor specification of requirements), skill mix (inappropriate staff, lack of application-specific knowledge), management strategy and others may interfere and must be avoided.*

- High initial, running and maintenance costs (iv): *It is suggested that for every project the Life Cycle costing Analysis should be done, and it should include initial, running and maintenance costs, showing the real value of the investment for decision making.*

The I-ThERM project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 680599.

STRATEGIES/ RECOMMENDATIONS-2

- Lack of financial support and lack of governmental incentives; policy and regulations restrictions (v; x): *Governments can offer options including provision of venture capital funds, tax-based incentives and procurement programs; also, protection of patented ideas, support of innovations, stimulation of further implementation of new ideas in business; financial assistance by venture capital and alternative sources of financing, low-cost loans and willingness through financial institutions to finance especially small entrepreneurs; support related to the techno-economic study on policy and regulations restrictions.*

- Size and available space limitations; lack of available infrastructure (vi; vii): *Financial means will be needed along with a Life Cycle cost Analysis for the viability of new implementations; regarding infrastructure, a study should be undertaken by competent consultants to show that the company is able to take on the new tasks and overcome any inefficiencies.*

- Production constraints and risk of production disruptions; risk of the system negative impact on the company operations (viii; ix): *Care should be given for cases where the lifetime of the WHR technology installed may differ from the remaining plant lifetime; the mitigation of any such risks can be achieved through independent feasibility and technical studies by competent consultants as not always the cheapest method leads to the better result.*

The I-ThERM project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 680599.

CONCLUSIONS

- Following the recommendations and the strategies for WHR measures there remain actions to be taken as future goals.
- Industry engagement workshop: A workshop with key stakeholders. The meeting can include discussion groups to address the key barriers. One issue is the relatively low importance placed on energy efficiency and therefore limited resource committed to managing energy in comparison to other corporate priorities. Hence, companies can be encouraged to commit additional resource to more sophisticated energy monitoring.
- To make the final outcomes widely available through I-ThERM's website. These outcomes will be adopted as far as possible in the packaging, installation, commissioning and demonstration of new technologies.
- Case study: The outcomes may be used as case study material. When proposing potential WHR options applied to particular industries, it is important to match technologies to appropriate industrial processes.

The I-ThERM project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 680599.

Thank you for your attention!

The I-ThERM project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 680599.