WASTE HEAT RECOVERY IN THE EU INDUSTRY AND PROPOSED NEW TECHNOLOGIES

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INTRODUCTION

- 70% of the total energy use in the industrial sector is for thermal processes (furnaces, reactors, boilers and dryers) and up to a third of this energy is wasted through losses.

- Heat recovery technologies can be classified into:
  - Direct utilizing: heat delivery to district heating or cooling or preheating
  - Power utilizing: electricity generation using generator
  - Cascade utilization: combining heating, cooling and power

- Waste Heat Recovery (WHR) technologies depends on:
  - waste heat stream
  - the composition of the waste heat stream
  - the available area

- WHR process temperatures can be classified according to temperature range as high (HT), medium (MT) and low (LT), with LT usually referring to temperatures reaching 100°C or less.
Methods for WHR include:

- transferring heat between exhaust gases and combustion air for its preheating
- transferring heat to the load entering furnaces
- generation of steam to electrical power

Benefits of using WHR devices:

- resource (fuel) saving
- generation of electricity and mechanical work
- reducing of cooling needs
- reducing of capital investment costs in case of new facility
- increasing of production
- reducing of greenhouse gas emissions
- transforming of the heat to useful forms of energy
CONVENTIONAL WASTE HEAT RECOVERY TECHNOLOGIES (CONTINUE)

Heat Recovery Technologies can be grouped into:

- Technologies that recover heat from a primary flow and make it available as heat of a lower or similar quality in a secondary flow.
  - Example technologies are HEs, recuperators and regenerators
- Technologies that recover heat from a primary flow and upgrade this to a higher temperature useful heat using another heat source as input
- Technologies that recover and convert heat from a primary flow to electricity.
  - Examples are the conventional Steam Rankine Cycle and the ORC. Other potential systems at different stages of research, development and application include the Organic Flush Cycle (OFC), the Kalina Cycle, the Trilateral Flush Cycle (TFC) and the Supercritical CO₂ (sCO2) Brayton Cycle

☑ Not adopted widely by industry due to:
  ☑ high costs
  ☑ long payback periods
  ☑ material constraints
CONVENTIONAL WASTE HEAT RECOVERY TECHNOLOGIES (CONTINUE)

Typical WHR devices for air preheating:
- Recuperators
- furnace regenerators
- recuperative and regenerative burners
- passive air preheaters
- shell and tube HEs
- finned tube HEs or economizers
- rotary regenerator or heat wheel
- preheating of load
- waste heat boilers
- and heat pumps
The breakdown of the energy consumption for 13 industrial sectors was estimated to be 3217.85 TWh in 2016.
I-THERM PROJECT

I–THERM Aim:

- develop and demonstrate technology solutions to address heat recovery from a wide range of primary flow streams
  - from temperatures of around 70°C to 1000°C
- optimum utilization of waste heat for heating, power generation or a combination of both
I-THERM
PROPOSED
WASTE HEAT
RECOVERY
TECHNOLOGIES

Heat Recovery solutions:

Innovative Heat Pipes (HPs):
Design will be optimized for a wide range of fluid stream types, temperatures and flow rates as well as uses of the recovered heat

Heat Pipe Condensing Economizers:
Heat recovery opportunities due to their very high heat transfer coefficient, the extremely high heat transfer surface area and the low gas side pressure drops

Trilateral Flush Cycle:
Thermodynamic power cycle whose expansion starts from the saturated liquid state rather than a vapour phase

Supercritical CO₂ Cycle:
Operates in a similar manner to other turbine cycles but uses CO₂ as the working fluid
FLAT HEAT PIPES

- Designed to recover heat mainly by thermal radiation from sources at temperatures greater than the temperature of the surface of the heat pipes

- Conditions required:
  - Heat should be transferred by thermal radiation
  - Open space near the radiant source should be available for the installation of the panels

Potential market:

- **Iron and Steel industry** is the best option for the use of other FHP systems due to the large amount of the wasted radiant heat during the formation of the various products from the casting, rolling and cooling processes

- 500 steel production sites are split between 24 EU countries and around 170 million tonnes of steel are produced every year

- 62% of the production is for flat products and 38% for long products
FLAT HEAT PIPES POTENTIAL MARKET - THEORETICAL RECOVERABLE HEAT FROM RADIATION

Process

- The slabs, blocks and plates exit the casting machine, they go through roll strip where they are formed, cut, identifies and picked up to the storage zone.

- The temperature of these products in the procedures where the utilization of the radiant heat is possible (after rolling mill) starts from 1200°C at the exit from the rolling mill and reaches 120°C at the conveyor through the laying bed.

Assumptions

- Heat recovery efficiency 75%
- FHP panel surface temperature 100°C
- Conveyor width 1 m
- Conveyor length 70 m
- Each plant may have 1–5 lines of conveyors
FLAT HEAT PIPES POTENTIAL MARKET - ESTIMATED TECHNICAL AMOUNT OF RECOVERABLE HEAT POTENTIAL PER COUNTRY

- 60% of production is flat products (usable)
- 40% of production is long products

Considering 30% of this space can be covered by FHP, the energy recovery potential in EU can be 33924 TWh/year.
HEAT PIPE CONDENSING ECONOMIZERS (HPCE) – POTENTIAL MARKET

- Able to be installed in harsh environment since will have high resistance in the corrosion and acidic gases.

- Can increase overall heat recovery and steam system efficiency by up to 10%

- Sixty million gas boilers are installed in the EU and represent one of the major space heating technologies

- The market today is mainly for the replacement of existing gas boilers rather than for new installations of boilers.
TRILATERAL FLUSH CYCLE – POTENTIAL MARKET

- TFC systems can be compared with the conventional ORC units installed in low to medium temperature (70°C – 200°C) processes in the industrial sector

- The advantage of TFC over an equivalent steam ORC:
  - its power recovery potential is high, twice that of ORC
  - eliminate the requirement for an extra cooling tower/heat rejection system

- ORC main manufacturers are Turboden, ORMAT and Maxxtec

- A list with the ORC units installed in EU in 2017 is presented by Tartiere and Astofi with 224 total number of units

- The main types of industries, based on the amount of share, are electric power generation, Glass, Metals, Cement & Lime
SUPERCRITICAL CO$_2$ CYCLE

- Aim of the I-Therm project is to develop and demonstrate a small modular supercritical sCO$_2$ power system that can be easily employed for a variety of HT heat recovery to power conversion applications.
- To have an idea of the size of the potential market of the proposed systems, the market of the conventional ORC systems in high temperatures is presented.
- The industries with most ORC plants are the Glass, Cement, Steel and Oil & Gas.
- 2016, the ORC technology represents a total installed capacity around 2701 MW, distributed over 705 projects and 1754 ORC units.
SUPERCRITICAL CO$_2$ CYCLE – POTENTIAL MARKET

259 Cement Plants in EU with 389 kilns:
- 11 of these plants have wet process where ORC is not convenient to be installed
- 19 plants there is no information on the technology
- 229 plants have the potential to install ORC systems in EU

Steel industry
- 190 Electric Arc Furnace with capacity of 101.7 Mt/year
- 11 of them are idle
- 362 rolling mills exist in EU steel industry with capacity 252 Mt/year

Glass industry
- 58 flat glass plants in EU with production of 7,500,000 tones of glass every year
- Campana et al. (2013) concluded that 58 plants of ORC can be installed with total power of 78.5 MW
CONCLUSION

- WHR from the I–ThERM project

- Waste heat potential in the EU has been estimated
  - 300–350 TWh/year based on the energy consumption breakdown from the 3217.85 TWh energy consumption of 2016

- Heat, which is lost by radiation and can be recovered with the proposed FHP panels
  - Estimated energy recovery potential in EU to be 33924 TWh/year

- The basic industrial sectors where the proposed technologies can be marketed are the:
  - Iron and Steel industry, and Cement Industries
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