# MODULE 1
# CHAPTER 1: DESCRIPTION OF WASTE HEAT AND COOLING

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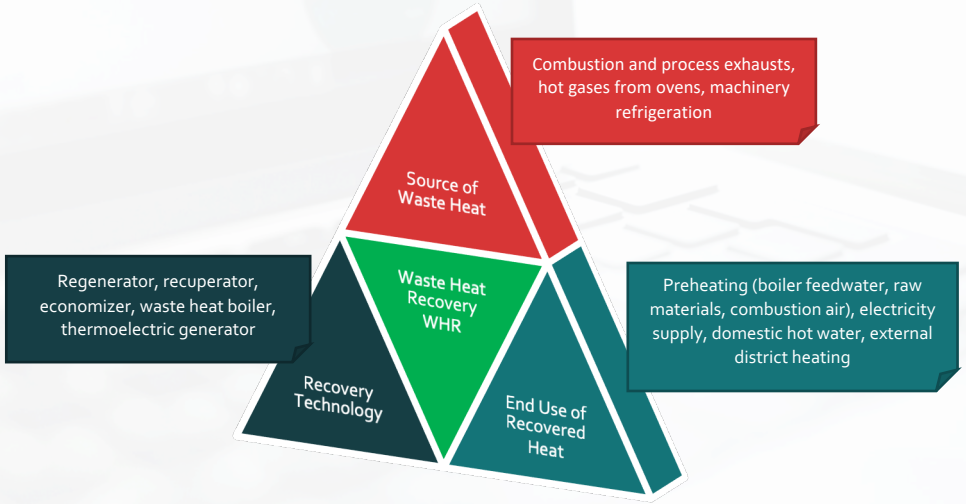
This Project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement N. 847097

# Preface

20-50% of the industry energy consumption ends as WH and 18-30% could be recovered

3 main components are required to accomplish it:

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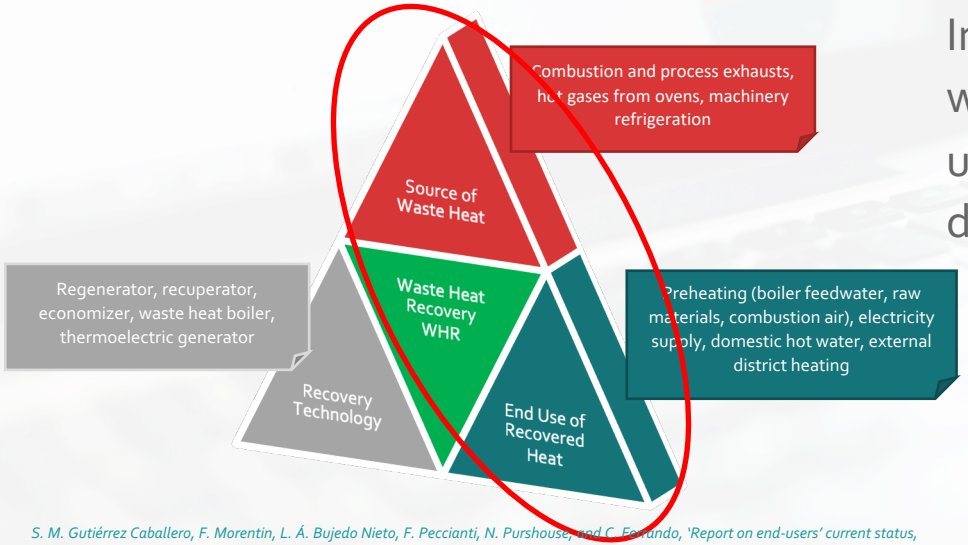
# Preface

Waste heat is generated along the industrial processes as a by-product in different forms, but the key factor is a suitable "end use" for the recovered heat




In Chapter 1, the main sources of waste heat and the possible end use of the recovered heat will be described

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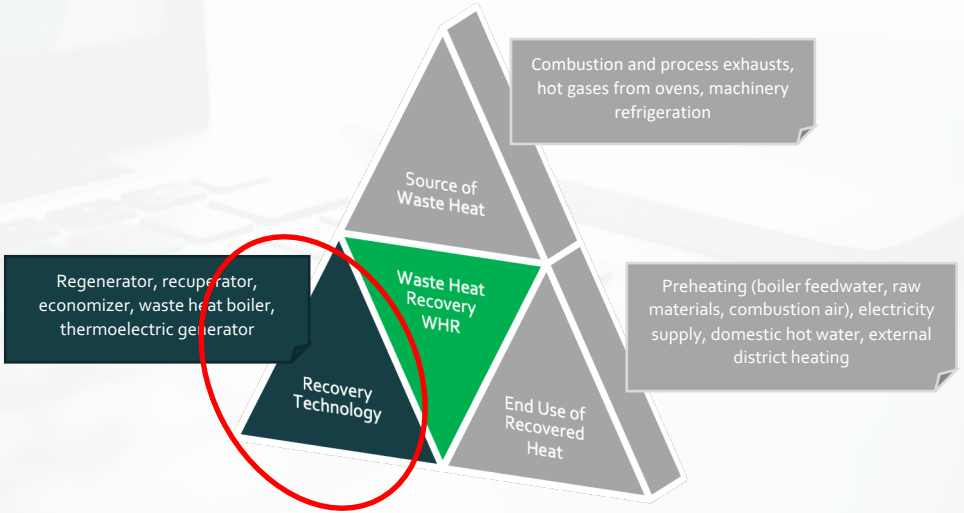
# Preface

There are different technologies available depending on the type and power of the waste heat source, the temperature ranges and the final use of the energy

In Chapter 2, individual technologies will be reviewed with a focus on operating principle, performance and typical applications

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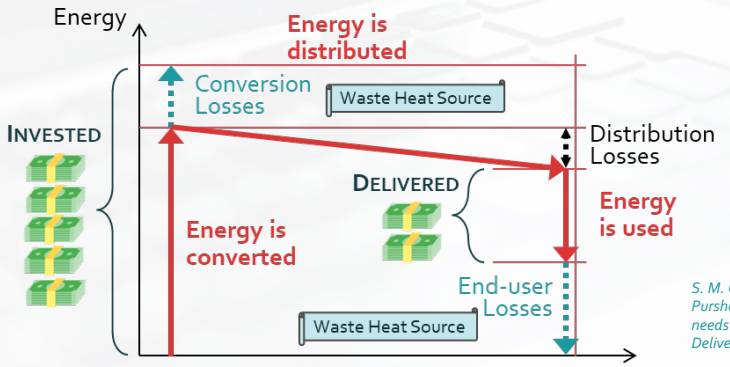
# Introduction

WH is generated along the industrial processes as a by-product in different forms such as combustion gases, heated water or heated products.

Conversion losses and end-user losses represent possible sources of waste heat, while distribution losses are non-usable system inefficiencies.

## Energy cycle and waste heat sources

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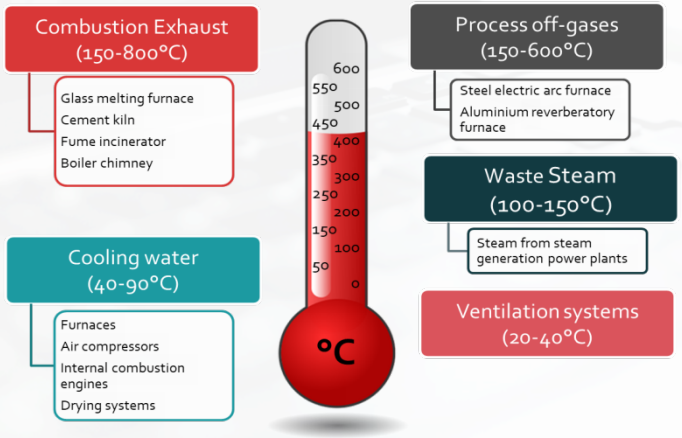
# Introduction

Most waste heat recovery devices transfer heat from a higher temperature effluent stream to another lower temperature inlet stream

WH "usefulness" will be determined by its temperature, so that the higher its temperature, the higher its quality

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# Sources of Waste Heat

## Non-Ferrous Metals

In this sector most WH comes from low temperature sources (<200°C)

Used for space heating or power generation through ORCs

## Aluminum

- Hall-Héroult process
- Most sources are at low temperature of 300°C or lower
- The amount of waste heat is limited
- Used for space heating and preheating of raw materials


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# Sources of Waste Heat

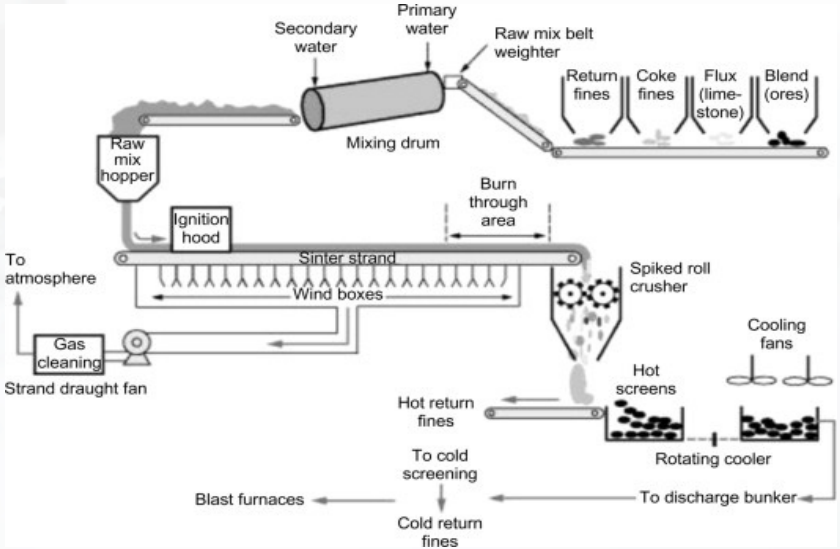
## Non-Ferrous Metals

### Zinc and Cadmium Roasting

- Exothermic process carried out at 900°C approximately
- Recovery through cooling systems
- Used to produce steam for power generation

### Sintering and roasting processes of other ores

- Process at high temperature
- Recovery from flue gases
- Used to preheat air or produce steam

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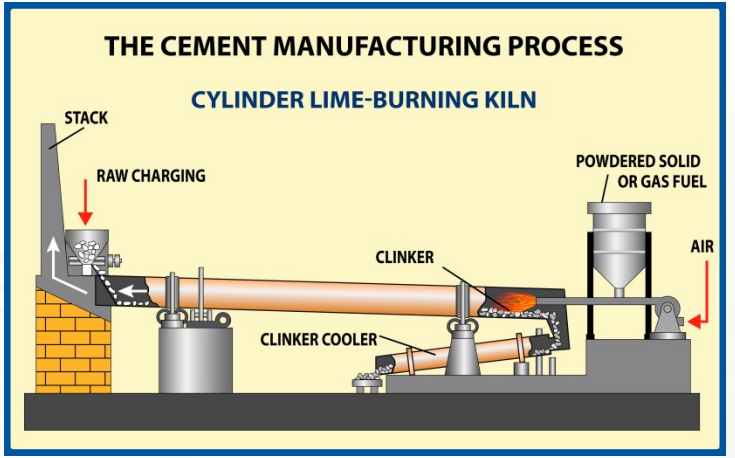
# Sources of Waste Heat

## Non-metallic minerals

### Cement

- Process: calcination and sintering a mix of components in a rotary kiln at high temperature
- A kiln uses approximately 3.300 MJ per tonne of product using 55% of the energy to drive the process
- The gases coming from coolers or preheaters have a typical temperature between 250-380°C
- 0.3 GJ of energy per tonne of clinker is calculated to be available in the exhaust streams

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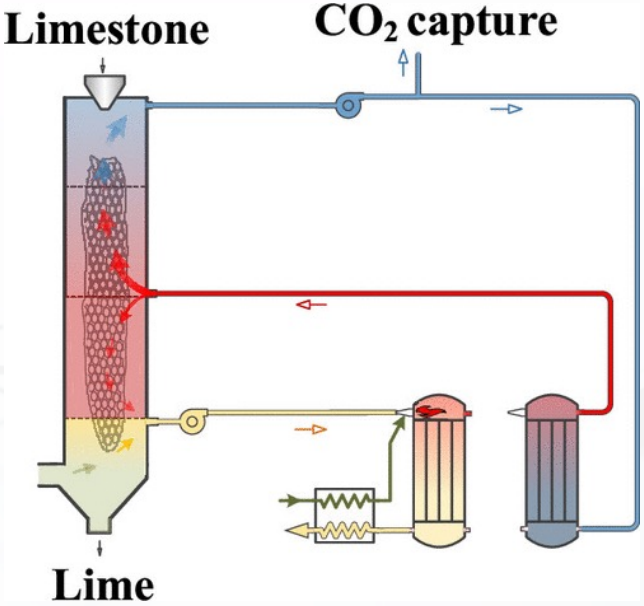
# Sources of Waste Heat

## Non-metallic minerals

### Lime

- Process: calcination of crushed limestone at approximately 900°C
- Used for pre-heating the limestone being fed into the process
- Cooling air from cooling the lime may be used as warmed combustion air

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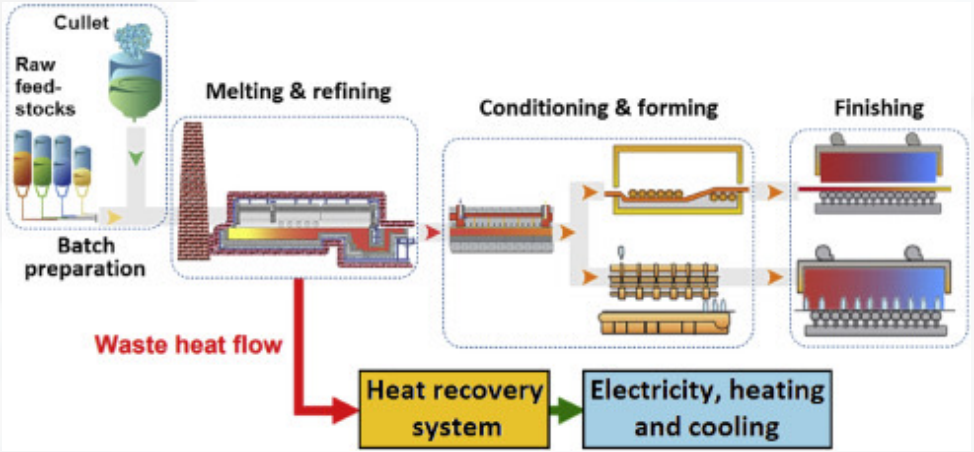
# Sources of Waste Heat

## Non-metallic minerals

### Glass

- Process: melting a mixture of sand, minerals and recycle glass in a furnace at a temperature of over 1500°C
- There exist examples of using ORC machines to electricity generation
- WH used for reheating combustion air

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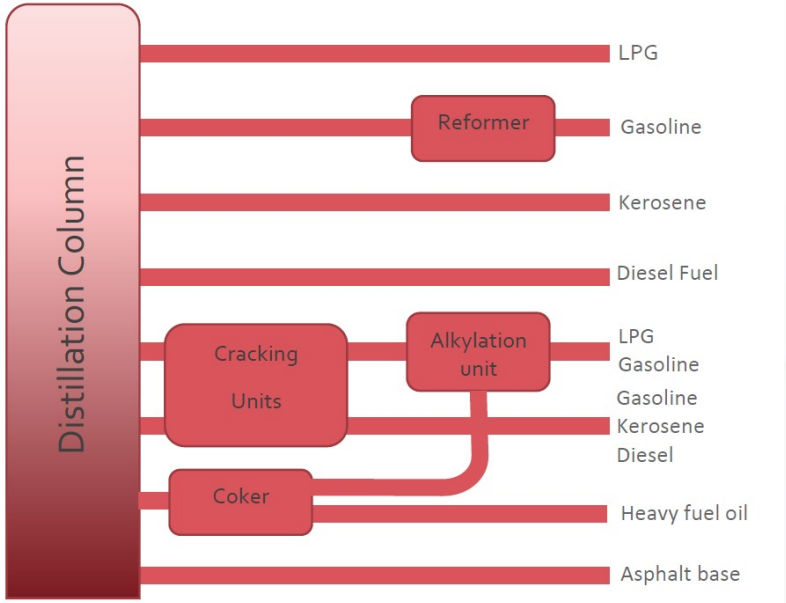
# Sources of Waste Heat

## Chemical and petrochemical

- Crude oil is heated to 400°C before be fed into a distillation column
- After distillation, the lighter fractions are reformed and hydrotreated to produce gasoline and diesel, while heavy fractions are cracked
- WH produced at medium and low temperature
- Used to preheat incoming feedstocks using heat exchangers

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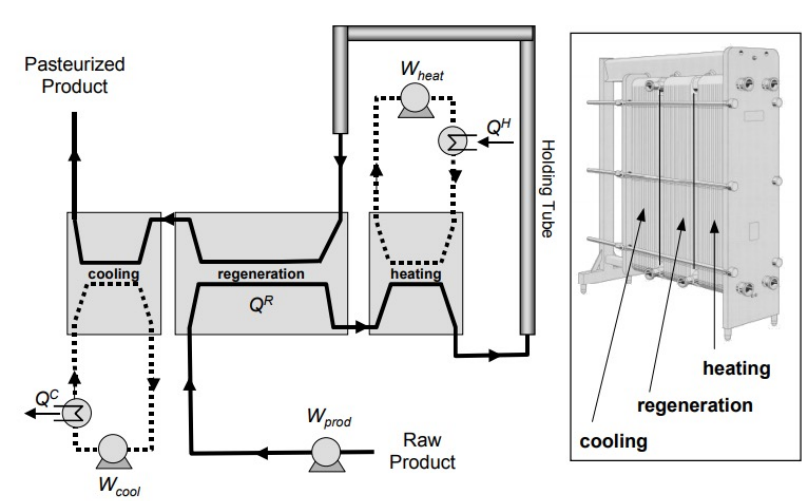
# Sources of Waste Heat

## Food and Beverage

- Processed: Baking, boiling, frying, drying, distilling, pasteurising and refrigerating
- Most processes are at low temperature (<260°C)
- WH from Pasteurisation can be used to warm the incoming product
- Using heat exchangers to warm the incoming product is very common

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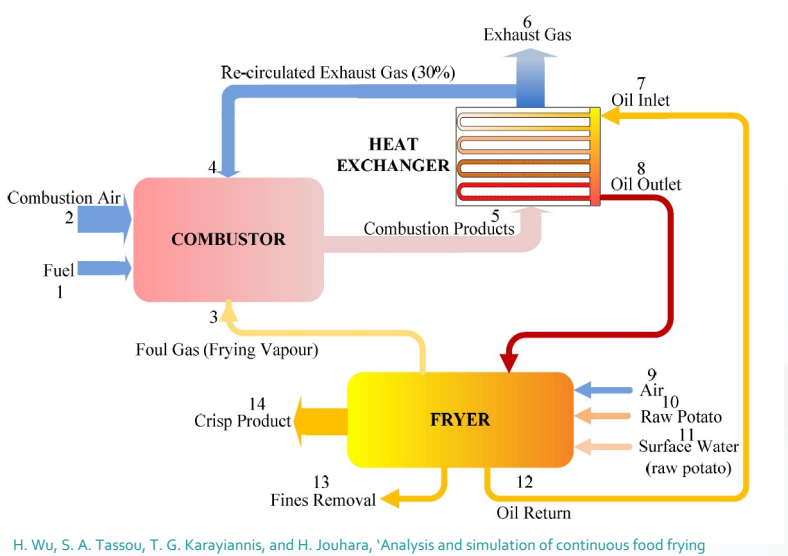
# Sources of Waste Heat

## Food and Beverage

- Baking ovens produce flue hot gases at >200°C. WH can be used to preheat combustion air
- Possible problems with dirty streams
- A solution to recycle frying vapours could be directly mix them with the combustion air pre-heating the entering stream and reducing the energy needed

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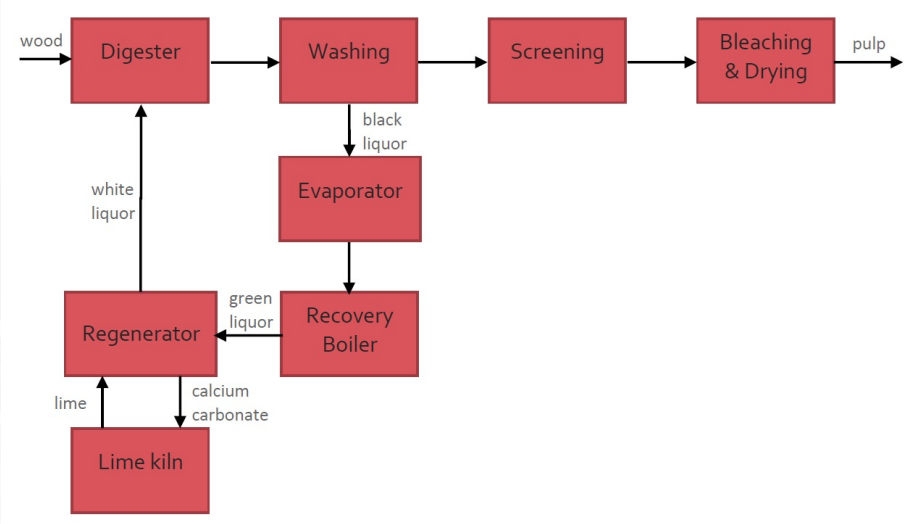
# Sources of Waste Heat

## Paper, pulp and printing

- Process: Kraft process. Wood is cooked at 170°C
- Tree bark and rejected pulp are often burned at paper mills to produce power and steam used in the processes
- Opportunities to recover energy from exhaust steam from the cooking and evaporating processes

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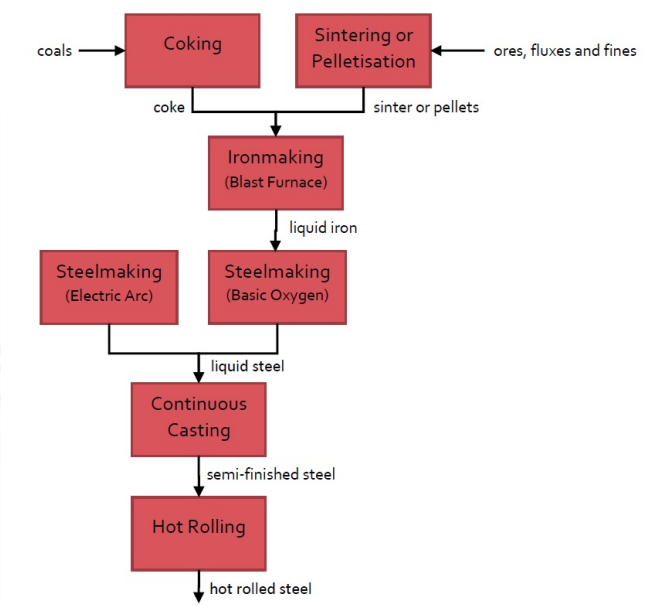
# Sources of Waste Heat

## Iron and steel

- Processes: Blast furnace and basic oxygen furnace (BF-BOF) process uses virgin ores. Electric arc furnace (EAF) process re-melt scrap and alloys
- 25% of the EAF input energy may be recovered to produce steam for power generation but this is rarely practised due to practical issues
- This industry produces hot steel products at high temperatures, over 700°C
- Economic payback and capital availability rather than technical feasibility typically limit the adoption of heat recovery solutions

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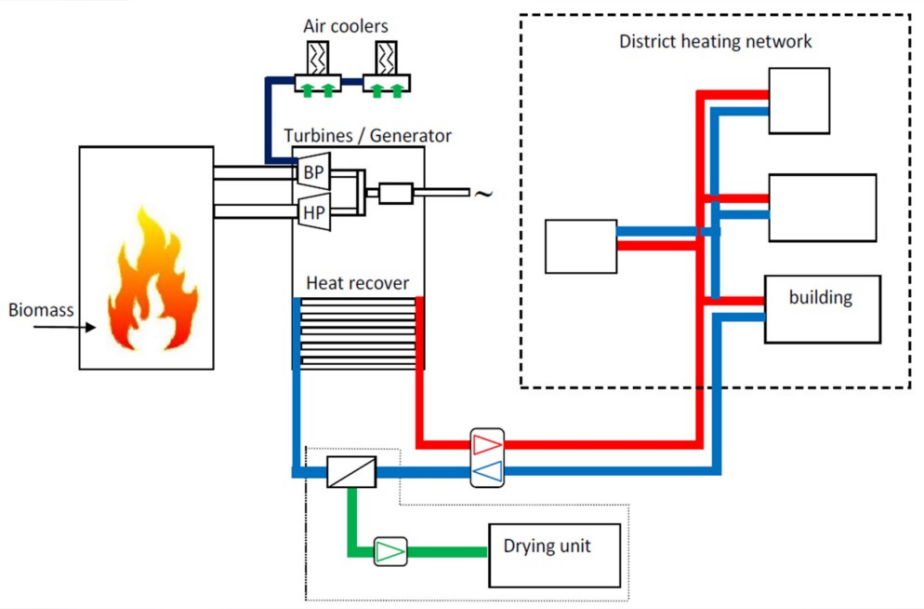
# Sources of Waste Heat

## Power and energy

- Combined heat and power stations are often used on to provide process heating and steam for industrial processes or heat for space heating
- WH mainly at temperatures less than 100°C and the rest at intermediate temperatures between 100 and 300°C
- Traditional incinerators handle temperatures between 1,000 and 1,300°C
- Hot exhaust gases can be used to produce steam for electricity generation

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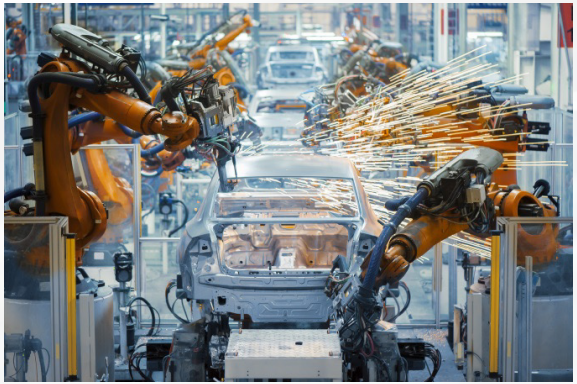
# Sources of Waste Heat

## Other industries

- Transport and machinery manufacture, textiles, mining, construction and wood processing, are assumed to be at temperatures less than 200°C which tend to be used in space or district heating applications



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# Recovery of Waste Cold

- Main source of waste cold energy found in the literature is that released during the regasification of liquefied natural gas (LNG)
- This gas in liquid state is transported to consumer countries at a temperature of -160°C
- Regasification energy may be harnessed to produce electricity either by driving generators by the direct energy of gas expansion or by using ORC machines
- In 5$^{th}$ Gen District Heating networks cold water is pumped to customers for equipment of air conditioning. Absorption chillers and conventional Heat Pumps can be used to achieve the correct temperature with very high efficiency

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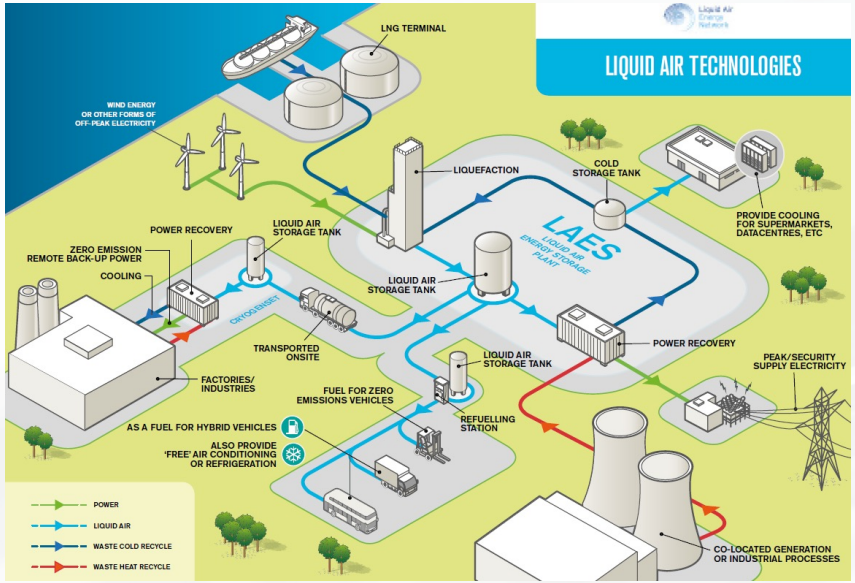
# Recovery of Waste Cold

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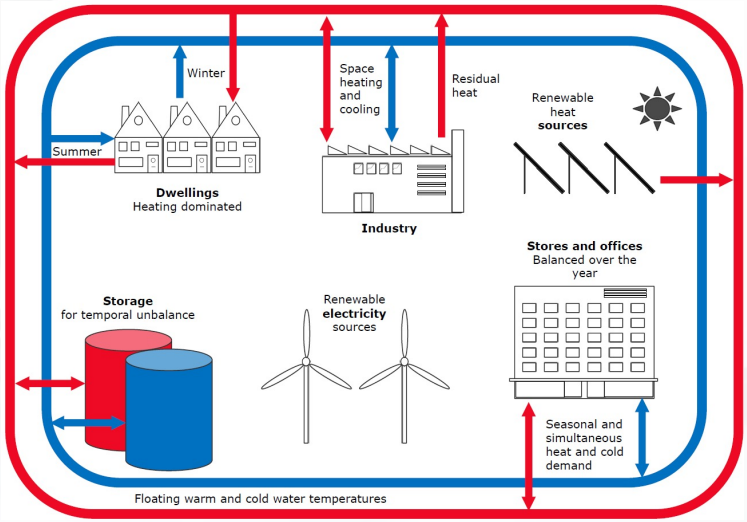


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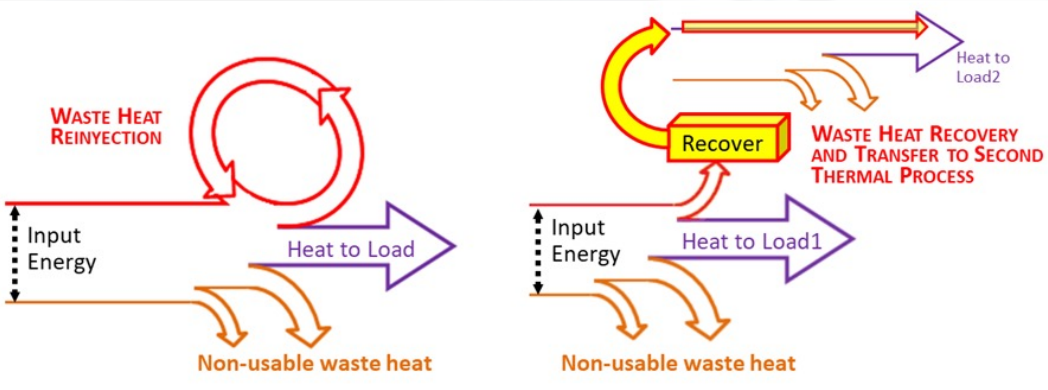
# End use of recovered waste heat

Two possible ways to use WH: internal use or external use

- **Internal**: the industrial facility itself transforms and consumes the recovered energy. Whether it is in the form of heat or it is transformed into other forms such as refrigeration or electrical energy.
- Direct recovery to the original process or recovery with transfer to a second process is considered
- Direct recovery facilitates temporal synchronization production of waste heat and its reuse

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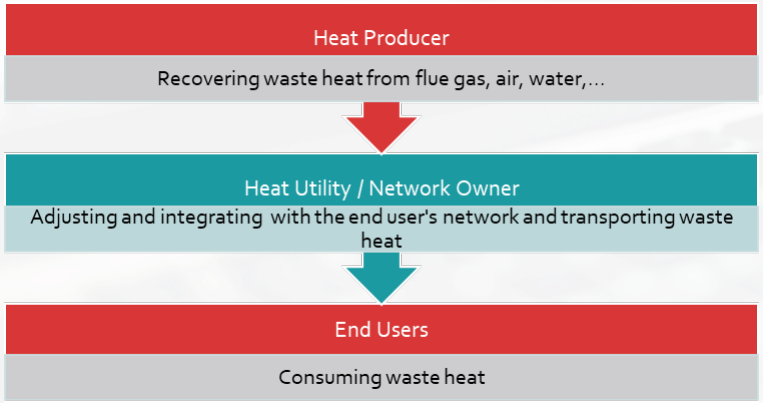
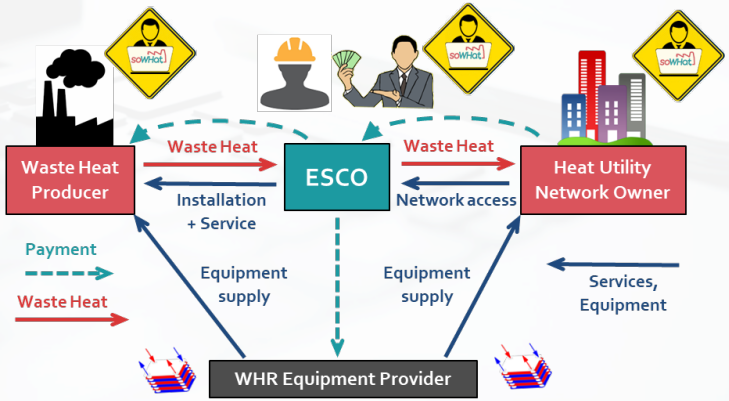
# End use of recovered waste heat

Two possible ways to use WH: internal use or external use

- **External:** possibility of introducing intermediate actors (ESCOs) between heat producers and end users
- ESCO finances the installation of heat recovery systems in the factory and remunerates the heat producer for the recovered heat which is supplied to the heat utility or the owner of the heat network, which pays to the ESCO

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# End use of recovered waste heat

The greatest challenge to implement a WHR scheme is finding the "end use" for the recovered heat. Some of the questions that must always be asked before considering the design of a WHR project could be the following:

- Where will you use the recovered heat?
- Is the heat sink close or far from the waste heat source?
- Is the heat sink appropriate for the heat source temperature?
- Will heat sink and heat source operate at the same time, all the time?
- Will its volume vary considerably, and often?

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*THANK YOU FOR YOUR PARTICIPATION*

# SOWHAT TEAM

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