WE CAN
DO SO
MUCH
TOGETHER

Performance evaluation of an ORC integrated to a waste heat recovery unit in a Steel mill

tecnalia Inspiring Business

Presented by Miguel Ramirez

tecnalia Inspiring Business

OUTLINE

INTRODUCTION

WASTE HEAT RECOVERY (WHR)

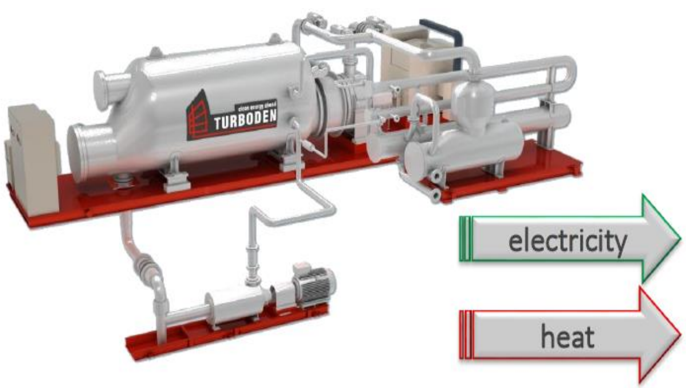
- European industry generates annually approx. 3700 TWh of heat and only 54% arrives to its final destination. (Eurostat, 2012)
- Assuming that 50% of total available waste heat can be recovered would imply a potential of **1000 TWh of useful heat per year.**
- The use of this amount of waste heat for heating, cooling and power generation would entail saving of fossil fuels, and a **reduction in GHG emissions of about 2200 million ton CO2/year.**

INTRODUCTION

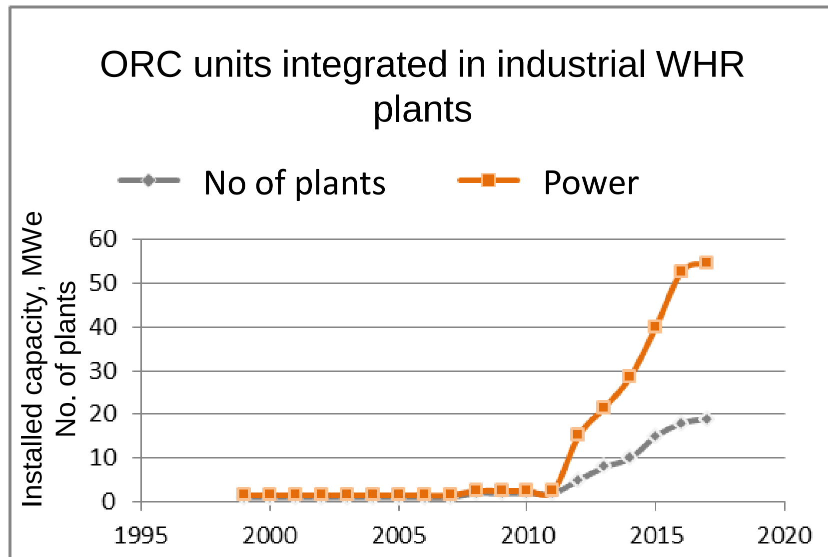
WHRU and ORC units

Industries with highest potential

	Cement	Steel & Metallurgy	Glass
Heat source temp	300° - 350°C	700° - 1200°C	350° - 450°C
Operating hours	up to 7900	< 7500	< 8500
ORC usual power	3-5 MW_e	2-10 MW_e	0,5-3 MW_e



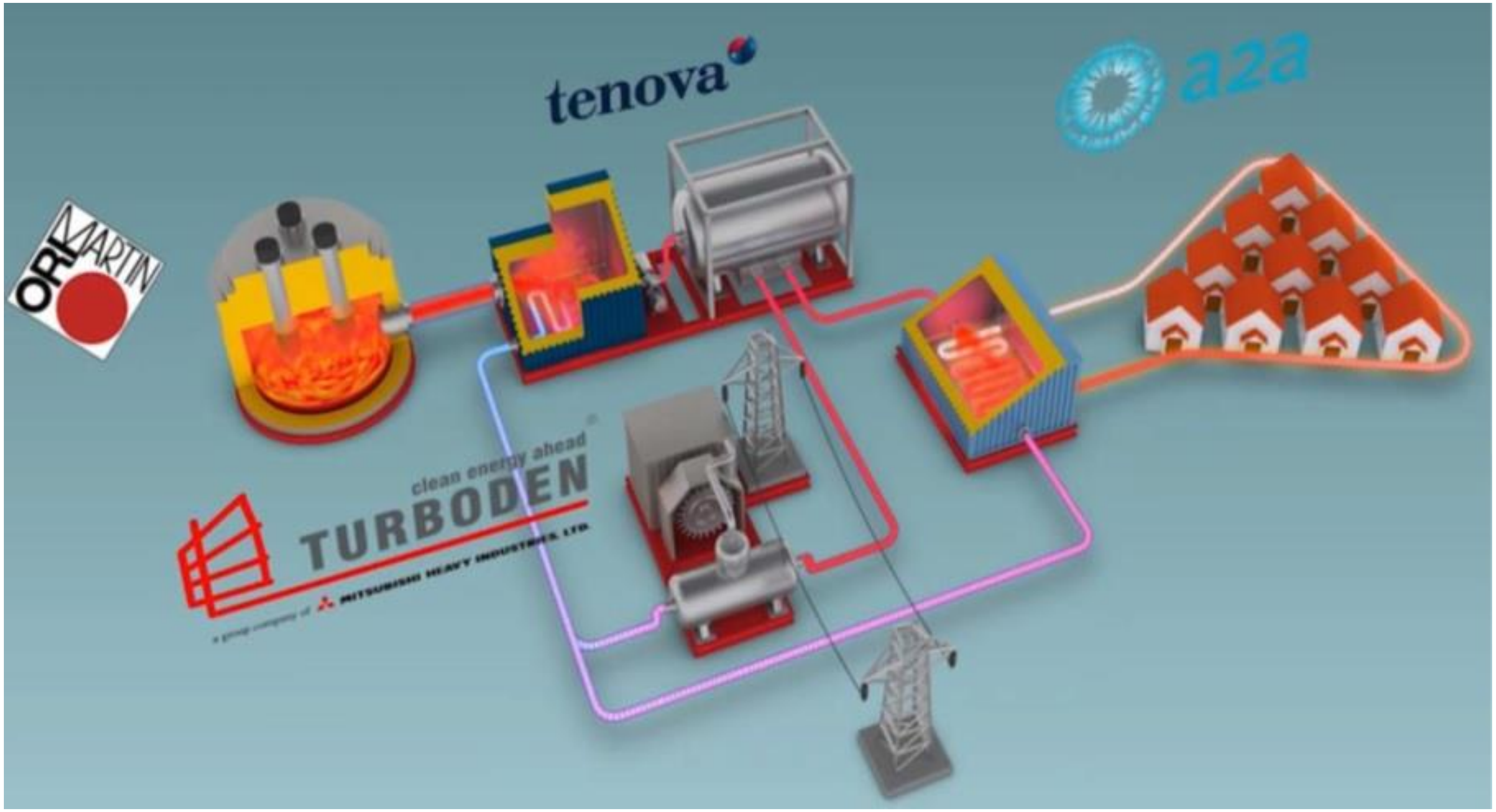
Source: Turboden s.r.l



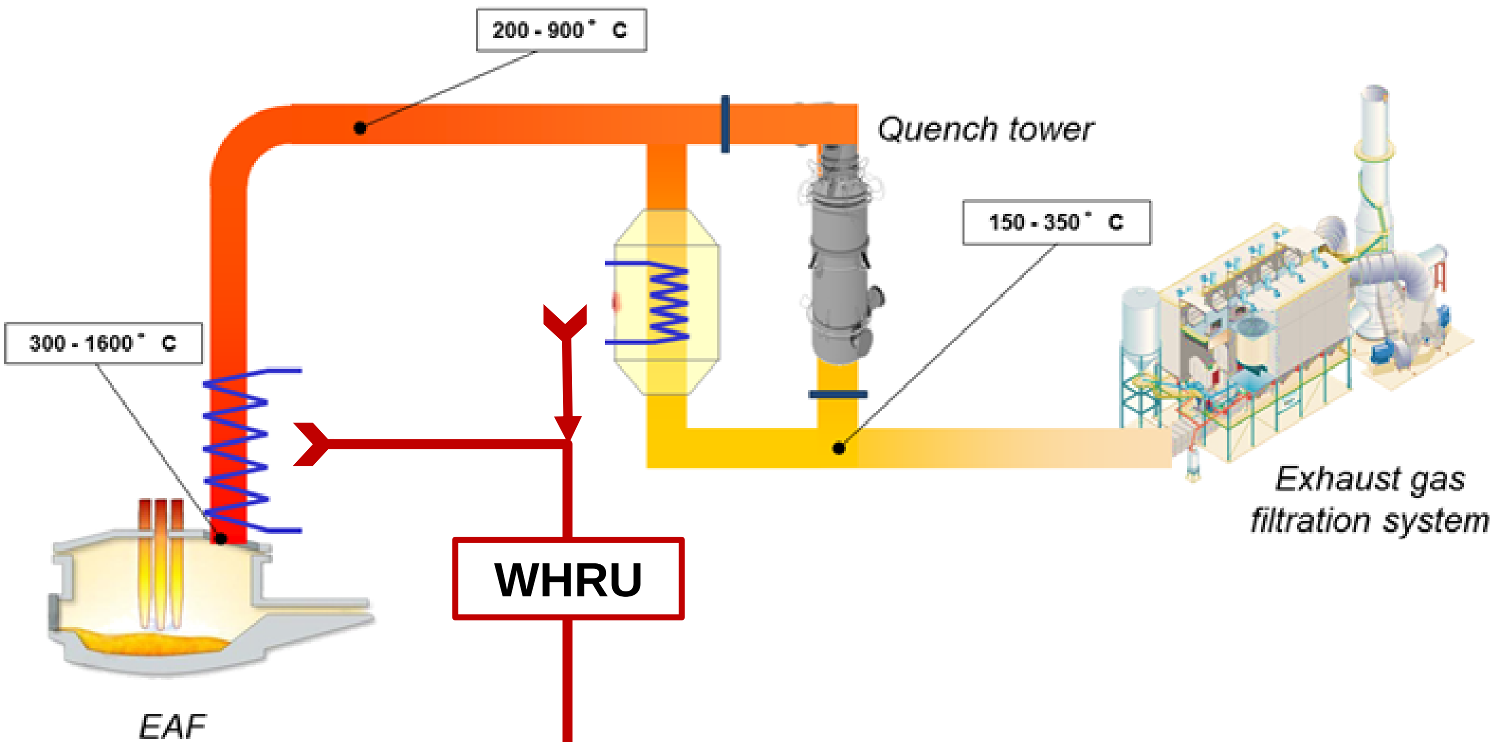
Source: FIRE, Federazione Italiana per l´uso Razionale dell' Energia & Turboden s.r.l.

PITAGORAS DEMO PLANT - BRESCIA

Process: Steel mill, Brescia, Italy
Electricity generation: April to October (approx. 1800 kW_{el})
District Heating: October-April (approx. 10MW_{th})



PITAGORAS CONCEPT



- Stops every 50min for tapping phase
- Temperature and volume rate fluctuations

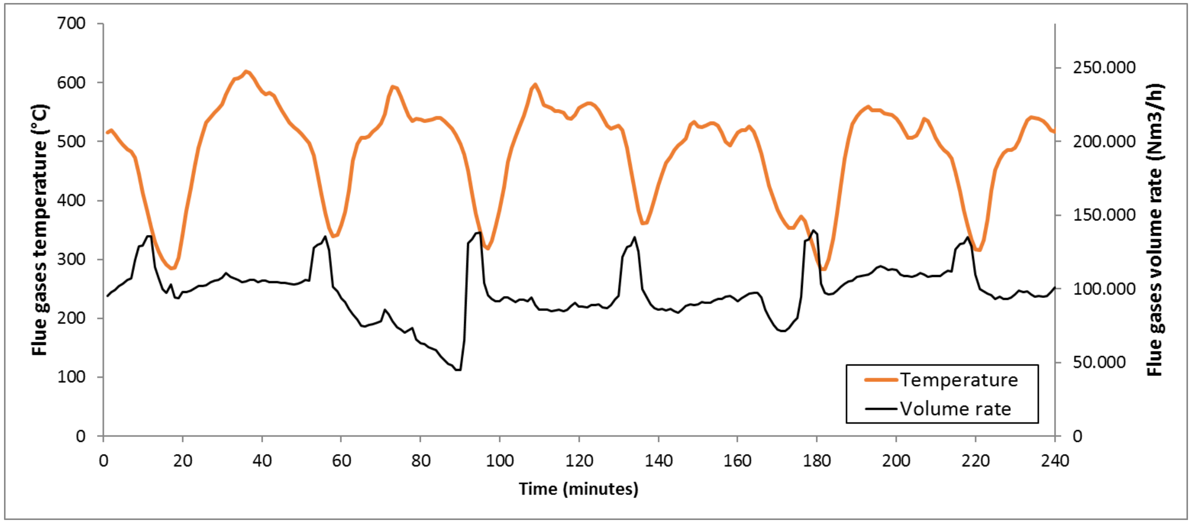
MAIN TECHNICAL CHALLENGES

- <u>Particles</u> in exhaust gases properties – deposition
- <u>Discontinuity of the available waste heat</u>
  The EAF works as a **batch process** due to the melting phase and the tapping phase
- <u>Heat source highly fluctuating</u>
  During the tapping phase the available waste heat is drastically reduced. High peaks of heat source during start-ups of the furnace.

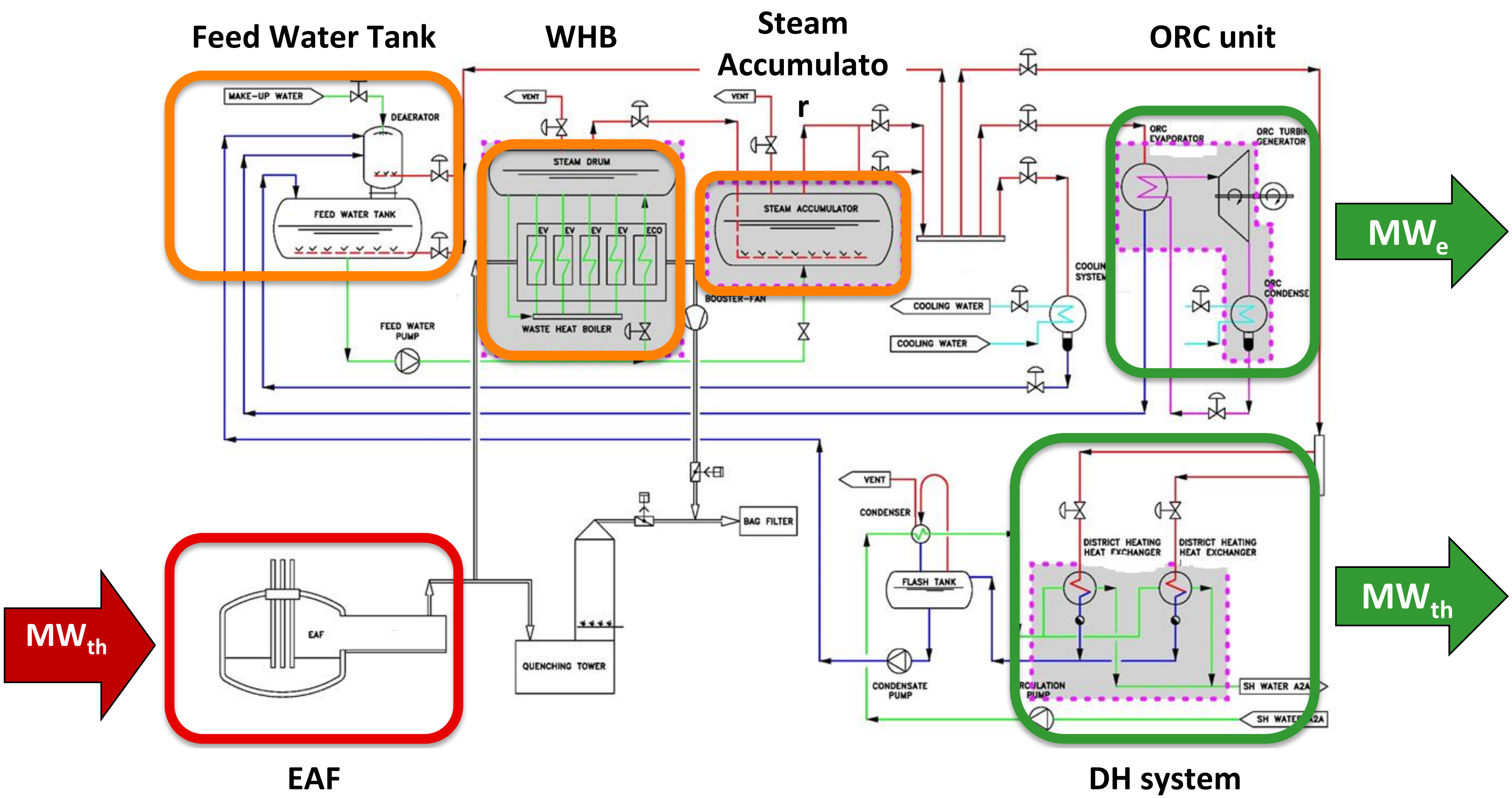
iRecovery® by TENOVA

STEAM ACCUMULATOR

Stabilizes steam supply, peak control and reduction



PROCESS FLOW DIAGRAM



DEMO PLANT (I)

Electric Arc Furnace (EAF)

- Mixed EAF: scrap melting with electrodes + natural gas burners.
- Flue gas flow partially directed to the WHRU or to the Quenching Tower, depending on operation mode.

Waste Heat Recovery

- Saturated steam generation via thermal exchange with EAF exhaust gases
- 4 Evaporators and 1 Economizer and Steam Drum
- Natural draft (no circulation pumps)
- Nominal Volume flow: 100.000 – 150.000 Nm^3/h
- Inlet waste gas temperature: 500 - 750 °C
- Boiler working pressure: 16 - 26 bar (g)
- Steam temperature: 204 - 228 °C
- Steam generation max: 30 t/h
- Pneumatic system to remove dust cake to maintain tubes clean.

tecnalia Inspiring Business

DEMO PLANT (II)

Steam accumulator

- Buffering capacity 6,0 MWht
- Volume 150 m3
- Admissible maximum pressure 30,0 bar(g)

Feed water tank

- Capacity 20,0 m3/h
- Volume 30 m3
- Admissible maximum pressure 6,0 bar(g)

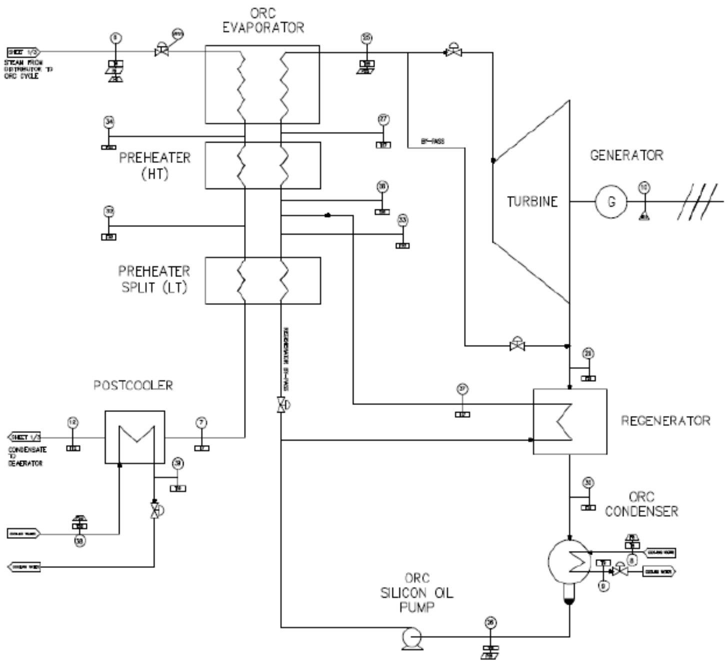
District heating station, A2A

- Nominal thermal power 10,0 MWth
- Steam flow rate 18,0 t/h
- Working pressure 10,0 bar(g)

DEMO PLANT (III)

ORC Turbine

- Working fluid: “MM” Silicone oil (hexamethyldisiloxane)
- Inlet pressure – working fluid: 7,8 bar(a)
- Outlet pressure – working fluid: 0,18 bar(a)
- Nominal thermal power input: 10,4 MWth
- Nominal gross power output: 1,88 MWe
- Nominal net electric power output: 1,82 MWe
- Net electric efficiency: 17,5%



MONITORING & DATA ANALYSIS

- Monitoring start: September 2016
- Data collection every 60 sec
- Temperature, pressure, volume rate, energy meter, gases and fluids…

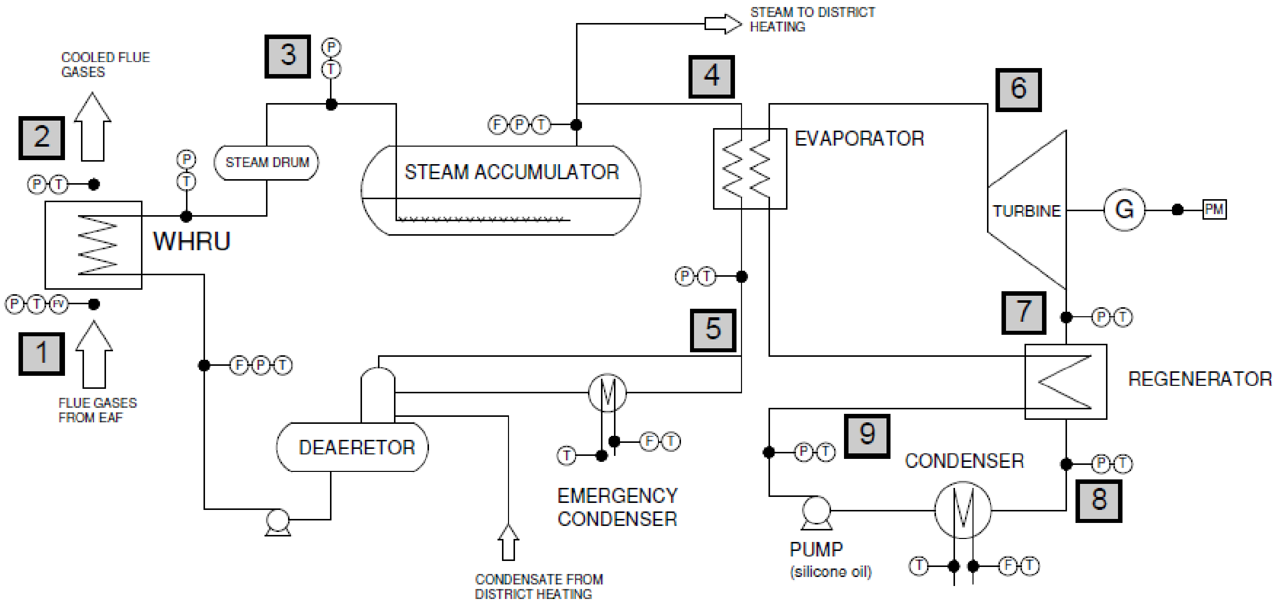
Equations:

$$Q_{fg} = V_{fg} \cdot \rho_{fg} \cdot (H_{in} - H_{out})$$

$$Q = \dot{m} \cdot (H_{in} - H_{out})$$

$$W_{ORC,net} = W_{OUT} - W_{ORC,Consumption}$$

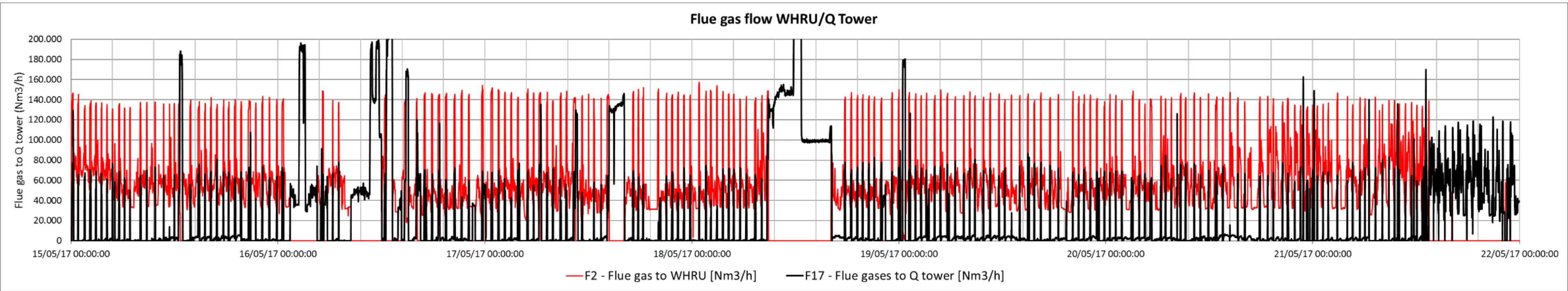
$$\eta_{ORC}\% = \frac{W_{ORC,net}}{Q_{evap}}$$

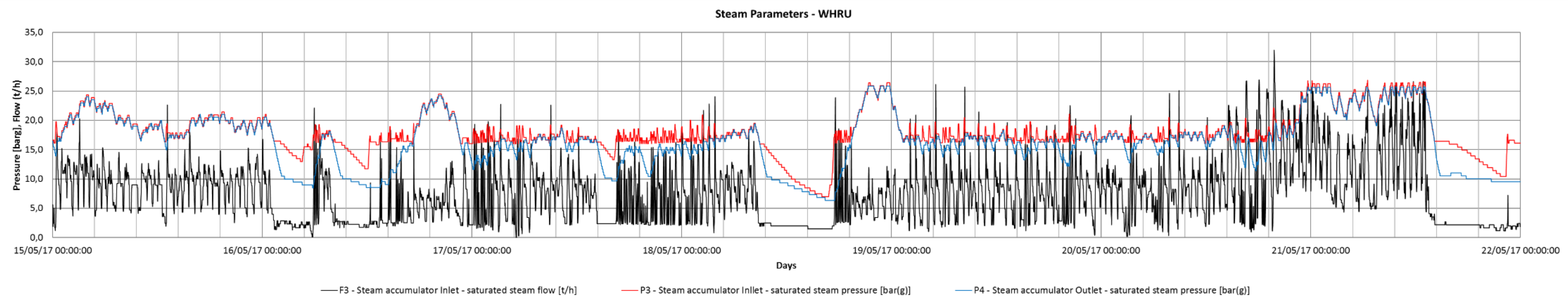


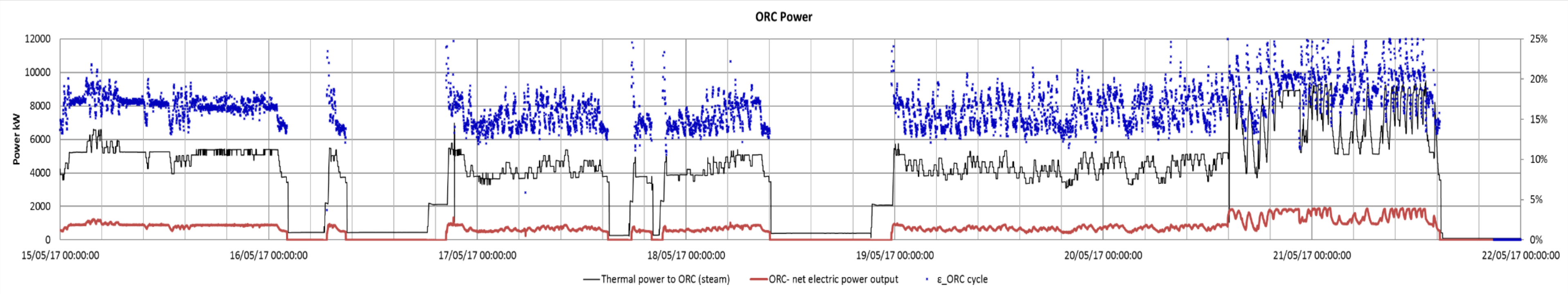
SENSORS

T	TEMPERATURE
P	PRESSURE
F	MASS FLOW METER
Fv	VOLUMETRIC FLOW METER
PM	POWER METER

DATA ANALYSIS



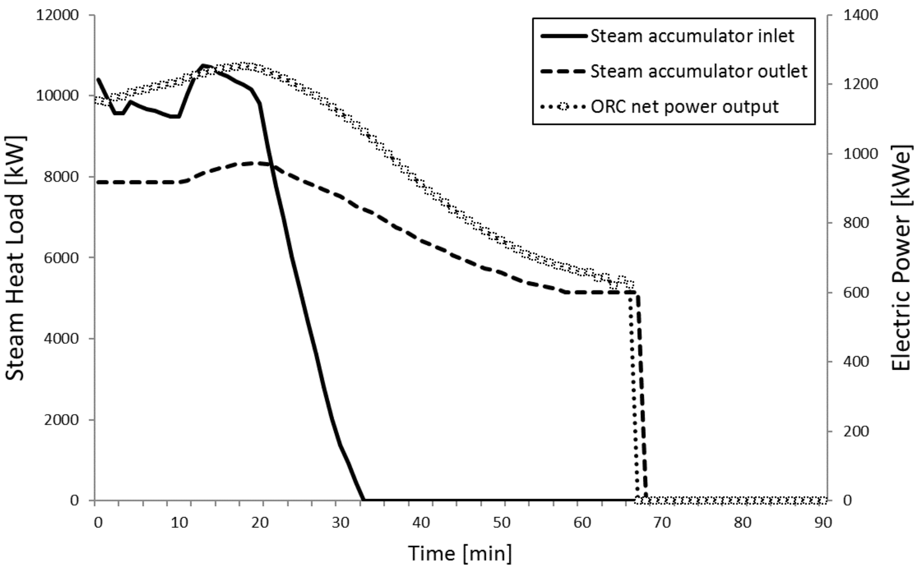




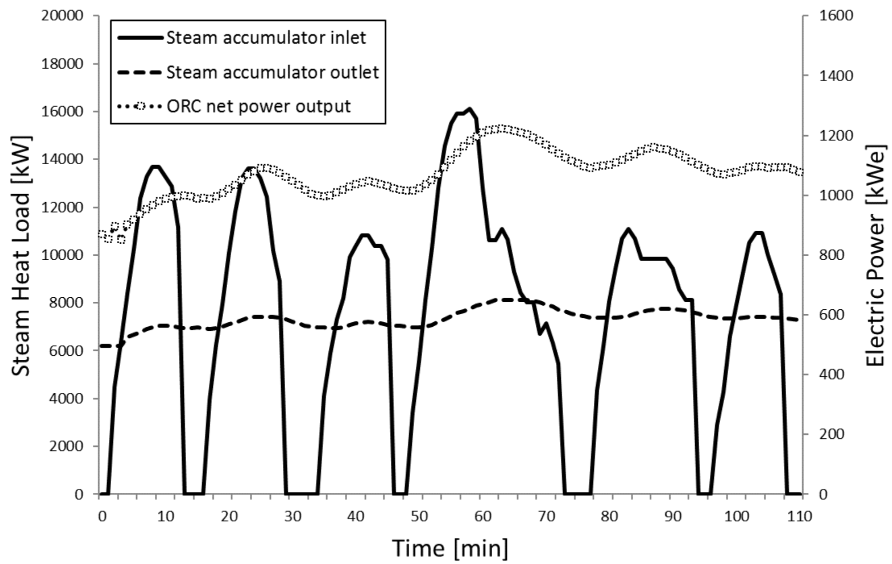
tecnalia Inspiring Business

RESULTS

STEAM ACCUMULATOR



a) Extended steam supply during the WHRU long stops

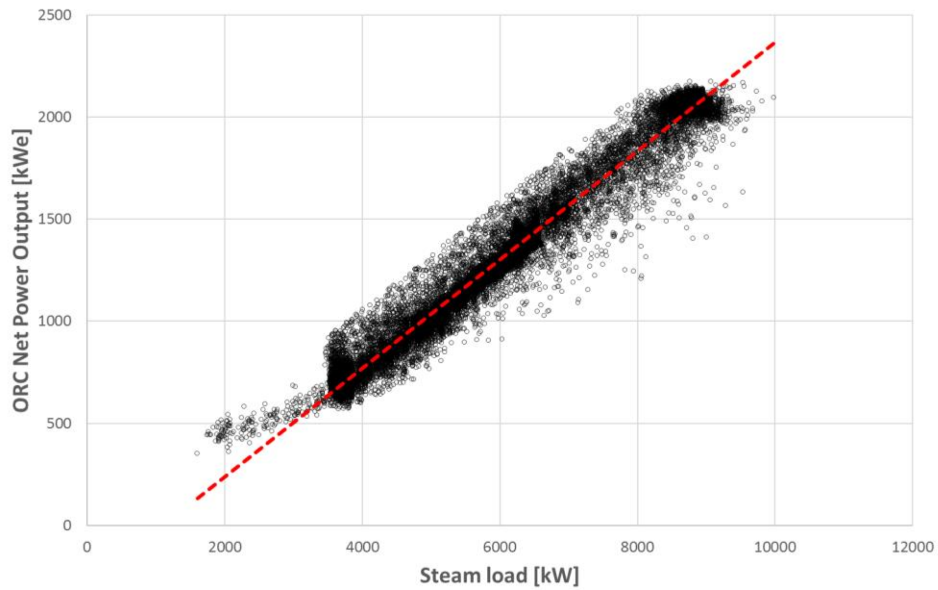


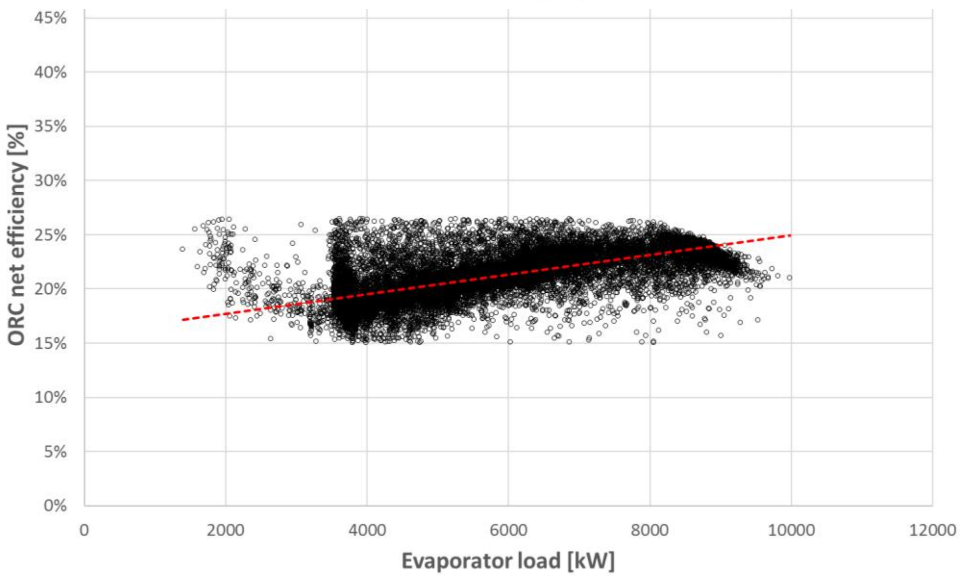
b) ORC output during discontinuous discharges of the WHRU

RESULTS

ORC PERFORMANCE

Parameter	Unit	Value
Flue gases inlet temperature	°C	529,6
Flue gases outlet temperature	°C	200,2
Flue gases flow rate	Nm³/h	50409,8
Steam evaporator inlet temperature	°C	180,9
Steam evaporator inlet pressure	bar	8,0
ORC expansor inlet temperature	°C	162,2
ORC expansor outlet temperature	°C	44,3
ORC expansor inlet pressure	Bar(a)	4,1
ORC expansor outlet pressure	Bar(a)	0,2
Heat load steam accumulator	kW	8953,9
Heat load ORC evaporator	kW	5722,8
Power self-consumption	kW	25,5
Net Power ORC Output	kW	1103,5
Net ORC efficiency	%	19,3





tecnalia Inspiring Business

ECONOMIC FIGURES

INVESTMENT		
Waste heat recovery system	6,4	Mio. €
ORC module	1,5	Mio. €
DH net connection	0,4	Mio. €
Miscellaneous (civil works and engineering)	0,8	Mio. €
Total Installation Cost	**9,1**	**Mio €**
Plant adaptation costs	1,1	Mio. €
Innovation costs	1,8	Mio. €
Total Project Cost	**12,0**	Mio. €
Investment subsidies: EC – Pitagoras project *	**2,5**	**Mio. €**
COSTS		
Operation and maintenance costs	**0,18**	Mio. €/a
REVENUES **		
Revenues from heat sold	**0,5**	**Mio. €/a**
Savings electricity costs	**0,4**	**Mio. €/a**

Preliminary economic evaluation shows **payback** period of **12 yrs.**
The specific incentive mechanisms based on White Certificates that are in force currently in Italy reduces the payback time of the plant to **4-6 years**.

tecnalia Inspiring Business

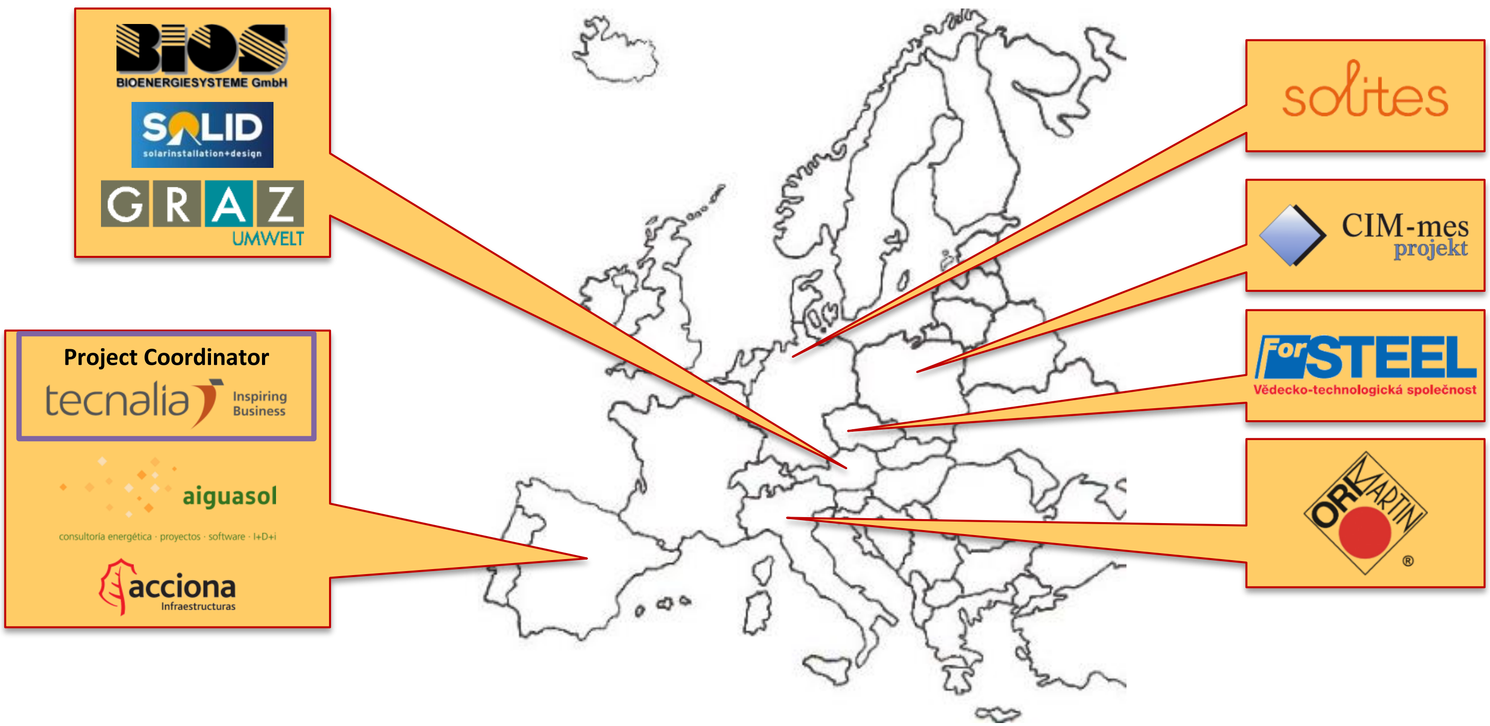
CONCLUSIONS

- A Waste Heat Recovery unit was installed in high peak fluctuation and discontinuous process of an EAF of a steel plant
- Waste heat is recovered using the iRecovery® of Tenova with an implemented dust removal system
- Fluctuation from the heat source was solved using a steam accumulator capable to extend the ORC operation for periods of approx. 50min
- Positive returns in terms of environmental benefits and energy efficiency, industrial competitiveness, social acceptance
- ORI Martin is the first steel industry to supply waste thermal energy to the urban district heating grid
- Process optimization still ongoing

CONSORTIUM

This project has received funding from the European Union Seventh Framework Programme FP7/2007-2013 under grant agreement n° ENER / FP7EN / 314596 / PITAGORAS.

PITAGORAS



THANK YOU

tecnalia Inspiring Business

Visit our blog:
http://blogs.tecnalia.com/inspiring-blog/

www.tecnalia.com