PITAGORAS

WASTE HEAT VALORISATION PILOT PLANT – BRESCIA

PITAGORAS (sustainable urban **P**lanning with **I**nnovative and low energy **T**hermal **A**nd power **G**eneration fr**O**m **R**esidual **A**nd renewable **S**ources) is a research project co-funded by the European Commission framed into the "FP7 – Smart Cities program".

The project focuses on the efficient integration of city districts with industrial parks through smart thermal grids. In particular, the project has worked on a waste heat recovery solution based on steam generation and Organic Rankine Cycle (ORC) technology in combination with steam condensers for the production of electricity and heat for district heating. The overall objective of the project is to demonstrate a highly replicable, cost-effective and energy efficient large-scale energy generation system that allows sustainable urban planning of low energy city districts.

In order to demonstrate the PITAGORAS-concept a demo-plant consisting of the waste heat recovery unit (WHRU), a steam accumulator in order to smooth the steam supply, an ORC module and the district heating infrastructure has been built and monitored.

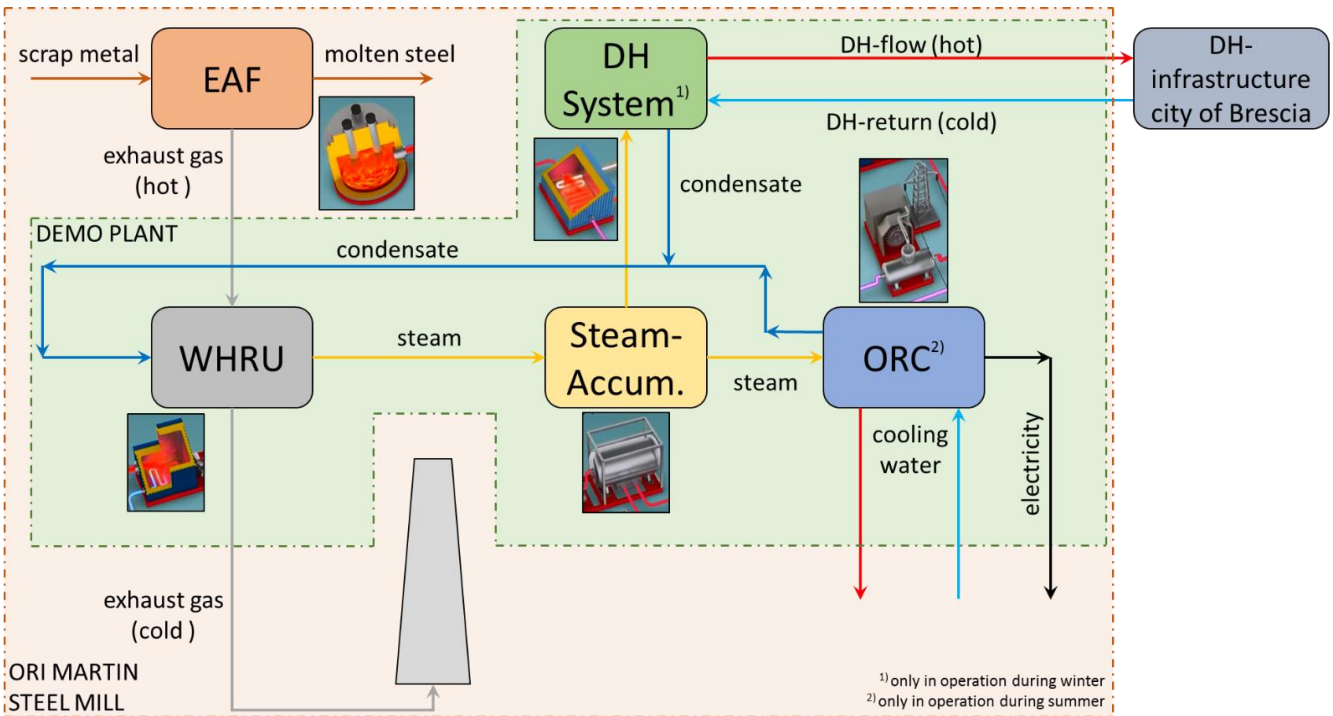
As location the steel mill in Brescia (Northern Italy) operated by ORI MARTIN S.p.A. has been chosen. A waste-heat recovery system with a nominal thermal capacity of 16 MW_{th} has been installed in the flue gas path of the existing electric arc furnace (EAF). The WHRU produces saturated steam which can either be used to power an ORC module for electricity production (nominal power 1,8 MW_{el}, during the summer period) or heat exchangers to provide district heat (nominal power 10 MW_{th}, during the winter period).

ORI MARTIN steel mill in the city of Brescia (Italy). Source: ORI MARTIN

System concept

The figure below shows a block diagram of the demo plant in Brescia. The source of the waste heat to be recovered is the flue gas from the EAF (used for melting of scrap metal for the steel production) installed at the steel mill. The flow rate of the flue gas varies over the course of the batch operation of the furnace. The flue gas average temperature at the entrance of the WHRU is around 500°C. This hot flue gas is then led into the WHRU, designed and installed by Tenova S.p.A., where it is cooled down to about 200°C by evaporating water and creating saturated steam as an energy carrier. To cope with the considerably high dust load of the flue gas, the WHRU is equipped with a suitable dust removal system.

The steam produced is then fed into a steam accumulator with a volume of 150 m³, which serves as a buffer storage to equalize the fluctuations in the steam production caused by the batch operation of the EAF to guarantee optimal operation of the downstream processes. The further usage of the steam is depending on the time of the year: during the summer period (mid-April to mid-October) the steam is used to power a water-cooled ORC-module, designed and installed by Turboden S.p.A., for electricity generation with a nominal power of 1,8 MWel to partially cover the electric own demand of the steel mill. During the winter period (mid-October to mid-April) the steam is led to two heat exchangers with a nominal power of 10 MWth in order to provide heat to the district heating system of the city of Brescia operated by A2A Energia S.p.A.. This mode of operation has been considered the most appropriate and efficient taking into account the specific boundary conditions of the plant as well as the heat delivery contract with A2A Energia.



Concept scheme of the whole process

Performance of the plant

The demo plant in Brescia is under a detailed monitoring campaign since end of September 2016. The campaign will at least continue until end of September 2017 in order to monitor a full year of operation including both operation modes: ORC and district heating.

The operation of the ORC was monitored until the 16th October 2016; after this the operation mode was changed to district heating supply. Below the main performance parameters for both operation periods are summarized.

Operation mode: ORC (26.09.2016 – 16.10.2016, 115 h of operation)	
average steam input to the ORC	6,8 MW
average net power output ORC	1,3 MW
average net efficiency ORC	19,3 %
heat input to the ORC	790 MWh
electricity output ORC	150 MWh
Operation mode: district heating (17.10.2016 – 30.04.2017, 4.280 h of operation)	
average heat input to district heating heat exchangers (steam)	5,2 MW
heat input to district heating heat exchangers (steam)	22,4 GWh
average heat output to district heating system	4,9 MW*
heat output to the district heating system	21,0 GWh

the stated average power is calculated over the whole period of operation

* the difference between the average and the nominal power exists due to the fact that the waste heat necessary for the nominal DH-output was not available during this first period of operation. In the future this number will be improved by means of process optimisation

Heat substation for heat delivery to the district heating network operated by A2A. Source: ORI MARTIN

Economics

The table below summarizes the main economic parameters including investment costs as well as the estimated operation costs and revenues for the Brescia pilot plant.

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 sellings	0,5 Mio. €/a
Savings electricity costs	0,4 Mio. €/a

* The possible incomes from the selling of White Certificates (the Italian incentive mechanism for renewable projects) are not included
** Revenues have been estimated for future plant operation (optimized and in regular operation)

Steam accumulator and steam pipes. Source: ORI MARTIN

Opportunities, benefits, barriers

The revalorisation of the waste heat from the EAF, which otherwise would be wasted, is the main benefit of this project. This means that with this waste heat it is possible to provide heat for about 2.000 homes. Additionally the operation of the ORC with a nominal electric output power of 1,8 MW reduces the amount of electricity to be purchased from the utility and thus saves costs. The installation of a system like this also results in the saving of fossil fuels and thus reducing the CO_2 emissions, about 8.000 ton of CO_2 can be avoided every year.

The main barrier of the project is the economic side due to low energy prices and high equipment costs. A first economic evaluation of the plant showed a payback period in the order of 12 years, which is typically considered as long, especially in an industrial company. Appropriate policies based on sustainability criteria, which might be reality in the future, could help to overcome these barriers. The specific incentive mechanisms based on White Certificates that are in force currently in Italy reduce the payback time of the plant to 4-6 years.

The PITAGORAS project shows an opportunity for many companies in the field of energy intensive industries (e.g. steel or glass industry) that the utilization of waste heat to provide electricity and district heat is possible.

Waste Heat Recovery Unit. Source: ORI MARTIN

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