**PROJECT FACT SHEET**

**EUROPEAN UNION CO-FUNDED PROJECT**

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**7th Framework Programme for Research and Technological Development (2007 ÷ 2014)**

**LARGE SCALE SYSTEMS FOR URBAN AREA AND/OR COOLING SUPPLY. ENERGY.2012.8.8.2**

*Project acronym:*

# PITAGORAS

# Sustainable urban Planning with Innovative and low energy Thermal And power Generation from Residual And renewable Sources.


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Project web site: https://www.pitagorasproject.eu

## 1. PROJECT SCOPE

PITAGORAS is a European funding project framed into FP7 – Smart Cities program. The project focuses on the efficient integration of city districts with industrial parks through smart thermal grids. Technologies and concepts for medium temperature industrial waste heat recovery, considering as well integration with renewable energy sources (RES), and heat and power supply to cities have been developed and demonstrated.

The overall objective of the project is to demonstrate a highly replicable, cost-effective and high energy efficiency large scale energy generation system that will allow sustainable urban planning of very low energy city districts.

## 2. PROJECT TECHNICAL DESCRIPTION

In concrete, Pitagoras has worked in the definition of two system concepts. On the one hand, a waste heat recovery system coupled with an ORC for electricity and district heat production for industries with high availability of medium temperature waste heat (>300ºC) has been developed. The main objective has been a real scale pilot plant in a steel mill in the city of Brescia (Italy), including the design, implementation, commissioning and monitoring. Based on the real design and monitoring data the project has analyzed and proposed solutions for the exploitation and replication of the developed concept into other boundary conditions.

On the other hand, the project has developed a second system concept based on industrial integration of solar thermal energy in combination with seasonal thermal energy storage (STES) concept for process heat and heat supply to district heating networks. The plant has been designed for a specific site in the city of Kremsmünster (Austria), in an industrial area of an oil and gas industry. Real implementation of this plant has not been performed within the Pitagoras framework but its exploitation and further replication possibilities have been analyzed.

## 3. MAIN RESULTS ACHIEVED

The technical activity of the project has been developed through six WPs. WP1 had as objective to establish the "Boundary conditions and requirements" for the systems to be developed in the project. Different types of industry mean different boundary conditions. The two case studies (Brescia and Kremsmünster) were analysed in detail and the initial requirements that the new systems had to fulfil for a successful development and implementation were concluded.

WP2 deals with "System concept assessment and final design" of both plants. The designs of the systems resulted as follows:

*Waste heat recovery plant with ORC for electricity and district heat generation for the ORI MARTIN steel mill in Brescia*: waste heat is coming from the Electric Arc Furnace (EAF) of the steel plant. A 16 MW Waste Heat Recovery Unit (WHRU) has been designed in order to produce saturated steam. The system is characterized by the high fluctuations of the waste heat; the integration of an accumulator has been therefore crucial. A short-term steam accumulator with a volume of 150 $m^3$ has been integrated to the system concept in order to appropriately handle the huge fluctuations of the produced steam. The steam will be used then for thermal energy production and supply to the city district heating (DH) network by means of steam/water heat exchangers (10 MW) or to feed the ORC unit to produce electricity (1,8 $MW_e$), which is the operation strategy followed in summer time.

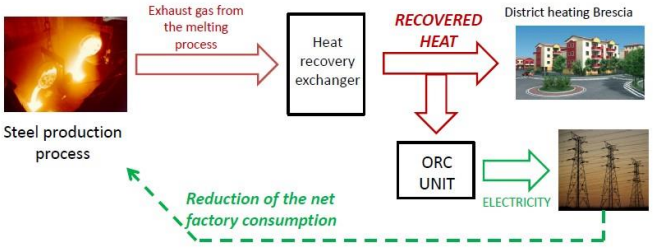


**Figure 1. Overview of the Pitagoras pilot plant in Brescia**

*Industrial integration of solar thermal energy in combination with STES, including the possibility of solar heat delivery also to the DH network*: the developed system concept is formed by a solar field of 9377 $m^2$, which is expected to produce around 4547 MWh/year of useful solar heat. The idea of reconverting an existing oil tank of 60,000 $m^3$ of storage volume (that is no longer used for oil storage) into a STES allows to store the surplus solar heat in summer and its use later on in winter months, significantly increasing the solar production capabilities, system performance and energy savings. The system layout of the PITAGORAS system was developed in detail by transient system simulation taking into account the specific prerequisites and needs of the different industrial processes and the aim of maximizing the solar thermal energy gain and the possibility of heat delivery into a district heating network.

**Figure 2. Overview of RAG premises and the four oil storage tanks, including the empty one. Source: SOLID**

Implementation of the real scale pilot plant for the demonstration of the waste heat recovery system designed in WP2 has been the main objective of WP3. The pilot plant was implemented during 2015 and was commissioned on January 2016. Until October 2016 several tests were performed to verify the operation modes and perform an initial tuning of the plant.

**Figure 3: the Waste Heat Recovery Unit (WHRU) installed at ORI MARTIN. Source: ORI MARTIN**

**Figure 4: Exchange unit with A2A heat district heating. Source: ORI MARTIN**

**Figure 5: Turbo-generator with Organic Rankine Cycle. Source: ORI MARTIN**

The main challenge was related with the discontinuous operation of the EAF. The furnace stops every 50 minutes for the taping phase and therefore the steam production is very discontinuous. The commissioning of the plant has been successfully accomplished; the production of electricity and heat in a stable way was the main challenge and it has been successfully achieved.

Another important challenge faced in this installation has been how to manage the Electric Arc Furnace dust as it is a sticky product that if not removed from steel pipes of the boiler the thermal transfer would be reduced in a big extent. Besides it is very abrasive and is a small particle size product. There is an automatic system which removes in an effective way the dust sticked to the pipes and according to the annual inspection of the Waste Heat Recovery Unit, there was not damage on the pipes.

WP4 was focused on the monitoring and performance assessment of the pilot plant. The plant has been monitored for one full year of operation from mid of September 2016 until beginning of October 2017, allowing the evaluation of both operation modes of the plant: DH mode as well as electricity mode. During the DH-operation of the plant around 21 GWh or heat have been supplied to the district heating network of the city of Brescia. During the ORC-operation around 1,8 GWh of electricity have been generated from the ORC module, giving an overall electric efficiency of the plant of about 15%. The average net efficiency of the ORC module amounted to 17,7%, which is well within the specifications by the manufacturer. Throughout this first year of operation about 29 GWh of primary energy consumption as well as roughly 5.600 ton of $CO_2$ emissions have been avoided by the operation of the Brescia pilot plant, compared to the conventional generation of electricity and heat. These figures are likely to increase over the coming years because of continuous optimisation of the performance of the plant.

WP5 has been dealing with market and business related issues mainly related to the Pitagoras waste heat recovery system. As expected, the Life Cycle Assessment (LCA) performed for the Brescia demonstrator has revealed the huge environmental benefits of this solution. The energy that has to be invested for the realization of the plant is paid back for instance in just a few months due to the large amount of zero-emission energy that is produced by the plant annually. The main barrier of these projects is however in the economic side. Even the projects are very site-specific, in general the initial investment are high and without subsidies payback periods that are above acceptable ranges for the industries are obtained. Payback times above 10 years have been concluded as typical for these systems under present boundary conditions. In the specific case of the Pitagoras pilot plant the payback time is reduced to 4-7 years considering the received subsidies and incentives. To face the current energy related challenges better energy policies based on sustainability criteria are necessary.

The main factors characterizing plant viability of waste heat recovery projects are found to be capacity factor and the energy prices. The current market potential of Pitagoras solution in the steel sector has resulted quite scarce under current boundary conditions. The current capacity factor of EU steel manufacturing industry is the major drawback for such rentability. However, plants with high capacity factor in countries with high energy prices are potential candidates for Pitagoras system implementation in an economically feasible way.

## 4. EXPECTED IMPACT

The development of low-carbon solutions for thermal energy supply to cities in order to help them to achieve the energy and environmental objectives is the main purpose of the Pitagoras project. District Heating plays an important role on achieving these objectives since it allows to make an efficient use of local resources such as waste energy and renewables. A standard and unique solution that is suitable for any city does not exist, but the solution must be a combination of different resources available locally. In this sense, the Pitagoras project's impact comes from the performed research regarding solutions based on industrial waste heat recovery and the use of solar thermal energy; two energy sources with high potential for the reduction of carbon footprint towards the development of smart cities.

One of the objectives of the Pitagoras project was to maximize the opportunities for future replication of Pitagoras concepts. Waste heat in industry has high potential for energy recovery. The Pitagoras concept can be replicated in industrial facilities that produce high amounts of waste heat, sectors such as steel, cement, glass, chemical, paper, thermal treatment of metallic parts, bricks and ceramic products manufacturing, etc. Industry generates approximately 4,000 TWh of waste heat annually in Europe (equivalent to the incident solar radiation in 3,300,000,000 $m^2$). Assuming that only 50% of total available waste heat can be recovered, there would be a potential of around 2.000 TWh of useful heat per year. This amount of energy is equivalent to 17,000,000,000 $m^3$ of natural gas. The recovery of all the available waste heat represents about 5% of the total EU consumption.

Considering in particular the specific industrial process addressed within the project, namely the steel melting in the Electric Arc Furnace (EAF), it is worth noting that about 25-30% of the energy used in the EAF is lost in the exhaust gases. It is estimated that up to 70% of the thermal power lost in the exhaust gases can be recovered, which is at a high enough temperature to produce either electricity or thermal energy with interesting efficiencies and economic added value, while reducing environmental impact.

On the other hand, there is an increasing interest of the use of solar thermal energy for DH applications, and it shouldn't be forgotten that solar energy for process heat can be applicable in several industries, increasing implementation opportunities, not only for oil industry as in the Pitagoras project, but others such as chemical, food, paper, textile and wood industry for example are as well interesting end-users.

Specifically, the Pitagoras demonstration plant of Brescia will annually produce the equivalent electricity of the electricity consumption of 700 families. Furthermore, it is contributing to cover part of the heat demand in the city DH network. The heat delivered from the pilot plant will approximately cover a 3% of total annual heat consumption of the network, which is estimated in 2000 homes approximately. Environmental and energetic benefits associated to this are evident, reducing the primary energy consumption and the $CO_2$ emissions considerably (≈10.000 ton $CO_2$/year expected in regular operation).

Concerning the developed system concept for Kremsmünster and according to estimations within the design phase, the system would save around 1.000.000 $m^3$/year of natural gas consumption and 2.900 ton$CO_2$/year.

It is expected that the realization of the Pitagoras project will have its impact in the short-future allowing further similar projects. Furthermore, it will contribute to reach the three priorities of Europe 2020 that the Commission proposed in its communication of March of 2010: 1) smart growth developing an economy based on knowledge and innovation, by boosting the use of renewable energy sources; 2) sustainable growth promoting a more resource efficient, greener and more competitive economy; 3) inclusive growth fostering a high-employment economy, through the market uptake of the technologies that are required in the developed systems.

## 5. ADDITIONAL INFORMATION

A promotional video has been developed within the project. It can be found in the following link: https://www.youtube.com/watch?v=7PPapTAzFUA

Technical information on the results of the project will be available in the project website: https://pitagorasproject.eu

**List of partners:**

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