Co-funded by the Erasmus+ Programme of the European Union

Master Degree in Innovative Technologies in Energy Efficient Buildings for Russian & Armenian Universities and Stakeholders

WASTE ENERGY RECOVERY FROM GAS EXPANSION IN URBAN NG NETWORKS

The experience from Genoa Demonstrator

Ing. Roberto Bergamino

IREN GROUP – IRETI SpA

IREN was set up on 1st July 2010 through the merger of Enìa and Iride and is at the top in the Italian multi-utilities sector occupying a leading position in its business areas, a balanced mix of regulated activities and free activities and a close integration between upstream and downstream activities.

Due to its production assets, its past and present investments, its position in all business areas, in all phases in the energy chain, and its roots within the country, IREN is one of the main Multi-utilities Groups on the Italian scene.

IREN Group operates in the following sectors: electricity, gas, district heating, integrated water service and environment, and it also provides other public utility services (telecommunications, public lighting, traffic light services, facility management).

IRETI, the new born company for electricity, gas and water distribution, is the owner and operates the GENOA Demonstrator.

Source: Company data

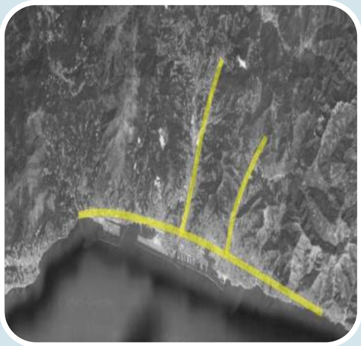
GENOA CITY Context

- Important seaport in northern Italy
- Peculiar geographical configuration, “sandwiched” between coast and hills/mountains, has strongly influenced its urban development and infrastructure system
- Urban development has linear yet **“polycentric” configuration** along three axes, which **does not allow for large scale district heating, but rather for several smaller networks**

Strategy for a reduction of CO_2 emissions

- Implementation of a series of actions in different areas, which include:
  - **Distributed generation** exploiting locally available but dispersed energy sources to diversify the energy supply mix
  - More district heating and/or cooling networks **(Micro-DHN)**

Motivation of the GENOA project

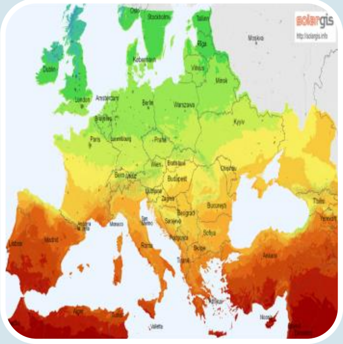


Complex territorial morphology

Urban areas are concentrated along the coast and two inland valleys

Complex urban texture

One of the biggest historical centre in Europe (UNESCO site)



Mediterranean climate

Mild and short winters

High development of NG distribution network

CELSIUS Project Team

IRETI S.p.A. as Project Responsible

Genoa Municipality as the Local Authority

University of Genoa as the R&D Partner

D'Appolonia S.p.A. to *Monitor&Evaluate all CELSIUS demonstrators*

Why CELSIUS ?

Difficulty of supply of hydrocarbons products

Increase of the energy consumptions

Rational use of energy

More effective use of energy through

ENERGY RECOVERY

Why CELSIUS / Why Turbo-expander ?

- Because, within CELSIUS, Genoa demonstrator answers the need for an **energy efficiency integration between industry** (i.e. the gas distribution activity by IRETI SpA) **and final consumers**

- Because we can achieve an **optimal utilization of the natural gas**, by:

  - Recovering energy that is converted to electricity to be distributed to the surrounding district
  - Rationalizing consumption patterns through remote control of both electricity and gas consumption
  - Helping final consumers to use efficiently gas

Key Technologies:

Expansion turbine for natural gas applied to drive an electric generator interconnected with the electricity grid to provide electricity to several utilities in the surrounding district

Remote control of both electricity and gas consumption

CELSIUS GENOA Demonstration Project

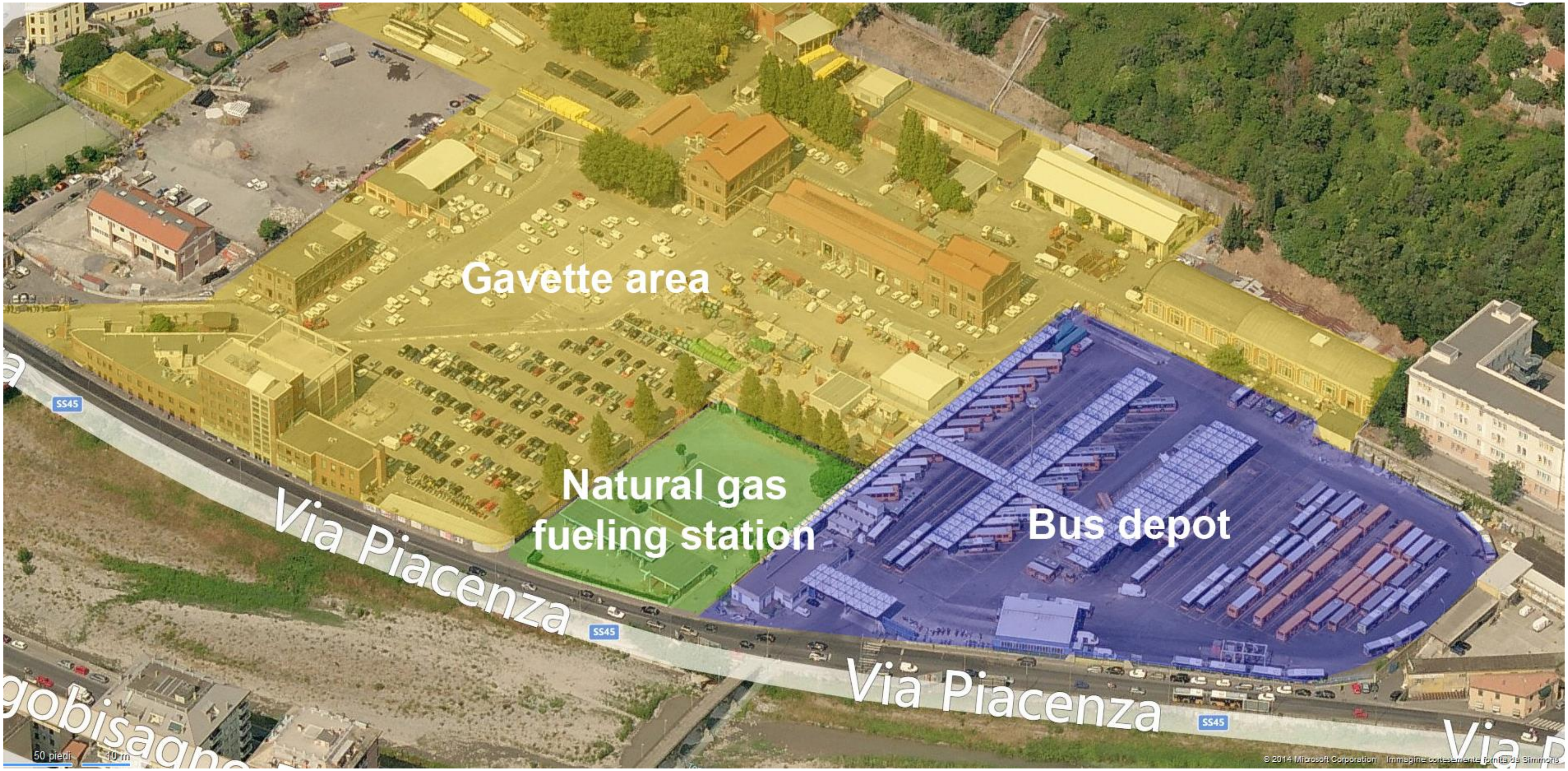
District characteristics:

- District comprehends dwellings as well as industrial, service and commercial end-users
- Moreover, it hosts **the gate station of the natural gas distribution network**, where the gas pressure is reduced from transmission levels (24 bar) to distribution levels (5 bar) and measuring and regulation take place
- Gavette site is managed by the multi-utility company "IREN Group" and hosts the other companies of the group IRETI, Mediterranea delle Acque, IREN Gestioni Energetiche

Objective:

Development of a **local energy generation and distribution network** consisting of:

- turbo-expansion process for natural gas to recover electricity from the natural gas pressure expansion process occurring within the gate station
- new district heating and cooling network **(micro-DHN)** associated to a CHP plant



Gavette area
Natural gas fueling station
Bus depot
Via Piacenza
Via Piacenza
SS45
SS45
SS45
50 piedi
10 m
© 2014 Microsoft Corporation Immagine cortesemente fornita da Simmons

Ecological and cheap energy source

- What is turboexpansion

  - **Turboexpansion is** the technology that, in the transport and natural gas distribution, with the use of a turbine realize the expansion of the gas producing electrical energy.

  - Within **CELSIUS project,** IRETI has selected the use of a turboexpander for natural gas decompression.

  - With the turboexpander, the pressure reduction produce an **energy recovery**.

  - The supplier of **Genoa Demo Turbo-expander (TURBINDE)** has more then 25 years of experience in the energy recovery by mean of natural gas decompression in the main pressure let down stations with many application that are perfectly operating.

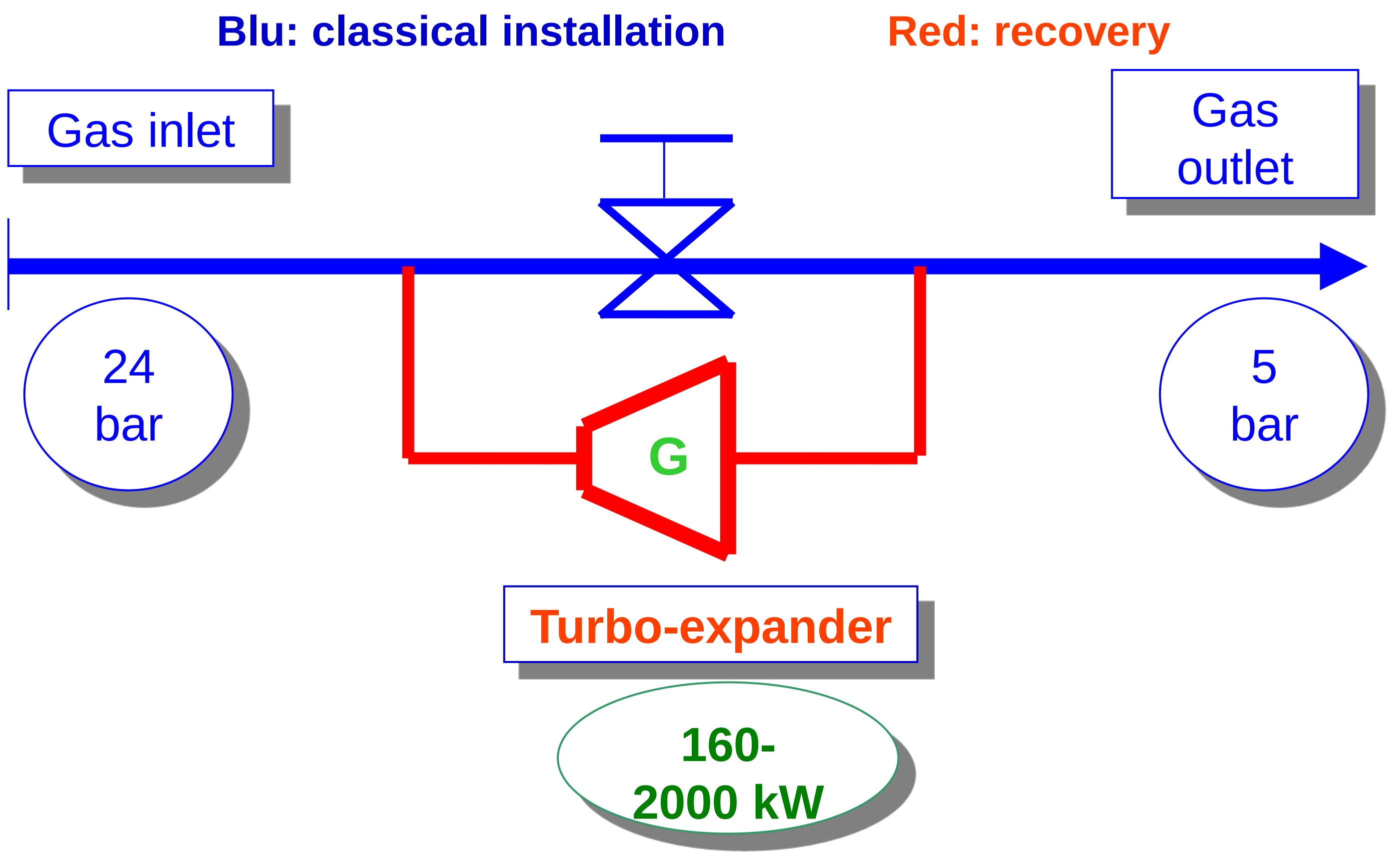
Operation principle

- **Basic principle**
  - Natural gas is distributed at high pressure to minimize the losses, but the end user normally need it at a lower pressure.
  - **Expansion turbines utilise the pressure drop to recovery the energy that otherwise would be lost.**
  - The pressure reduction is usually obtained by a pilot-controlled pressure regulator: the mechanical energy of the gas is thermally dissipated for the Joule-Thomson effect.
  - With the use of an expansion turbine mechanical pressure energy of the natural gas is transformed in kinetic energy, and afterward in electrical energy in the generator.

– Examples
  – Typical installation are in the let down station of the towns, where is possible to recover from 160 to 3000 KW

Operation principle

- Two possibility



Operation principle

- **Theory**

The available potential energy may be calculated from the enthalpy difference between inlet and outlet of the turbine, multiplied for the mass flow.

Energy recovered (kJ/h) = Difference of enthalpy (kJ/kg) x Flow (kg/h)

Radial expansion turbine are designed for a high working range: the efficiency is high even at the lower loads.

The main contribution to the power is the flow of the turboexpander, but also a high enthalpy difference (high pressure drop) permit a significant energy recovery.

Example

– Inlet Temperature:	60 - 90 °C
– Outlet Temperature:	0 - 10 °C
– Inlet Pressure:	20 - 70 bar
– Outlet Pressure:	5 - 10 bar

Operation principle

- **Practical**

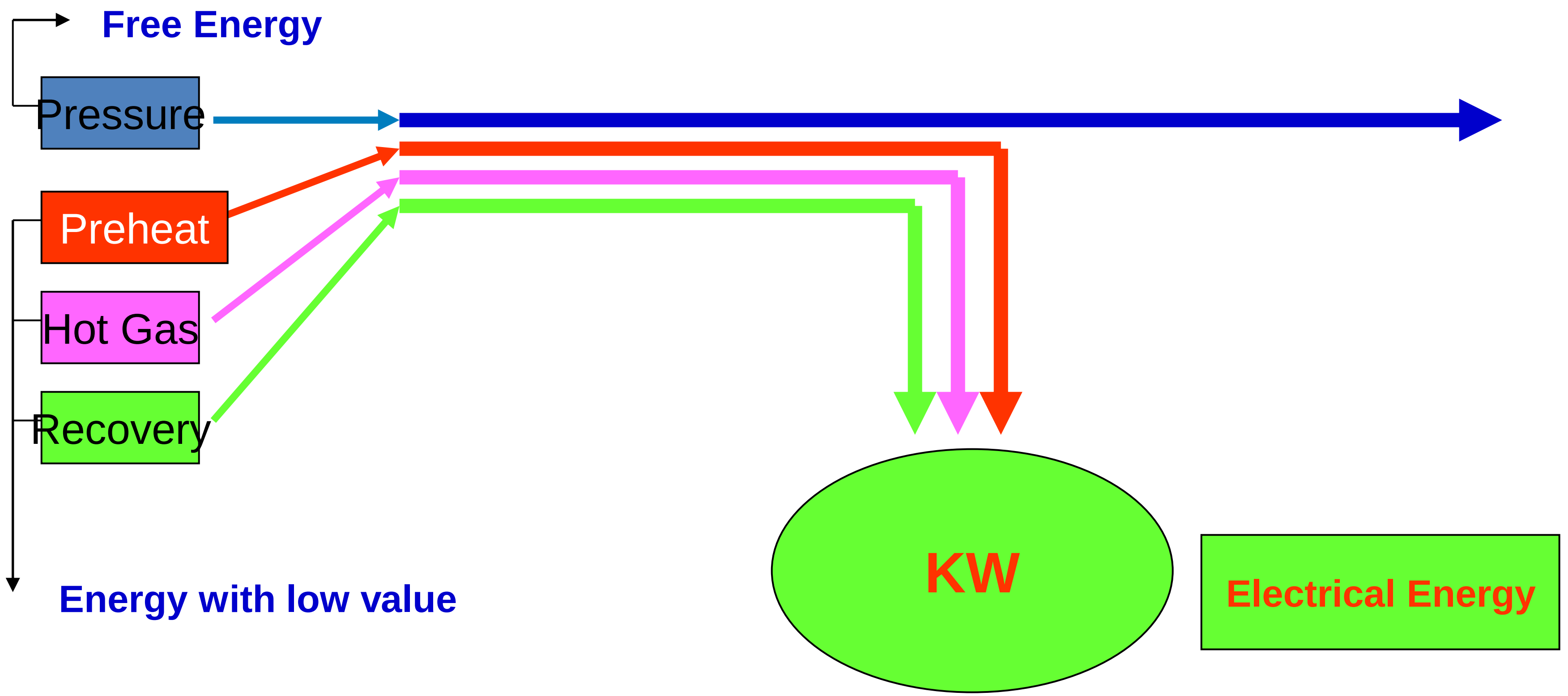
In the majority of the applications, the components (piping and valves) do not admit a outlet temperature of the turbine too low, the hydrocarbons that are present in the gas may condense if the gas become too cool. The best outlet temperature of the turbine is between 5 and 15 °C .

For this reason the **gas must be preheated before the expansion**.

The thermal energy that is needed for the preheating of the gas is transformed in the electrical energy produced.

- Example
  - It is possible to use a cogeneration (production of heat and electrical energy). The gas that is burned produce also electricity, the total efficiency is higher than a conventional energy production.
  - Often is available **a free or a recovery thermal source** at low temperature (80–100 °C) that permit to increase the total efficiency of a turboexpansion plant of natural gas.

Flow chart

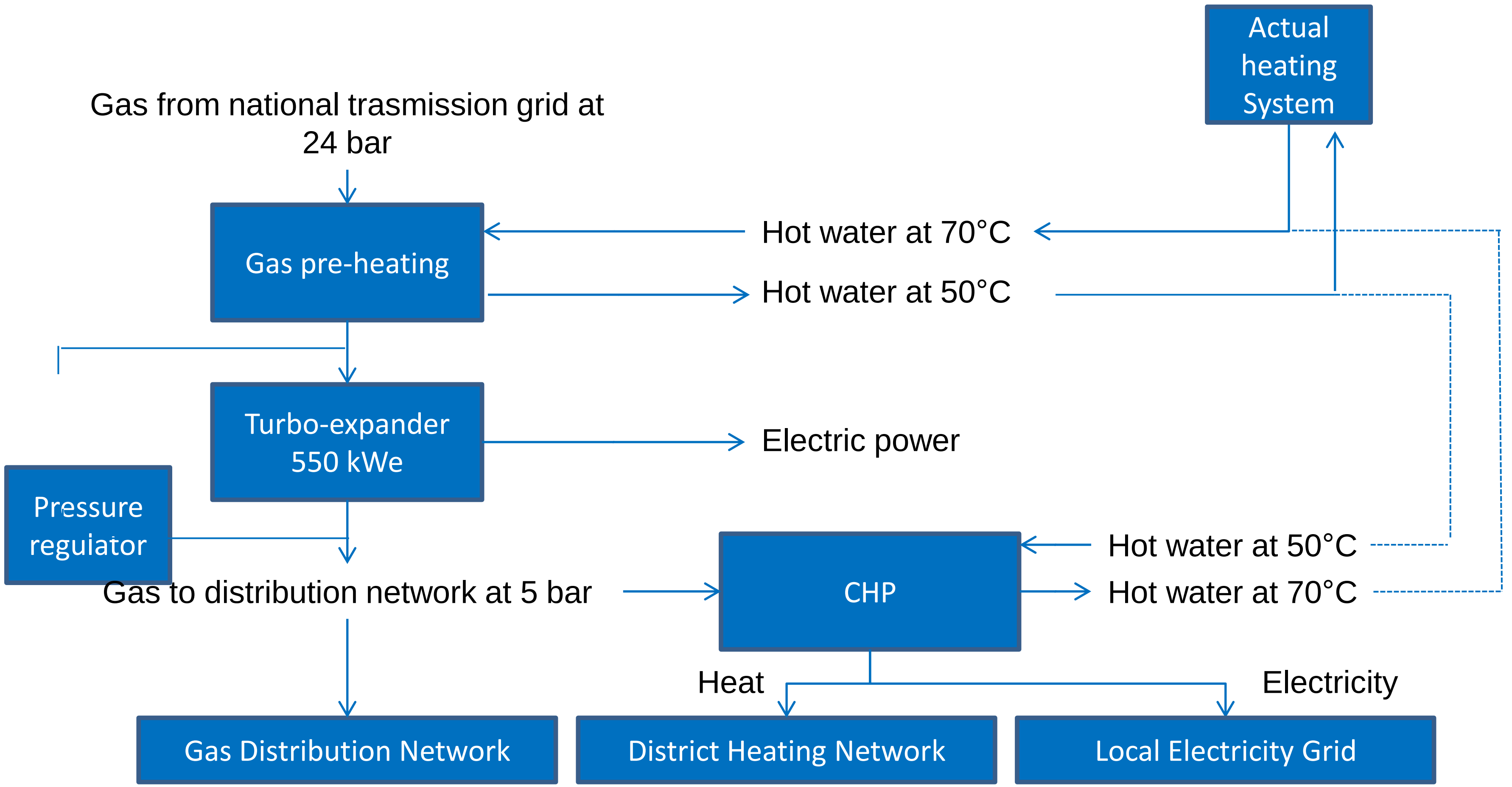


Free Energy
Pressure
Preheat
Hot Gas
Recovery
Energy with low value
KW
Electrical Energy

When a turbo-expander can be used

- **Mandatory characteristics**
  - Availability of natural gas at high pressure that must be expanded at low pressure
  - Availability of gas flow distributed during the year
  - Use of electrical energy in the own grid or possibility of selling of electricity

- **Favourable characteristic**
  - Possibility of using a free thermal source for gas preheating


Actual heating System
Gas from national trasmission grid at 24 bar
Gas pre-heating
Hot water at 70°C
Hot water at 50°C
Turbo-expander 550 kWe
Electric power
Pressure regulator
Gas to distribution network at 5 bar
CHP
Hot water at 50°C
Hot water at 70°C
Heat
Electricity
Gas Distribution Network
District Heating Network
Local Electricity Grid

Genoa Demonstrator - Results and Outlook

Technical data:

- Electric Power : 526 kWe CHP
  550 kWe Turbo-Expander
- EE Production (estimated on 5.000 hours operating):
  2.300 MWh per year (CHP)
  2.800 MWh per year (TE)
- Environmental Savings: 1200 ton CO_2/year

Economics:

- Total investment cost : 3.021.000 €
- EU contribution: 1.497.000 €

Technical KPIs

ID	KPI
GE1T1	Ratio between the gas flow rate through the turbo-expander and the gas flow rate through the lamination valve
GE1T2	Yearly amount of net electric energy produced by the turbo-expander
GE1T3	Yearly amount of net electric energy produced by the CHP system
GE1T4	Total produced net electric energy
GE1T5	Yearly amount of thermal energy produced by the CHP
GE1T6	Yearly amount of thermal energy provided by the district heating
GE1T7	Ratio between the yearly amount of thermal energy used for gas heating before the expansion in turbine and the yearly amount of thermal energy produced by the CHP
GE1T8	Ratio between the yearly amount of thermal energy provided by the district heating network and the yearly amount of thermal energy produced by the CHP

Environmental KPIs

ID	KPI
GE1En1	Variation of emissions for the main considered pollutants connected to the electric energy production compared with the baseline situation
GE1En2	Variation of emissions for the main considered pollutants connected to the thermal energy production compared with the baseline situation
GE1En3	Yearly GHG savings

Economic KPIs

ID	KPI
GE1Ec1	Yearly savings generated by self-production of electric energy with reference to baseline situation;
GE1Ec2	Yearly cost for natural gas burnt in the CHP
GE1Ec3	Yearly cost for natural gas burnt in boilers
GE1Ec4	Savings arising from the reduction of natural gas consumption
GE1Ec5	Cost of maintenance of the turbo-expander per each kWh of net produced electric energy
GE1Ec6	Cost of maintenance of the CHP per each kWh of net produced electric energy
GE1Ec7	Yearly cost of maintenance of the entire system
GE1Ec8	Variation in the bill for end-users for thermal energy consumption

Social KPIs

ID	KPI
GE1S1	Number of working hours used for running and maintaining the TE-CHP system
GE1S3	Number and type of possible complaints (e.g. for noise) by the citizens living in the neighbourhood
GE1S4	Number of additional end-users benefitting of the implementation of the new system

Project timeline

Design phase (Apr.2013 - Apr.2015)

- Design and tender to procure the turbo expander
- Design of the CHP and related size of the micro DHN
- Civil works for preparing the area to install the turbo-expander and the micro DHN pipelines: design of underground works and foundations
- Authorizations procedures

Installation phase (May 2015 - May 2016)

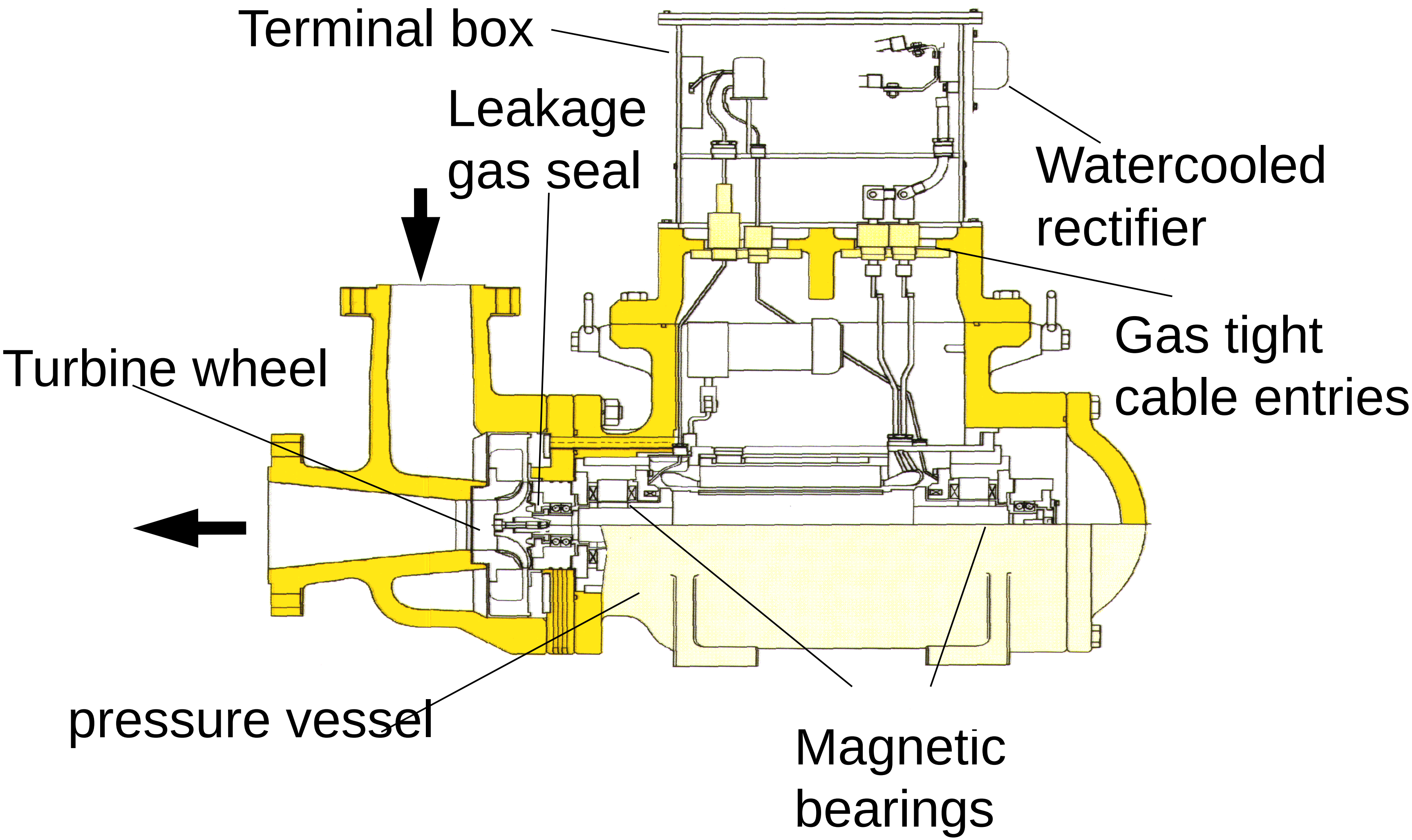
- Finalization of the civil works
- Installation of TE, CHP and pipelines

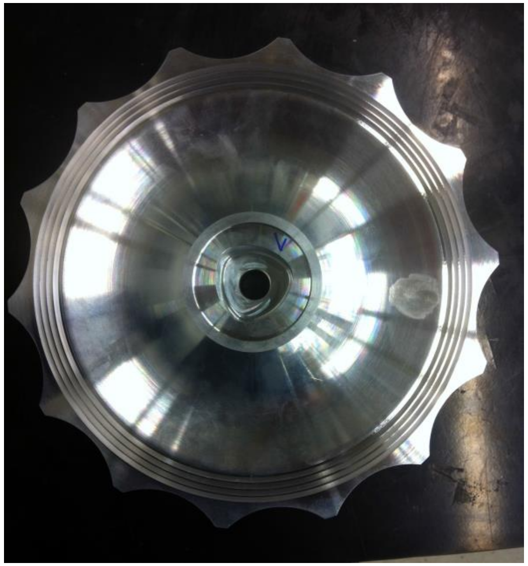
Operation phase & Monitoring (from June 2016)

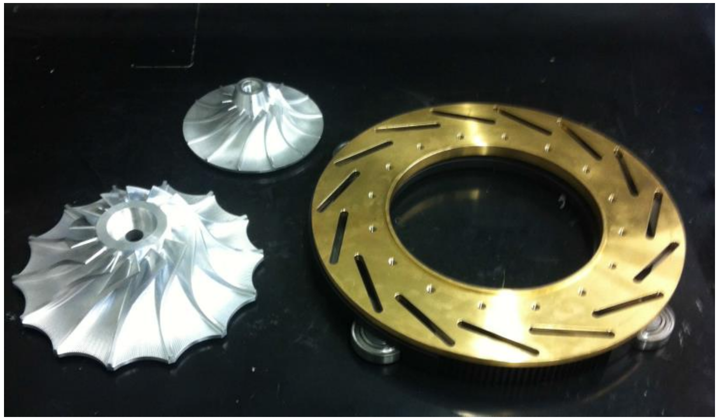
Genoa Demonstrator – Further Expansion

Potential of upgrading / replicability of the Genoa demonstrator

- ✓ **Integration of the Genoa demonstrator** with a natural gas station for private and public vehicles and a public school located nearby
    - ✓ Provide electrical supply
    - ✓ Storage of mechanical energy through high pressure gas accumulation
    - ✓ Use of return water of the DH network for intercooling process
- ✓ The extension of the project can reinforce **the role of the Genoa demonstrator as an example for further achievements in other cities,** aimed to a wide replication of the implemented solutions


Terminal box
Leakage gas seal
Watercooled rectifier
Turbine wheel
Gas tight cable entries
pressure vessel
Magnetic bearings



JCB


GEHL


VERNAZZA
LOGISTICS


Macchine Edili
REPETTO
VERNAZZA










Thank you for the attention