"BARREDO COLLIERY"

DISTRICT HEATING

INSTALLED POWER CAPACITY: 2.2 MW

HULLERAS DEL NORTE S.A., S.M.E. (HUNOSA)

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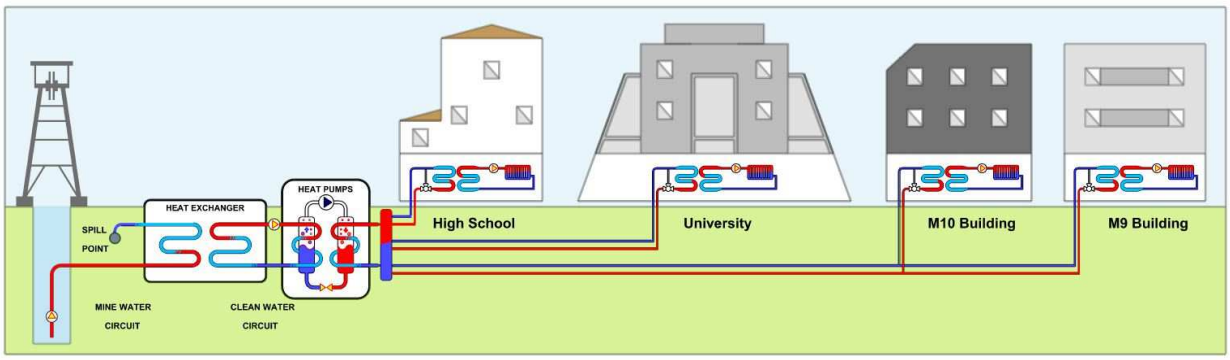
MOTIVATION

Mieres has been traditionally a city closely linked to the activity of coal mining, with several collieries situated along River Caudal valley. The decision of finishing the extraction of coal represents for the company Hunosa, previously the main national actor in this sector, an important challenge for the next decades.

Between the innovative projects in managing the non-active collieries is the use of water from the mines, and in our particular case, the harnessing of the geothermal gradient of water pumped from the flooded mines.

Since 2009 it was developed a geothermal exploitation facility using a heat exchanger and heat pumps located in different buildings in Mieres, with a very positive result.

The actual project that now has been completed involves the development of a District Heating with a unique Generation Plant with 2 heat pumps in the own facilities of Barredo Colliery. The heat pumps benefit by heat exchangers using the temperature of the water pumped from the main shaft of the mine at 23°. Subsequently it feeds, using an underground pipe network, two public buildings and a total of 245 dwellings, at a maximum distance of 900 metres. The energy supply may be set at different working temperatures.



Scheme District Heating Barredo

The network has a power capacity of about 2 MWt, suppling energy to the buildings heating systems and also for the domestic water. It keeps the previous natural gas boilers out of service most of the time, with a total installed capacity of 6,274 kW. The new facilities are GHG-free and reach a theoretical annual CO_2 emission reduction of 653 ton. These facilities have provided also the renovation of some old buildings of the colliery as part of the industrial heritage of the region.

The project was co-financed by FEDER funds for the "2017-2018 call for subsidies co-financed by the European Union through the European Regional Development Fund (ERDF), allocated to companies, to promote the transition to a low-carbon economy in all sectors". The amount of the subsidy was 503,125 € for an investment of 1,421,541 €.

The facilities has become the greater geothermal district heating in Spain, and a starting point for future projects in the Asturian Carboniferous Basin.

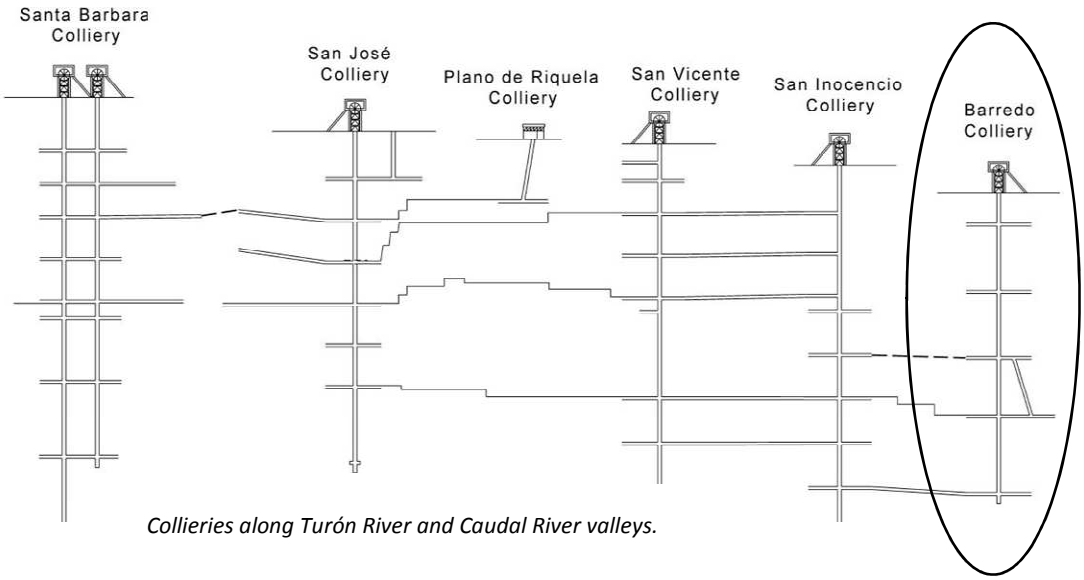
INTRODUCTION

The geothermal energy related to mining activity is a renewable resource that paradoxically has been created artificially. In its original condition, the Central Asturian Carboniferous Basin didn´t content large size aquifers. The very intensive mining development, since the ending of XIX century, has created a complex net of galleries that modifies completely the natural state of the subsoil, increasing water infiltration and generating a hydrological system that could be compared to a karst formation.

Once it was decided that underground mines should be closed, it starts the stage of flooding. Then, the water is not pumped anymore and it fills the excavated voids. This filling process happens until a security level that must be maintained pumping at a constant flow. If not, it could occur damages in those potential floodable areas, difficult to predict, as we face now a new aquifer modified by the mining activity, that have to cohabit with new infrastructures or buildings that were constructed under an artificially depressed phreatic level, during more than a century of mining operations.

Once the permanent pumping stations are stablished, it is feasible to develop projects using this pumped water in order to reduce partially the eternal costs of water pumping. Among these projects is the geothermal use of mining water, as this water has certain characteristics, such as pumped flow quantity, temperature and quality; that makes it potentially useful and profitable. This resource is an innovative solution of Circular Economy creating from a problem (the eternal pumping costs) a source of wealth and a sustainable resource.

In our particular case, Barredo Colliery has the lowest ground level from a serial of closed and flooded collieries which underground galleries are interconnected and let the water move into lower levels. In addition, this colliery is situated in Mieres, with an approximated population of 38.000 people.



Collieries along Turón River and Caudal River valleys.

With the intention of minimizing pumping costs, and because of its location at the lowest level, a high percentage of the pumped water from this system of interconnected collieries is pumped from Barredo Colliery.

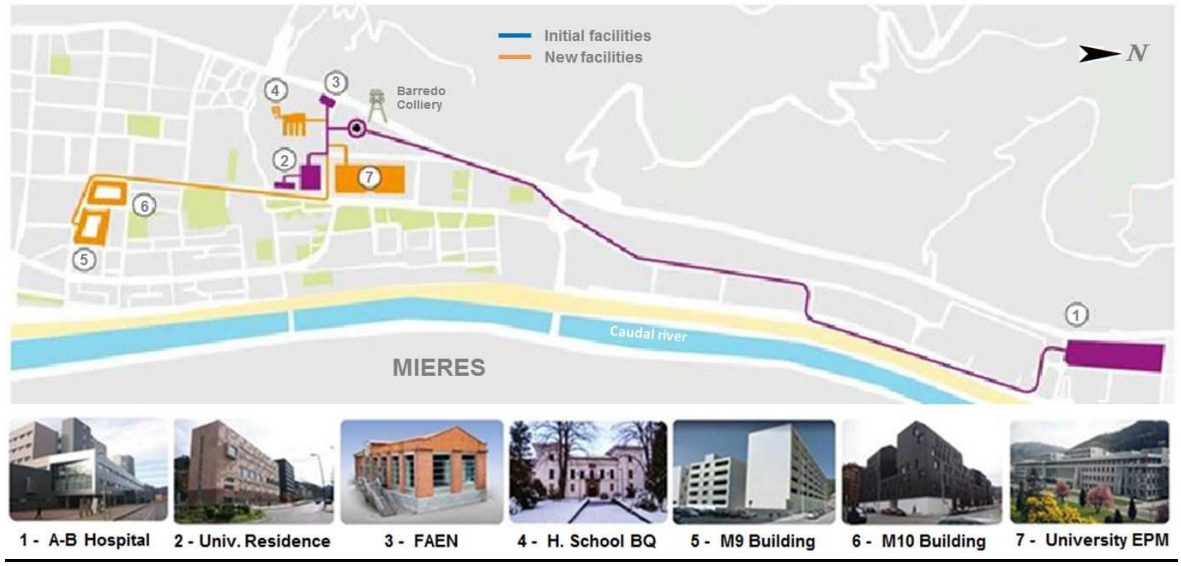
The water, that initially is introduced in the subsoil filtering between the joints and natural fractures of the ground and finally travels along the mining galleries, increases its temperature during its route successively.

This enables an average **annual pumped water** extracted from Barredo Colliery of **3.96 Hm^3** (measured between years 2002 and 2018), at an average temperature of **23° C**. Taking into account a thermal gap of 5° C for the commercial heat pumps acquired, we can consider a **theoretical thermal power** of **2.63 MW**.

INICIAL GEOTHERMAL FACILITIES

During the period 2009-2016 were placed the first underwater pumps in Barredo Colliery and thereafter, as a pioneer initiative in Spain, were developed the initial geothermal facilities with the installation of one heat exchanger in Barredo Colliery, and different heat pumps in several buildings of Mieres to benefit from geothermal energy (Álvarez-Buylla Hospital, Research Building of University of Oviedo, the Energy Asturian Foundation FAEN, and the Student Residence of University of Oviedo).

As a whole, the initial geothermal facilities, including the power supplied by the heat pumps, involve an installed power capacity of 4 MWt.



Scheme of District Heating in Barredo Colliery

NEW GEOTHERMAL FACILITIES

During the development and operation of the initial Project and realizing the last technologies in thermal generation systems (heat pumps), that allows getting heat water at a higher temperatures rates (up to 85°C) with positive COP ratios and, allowing therefore, the integration of all types of buildings, it was decided to modify the scheme for the future development of new geothermal projects, because there were different aspects that limited the possibilities for new facilities:

- The own infrastructure of the collieries areas made technically difficult to add new systems for heat exchange or water pumping.
- The ratio consumption/distance from the potential clients is a critical economic factor.
- The installation of heat pumps in the buildings boiler rooms use to be difficult, because of the installed electric power required and also because of its limited dimensions.

All these reasons made that finally the development of the new geothermal projects were not seen in a fragmented manner, as particular services to individual clients, but as a whole, concluding then that the more reasonable, profitable and efficient way to extend the potentiality of geothermal resource is the development of a **district heating**.

Our District Heating consists basically of a pipeline system that allows connecting different energy sources to several energy consumption spots, with a more efficient use of energy and the utilization of the renewable energies (easier to integrate in these centralized systems), reducing significantly the atmospheric greenhouse gas emissions and other gases and particles environmentally harmful.

In this way, at the end of 2018 started the construction of the new geothermal heating district benefiting of water pumped from Barredo Colliery. In May 2019 the works were finished. The new geothermal facilities allows feeding three different circuits, being two of them at high temperature*: Escuela Politécnica de Mieres (EPM)* and High School Building (*Bernaldo de Quirós*), and another at low temperature (*buildings M9 y M10 Vasco Mayacina*). The reason for these last buildings is that they use a climate system at low temperature, improving our equipment efficiency when its heat demand does not co-exist with those building working at high temperature.

The new Geothermal District Heating in Mieres implies a heat power capacity of 2 MWt, increasing the total power capacity up to 6 MWt, conforming the largest Geothermal District Heating in Spain, providing service to 4 new clients.

PREVIOUS CONDITIONS OF BUILDINGS

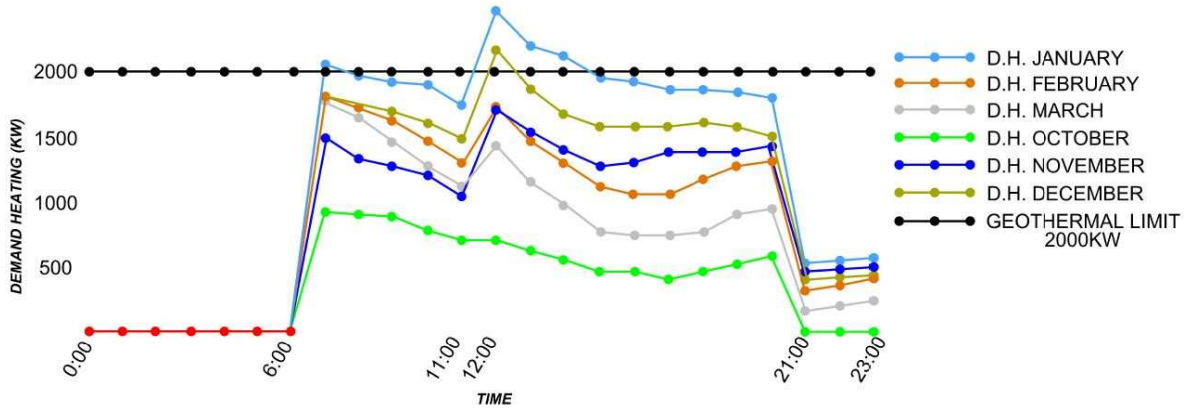
Before this District Heating project, all buildings used natural gas as primary energy. In addition, each of them had their own natural gas boiler facilities. In the next table, power installed and set point temperature is showed:

	Total Capacity (kW)	*Set point temperature(ºC)*
University	3,354.4	80
High School	639.6	70
"M9" Building	600	45
"M10" Building	1,680	45
TOTAL	6,274	

Gas boilers were used to provide heating and domestic hot water in the buildings, with the exception of the university, which only provides heating.

While the first two buildings use a conventional heating system, M9 and M10 have been recently constructed and uses radiant floor. The buildings have then different heat demands and require different set point temperatures. Two different future working modes will result.

Also the kind of building is relevant. While public buildings (University and High School) require heating only during working hours, residential buildings (M9 y M10) will require low temperature service constantly. It makes possible to diversify energy production and make the project viable.



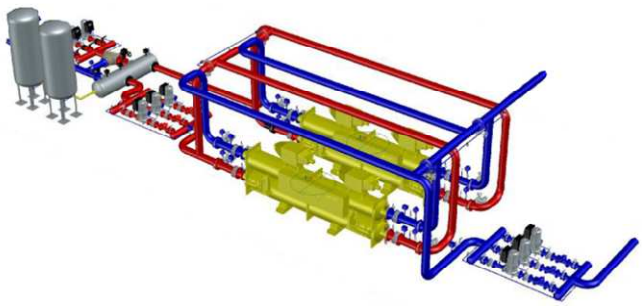
Heat Demand during the year

CURRENT CONDITIONS OF BUILDINGS

The new district heating installation centralizes the heat generation in the facilities of the extraction machine of the Barredo Colliery. The mine water is extracted by means of submersible pumps located in the vertical shaft of the mine. As mentioned above, water is at a constant temperature of approx. 23°C during the entire year. These pumps have a nominal flow of 330 m3/h and a power capacity of 83 kW each.

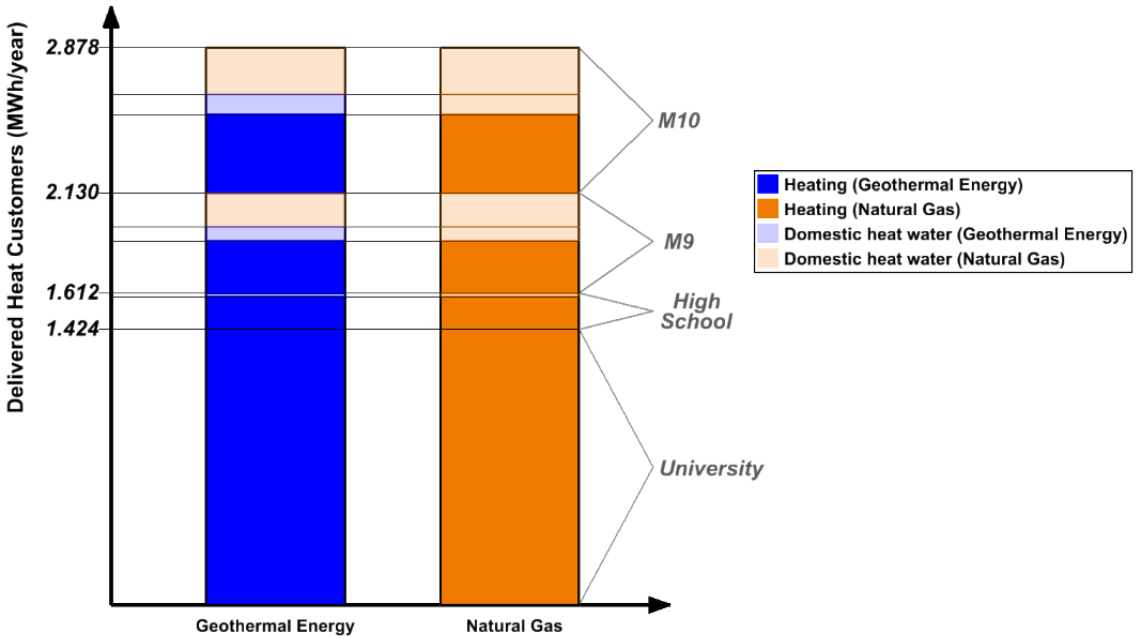
Submersible pumps at vertical shaft

Two heat pumps, located in the generation plant, are used to increase the temperature required to meet the demand. Total capacity of heat pumps is 2 MW.



Heat pumps at generation plant

This project supplies 2,462.88 MWh/year of geothermal energy to consumers. Maintaining, as it has been said, a contribution by means of natural gas boilers for



domestic hot water in residential buildings.

Depending on the delivery temperature, there are three different distribution networks: two of them at high temperature and the other at low temperature.

A. <u>High temperature network</u>

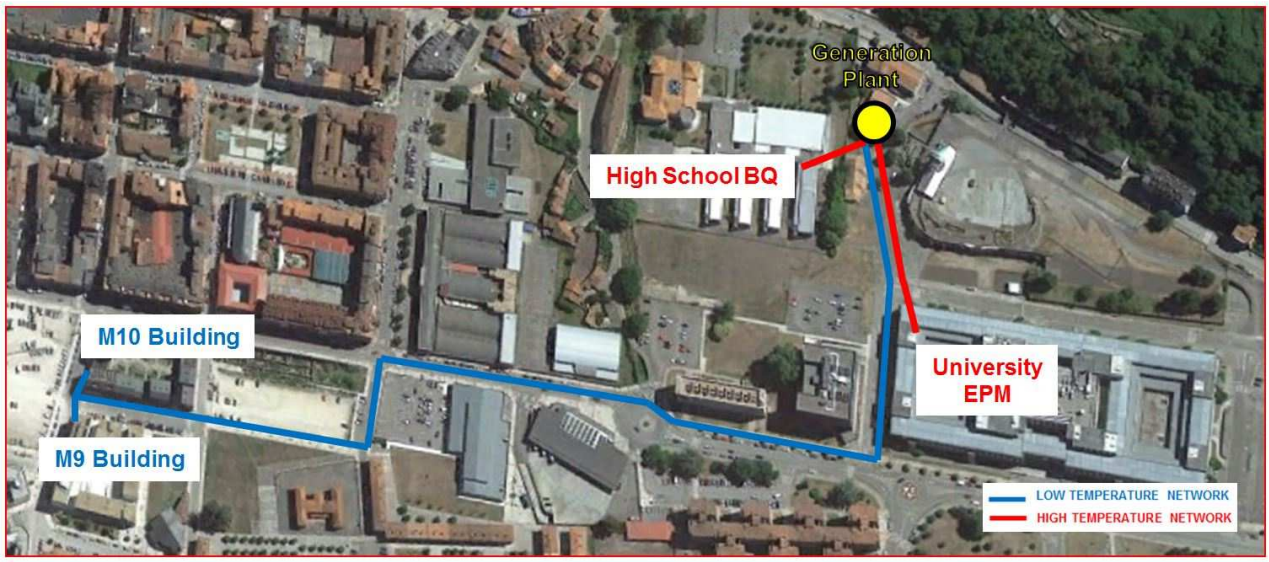
To date, geothermal energy had been used to low flow temperature in heating (45-50°C). Nevertheless, technology development and new refrigerants used have increase the flow temperature in heat pumps to 85°C. In this project, refrigerant used is R1234ze.

This new situation enable us to heat traditional heating systems, giving us access to new potential customers who are interesting for their high consumption. However, heat pumps performance (COP) is reduced when the set-point temperature is increased. Likewise, when heat pumps operate with moderate

thermal gaps (low temperature network) they maintain a COP around 5. While in these conditions, the COP decreases to almost 3.

In order to reduce this effect and optimize the efficiency, this project is intended to work in a variable set-point temperature according to the outside temperature.

In that way, the two high temperature networks connect with the University (EPM) and with the High School Bernaldo de Quirós. Both of them are the closest from Barredo Colliery which makes possible the high temperature network.



Scheme of High and Low temperature networks

B. Low temperature network

In order to optimise the ratio of installed power to produced energy, it is necessary to try to access a larger number of customers, whose demand does not match over the same period. This would be the case for the dwelling buildings, M9 (114 dwellings) and M10 (131 dwellings).

This network is a moderately high distance from the generation plant. However, it takes some advantages. These buildings are designed with radiant floor, so the low temperature required gets high performance of the heat pumps. Heating and preheating domestic hot water is produced by geothermal energy, final domestic hot water is achieved by natural gas boilers.

ENVIRONMENTAL BENEFITS

The environmental benefits of implement this project are remarkable for several reasons.

Firstly, the natural gas boiler service of each individual building is replaced by the new installation at a centralised location away from the city centre. As result, pollutant emissions are reduced for neighbours. In addition, it also reduces emissions from

combustion fossil fuels, which contribute to the greenhouse effect and ozone depletion, such as CH_4 and NO_X.

On the other hand, the primary energy used in the facility is electrical energy. This is delivered by an agreement that guarantees its renewable sources. Due to this and according to the *Spanish Ministerio de Transición Ecológica*[1], the emission coefficient of electricity production is considered zero. It represents a total reduction of 653.27 tonCO2/year with respect to the use of previous natural gas system.

Scheme of Energy Transition of Hunosa Company

In accordance with the above, this facility has a CO_2-free production.

Other environment advantage is the refrigerant. R1234ze is an environment-friendly low-GPW refrigerant. The compromise is a Global-warning potential close to zero.

The development of this new refrigerant is based on the reduction of greenhouse gases emissions according to the Kyoto protocol and F-Gas regulations of the European Union. R1234ze, made from HFC products, reduces the impact of GHF by 80% in compared to previous CFC-based refrigerants[2], such as R134a.

IMPACT ON THE COMMUNITY

The use of renewable energy and electricity replacing the use of gas boilers has leaded to an obvious environmental enhancement in the city of Mieres, where polluting gases and particles emissions related to the new facilities has been completely removed.

On the other side, for Hunosa it represents a new business opportunity in this very difficult moment due to the requirement for closing the coal mines. This economic savings also transfers to different families and public institutions, with the supply of its heating demand at a lower price.

Also the execution of the project has leaded to employment opportunities and economic activity for the region. During the operating phase there also some job opportunities, specially focused on the maintenance of the facilities.

Finally, an old building of Barredo Colliery it has been used as the Generation Room, placing the heat pumps. This building was previously the one for the coal extraction

[1] Ministerio para la Transición Ecológica (2019). *Emission Coefficient.* (https://www.miteco.gob.es/es/cambio-climatico/temas/mitigacion-politicas-y-medidas/factores_emision_tcm30-479095.pdf)

[2] Carrier. Designing innovative solutions (2019). *Heat pumps AquaForce PureTec*

machines of Barredo Colliery. Because of this reason the building was renovated without modifying its architectural typology of the original construction, maintaining also the old equipment. Thus, we achieve preserving this of industrial heritage of great value. In so doing we intend to create an educational space for exposure and promotion.

Generation plant before and after the District Heating

FUTURE IMPLEMENTATION

Beyond the aims achieved with these new facilities, and once demonstrated its applicability as source of wealth and improvement of environmental conditions, Hunosa keeps its interest in geothermal energy, working in a new project called District Heating Fondón Colliery (Langreo), which is still in draft stage. The new facilities could involve an annual reduction about 400 equivalent tons of CO_2 per year.

This project consider also renovation of the warehouse of Fondón Colliery. The renovation will be made again with materials and design suitable with the city landscape and the requirements for the heritage conservation.

Scheme of District Heating in Fondón Colliery