HEAT PUMP IN THE CENTRAL MINING AREA OF ASTURIAS

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Abstract: In the central area of the Principality of Asturias, situated in the north of Spain, a large coal field has been mined since the early years of the 19th century in several exploitation units which along all these years have created an underground void network that represents an actual big water reservoir from which some value added can be obtained.

A large data base gathering all the parameters related with the waters filling the mine voids has been created. Besides all the quality-related data as metal and other pollutants content, flow and temperature are the ones in which we will focus our study. Actually more than 30 million cubic meters of water are pumped every year with temperatures ranging from 19 to 24 degree Celsius.

Furthermore, all the pumping stations are situated within an intensively populated area and close to university, hospital and other public services big buildings.

The present paper aims to analyze the low enthalpy energy content of the flowing waters pumped from the mines and to calculate which amount of that energy might be put in a profitable way into market as domestic, industrial or social buildings heating-cooling systems.

Key Words: ***heat pumps, minewater, underground void network, low enthalpy energy.***

1 INTRODUCTION

The long history in the Asturian Coal Mining Industry has created a huge underground void which has altered the natural flow within aquifers and in water levels. Mining works have created an aquifer with a triple porosity.

Two hundred years ago, before mining activity, there were small aquifers in the different sansdstone strata within the carboniferous basin in the central area of the Principality of Asturias in northern Spain.

At present, hundreds of kilometres of underground mine infrastructure, shafts, drives and stopes, which behaviour may be like those of karst aquifers. In fact, as we will show, the mining voids as a whole actually work as a big underground water reservoir.

Currently, the water flowing towards the mining voids is being pumped out. In the forthcoming years, under the restructuring and concentration policy of the mining industry in Spain, most of the voids will be filled with water. Considering that most of the mines are within short distance to main towns and main new industries, we plan to take advantage of the pumped water to supply heating and hot water to the surrounding population and industrial districts by means of heat pump technologies.

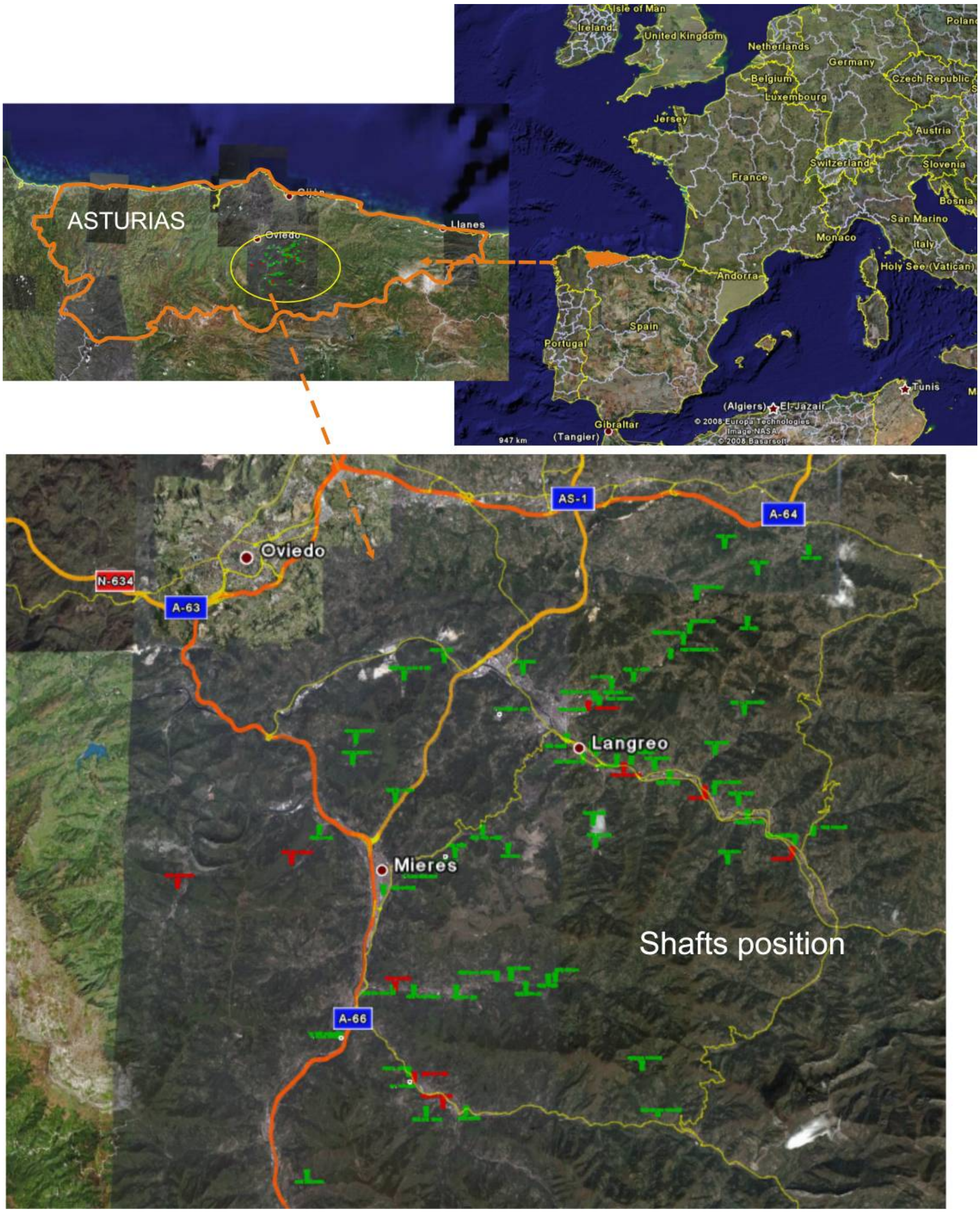

Figure 1: Hunosa Mining Places

2 WATER RESOURCES

In table 1, we summarize the amounts of pumped water per year per mine or pumping station. The total flow reaches 36.8e6 m^3 per year in the whole carboniferous basin. It is reckoned that when the mining activity had come to an end, the water flow at our disposal will be increased. We are now developing a water flow model within the hidrogeological scenario. That will be a good tool which will help us in predicting the behaviour of the future water reservoir.

Table 1: Average pumped water flow (2004, 2005, 2006) (m³/month)

	SAN NICOLAS	SANTIAGO	SAN JORGE	MONTSACRO	SAN ANTONIO	SAN JOSE	BARREDO	SANTA BARBARA	POLIO	TRES AMIGOS	FIGAREDO	TOTAL CAUDAL
jan	226190	212783	50544	16560	419470	507825	198644	146842	283572	86141	283152	**2431723**
feb	207418	190440	35760	13344	315287	413026	202987	199950	194350	89208	288148	**2149918**
mar	262820	289969	55296	17952	447694	578372	222182	329594	269547	137700	461910	**3073036**
apr	209455	192409	38976	17616	280987	400674	233993	147566	154823	77023	329858	**2083380**
may	189663	176728	40032	18048	266824	375663	177991	245183	197165	64449	267238	**2018984**
jun	170338	130456	29424	17280	222236	316577	135425	41529	194516	40415	238349	**1536545**
jul	152933	116055	24480	13968	205131	263656	110890	90611	125421	37564	209843	**1350552**
aug	140992	105224	21216	12720	199946	218025	97600	51017	103032	26939	178499	**1155210**
sep	110998	95177	17665	10416	194623	180382	79734	44555	108994	30845	163797	**1037186**
oct	124768	91278	22248	11176	222989	174577	86134	19208	100154	72567	167910	**1093009**
nov	137508	97976	26712	9720	265175	204179	73852	24097	111116	84224	169417	**1203976**
dec	162971	119194	34488	8784	280738	296212	97563	51577	117917	87648	188203	**1445295**
total	**2096054**	**1817689**	**396841**	**167584**	**3321100**	**3929168**	**1716995**	**1391729**	**1960607**	**834723**	**2946324**	**20578814**

	CARRIO	SOTON	CEREZAL	Mª LUISA	FONDON	CANDIN I	CANDIN II	MOSQUITERA	SAN MAMES	SAMUÑO	TOTAL NALON
jan	502813	357432	139915	184328	60342	61834	4640	237434	39600	196238	**1784576**
feb	356981	325255	112043	158156	68251	64346	5594	249026	40656	187654	**1567962**
mar	532600	430811	147611	184076	81743	70189	10450	373637	55440	284308	**2170865**
apr	306008	345424	85620	142613	81069	61835	10480	268094	58608	242011	**1601762**
may	328197	282036	105412	137879	59644	53062	7364	249910	96621	212356	**1532481**
jun	237217	247945	85023	114914	64525	57921	8562	212818	83785	219597	**1332307**
jul	156304	198061	75989	103656	55942	54760	10200	170567	79207	241068	**1145754**
aug	146435	176332	70443	93794	44768	51778	6426	142319	100811	209778	**1042884**
sep	130901	165653	62816	89709	35746	47458	6112	123978	19054	159197	**840624**
oct	142100	165936	74152	116686	37620	45816	4560	155659	36960	222104	**1001593**
nov	175244	162218	73736	117680	33004	42812	4800	137467	17650	195317	**959928**
dec	274400	231435	95368	136291	38696	44472	6000	172715	37826	202258	**1239461**
total	**3289200**	**3088538**	**1128128**	**1579782**	**661350**	**656283**	**85188**	**2493624**	**666218**	**2571886**	**16220197**

3 ENERGY RESOURCES. WATER SOURCE HEAT PUMP TECHNOLOGIES DEPLOYMENT IN THE CARBONIFEROUS, CENTRAL BASIN OF THE PRINCIPALITY OF ASTURIAS.

As it is well known, a heat pump wins the heat from a low temperature source and increases the heat to a larger temperature. The heat pump energy waste is always smaller than the won thermal energy from the cold source.

As an example, we show in figure 2 the evolution of heating costs in Pennsylvania, USA. (U.S. Dep. Of Energy (Watzlaf y Ackam, 2006)).

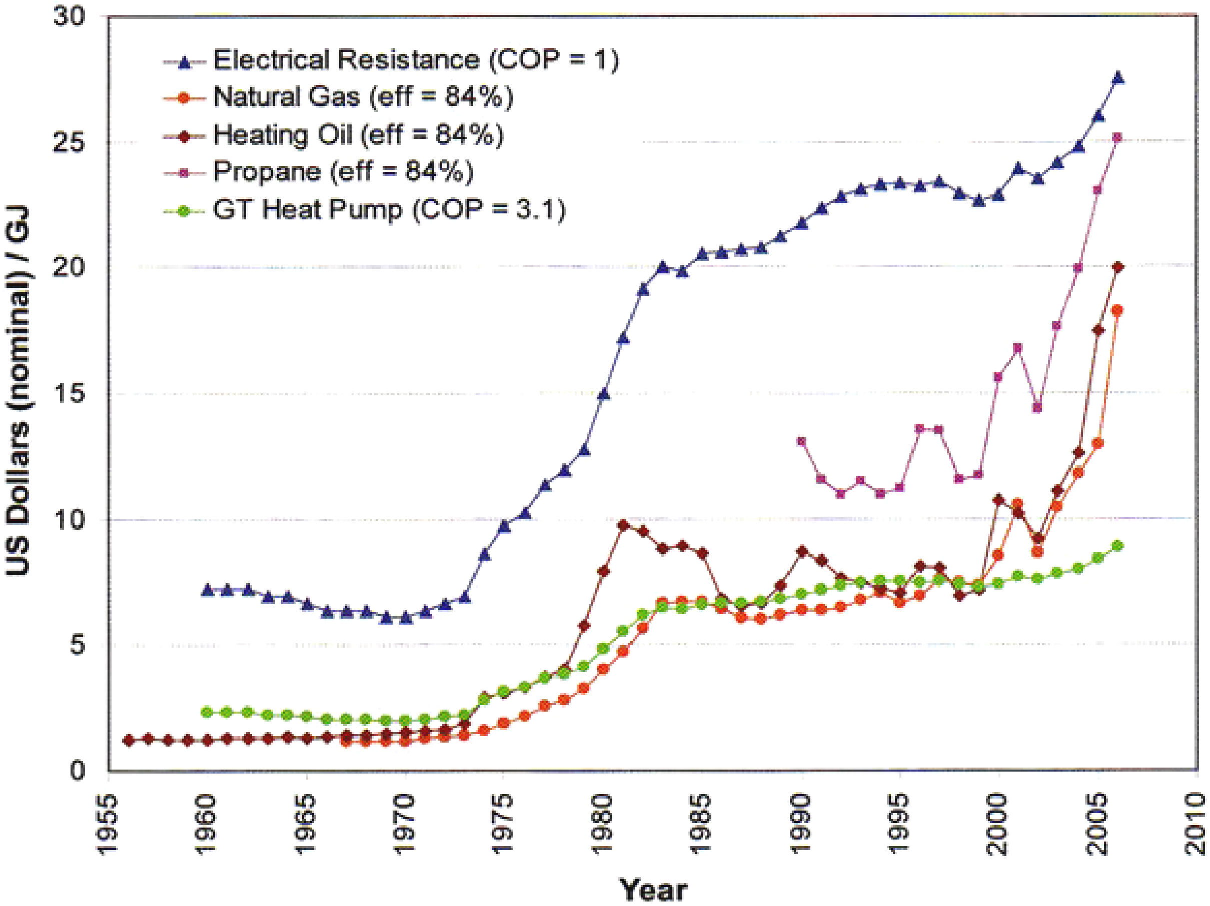

Figure 2: Energy Prices ($/GJ)

Regarding this chart and considering the energy prices forecast for the next years, HUNOSA is developing studies to finally deploy water source heat pumps technologies to recover the energy of the mine water in the central area of the Principality of Asturias, Spain. To start with we are focusing in two main projects. On the one hand we will develop a small scale pilot project in the scope of FLOMINET, an European project, funded by the Research Fund for Coal and Steel (RFCS), and on the other hand, a big scale project, which will supply energy to new University buildings currently under development.

In this paper we will focus on the big project, intended to supply heating, cooling and hot water to the University new buildings which are being developed in the surroundings of Pozo Barredo, a coal mine, in the municipality of Mieres, Principality of Asturias, Spain.

Figure 3: University New Buildings

For this project, we will use the water pumped from Pozo Barredo where 1.7e6 m^3 are pumped every year. But this is not an isolated mine. As is it usual in coal mining areas around Europe, most of them are interconnected, creating an underground voids network which truly behaves as a huge water reservoir. Pozo San Antonio, Pozo Santa Barbara and Pozo Figaredo are the other three mines interconnected with Pozo Barredo. In the following table, we summarize the yearly flows in the four coal pits and their temperature.

Table 2; Average pumped water flow envolved on Pozo Barredo's project

Coal Pit	Water flow (m^3/year)	Water temperature (ºC)
Barredo	1716993	20.8
Figaredo	2946325	17.5
Sta. Bárbara	1391727	18.9
San José	3929166	20.3
TOTAL	**9984211**	**19.4**

To asses the energy potential of all the mining exploitation in the scope of HUNOSA, we consider an average temperature of 20ºC and a water flow of 36.8e6 m^3 per year.

The thermal potential in the cold source is:

$$Pf = (\Delta T \times V \times Ce \times \rho)/T \quad (W_{th})$$

Where:
T= Thermal gap, 5 ºC

V= Water Flow per year, $36.8 * 10^6$ m^3.
Ce= Water Specific heat. 4186.8 J/Kg ºC
ρ= Density
T= Seconds a year, 365*24*3600 s

Therefore

$Pf = 24.43\ MW_{th}$

The Coefficient of Performance (COP) is the rate between the generated energy and the energy supplied to the heat pump. In our case, the water temperature range varies from 12ºC to 17ºC or bigger in some of the mines. Then the COP may reach values bigger than 5, being able to produce hot water at 45 º C (CIATESA 2007)

The thermal potential of the hot focus is:

$Pc = Pf + We$

Where We is the energy consumed by the heat pump compressor. Therefore:

$COP = Pc / We = (Pf + We)/ We = 1 + Pf /We > 5$

$We \approx 6.11 MW$

Though obviously the use of heat pumps adapted to the cold focus temperature, around 20º C, and the working conditions between 15ºC-20ºC, would increase the COP, considering the current heat pumps we can presume that the consume of 4.5 MW_e would generate 24.43+6.11 = 30.54 MW_{th} of heating-cooling power.

The heat pump will be working 24 hours a day, the yearly heating energy at disposal would be 30.54*24*365 = 267490 MWh_{th}, being the energy consumption of 6.11*24*365 = 53 498 MWh_e

In addition a big reduction in CO_2 would be achieved, taking into account that for that same thermal energy:
:

- Burning gasoil C, 3.070 tons of CO_2 /tep would be emitted (IDAE, 2005), equivalents to 0.264 t/MWh_{th} , which in total is 70617 t of CO_2.
- Burning natural gas, 2.337 t CO_2 /tep would be emitted (IDAE, 2005), equivalents to 0.201 t de CO_2 per MWh_{th}, which is 53765 t de CO_2.
- Using heat pumps, the energy consumption would be 53.98 MWh_e which in Asturias would mean 0.855t of CO_2 per MWh (FAEN, 2006), therefore the total emission would be 45741 tons of CO2.

To end with, the financial balance dictates the success of the Project:

The cost per kWh_{th} generated by means of heat pump is the price of electrical kWh/COP. The average price of kWh in Spain for industrial customers like HUNOSA is 0.0757 €/kWh (EUROSTAT, 2007), the final cost will be: 0.014 €/kWh_{th}.

If we compare this cost with the one of the natural gas heating:
The natural gas per GJ for private homes is 11.75 € and 7.24 € for big costumers like the Industry. If the natural gas heating performance is 90 %, the final price would be: 7.24/277*9=0.29€/kWh_{th} for large consumers and 11,75/277*0.9=0.471 €/kWh_{th} for homes, amounts much bigger than the 0.014 €/kW_{th} obtained with heat pumps.

4 CONCLUSIONS

According to the preliminary studies we are undertaken, the minimum water flow HUNOSA pumps every year reaches more than 36e6 m^3 which may be use as a thermal energy source. The present water flow along with its temperature allow us to state that HUNOSA is able to supply 267 GWh_{th} every year, taking advantage of the low enthalpy thermal energy contained in the mine water in all the shafts using water source heat pump technologies and its distribution either via district heating or directly to big public buildings and industries. Even considering the pumping costs, heat pump technologies are truly competitive comparing with other conventional systems, like gas-oil and natural gas. In addition, it is expected that this competitiveness will be improved according to the market forecasts for natural gas prices.

Furthermore, the use of this heat source diminishes CO_2 emissions. Should we use gas-oil or natural gas then the emissions would be respectively 55% and 18% bigger than those of the heat pump technologies. Therefore we can state that heat pump technologies are a good tool towards greenhouse gases emission mitigating.

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