VOLUME 2 ISSUE 2
MAY-AUGUST
YEAR 2018
ISSN 2530-8157

BUILDING & MANAGEMENT http://polired.upm.es/index.php/building_management/

L. de Pereda, J. Fernández, H. Lanao and M. Durango, "Use of the thermal energy of the urban Wastewater network for the thermal conditioning of the swimming pool of the Moratalaz Sports Centre. Madrid". Building & Management, vol. 1(3), pp. 66-80, 2018

http://dx.doi.org/10.20868/bma.2018.2.3766

PAPER BM_18_02_07 RECEIVED 14/07/2018 REVISED 13/08/2018 ACCEPTED 23/08/2018 PUBLISHED ONLINE 31/08/2018

GESTION EN EDIFICACION B&M BUILDING & MANAGEMENT
ESCUELA TÉCNICA SUPERIOR DE EDIFICACIÓN

Use of the energy of the urban Wastewater network for the thermal conditioning of the swimming pool of the Moratalaz Sports Centre. Madrid

Aprovechamiento de la energía de la red urbana de aguas residuales para el acondicionamiento térmico de la piscina del Polideportivo de Moratalaz. Madrid

LUIS DE PEREDA
Architect, Urban Planner. Project Director. Advanced and Sustainable Systems, ENERES. luisdepereda@eneres.es

HUGO LANAO
IE. Energy Efficiency Manager. Advanced and Sustainable Systems, ENERES.

JOSÉ FERNÁNDEZ
ICCP. Managing Director. Advanced and Sustainable Systems, ENERES.

MARTA DURANGO
ICCP. Construction Manager. Advanced and Sustainable Systems, ENERES.

- The challenge is to overcome the current, legal, contractual, economic and private management, political and economic models of the systems that transform, distribute and channel resources, and create the channels and the principles and means of government and operation that will allow the natural flow and exchange of energy and other resources among them, in favor of the global equilibrium.

Underground networks of urban infrastructures channel fluids, water, sewage, air, mechanical and thermal vehicles, store resources of all kinds, and interact with the underground mean, which allows to preserve a moderate rate of intensity and temperature of the thermal energy that they store and transport, all of it very close to the potential users that these resources could serve as primary resources. It is the case of the Municipal Sports Center, CDM, of Moratalaz, an installation that gives sporting services to about 600,000 users per year and has equipment voraciously consumer of energy resources as it is, in our case, the indoor swimming-pool. The heating of the swimming water, the dehumidifying of the air, the heating of the space and the heating of water of the pool are solved with the production of heat by means of gas boilers. The close existence of a municipal waste-water collector, which runs alongside the CDM, has allowed the existing heat production installation to be hybridized with a new one based on a thermal exchanger, directly installed in the collector's gallery. The monitoring of the operation and consumption of the system has allowed to verify a percentage reduction of emissions of 37.5% and a percentage reduction of energy costs of 39.2%, in the first stage of operation.

Urban Infrastructure; Energy; Recovery; Efficiency

- El reto es superar los modelos actuales, jurídicos, contractuales, económicos y de gestión particular, política y económica, de los sistemas que transforman, distribuyen y canalizan los recursos y crear los canales los principios y los medios de gobierno y operación, que permitan el flujo natural de energía y otros recursos entre ellos, en pro del equilibrio global.

Las redes subterráneas de las infraestructuras urbanas canalizan fluidos, agua, agua residual, aire, vehículos de todo tipo, almacenan recursos de todo tipo, e interaccionan con el terreno lo que permite preservar una tasa moderada de intensidad y temperatura a la energía térmica que almacenan y transportan , muy cerca de los potenciales usuarios a los que estos recursos podrían servir como recursos primarios. Es el caso del Centro Deportivo Municipal, CDM, de Moratalaz, una instalación que da servicios deportivos a cerca de 600.000 usuarios al año y cuenta con equipamientos vorazmente consumidores de recursos como es, en nuestro caso, la piscina cubierta. El calentamiento del agua de nado, la deshumectación del aire, la calefacción del espacio y el calentamiento de agua caliente sanitaria de la piscina se resuelven con la producción de calor mediante calderas de gas. La existencia de un colector municipal de aguas residuales, que discurre junto al CDM ha permitido hibridar la instalación existente con otra de intercambio instalada en la galería del colector. La monitorización del funcionamiento y consumos del sistema ha permitido verificar una reducción porcentual de las emisiones de un 37,5% y una reducción porcentual de los costes de energía de un 39,2%.

Infraestructuras urbanas; Energía; Recuperación; Eficiencia

1. INTRODUCTION

1.1. ENERGY USE OF UNDERGROUND URBAN INFRASTRUCTURES

On May 25, 2011 the Director General of the energy and mines industry of the Community of Madrid and Vice-president of the Energy foundation of the community of Madrid, FENERCOM, Mr. Carlos López Jimeno, presented a guide on the energetic use of the Underground Urban Infrastructures [1] , within the framework of a conference on energy use of underground urban infrastructures. The guide was written by technicians who at that time were executing in

Spain projects and works in the area of extraction and exchange of energy through geothermal construction and underground infrastructures. The most experienced companies and agencies, of our European environment were also convocated and involved in this area.

The guide contextualized and documented the actions that, in the field of energy use of underground urban infrastructures, tunnels, metro, parking lots and sewage networks, have been executed in several countries for decades.

This compilation and documentary effort was an answer to the mandatory need of proposing alternatives to the current energy model, with another one based on the recovery and use of the huge quantities of wasted energy that are generated in all the systems and subsystems of the energy ecosystem, among others the one of underground infrastructures, and, also, their use as primary energy resources to cover the demand of primary resources of the same systems or of other systems, close by, adjacent or overlapping, as is the typical case of urban infrastructure networks.

The distributed nature of the capture, the exchange and application, and the low thermal intensity of the enormous energy resource that comes from underground infrastructures are common characteristics to all the exposed cases. In addition to logically spinning the documentary structure of each chapter, the guide makes a shallow analysis of the potential of each infrastructure and even uses this study, to propose, as a model of action, interventions that address the use of the integrated energy potential of all resources, geothermal, air and water, offered by the existing network.

The guide explained and illustrated the mechanisms and principles of geothermal exchange through the ground, water and air, using as exchangers the structures of the underground networks, which in the various means allow transfer and exchange of cost free energy, and its application to the inner environmental conditioning of buildings and public spaces by means of energy exchange and supply techniques, by means of heat pump and coupling to efficient systems of transfer of energy to the inhabited spaces or to industrial facilities and processes.

Figure 1: 2010/2018. First publications, Associations and Projects, for energy use of urban underground infrastructures in Madrid, Spain. Source: FENERCOM, Madrid Subterra, ENERES.

1.2. ENERGETIC USE OF UNDERGROUND URBAN INFRASTRUCTURES

The energetic use of urban underground infrastructures implies operating according to a new energy model, a new context for energy efficiency, oriented to balance and surpassing the current, centralized, unidirectional models that are focused on the increasing generation and sale of energy generating of huge quantities of pollution and waste [2]. The new model allows to enhance, through natural logic preceding the application of the technique, the transformation of energy residues into primary energy resources. This transformation is possible because we actually have the knowledge, the experience and the technical resources, some of them of very old origin and tradition, that allow their realization in three essential areas: 1.- That of the recovery of the energetic resources, 2.- That of their treatment and adequacy, and 3.- That of their use. Any approach that does not close the circular cycle that passes through these three areas cannot be considered complete.

It is necessary to understand that the different systems and urban subsystems, are not isolated, although today they are managed as such, but integrated into a multidimensional reality where energy flows occur not only within each plane of exploitation, but between them and in every direction.

This integrated reality is an energetic ecosystem, to which we aim to provide balance and sustainability.

From this point of departure, it is easy to understand that the mechanisms of rebalancing go through the transfer of the surplus energy resources existing in one part of the ecosystem to another part of it where energy is demanded, through the capacity of exchange of energy within the whole ecosystem, by the correction of imbalances and by the symbiotic action between the different systems and subsystems, of infrastructures, for the transfer of energy to the inhabited spaces or to industrial processes.

The fields of interaction between energy-consuming systems and usable residual energy systems are multiple, the interaction is carried out through the identification of recoverable resources, potential suppliers and pathways. of transfer. The context is that of an intelligent city, managing the balance between resources and information, in a network. (Figure 2).

Information and communication technologies already support

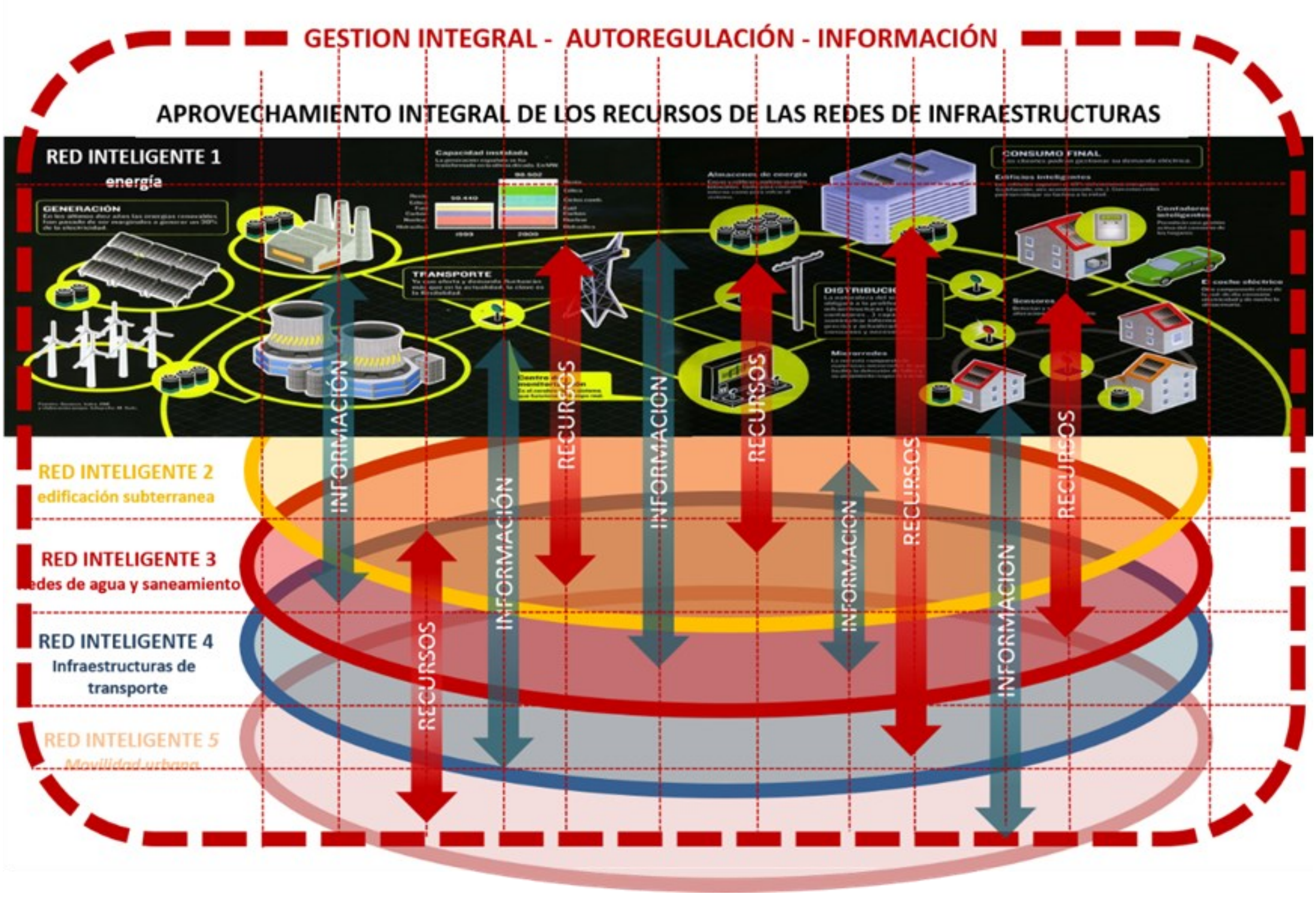


Figure 2: The fields of interaction between energy-consuming systems and usable residual energy systems. Source: ENERES.

the actions that drive to knowledge, interpretation, decision and action, and allow to reconfigure in real time the internal structure of interrelations of the ecosystem to adjust it to the scenarios of maximum efficiency.

The challenge is to overcome the current, legal, contractual, economic and private management, political and economic models of the systems that transform, distribute and channel resources, and create the channels and the principles and means of government and operation that will allow the natural flow and exchange of energy and other resources among them, in favor of the global equilibrium.

The harmonious development of cities is linked to a balance between its density and its complexity [3], which resolves the richness of interactions that characterize urban life. The physical resolution of the systems and endowments that support this density of uses would be impossible without giving the city a sufficient network of basic infrastructures that guarantee the rights and the services of the citizens.

On the other hand, the progressive recovery of urban space for its civic use poses to the need to orient the field of development of the network of infrastructures, services and endowments, towards the underground space. The subsoil [4] offers us not only space, but also water, materials and energy.

The integral planning of the underground space and the adequate management of its resources is a fundamental aspect, and it has to be oriented to define the field of interactions, conflicts and synergies, among the multiple uses that it integrates; and then define the objectives and criteria of sustainability according to the different conditions: urban, geological, biological, economic and cultural. The field of opportunities emerging from integrated management of underground resources includes the use of subsoil energy resources for energy capture, exchange and storage.

Geothermal exchange allows the inertial use of the underground and also of the constructed mass of buildings and infrastructures, for the accumulation of large quantities of thermal energy with low intensity within moderate temperature bands. Ground is therefore a means to accumulate the thermal energy generated, and often considered residual, by industrial systems and urban infrastructures and to propitiate its reuse with very low costs, and very long-life cycle (Figure 3).

Geothermal exchange is also a resource linked to the distributed generation of thermal energy, and, associated with the use of the geothermal heat pump with open or closed -circuit capture, allows the extraction and exchange of renewable energy sources and also the use of "residual" energies from different sources.

Underground urban infrastructures integrated into the Energy Networks Act as A virtual plant of generation integrated by systems of distributed generation, storage and consumption, in dynamic interaction with other systems of the urban network. Precisely this direct contact with the terrain in the context of the interaction with air, water, mechanical systems and people, provides the capacity to exchange heat with the ground, and to act either like:

- Collectors, of the geothermal energy, from many different sources, that in huge quantities surrounds us.
- Exchangers, to transfer or absorb the energy to the ground or to the buried infrastructure networks and other means with which they interact.
- Accumulators, for the seasonal exchange of energy or to absorb the gap between periods of generation and periods of energy consumption, of the infrastructure systems themselves or with other production and consumption means with which they interact.

For the exploitation of the geothermal potential of all these buried systems there are numerous procedures, depending on the use that is going to be given to the energy extracted or injected to the ground.

Some of these systems of underground infrastructures are networks of conduits, galleries and pipes, that circulate fluids, water or air, and directly exchange energy with the ground, but the case in which we focus on this communication belongs to the large family of underground structures, built on fabric or concrete of high thermal conductivity, which can be thermally activated for their use as exchangers, incorporating energy transfer circuits in closed loop that exchange heat with residual water.

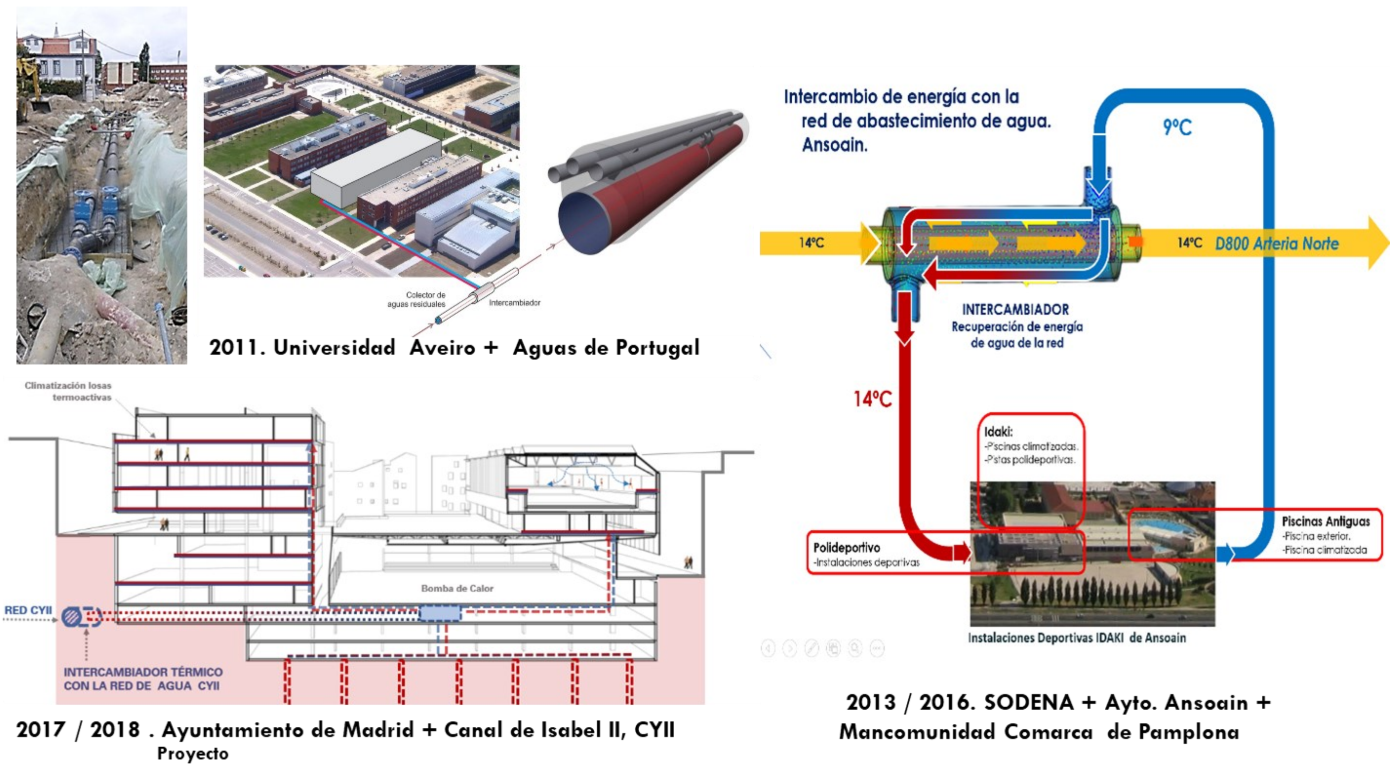


Figure 3: Cases Implemented and projected in Portugal and Spain for energy exchange and recovery in urban water distribution networks and wastewater infrastructures. Source: ENERES.

2. The Moratalaz Sports Centre and the opportunity for efficiency

The case we expose in this communication has all the characteristics that allow integration exchange facilities with wastewater in existing thermal energy facilities with other traditional generation systems, with the aim of the most efficient use of recovered energy resources.

The first key feasibility factor is the identification of an unresolved potential for efficiency in a constant and intense consumer, such as the Municipal Sports Center Moratalaz, CDM.

Built in 1990, the CDM accounts a constructed surface of 7.350 m^2, it is operated by 136 Employees, and provides service annually to 580,000 users, 12 to 14 hours a day, all the days of the year. In Table 1 annual consumptions and emissions are shown.

	Electricity	Gas	Water
Annual Consumption CDM	661,658 kWh. Year	1,359,206 kWth./year	121,946 m^3/year
Annual Emissions CDM	218,347 kg CO/year	277,278 kg CO/year	
Annual Consumption Indoor Pool		960,703 kWth./year	
Annual Emissions Indoor Pool		195,980 kg CO/year	

Table 1: Annual consumptions a emissions in CDM and Indoor Pool.

The building complex of the CDM constitutes a system with enormous potential for additional efficiency though the use of crossed-energy resources. An integrated intervention on all the systems with potential of reduction of energy consumption can solve, with very low consumption and much quality of service, the demand of the complex:

- The envelope bioclimatic improvement.
- The choice of environmental conditioning systems suitable to the resources of the medium.
- The use of renewable energies, in particular the Solar thermal, for the production of heat.
- The injection of recovered energy to new and existing heat generation systems.

These actions of improvement are being implemented in the CDM of Moratalaz in successive projects of efficiency, which, as is our case, are executed in an isolated basis and, therefore, it is very important to envisage their future integration, and comprehensive operation and management, with the rest of the complex technical systems and the extension of their coverage beyond the current limits that already justify their application.

The indoor pool of the CDM of Moratalaz in Madrid is a resource that requires a constant injection of heat applied to air conditioning, dehumidifying, heating of swimming water and the production of ACS. The heat production is today solved with two gas boilers (Figure 4).

The second determining factor is the existence of energy resources usable in the environment and in the context of the existing building. The case of the CDM of Moratalaz, a main existing resource is a municipal waste water collector, which collects the water poured by the important residential areas of the Altos de Moratalaz neighborhood, which ensure a minimum flow of 50 l/s of residual water at an average temperature of 15 ° C. The collector runs parallel to the CDM and the third feasibility factor is that a direct connection is possible between the network integrated exchange system and the technical room of the building of the indoor pool, where the heat pump and the exchangers that connect with the interior building systems, can be located.

Hot water Production | Dehumectation | Pool water heating | Heating

Figure 4: Indoor pool of the CDM of Moratalaz in Madrid.

The collector was visited and assessed, the stability of the flow and the temperature residual water were verified, and an execution project was drafted for the City of Madrid, including (Figure 5):

a. Accurate calculation of Exchange performance parameters.

b. The engineering and design of the steel exchanger which is integrated into the collector's gallery.

c. The engineering of the process of execution of the works and the auxiliary elements necessary for the connection between the collector and the sports centre.

d. The design of necessary access wells for the personnel and to introduce the sections of the exchanger that are integrated in the gallery.

e. The engineering and design of the equipment and facilities that allow the transformation and application of the recovered heat to the production of ACS and to the heating of the pool.

f. The design and engineering of the measurement and control systems.

3. Methodology

3.1. Technical principles and available technology for energy exchange with wastewater

Recovery and use as primary resources of wastewater energy has a very important potential [5]. More than 15% of the energy that we introduce in our homes, is wasted when leaving them incorporated into sewage, which flows through the geothermal field of the subsoil at temperatures between 15ºC and 20ºC.

The engineering, design and manufacture of the exchange systems that have been installed in the gallery of the municipal collector of Moratalaz come from Swiss experience, more than thirty years of development of systems of thermal exchange with the water networks and sewage.

Figure 5: Very close to the CDM runs an accessible wastewater collector an average temperature of 15 ° C and with an average flow of 50 L/s = 180 m³/h. A continuous and free resource of wasted energy and a huge efficiency opportunity.

The exchange technique, both in new collectors with the integrated heat exchanger and in existing collectors and galleries, to which a custom-designed exchanger is incorporated, is highly developed and is very reliable both in its performance and in its functionality in the integration into a collective system so important and demanding in terms of operability and maintenance, as is the sewerage. Up today it has produced a full range of technology solutions for custom made exchangers, suitable for various types of Networks, pressurized or not pressurized , type of water, etc. [6].

The technology of reversible water-water heat pump and the systems that allow the use of heat or cold at moderate temperature are also developed with a high level of maturity and efficiency

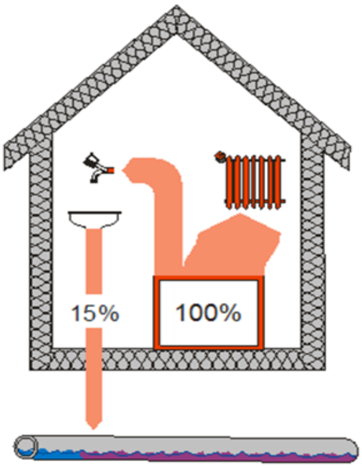
All the technical and technological fields that allow to develop a reliable, efficient and guaranteed system of thermal exchange and use of the energetic resource are ripe and experienced, then in this project in Moratalaz an expert application is made and even when it is innovative in Madrid and Spain, it is warrantied in its performance and completely safe.

The Waste water energy recovery technique is based on the development of materials and manufacturing processes that produce high-performance steel exchangers and very low maintenance.

They provide the exchange devices built into existing networks and others for new collectors. With the interaction of a heat pump we can supply cold or hot water at moderate temperatures to buildings that, prepared to take advantage of it, can heat air or water with this recovered resource. (Figures 6 and 7).

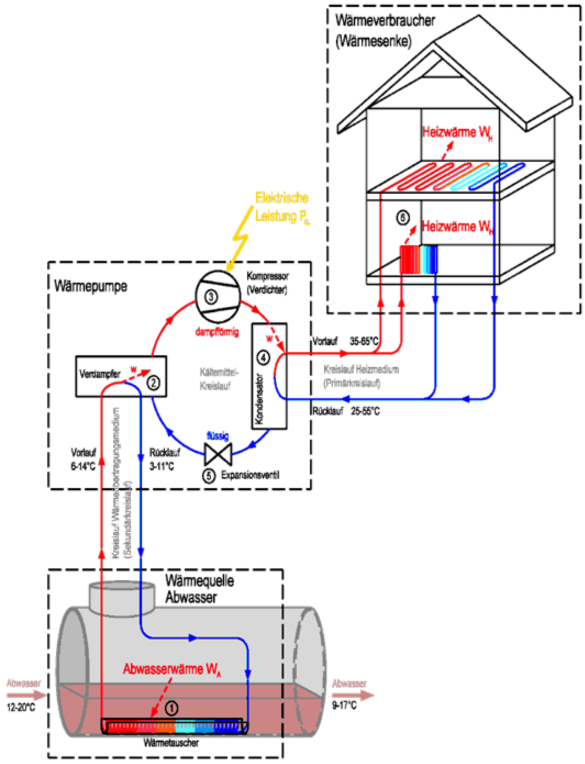
The steel exchanger custom designed for the CDM of Moratalaz is composed of 48 sections of 3m length.

They were introduced one by one through a connection, once in place they were anchored to the masonry walls of the collector. They are constituted by a channel of exchange built with a high pressure inflated steel double skin exchange camera and go and return pipes of a closed tinkelman system circuit.



1. Energy discharge

2. Energy capture



3. Exchange, transfer. Use

Figure 6: Heat exchange process.

Figure 7: Collector with an integrated heat exchanger. Source: KASAG.

A heat exchanger was designed and manufactured up to measure to fit in the geometry of the existing collector. It is a heat exchanger of 144 meters of total length integrated by 48 sections, of 3m length. (Figure 8).

With a thermal jump of 4.38 °C and a flow of 46m^3/h the exchanger has a total exchange power of 235.7, 1 kW.

The minimum flow rate of 50 L/s, and the average temperature of 15 °C, of the residual water in our collector, allows an excellent use of the residual water energy resource. (Figure 9).

The monitoring of the operation of the Exchange system, in the first months of operation, is yielding very positive results and a higher performance compared to the project simulations.

3.2. TECHNICAL PRINCIPLES AND AVAILABLE TECHNOLOGY FOR ENERGY EXCHANGE WITH WASTEWATER

The water flow rate of 45.64 m^3/h ≈ 46 m^3/h (1) driven by the circulating pump B1 leaves the BC at 6.7 °C and is inserted into the sewage exchanger for heating.

The residual water temperature that will run through the

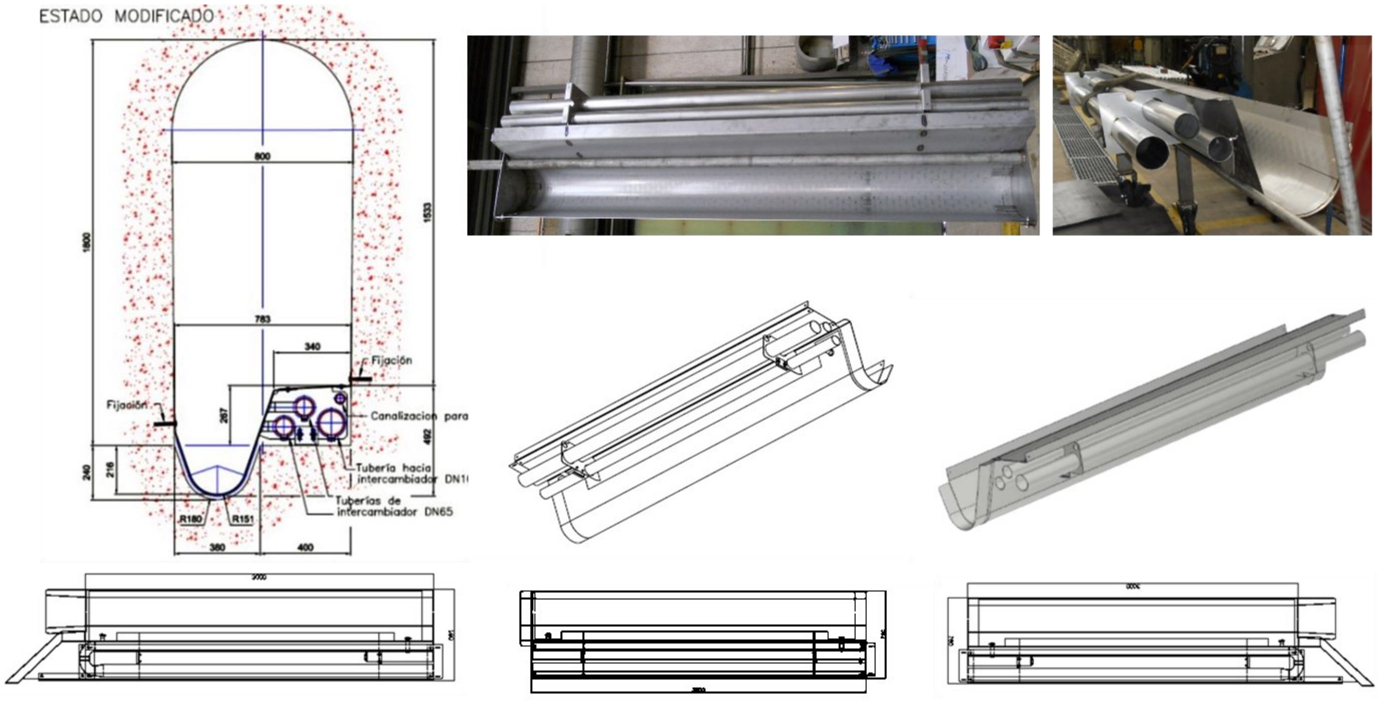


Figure 8: Heat exchanger designed and manufactured up to measure to fit in the geometry of the existing collector.

sewage exchanger is at an average temperature of 15 °C with an average flow rate of 50 L/s = 180 m^3/h.

After traversing the entire exchange surface and exchanging heat with the flow rate of 45.64 $m^3/h \approx 46$ m^3/h (1) of the chiller, the temperature of the wastewater will be slightly reduced and will be 13.86 °C, maintaining the same flow rate of 180 m^3/h. The flow rate of 46m^3/h of 6.7°C after being heated by the sewage exchanger will reach a temperature of 11 °C. The flow rate of 46m^3/h of 11 °C will be introduced to the heat pump, HT (Figure 11).

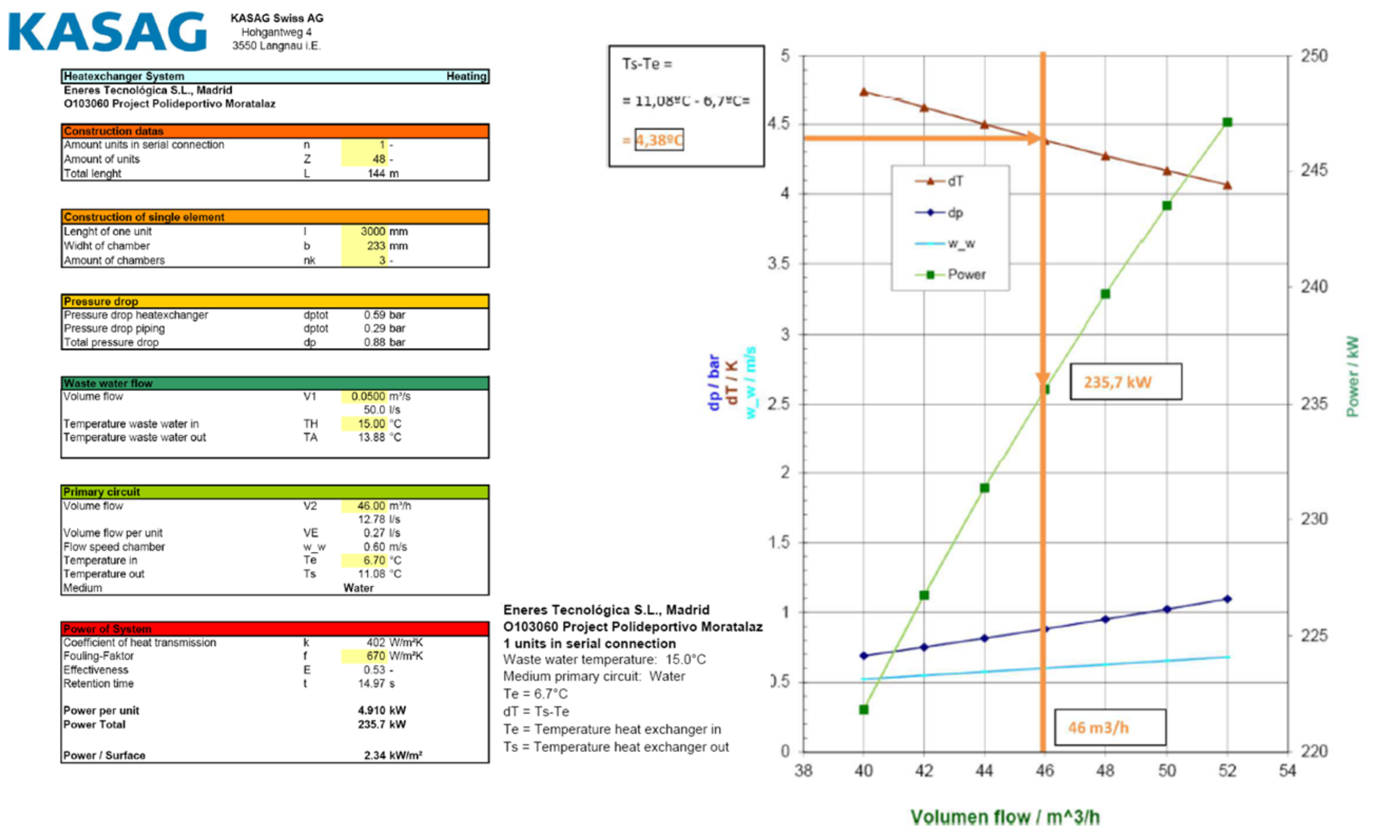


Figure 9: Heat-exchanger system data. Project Polideportivo Moratalaz. Source: Eneres, KASAG.

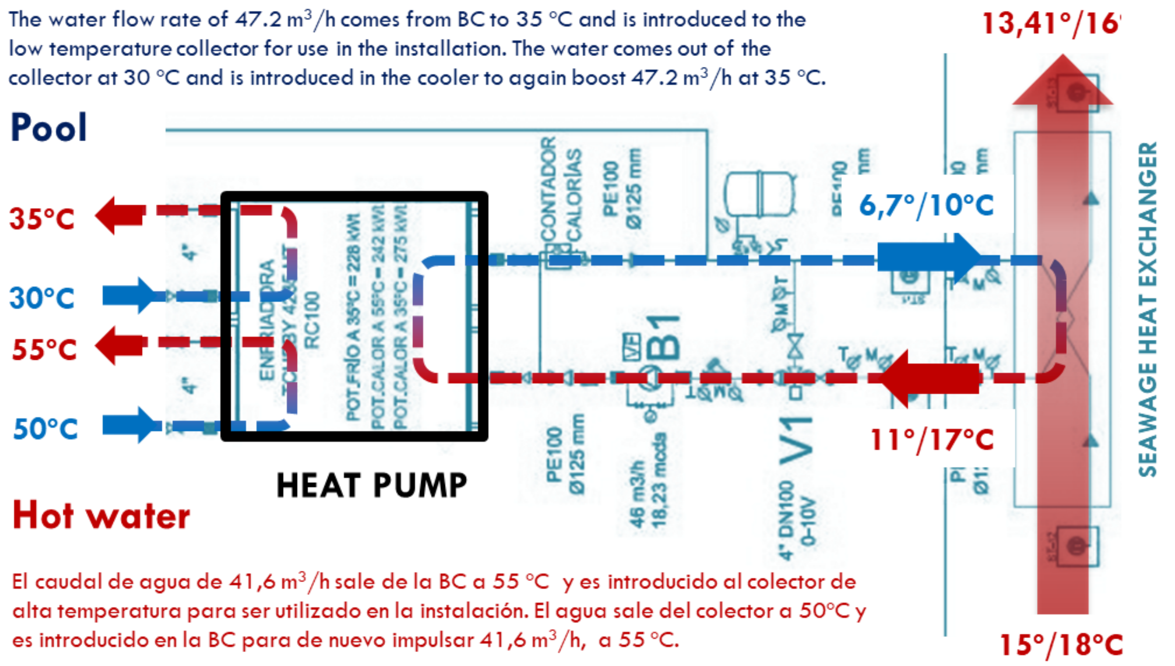


Figure 10: Application of heat recovered to the heating of the pool and to the production of hot water. Source: Eneres.

The exchanger integrated in the collector works against a heat pump that, on the side of the exchanger, its cold focus, produces a water flow of 45.64 m³/h at 6.7 °C, since it produces a cooling power of 228 kWt. This power is dissipated; trough the sewage exchanger, and the temperature of that water flow rises 4.3 °C and a final temperature of 11 °C is obtained. This water flow of 45.64 m³/h heated to 11 °C is again introduced into the cooler.

The pump in its low temperature hot bulb (heat dissipater) produces a water flow of 47.25 m³/h (24) at 35 °C (21), since it produces a calorific power of 274.75 kWt. This power is provided to the installation, so the water temperature decreases by 5 °C (23) and the temperature that again enters the cooler to be heated is 30 °C.

The heat pump in its hot focus at high temperature (heat recovery unit) produces a water flow of 41.45 m³/h at 55 °C, since it produces a calorific power of 241.00 kWt. This power is provided to the installation, so water temperature decreases by 5 °C and the temperature that again enters the cooler to be heated is 50 °C.

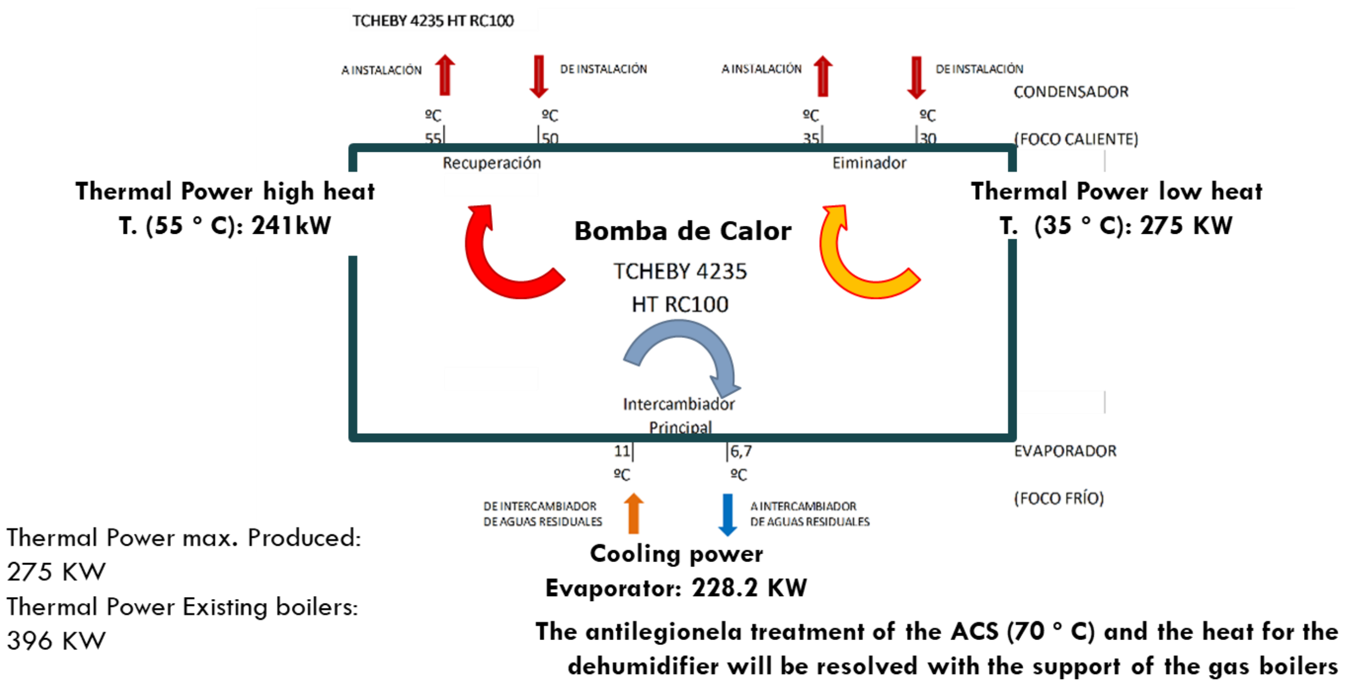


Figure 11: Application of heat recovered to the heating of the pool and to the production of ACS. The anti-legionella treatment of the ACS (70 ° C) and the heat for the dehumidifier will be resolved with the support of the gas boilers. Source: Eneres.

3.3. Execution of the works of the exchanger and connection to the CDM

There were two different phases in the execution process:

1. Accurate calculation of Exchange performance parameters:
   - Construction of Access well.
   - Water Diversion Works.
   - Communication between well and technical room.
   - Communication between technical room in and the room of CDM installations.
2. Technical facilities and equipment, to be implemented in:
   - The public sewer collector gallery.
   - The connection ditch to the technical room.
   - The technical room of the Municipal Sports Centre.

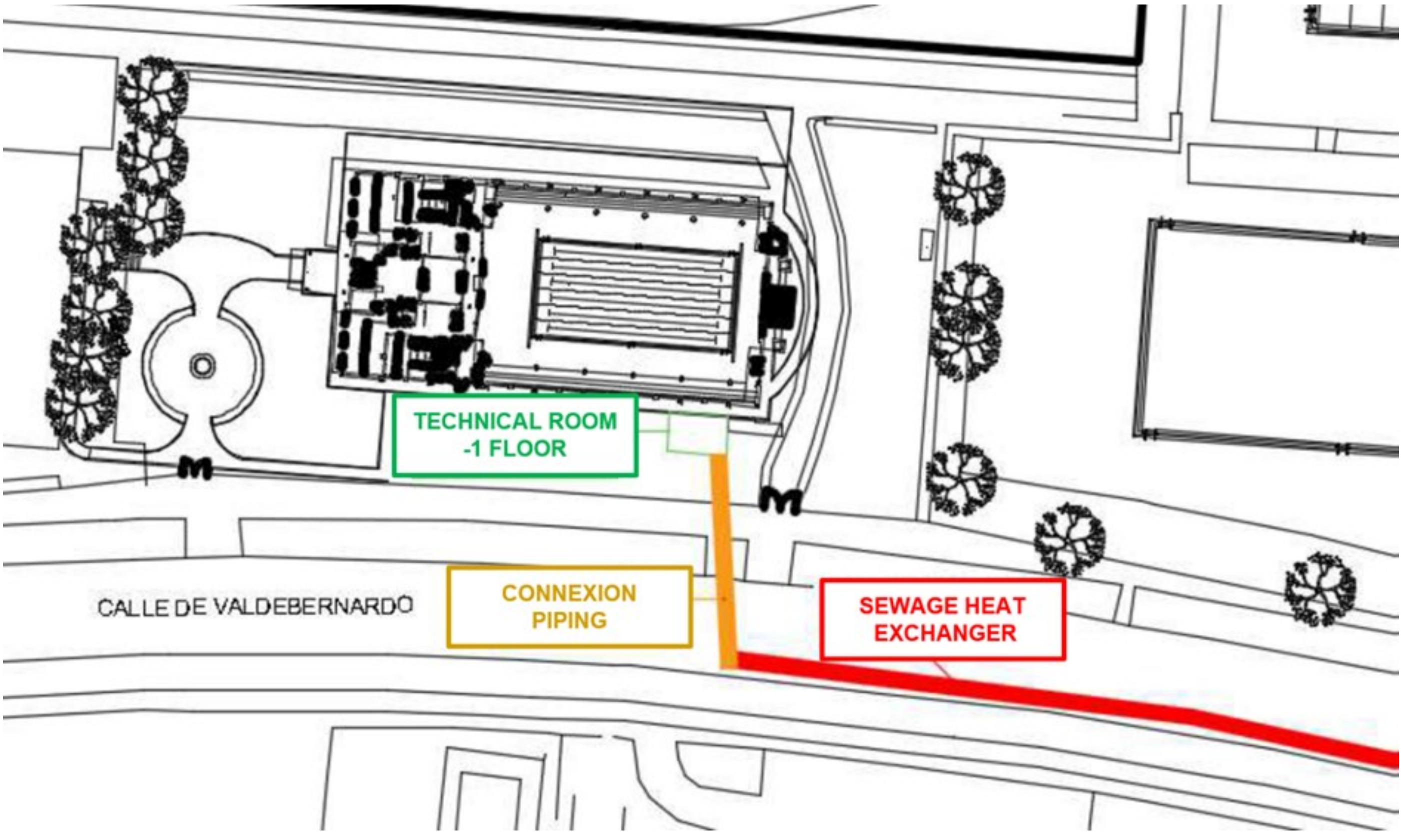


Figure 12: Phases and locations of execution of the civil works and equipment implementation, necessary for the installation of the exchanger in the collector and the connection to the technical room of the swimming-pool. Source: Eneres.

The installation works began with the construction of an access well for personnel and equipment, the materials for the works and the sections of the heat exchanger. Two temporary "dams" at the ends of the section where the exchanger were installed, and a pumping installation, which allowed to work "dry" without to interrupting the operation of the collector.

First of all, we ensured that the horizontal area provided for the exchanger's installation along the gallery, planned for the execution of the works, was dry, to allow the assembly of the exchanger sections. To do this we installed a gallery bypass for waste water, that operated during the period of execution of the works, estimated in 36 days. (Figure 12).

The installation of the bypass system included special equipment:

- 7 HP Sewage bilge pumps.
- 3 "Hose for pump 7 CV, 300 ml.
- 1 Generator of 20 kvass, with hose and earthing.
- Execution and subsequent removal of the brick temporary dams, of 0.5 m. height.

Once all the works have been completed, connection trench work began, through the street and also inside the sports center.

The introduction of the exchanger sections, 48 sections of 3m in length, is a delicate and laborious operation. From the transport vehicle that carries each section, it is hanged and introduced down vertically through the well, pivoting in the area of junction with the Collector's gallery, and then placed in its definitive location along the gallery. (Figure 13).

From the access well, the connection of the exchanger runs to the cold focus of the heat pump into the technical room of the sports center.

The connection is made with two conduction pipes, Figure 15b , that will run up the well from the level of the sewage collector, located at a depth of 11.5 m to the surface. From the top of the well to the technical room where the heat pump is located

Figure 13: Left, plane of section and photograph of the containment dam and the pumping installation that allows the installation, on dry work area, of the exchanger and the pumping bypass for wastewater. Right, photograph and section of the access well. Source: Eneres.

Figure 14: Outline and photographs of the delicate introduction process of the 48, 3m sections of the exchanger, stacked into the well, pivoting into the collector's gallery and placed along it. Source: Eneres.

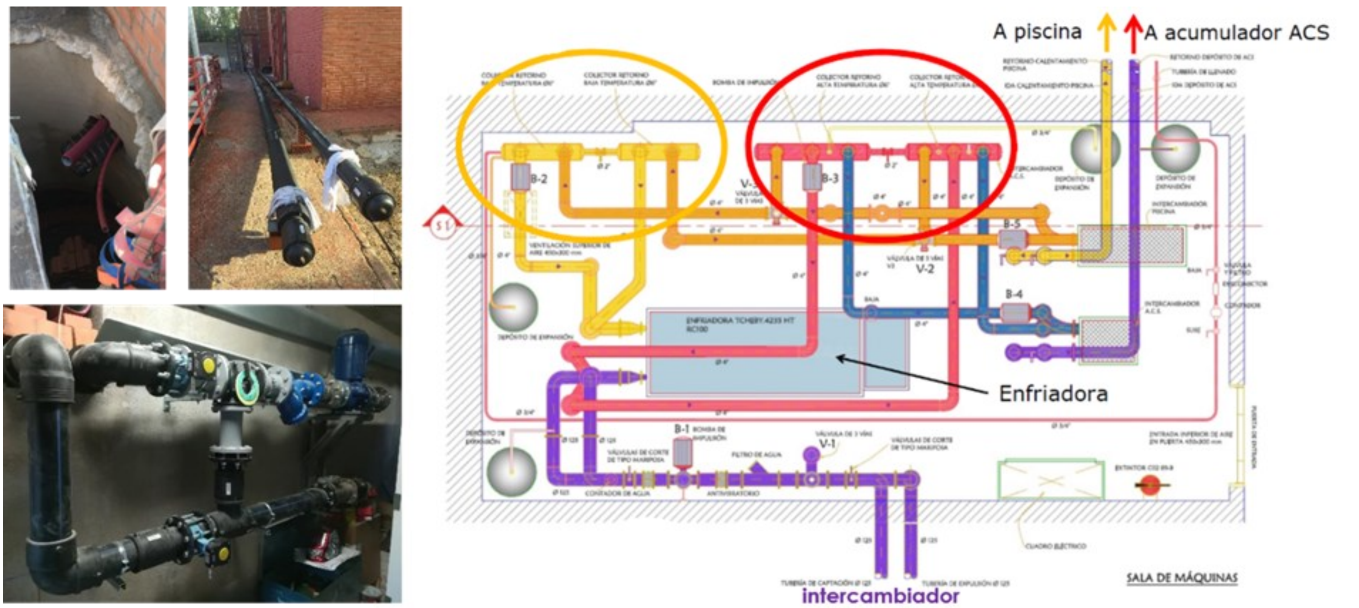


Figure 15a: Connection installation between the Interchanger integrated in the municipal collector and the technical room of the indoor pool. Source: Eneres.

Figure 15b: Connection installation between the Interchanger integrated in the municipal collector and the technical room of the indoor pool. Source: Eneres.

the connecting pipes run through a ditch that passes directly through the wall of the technical room and crosses it to connect directly with the conduits of liaison with the adjacent heat pump. (Figure 14).

4. Control system

The control system allows monitoring and operation of the system and its integral management. It is based on industrial PLC, programmed in language of function blocks and equipped with communication by BUS (Industrial Ethernet Profibus) and Web server of Communications and liaison (Figure 16).

There are 2 differentiated control modules, communicated with each other by means of a connecting Bus (Industrial Profibus Ethernet) made in cable of 4 pairs twisted in helicoid CAT6.

The connection of data between them is solved with a switch of 4 ports (router if it has own network in sports Center with fixed IP) of general purpose, so that its maintenance is very low and easy its replacement in case of breakdown.

This equipment has a wireless connection system WSP that allows access to it by means of 2 keys (Network and own PLC) that is designated by the person in charge of the maintenance at the moment of the start up, and that they are registered in the documentation of the Project relating to control chapter.

Also, a digital copy of the program, hosted on the equipment was attached so that its replacement, repair and modification can be carried out by any technician with familiarity with the handling and programming of these kind of control and management equipment. For data security reasons, the reading/recording of data and records will be protected by key designated at the time of the installation start-up.

Each of these modules is housed in an independent control Panel IP65, located in the engine room itself to be controlled (one in the new room of the heat pump and the remaining in the old boiler room existing), near the elements to be controlled/ Monitor to minimize distortions and interference due to cable length.

All monitoring/control communications will be made with halogen-free shielded cable with drainage wire, regardless of the signal they drive, thus ensuring a homogeneity in the installation and the highest standard of quality in the Wiring/ connection.

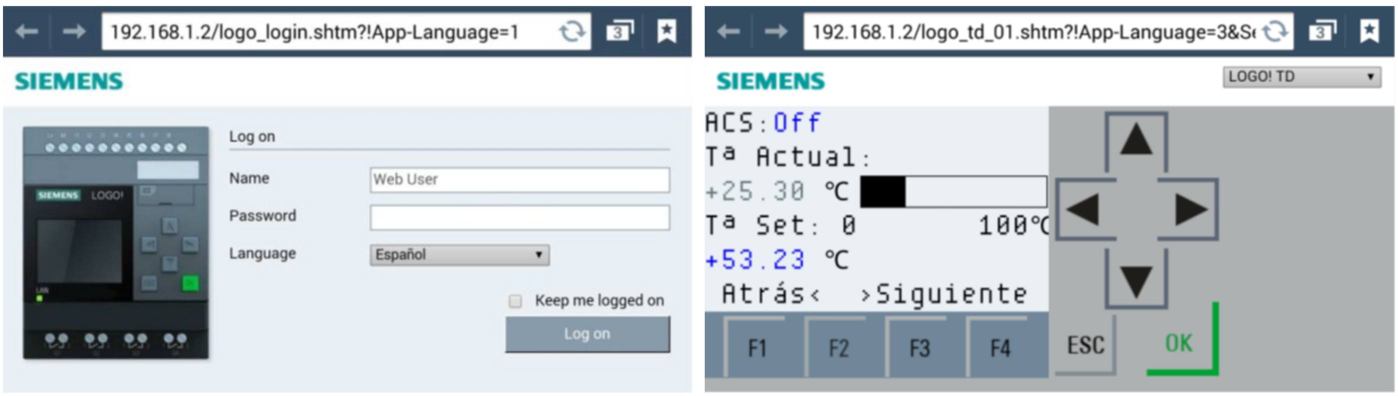


Figure 16: User interface of the control system that allows the integrated management of the system. ource: Eneres.

5. CONCLUSIONS

5.1. BALANCE OF EMISSION REDUCTION

The performance coefficient of the system, is high because of the optimized balance between source and production temperatures. As we are working with continuous and renewable sources, the reduction of gas consumption is very important and also the reduction of emissions. (Figure 17).

5.2. BALANCE OF ENERGY CONSUMPTION REDUCTION

The economic saving that derives from the efficiency of the new hybrid system, compared to the existing system of heat production is very important, almost 40%. Moreover, if we consider that the installation carried out can, without any problem, provide service to other facilities not only demanding of heat but also of refrigeration, by the very nature reversible of the system of exchange with the sewage. (Figure 18).

5.2. HYBRIDIZATION OF SYSTEMS FOR EFFICIENCY.

The hibrizacion of systems, the progressive incorporation to existing buildings and energy systems of technical resources and new modes of management that allow to take advantage of residual and renewable energy sources is an emergent field of enormous relevance.

The performance carried out at the Municipal Sports Centre in Moratalaz, CDM, has shown the possibility of intervening progressively in the energy systems of buildings that have a very high consumption of resources and to incorporate three types of lines of Efficiency:

CÁLCULO COP PROMEDIO DE LA ENFRIADORA

% tiempo produciendo agua a 35ºC	75%
% tiempo produciendo agua a 55ºC	25%

(14)	COP ENFRIADORA a 35ºC	5,78
(46)	COP ENFRIADORA a 55ºC	3,54
	COP ENFRIADORA PROMEDIO	5,22

$$\frac{(5{,}78 * 75\%) + (3{,}54 * 25\%)}{75\% + 25\%} = 5{,}22$$

CÁLCULO COP PROMEDIO

% tiempo produciendo agua a 35ºC	75%
% tiempo produciendo agua a 55ºC	25%

(16)	COP SISTEMA a 35ºC	4,42
(48)	COP SISTEMA a 55ºC	3,17
	COP SISTEMA PROMEDIO	4,11

$$\frac{(4{,}42 * 75\%) + (3{,}17 * 25\%)}{75\% + 25\%} = 4{,}11$$

COP del Sistema	4,11
kg CO2 / kWt h producidos con electricidad	0,357

	ACS	toneladas de CO2 producidos con electricidad anualmente
Demanda E térmica [kWt h/año]	507.251,45	44,05
Demanda de E eléctrica [kWe h/año]	123.390,36	
Demanda E térmica restante [kWt h/año]	338.167,64	
E térmica producida por las calderas para cubrir esa demanda [kWt h/año] (considerando rto caldera)	384.281,41	78,39
TOTAL TONELADAS DE CO2 PRODUCIDAS CON BOMBA DE CALOR E INTERCAMBIADOR AGUAS RESIDUALES + APOYO CALDERAS DE GASOIL		122,44

TONELADAS DE CO2 PRODUCIDAS ANTES DE IMPLANTACIÓN NUEVO SISTEMA	195,98	100,00%
TONELADAS DE CO2 PRODUCIDAS TRAS DE IMPLANTACIÓN NUEVO SISTEMA	122,44	62,48%
TONELADAS DE CO2 EVITADAS TRAS DE IMPLANTACIÓN NUEVO SISTEMA	73,54	37,52%

Figure 17: Balance of the emission reduction of the integrated system. Source: Eneres.

- Systems and technology for the recovery of residual and renewable energy in the next environment of the CDM installations.
- Efficient systems and technology for the utilization of the recovered resources thermal conditioning of the CDM.
- Progressive improvement of monitoring and efficiency management through control devices appropriate to these strategies.

As indicated earlier in the CDM, there is an important untapped potential to increase the performance of the facilities performed and the energy resources recovered, and also an important potential for improvement with other renewable sources of Energy that are present in that location:

- Use of the resource of thermal exchange with wastewater to feed the refrigeration systems of sports halls, gymnasiums and offices. This can be used directly by the installed heat pump and exchange systems, and the recovery of the residual "cold" from the water heating process.
- Integrate night-free cooling systems that take advantage of the thermal amplitude of Madrid's climate.
- Incorporate thermal resources from solar thermal uptake.
- Working in the integration of control systems, monitoring and management.
- Incorporating efficient, moderate-temperature systems for efficient heating and cooling.

If the performance in the CDM of Moratalaz has obtained notable results in the reduction of emissions and the reduction of energy consumption, it has also shown that hybridization of energy thermal systems can be a progressive and continuous process of improvement, in a planned basis, that, without Disrupting the use and service of buildings and infrastructures will propel them to levels of excellence in efficiency and quality of service.

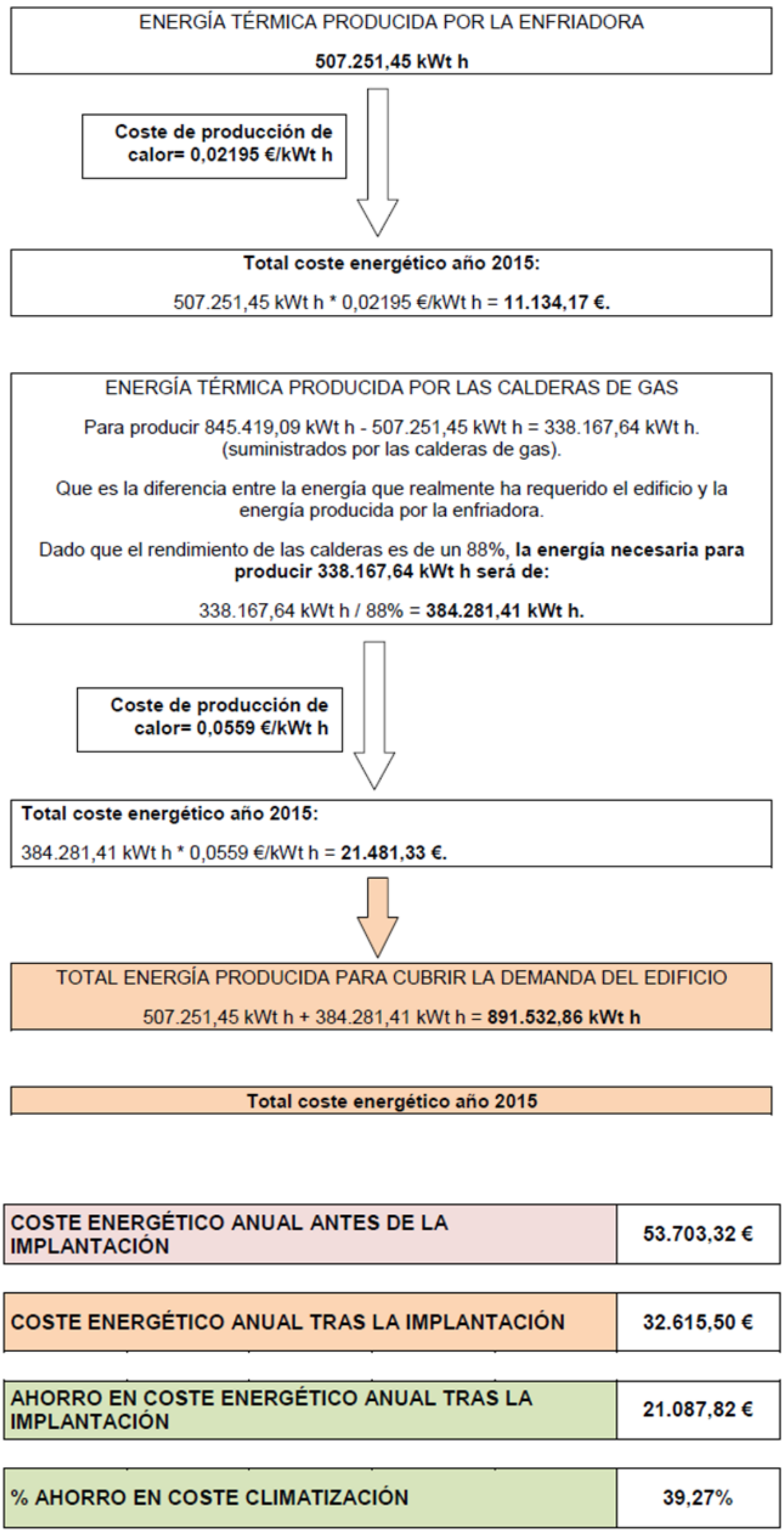


Figure 18: Balance of economic savings resulting from residual energy recovery and system hybridization. Source: Eneres.

7. REFERENCES

[1] L. De Pereda et Alt, "Guia sobre aprovechamiento energetico de infraestructuras subterráneas", Fundación de la Energía de la Comunidad de Madrid, 2011.

[2] Guidebook to IEA ECBCS Annex 37. Low Exergy Systems for Heating and Cooling of Buildings. Edited by Mia Ala-Juusela, VTT , Finland. 2003

[3] Paola Pulido Barrera, Jesús Rosales Carreón∗ , Hugo J. de Boer 2016."A multi-level framework for metabolism in urban energy systems from an ecological perspective". Department of Innovation, Environmental and Energy Sciences, Copernicus Institute of Sustainable Development, Utrecht University, Heidelberglaan 2, 3584 CS Utrecht, The Netherlands , 2018.

[4] Rueda, Salvador. EL URBANISMO ECOLÓGICO. 2018.

[5] Andrea Ramirez. "Why sustainable management of the subsurface needs a feminine touch"Copernicus Institute, November 2015

[6] Beat Kobel, Yann Roth, Ryser et Alt. "Heizen und Kühlen mit Abwasser" Baudirektion Kanton Zürich. 2010.

WHAT DO YOU THINK?

To discuss this paper, please submit up to 500 words to the editor at bm.edificacion@upm.es. Your contribution will be forwarded to the author(s) for a reply and, if considered appropriate by the editorial panel, will be published as a discussion in a future issue of the journal.