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CASE STUDY: OPTIMIZATION OF HEAT RECOVERY SYSTEMS

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Abstract: This article presents different practical cases of the use of residual process heat. It describes the practical methodology for defining savings opportunities, the generation of baselines and performance indicators that allow the level of savings to be evaluated over time. Two practical examples from different sectors are presented. In each case, the work methodology, the definition of the consumption baseline, the performance indicators developed and their monitoring, as well as the method of calculating the savings are presented. Finally, the savings obtained, the investment levels made and the payback periods are presented.

Keywords: heat recovery, residual heat, energy efficiency, energy services.

INTRODUCTION

There are various factors that define the execution of projects within organizations. From an elaborate and clear methodology for detecting improvement points, to erratic ideas coming from the most diverse areas. This happens both in small organizations and in the largest structures. Energy saving and efficiency projects in general, and the use of residual heat from processes in particular, are not alien to these disparate approaches. Without prejudice to what happens in other areas, in these cases it is necessary to correctly apply a methodology to address the problem at hand, in order to make viable and efficiently put into practice what is projected, in order to achieve the projected savings in a sustained manner.

This article presents a methodology for addressing these projects, supported by practical examples, in order to clearly describe the execution process of these projects, the different barriers that exist when putting them into practice and the way to measure their results.

To this end, two examples of successfully executed projects will be used: on the one hand, the implementation of a heat pump in an airport, extracting heat from the airport's duty-free shop area and dumping it into the hot water circuit to condition the different areas of the premises in mid-season and winter, and on the other hand, the use of residual energy in a refrigeration industry, coming from the heat released into the atmosphere through the refrigeration cycle. Although they are two examples from very different areas, the approach methodology is similar.

WORKING METHODOLOGY

IDENTIFICATION OF IMPROVEMENT PROJECTS.

As it was mentioned above, the identification of improvement projects can have different origins, from an energy perspective, one of the ways to address the problem is by carrying out an initial audit, which can be global for the plant or facility under study or specific for a system or set of isolated systems.

In the cases included in this article, for the refrigeration industry, an approach is made to the steam and cold generation system of the production process and in the case of the airport facility, the building's cold/heat systems are studied in particular.

In any case, in order to generate a reliable consumption baseline, it is necessary to have precise data regarding energy consumption and dependent variables that affect that consumption.

This point is usually the most complex to address, because reliable and quality information is required to define the baselines that will allow determining which projects can be carried out and which must be discarded.

In cases of using residual heat, the following factors must be taken into consideration:

1- Thermal needs of the facilities/ processes: this refers to what type of heat the process requires, for example, if we need to condition a room in winter, we must take into account what temperature it must be conditioned to and what volume of air. Generally, if it is necessary to condition air at 20-24C, hot water at 50-55C can be used. However, if we want to use hot air to dry a product at, for example, 130-140C, we will surely need to generate steam at 8-10 barg in order to obtain these process air temperatures.

2- Sources of residual heat: on the other hand, we must evaluate whether it is possible to use part of the residual heat from the process as heat sources for the saving systems. If this use is possible, the performance will be significantly increased compared to using only equipment that is more efficient than the existing one. In turn, the simultaneity of residual heat with the need for heat must be studied, and finally, the locations of the heat sources and the places of use must be taken into consideration.

After knowing the energy consumption of the facilities, identifying the thermal needs of the processes/facilities and the residual heat sources that we can use, it is possible to define the possible savings projects.

PLANNING AND PRIORITIZING IMPROVEMENT PROJECTS.

When planning and prioritizing improvement projects, it is advisable to take into account certain points:

1- Level of savings generated by the project.

2- Difficulty of implementing the project.

3- Capacity to measure parameters to calculate the savings generated.

4- Level of investment/financing required for the execution of the project.

The prioritization of one of these points with respect to the others will depend on multiple factors, so it would be incorrect to put one before the other.

IMPLEMENTATION OF PROJECTS AND CALCULATION OF SAVINGS.

When implementing projects and later when calculating the savings from the installations carried out, it is desirable (although not always technically or economically viable) to take into account the following points:

1- Capacity and ease of return to the previous situation

It is good to have the capacity to return the system to the situation prior to the implementation of the savings project, in order not to hinder the normal operation of the installation on the one hand (in the event of any possible failure in operation), and not to generate rejection of the new system due to possible adjustment failures in the start-up on the other.

2- Backup equipment

It is also desirable that there be backup equipment within the new installation, as long as the repayment periods do not skyrocket, which allows the new proposed installation to operate efficiently.

3- Calculation of savings

If possible, and the project warrants it, it is desirable to use a measurement and verification protocol to define the baseline and calculate savings, validated by the various parties involved in the project.

EXAMPLES OF IMPLEMENTED PROJECTS

INCORPORATION OF HEAT PUMP IN AIRPORT.

There are facilities which have heat and cold needs throughout the year. In these cases, it is a good practice, as long as the required temperature levels allow it, to use a heat pump type equipment, which is capable of supplying heat (totally or partially) and cold (also totally or partially) to the facility.

The following diagram summarizes the operation of the system in the different seasons, prior to the incorporation of the savings measure.

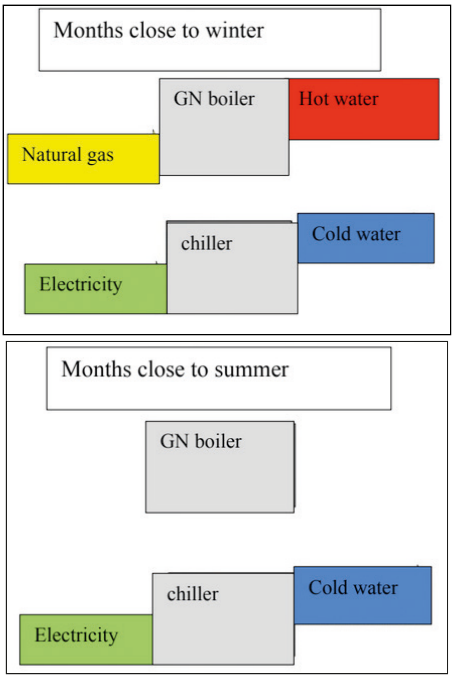

Figure 1: *Operation of the system prior to project execution.*

For the generation of hot water, a natural gas boiler is used, with the following characteristics:

Thermal power: 1,165kW

Maximum efficiency: 92%

Natural gas consumption for two years is presented below:

For the generation of cold water, there are two chillers with a capacity of 750TR each.

With the data collected, taking into account the costs of natural gas and the efficiency of hot water generation, the new system is sized, prioritizing the replacement of the hot water generation system.

Therefore, the new operating scheme is as follows:

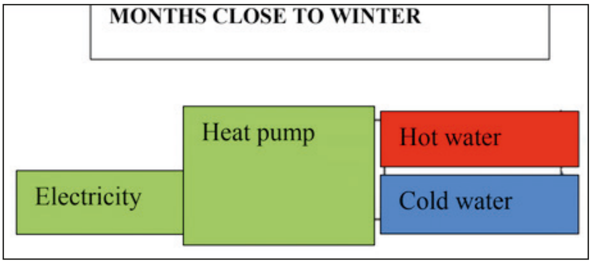

Figure 3: *Operation scheme after project execution.*

According to the surveyed installation, the characteristics of the equipment to be installed, according to the data obtained from the manufacturer's software, are as follows:

Number of units: 2

Compressors: 5 reciprocating/unit

Refrigerant: R134a

Consumption: 133 kW/unit

Heating capacity: 361 kW/unit

Cooling capacity: 228 kW/unit

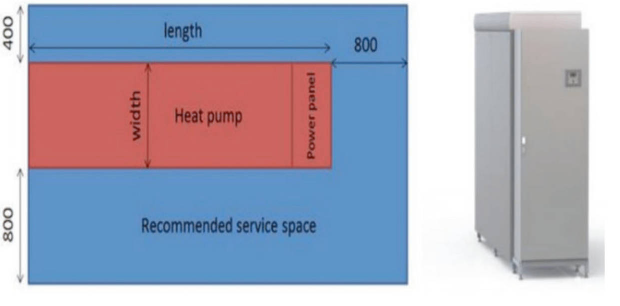

Figure 4: Specifications of the equipment to be installed.

In this case, it is vitally important to keep in mind the simultaneous operation of the cooling/heating systems for correct system operation and the required balance between

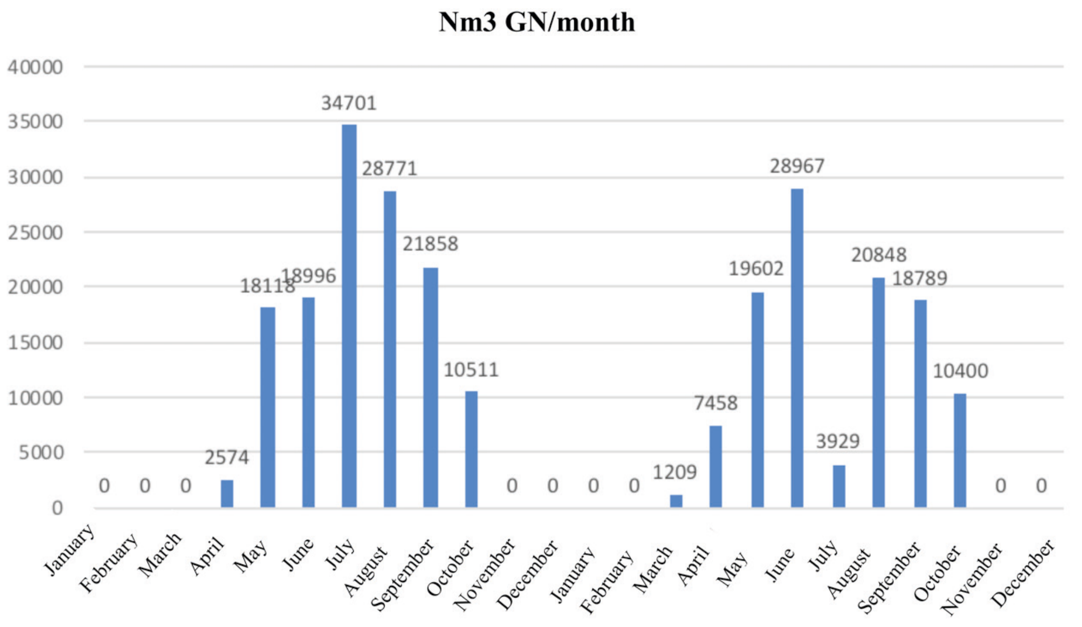

Figure 2: *Natural gas consumption for two consecutive years.*

them. To this end, redundant hot water generation and thermal load simulation systems on the cold side have been installed, in order to improve the operating conditions of the heat pumps at all times.

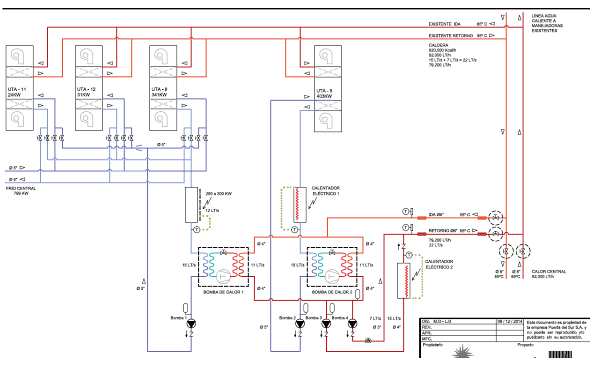

Figure 5: Incorporation of equipment into the existing installation.

As it can be seen in Figure 5, a 300kW fan coil has been installed on the cold side of heat pump 1, in order to extract heat from the ambient air (placed in the building's general air extraction ducts) and two 300kW electric heaters each, one on the hot side and one on the cold side of heat pump 2.

With these redundancies, the correct operation of the system is ensured at all hours of the year, although not maximizing savings under all conditions, it does allow maintaining comfort conditions at all times, with different levels of savings, depending on the different equipment that is operating simultaneously.

In the system's design condition, cold water is sent to the AHUs (Air Treatment Units) that require it, the return of cold water passes through the evaporators of the heat pumps, generating hot water on the other side, which is sent to the entire hot water circuit of the airport. If the consumption of cold and heat is not properly balanced, the support systems act in a staggered manner, in order to maintain the defined comfort conditions.

To calculate the project savings, the electrical energy consumption of the heat pumps, the electric hot water heaters, and the fan coil are measured. In turn, the inlet and outlet temperatures of cold and hot water from the heat pump are measured, as well as the inlet and outlet temperatures of cold water to the fan coil.

To calculate the natural gas savings, the heat input to the system is determined from the inlet and outlet temperatures of hot water to the heat pumps and the hot water flow rate (which is almost constant in the closed circuit). Subsequently, the natural gas consumption with the old system and its performance are calculated, and the electrical energy consumption of both the heat pumps and the electric heaters is subtracted from it.

On the other hand, to calculate the savings in the chiller, the inlet and outlet temperatures of the cold water from the heat pump on the evaporator side are taken, together with the cold water flow rate, subtracting the heat supplied by the fan coil from the temperature data at the inlet and outlet of the fan coil. This is compared with the performance of the chiller (which in the winter months at low load, has a COP of 1.7), in order to obtain the electrical energy savings in the cooling system.

With the installation of the heat pump, the average monthly consumption of 24,500 Nm3 of natural gas is eliminated during the months of use, replacing it with 87,000 kWh of electric energy. This implies an average monthly saving of USD 17,800.

On the other hand, the use of heat pumps allows the chiller to be turned off in the winter months, resulting in an electric energy saving of USD 16,500 per month. Considering both aspects, the total saving is USD 190,000 per year.

The cost of the heat pumps with their peripherals and installation has amounted to a total of USD 447,000. Under the above conditions, the simple payback of the investment is 2.4 years.

HEAT RECOVERY IN THE REFRIGERATION INDUSTRY

In all refrigeration industries, the heat extracted from the meat is released into the atmosphere through a refrigeration cycle.

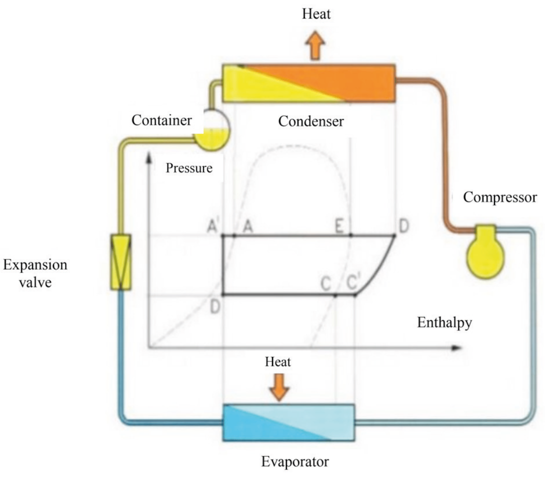

Figure 7: Conventional cold cycle

On the other hand, steam is used to heat water, through a boiler and exchanger.

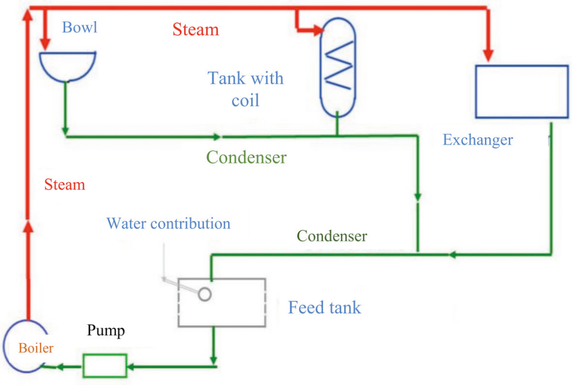

Figure 8: Generation of hot water from steam

In this particular case study, the consumption of wood for steam generation amounts to 20 tons/day, with an associated cost of USD 70/ton of wood, and a steam generator/heat exchanger system efficiency of 82%, which implies a cost of USD 43/MkCal per million kCal.

There is significant potential for savings by combining the two systems in order to use the heat released into the environment by the condensers to heat water in a much more efficient system (heat pump) than that currently used for hot water generation:

Although the electricity that powers the heat pump is more expensive than the wood

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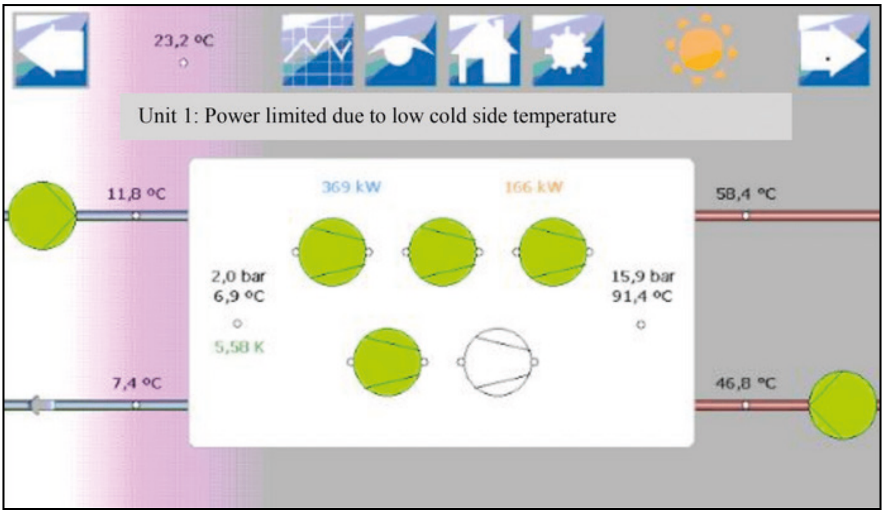
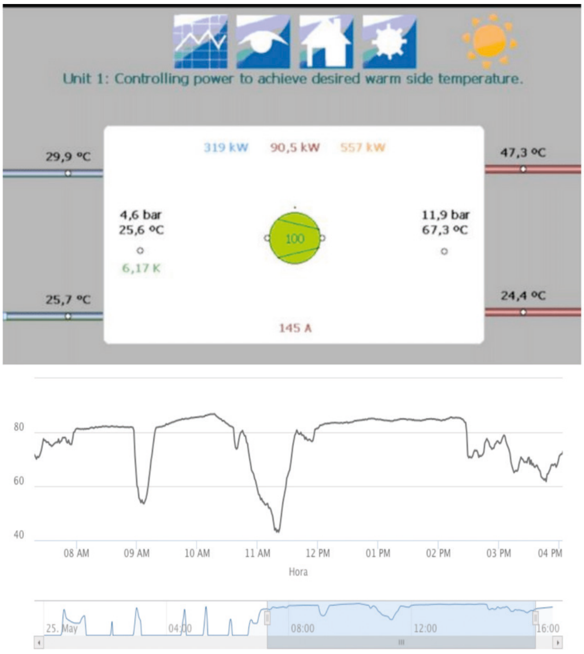


Figure 6: Operation of the equipment

used in the boiler (comparing the energy costs alone), the difference in efficiency between the boiler (80-85%) with exchanger (85-90%) and the heat pump (650-700%) means that there is a significant saving in water heating costs.

The high efficiency of the proposed system is due in part to the fact that the heat supply source for the heat pump (the condensers of the cooling system) is fairly constant throughout the year, and the heat required by the heat pump evaporator is in the order of 15-20% of the capacity of the condensers of the cooling system. This allows not only the new system to work at an optimal performance point in almost any condition, but also allows the central cooling system to have some leeway at times of greatest demand, allowing it to work with a lower condensation pressure.

In this case, the savings are measured with a calorie counter, based on the sonorization of the inlet and outlet temperatures of the hot water, as well as the flow rate of the water circulating through the heat pump.



Cooling Power: KW – Heating Power: KW – Consumption Power: KW

Figure 10: Measurement of heat generation and energy consumption.

Based on this data, the million kCal of hot water amounts to a cost of USD 17/MkCal, which translates, for a monthly expenditure of approximately 500 tons of firewood, into a monetary saving of approximately USD 17,500 per month.

In turn, there are additional benefits from the implementation of this project, such as: decreased demand for steam from

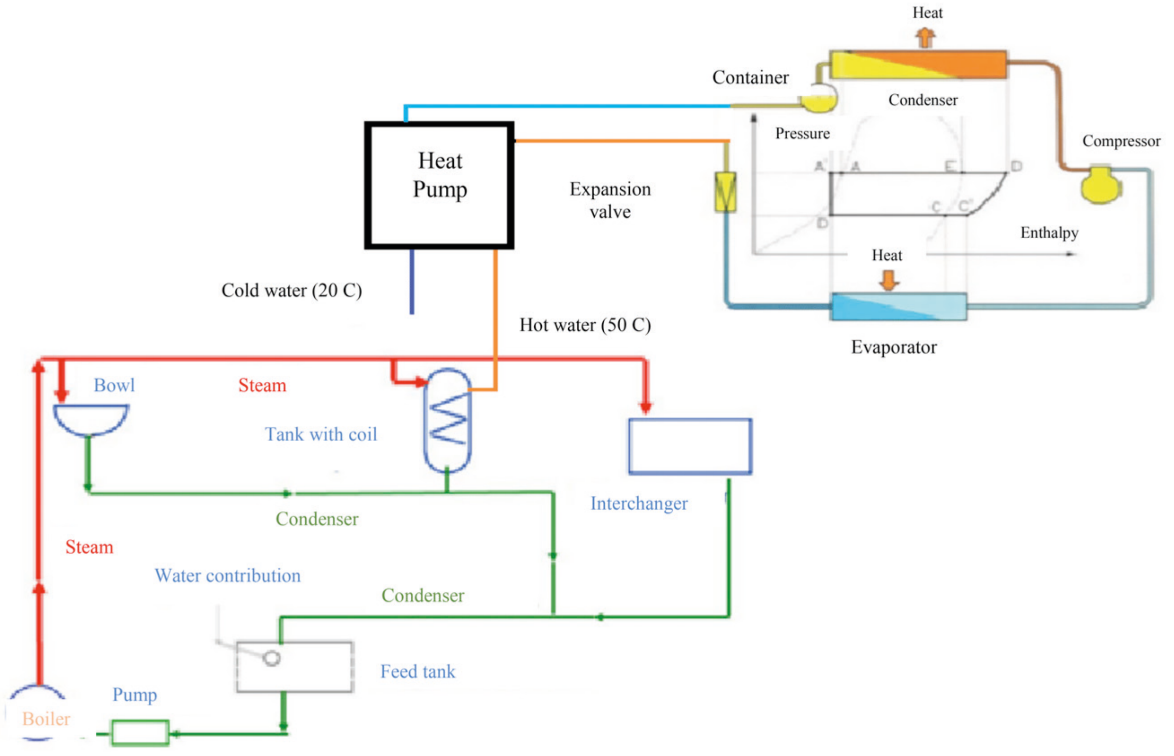


Figure 9: Combination of both processes.

the generator, savings in operating costs in the steam generator, savings in electricity in the cold condensers, as well as water and chemicals for its treatment, and savings in electricity in the cold compressors due to decreased condensation pressure (taking into account that a minimum condensation pressure must be managed, which must not be lowered).

Without taking into account the additional benefits mentioned above, for a total investment of the turnkey project of approximately USD 250,000, a simple repayment period of 16 months is obtained.

CONCLUSIONS

It is possible to conclude from what has been stated in this article that, although there is usually a significant potential for savings in relation to heat recovery systems, and their application is possible in a wide variety of areas, it is necessary to have prior feasibility studies in order to determine with the greatest possible certainty the potential for savings of the project based on the heat needs of each installation. Subsequently, it is desirable to have redundant or support systems that allow the normal operation of the installations to continue, even if there are failures in the new systems. Finally, the calculation of savings must be able to adapt to the different realities and variations in the operation of the installations, and can be supported by measurement protocols duly ratified by all parties, in order to obtain accurate results.