MULTITRACES

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

Collection of study cases made by international students for rural business in Spain

TITLE OF THE PROJECTS

MATCHING ENERGY DEMAND AND ENERGY PRODUCTION

Giulia D'Agostino

Email: giuliaadagostino@gmail.com

Nefeli Saia Machairidou

Email: nefelimah1d16@gmail.com

STUDY OF TURBINE ENERGY PRODUCTION

Dumitru Blănaru

Email: dumi.blanaru54@gmail.com

Petrică Țibuleac

Email: petricatibuleac999@yahoo.com

THE IMPACT OF DIGITAL CONTROL SYSTEM ON THE WATER PRODUCTION

Tatiana Moreno Bastidas

Email: s287926@studenti.polito.it

Iliana Seferidou

Email: ilianasef@hotmail.com

MENTORS:

University of Alicante

Oana M. DRIHA,
José Manuel CASADO
Raquel SIMÓN

Comunidad de Regantes de Pliego

Martín JIMÉNEZ

José Ángel PEREZ

MULTITRACES

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

PRESENTATION OF THE COMPANY COMUNIDAD DE REGANTES DE PLIEGO

The Region of Murcia

Figure 1. Region of Murcia, Spain

History

The history of the region of Murcia is complex, rich and extensive, involving in many periods that of the whole of the Region of Murcia (Figure 1).

The duality between field and orchard is a constant throughout the history of the Murcian municipality and has determined the human settlements in the districts located in both geographical spaces.

The Roman era begins with the conquest by Scipio, in 209 BC, of Carthago Nova, an important economic and political center of the western Mediterranean. The city acquired great importance in this period largely due to the exploitation of the rich mineral deposits scattered along the Murcian coast. Meanwhile, in the interior of the region, Romanization led to the creation of some sparsely populated rustic towns.

Later, the period of Arabic domination started in 713 when General Abdelaziz arrived in the region to confront the Hispanic-Visigothic army of Teodomiro in Cartagena.

The city of Murcia was founded by Abderramán II in the year of 825, and during this time a period of economic growth began. The Arabs took advantage of the course of the Segura River, near the city, to create a complex network of ditches, pipes, weirs, waterwheels and aqueducts. These are the antecedents of the current irrigation system, which served to take advantage of the resources of the fertile Segura orchard. Until the second half of the 11th century, Murcia was not an independent kingdom and the city paid vassalage to the kings of Almería. With independence, and throughout the 12th century, Murcia became a great economic and political center, which led to an increase in public works, with the construction of numerous religious buildings and fortresses.

However, the border pressure exerted by Castilla and the political disorders of Lorca, Mula, Cartagena and Aledo, generated a period of instability. As a result in 1243 the kingdom of Murcia submitted to the vassalage of Castile. Later, in 1375, Castile and Aragon signed an agreement establishing the dividing line between the two kingdoms but border instability persisted until the final conquest of Granada in 1492, giving way to a time of greater balance.

With the achievement of peace, a phase of rapid economic and demographic growth begins, with all the cities of the kingdom flourishing throughout the 16th century. The alternation of peak times with others of marked decline is a constant in the history of this region. Thus, the 17th century was marked by great droughèèèts, the origin of plagues, epidemics and food shortages. After the hard interval of the War of Succession between 1702-1713 there is a new recovery process: the cultivated surface is increased extraordinarily, the irrigated areas are expanded, the population registers a great increase and the effects of the progressive trade opening. As in other times, this economic splendor is reflected in the increase in constructions.

After this golden age, the 19th century opened with a new crisis caused by a period of drought, followed by major floods and the war against Napoleon. It was not until the middle of the century that the situation was reversed. The economic activity was extended to the exploitation of mineral deposits, also beginning the process of industrialization. Despite this, the region would reach the 20th century with an industry of foreign capital and a trade that had not been able to cross regional borders. With the dictatorship of Primo de Rivera during the years 1923-1929, Murcia joined the rhythm of the country, promoting industry and strengthening the canned, citrus and pepper sectors, modernizing its agriculture.

Geography

The Autonomous Community of Murcia is located in the southeast of the Iberian Peninsula. It occupies a total area of 11,314 km2, which represents 2.2% of the national territory. Located in the Arco del Mediterráneo, it borders to the east with the province of Alicante; to the west

with Granada and Almería; to the north with Albacete and to the south with the Mediterranean Sea.

Economy

With an area 11.314 km2 and 1.518.486 inhabitants, this region represents the 20% of national exports of fresh fruit and vegetables from Spain, with more than 309,618 hectares of agricultural area of which 83% of the land is irrigated.

A practice that was introduced on a large scale in the VIII century by the Moorish population on which the agriculture of the region depends.

The capacity of exporting companies, their cultivation techniques and the professionalism of farmers and irrigators, are the characteristics for which this region is known as “the Orchard of Europe”.

The orography and climate of the place mean that almost all kinds of products can be grown on its land. However, it has a special disadvantage : the drought. The lack of rainfall is a problem that has affected farmers for decades.

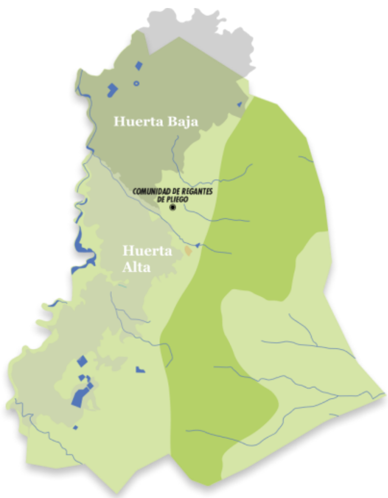


Figura 2 Municipality of Pliego, Murcia, Spain

The Municipality of Pliego Fig. 2, covers 29.34 km2, with 3.868 Inhabitants, from which 69% were born there.

The Municipality has 185 companies distributed in the sector of transport and commerce, service, construction and industries.

This region has a crop land of 1087 ha of which 585 ha are irrigated and divided into two (2) types of crops: woody crops like non-citrus fruit trees, apricots, citrus, olives groves for oil and herbaceous crops like tubers and vegetables. But as we mentioned before the region has a semi-arid climate so during the hot season the daily average temperature is 30°C.

Comunidad de Regantes de Pliego

Overview

The irrigation communities in Spain are ancient communities, unique in the world and very efficient with the aim of managing the scarce water resource to be distributed with the utmost rigor and equity. Irrigation Communities organize the collective use of public, surface and underground waters that are common to them. Their priority function is the distribution and administration of the water granted, subject to regulations sanctioned by the Administration and drawn up by the users themselves.

The irrigators Communities are defined as the grouping of all the owners of an irrigable area, who are bound by law, for the autonomous and common administration of public waters, without intention of profit. (Campo García, 2014). It then refers to a specific area of irrigable land, which enjoys a water concession to irrigate that area of land. In this way, it is indicated that the water concession is given to the land, and not to the owner of the land, so called "comunero". Therefore, when a community member sells his land, he is transferring, together with his property, that right that corresponds to the land.

History of the company

The history of the company starts in 1992 with the foundation of Comunidad de regantes de Huerta Baja by Martín Jiménez Fernández . A sector that in its beginnings was abandoned and without an irrigation system. It came from managing no other irrigation system than the traditional one, with an abandonment or no cultivation of the land with percentages around 70-80%.

A few years later in 1996, was founded Comunidad de Huerta Alta. But the irrigation system was poorly designed, subject to continuous breakage due to the large differences in altitude. And in 2013 to improve the efficiency of irrigation systems and better manage the water resources, the two entities were unified as Comunidad de regantes de Pliego and were allocated 5 million euros to fix the irrigation system of Huerta Alta and build the irrigation system of Huerta Baja from scratch.

From 2014 as part of the integration of the communities they started a modernization program that led them to:

1.The installation of remote control systems.

2. The construction from scratch of a ring system for Huerta Baja. Meanwhile on Huerta Alta the existing system was modernized to a Branched system.

3.The covering of two of the basins to prevent water lost by evaporation of 20 to 30%

4.The installation of 1,773 photovoltaic panels divided into two plants.

In 2020 all these changes led the company to win "Sostenibles por naturaleza" an award for the efficient and sustainable use of water.

Entity unification process

Irrigation Community "Huerta Baja", was constituted by the users who have the right to use the waters of Trasvase-Tajo Segura, as well as the aquifers of "La Esperanza" and "Caños". Including those of the so-called new ones of the "Juncal". The irrigable surface included the traditional irrigation of the Huerta Baja and the irrigation of the Juncal.

Irrigation Community "Huerta Alta". Its constitution includes the irrigators of the Agrarian Transformation Societies "El Cherro" and "Las Anguilas", owners of the groundwater from the set of wells called "El Prado". The irrigable surface is divided into two sectors, Sector I ("El Cherro") and Sector II ("Las Anguilas"), corresponding to the previous irrigable surface mentioned. It is also constituted with the purpose of managing the resources that may correspond to it from the Transfer-Tajo Segura and the Pliego River Dam.

They had not one associative entity, but 5 associative entities managing the irrigation system, which was not sustainable economically or in terms of efficiency. With this plan they managed to have a base entity where all the plots, farmers in the municipality of irrigated land of sheet and part of mula, are all integrated into a base community as the first issue that had to be resolved. All this with the aim of contributing to the improvement of the management of water resources that are destined or could be destined to the irrigable area.

On March 22 of 2015, the Segura Hydrographic Confederation approved the modification of the ordinances and regulations of "Huerta Alta" Irrigation Community, which is renamed the Pliego Irrigation Community, as an ordinary community that integrates users of the former "Huerta Alta" and "Huerta Baja" Irrigation Communities, declaring the "Huerta Baja" Irrigation Community and the Pliego General Irrigation Community extinct.

The company currently

Comunidad de Regantes de Pliego, is a small company in terms of area with 400 parcels on approximately 850 hectares of irrigable area distributed between Huerta Baja and Huerta Alta, but large in number of community members, with around 1,500 "comuneros". Is located in the Region of Murcia, Spain, and more precisely in the municipality of Pliego.

The modernization plan gave results, obtaining benefits in the communication and action systems in the containers, implementing these changes in the technique, and the channeling of hydrants. As well as the use of innovative technology for the use and control of this irrigation, making the irrigation system even more efficient, directly controlled by the farmer through applications that can be used on any mobile device, tablets or computers.

In this way, it can be seen that the crop is receiving the water that the farmer previously programmed, the guarantee of that supply and that control generates an increase in planting in the areas that were without any planting, increasing the sustainability of agricultural resources, having water as a fundamental resource.

Thus advancing on the one hand in the system of evaporation losses in areas such as Murcia due to the high temperatures in the summer, which meant an evaporation loss in the reservoir of around 25%, which could be detected, controlled and classified.

However, one of the priority objectives that the company continues to have, is the reduction of energy costs to 0, changing electricity consumption for renewable energy.

MULTITRACES

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

1. MATCHING ENERGY DEMAND AND ENERGY PRODUCTION

Mentors:

Assoc. Prof. Dr. Oana Driha

Dr. Raquel Simón

Universitat de Alicante

Students:

Giulia D'Agostino

Politecnico di Torino, Italy

Nefeli Saia Machairidou

University: International Hellenic University, Greece

Company:

Comunidad de Regantes de Pliego

Martín Jiménez

José Ángel Perez

Content of the project

Executive summary

In this project we are analyzing in detail all the ways the circular economy is connected to agriculture to help the company shift to more sustainable ways of operation. We worked together with the Comunidad de Regantes de Pliego in order to find out how such programs can work in practice. For this project, we had to conduct research on ways to save energy and water in order to find balance between energy demand and energy production.

First, we started by giving an overview of the region of Murcia and Pliego, we presented in detail different demographics, as well as environmental characteristics, and then we proceeded with a small introduction concerning the history of the company as well as irrigation in Spain in the previous years. Then we pointed out their future goals and explained all the reasons why we need energy in the irrigation process and the water management sector and made clear that correct management can be beneficial to companies in the sector of agriculture, both economically and ethically. The information we gathered and all the data we were given by the company during our visit, as far as energy goes, show that currently Comunidad de Regantes de Pliego, is in a deficit, so extra energy is needed to be produced, in order to operate all their system without having uncontrollable expenses. Renewable energy in the water management sector seems to be one of the best solutions in that case as it is environmentally friendly, works under the outlines of circular economy, and simultaneously it would provide the extra energy needed while also contributing to water saving that is vital for the company. The objective of our project is to find balance between energy demand and energy production, minimizing the current existing gap by combining energy and water saving measures through the production of electric and hydroelectric energy.

The contribution of the European Union, through policies concerning the circular economy, agriculture as well as energy efficiency, play a very important role in providing companies, workers, and farmers with all the important information they need, ways of implementing such strategies and also financial support programs. Ensuing we analyzed in detail the situation of the company in the supply chain sector, and how it operates. Later we focused on showcasing the modernization plan of Comunidad de Regantes de Pliego, in detail, clarifying the differences between Huerta Alta and Huerta Baja, that took place from 2014 until 2020 and proceeded to define some existing solutions in the energy demand and consumption problem by using case studies. We then made sure to describe the chosen solution and our proposal basing our ideas on information we found on precision agriculture for water and energy saving measures, as well as hydroelectric energy production and conducted a SWOT analysis. In the second part we examined the specific system we are proposing, we have presented in great detail all the information we were able to gather considering the technicalities of our proposals, which include different types of sensors and the field they wield, focusing on water flow sensors or flow meters and presenting a particular product including all its characteristics. Simultaneously we presented the way hydroelectric plants could help the Comunidad de Regantes de Pliego, fill in the gap between energy demand and energy production and pointed out exactly why its' implementation would be functional and

beneficial in the long run from an economic point of view as well as a circular economic point of view.

After that we examined all the outcomes of our proposal and categorized them. The categories include local development, advanced farming techniques, energy, sustainability and last but not least, fundings. We were able to do that by creating scales in micro, meso and macro level and timeframes, short term, medium term, and long-term periods. Based on those we also pointed out the impact of our proposed solution to the environment and the ecosystem of Pliego, Murcia and concluded that there will be a positive effect on the socio-economic part and an overall greater result on the energy level demand and production, for the company, because the hydroelectric plant we propose as well as the use of sensors in order to monitor waste water, will help the company as well as farmers working on the surrounding area to not rely on worldwide fuel sources and local water providers. Lastly, we inspected the economic side of our proposal and presented an economic overview, starting from 2020, which is the year the modernization plan of the company was finalized and forecasted the benefit of the company in the next years until 2024. We took under consideration that the biggest amount of the company's income, originates from European fundings and used the balance sheets we could find on the company's website in order to calculate the total amount of the investment for our proposal and then proceeded to make a forecast of the benefits in the span of the next five years while also calculating the net present value, and internal return rate, in order to examine the profitability of our proposal and then predicted the payback period, which indicates the amount of time the company will need to recover all the expenses made after the proposed investment. In conclusion with the research, we conducted for the Multitraces Circular Economic project in the part of matching energy demand with energy production, the best ways to work more sustainably and ethically, is by managing the water usage in detail and making sure that no amount of water is wasted, with the help of different sensors. Then using the extra water to produce hydroelectric energy, through water generated turbines, we realized that the company is led to energy saving measures that bring the Comunidad de Regantes de Pliego closer, to a more balanced way of operating regarding the amount of energy demanded and the amount of energy produced. Finally we believe that our proposal can only benefit the company.

1. Project overview

2.1 Introduction

With the impact of climate change being felt by farmers across the EU, the need for irrigation has become an increasing issue. Water saving and energy saving are key challenges for farmers and irrigation communities.

1.1.1 Use of energy in the irrigation water management sector

Irrigation is mostly considered as an effective way to increase agricultural production, supplying the amount of water necessary for the growth and development of crops. But at the same time the agricultural sector is also known for being the sector that consumes the largest amounts of this source - and, as a consequence, of energy - and is most affected by its scarcity. Especially in areas with semi-arid climates where low precipitation added to high temperatures, causes scarcity of water resources and puts them in emergency situations.

Is here where irrigation water management has an essential role, establishing proper timing and regulating irrigation so that it covers the necessary water requirements of the crop without wasting water, energy, plant nutrients or degrading the soil, all looking for greater efficiency.

Water and energy are intrinsically bound. All irrigation systems require energy, which is dissipated along the system. The difference between systems lies in the amount of energy needed and the way it is dissipated. While traditional systems used only gravity to convey water to the fields, modern systems generally require external sources of energy. Modern irrigation is closely tied to the use of energy. The advent of diesel and electric motors in the mid-twentieth century led to the development of pressurized irrigation systems and allowed the intensive use of groundwater. Access to energy boosts irrigation wherever water resources are available and the rainfall is not sufficient to meet crop water needs.

These modern irrigation systems consume energy at the pumping stations (to lift water from the source and to pressurize it in the distribution network), to filter the water, along the pipes, when the water flows across the network components, and to apply the water uniformly. Design constraints and improper design or operation and management lead to extra energy needs that could be potentially saveable or recoverable. Water users are interested not only in saving energy, but also in reducing energy costs.

1.1.2 Renewable energy production in the water management sector

Using renewable energy in pumping and irrigation can therefore not only reduce greenhouse gas emissions, but also lower the costs of buying diesel or kerosene fuels and increase the sources of income for large and small-scale farmers and irrigation communities. In addition, regions that are off-grid or without reliable access to electricity due to constant blackouts can benefit from renewable energies. If efficient irrigation methods like drip irrigation are implemented, valuable water resources can be saved and the use of arable land for irrigated crops increases, leading to an extra source of income. The additional vegetated land cover will furthermore allow the protection of the increasingly threatened soil resources. A win-win for the community and the environment.

Using clean energy for irrigation such as solar power, hydropower or wind can increase production and create access to electricity while saving financial resources.

But, as mentioned before, the sources of renewable energy for water pumping and transport do not necessarily promise sustainability if water resources are not used with responsibility. Especially countries with low rainfall rates, such as Spain and in particular the region of Murcia, where irrigation makes the biggest difference for agricultural production, usually extract the required water from groundwater reservoirs, which are invisibly threatened from water resource overuse.

1.1.3 The objective of the project

For the reasons underlined above, the project will focus on the energetic efficiency of the irrigation systems. The aim of the project is to fill the gap between the energy demand and the energy production through the combination of water and - as a consequence - energy saving measures, and the production of renewable electric energy.

Talking about the goals of the Comunidad de Regantes de Pliego, their first focus is on the efficiency of the system. Their aim is to save water and energy teaching to the farmers how to irrigate the crops properly and to reach energy self-sufficiency, producing their own renewable electric energy. In fact, thanks to the modernization plan that the company carried out during the period 2014-2020, 1773 solar panels were installed in two different photovoltaic plants. The company currently uses the photovoltaic energy produced by itself to contribute to the extraction and the pumping of the water. However, the amount of energy they produce is still not enough to cover their entire needs, and for this reason they have to purchase the rest of the energy from the public electric network.

The interest of the Irrigation Community of Pliego in the optimization of energy consumption, is related to the guarantee of continuous supply and the reduction of operating costs, which can lead them to make more efficient use of the resources available. At the same time, the company pursues projects and initiatives related to the sustainable development of the rural area: collaborating with the Universitat de Alicante on the MULTITRACES Project, they work on the adoption of the Circular Economy approach in the water management sector.

1.1.4 Circular Economy in the water management sector

It is important to understand the value of the circular economy in the water management sector. The water currently available around the world will only be enough if we find ways to use it and manage it thoughtfully. Rapid population growth in recent years means more and more water is needed and energy demand is increased. At the same time climate change and the excessive use of pollutants increases the need for fresh water both for consumption as well as for usage in the agriculture industry, as water is vital for cultivation. In the water industry Take-Use-Discharge is the model we most commonly see and it is the least beneficial and also not at all sustainable. In a circular economic model there is great opportunity for governments, companies, and businesses to find new ways and work innovatively to reuse and recycle water, in order to realize all the ways we can regenerate the environment. Sustainability is very important, especially when the resources we have are limited. Working in such ways can help reuse water to produce energy and simultaneously it helps with preserving natural systems. The energy needed for production could be found and produced by the company in order to limit expenses and work more efficiently. Even though the cycle of water is in a way recyclable, circular economy helps use maximum amounts of water.

In the last two decades water management in Spain has been going through a gradual transition due to growing water problems. Spain has historically solved its water policy issues by regulating the water supply through the state-subsidized construction of extensive infrastructure. Lately it is mostly focused on sustainability of the resource. Law changes have been really affecting that change, specifically: The 1985 Water Law, The 1999 Water Law reform, The European Union Water Framework Directive (2000) and lastly the 2001 and 2004 Laws of the National Hydrological Plans. Intense urbanization lately, economic problems, droughts and growing conflicts about water management are some of the reasons why Spain has to focus on solving such problems.

1.1.5 EU Policies

The European Union also plays a huge part in the policies farmers all over the continent follow concerning agriculture and energy.

Eu Policies regarding agriculture

1.The Common Agriculture Policy (CAP) is the policies and rules every farmer operating in the European Union has to follow to ensure safe farming and food security.

The latest Common Agriculture Policy (CAP) will be in operation from 2023, it is an updated version of the previous CAP that will be more focused on sustainability and greener agriculture practices. It is based on the European Green Deal in order to help protect agriculture and forestry furthermore.

The objectives of the policy include:

- National Strategic Plans: each European country will have to create their own, unique CAP strategic plan, following the specific objectives provided by the EU Commission, combining funding for income support, rural development and market measures.

- Performance and results focus: The CAP legislation has set specific indicators that will help monitor and evaluate the performance of each country, annually, focusing on the goals they should reach.

It is important to note that the new CAP contains reforms of olders policies in order to help the transition to sustainable agriculture and forestry in Europe.

Another very important European Policy is the 2. European Agricultural Fund for Rural Development (EAFRD), it focuses on competitiveness in agriculture, and it ensures that farming is done in a sustainable way and it is a way to achieve a balanced territorial development across the rural areas of Europe that will help create and maintain employment.

At the same time the European Agriculture Guarantee Fund (EAGF) is a policy that helps support farmers economically in specific ways, they provide a basic funding scheme as well as a sustainable farming methods scheme. All the payments are given, ensuring food safety, environmental and animal safety.

Producing their own electric energy, the Comunidad de Regantes will reach a more self-sufficient system, generating an output that will become a new input for their own supply chain, becoming independent from the public network and reaching the objective of the 0 emissions adopting a CE approach.

Eu Policies regarding energy

1.The European renewable energy directive

Although the Renewable Energy Directive (2009/28/EC) was amended in 2018, the Commission recommended another change in 2021 to better match it with growing climate aspirations. The regulation establishes a single objective for the quantity of renewable energy in the EU's energy consumption by 2030, which is presently set at 32%. The suggested modification and the REPowerEU plan, both released in May 2022, indicate further evolution of the objective to accelerate renewable adoption in the EU.

The directive defines uniform principles and standards for removing barriers, stimulating investments, and driving cost reductions in renewable energy technology, as well as empowering communities, consumers, and enterprises to engage in the clean energy transition.

2.The National energy and climate plans (NECPs)

The NCEPs objective is to reach the EU's 2030 energy and climate goals. All EU nations must develop a 10-year integrated national energy and climate plan (NECP) for the years 2021 to 2030. The guidelines, which were enacted as part of the Regulation on the Governance of the Energy Union and Climate Action (EU/2018/1999), required the final NECP to be presented to the Commission by the end of 2019.

The NECPs' coverage areas include:

- energy efficiency
- renewables
- greenhouse gas emissions reductions
- interconnections
- research and innovation

This method necessitates cooperation across all government ministries. It also offers a degree of planning that will facilitate both public and private investments. As all European nations are utilizing the same template, they are able to collaborate and improve efficiency across the continent.

1.2 State of art

In this section we will analyze in depth the current situation of the company in terms of energy consumption and energy production, and case studies on existing solutions and research on water and energy saving measures and hydroelectric energy production.

1.2.1 Supply chain

The supply chain of the Comunidad de Regantes de Pliego consists of five steps before the water reaches the cultivated fields: extraction, transport, containment, filtering and distribution.

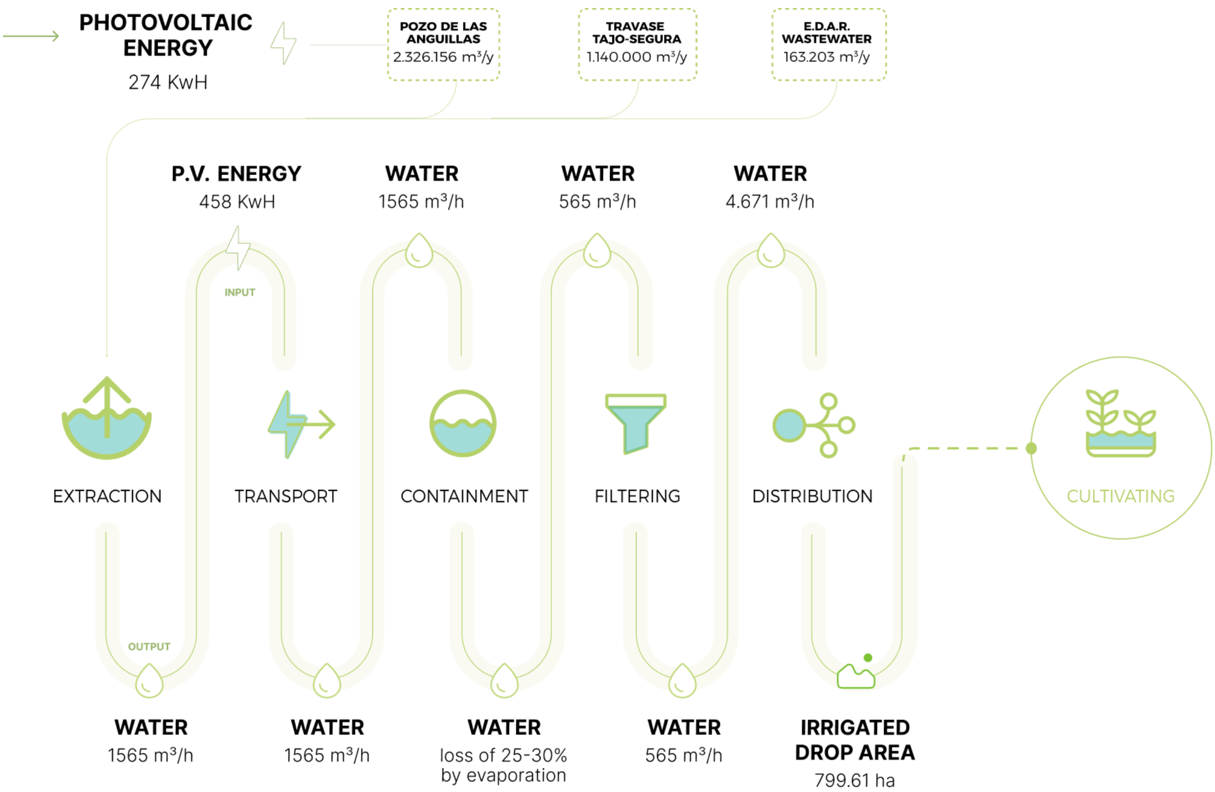


Figure 01. Supply chain of the Comunidad de Regantes de Pliego

Extraction

The chain begins with the extraction of the water. The total amount of water that the company manages is about 3,629,359 m^3/year. The Comunidad de Regantes de Pliego obtains water from three different sources:

1. Pozo de las anguilas
2. Trasvase Tajo-Segura
3. The E.D.A.R.

Pozo de las Anguilas is the main source of groundwater for the Comunidad, in fact they obtain from it the majority of the water they use for a total of 2.326.158 m^3/year.

The Trasvase Tajo-Segura provides 1.140.000 m^3/year of surface water, especially during the hot season.

Finally, the E.D.A.R. (Estaciòn Depuradora de Aguas Residuales) is the waste water purification station of Pliego that is managed by the Confederaciòn Hidrogràfica del Segura. They provide a certain amount of water purified by the E.D.A.R. to all the local Comunidades de Regantes and for this reason, the Comunidad de Regantes de Pliego obtains 163.203 m^3/year of reclaimed water. This phase - water extraction and pumping - represents 90% of the total energy used by the company to develop its activity. And although the company has photovoltaic power plants, this only represents 17% of the total energy needed for operation between the extraction and transport of water, leaving 83% that must be acquired from the electrical network.

Transport

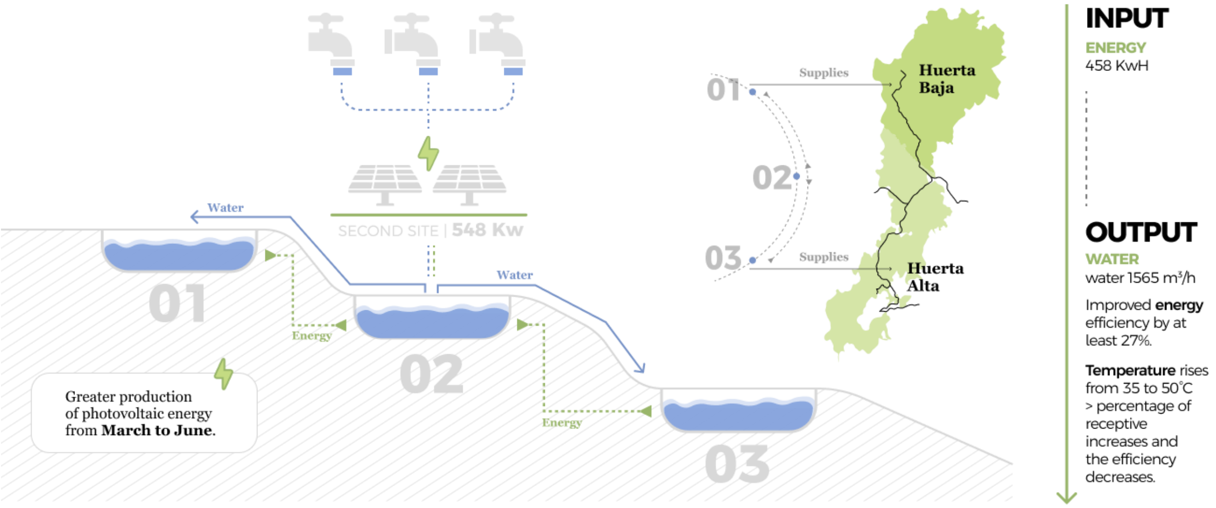


Figure 02. Position of the basins of the Comunidad de Regantes de Pliego.

Since all the basins are at a different levels, the company needs energy to transport the water from one basin to another and for that they use the energy provided from the solar plant, for self-consumption with anti-spill to supply all the electrical receivers, that hang from the main transformation center of the Comunidad de Regantes de Pliego.

The basin on the top supplies the entire Huerta Alta and the one on the bottom supplies the entire Huerta Baja, but there is only one central unit, which is the one that has the water pumps that communicate the water from the lowest to the highest. When there is sun this energy is used to carry water from one basin to another.

Containment

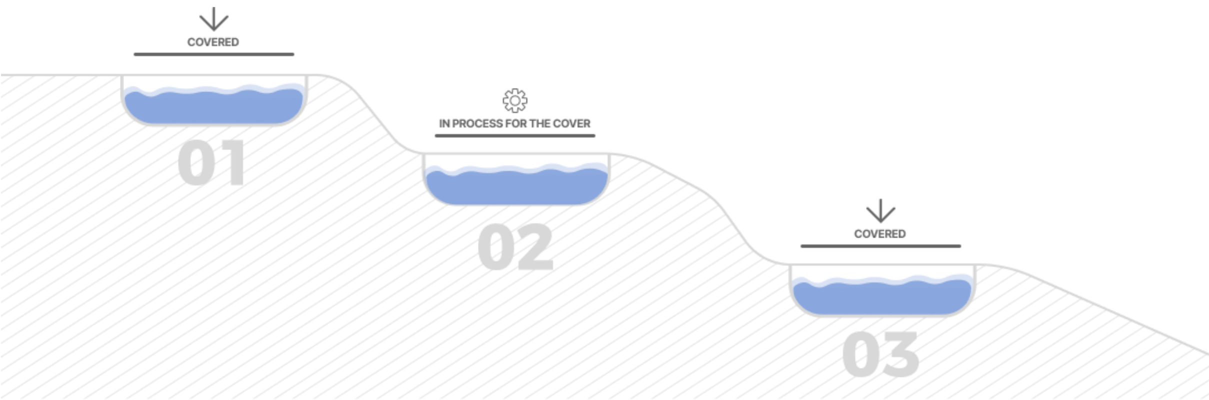


Figure 03. Covering of the basins of the Comunidad de Regantes de Pliego.

For the containment the company has at its disposal three basins in operation and contain the mainstream of 1,565 m^3 of water. At the moment just two of them are covered, so they still have a water loss that represents 25-30 % by the evaporation of water from one of the basins. However, the company received the approval by the European Commission for a project involving the coverage of the last basin. It will be financed by the NextGenerationEU fund and will be developed in 2023.

From the higher basin to the lower one, there is a difference in altitude of 40 meters.

Filtering

Before the water is distributed to the two main points of Huerta Alta and Huerta Baja, there are two points of filtering that work with a mechanical system to clear the water and remove any impurities, positioned in correspondence with the basins.

Distribution

The company provides 4,671 m^3 per hectare of water that gets to the fields thanks to the force of gravity as they are located high above the fields, reaching approximately 800 ha of crop area.

1.2.2 Energy use in the supply chain

As mentioned before, the electric energy is fundamental during the steps of the supply chain, in particular during the extraction of the groundwater from Pozo de las Anguilas and during the transport from a basin to another to pump the water through the pipes.

The Comunidad de Regantes de Pliego installed 1773 photovoltaic panels distributed in two different photovoltaic plants: the first produces 458 kWh and it is mainly used to extract the groundwater; while the second produces 274 kWh of electric energy and it is used mainly to transport the water between the basins.

We have to underline, one more time, that in the Region of Murcia the temperature reaches 50° during the hot season, and this compromises photovoltaic energy production.

The extraction of the water takes the 90% of the energy needed by the company, and, unfortunately, the photovoltaic energy they produce only covers the 17% of their requirement.

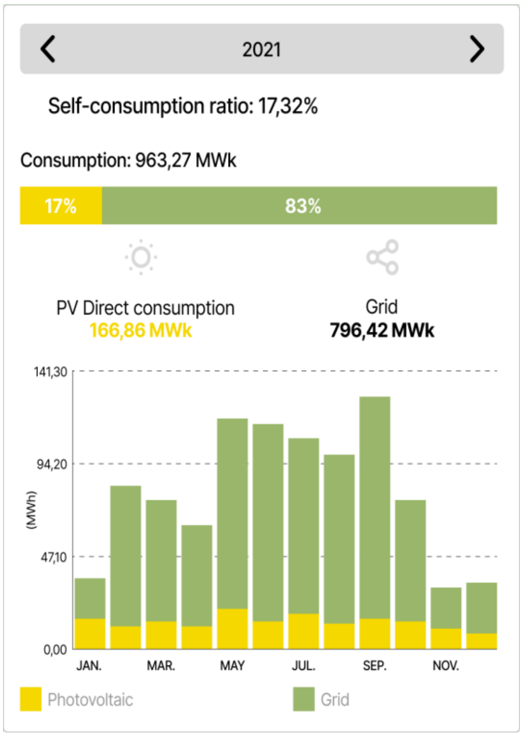


Figura 04. Energy Consumption in 2021 of the Comunidad de Regantes de Pliego.

In the figure above we can see how in the 2021 the contribution of photovoltaic energy was just 166,86 MWk while the amount of energy purchased by the electrical grid was 796,42 MWk. This means that photovoltaic energy is not the best option to obtain the necessary quantity of energy required for the extraction and the pumping of the water. Despite the measures developed through the Modernization Plan 2014-2020, the level of auto-produced energy is not sufficient.

1.2.4 Facilities and Modernization Plan 2014-2020

During the period 2014-2020 the Comunidad de Regantes de Pliego completed a Modernization Plan that allowed them to improve the transport, distribution and storage of water and that was carried out by the Ministry of Water, Agriculture, Livestock and Fisheries. The plan was part of the Rural Development Program of the Region of Murcia 2014-2020, that was financed by 63% by the European Agricultural Fund for Rural Development (EAFRD), 25.90% by the Autonomous Community and 11,10% by the Ministry of Agriculture and Fisheries, Food and Environment.

The works included 17 actions carried out simultaneously in the two sectors of Huerta Alta and Huerta Baja that allowed them to replace the current system of irrigation by surface with a localized drip irrigation system; it included a system of automation of irrigation, that helps the management of the system through a device with internet; and, the implementation of renewable energy plants.

The activities on the sector I Huerta Alta covered 351 hectares with a budget of 3 million euros. Among the actions carried out, the improvement of individual irrigation systems and an extension of the existing irrigation network stood out. In addition, agroclimatic stations were implemented with the aim to favor the decision-making of farmers, the efficient use of water and the reduction of the water footprint.

The weather stations allow greater control, through data of all the environmental and agronomic variables that influence crop development. The company currently has 7 meteorological stations distributed as follows:

- Filtering Station Sector 1, Huerta Alta- Prado
- Station Take 2 of Anguilas - Sangrador
- Station Take 6 of Anguilas - Mill
- Station Take 7 of Cherro - Los Taviras
- Filtering Station Huerta Baja - Oliverica
- Closed - Station H31 Huerta Baja - Cabecicos
- Station Take 17 Huerta Baja - Cañada Los Melgares

At the same time the Comunidad installed 16 humidity sensors based on the different types of soil that, in addition to the data of the weather stations, give the farmers useful insights about irrigation timing and the necessary amount of water.

Moreover, to reduce the evaporation of water from the basins (that reaches 25-30% during the hot season) two raft covers were installed on two of the three basins. The last one that is currently uncovered, will be covered in 2023.

In Sector II Huerta Baja, which has 426 hectares of land and a budget of 5.8 million euros for the modernization plan, the reservoirs were updated. In addition, a general driving system with a length of 3911 meters and filtering station was developed.

It was thanks to the modernization plan that also the 1773 photovoltaic panels were installed. They're distributed in two different sites both located in sector II Huerta Baja: the first one produces 458 kWh while the second produces 274 kWh of energy.

1.2.4 Water saving measures: telecontrol system

We have to put the attention on the telecontrol system that the Comunidad implemented thanks to the modernization plan. It is deeply analyzed in the MULTITRACES project n.4 called "*The impact of digital control systems on water management*".

What is important to say here, is that the remote control contributes to the optimization of energy consumption through the programming of the installation according to the schedule and type of rate, helping to reduce costs. It also allows various operations to be carried out remotely thanks to computer, electronic and telecommunications technologies.

In addition, the system allows remote action on the elements of the hydraulic networks, (the hydrants), from which water is provided to the irrigator. The basic functionality of a Telecontrol System is to centralize the information. This is why the remote control installations facilitate the automatic and remote reading of the volume of water used, and allow the opening and closing of the valves controlled remotely.

An advantage is the optimization of energy consumption, which guarantees continuous supply of energy and the reduction of operating costs, which can lead them to make more efficient use of the resources available.

It is also used by the Comunidad de Regantes de Pliego to collect data from the weather stations and the humidity sensors to provide to the farmers through their website. Parameters such as rainfalls, temperature, solar radiations and soil humidity help them to establish the amount of water necessary for the irrigation.

For these reasons, the remote control system is an instrument that allows decisions to be made based on the collection and analysis of data that contribute to improve the efficiency of the use of resources.

1.2.5 Case Studies in existing solutions

In the following section we will present some interesting case studies related to hydroelectric energy in the water management sector, smart irrigation, Agriculture 4.0 and precision agriculture in order to look at existing solution that can be taken into account as possible implementations in the Comunidad de Regantes de Pliego’s management activity.

The SmartLand project

The SmartLand project was born to optimize the use of water resources (and save energy). It involves the Laimburg Experimentation Center, the Sudtiroler Beratungsring (the Consultancy Center for Fruit Growing) and the Alperia company , the most important electricity supplier in the province of Bolzano, in Italy.

SmartLand is a 4.0 irrigation project that saw the installation of 120 tensiometers in the field. These are sensors capable of measuring the availability of water in the soil and are therefore useful for understanding whether apple trees need to be irrigated or not. The sensors,

developed by Alperia, send the measurements to a gateway thanks to the Lorawan protocol which allows the sending of data packets through a low frequency transmission protocol and reduced energy consumption (it is the same used for the meters on home radiators). The data uploaded to the cloud is available in the form of a graph on smartphones for farmers and company technicians. When the water availability curve begins to fall, approaching a critical level, the farmer can start the plant (provided no immediate rain is expected).

The graph shows to the users whether, a few hours after the end of the irrigation cycle, the water availability has returned to the desired level, or if there is a need to change its duration to ensure better supply. This results in double savings as water is only irrigated when necessary and only the quantity of water useful for the plants is introduced into the system and potentially it is possible to save up to about 30% of water and, as a consequence, of energy.

A novel optimization method for using hybrid renewable systems to achieve zero net energy consumption in water irrigation systems:Energy savings by adopting precision agriculture in rural USA

The enhancement of sustainability is clearly shown on the many targets contained in the various sustainable development goals, for this reason the managers of water resources must identify new strategies, and specify the cost of new investments while also developing decision-making plans. This study suggests a new optimization method that will help water managers decide whether to deploy solar systems and microhydropowers, when their facilities feature pump stations that serve as energy consumption sites. The proposal of this case study indicates that there is a need for a system-wide new plan, taking into account hydraulic optimization on the one hand and developing photovoltaic optimization on the other, where the optimal capacity is correlated with the surface area to be filled considering the ideal tilt angle. The batteries' capacity is maximized based on the current hourly energy balances for every day of the year. At the same time there is possibility to acquire the maximal capacity required in order to deal with periods of energy scarcity and possibly accumulable excess energy. The two simulated annealing techniques that choose the optimum site for the microhydropowes system and the best machine from a database of pumps that may function as turbines are used to later add to the new suggested methodology. The feasibility analysis demonstrated just how attainable all these proposals can be, both for the micro-hydroelectric plant and the photovoltaic panels, as a function of area and discount rates, resulting in savings of more than 15% when compared to current systems that are connected to the grid of the supply pump stations.

Water and energy are the biggest factors in agriculture. Without their use, no crops would be cultivated. As the years go by and global warming is getting worse day by day, and we need to find ways to be more sustainable and contribute to the protection of our climate, by working smart and efficiently. Sustainable agriculture means focusing on energy and water saving. Precision agriculture seems to be the best solution, as it focuses on providing to the farmers all the data they need to make sure no water or energy is wasted.

A study conducted in North Dakota, USA showed that farmers who adopted precision agriculture systems and used GPS, or auto-steering farming vehicles ended up saving almost 52% of energy usage. This meant that the farmers saved energy and noticed a financial improvement depending on the size of the farm and the cost of the equipment they invested on.

The impact of transition from flood to sprinkler irrigation on water district consumption, Spain (Nogues and Herrero,2003) - Water saving

This study was conducted on the area of Aragón, Spain and was focused on showcasing all the ways smart irrigation systems help save energy and mostly water. A map that divided all the types of soil in the cultivated area called the “Irrivol” method, was studied and provided the estimated water amounts needed for each soil and every crop. Soils that were evaluated as LEU,IPP and FAO were the ones with the highest productivity level and so the farmers changed their traditional flooding systems to sprinklers. The study took place in 1993,1994,1996 and 1998 and the results showed that there was about 7% more water saved by using sprinkler systems.

Agricultural-to-hydropower water transfers: sharing water and benefits in hydropower-irrigation systems

Water is vital for farmers and agriculture and due to increasing socioeconomic and environmental problems the need for clear water is increasing. A smart way to always ensure access to such water is to collect it (rainwater) and store it in basins. The problem that occurs after doing that, is the energy that is needed to preserve it and then transfer it. Hydroelectric energy could be the solution to that problem as it can be produced by the farmer and therefore help in saving energy and limiting energy costs. The farmers' demand for water, later affects the price of the crop as well as its quality, which showcases just how important irrigation management is. In this case study the benefits of the Maipo river basin are analyzed. In conclusion under dry conditions, water value increases and at the end the annual expected benefits seem to increase by around 6%.

1.3 Description of the chosen solution: combining energy saving with energy production

Having analyzed the most important problems and the opportunities that were highlighted in the previous points, we delivered two main strategies related to the two main criticalities identified: water and energy consumption and renewable energy production. On the one hand we have the excessive use of water for irrigation, due to the lack of knowledge of some community members about the correct amount of water required according to the crops and the

best management practices of the system. This generates a greater water consumption and therefore energy consumption during the pumping and transport phases. On the other hand, even if the company already produces its own electric energy thanks to their photovoltaic plant, it is not sufficient to cover all the amount of energy they currently need. For this reason, they still use the electric energy they obtain from the public electric grid.

Water consumption and energy consumption are closely connected, so our project proposal is about combining the implementation and disclosure of water saving measures related to Agriculture 4.0 and so precision agriculture technologies and the integration of a new energy source: the hydroelectric energy.

In this way, we will fill the gap between the energy demand and energy production, by reducing the demand and boosting the production, opening the way to the self-sufficiency of the system.

1.3.1 Precision Agriculture to save water and energy

Precision agriculture is just a part of the Agriculture 4.0 revolution. It is also known as "site-specific crop management," and it is "an information and technology based agricultural management system used to identify, analyze, and manage variability within fields for the improvement of profitability, sustainability, and environmental protection". Fields are often different in soil types, altitude, soil chemistry, fertility, productivity and types of cultivation. The application of precision agriculture practices, makes producers able to specify the farm input needs (including nutrient and pesticide application and irrigation) throughout an individual field.

Free public access to the Federal Global Position System (GPS) made it economically feasible for producers to use new precision tools, techniques, and services to enhance their efforts to save energy and reduce costs. These include yield monitoring, grid soil sampling, variable-rate application of nutrients, remote-sensing applications, soil electrical conductivity monitoring, and zone soil sampling.

In addition to cutting production costs and saving energy, precision agriculture reduces environmental pollution and improves water quality by reducing nutrient runoff. Other benefits include:

• Improved crop yield;

• Reduced compaction by limiting traffic to specific travel lanes;

• Increased opportunity to operate equipment after dark;

• Labor savings through reduced implement overlap; and

• More accurate farming records

Sensors are really important in monitoring and paying close attention to details during the irrigation process, and even though they are usually perceived as an expense, in the long run

they prolong the life of the irrigation system and provide the best and most sustainable results. Their most important goal is to help use the full potential of the resources. Even the smallest change in temperature, the power and the direction of the wind or rainfall can have a huge impact on the crops and specific management is needed. Smart irrigation systems can help adapt to changes and react rapidly. With the use of sensors, the farmer has the ability to extract the most out of all these natural phenomena and use them to his/her advantage. Furthermore, they help farmers manage everything remotely through applications and websites without having to check every change by physically being there. This saves time, money, and energy and ensures access to data 24/7, every day of the year.

1.3.2 Hydroelectric energy production

Photovoltaic energy is not enough to cover the amount of energy needed by the Comunidad de Regantes the Pliego, and they need an alternative source of renewable energy. The territory of Pliego is characterized by continuous differences in altitude: this reflects also on the activity of the Comunidad de Regantes, since the infrastructure of the company creates waterfalls of around 40 meters. This characteristic makes it feasible and advantageous to include a system that allows them to generate energy while the water is in motion: a hydroelectric plant.

This topic is deeply studied in the MULTITRACES project n.3 *“Study of turbine energy production (for waterfalls)”,* where the enrìgineers studied the turbine that represents the best option for the Comunidad de Regantes de Pliego, taking into account the characteristics of the territory, the pressure and the quantity of water, the type of infrastructure and the goals of the company.

Hydropower is by far the most mature renewable energy used for electricity generation, being totally inexhaustible and carbon-free. Hydropower plants, have found particular importance because of their low installation and operating costs, short construction time, robust and reliable technology, The adoption of hydropower plants has been recommended in rural or marginal areas because they do not require major construction works, can be operated entirely by remote control with little operating personnel, and enhance rural electrification.

The territory of Pliego and the very structure of the water supply and pumping route for irrigation that present differences in altitude of enevn 40 meters, appears favorable for the implementation of this technology.

By the adoption of a hydroelectric plant, the transformation of the movement of water into energy will become a strategy for providing services, covering the 83% of electrical energy that they have to pay with renewable energy that the company itself can generate.

In the case of the company, water is both an input and an output: an input since they have to extract water from Pozo las Anguilas, Trasvase Tajo-Segura and E.D.A.R. to provide their service; and an output due to the fact that water itself is the service they provide to the farmers.

The hydroelectric plant will allow the company to generate a double input for the supply chain from the movement of the water.

The installation of a turbine in correspondence with the waterfalls to produce electric energy will open the way to reach the energy self-sufficiency of the system and, in a future perspective, even to sell the surplus of produced energy.

1.3.3 SWOT analysis

Taking into account the diagnosis of the territory and the company we developed a SWOT analysis that focuses on the use of water and energy in the supply chain of the company and also in the agricultural processes.

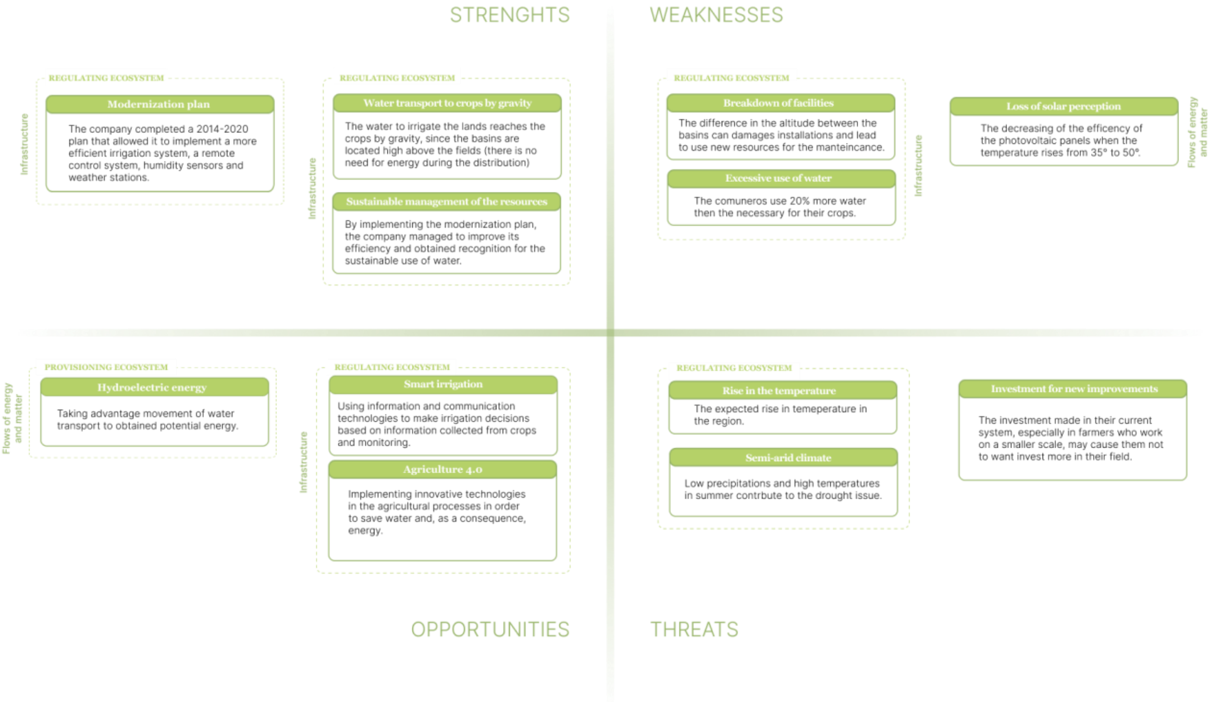


Figure 05. SWOT analysis

Strengths

The strengths of the company mainly concern the regulation actions. By implementing the modernization plan started in 2014 the company managed to improve its efficiency by the implementation of remote control systems, the construction from scratch of a ring system on Huerta Baja that allows farmers to independently turn on and off the irrigation on its own field. Meanwhile on Huerta Alta the existing system was modernized to a branched system in which turning on or off one of them, implies others connected to it, the covering of two of the basins to prevent water lost by evaporation of 20% to 30% and the installation of 1,773 photovoltaic panels.

And then in 2020 they finished the modernization, and all of these changes led the company to win "Sostenibles por naturaleza" an award that recognizes the efficient and sustainable use of water.

Finally it must be mentioned as a strength that the company does not need energy during the distribution stage to crops, since the system was designed so that the basins that contain the water were located above the fields, so the water reaches the crops by gravity.

Weaknesses

An important aspect we have to consider is that, due to the lack of knowledge of some community members of the required amount of water depending on the crops and the best system management practices, almost 20% of farmers use more water than is necessary, generating greater consumption of water and therefore energy.

In terms of infrastructure, the differences in the altitudes between the basins makes the system more prone to breakdowns in the transport step which lead to use more resources for the maintenance. And regarding other infrastructure installations such as the solar panels, it must be considered that they have a maximum percentage of solar radiation reception. The hottest months of the year are between July and August, the temperature of the zone rises from 35 °C up to 50 °C, and as the percentage of receptacles increase the efficiency of the solar panel decreases, which means a loss of energy for the company.

Opportunities

Within the regulation of flows matter we can identify the opportunity to take advantage of the movement of the water during the transport stages produced by the difference in height between the water level of the reservoir, taking advantage of this movement to create hydroelectric energy as a new source of supply, making the system even more self-sufficient.

As an approach to water management is Precision Agriculture (PA) that is just a part of the more complex system of the so called Agriculture 4.0, an opportunity with which the company can use information technology to ensure that the crops and soil receive exactly the amount of resources needed, based on the crops' irrigation cycles. Helping to reduce the current percentage of farmers that use more water than necessary, due to the lack of knowledge of these factors and increasing productivity limiting waste.

Threats

For the main threats for Comunidad de Regantes we have to analyze the external factors, attributed to the environment in which the company operates, first as the region of Murcia has a semi-arid climate with low precipitations, the average daily temperature is 30 °C and on the

hot season, the expected rise in temperature is an factor that must be taking into account mainly for the drought issue.

The last threat is related with the investment for new improvements, since smaller scale farmers see more investments as something unsustainable and unnecessary preferring to leave the systems as they are.

2. The system

2.1 Specifications of the system

In this part we will present in detail the proposed solutions. We will talk about the main technical characteristics of the sensors and the hydropower plant we want to propose, related to their introduction within the current system of the Comunidad de Regantes de Pliego. Further specifications about the hydroelectric plant are present in the MULTITRACES project n.3 *“Study of turbine energy production (from waterfalls)”*.

2.1.1 Introduction of new precision agriculture tools feasibility

Irrigation sensors are already used by Comunidad de Regantes de Pliego to ensure that the plant, as well as its surrounding soil, holds just the right amount of moisture. They work perfectly in reducing the excess amount of water used.

There are a few different types of sensors used in agriculture; some of them include:

- Soil moisture sensors: these sensors have the ability to measure the tension in the soil. Their technology is not as advanced as they still need to be checked manually. They are widely used today and they are becoming more and more popular.
- Flow sensors, or flow meters, track water that might be flowing through the irrigation system even when it is not needed, and they can provide this overflow usage information to the farmer to stop it. An alert will be sent to the manager of the water system to prevent overflow, excessive water usage, and water waste. In the case of flow sensors, the farmer is not obligated to be physically there and can manage and have access to the information through applications. It is a great way to save energy because water leakage can ruin the corps. Therefore, the damage as far as cost goes is greater. They are very commonly used nowadays as they require minimum effort and offer valuable information.
- Capacity sensors: these also provide moisture measurements, but they operate differently as they get information from the electrical charge of water.
- Rain sensors: they analyze the crops and make sure they use the right amount of water needed for every type of crop, so wastewater is limited. They operate by collecting data

  on the moisture levels of the soil and watering it as much as needed after a rainfall. This protects the crops and limits the expenses.
- Freeze sensors: such sensors ensure that the crops will not freeze during the cold months of winter. Even though Spain does not suffer from extremely cold weather, with global warming nowadays, being prepared for every condition is probably the best option. It is common to use sprinklers to protect plants from freezing winds, but they are not always effective. These sensors stop irrigation when temperatures drop below zero.
- Wind sensors: With extreme winds, areas, water can be scattered all through the cultivated areas causing the plants to get more water than they need sometimes or not enough. Wind sensors help the farmer achieve higher levels of irrigation efficacy by stopping the irrigation process when winds reach a specific threshold. These can be added extra to an already existing irrigation system, contributing to water and energy saving.

Our proposal to the Comunidad de Regantes de Pliego would be the usage of flow sensors or flow meters as it can be a problem in any area, no matter the climate and exterior conditions.

We believe that the best way to set up an irrigation system is firstly by mapping the area and dividing the crops into categories, depending on the amount of water they need, what type of soil is ideal for them, etc. That way, the farmers have a perfect idea of how to then treat the crops. Flow sensors or flow meters make sure that after all this is done, no water used to water the plants is flowing through the irrigation system without a reason, and they can also identify any errors in the system that might be wasting water. In this case, an alert is sent to the farmer and the problem is quickly identified and solved without causing huge problems to the crops, such as over-watering. At the end, no amount of water will be wasted, and therefore the farmer will save water and energy. This system is beneficial to the farmer in the long run.

We propose a specific water flow sensor by Omega:

Fig. 06 The inline flow meter 1.5-15 GPM, 15-135 SCFM

Some of the main characteristics of the product include:

FL-500 Series in-line water and air flowmeters feature rugged construction, easy installation and measure direct reading flow rates for water and air at atmospheric pressure and 90 psi.

For added versatility, FL-500 Series flowmeters can be ordered with electrical proximity switches that should be ordered separately to indicate specific flow rates. Settings can be easily adjusted with a screwdriver.

Features

- Accuracy: ±5% FS
- Construction:
- Flow tube and float: PVC
- Internal wetted parts: 316 SS heads
- Brass Female NPT Seals: FKM
- Liquid Service: 200 psig @ 70°F (21°C)
- Gas Service: 100 psig @ 70 °F (21 °C)
- Maximum Temperature: 150 °F (66 °C) @ 25 psig

- Pressure Drop: 4 psig FS
- Dimensions: 177.8 mm (7") long
- FL-505 to FL-515: 2" (50.8 mm) dia
- FL-530 to FL-550: 76.2 mm (3") dia

In parallel to the introduction of this new type of sensors, the mapping of the crops is necessary. Mapping the crops will help the farmers and the Comunidad de Regantes de Pliego to have more precise data about the real necessary amount of water for each type of product.

This, together with the cross data of the new sensors, the humidity sensors and the meteorological data, will allow the Comunidad to save even more water and, as a consequence, energy.

2.1.2 Implementation of a hydroelectric plant feasibility

As mentioned before, another feasible option for the Comunidad de regantes de Pliego to implement hydroelectric energy production. Analyzing the technical feasibility of the system, we have to say that the implementation and the functioning of a micro-hydroelectric plant is not particularly difficult. First of all, it is fundamental to have a sufficient water drop (elevation gain of even a few meters) and a good water flow value. It must be said that it is difficult to assume the costs for the hydroelectric plants, due to the variable economic weight of the civil works. In any case, the plants are built only with prospects of economic return in less than 20 years and moreover, they have a long service life, estimated at least 25-30 years, but in many cases it can safely reach 50 years and over.

Environmental integration

In order to evaluate the inclusion of the plant in the local operative area of the Comunidad de regantes de Pliego, we studied the facilities and the infrastructures they already have to identify pipes that can be used for the new plant. This is a list of the active pipes and basins in the Comunidad’s network taken from their dossier:

- EDAR basin (vol. 45.000 m3, 322m of altitude)
- EDAR impulsion (322m of altitude)
- Regulation basin (vol. 230.000 m3, 405m of altitude)
- Regulation basin (vol. 20.000 m3, at 412m of altitude)
- Regulation basin (vol. 320.000 m3, at 416m of altitude)
- Regulation basin (vol. 20.000 m3, at 416m of altitude)
- Basin DE COTA, water well (vol. 40.000 m3, at 457m of altitude)
- Pipe (Ø 315 mm PVC)
- Pipe (Ø 400 mm PVC, at 385m of altitude)

- Pipe (Ø 400 mm PVC, at 430M of altitude)
- Pipe (Ø 400 mm PVC, at 330m of altitude)
- Pipe (Ø 250 mm, at 405m of altitude)
- Pipe (Ø 315 mm PVC, at 457m of altitude)
- Pipe (Ø 250 mm, at 412m of altitude)
- Pipe 2x (Ø 300 mm at 412m of altitude ca.)
- Pipe (Ø 500mm PVC, at 416m of altitude)

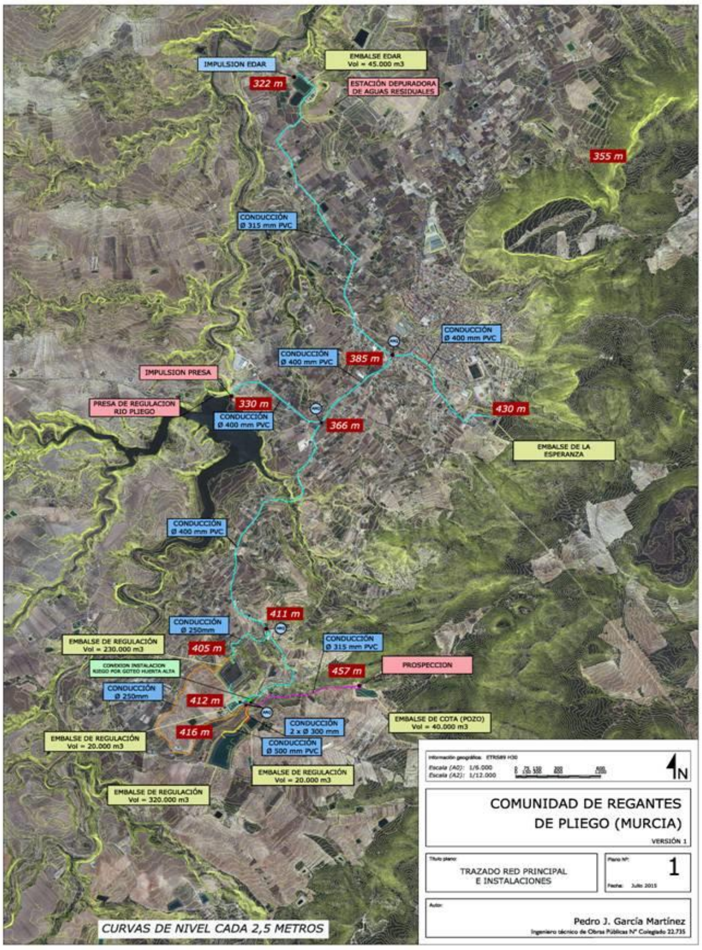


Figure 06. Main network layout and facilities (Comunidad de regantes de Pliego, 2022)

The specifications of the hydroelectric plant in terms of location, type and characteristics are deeply analyzed in the MULTITRACES project n.3 *"Study of turbine energy production"*.

As previously said, for the hydroelectric turbines it is sufficient to have a reasonably constant water flow and a water jump of at least a few meters. The plant will convert the potential energy of a mass of water, which flows naturally with a certain difference in altitude, into electricity at the lowest point of the plant, where it is located. For these reasons, in our specific case, the water that will be exploited will come from the changes in altitude of one irrigation water supply system to another through the 400mm PVC pipes the Comunidad de Regantes de Pliego is currently using.

In addition to the environmental assessment, to create a plant, it is necessary to draw up a technical and economic feasibility study to verify that there are conditions to carry out the intervention. Both aspects are indispensable, the inapplicability (technical or authorization) or the unsustainability (financial) of even one of the two determines the non feasibility of the intervention. Anyway, the introduction of a hydroelectric plant has numerous strengths, such as no environmental impact as the system has no emissions, simplicity of installation, no landscape impact, easy access to the power plant and easy connection to the electricity grid.

Hydropower, otherwise known as hydroelectric power, offers a number of advantages to the communities that they serve. Hydropower and pumped storage continue to play a crucial role in our fight against climate change by providing essential power, storage, and flexibility services.

2.2 Benefits of the solution from the circular economic point of view

According to the Circular Economy, we should find ways to work more sustainably in the future, making sure that we are producing the least amount of energy possible and valorising it to the maximum. The main focus of the circular economy in agriculture is to ensure that cultivation is performed in ways that are as “green” as they can be. In our case, in order to match energy demand with energy production, we have conducted a research on ways the farmer can save water and, therefore, energy. Our main proposal is the use of precision agriculture, such as different types of sensors in the cultivated areas in order to get data that provide information about the soil, the plant, and the water demands during different periods of the year (summer, winter, rainy periods, etc.). We mainly focus on flow sensors as we know that the Comunidad de Regantes de Pliego already uses humidity sensors. The first gathers information about the water flowing through the cultivated areas and alerts the farmer in case of leakage, so no water is wasted and no damage happens to the crops due to over watering, by accident, for example. The latter already informs the farmers on the amount of water needed due to exterior conditions. At the same time, we believe it is worth mentioning that crop mapping is really important because every type of crop has different needs and is cultivated best under specific conditions. If this is done, precision agriculture works more efficiently. Lastly, we suppose that the use of hydroelectric plants could be useful in producing extra

amounts of energy and therefore lowering energy costs. They seem to be a great solution in energy production and their cost is not too high, in the long run companies have noticed a positive impact of their project after using hydroelectric panels, and in the case of Comunidad de Regantes de Pliego, extra energy production could be vital.

2.3 Outcomes of the project

The analysis of the proposal evidenced all the consequences that the project could have for the whole scenario. These impacts reflect on both the company and the territory, so a further analysis is needed to better understand the future perspective.

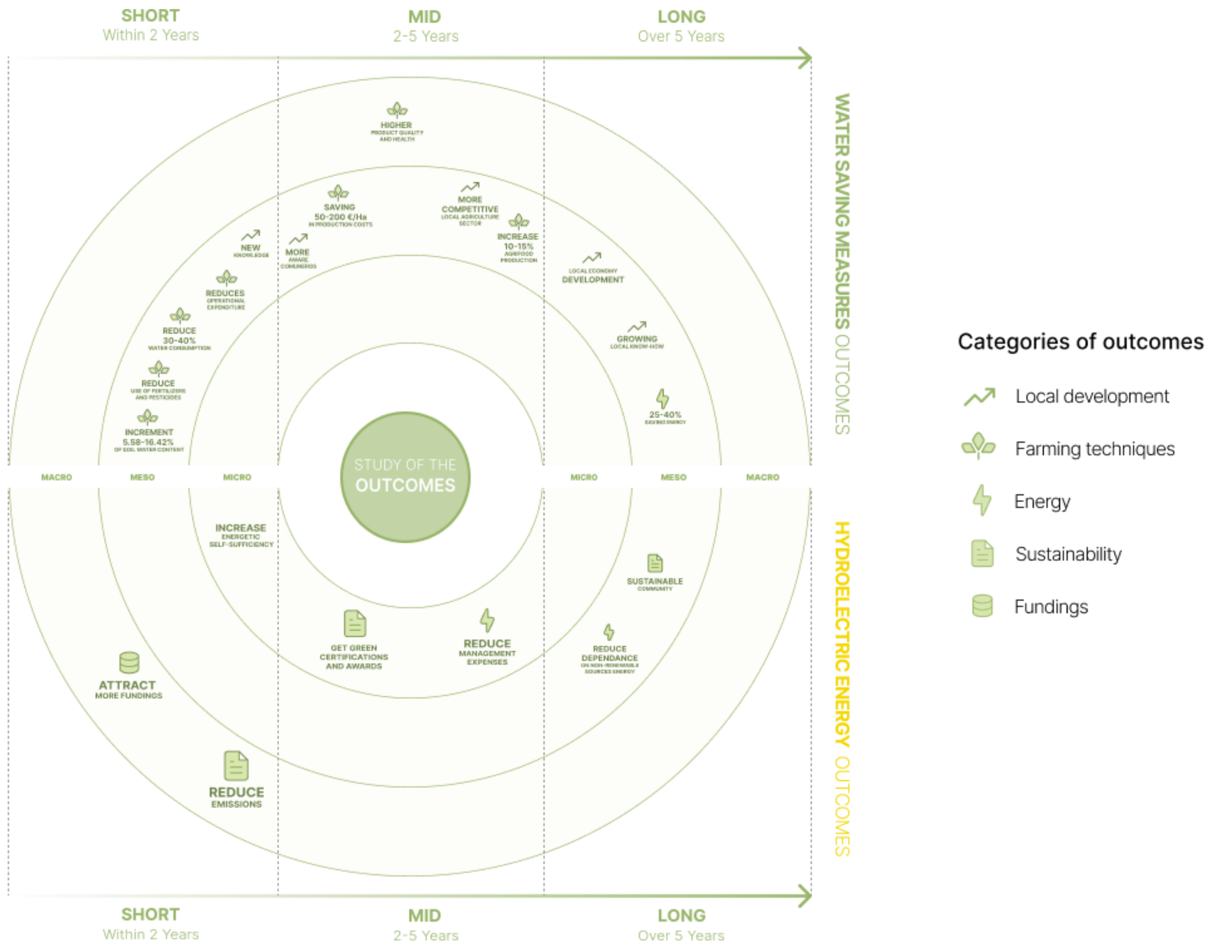


Figure 07. Study of the outcomes of the project

In this part we will discuss the outcomes generated by the new systemic model in relation to different possible scales, timeframes, actors and categories of impact: we take into account a short, mid and long term talking about timing; a micro, meso and macro area talking about spatial dimension; and economic, social and environmental as categories of impact.

2.3.1 Outcomes categorization

Local development

The outcomes of the project will bring to a general local development from many points of view. Being able to encourage the cultivation of the uncultivated areas, which currently correspond to 30% within the irrigable area and the introduction of new agricultural techniques will increment the local economy since it will lead to an increase of the agri-food production. Moreover, by introducing new agriculture techniques the local know-how will grow and also the agriculture sector will be more competitive. As we explained

Advanced farming techniques

The introduction of precision agriculture techniques, in the perspective of the Agriculture 4.0, will significantly impact all the economic, environmental and social aspects of both the company and the territory. Regarding the economy, they will allow the Comunidad, and so the farmers, to save water and, as a consequence, energy and money. On the environmental side, the advanced technique will reduce the use of pesticides and fertilizers, ensuring a higher product quality and health that reflect also on the social system that will be also affected by a reduction of human labor, thanks to particular techniques and technologies. In this way, there will be a reduction in the irrigation water consumption while increasing the agrifood production. In addition it will represent a precious resource for the crop land resilience, incrementing the water and minerals soil content.

Energy

Energy consumption is one of the focuses of the project proposal. Of course, the introduction of a hydroelectric plant that produced electric energy from the movement of the water will increase the self sufficiency of the company, potentially making the system totally autopoietic. As a direct consequence, the dependence on non-renewable sources of energy will be dramatically reduced, and so will be the management and operating costs for the company.

Sustainability

All the measures we implemented in the project are aimed to reach a higher level of economic, social and environmental sustainability. The system will contribute to reducing energy and water consumption, emissions, risks for the citizens and unnecessary costs, helping resilience and local development and promoting sustainable processes and communities. For a sustainable and efficient use of water, the Comunidad won an award in 2020: the implementation of the systems may lead them to receive further acknowledgements.

Fundings

Finally, talking about the future economic perspective for the company and the territory, the initiatives related to innovative agriculture techniques, energy efficiency, circular economy and water saving measures can attract new fundings for further research and development projects. It can make the network of relationships expand, involving new actors and investors. This is a crucial aspect from a future growth point of view, since it will allow the company and the territory to reach even more goals in terms of resilience and sustainability.

2.3.2 Scales

Micro level

The micro level outputs regard the single initiatives inside Comunidad de Regantes de Pliego, but as the community boundaries involve those lands common to the water resources, the crops owners among the industrial agricultors and the smallholders, are also taking into account inside these spheres of impact.

Meso level

The meso level regarding the group of initiatives impacting locally in the municipality of Pliego and more over to those of who are integrated in the irrigable area and its surroundings.

Macro level

The macro level groups the region of Murcia, Spain and the international sphere, that are principally taken as outputs that could also have a direct impact to the company but if we see the whole picture, can possibly impact more than the immediate context.

2.3.3 Timeframes

The proposed projects are projected at three different times within their implementation throughout the year: Short- term, including the first 2 years, Medium-term within 2 and 5 years, and long term above the 5 years.

Short-term period

In the short term, it is expected to attract more funding to the community for the development of new projects, the increment of water soil conditions, the generation of at least a 60% of energy needed leading to self- sufficiency, the reduction of emission within the activities they carryout and the reduction of operational expenditure, both for the company and the community.

Medium-term period

In the medium term it is expected to have an aware community about the use of the resources. Also saving in the productive cost of around the 50-200 euros per ha; the production of a higher quality and quantity of products consequently having a more competitive local agriculture sector thanks to the initiatives of the company. Reducing the management expenses, finally obtaining green certification of renewable energy production around the world, delivering value for generators and proof of claims for consumers.

Long-term period

It is expected to achieve long - term resilience benefits reflected on the local economic development taking into account the sustainable bases, impulsing the local know-how and making a more efficient use of the resources. Finally looks to reduce at 100% the use of electrical energy, arriving at self-efficiency and also thinking of income joining as providers from the sale of the extra energy to the local energy network.

2.4 Impacts on the environment

The proposed solutions have the aim to produce a positive effect on the economic, social and environmental ecosystem surrounding the Comunidad de Regantes de Pliego. In particular, precision agriculture leverages technologies to enhance sustainability through more efficient use of land, water, fuel, fertilizer and pesticides. Essentially, farmers who use precision agriculture technologies use less to grow more, reducing both cost and environmental impact.

At the same time, hydroelectric energy is a water fueled renewable source of energy. The energy generated through hydropower relies on the water cycle, which is driven by the sun, making it renewable, thus allowing each state to produce its own energy without being reliant on international fuel sources.

2.4.1 Benefits of the project on the ecosystem services

In this part, the impacts of the project on the ecosystem services are analyzed. The project in its totality has a great impact on the environment since it regards water, agriculture and energy at the same time. The aim of the proposal is to improve the efficient use of the resources, in a perspective of sustainable development and territorial resilience, for these reasons, the impacts on the ecosystem services are potentially positive. The graph above, shows the impacts of both the proposals that make up the project, the precision agriculture system development and the hydroelectric energy production, highlighting how they impact the ecosystem.

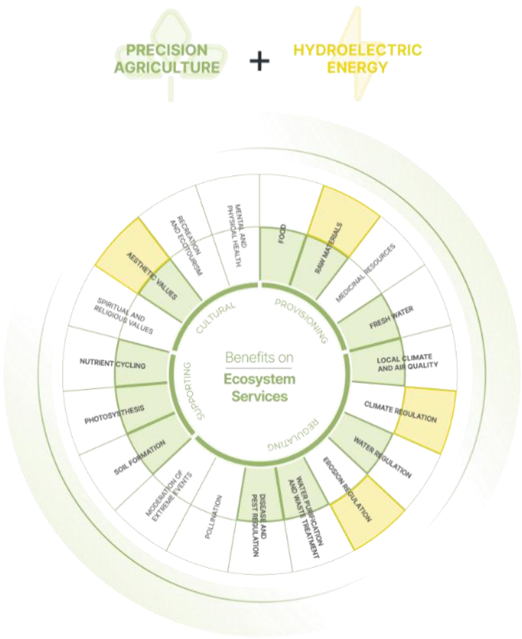


Figure 08. Benefits of the project on the ecosystem services

A. Provisioning services

Food and Raw materials

Within this category we see that the proposal has a positive impact on food, since by improving crop conditions, these will benefit in terms of productivity (quantity) and product quality, for both those dedicated to self-consumption agriculture that represents the 80% and the industrial farmers that represent the 20%. This industrial production has current cultivation figures of 30% represented by apricot, 5 - 10% of production of olives and almonds, 10-15% of citrus fruits. The rest corresponds to vegetables, which have been cultivated for 4 or 5 years after of the modernization plan; greater crop diversification is created, with the implementation of the strategy, as it happens after the modernization since by making a more efficient use of water, there is a greater amount available for new types of crops, having as a reference the different cycles depending on the type of crop and the different zones identified within the irrigable area; the project can also minimizes the cost of materials and resources that must be available such

as water, seeds, energy and use of fertilizers, leaving irrigators with a higher quality of water available to be used in crops.

Moreover, by introducing the hydropower plant within the supply chain of the Comunidad de Regantes de Pliego, there will be a new form of renewable energy (in addition to the photovoltaic energy they already produce) useful to reach the complete auto-sufficiency of the system. This source of renewable energy will reduce the dependence on non-renewable sources, making the processes of extraction and transport of the water more sustainable, arriving to reach the 0 emissions goal.

Fresh water

The system conditions given by the implementation of the strategy represent positive effects in terms of quality and healthiness of the water that irrigates the fields, since an efficient management of resources often implies less consumption and use of fertilizers and pesticides.

B. Regulating services

Water regulation

Checking supplied irrigation volumes by using processed satellite images, it is possible to identify a classified map of crop growth trends and verify that the growth curve is linked to the established water supply; applying the strategies in which differential irrigation is integrated, this technique allows water savings that can represent up to 10% while maintaining crop yields at competitive levels. Based on the application of different amounts, shifts and times, even within the same field, according to homogeneous management areas identified based on soil variability.

Water purification and waste treatment; disease and pest regulation

Strategy implementation can also include monitoring wet soil conditions, by having more information on when to irrigate they can prevent the 20% of the actual excessive water use in irrigation and avoid runoff. At the same time, reducing the generation of conditions that can lead to favorable environments for bacteria or pests developed by the same humidity conditions. It could also maintain soil conditions by reducing the amount of pesticides needed.

Climate regulation

Other important consequences are present in the climate regulation as producing new green and renewable energy (making the system self-sufficient) will reduce GHG emissions deriving from the use of electricity.

C. Supporting service

Nutrient cycling

Since the crops conditions are improved and the wet soil controlled, the percentage of nutrients received increases and the genetic potential of the crops is maximized.

Photosynthesis

Implementing new agricultural techniques that allow other positive effects to be obtained, such as the increase in agricultural production (10-15%), since the reflected light increases photosynthesis.

D. Cultural service

Bearing in mind that the local knowledge linked to water is territorially contextualized, due to the cultural norms of water distribution, which have been regulated by the Irrigation Community since 1992. This, together with the reference people in the community, are aspects that are integrated into the network of actors and knowledge, empowering cultural identity and sense of belonging, both with the irrigation community and in their role as farmers. Improving the technical capacities of around 1,500 comuneros that are part of the community and requalifying the irrigation sector, developing totally local know-how.

Being able to encourage the cultivation of the uncultivated areas, which currently correspond to 30% within the irrigable area, managing to highlight the value of water for the plegueros that goes beyond the eco-productive. Coming to have a symbolic meaning with socioeconomic benefits and see it as a strategic element.

Aesthetic values

The landscapes of the water, the route and location of the basins form a mosaic in which irrigated crops and the zoning of vegetation are intermingled. As well as the integration of architectural and engineering elements that are integrated into the cultural landscape of great value, for the efficiency of the irrigation system.

The adoption of the hydropower plants is also less disrupting in the surrounding landscape, compared to the photovoltaic ones.

3. Investment cost and profitability analysis

3.1 Cost of the proposed solution

Our proposed solution is to install flow sensors to minimize the amount of water that might be wasted starting from 2022. A flow sensor costs around 100-250 euros depending on the quality.The area that the Comunidad de Regantes de Pliego covers, is around 850 hectares and corresponds to the communities of Huerta Alta and Huerta Baja.

We suppose that as the Comunidad de Regantes de Pliego already uses 16 humidity sensors, 16 water flow sensors would be the right amount. In this case, the total cost of our proposal would be: (amount of flow sensors = 16) * (cost of flow sensors = 228.57 euros).

So = 228.57 * 16= 3.657,12 €.

As far as energy goes we are proposing the use of turbines, to produce more energy. The amount of money needed for the installation of the turbine is around 40.000 €

The amount of money spent by the company for the installation of solar panels in 2020 is zero as the total investment is 100% funded by public administration.

The total cost of our proposed solution, to match energy demand and energy production and work more efficiently is 3.657,12 + 40.000 = 43.657,12 €

3.2 Benefit of the proposed solution

The economic benefit is the amount of money spent on the project of installing the flow sensors minus the amount of money the company earned by energy saving in the next 5 years.

Our solution benefits the farmer mainly economically because no water or extra energy is wasted. At the same time, flow sensors can help in implementing a more sustainable way of operating.

The company's main source of income comes from European funding.

In the following table, some of the main figures can be seen regarding total investment, cash inflows from fundings, total assets net and passive.

	2020	**2021**	**2022**	**2023**	**2024**
Total Investment	40.000	-	-	-	-
Cash flows - Results of the year	4.344,67	28.541,67	21.146,89	25.507,38	30.766,99

Total assets net and passive	9.477.445,30	8.511.843,83	7.616.412,49	6.827.788,21	6.120.820,26

Figure 09: Table on Economic metrics of the company from 2020-2024

From 2022 until 2024 the presentation on the table is a forecast based on calculations that we have done taking into consideration that following our proposal, energy, money, and water have been used wisely and the waste is minimized therefore the Comundad de Regantes de Pliego has been benefited economically.

3.3 Net present value

We are considering a 5 year time period for our project starting in 2020 and working with a forecast for 2022-2024

NPV 2022	30.025,92
Investment Cost	40.000
Benefit at the time	5.589,13
Cashflow at the time	21.146,89
Expected Exploitation time of the project	20
r = 5%	0.05

Figure 10: Table of NPV Calculation for 2022

3.4 Payback period

Due to our proposals, we believe that there will be significant economic changes in the near future for the Comunidad de Regantes de Pliego. The payback period showcases the amount of time that the company will need to recover, find balance in expenses and profits, and finally earn money after following our proposal. Our forecast for the payback period is between 2 and 3 years.

Initial investment	40.000
Average cash flow	22.061,52

Figure 11: Table of Payback Period Calculation for 2022

3.5 Internal Return Rate

IRR= 28%

Year	Cash Flows
2020	4.344,67
2021	28.541,67
2022	21.146,89
2023	25.507,38
2024	30.766,99

Figure 12: Table of Internal Return Rate 2020-2024

4. Conclusions

Regarding our research for the Multitraces Project focusing on Circular economy, and working with Comunidad de Regantes de Pliego, with our main objective to match energy production and energy demand, we have divided our project into three parts. In the first part - chapter one we introduced the company and the territory of Pliego, Murcia and constructed a project overview including an small introduction on energy usage of the company currently, and the benefits of renewable energy production with hydroelectric plants such as turbines, as well as its connection with the Circular economy. We then mentioned a few European policies regarding agriculture and energy, and then presented information on the supply chain and energy consumption in that field, and also focused on the modernization plan of the company in the last years. To further support our ideas we displayed a few case studies. Finally we wrote a detailed description of our proposal and mentioned the benefits of precision agriculture and hydroelectric energy by creating a SWOT analysis. In the second part - chapter two, we referred to the system. We further analyzed all the technical information we found regarding our proposals, again through precision agriculture, pointed out the benefits and created a time frame. We also focused on the impacts of our proposals on the environment and the ecosystem of the area. In the final part of our project we conducted a CBA (Cost - Benefit Analysis) on our proposal and presented a forecast regarding the total cost and cash flow of the Comunidad de Regantes de Pliego, for the next few years until 2024, we also used specific indicators such as the NPV, IRR and Payback Period.

5. References

1. Belaud, G., Mateos, L., Aliod, R., Buisson, M., Faci, E., Gendre, S., Ghinassi, G., Gonzales Perea, R., Lejars, C., Maruejols, F., & Zapata, N. (2020). IRRIGATION AND ENERGY: ISSUES AND CHALLENGES. *Irrigation and Drainage*, *69*(S1), 177–185. https://doi.org/10.1002/ird.2343
2. BIO Intelligence Service (2012), *Water saving potential in agriculture in Europe: findings from the existing studies and application to case studies*, Final report prepared for. European Commission DG ENV, pg. 68-69. https://ec.europa.eu/environment/water/quantity/pdf/BIO_Water%20savings%20in%20agiculture_Final%20report.pdf
3. Bora, G. C., Nowatzki, J. F., & Roberts, D. C. (2012). Energy savings by adopting precision agriculture in rural USA. *Energy, Sustainability and Society*, *2*(1). https://doi.org/10.1186/2192-0567-2-22
4. Campo García, A. (2014). *Las Comunidades de Regantes de España y su Federación Nacional: Vol. 2º* (26 ed.). Paseo de la Habana. http://www.geoscopio.net/empresas/fenacoreweb/Libro%20regantes%20 FENACORE.pdf
5. *CAP funds*. (2022, June 21). Agriculture and Rural Development. https://agriculture.ec.europa.eu/common-agricultural-policy/financing-cap/cap-funds_en
6. *Common agricultural policy*. (2022). European Commission - European Commission. https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy_en
7. *Comunidad de Regantes de Pliego*. (2022). Comunidad de Regantes de Pliego. https://crpliego.es/
8. Comunidad de Regantes de Pliego, *Proyecto a ejecutar a través del plan de recuperación, transformación y resiliencia. (2022)* https://crpliego.es/wp-content/uploads/2022/03/Proyecto_Plan_Recuperacion_Transformacion.pdf
9. *EUR-Lex - 0301_1 - EN - EUR-Lex*. (2021). EUR-Lex. https://eur-lex.europa.eu/EN/legal-content/summary/european-agricultural-fund-for-rural-development.html
10. Interview with Jose Angel, administrator of the company, Martín Jimenez founder of Comunidad de Regantes Huerta Alta, Huerta Baja. (2022).
11. Irmak, S. (2014). *Plant Growth and Yield as Affected by Wet Soil Conditions Due to Flooding or Over-Irrigation*. University of Nebraska, Lincoln Extension. https://extensionpublications.unl.edu/assets/pdf/g1904.pdf
12. *Irrigazione smart? Una questione di risparmio idrico (e di energia)*. (2022, February 10). AgroNotizie. https://agronotizie.imagelinenetwork.com/agrimeccanica/2022/02/10/irrigazione-smart-una-questione-di-risparmio-idrico-e-di-energia/73865
13. J.J. Pardo, A. Domínguez, B.C. Léllis, F. Montoya, J.M. Tarjuelo, A. Martínez-Romero. (2022), *Effect of the optimized regulated deficit irrigation methodology on quality, profitability and sustainability of barley in water scarce areas, Agricultural Water Management, Volume 266.* https://doi.org/10.1016/j.agwat.2022.107573.

14. *La Comunidad de Regantes de Pliego inaugura una parte del mayor parque solar fotovoltaico de España asociado al regadío - Noticias - PDR*. (2019). La Comunidad de Regantes de Pliego inaugura una parte del mayor parque solar fotovoltaico de España asociado al regadío. https://pdr.carm.es/-/la-comunidad-de-regantes-de-pliego-inaugura-una-parte-del-mayor-parque-solar-fotovoltaico-de-espana-asociado-al-regadio
15. *Las obras de mejora de la Comunidad de Regantes de Pliego mejorarán el transporte, distribución y almacenamiento del agua*. (2018). https://pdr.carm.es/-/las-obras-de-mejora-de-la-comunidad-de-regantes-de-pliego-mejoraran-el-transporte-distribucion-y-almacenamiento-del-agua
16. M. (2020, october 22). *Pliego y la calle del Agua*. Páginas Árabes. https://paginasarabes.com/2012/01/14/pliego-y-la-calle-del-agua/
17. Mendes, Susana & Valín, M.. (2021). Actas-II-Simpósio-Ibérico-de-Engenharia-Hortícola.https://www.researchgate.net/profile/Susana-Mendes/publication/354605809_Actas-II-Simposio-Iberico-de-Engenharia-Horticola/links/61421a5428667828a8980ad8/Actas-II-Simposio-Iberico-de-Engenharia-Horticola.pdf#page=98
18. Mercedes Garcia, A. V., Sánchez-Romero, F. J., López-Jiménez, P. A., & Pérez-Sánchez, M. (2022). A new optimization approach for the use of hybrid renewable systems in the search of the zero net energy consumption in water irrigation systems. *Renewable Energy*, *195*, 853–871. https://doi.org/10.1016/j.renene.2022.06.060
19. Mérida García A., Gallagher J., McNabola A., Camacho Poyato E., Montesinos Barrios P., Rodríguez Diaz J.A. *(2019). Comparing the environmental and economic impacts of on- or off-grid solar photovoltaics with traditional energy sources for rural irrigation systems.* https://doi.org/10.1016/j.renene.2019.03.122
20. *New CAP: 2023–27*. (2022, June 28). Agriculture and Rural Development. https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/new-cap-2023-27_en
21. *Proceso de unificación de las Comunidades de Regantes de la Huerta de Pliego*. 2022. Comunidad de regantes de pliego. https://crpliego.es/
22. R. (2020, 11 july). Región de Murcia, huerta de Europa como Marca España. *La Opinión de Murcia*. https://www.laopiniondemurcia.es/comunidad/2020/07/11/region-murcia-huerta-europa-marca-33958455.html
23. Regantes De Pliego, C. (2020). *Estaciones Meteorológicas*. Comunidad de regantes de Pliego. Retrieved 2022, from https://crpliego.es/index.php/estaciones-meteorologicas/
24. Tilmant, A., Goor, Q., & Pinte, D. (2009). Agricultural-to-hydropower water transfers: sharing water and benefits in hydropower-irrigation systems. *Hydrology and Earth System Sciences*, *13*(7), 1091–1101. https://doi.org/10.5194/hess-13-1091-2009
25. Yahya, N. (2018). Agricultural 4.0: Its Implementation Toward Future Sustainability. *Green Urea*, 125–145. https://doi.org/10.1007/978-981-10-7578-0_5

STUDY OF TURBINE ENERGY PRODUCTION (FOR WATERFALLS)

Coordinators:

Prof. Dr. Ing. Liliana Topliceanu

Assoc. Prof. Dr. Oana Driha

Prof. Dr. José Manuel Casado

Students:

Dumitru Blănaru

Petrică Țibuleac

Company:

Comunidad de Regantes de Pliego

Martín Jiménez

José Ángel Perez

Content of the Project

1. Project overview

1.1 Introduction

The proposed project aims to help solve a problem faced by the irrigator community in Pliego. Producing green energy for the company's internal consumption by installing a hydraulic turbine. The purpose of this project is to implement a solution to reduce the electricity costs of the irrigator community.

Agriculture is one of the oldest and most important human activities. Agriculture has its origins once man stopped being nomadic and small communities began to form. So that fishing and hunting were no longer the only sources of food.

The plants and crops developed are highly dependent on climatic factors, including rainfall and water sources, necessary for vegetation to flourish.

Since 2017, the Murcia region has been facing one of the most severe droughts, where the water supply for agriculture has been drastically limited. The main problems were caused by overexploitation and the fluctuations of these water flows, agriculture representing the main consumer, requiring a very large volume of water, about 4,500 mc/ha.

The Community of Irrigators from Pliego managed to build, in 2014, with the help of financing, one of the most advanced irrigation systems in Europe, helping to reduce water waste. This system is equipped with several water tanks, which can store the water extracted from the underground waters of the rivers in the region, distributing it further to the farmers.

The problem is the high energy consumption required by water extraction systems.

The community of irrigators in Pliego compensated for the necessary energy consumption with the help of a photovoltaic panel installation, in the context of long and sunny days. In order to increase energy production for its own consumption, it is planned to install a hydraulic turbine. Although this requires high investment costs, it is profitable because it does not affect the environment, having minimal operating costs.

Following a hydrographic study, the installation of a Francis hydropower turbine is the optimal solution.

KEYWORDS: Turbines, Hydraulic power, Electrical energy, Water flow, Fotovoltaics, Water management, Irrigations systems, Drought.

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

1.2. State of art

1.2.1. Historical framework of the context

More than 10,000 years ago, hunter-gatherer settlers began the transition to stable settlements based on agriculture and animal husbandry. This happened for the first time in the southern territory of Eurasia, also known as the Fertile Crescent in terms of the cradle of civilization of farmers. The diversity of wild plants that were suitable for domestication and the surrounding wild animals that had the same role, such as sheep or goat, made this transition possible. Human curiosity has led to the attempt of new plant specimens, of which the most important were and have remained in history those with the largest seeds, such as barley and wheat, rich in nutrients and proteins, such as mace and lentils, domesticated plants more than 8000 years ago.

This agrarian revolution supported the numerical growth of the population that approached the new lifestyle and was the basis for the development of large cities and powers.

After several attempts, these societies approached fertile territories near rivers (Nile, Tigris, Euphrates, etc.) due to the need for water to grow crops.

The increase in the number of individuals also required a development of agriculture and the amount of plants and cereals produced. This was possible through irrigation systems that had the role of transporting water from underground sources or from the surface to planted crops.

The first to have this advantage were, of course, civilizations with a large number of individuals. One of their societies was Mesopotamia, which developed an irrigation system to prevent the agricultural area of this region from being confined to the banks of major rivers.

The water needed for irrigation was taken to the cultivated areas through canals. The largest came directly from rivers and served as the basis for a hierarchical network of small canals and ditches. The system could also include tanks used to regulate the flow of rivers, high canals and sometimes aqueducts, depending on the terrain.

The most remarkable constructions of that time that represented a technological evolution in terms of irrigation systems were the Suspended Gardens of Babylon.

The Suspended Gardens of Semiramide or, more precisely, the Suspended Gardens of Babylon were built in ancient Babylon. They were located on the eastern side of the Euphrates River, about 50 kilometers south of present-day Baghdad in Iraq. They were built by King Nebuchadnezzar II (605-562 BC) son of Hamurabi.

The gardens consisted of terraces in the amphitheater, with a side of about 123 meters and occupied an area of 15,000 m, rising in four terraces to a height of 77 meters. The terraces were supported by stone walls, at a distance of three meters from each other. The spaces between the walls were covered with vaults made of stone blocks over which was placed a layer of reed over which followed a double row of burnt bricks, tied together with mortar and finally covered with lead sheets, for a good water-repellent insulation. Over the lead foil is said to have been a layer of earth, thick enough for the roots of the largest trees.

Hydraulic machines were used to spray the gardens, which raised the water from the Euphrates to different levels. Beneath the roots of the plants were a series of canals, which constantly moistened the soil. Due to the possibilities of maintaining a continuous humidity, not only rich flower terraces but also fruit trees, or certain species of tamarix and palm trees could grow on the terraces.

Another civilization known for its way of using freshwater resources was the Roman Empire which, in addition to their important involvement in the development of irrigation systems, laid the foundations of a new method of using water, namely drains and common baths. It is known that these people loved water and used it both for agriculture, sailing but also to support the comfort of life of citizens. The most important constructions developed by the Romanians were the huge aqueducts, stone bridges with the help of which drinking water is transported to the city or to the agricultural lands. Along with the developed canals, with several layers of stone and sand, this construction has remained in history as a landmark for modern irrigation systems and the evacuation of waste from major cities.

The Roman Empire also introduced advanced irrigation and water management systems in Spain once the Romans conquered the territory in 209 BC when they occupied the Murcia Region.

The region is located in **southern Spain**, with access to the Mediterranean Sea in the south. With a total area of 11,313 km ^ 2 the region has an average elevation of 537 m and the highest point is at 2,484 m, the peak "Los Obispos". It is bordered by the **Andalusian Region** to the west, the **Valencia Region** to the east and the **Castilla La Mancha** to the north.

Due to the opening to the Mediterranean Sea, it has experienced an economic evolution based on **trade** and **agriculture**. It was one of the main regions that knew agriculture and animal husbandry in antiquity, the main activities in this region. This fact led to the easier transition of hunter-gatherer societies to urban settlements.

In this area there is a **population of 1,511,251** as at the beginning of 2020, of which almost a third (30.4%) live in the municipality of Murcia, and nearly another sixth (14.3%) live in the municipality of Cartagena along the south coast. It makes up 3.0% of the Spanish population. In addition, after Ceuta and Melilla, Murcia has the highest population growth and the **highest birth rate in the country 13.00 per 1,000**, in 2004.

The demographic analysis shows a proportion of 50.1% men, who have an average age of 39 years, respectively 49.9% women, with an average age of 41.5 years. Going out to sea has fostered the cultural enrichment of people in terms of navigation and use of maritime resources for which they have been and remain globally recognized throughout history.

The Mediterranean Sea also brings to the Iberian Peninsula, but especially to this region a Mediterranean climate which means that temperatures **usually vary between 4°C and 33°C** and rarely drop below 0°C or exceed 36°C.

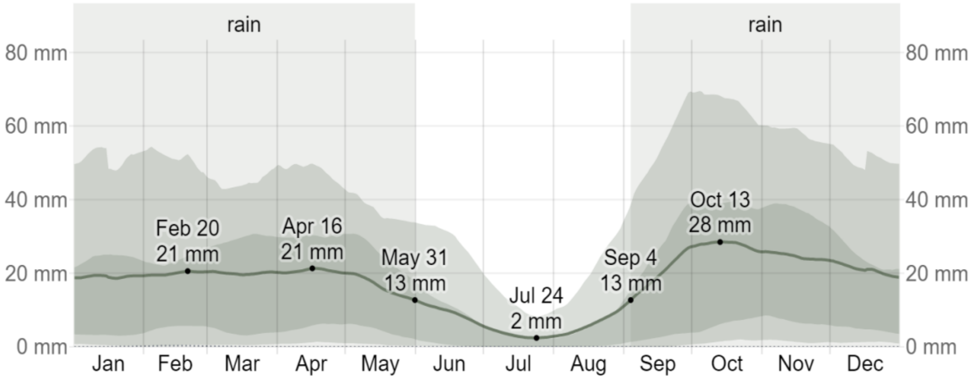


Figure 1.1 - Average Monthly Rainfall in Murcia, Cedar Lake Ventures,(May, 2018)

Winters are long, cold and the sky is cloudy. The cool season lasts for 3.9 months, from November 17 to March 14, with an average daily high temperature below 20°C. The coldest month of the year in Murcia is January, with an average low of 4°C and a high of 17°C. In terms of humidity and precipitation, October is the most favorable from this point of view, with a sliding 31 day rainfall of at least 13 millimeters.

Summers are very hot, humid and the sky is clear. The hot season lasts for 3 months, from June to September, with an average daily high temperature above 30°C. The hottest month of the year in Murcia is August, with an average high of 33°C and a low of 21°C. During the summer there is a chronic insufficiency of precipitation, the average being 6% days with less than 1 millimeter of precipitation. **The driest month is July, with an average of 0.5% days with at least 1 millimeter of precipitation.**

Ventures(2018)

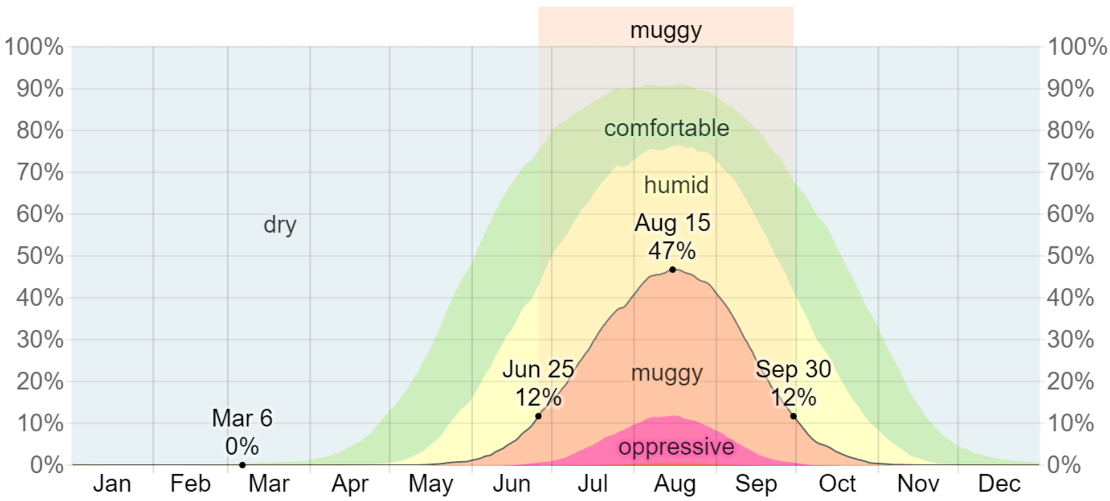


Figure 1.2 - Humidity Comfort Levels in Murcia Region,Cedar Lake

That's why **droughts are not new in Spain**. The Iberian Peninsula has suffered from recurring rights for many decades. The continuous rise in temperature and longer droughts brought on by climate change are expected to have a far-reaching impact, particularly for the water supply and some sectors of the economy like Spanish agriculture.

In late 2017 the region of Murcia and the rest of the Segura basin are facing one of the most serious droughts in recent history, with water supplies to agriculture already having been cut back drastically and the threat of restrictions to domestic supply becoming more and more real with every day that no significant rainfall replenishes supplies in the near-empty reservoirs. Which has made water a factor of attraction for human settlements and settlements.

The springs remained the main resources available in the semi-arid areas within the Region of Murcia, such as in the districts of Mula, Pliego and Bullas.The region's hydrographic network consists mainly of the Segura river and its tributaries:

- **Mundo River**, which originates in Albacete); it contributes the greatest volume to the Segura.
- **Alhárabe River** and its tributary the Benamor.
- **Mula River**.
- **Guadalentín**, **Sangonera** or **Reguerón**

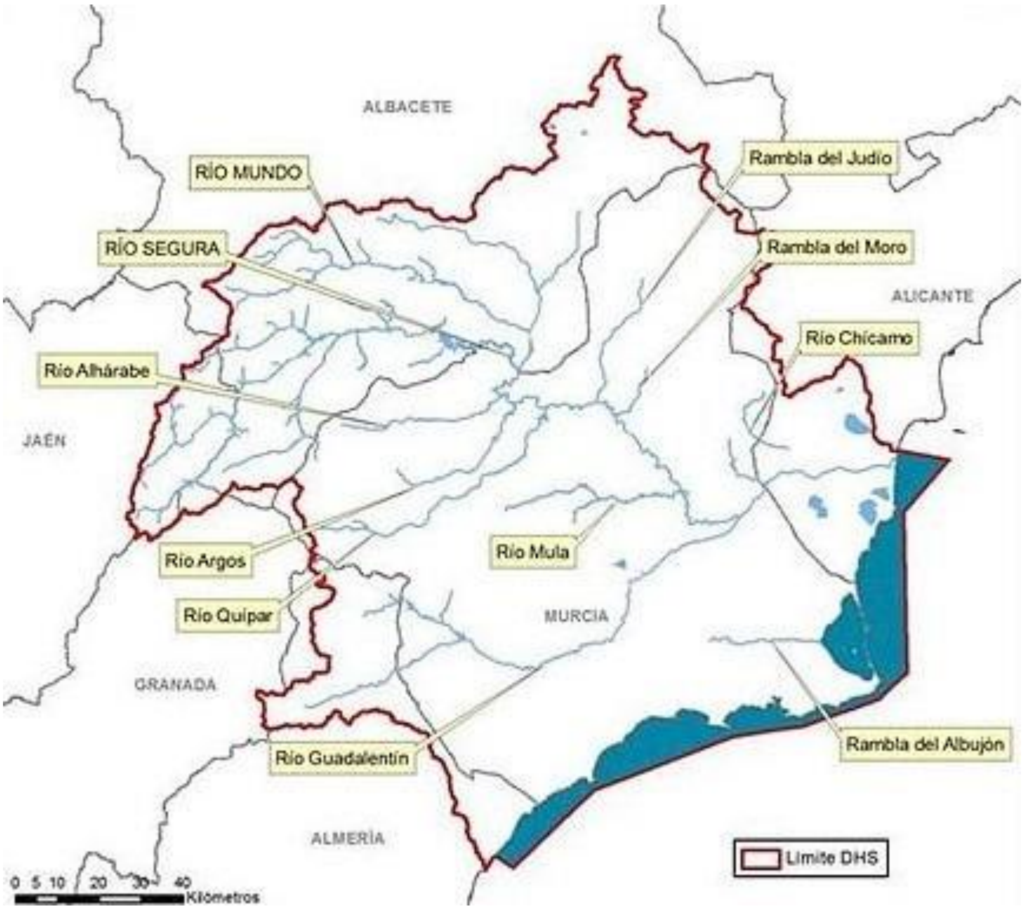


Figure 1.3 - Hydrographic map of Murcia Region, Wikipedia

Overexploitation and fluctuations in these flows have caused ongoing problems. The main source of consumption is agriculture, which **requires 767,417.7 m^3 of water** by 2020 for irrigation, which **means 4,500 m3/ha**. This entails a significant loss. In order to reduce losses and make the most of groundwater, the help of a well-developed irrigation system is needed, which also helps to monitor the use of the main resource, water. The Region of Murcia has long used this method to support and develop agriculture.

With the help of an **investment in 2014**, the Community of Irrigators in Pliego managed to build one of the most advanced irrigation systems in Europe that helps reduce water waste. With the help of accumulation basins they can store water extracted from the groundwater of the rivers in the region and then distribute it to consumers, in our case, farmers.

This process requires a **high consumption of electricity** to extract water. To implement the new form of resource exploitation, based on a circular economy, which represents a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible, the community of irrigators in Pliego compensated this energy consumption necessary for the operation of water extraction, storage and distribution systems, with the help of **an installation of 1,773 photovoltaic panels** divided into two solar power plants. They **produced 166.86 MWh** in 2021.

This is possible due to the long and sunny days during the summer season. The brighter period of the year lasts for 3.3 months, from May 7 to August 18, the longest day having 14 hours and 48 minutes and brings an average daily incident shortwave energy per square meter above 6.9 kWh. The brightest month of the year in Murcia is June, with an average of kWh.

Instead, the darker period of the year lasts for 3.4 months, from October 28 to February 10, reaching, in December, only 9 hours and 32 minutes. This leads to an average energy production per square meter below 3.5 kWh. The darkest month of the year in Murcia is December, with an average of 2.4 kWh. But these are not enough because the energy consumption registered in 2021, from the national network was **796.24 MWh**.

1.2.2. Existing solutions

In the natural riverbed, energy is wasted by rubbing against the walls (causing soil erosion) and by rubbing and collisions between liquid particles. In this case, this energy loss is achieved by the friction with the pipes of the water transport system between the two accumulation basins.

The recovery of part of this energy is very important and possible only by achieving a hydropower development, whose main purpose is to obtain a concentrated fall.

Although hydropower facilities require high investment costs, the exploitation of hydraulic energy is convenient, because it is done without polluting the environment and without consuming energy substances (water is completely and unaltered returned to the natural cycle), which leads to extremely low operating costs.

In order to transform hydraulic energy (available in kind) into stereo-mechanical energy (easily convertible into electricity), the hydroelectric power plant is equipped with hydraulic machines.

Hydraulic machines are technical systems made up of rigid components with well-defined movements that transform hydraulic energy into mechanical energy and vice versa. These hydraulic machines are divided into two important branches: hydraulic turbines and pumps.

1. Hydraulic machines that convert mechanical energy into hydraulic energy are called "hydraulic generators" or pumps.
2. Hydraulic turbines, also called "hydraulic motors"convert hydraulic energy into mechanical energy.

If the machine allows a double operation, both as a turbine and as a pump, it is called a reversible hydraulic machine.

The principle of a hydraulic turbine is based on Newton's second law of motion. He states that the force is directly proportional to the change in momentum. If there is any change in the water impulse, then a force is generated as a result. This rotational energy is used to convert it into electricity by coupling the turbine to a generator in hydroelectric power plants.

Turbines are classified according to certain main characteristics. They are found in all types of hydraulic turbines and define their functionality. The main features that will form the basis of our analysis for differentiating turbine types and choosing the right variant will be:

- flow rate Q, [m3 / s]
- fall H, [m. col. the water]
- power P, [KW] / [CP]
- speed n, [rot./min].
- yield ηT
- geometric suction height Hs, [m col. the water]

- cavitation coefficient σ
- Specific turbine hydraulic energy E, [J / kg]
- Degree of reaction of a hydraulic turbine R

Of all these, the most important is the specific hydraulic energy of the turbine, E, measured in [J / kg] which is defined as the specific energy of the water available between the reference section of the hydraulic turbine suction (high pressure section) and the reference from turbine discharge (low pressure section). Depending on the type of energy transformed, hydraulic turbines are classified into **three distinct groups**:

A. Hydraulic turbines **which transform only the specific potential position energy.**

B. Hydraulic turbines with action **which transform only specific kinetic energy.**

C. Hydraulic jet turbines **which transform the specific potential pressure energy and the specific kinetic.**

A. Hydraulic turbines, which transform only the specific potential position energy.

In the case of these turbines, the degree of reaction is zero because the pressure is constant and equal to the atmospheric one, and the speeds in the reference sections are negligible, or have quasi-equal values, so the kinetic term is canceled. This category includes the water wheels.

From antiquity until the 18th century, water wheels were the most common "hydraulic turbines". Gravitational water wheels (figure 1.4) use the potential position energy of watercourses.

Figure 1.4 - Gravitational water wheels [Village Museum, Bucharest]

They have a horizontal shaft and a large diameter rotor. The rotor consists of straight or simply curved blades, fastened to the periphery of the rotor between two circular crowns (the fixing of the blades is parallel to the axis and at a suitable angle of attack).

These water wheels are fed at the top of the rotor, generally at the highest point, where the wheel admits a horizontal tangent, or at a point on the circumference of the wheel about 75% away from its base.

B. Hydraulic turbines with action, which transform only specific kinetic energy.

This category includes:

1. Water wheels with action;
2. Pelton turbines.
3. Bánki (or Ossberger Michell) transverse hydraulic turbines
4. Turgo hydraulic turbines.
5. Transverse current marine turbines
6. Darrieus type
7. Gorlov type
8. Achard type.

For our study the most relevant hydraulic turbines with action are the Pelton type turbines and Bánki (or Ossberger Michell) transverse turbines. We will also discuss about water wheels with action because it has meant a technological advance and an important model in the field of hydraulic motor design.

1. Water wheels with action

If a waterfall is not available (in areas with a gentle slope), but the flow of water is constant and sufficient, water wheels with action can be used (figure 1.5), which uses the kinetic energy of watercourses.

The water wheel in figure 1.5.a has a rotor made up of a circular crown on the circumference of which straight blades are mounted (the spindle of each blade is fixed radially). Unlike gravitational water wheels, in action water wheels, water hits the blades at the bottom of the rotor, giving it a rotational motion. The unfavorable feature is that the efficiency obtained with this type of water wheel is very low.

(a)

(b)

Figure 1.5 - Water wheels with action [Village Museum, Bucharest]: (a) rotor with straight blades; (b) rotor with buckets and inclined gutter directing the water jet towards the buckets.

Figure 1.5.b shows a water wheel with horizontal shaft action, whose rotor is provided with buckets (carved in wood). This type of turbine is the basis for the idea of sizing the Pelton turbine, only it has simple cups, made with a single concavity. The modification made to this water wheel with action compared to the one in figure 1.5.a is that an inclined gutter directs the water jet towards the buckets, at the top of the rotor. This increases the efficiency of the installation.

Both gravitational and action water wheels were widespread. These were found in the water mills used to grind grain. They have successfully replaced the need for mechanical energy of animal origin.

2. Pelton turbine

Under the name of Pelton turbine are grouped hydraulic motors with total action, covering the range of specific speeds between 2 and 50. In 1880, Lester Allan Pelton (born 1829 in Vermillion, Ohio and died in 1908) patented the Pelton Turbine: a turbine with rotor cups profiled to allow division of the jet and the symmetrical deviation of the two resulting subjects. Since 1883, this turbine has reached a yield of 90.5%. It has a wide application and is frequently used in current technology.

Due to the low specific speed, the field of use is restricted in the area of high falls (between 400 and 2000 m) and low flows(between 1 and 38 m^3/s) ; therefore, there are power plants equipped with Pelton turbines exclusively in mountainous areas (the only form of relief with such large level differences).The obtained power varies in the range (0.440 - 234) MW, and the optimal yields have maximum values of 93%.

The principle of operation presupposes that the jets of water, rearranged with the help of the injector, hit the cups, imprinting a rotational movement of the rotor, with a certain angular speed. The water then falls into the discharge tank (free surface tank) below the rotor, from where it is discharged through a drain. In general, the Pelton turbine shaft is vertical and the water jets have the same speed, being located horizontally. In general, Pelton turbines consist of three main members: the rotor, the injector and the housing.

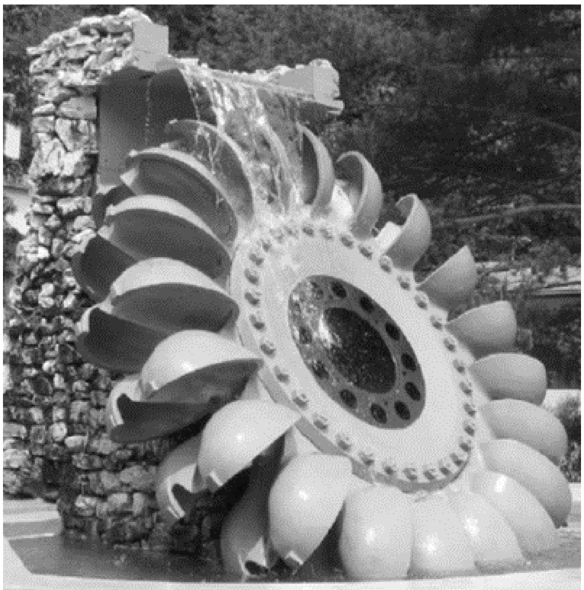
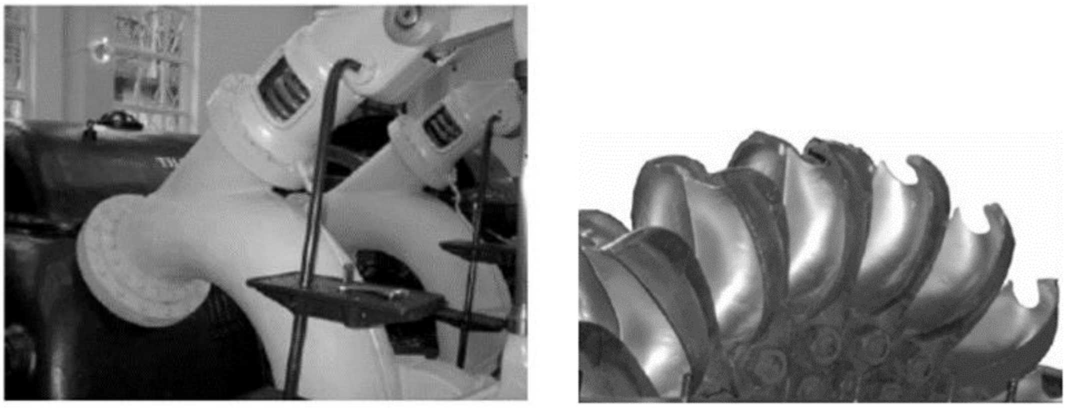


Figure 1.6 - Pelton turbine rotor [Lotru Ciunget Hydroelectric Power Plant, July 2003]



(a) *(b)*

Figure 1.7 - (a) The rotor blades of a Pelton turbine [Dobreşti Hydroelectric Power Plant, November 2003]; (b) Pelton turbine injectors [Moroieni Hydroelectric Power Plant, November 2003]

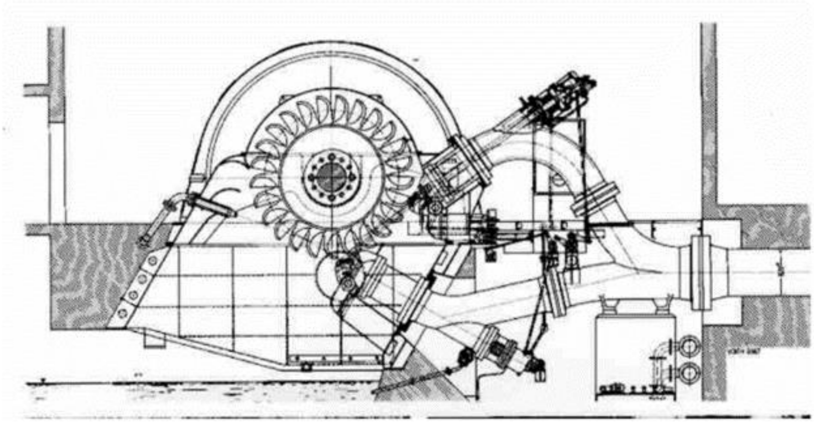


Figure 1.8 - Hydroelectric installation with a Palton turbine

Pelton microturbines have a low field of use in the area of very low flow rates Q = (0.02 - 1) m / s and large falls H = (30 - 400) m. The optimal yield has values of about 90%, and the power obtained is very low: P = (2 - 1000) kW.

In figure 1.9 the diagram of a Pelton turbine with 4 injectors is presented. In this case all 4 injectors (can be a maximum of 6 injectors) are supplied by a single supply pipe surrounding the turbine. The supply of large turbines can be done through two distribution pipes, arranged symmetrically with the turbine axis.

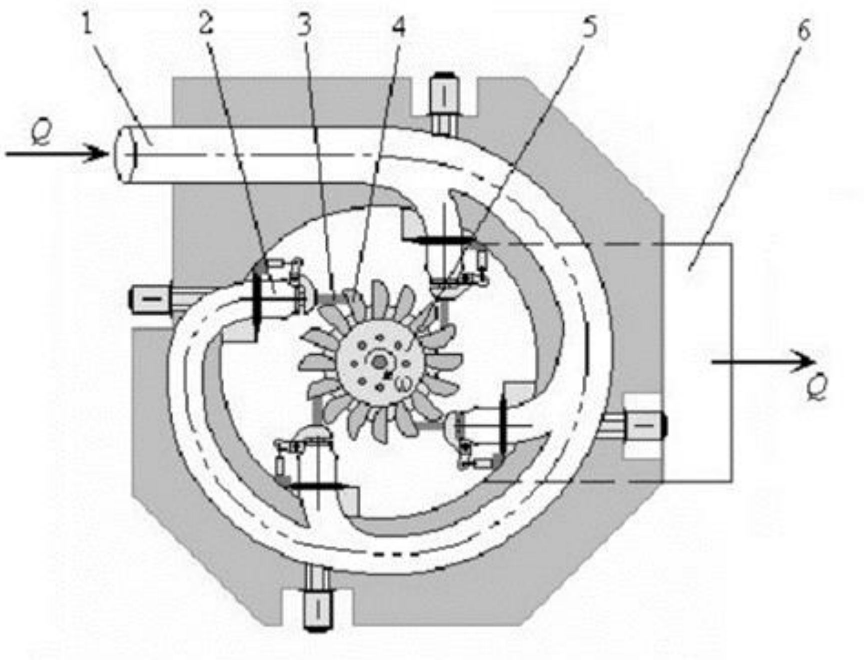


Figure 1.9 - Pelton turbine diagram with 4 injectors: (1) supply pipe; (2) injector; (3) water jet; (4) rotor bucket; (5) rotor; (6) discharge basin

Among the hydroelectric power plants equipped with Pelton turbines with vertical shaft, we mention the following:

- Lotru Ciunget Hydroelectric Power Plant in Romania, an underground power plant equipped with 3 Pelton turbines with 6 injectors each. In 1972, the turbines equipped with rotors built by Neyrpic, rotors with 20 buckets each, were put into operation (figure 1.6). Between 1996 and 2002, turbine rotors were replaced by rotors produced by Sulzer. The new rotors had 21 buckets and a rotor diameter of 2.95 m. The nominal power of a turbine is 170 MW, the nominal flow of a turbine is 26.67 m3/s, respectively the synchronous speed is 375 rot / min. The power installed in the plant is 510 MW, and the installed flow is 80 m3/s. Currently, the gross drop is 792.5 m (calculated as the difference between the normal retention level of 1289 mdM in Vidra Lake and the elevation of 496.5 mdM at the water outlet of the injectors). The maximum gross drop is 809 m. The hydraulic pressure losses on the main hydraulic circuit are about 40 m under nominal operating conditions. The maximum efficiency of the turbines is 92%.
- The Moroieni Hydroelectric Power Plant, on the Ialomiţa River, is equipped with 2 Pelton turbines (figure 1.7.b), of 7.5 MW each. The installed power in the plant is 15 MW, the installed flow is 8.5 m /s, and the gross drop is 232 m.
- Dobreşti Hydroelectric Power Plant, on the Ialomiţa River, a small power plant, with historical value, equipped with 4 Pelton turbines (figure 1.7.a), of 4 MW each, put into operation in 1930! The installed power in the plant is 16 MW, the installed flow is 7 m3 / s, and the gross drop is 305 m.
- Oschenik III Hydroelectric Power Plant in Austria, equipped with 5 Pelton turbines with 2 injectors (with a rotor diameter of 1.825 m). The power of a turbine is 42.8 MW, so the power installed in the plant is 214 MW. The net fall is 1130 m.

3. Bánki (or Ossberger Michell) transverse hydraulic turbines

In 1917, Donát Bánki invented an action shaft with a horizontal shaft, in which water passes twice through the blades.

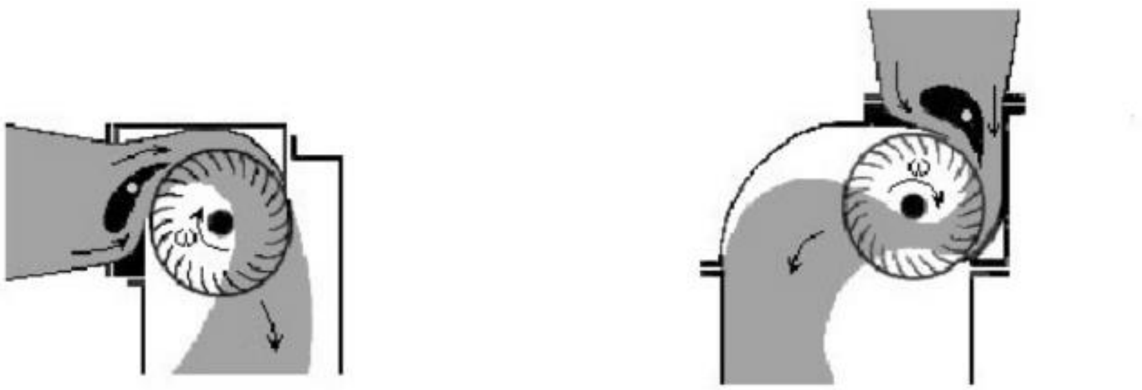
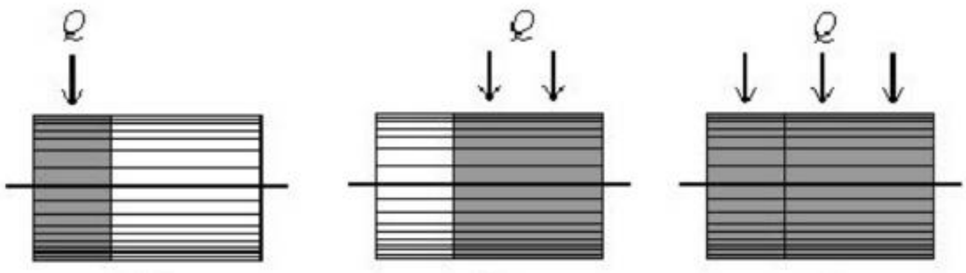


Figure 1.10 - Bánki turbine (Ossberger-Michell): (a) water intake in the horizontal direction; (b) vertical water inlet

Figure 1.11 - Bánki turbine rotor: (1) shaft; (2) circular blade support disc; (3) horizontal blade, simply curved

The cylindrical rotor of the turbine (figure 1.11) consists of two circular disks, perpendicular to the shaft at a distance from each other, which divide the turbine shaft in a portion of 1: 2 (a compartment has a volume equal to one third of the volume total and the other compartment has a volume equal to two thirds of the total volume).

Between these discs, on the outer circular crown of each disc, are mounted blades parallel to the horizontal axis; the blades are simply curved.



(a) *(b)* *(c)*

Figure 1.12 - Ossberger-Michell turbine rotor compartmentation, for: (a) low flow rates; (b) average flows; (c) high debts

The main reason why Bánki turbines are designed in this way is to facilitate use with the highest possible efficiency for a wider range of flows. These can vary between 0.02 and 10 m ^ 3/s. The optimal falls are small and medium, with a value between 1 and 200 m. The powers generated by this type of hydraulic turbine are relatively small, with values not exceeding 1500 kW.

Yields also differ depending on the capacity used.

- For low flow rates, in which case only one third of the total surface of the rotor will be used, the efficiency will have the value of 70% in the vortex cycle.

- When we talk about medium and high flows, which involves the use of two thirds of the rotor, respectively the entire turbine, the yields can vary between 80% and 82%.

The Ossberger-Michell (Bánki) turbine is a cheap turbine, easy to manufacture and easy to operate, and is still produced for micro hydropower plants. For example, in 2004, at the Gants Mill in the U.K., an Ossberger-Michell turbine was put into operation, producing a power of up to 12 kW.

C. Hydraulic jet turbines which transform the specific potential pressure energy and the specific kinetic.

In general, in the case of jet turbines, the size of these turbines is large and the position term can be taken into account. Degree of reaction of reactive hydraulic turbines is subunit.

The following hydraulic turbines fall into this category:

1. axial-radial turbines Fourneyron, respectively Boyden;
2. Francis radial-axial turbines;
3. Dériaz diagonal turbines;
4. Axial turbines, which are divided into the following construction types:
    1. Kaplan
    2. Semi Kaplan
    3. Helical
    4. Bulb
    5. Straflo
    6. S-type tubular

1. Axial-radial turbines fourneyron and boyden

The first hydraulic jet turbine was invented by Johann Andreas von Segner, in the period 1735-1755 together with the studies carried out by Daniel Bernoulli and Leonhard Euler which led to the realization of the theoretical bases of hydrodynamics in the first half of 18th century.

Segner used theoretical studies on the reaction effect of Daniel Bernoulli and designed a turbine rotor, later called the Segner rotor.

The principle of operation is described by the outlet of the water stream from a cylinder provided at the bottom with several horizontal blades, curved in one direction; the water passing through the blades produces a back pressure capable of rotating the cylinder in the opposite direction.

Segner's studies influenced Euler. He issued the idea to use a steering apparatus and designed an open chamber reaction turbine and rotor.

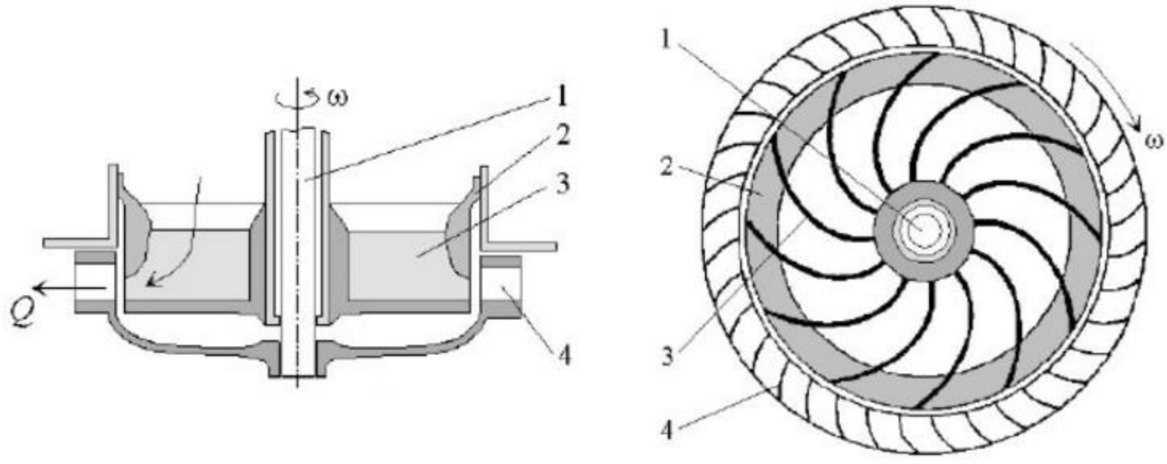
Between 1824 and 1834, professor of mechanics Jean-Victor Poncelet studied jet turbines and water wheels in order to improve their efficiency.

The first rotor that really took into account the advanced principles of hydrodynamics of water flow in the rotor was mounted on a Poncelet Turbine, designed by Jean-Victor Poncelet. The specificity of this rotor had the peculiarity of having curved blades, located at the periphery of a circular crown. Water supply was made to the lower part of the rotor, in an inclined direction, and due to the curved rotor blades the water entered the rotor without shock.

Benoît Fourneyron 17 patented in 1834 the first closed hydraulic turbine, called the Fourneyron turbine. This was the first modern reaction turbine, applicable to falls between 30 cm and a few tens of meters.

Fourneyron arranged a 112 m drop in 1837. The water reached a rotor at a speed of 46 m / s, producing a power of 45 kW. The Fourneyron turbine is an axial-radial turbine (figure 1.13). The Fourneyron turbine does not have a vacuum cleaner, the water coming out of the rotor being centrifuged.

The principle of operation assumes that water, from an open chamber, enters axially into the steering blades (curved in a single plane) and exits radially from the steering apparatus, then passes through the rotor blades (which are also simply curved, but inversely to steering blades, according to figure 1.13.b).



(a) (b)

Figure 1.13 - Fourneyron turbine in (a) cross section and (b) parallel plane view: (1) shaft; (2) cylindrical valve; (3) steering blade; (4) rotor blade

In 1844, Uriah Atherton Boyden 18 designed and patented an axial-radial turbine, an improved variant of the Fourneyron turbine: the Boyden turbine. It had an open frustoconical chamber, which imprints a helical motion on the water at the turbine inlet and ensures a shock-free inlet to the steering blades.

Boyden also improved the cylindrical valve that regulates the flow at the inlet to the rotors and added a diffuser (vacuum cleaner), which recovers some of the kinetic energy.

The optimum efficiency of the Boyden turbine reached 88% at Appleton Mills. The Boyden turbine proved to be expensive, but offered high yields and operational reliability. The success of this new turbine was felt in the 1950s, when water mills in the textile industry in New England, USA, were replaced by Boyden turbines.

James Bicheno Francis was one of the supporters of this turbine.

2. Francis radial-axial turbines

The most important result of the collaboration between James B. Francis and Uriah A. Boyden was the development of a radial-axial turbine, which combined the design initiated by Samuel B. Howd for a turbine with radial inlet and axial outlet, with elements of the Boyden turbine. Thus, in 1949, the radial-axial reaction turbine called the Francis turbine was patented.

Currently, the field of use of Francis turbines is very wide. The Francis turbines cover a very wide flow range, with values between 1 and 980 m3/s. The falls can be medium and large with values between 11 and 750 m.

The power obtained varies between 0.5 and 809 MW, and the optimal yields have very high values, the maximum reached being 95.6%.

With this type of turbine, a maximum power of 978 MW was obtained and it corresponds to pairs of flow-height values Q, H located between 350m^3 /s - 300.m and 980 m^3 /s and 107 for a yield η = 95.0 The specific speed varies in the range: N ∈{ 0.082 and 2.97}.

Francis microturbines have a limited field of use in the area of small flows with values between 0.05 and 1 m^3/s; and medium falls, H ∈{ 20 and 150 } m. The optimal yield has lower values, around 85%, the power P obtained being between 8 and 1250 kW. The specific speed of these microturbines is: N ∈{ 0.338 and 1.896 .

The shape of the rotor of Francis turbines varies depending on the speed. Thus, the following are distinguished:

1. Slow Francis turbines (figure 1.14), for small dynamic speed values. These correspond to small flows and large falls;
2. normal Francis turbines (figure 1.15), for average dynamic speed values and correspond to average flows and drops;
3. Fast Francis turbines, for high dynamic speed values that correspond to high flows and low drops.

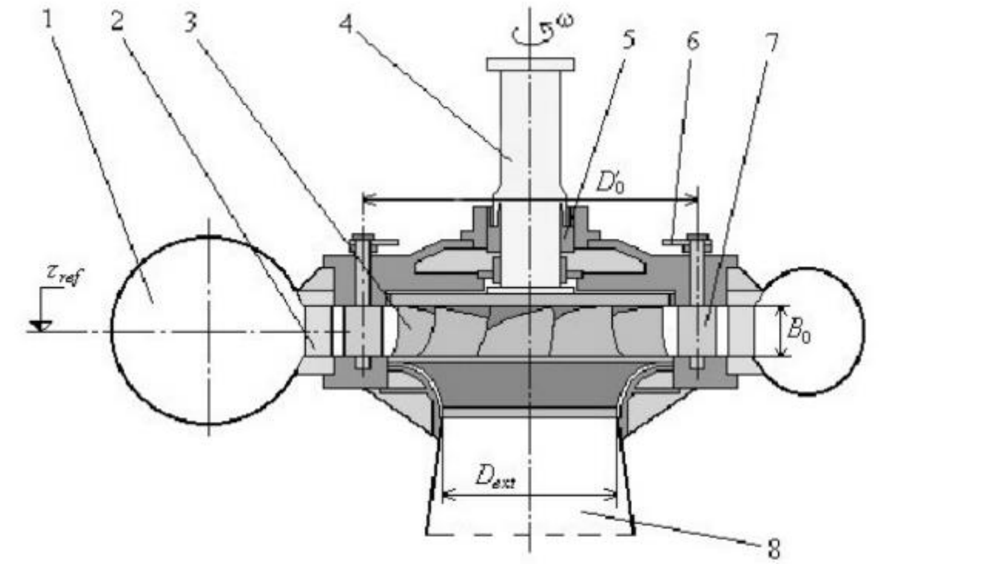


Figure 1.14 – Slow Francis turbine: (1) metallic spiral chamber; (2) stator; (3) rotor; (4) vertical shaft; (5) radial bearing; (6) operating mechanism of the steering device; (7) radial steering device; (8) crank vacuum cleaner

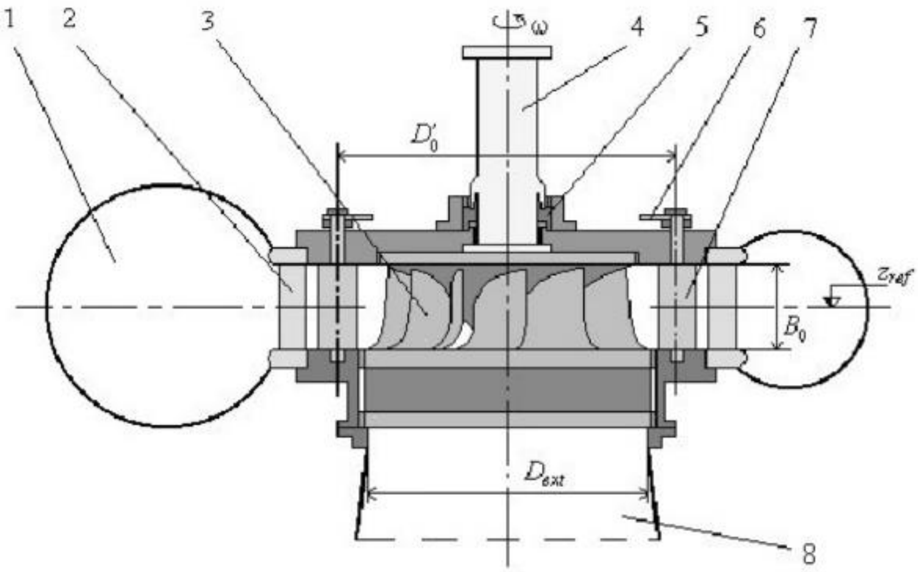


Figure 1.15 – Normal Francis turbine: (1) metallic spiral chamber; (2) stator; (3) rotor; (4) vertical shaft; (5) radial bearing; (6) operating mechanism of the steering device; (7) radial steering device; (8) crank vacuum cleaner

The hydraulic route of the Francis turbine includes the following elements (figures 1.14 and 1.15):

1. The spiral chamber (1), fed from the forced pipe of the hydroelectric installation; the spiral chamber has a circular section and is made by welding metal ferrules;

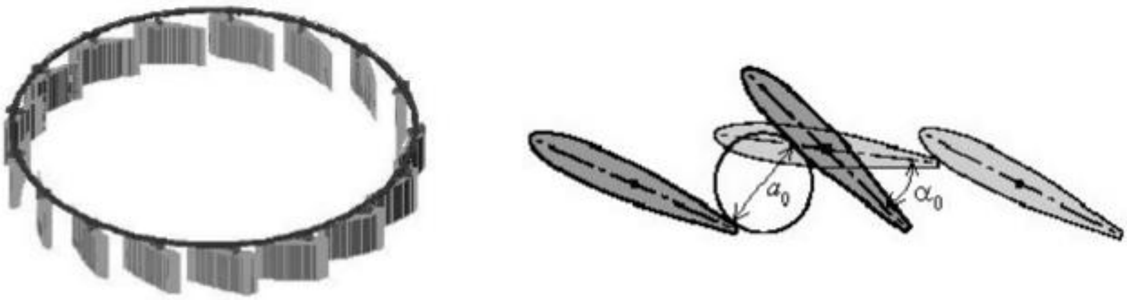
2. The stator (2) with fixed blades, which gives the water a helical movement, respectively which stiffens the spiral chamber;
3. The guiding device (7) whose blades are adjusted with the help of the actuation mechanism (6), ensuring the flow variation between the zero value (directing device fully closed) and the maximum value (directing device fully open); the positions of the guide vanes and the sizes that characterize them are detailed in figure 1.17;
4. The rotor (3) with a large number of fixed, double-curved blades; respectively the crank vacuum cleaner (8), which directs the water to the discharge basin downstream.

(a) (b)

Figure 1.16 – Francis turbine rotors: (a) slow rotor [CHE Vidraru, July 2004]; (b) normal rotor [Brădișor Hydroelectric Power Plant, July 2003]

Francis turbine rotor types:

- The slow Francis rotor (figures 1.14 and 1.16.a) is characterized by the low height of the blade at the entrance (height equal to the height of the steering device); long rotor blade, so the rotor has a large peripheral diameter (by default, the hydraulic efficiency is weaker, because the hydraulic load losses in the rotor increase); the entrance edge has the same diameter on the outer crown of the rotor (located at the bottom of the blades) and on the inner crown of the rotor (located at the top of the blades); the ratio between the diameter of the rotor at the entrance to the blades and the characteristic diameter Dext of the rotor is above unity (the characteristic diameter of the Francis turbine rotor is the diameter of the outer crown at the exit from the blades).



(a) (b)

Figure 1.17 – Direction device: (a) direction blades caught by the adjustment ring, in the open position; (b) defining the opening angle of the steering apparatus blade in the open position, respectively the presentation of the blades in the closed position

- The normal Francis rotor (figures 1.15 and 1.16.b) is characterized by the high height of the inlet blade; shorter rotor blade and smaller peripheral diameter rotor than the slow rotor; the entrance edge has a larger diameter on the outer ring of the rotor than on the inner ring; the ratio between the diameter of the rotor at the entrance to the blades on the inner crown and the outer characteristic diameter of the rotor is subunit; the ratio between the diameter of the rotor at the entrance to the blades on the outer crown and the characteristic outer diameter of the rotor is quasi-unitary.
- The fast Francis rotor has characteristics such as: high blade height at the entrance; short rotor blade and rotor with a smaller number of blades; the entrance edge has a larger diameter on the outer ring of the rotor than on the inner ring; the ratio between the diameter of the rotor at the entrance to the blades on the inner crown and the outer characteristic diameter of the rotor is subunit; the ratio between the diameter of the rotor at the entrance to the blades on the outer crown and the characteristic outer diameter of the rotor is subunit. This rotor can be characterized as an external crown diagonal rotor (in contrast to the Dériaz diagonal turbine rotor, which does not have an external crown).

Depending on the position of the Francis turbine shaft, two types of diffuser vacuum cleaners (vacuum cleaners) can be distinguished, namely **curved vacuum cleaners**, respectively **rectilinear frustoconical vacuum cleaners** (figure 1.18), depending on the position of the Francis turbine shaft. The corresponding suction heights Hs are specified, calculated as the difference between the reference level Zref of the turbine and the level of the free surface Ze in the discharge basin.

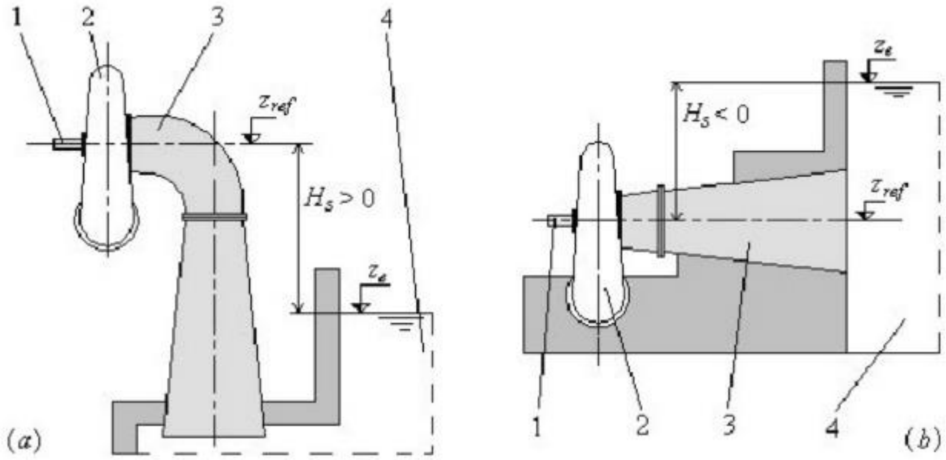


Figure 1.18 – Francis turbine with horizontal shaft (a) with cranked suction; (b) with rectilinear vacuum cleaner: (1) shaft; (2) metallic spiral chamber; (3) vacuum cleaner; (4) discharge basin

Among the hydroelectric facilities that use Francis turbines can be counted:

1. The Vidraru hydroelectric plant on the Argeş river, equipped with 4 Francis turbines (the rotor is shown in figure 1.16.a), put into operation in 1966. The power of one turbine is 55 MW, so the power installed in the plant is 220 MW, and the installed flow is 90 m3/s; the gross drop is 324 m.
2. The largest hydroelectric power station equipped with horizontal shaft Francis turbines is the Hornberg Hydroelectric Power Station in Germany, equipped with 4 turbines (rotor diameter 1.7 m; PIF 1970). The power of a turbine is 262 MW, so the power installed in the plant is 1048 MW. The net drop is 652 m.

The Francis turbines were also built in the reversible version, in which case the hydraulic machine works both in pumping mode (for example at night, when there is a surplus of power in the energy system), and in turbine mode (providing electricity, for example , at peak load).

Such a reversible hydraulic machine is located in a pumped storage hydroelectric plant. Among the pumped-storage hydroelectric plants equipped with Francis-type turbine-pumps, the following stand out:

1. Luxembourg's Vianden Reversible Pumped Hydroelectric Plant, an underground plant located in the heart of Mount St. Nicholas. Between 1962 and 1964, 9 hydro aggregates with a horizontal shaft were put into operation, composed of a Pelton turbine (with a power of 100 MW), a motor-generator, a pump (with a power of 69 MW), a coupling and a small turbine necessary to start the pump and bring it into synchronism. was expanded in 1976 by the inclusion of the 10th hydro unit 26, a Francis-type reversible turbine-pump with a vertical shaft and a power of 200 MW in the turbine cycle and 215 MW in the pumping cycle. The total power installed reaches

the value of 1100 MW in the turbine cycle, and the total power required for pumping reaches the value of 836 MW. The net drop varies between 266.5 m and 291.3 m. The total turbine nominal flow rate in the plant has the value of 432.5 m3/s, and the total pumped nominal flow rate has the value of 263 m3/s. The pumping cycle is daily, with a duration of use of the pumps of 7 and a quarter hours. The daily duration corresponding to the turbine is 4 hours and a quarter. The Vianden pumped hydroelectric plant is the largest of its kind in Europe.

3. *Kaplan turbine*

This turbine has a propeller-type rotor with a vertical hollow shaft. The rotor consists of a hub on which between 4 and 8 blades are fixed. The blades can rotate through a system controlled by a rod inside the hollow shaft, depending on the available water flow.

The first Kaplan turbine was built at the Storek factory in Brno in 1918 and was put into operation in 1919 at the water mill in Velm, Austria, where it remained until 1952. Patented in 1920, the technology was thought up by Viktor Kaplan. The major innovation was the dual adjustment of the rotor blades and the steering gear blades (the blades can swing around their axis during turbine operation), thus ensuring a fine tuning of the turbine flow and a flattened performance curve relative to the characteristic allure efficiency of other hydraulic turbines.

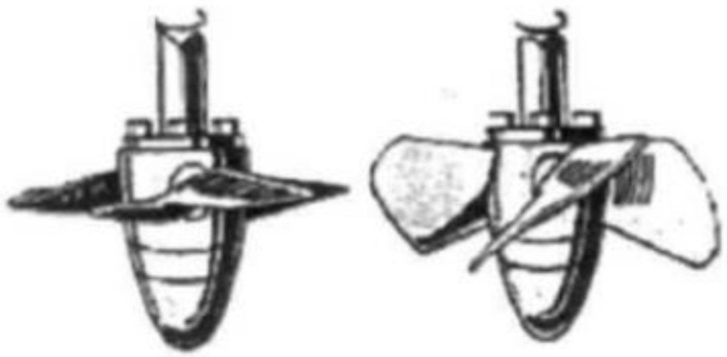


Figure 1.19 - Extreme positions of the rotor blades of a Kaplan turbine

The field of use of Kaplan turbines is very wide. Kaplan turbines cover a very wide flow range Q= (1 ; 980)m^3 /s, for small and medium drops H ∈{ 1 ; 80} m. The obtained power varies in the range P= (0.009; 217) MW, and the optimal yields have very high values between 92 and 94%. The proposed maximum power is obtained for Q = 980 m3/s, H = 24 m and η = 94.0. The specific speed is: N ∈{ 1.34 ; 5.95}.

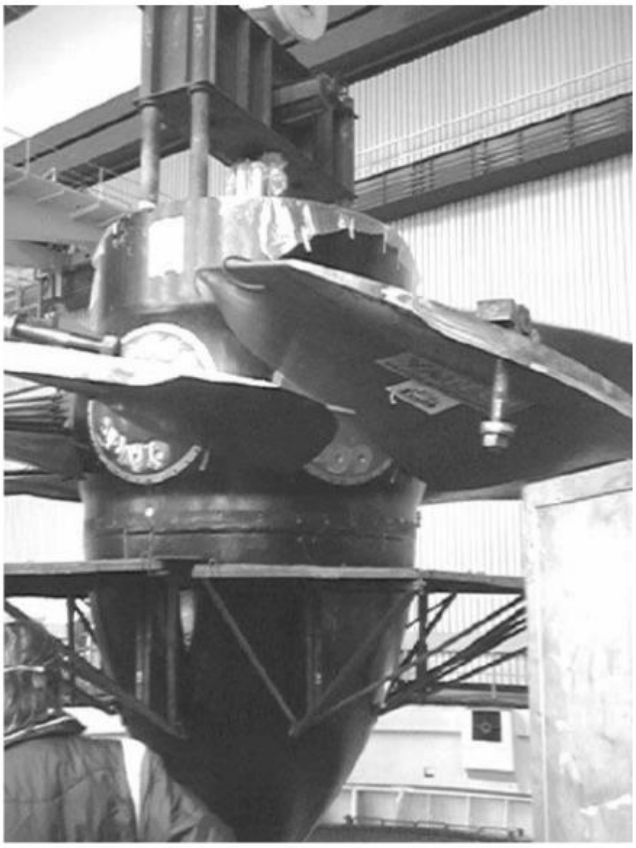


Figure 1.20 – The rotor of the Kaplan turbine [Hydroelectric power station "Iron Gates I", May 2003]

The hydraulic path of the Kaplan turbine includes the following elements (figures 1.21): the semi-spiral chamber, with a trapezoidal section (the flow being high, the cross-section is large, so it is made by concreting, with a polygonal shape); the stator with fixed blades, which gives the water a helical movement, respectively which stiffens the semi-spiral chamber; the steering apparatus whose blades are adjusted with the help of actuation mechanisms; rotor with adjustable blades; respectively the crank vacuum cleaner, which directs the water to the discharge basin downstream.

The direction of water flow at the entrance to the turbine, respectively at the exit, is diagrammed (figure 1.21). The turbine has back pressure during discharge, the suction height being negative.

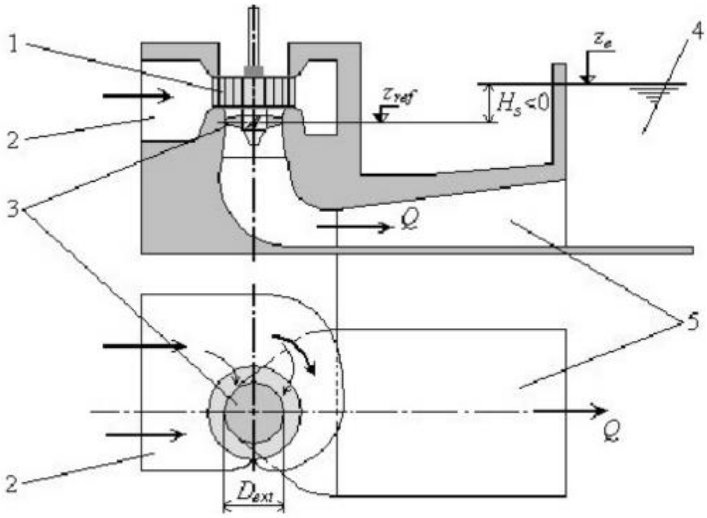


Figure 1.21 – Schematic of the Kaplan turbine: (1) stator; (2) concrete semi-spiral chamber; (3) rotor with adjustable blades; (4) discharge basin; (5) crank vacuum cleaner

Among the hydroelectric plants equipped with Kaplan turbines, we mention the following:

1. The "Iron Gates 1" hydroelectric plant on the Danube, located about 15 km upstream from Turnu Severin, built in partnership with Serbia (former Yugoslavia), equipped with 12 Kaplan turbines, put into operation in 1971 (6 Kaplan groups are in the Romanian plant from the left bank and 6 groups in the Serbian center from the other bank of the Danube). The turbine rotor has a diameter of 9.5 m, being among the largest in the world. The refurbishment of the hydropower equipment in the Romanian power plant "Iron Gates 1" began in 1998 (through a contract signed with VA TECH HYDRO), and currently 5 of the 6 groups have been refurbished. The power of one turbine is 191.2 MW. The power installed in the Romanian power plant is 1147 MW, and the installed flow is 4710 m3 /s. The gross drop is 28.5 m.
2. The "Tower" hydroelectric plant, on the middle Olt, equipped with 2 Kaplan turbines (PIF 1982). The power of a turbine is 35 MW, so the power installed in the plant is 70 MW. The installed flow rate is 330 m3/s. The gross drop is 24 m.

In modern technology, three main types of turbines have been imposed: Kaplan, Francis and Pelton. Lately, bulb turbines, which are actually Kaplan without a spiral chamber, and Deriaz-Kviatkovski turbines, which are Francis turbines with adjustable rotor blades, have been derived from them.

The research regarding the operation, construction and reliability of these machines, but above all the daring of the specialists, led to achievements of great efficiency, appreciable powers of a group operating at high revolutions and with low specific weights. Each type of machine has its field of use, in which it presents high technical-economic performance indices.

Type	Bulb	Kaplan	Francis	Pelton	Pump
Unit capacity, up to MW	80	300	1000	400	500
Head, m	0.5–30	30–90	up to 700	up to 1800	1300
Efficiency, %	92	95	96	95	94
Plant type	Run-of-river with low heads	Small reservoir and run-of-river	Reservoir	Big reservoir	Pumped storage

1.3. Description of the chosen solution

Following the hydrographic studies in the construction area of the hydroelectric facility, it was concluded that a Francis type turbine, whose characteristics were presented in the previous chapter in a broad manner, is the most suitable for our case study.

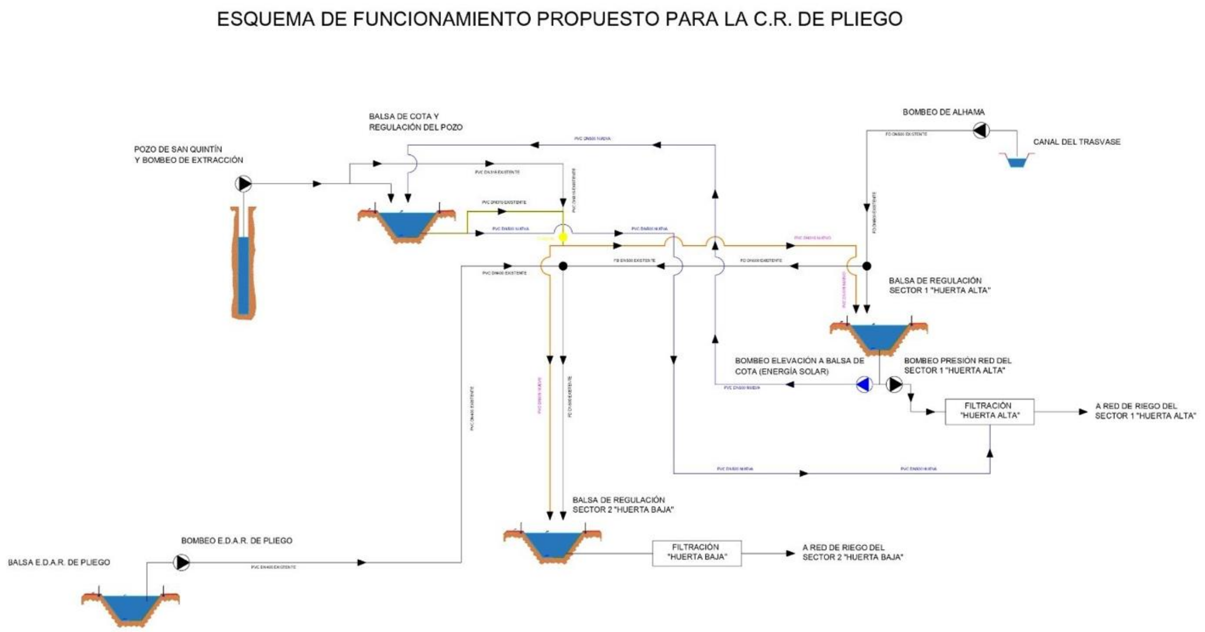


Figure 1.22 - The proposed scheme for the installation of the hydropower plant

The turbine will be installed in a mixed-type hydropower plant, with a dam and diversion. This scheme combines the advantages of both types of arrangement. The lake of the dam in our case is used to accumulate the flow and use it during the dry time of the year; the diversion channel gives the convenient solution for increasing the fall without great heights for the dam.

Usually, the bypass is done with the help of a channel. If, due to local conditions, the channel cannot be built, other types of derivation, much more expensive, are applied: galleries, adduction pipes, etc. The pipe gallery is more advantageous because it is dug in the shortest direction between the lake and the hydroelectric plant, which is advantageous compared to the open channel, which has to go around the mountain following a level curve, which is not allowed for geographical reasons, the positioning of the reservoirs, respectively of the power plant, being in an environment with a relatively low relief level. In the practice of hydropower installations, both free-draining galleries, which work with incomplete filling, and pressurized galleries are applied. The most suitable in the case of the studied hydropower development are the pressure galleries, these being already existing.

Aiming at obtaining maximum advantages for the national economy, the water course is arranged and used for multiple purposes: energy, river transport, water improvements, water supply. Such use is called complex use.

Figure 1.23 - The satellite image of the position of the hydropower facility

The appropriate hydroelectric arrangement for the requirements of the Community of Pliego irrigators will be composed of the following constructive elements:

1. The three reservoirs that will generate, during river transport between first to second and third, hydraulic energy that will then be transformed into electrical energy.
2. Ducts with the role of leading the flow from the water intake to the balance chambers. These will be executed both in the form of channels with a free face, as well as in the form of pipes or galleries under pressure.

3. Balance rooms. In the case of pressure adductions, the installation is called a balance castle, being executed in the form of a vertical pool with a free level. The wave of pressure increase, which originates in the forced pipe following a possible water hammer, will be reflected near the free level. Thus, the water castle, on the one hand, removes the pressure increase in the gallery, on the other hand, by reflecting the wave, it determines the conditions of the indirect blow, reducing the pressure increase in the forced pipe.

4. Forced pipes. They have the role of leading the water from the balance chamber to the hydraulic turbine. Due to the high static and dynamic stresses, the forced pipes are made of high strength steels (1700 daN/cm³). Usually the thickness of the sections is different, being greater near the plant. The sections are welded together directly on site; before commissioning, however, pressure tests are carried out, during which the efforts in various areas are determined by tensometry. Powering the turbines of a power plant will be done with a separate pipe for the aggregate. The route of the forced pipeline is chosen as short as possible, both for economic reasons and to reduce the overpressure caused by the ram blow.The placement of the forced pipeline is done on several anchoring massifs and on a large number of intermediate supports.The anchor mass is a concrete body in which the pipe is embedded. The forces acting along the axis of the pipe are taken over by the anchor masses that do not allow the pipe to move in this direction. Transversal forces as well as frictional forces that appear when the length of the pipe changes, due to temperature variations, are transmitted on the intermediate supports. In order to avoid extremely high axial forces, generated by temperature variations, a compensation sleeve is mounted after each anchor mass.

5. Forced pipeline valves.They have the role of reducing the flow rate or stopping the flow. Usually the valves are mounted at the upstream end of the pipeline. Sometimes valves are also placed at the downstream end, in order to have the possibility to close the access of water to the turbine without emptying the pipe. The valves on the upper part are usually arranged in a specially arranged building, called the valve house, which ensures the protection of the valves and the handling devices against the weather. The valves from the lower part were placed either in front of the power station building, when they have their own room, or even in the power station building. In order to avoid the formation of a vacuum when emptying the pipe, ventilation valves are installed in its upper part. The filling of forced pipes must not be done too quickly; sometimes small-diameter bypass pipes (by-pass), fitted with valves, are used to fill the forced pipe. The by-pass is calculated for a flow rate of approximately 1/20 of the installed flow rate and allows equalizing the pressure on the two sides of the main valve, which reduces the maneuvering effort. The following types of valves are frequently used at hydroelectric plants:

   - flat valves;
   - butterfly valves:
   - cylindrical valves:

- ball valves;
- empty jet valves (Johnson)

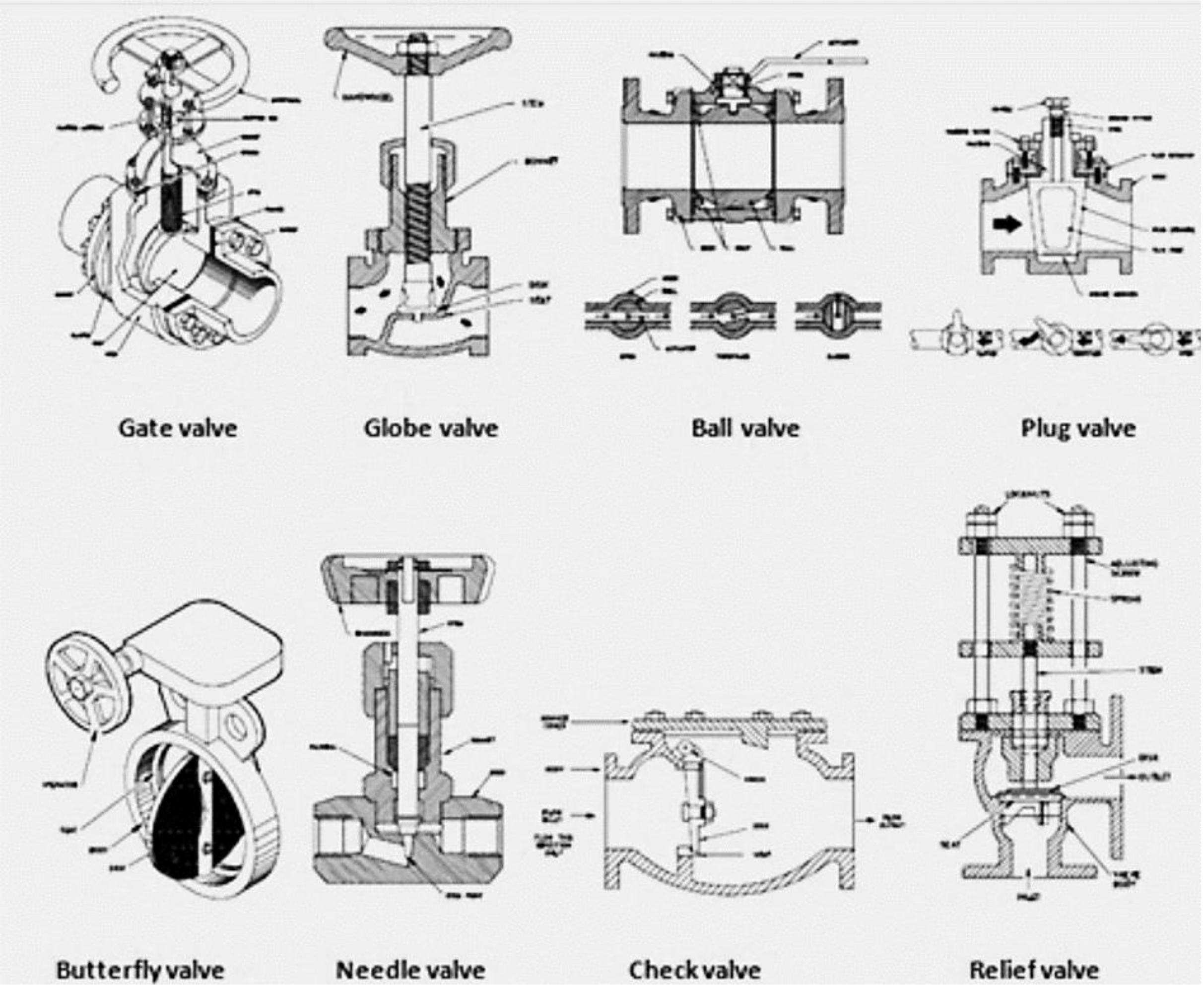


Figure 1.24 - The main types of valves

6. The hydroelectric plant. It represents the set of electromechanical equipment, together with the related buildings, in which the hydraulic energy is successively transformed into stereo mechanical energy and then into electrical energy. The electromechanical equipment includes: hydraulic turbines, electric generators, valves, speed and pressure regulators, pressurized oil installation, compressed air installation, transformer station (can be located in the power plant building or next to it), etc. Depending on the position of the plant in relation to the surface of the land, the plants can be aerial (placed on the surface of the ground) and underground. In the present case, a location on the surface of the ground would help both from an economic and technical point of view.
7. Escape channel. It transports the turbine flow to the return points in the second storage basin. Although the canals can also be made in filling against the natural ground, they are usually executed in excavation.

1.3.1. Swot analysis for Francis turbine

The following table depicts the strengths, weaknesses, opportunities, and treats of the Francis turbine.

STRENGTHS	WEAKNESSES
Wide use in the field of electricity production with the help of hydraulic energy Mixed operation, both as a turbine, producing electricity, and as a pump. Applicability in the case of a wide range of hydrographic and geographical conditions. Simple construction, robust and reliable High performance with yield values around 96%	The need for a more complex hydropower arrangement to protect the hydraulic equipment against overpressure or water hammer.
OPPORTUNITIES	**THREATS**
Affordable maintenance due to the large number of manufacturers and suppliers of spare parts for this type of turbine.	The appearance of the phenomenon of premature cavitation that requires more careful attention.

Table 1 - SWOT analysis for Francis turbine

2. Calculation and design of the turbine energy production

2.1. Input data of the project

In order to solve the need of the Community of irrigators of Pliego, to supplement the production of electricity from the capture of the hydraulic energy of the water, in the fluvial transfer process from the first reservoir to the other two, the characteristic parameters of the Francis type hydraulic machine will be studied.

A. Turbine flow rate

It is defined as the amount of water that enters the machine per unit of time. The flow is expressed in units of volume (Q), weight (G) or mass (m), related to the unit of time.

B. Turbine fall

It is defined starting from the notion of specific energy of the liquid, which is expressed as total energy E related to the weight of the fluid (G) or to the mass (m). So:

$$e = \frac{E}{G} = \frac{p}{\gamma} + z + \frac{v^2}{2g}$$

$$Y = \frac{E}{M} = \frac{p}{\rho} + gz + \frac{v^2}{2}$$

The drop, because it expresses the energy consumed by the machine to perform mechanical work, is defined as the difference between the specific energies at the input and output of the system (the system can be the entire hydropower plant or only the turbine).

If we consider the section from the entrance to the turbine marked with "i" and from the exit with "e", then the drop of the turbine is expressed in the form:

$$H = \frac{p_i - p_e}{\gamma} + z_i - z_e + \frac{v_i^2 - v_e^2}{2g}$$

Based on the notations in figure 2.1, in the case of Francis type turbines, write the following relation for the turbine drop:

$$H = \frac{Q_I}{Q_I + Q_{II}}\left(z_i + a_i - z_{eI}\right) + \frac{Q_{II}}{Q_I + Q_{II}}\left(z_i + a_i - z_{eII}\right) + \frac{p_{mi}}{\gamma} + \frac{v_i^2}{2g}$$

where pmi represents the manometric pressure, respectively the manometer indications at point "i".

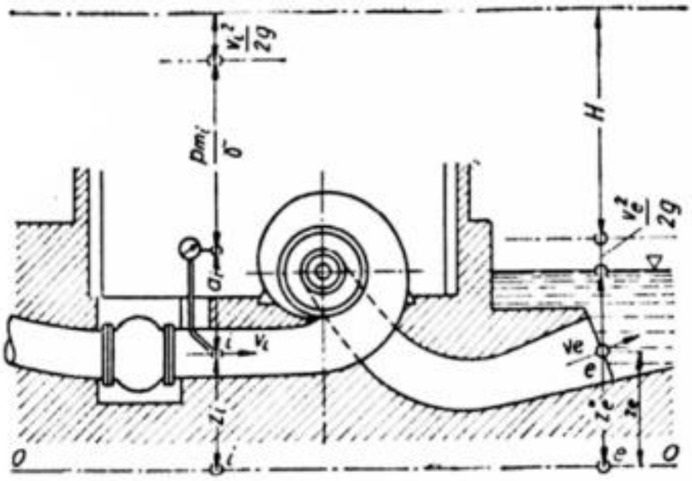


Figure 2.1 - Input and output parameters for the Francis turbine.

C. The gross fall of the arrangement

The gross drop Hb is defined as the difference between the specific energy of the fluid in the reservoir (upstream) and in the escape channel (downstream of the plant), (fig.2.2)

$$H_b = e_{Am} - e_{Av} = \frac{p_{Am} - p_{Av}}{\gamma} + z_{Am} - z_{Av} + \frac{v_{Am}^2 - v_{Av}^2}{2g}$$

If we take into account that *pAm=pAv* , *vAm=vAv= 0* result

$$H_b = z_{Am} - z_{Av} \quad ; \quad Y_b = g\left(z_{Am} - z_{Av}\right)$$

So, the gross drop represents the vertical difference between the elevations of the water in the reservoir and in the plant's escape channel.

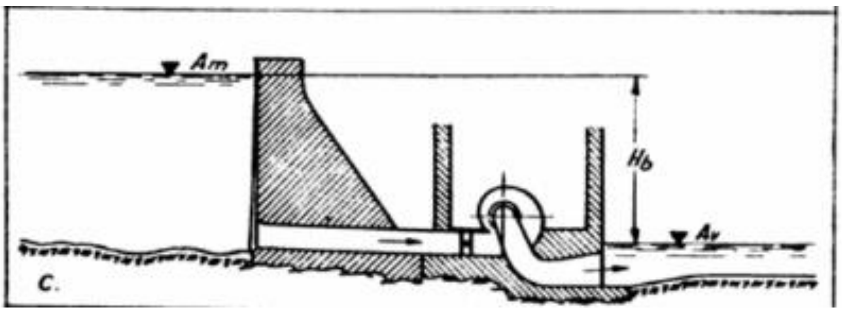


Figure 2.2 - The gross fall of the arrangement of the hydroelectric plant with a Pelton turbine.

D. Useful or effective fall

The useful or effective drop is the useful specific energy delivered by the turbine to the shaft, after part of the turbine drop has been spent to cover the energy losses in the machine.

$$H_u = H_{ef} = H - \sum h_{pT}$$

Often, instead of hydraulic losses, the notion of hydraulic efficiency is introduced, defined as follows:

$$\eta_h = \frac{H - \sum H_{pT}}{H} = \frac{H_u}{H}$$

E. Turbine power and efficiency

As we refer to the gross drop, the turbine drop or the useful drop, we will get: Pam - the power of the installation, Pa - the hydraulic power or the power absorbed by the turbine, P - the useful power obtained at the machine shaft. The calculation relations of the mentioned powers are:

$$P_{am.} = \gamma QH_b \quad ; \quad P_a = P_h = \gamma QH \quad ; \quad P_u = \gamma QH_u$$

By yield or efficiency is meant, in general, the ratio between the useful energy "Eu" provided by a system and the absorbed energy "Ea". The efficiency of the turbine is determined as follows:

$$\eta_T = \frac{P}{P_a} = \frac{P}{\gamma QH} = \frac{M\omega}{\gamma QH}$$

where M and ω represent the motor moment at the turbine shaft and the value of the angular velocity.

F. Turbine speed

The turbine speed is defined as the number of revolutions per unit of time. It is denoted by "n" and is expressed in rpm.

G. The cavitation coefficient

If the geometric suction height of the turbines exceeds a certain value (theoretically 10.33 m), an accentuated depression is created at the exit from the turbine rotor, which facilitates the appearance of areas filled with vapors. Thus the turbine works in cavitation.

The cavitation phenomenon is a complex physical process that occurs in a liquid stream in the area of high speeds and low pressures. The primary effects of cavitation are: loud noises and vibrations, intense destruction of the material from which the flow parts of the turbine are built and decrease in efficiency. These manifestations intensify when a certain regime called limit is exceeded. The cavitation coefficient, defined by Prof. Thoma, was expressed in the form:

$$\sigma = \frac{A - A_t \mp H_s}{H}$$

where: A - represents atmospheric pressure (m water column), At - water vaporization pressure (milliliters water column). Knowing the value of the cavitation coefficient allows the calculation of the maximum suction height, respectively the installation conditions of the turbine:

$$H_{s\,adm.} \leq A - A_t - \frac{h}{900} - \sigma H$$

Following the analysis in the turbine installation area, the following values of the hydrographic and positional factors were determined:

• Material: PVC 16 atm

• Diameter: 315mm

• Average pressure: 3.2 atm (turbine location point).

• Average flow: 100 m3/hour

• Average operating range: 8 hours/day

• Difference in levels between reservoirs: 32 meters

• Angle of the conduit with respect to the horizontal: 3∘

2.2. Calculation and design of the final solution

In the present case, in a purely theoretical hypothesis, we have:

- H= 32m - a small waterfall and also a small flow
- Q = 0.027m3/s – a small flow.
- P = γQH – the theoretical power that the turbine can produce.

γ water 20 (Specific gravity at 20 0 Celsius = 998.2 kg/m3 or 9790 N/m3. γ water at 4 = 1000kg/m3 or e 9806N/m3. As the installation would be used more during the summer as a water average of 23 can be considered the specific gravity at 20 degrees Celsius.

This results in

P= 97900.02732 =8458,56 w or 8,458kW.

Determining the constructive solution based on these data requires the calculation of the specific speed ns <rot/min>.

In Hitachi Review the diagram in figure 2.3 is presented which shows the relationship between the critical specific speed at a global suction height. Thus, for the Francis turbine we can write:

nS=13000H+20 nS=250 [rot/min]

Taking into account that the specific critical speed is obtained for the power expressed in kW, we can determine the turbine speed:

$$n_{\langle rot/\min\rangle} = n_{S\langle rot/\min\rangle} \frac{H^{5/4}_{\langle m\rangle}}{P^{1/2}_{\langle KW\rangle}}$$

n = 26.169250 = 6542.49 [rot/min]

Considering that the turbine is directly coupled to the generator, the "n" speed must be a synchronism speed.

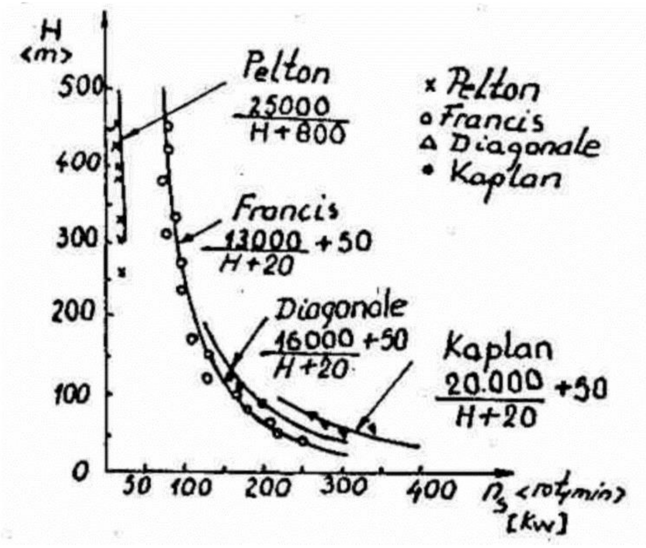


Figure 2.3 - The relationship between the critical specific speed at a global suction height

According to the graph, the diagonal Francis turbine results.

Knowing the normal flow Q with the relation:

Q= PHηT T=PQH T=0.94

estimating the turbine efficiency ηT considering the relation offered by Prof. Dorin Pavel [1] for ηmax:

ηmax=0,87+10-4ns-510-7(ns-100)2 ηmax= 0.88

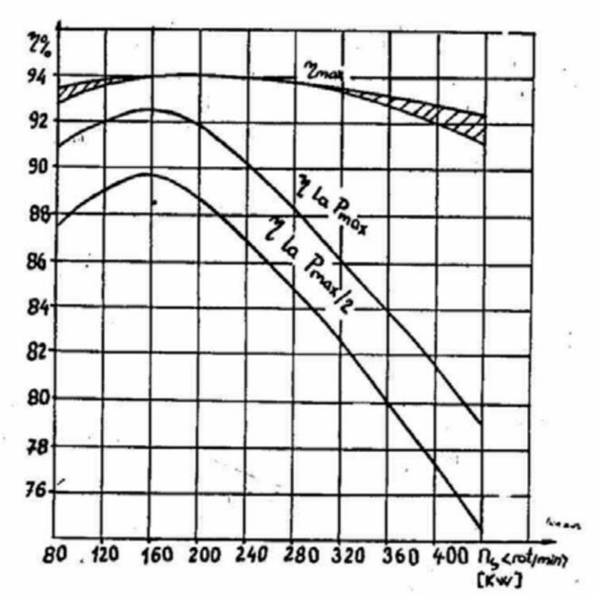


Figure 2.4 – Francis turbine efficiency

Following the calculations, it can be concluded that the production of electricity is due to the arrangement of the hydroelectric installation. For economic reasons, the power of the assembled turbine will be 10kw, with an annual output equal to 29.2 MW in a working regime of 8 h/day.

2.3. Benefits of the solution from point of view of circular economy

The process of extraction, distribution and storage of the water consumes a noticeable amount of energy. Besides, distribution and irrigation are two activities that involve a massive quantity of water. In order to reduce this, the main source, on which the Pliego irrigation system relies on, is transformed into electricity, so that the turbine replaces electricity consumption.

The turbine has been chosen taking advantage of the relevance of renewable energy, environmental-friendly, which boosts the circular economy. Moreover, another advantage is also the possibility of not deteriorating nor degrading the water used as the water gets in and out of the system. Thus, there is no negative effect on the environment.

In another train of thought, the byproducts like humic acid are sold at a fair price as soil conditioners that enhance the fertility and the resistance of the soil. Also, the increase of the crop fields and the decrease of the pesticides and fertilizers, such as phosphor. It improves the quality of groundwater, by reducing leaching and by promoting local biodiversity. And last but not least, social innovation contributes to sustainable agriculture and to clean groundwater resources in the long term.

3. Investment cost and profitability analysis

3.1. Cost of the proposed solution

The economic study will be represented by the comparison of three hydraulic-electrical systems, manufactured by three companies with a history of manufacturing this equipment.

The installation costs are negligibly different in all three cases. The main expenses are made on the equipment itself: turbine + generator + transformer.

The final costs are 10-12% higher than the estimated costs and they do not include labor for the construction of the hydropower plant.

As a rule, in the field of setting up hydropower installations, it is known that the price per 1 kW of installed power varies between 1,500 and 3,000 EUR. Knowing that we are dealing with a 10kW turbine, we chose to keep a limited budget, which was respected, of EUR 30,000.

For the first option, we opted for a Francis turbine of 10 kW with an efficiency of 80% built and distributed by Suneco. This option is also the most expensive on the list.This installation requires an initial cost of 23,475

EUR.

Initial investment budget

Target investment budget	€	30,000	30,000.00 €
The total cost of the investment	€	23,475	23,475.00 €
You are within budget, the difference is by	€	6,525	

Article	Description	Cost		Amount	Sum		Note
Hydraulic-electrical equipment	10 kW Francis turbine kit + Generator made by Suneco	€	14,700	1	€	14,700	
Hydropower plant	The turbine room, the water castle, the annex facilities			1	€	7,350	It represents 50% of the total purchase cost of hydraulic and electrical equipment
Flow control valves and equipment	Butterfly solenoid valve	€	150	2	€	300	
	Pressure sensors	€	40.00	10	€	400.00	
	Gauges	€	35.00	5	€	175.00	
	Valve	€	20.00	5	€	100.00	
	Insulation gaskets	€	15.00	30	€	450.00	
Total					€	23,475	

For the second option, I chose a 10kW turbine, produced in China by Xinda Green Energy CO. This turbine comes with a generator, the kit costing 10,000 EUR. In addition to this amount and the fitting one, it is necessary to invest in a transformer. As a rule, its price varies between 1500 and 2000 EUR. The efficiency of this turbine is 80%.

Initial investment budget V2							
Target investment budget		€	30,000			30,000.00 €	
The total cost of the investment		€	18,125			18,125.00 €	
You are within budget, the difference is by		€	11,875				
Article	**Description**	**Cost**		**Amount**	**Sum**		**Note**
Hydraulic-electrical equipment	10 kW Francis turbine kit + Generator made by Xinda Green Energy	€	10,000	1	€	10,000	
Aditional electric equipment	Electrical transformer	€	1,700.00	1	€	1,700.00	
Hydropower plant	The turbine room, the water castle, the annex facilities			1	€	5,000	It represents 50% of the total purchase cost of hydraulic and electrical equipment
Flow control valves and equipment	Butterfly solenoid valve	€	150	2	€	300	
	Pressure sensors	€	40.00	10	€	400.00	
	Gauges	€	35.00	5	€	175.00	
	Valve	€	20.00	5	€	100.00	
	Insulation gaskets	€	15.00	30	€	450.00	
Total					€	18,125	

The third option chosen is represented by a turbine with the same power compared to the other two, only with a lower efficiency of only 78%, also manufactured in China, but this time by those from Chengdu Forster Technology.

Initial investment budget V2							
Target investment budget		€	30,000			30,000.00 €	
The total cost of the investment		€	14,175			14,175.00 €	
You are within budget, the difference is by		€	15,825				
Article	**Description**	**Cost**		**Amount**	**Sum**		**Note**
Hydraulic-electrical equipment	10 kW Francis turbine kit + Generator made by Chengdu Forster Technology	€	7,500	1	€	7,500	
Aditional electric equipment	Electrical transformer	€	1,500.00	1	€	1,500.00	
Hydropower plant	The turbine room, the water castle, the annex facilities			1	€	3,750	It represents 50% of the total purchase cost of hydraulic and electrical equipment
Flow control valves and equipment	Butterfly solenoid valve	€	150	2	€	300	
	Pressure sensors	€	40.00	10	€	400.00	
	Gauges	€	35.00	5	€	175.00	
	Valve	€	20.00	5	€	100.00	
	Insulation gaskets	€	15.00	30	€	450.00	
Total					€	14,175	

The package contains the 10 kW Francis turbine and the generator. Also, along with the cost of this package, the cost of an electrical transformer will also be taken into account. The amount required for the purchase of the hydraulic and electric equipment amounts to EUR 9,000. This option is also the cheapest.

3.2. Benefit of the proposed solution

All three turbines have a power of 10 kW. From here it can be deduced that in one hour of operation these turbines, in the most ideal case, will produce 10 kWh. The working time being 8h/day, the aggregate will produce 80 kWh/day of operation.

The turbine can work throughout the year because it will be necessary to control the water level and limit it, which will favor the continuous transfer of water between the three basins. Over a period of one year with minimal maintenance, the turbine reaches the level of **29.200 kW** of electricity produced.

This fact leads to the reduction of the annual expenses by **4.818 EUR** for the electricity bought from the national suppliers, used for the extraction of water from the underground.

3.3. Net present value

Net present value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows over a period of time.

For the Community of irrigators from Pliego, this calculation can be made and it turns out that the difference between income and expenses is equal to:

3.4. Payback period

The term payback period refers to the amount of time it takes to recover the cost of an investment.

The initial investments made for hydropower development can only be amortized depending on how much electricity it produces. Taking into account the calculations made in point 3.2, the installation has an annual income of 4818 EUR, which means that the amortization of the arrangement with the lowest price, of 14,175 EUR, can be achieved in **2.9 years**, the second solution will require a time of **3.7 years** and for the last and most expensive hydra-energetic arrangement, with the cost of 23,475 EUR, it will take **4.8 years** for the total amortization of the costs.

To these periods of time, 20% of the total time required for depreciation is added in case the installation requires more detailed maintenance, which leads to longer periods of inactivity.

3.5. Internal return rate

The internal rate of return (IRR) is a metric used in financial analysis to estimate the profitability of potential investments. IRR is a discount rate that makes the net present value (NPV) of all cash flows equal to zero in a discounted cash flow analysis.

4. Conclusion

Being known for the qualities of this liquid, water is one of the most important aspects of our human life and ecosystem. It is noticeable that a country like Spain needs a generous amount of this certain component. Sustaining basic human needs and maintaining a friendly environment so that the irrigation process could be efficient is a challenge and a struggle, because of the unbearable and arid climate and the lack of rainfall. Since the role of the water is crucial in many natural circuits, there will be no difference in this case either. Though it is a basic element, a better solution was found. Thus, this turned the water into a developed solution, starting from a plain part and going towards a complex and improved system. It is well known that irrigation is an intricate activity to do and that it consumes plenty of resources for water extraction. Even though there were many solutions to choose from, it was simply not enough to endure the waste and the substitution of the lost energy.

Hence, this certain fluid turned out to be one of the most imperative pieces of the whole system, extracting the energy from water with the help of a Francis turbine, being the only yet effective solution in Spain's situation. Thanks to its position, this device will ease the way the liquid gets in the secondary basins, in case the main one may overflow. Besides, in this certain situation the environment protection is a key aspect, which is achieved by this turbine. Not only is it environmentally-friendly, but it also plays two main roles, the first one being an electricity producer and second, a pump. With the help of its simple construction, impressive costs won't be needed. Even though, like in any other situation, this equipment may have advantages and disadvantages, the crucial side is showing effectiveness in this matter.

Creating and searching for useful and improving solutions is a critical aspect of this problem, which is not only affecting Spain, but also the whole planet, according to the climate and living conditions.

5. References

1. Study case: „Land use and climate change impacts on soil organic carbon stocks in semi-arid Spain"; February 2012 Journal of Soils and Sediments; Authors: Juan Albaladejo Noelia Garcia-Franco Antonio Ruiz-Navarro María Almagro Javier García-Pintado M. Martínez-Mena Roque Ortiz https://www.researchgate.net/figure/Topographic-map-of-Murcia-Province-showing-the-location-of-the-soil-profiles-used-in-this_fig1_257680317

2. "Climate and Average Weather Year Round in Murcia Spain",Cedar Lake Ventures, Inc. ,(May, 2018) https://weatherspark.com/y/40195/Average-Weather-in-Murcia-Spain-Year-Round#Sections-GrowingSeason
3. "Region of Murcia – Maps, History, and Culture"; https://www.mapofus.org/region-of-murcia-maps/
4. Study Case: "Geography and dynamics of economic activities"; by The Observatory of Economic Complexity (OEC); (2020) https://oec.world/en/resources/about
5. "What is Water Turbine : Working & Its Applications" https://www.elprocus.com/water-turbine/
6. "What are Spain's Main Exports and Imports", (2020) https://www.icontainers.com/us/2020/01/21/spains-main-exports-and-imports/
7. Study case by REPSOL "Circular economy" https://www.repsol.com/en/sustainability/circular-economy/index.cshtml
8. Proceso de unificación de las Comunidades de Regantes de la Huerta de Pliego. 2022. Comunidad de regantes de pliego. https://crpliego.es/
9. "Circular economy: definition, importance and benefits"; (2022) https://www.europarl.europa.eu/news/en/headlines/economy/20151201STO05603/circular-economy-definition-importance-and-benefits
10. Study case by Murcia Dreams named "Murcia City" https://murciadreams.com/area/murcia-city
11. "Water and civilization: learning from the past" https://www.wearewater.org/en/water-and-civilization-learning-from-the-past_338471
12. "A Brief History of Water and Health from Ancient Civilizations to Modern Times"; by IWA Publishing https://www.iwapublishing.com/iwa-publishing
13. "Information about Francis turbine"

https://www.renovablesverdes.com/ro/turbina-francis/#Caracteristicas_principales

14. "Causes and Solutions of Water Turbine Cavitation" https://www.fstgenerator.com/ro/news/20220308/
15. "Francis hydraulic turbines; Fundamental parameters, Design calculations", by Ioan Padurean, Anton Iosif; publishing house Eurostampa
16. "Electrical installations" by Dan Stematiu, Conspress Bucharest, 2008
17. "5kw-35kw Francis turbine generator for grid and off-grid usage"; Mong Kok Road, Kowlon, HK Company https://www.hs-dynamics.com/product/10kw-35kw-francis-turbine/
18. "Micro Hydro Francis Water Turbine Manufacturers From 10 Kw to 70 Kw"; Focus Technology Co. https://cdforster.en.made-in-china.com/product/yZGQAhSDZuco/China-Micro-Hydro-Francis-Water-Turbine-Manfacturers-From-10-Kw-to-70-Kw.html
19. 10KW Hydro turbine generator https://www.micro-hydro-power.com/10kw-hydro-turbine-generator/
20. Tubo PVC saneamiento ø315mm SN2 compacto https://mundoriego.es/producto/tubo-pvc-saneamiento-315mm-sn2-compacto/
21. Corporate Catalogs https://www.comeval.es/descargas/catalogos-corporativos/

22. Double Flange type butterfly valve
23. https://thebellowssealedvalve.com/products/butterfly-valves/231544-2/
24. "Francis Turbine – Diagram, Working, Parts , Advantages, Applications"; by Learn Mechanical Engineering https://learnmech.com/francis-turbine-diagram-working/
25. "Map of the hydrographic network of the Segura watershed", by Wikipedia https://es.wikipedia.org/wiki/Archivo:Mapa_de_la_red_hidrogr%C3%A1fica_de_la_demarcaci%C3%B3n_hidrogr%C3%A1fica_del_Segura.jpg
26. "STUDY OF COMPRESSED AIR AS AN ALTERNATIVE TO FOSSIL FUEL FOR AUTOMOBILE ENGINES", Authors: Prof Bharat Raj Singh, Onkar Singh https://www.researchgate.net/publication/265679036_STUDY_OF_COMPRESSED_AIR_AS_AN_ALTERNATIVE_TO_FOSSIL_FUEL_FOR_AUTOMOBILE_ENGINES
27. Study Case "Fundamental of valves and their types" by Star Web Maker https://www.ispatguru.com/fundamental-of-valves-and-their-types/
28. Study Case "Spain electricity prices" by Global Petrol Prices https://www.globalpetrolprices.com/Spain/electricity_prices/#hl223
29. Information about the electricity price exchange by Red Eléctrica de España https://www.esios.ree.es/es?locale=es
30. Study Case "Payback Period" by JULIA KAGAN https://www.investopedia.com/terms/p/paybackperiod.asp

4. THE IMPACT OF DIGITAL CONTROL SYSTEM ON WATER MANAGEMENT

Mentors:

Assoc. Prof. Oana Driha

Prof. José Manuel Casado

Universitat de Alacant

Company:

Comunidad de Regantes de Pliego

José Ángel Perez

Students:

Tatiana Moreno Bastidas

Politecnico di Torino, Italy

Iliana Seferidou

International Hellen
University, Greece

Content of the project

2.3.4. Impact on the Ecosystem services

3.Investment cost and profitability analysis

3.1 Cost of the proposed solution

3.2 Benefit of the proposed solution

3.2.1. Direct Costs

3.3 Net present value

3.4 Payback period

3.5 Internal Return Rate

4. Conclusion

5. References

Executive summary

In this paper we analyze the benefits connected to integration of the telecontrol and automation systems in water irrigation management. This process was developed together with the company of Comunidad de Regantes de Pliego in order to find out what have been the real impacts that the integration of these systems has brought within their supply chain after the modernization plan finished in 2020. For this project, we analyzed different spheres related to the impacts of the system from the inside of the company to outside at the level of environmental, social and economic impacts.

Problem statement

Murcia, the region where the Pliego Irrigation Community company is located, is characterized by its semi-arid climate where low rainfall added to high temperatures causes scarcity of water resources. Paradoxically, this region represents 20% of Spain's national exports of fresh fruit and vegetables, with more than 357.738 hectares of agricultural land during 2021 (CREM, 2022), of which 83% of the land corresponds to irrigable area. The work carried out by the irrigation communities is therefore vital for the proper management of water resources in agriculture, supplying the amount necessary for the growth and development of crops. To improve the current systems, it is necessary to consider the integration of new technologies such as remote control that allow a more efficient use of resources.

Solution

The irrigation modernization plan carried out in the irrigation community, brought with it the implementation of the remote control and system automation system. With the integration of this technology it has been possible to generate both energy and water savings, which also allowed to reduce the price of water, from 0.30 cents to 0.28 cents per m3 for the farmers.

The remote control and automation systems are supported by humidity sensors and meteorological stations that are distributed in the almost 850 hectares corresponding to the irrigable area within the Irrigation community of Pliego.

The sensors help measure variables such as soil moisture, surface or subsoil temperature, and conductivity, allowing to have accurate and live information on soil conditions. On the other hand, the meteorological stations take data from all the environmental and agronomic variables that influence the development of the crop such as temperature, pressure, humidity, rain, evapotranspiration, wind and solar radiation. All this data allows future irrigation planning together with soil moisture to know when to water the crop.

The integration of other technologies is also proposed to improve the accuracy of the data within precision agriculture. Crop mapping is considered one of the most efficient, allowing crop zoning and thereby knowing the corresponding irrigation cycles for each crop found in the area.

Value

The remote control system becomes an information and management tool that also allows visualizing and controlling the water supply. Without the need to physically see the counters, it is possible to know the volume consumed by each farmer, when it is done, what flow is being derived from the network, and the state of the pressures. A whole complex hydraulic system, such as that of the Community of Pliego Irrigators. Allowing to establish a whole water distribution control system that is integrated into the DNA of both the community and the farmers. Having a system that is controlled, which enhances the possibilities of improving the way in which resources are used in each one of his crops.

Final thoughts

Promoting the modernization and technification of irrigated agriculture makes it possible to increase the efficiency of irrigation, which leads to water and energy savings through the improvement of systems.

Water is an increasingly scarce commodity, subject to growing demand, which is why it is essential to integrate a mechanism to have a sufficient quantity, generating the least possible impact on the environment. A point where supply management tools face demand management and change the paradigm from generating more with greater quantity to generating more with a responsible use.

Positioning the remote control system as the means that allow the rational use, automatic and centralized management of the irrigation network. Providing the Pliego Irrigators Community first, with an efficient and automated system; efficient insofar as it specifies when and how much quantity should be used, and automated, reducing the hours of work destined to irrigate the fields, improving the quality life of farmers.

Second, it allows them to join information societies through the implementation and management of new technologies. And third carry out technical management operations, such as actions on the opening and closing of valves, sensor readings, economics with the reading of counters and finally the administration of the irrigators, plots and crops that comprise it.

1. Project overview

1.1 Introduction

1.1.1 Use of telecontrol in the irrigation water management sector

Irrigation is mostly considered as an effective way to increase agricultural production, supplying the amount of water necessary for the growth and development of crops. But at the same time the agricultural sector is also known for being the sector that consumes the largest amounts of this source, and is most affected by its scarcity. Especially in areas with semi-arid climates where low precipitation added to high temperatures, causes scarcity of water resources.

Is here where irrigation water management has an essential role, establishing proper timing and regulating irrigation so that it covers the necessary water requirements of the crop without wasting water, energy, plant nutrients or degrading the soil, all looking for greater efficiency.

This is why remote control systems have become a fundamental tool when it comes to managing resources. These systems contribute to the optimization of energy consumption through the programming of the installation according to the schedule and type of rate, something that undoubtedly helps to reduce costs. These systems allow various operations to be carried out remotely thanks to computer, electronic and telecommunications technologies.

In addition, the system allows remote action on the elements of the hydraulic networks, (the hydrants), from which water is provided to the irrigator. The basic functionality of a Telecontrol System is to centralize the information. This is why the remote control installations facilitate the automatic and remote reading of the volume of water used, and allow the opening and closing of the valves controlled remotely.

In irrigation communities, automation and remote control is a system that helps improve competitiveness, facilitates the planning and execution of infrastructure maintenance tasks, and helps optimize available water, since it allows irrigation at any moment of the day.

1.1.2 Interest of the company and circular economy

The interest of the Irrigation Community of Pliego in integrating the remote control system within its modernization plan is then reflected in the search for the optimization of energy consumption, the guarantee of continuous supply and the reduction of operating costs, which can lead them to make more efficient use of the resources available.

This is where the concept of circular economy is integrated into the project, since irrigation management is here similar to the role that ecodesign plays within the circular economy, creating a certain product or service using the least amount of resources, optimizing the amount of materials and energy, protecting resources and reducing emissions.

The remote control system is then an instrument that allows decisions to be made based on the collection and analysis of data that contribute to improve the efficiency of the use of resources.

1.1.3 Objective of the project

The objective of this project is to analyze the impacts of the implementation of remote control systems in the irrigation water management of the Pliego Irrigation Community, taking into account the various spheres that make up its context, from environmental, social, cultural and economical aspects. Which in turn are reflected in the local reality being a company that integrates almost 1,500 community members of the region.

1.1.4 EU Policies

The EU is at the forefront of international efforts to promote economically, environmentally and socially sustainable development to address the planetary crisis and in particular to fight climate change. On 11 December 2019 the European Commission presented The European Green Deal – a roadmap for making the EU's economy sustainable by turning climate and environmental challenges into opportunities across all policy areas and making the transition just and inclusive for all.

The European Green Deal is Europe's structural response and new growth strategy that sets out ambitions to transform the EU into a modern, resource-efficient and competitive economy where:

- There are no net emissions of greenhouse gasses by 2050
- Economic growth is decoupled from resource use
- Natural capital is protected, sustainably managed and restored
- The health and well-being of citizens is protected from environment-related risks and impacts
- No person and no place is left behind.

The EU Green Deal

- Provides a roadmap with actions to boost the efficient use of resources by moving to a clean, circular economy and stop climate change, revert biodiversity loss and cut pollution;

- Outlines investments needed and financing tools available and explains how to ensure a just and inclusive transition;
- Covers all sectors of the economy, notably transport, energy, agriculture, buildings, and industries such as steel, cement, ICT, textiles and chemicals.

EU Green Deal - Main Points

Circular economy. Circular economy is a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing energy and material loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling. This is in contrast to a linear economy which is a ‘take, make, dispose’ model of production.

- The new Circular Economy Action Plan, March 2020, includes a sustainable product policy with prescriptions on how we make things, in order to use less materials, and ensure products can be reused and recycled.
- Carbon-intensive industries like steel, cement and textiles, will also focus the attention under the new circular economy plan. One key objective is to prepare for “clean steelmaking” using hydrogen by 2030. New legislation was presented in 2020 to make batteries reusable and recyclable.

Agriculture. There is an important interaction between agricultural and environmental policies. The recently published Farm to Fork strategy is aiming to make food systems fair, healthy and environmentally-friendly. Another important legislative framework is EU Common Agricultural Policy (CAP), that has been increasingly adapted for integrating environmental concerns and to serve sustainability purposes better.

1.2 State of the art

1.2.1 Supply chain

The supply chain of the Comunidad de Regantes de Pliego consists of five steps before the water reaches the cultivated fields: extraction, transport, containment, filtering and distribution.

Extraction. The chain begins with the **extraction** of the water. According to the dossier of the company the total amount of water that the company manages is 3,629,359 m^3/year. Comunidad de Regantes de Pliego obtains water from three different sources:

1. Pozo de las anguilas

2. Trasvase Tajo-Segura
3. The E.D.A.R.

Pozo de las Anguilas is the main source of groundwater for the Comunidad, in fact they obtain from it the majority of the water they use for a total of 2.326.158 m^3/year.

The Trasvase Tajo-Segura concession in favor of the General Irrigation Community has a maximum volume equal to 1,140,000 m3/y of surface water, for agricultural irrigation.

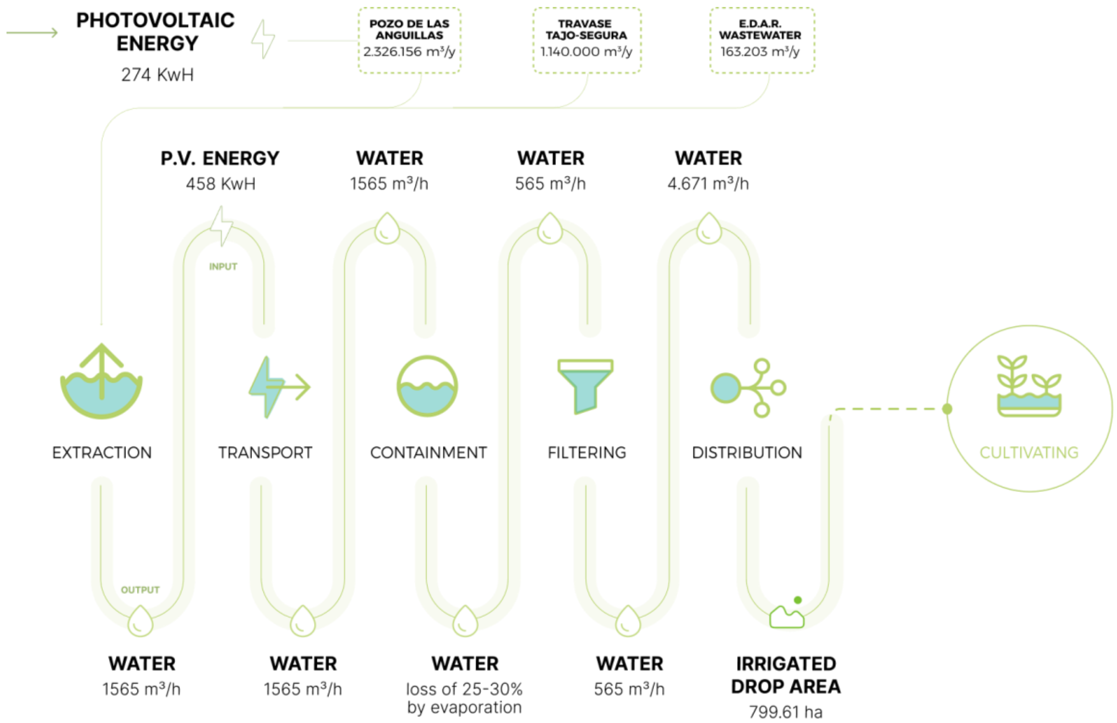


Figura 3 Supply chain, Comunidad de Regantes de Pliego

Finally, the E.D.A.R. (Estación Depuradora de Aguas Residuales) responsible for the waste water purification station of Pliego, is managed by the Confederaciòn Hidrogràfica del Segura. Providing the amount of water purified by the E.D.A.R. to all the local Comunidades de Regantes. From this entity the Comunidad de Regantes de Pliego obtains 163.203 m^3/year of reclaimed water.

This phase - water extraction and pumping - represents almost 90% of the total energy used by the company to develop its activity. And although the company has photovoltaic power plants, these only represent 17% of the total energy needed for operation between the extraction and transport of water, leaving 83% that must be acquired from the electrical network.

Transport. Since all the basins are at a different level, the company needs energy to transport the water from one basin to another, For that they use the energy provided from the solar plant, for self-consumption with anti-spill to supply all the electrical receivers, that hang from the main transformation center of the Comunidad de Regantes de Pliego.

The basin on the top supplies the entire upper orchard and the one on the bottom supplies the entire lower orchard, but there is only one central unit, which is the one that has the water pumps that communicate the water from the lowest to the highest. When there is sun this energy is used to carry water from one basin to another.

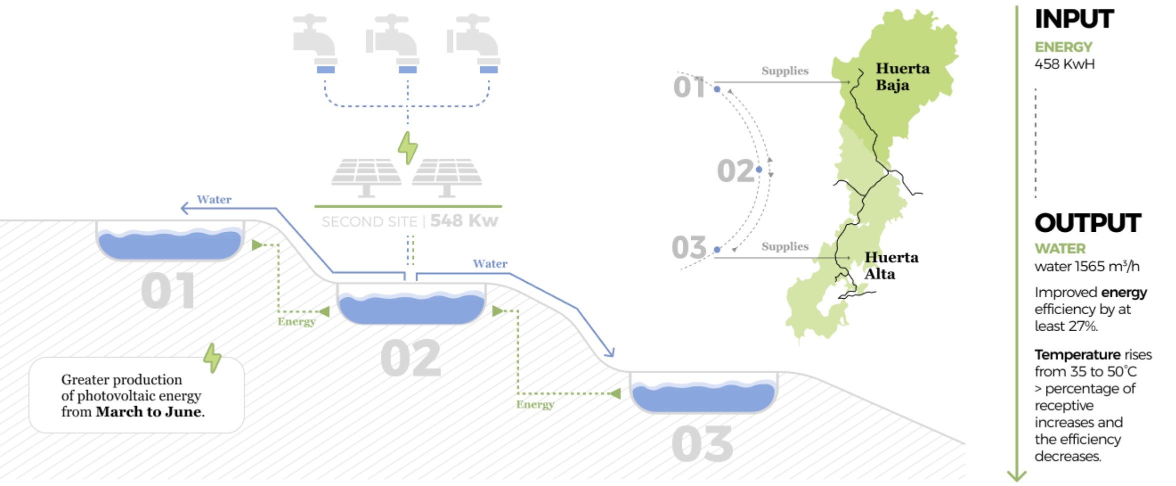


Figura 4 Position of the basins, Comunidad de Regantes de Pliego

Containment. For the containment the company has at its disposal three basins in operation and contain the mainstream of 1,565 m3 of water. At the moment just two of them are covered, so they still have a water loss that represents 25-30 % by the evaporation of water from one of the basins. However, the company received the approval by the European Commission for a project involving the coverage of the last basin. It will be financed by the NextGenerationEU fund and will be developed in 2023.

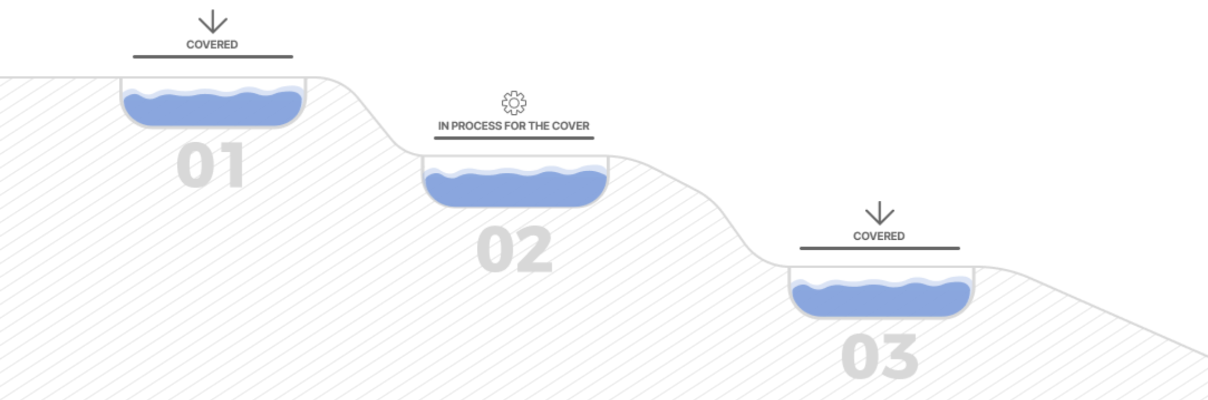


Figura 5. Basins and its disposal, Comunidad de Regantes de Pliego

Filtering. Before the water is distributed to the two main points of Huerta Alta and Huerta Baja, there are two points of filtering that work with a mechanical system to clear the water and remove any impurities, positioned in correspondence with the basins.

Distribution. The company has provided 4,671m3 per hectare. The water gets to the fields thanks to the force of gravity as they are located high above the fields, reaching approximately 850 ha of crop area, and thanks to the installation of the telecroltrol systems, the irrigation of the crops. It can be carried out from anywhere, without having to go directly to the plots or crops and program, close or open the water pipes for irrigation through devices such as tablets, computers, telephones, among others. Allowing the irrigation task to be carried out based on the data collected in the field, thanks to humidity sensors and weather stations, farmers have precise information on the state of the crops, which allows them to manage the irrigation cycles for each one of his crops.

1.2.2 Telecontrol systems in irrigation

Spain has become a world leader in modernized irrigation. According to the newspaper Ágora, in an interview with the president of the National Federation of Irrigation Communities, (Fenacore). It is estimated that remote control systems have been implemented in more than

one million hectares in the country, information that was presented after the last edition of the Survey on Surfaces and Crop Yields in Spain (ESYRCE) carried out by the Ministry of

Agriculture, Fisheries and Food of Spain during the year of 2020. It is stated that more than 76% of the irrigated area is in Spain, of which almost 3 million hectares are modernized.

By implementing these systems, irrigation on demand has been possible, especially in those cases in which it is necessary to establish shifts and night irrigations are carried out. The greatest advantage is that it prevents the irrigator from having to go to the farm or croplands after hours, if it is then is when is his time to irrigate, which significantly improves the farmer's quality of life.

The integration of these remote control systems can reduce costs, since they make it possible to choose the moment to irrigate and help to carry out these tasks during the off-peak hours. That corresponds to the time slot between 00:00 and 08:00, during the week and throughout the whole day on weekends and holidays. Hours when electricity is cheaper.

However, it must be taken into account that its implementation requires economic investment and maintenance. According to the president of Fenacore, Andrés del Campo

> modernization and the incorporation of technology to make more efficient use has allowed us to produce more with less water, but with a higher cost of energy. For this reason, it is urgent to reduce the bill to accelerate the modernization of the 902,000 hectares still pending and continue extending the remote control systems. (Campo, quoted in Ágora, 2020)

1.2.3 Facilities and Modernization Plan 2014-2020

During the period 2014-2020 the Comunidad de Regantes de Pliego completed the modernization plan that allowed them to improve the transport, distribution and storage of water. This modernization plan was carried out by the Ministry of Water, Agriculture, Livestock and Fisheries, as part of the Rural Development Program of the Region of Murcia 2014-2020. This initiative, according to the counselor of Water, Agriculture, Livestock and Fisheries, was financed 63% by the European Agricultural Fund for Rural Development (EAFRD), 25.90% by the Autonomous Community and 11,10% by the Ministry of Agriculture and Fisheries, Food and Environment. (Del Amor, quoted in Retema Magazine, 2018)

The works included 17 actions carried out simultaneously in the two sectors of Huerta Alta and Huerta Baja that allowed them to replace the current system of irrigation by surface with a localized drip irrigation system; it included a system of automation of irrigation, that helps the management of the system through a device with internet; and, the implementation of renewable energy plants.

The activities on the sector I Huerta Alta covered 351 hectares with a budget of 3 million euros. Among the actions carried out, the improvement of individual irrigation systems and an extension of the existing irrigation network stood out. In addition, agroclimatic stations were implemented with the aim to favor the decision-making of farmers, the efficient use of water and the reduction of the water footprint.

The weather stations allow greater control, through data of all the environmental and agronomic variables that influence crop development. The company currently has 7 meteorological stations, distributed in the area.

Moreover, to reduce the evaporation of water from the basins (that reaches 25-30% during the hot season) two raft covers were installed on two of the three basins. The last one that is currently uncovered, plans to be covered during the year 2023

In Sector II Huerta Baja, which has 426 hectares of land and a budget of 5.8 million euros was allocated to allow the development of the modernization plan, where the reservoirs were updated. In addition, a general driving system with a length of 3911 meters and filtering station was developed.

Finally 1773 photovoltaic panels were installed and were distributed into two different plants, one with greater energy production potential than the other.

It should be noted that as mentioned by the water councilor Miguel Ángel del Amor the region already has 85 percent of its irrigable surface modernized and reuses 98 percent of the water. In addition, on one of his visits to Pliego he stressed that "the new Water Pact reiterates the commitment of the Region to move forward in the reuse of water and the improvement of existing facilities". (Del amor, quoted in Retema magazine, 2018)

1.2.4 Existing solutions: case studies

Aquarson by Arson and Neiker-Tecnalia. The project is an initiative to improve the management of water resources. With this objective, the Basque company Arson on remote engineering and the knowledge of Neiker-Tecnalia (Basque Institute for Agricultural Research and Development) on agronomy and water needs of crops have joined forces.

Aquarson's technology makes it possible to establish a network of remote equipment communicated by radio frequency which, connected to a centralized management and control software, sends irrigation instructions to the hydrants. Likewise, it collects information on the irrigation tasks carried out and the hydraulic operation of the installation. The irrigation instruction is sent from a management and control application tool, expressly designed for the management of irrigation systems and installed on a computer located in the Irrigation Community offices.

Among the benefits provided by this technology, the possibility of combining various communication methods stands out. The system is capable of establishing its communications by combining GPRS, radio frequency and cable technology (among others) to adapt to the needs of each installation, depending on the type of handling and management required, the size of the irrigated plot and its orography. (Aquarson, s.f.)

i**ControlRemote by AISco.** This remote irrigation management product uses GSM technology to monitor and manage the irrigation systems from just one place using the mobile phone. With this system it's possible to find all charts and reports that will help to make the good decisions for the maximum productivity of the operations.

The webpage helps farmers to facilitate the process of organizing, monitoring and controlling irrigation. The system works by installing the control device and linking it to pivots, pump, temperature and humidity sensors, and supports connecting to the mobile phone network, the Internet, and controlling and following up operations through smart phones.

This system integrates three tools, **iControlRemote** displays historical operations in a graphic format and visualizes the status of the irrigation systems during the growing season.

iControlPump which is the automation and remote management tool for pumping. It's well-known problem-free connection between the pumping process and the solenoid valves even on irregular land or where there is no mobile telephone coverage. The last tool is **iControlTotal** which is a remote management and automation tool for pumps, solid set, drip and pivots using the Internet. It helps to increase precision control of the frequency of weather conditions. A multifunctional product custom-designed according to each field's needs thanks to the expansive available features catalog. (Aiscosolutions, s.f.)

Smart irrigation in Barcelona: introducing the new system. The new smart irrigation system of parks and gardens in Barcelona, one of the leading Smart Cities in the world. The implementation of this new system was created in collaboration with the Barcelona City Council.

The sensors gather information about humidity, salinity, temperature, wind and several other factors that automatically regulate the amount of water by means of a program that can be managed with computers, smartphones and tablets. The graphical user interface is really friendly, as you it's shown:

The general manager of Water Cycle in Barcelona, Antoni Vives, stated that this new Smart irrigation system will enable up to a 25% saving of water and that it’s a system that many cities in the world arguably will implement.

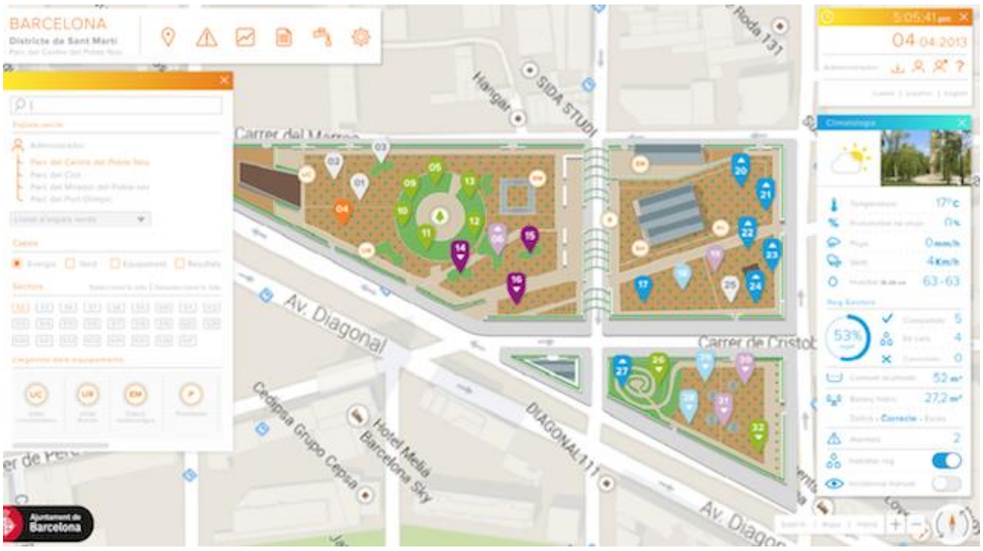


Figura 6 Screenshot Smart irrigation in Barcelona, 2014

Remote-control and Supervision of Irrigation Systems: An Attempt to Better Water Management. This study addresses the control of irrigation systems to ensure proper management of water use. First, we considered the management problem of open channels. For this purpose, a fuzzy controller for the irrigation canal has been developed to control the flow emitted from the dam to meet the settings set downstream of the system and the user's requirements at various abstraction points. did. In the second stage, the supervision stage of the agricultural irrigation system was proposed. The purpose was to control the water distribution of the various plots to be irrigated. To this end, the water management system under consideration, its equipment, and its control software architecture were presented. A functional survey of the system was performed using the GTST-MPLS method (Goal Tree Success Tree-Master Plan Logical Diagram). Finally, monitoring tools related to the developed irrigation system were presented.

1.3 Description of the Company's system

Through the modernization process, the Pliego Irrigation Community company was able to incorporate a remote control system with **Batchline Control** through the **Irrigest Irrigation**, a community control and management application that makes possible to facilitate preventive maintenance tasks and add value to its traditional ditches.

The community is integrated to Batchline Control under the name of Comunidad de Regantes TTS de Pliego sector ll. It handles remote management of the irrigation network and the discharge network, including the control of 8 discharge network stations (transfer intakes, reservoirs, pumps and filter stations) and 146 groups of hydrants.

This remote control system has at its disposal the information that is collected through the 7 meteorological stations that the community has, in order to know the climatological variations of the irrigable zone, information that is integrated into the system and is later communicated to the community members. The second source of information integrated into the system is found in the humidity sensors that are distributed by zones within the company's almost 850 hectares of irrigable area. This technology allows to collect information regarding moisture in soil, surface/subsoil temperature and conductivity. Data that after being processed by the systems, leads to greater knowledge of the current state of crops and leads to better use of irrigation water.

1.3.1. Telecontrol system - Batchline Control, Irrigest

The remote control system uses radio frequencies and GRPs that maximizes the water-energy efficiency of the crops. It allows managing the operation of the irrigation facilities according to the irrigation plan, the electrical consumption of variable speed drives and the water consumption in terms of water flows, pressures and consumption.

The system allows irrigation to be planned according to the relevant information that is available in order to later analyze all the data stored on a server. It monitors the behavior of the installation in real time and, with its analyzes and recommendations, increases the profitability of the operation with a reduction in costs and an increase in production.

It allows pumping systems to be put into operation, reads meters and allows opening and closing valves, from any mobile device. Having the advantage of being able to control it remotely through the Web. The system prevents the farmer from having to go to the field to put the irrigation valves into operation, having the possibility of doing it anywhere, at the most convenient times, taking into account all the data that is collected and stored. The system allows:

Change irrigation schedule dates. Change the dates of the irrigation program must be modified. Start Date and End Date of the irrigation program

Open and close the water outlets. The initial operation of the irrigator is related to the need to turn on and off the water from the phone, computer or tablet.

This is done through the (Activate) and (Deactivate) functions in the Irrigation Program Configuration section.

Having made a previous programming of 24 hours seven days a week. This refers to the time that the availability of water during this previously determined time.

When the irrigation program is (Activated), the hydraulic valve opens and the irrigator has water in his irrigation head; If the irrigation program is (Deactivate) the hydraulic valve cuts off the water supply and the irrigator's irrigation head runs out of water, that is, it closes.

Advanced Scheduled Irrigation Operations. It is used when Program no. 1 has already defined the general irrigation plan for the plantation as it shows in figure 6. It means that the person has already defined the days they want to irrigate, the start time, the duration and the irrigation intervals, which can be up to 4 intervals per day.

This information can be changed, and once configured the registered information is sent to its application in the telecontrol system.

But there may be a need to have water at a time when program No. 1 does not have to water. For this it is necessary to activate program No. 2 to change it to an alternative irrigation program and be able to open (activate) or close (disable) manually, as it shows in figure 7.

Consult the history of consumption. With a daily, weekly, monthly summary of the volume of water used.

Consul the reading history. Which allows to know:

- The consumption in a certain period- according to date range, week and daily
- Know the irrigation flow
- Check if the irrigation is working as planned, since it does not have a change in the number of drippers.

Figura 7 Irrigation setting of program n1 Font: CR ARGOS, 2022.

Figura 8 Irrigation setting of program n.2 Font: CR ARGOS, 2022.

1.3.1.1 Meteorological data tool.

These stations allow greater control, through data of all the environmental and agronomic variables that influence crop development. The company currently has 7 meteorological stations distributed as follows:

- Filtering Station Sector 1, Huerta Alta- Prado
- Station Take 2 of Anguilas - Sangrador
- Station Take 6 of Anguilas - Mill
- Station Take 7 of Cherro - Los Taviras
- Filtering Station Huerta Baja - Oliverica
- Closed - Station H31 Huerta Baja - Cabecicos
- Station Take 17 Huerta Baja - Cañada Los Melgares

The systems take into account different variables as is shown in figure 8 and 9**.** Taking temperature represented in (ºC), pressure represented in (mbar), humidity represented in percentage (%), rain measured in (mm), evapotranspiration in (mm/hr) and wind represented in (km/h).

One more variable that is taken into account but is only collected at the Huerta Alta-Prado station, also measures solar radiation (W/m2). This information captured by the sensors is sent in real time via GSM/GPRS, so that it can be monitored through from any device connected to the Internet. All these parameters are collected to plan future irrigation along with soil moisture to know whether or not to irrigate the crop.

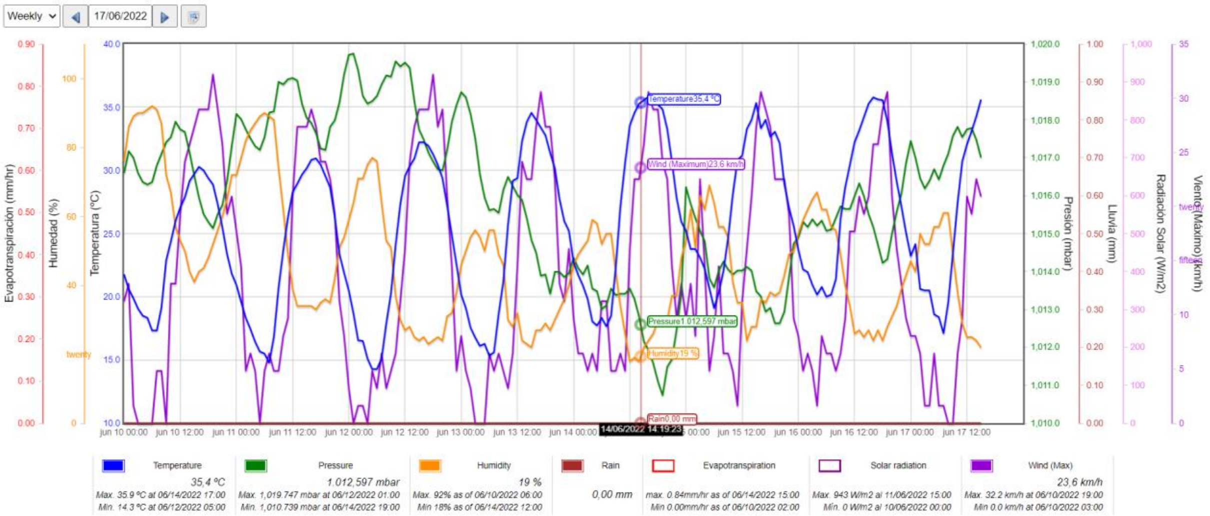


Figura 9 History values from the 13 to 17 of June 2022. Filtered Station Sector 1 - Prado

Font: Comunidad de Regantes de Pliego, 2022.

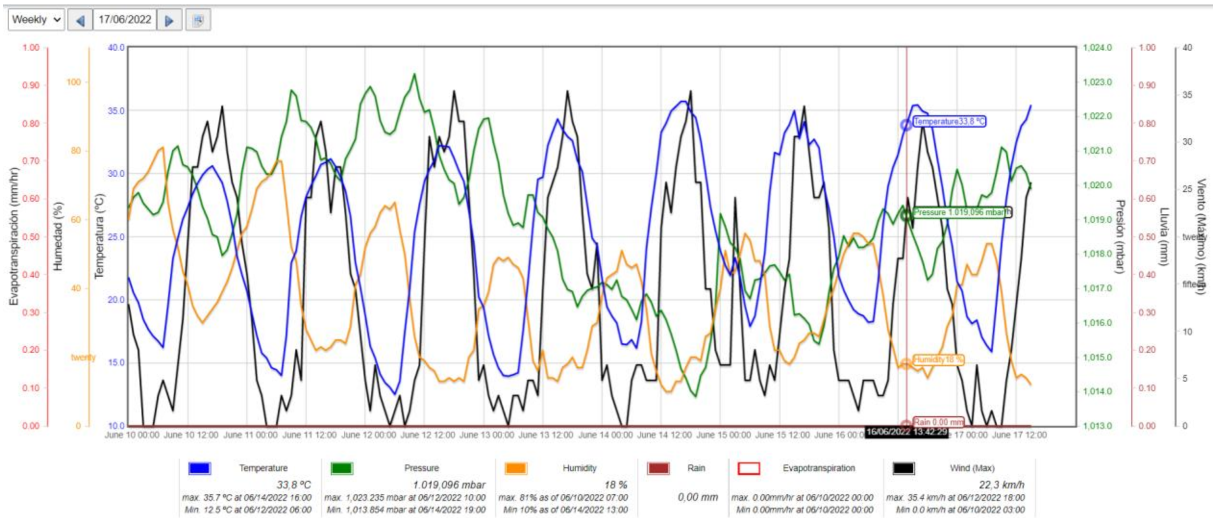


Figura 10 History of values from the 13 to 17 of June 2022. Station take 2 of Anguilas - Sangrador

Font: Comunidad de Regantes de Pliego, 2022.

1.3.1.2 Humidity, conductivity and temperature data tool.

Currently the company has 16 humidity sensors that are distributed in the almost 850 hectares corresponding to the irrigable area of the community between Huerta Alta and Huerta Baja. These humidity sensors consent to measure variables such as the moisture in soil , the surface or subsoil temperature and the conductivity. These sensors are installed in different areas taking into account the characteristics of the type of terrain, which in turn determine the type of crops that are produced there. These probes have the following specifications:

- They are power by : 3 AA batteries

- They have a configurable humidity reading period according to irrigation needs (from 2 minutes to 1 hour)
- Autonomy of : 2 years with measurement every hour.
- Data transmission is carried out: via LoRa radio frequency with a range of up to 700m radius to the Hub/Receiver/Station.
- It has protection against humidity and high temperatures with IP65 approved box.
- Configurable anti-corrosion stainless steel rods to measure at different depths.
- Conductive trend reading (+-0.5ds).
- Reading of surface temperature and subsoil temperature (accuracy of ±1ºC).

These PlantaeSonda sensors allow measuring the humidity of the soil at different depths and automatically, the conductive trend and the surface/subsoil temperature, without the need for cables or installations focused on optimizing irrigation and saving water.

Knowing the humidity, it will be possible to adjust the irrigation cycles, quantity, frequency and duration, to provide the crop with the water it needs within the Easily Assimilable Water zone, as is shown in figure 10. The conductivity reading allows salinity levels to be kept below harmful thresholds for plants.

The two types of depths surface and subsoil the first one allow to measure the surface temperature, which helps to take measurements against frost and other applications. And the subsoil temperature (up to 60cm deep) reflects the state of the root activity of the crop and improves the application of fertilizers and treatments.

These sensors are customizable in measurement depth (up to 1 meter) and reading frequency (from 2 minutes to 1 hour per reading). The probes can be installed both on the surface and buried according to the client's preferences and irrigation characteristics.

In addition, the probes are configured with agronomic algorithms based on the type of soil in which they are installed and its level of conductivity.

The probe housing is IP65 certified, resistant to water and other chemical elements, thus allowing the sensors to be perfectly compatible with the application of irrigation and other phytosanitary products.

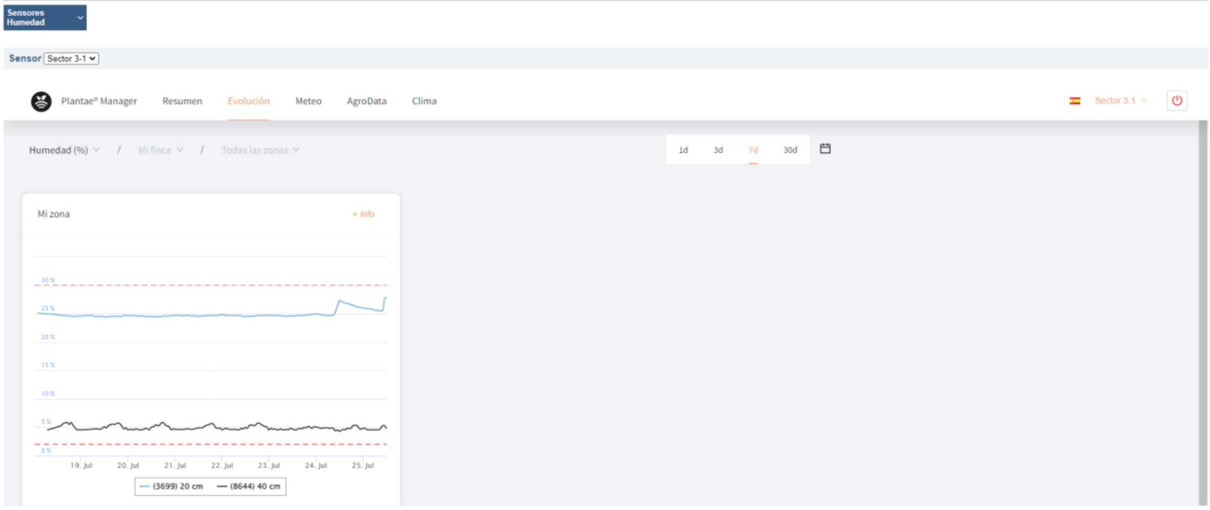


Figura 11 Percentage of humidity in the area of a community member

Figura 12 Installation of humidity sensors, Comunidad de Regantes de Pliego

Font: UPA, 2022.

Figura 13 Installation of humidity sensors, at two different levels Comunidad de Regantes de Pliego
Font: UPA, 2022.

Figura 14 Humidity sensors in crops of Comunidad de Regantes de Pliego after 2 years

1.3.2 SWOT analysis

To better understand the general situation with the implementation of the system in the company, a SWOT analysis(figure 11) was carried out identifying the strengths, weaknesses, opportunities and threats. The following graph shows how some points were re grouped in areas of impact, whether at the cultural, regulation and provision levels. The type of output was also taken into account at the level of knowledge and communication, infrastructure and flows of energy and matter.

Strengths. The strengths of the company mainly concern the regulation actions. By implementing the modernization plan started in 2014 and with it the telecontrol system in terms of flow of matter and energy is considered the **optimization of energy consumption**, as the company can start pumping the water when they see it most convenient, taking into account the most economical tariff periods. It **reduces operational cost** preventing overflow, detecting leaks in pipes, situations that would imply an expense for the company. Allows **smart irrigation** of the fields since the system integrates information and communication technologies to make irrigation decisions based on information collected from crops and monitoring.

In the same way the system helps **rationalize water** controlling the opening and closing of hydrant valves by endowment and a more rational distribution of water is carried out. And finally **facilities irrigation,** avoiding farmers having to go to the fields and to different crops to activate the irrigation systems.

Regarding Infrastructure, it's an **open system,** allowing the integration of hydrants from other manufacturers, as long as they follow the OPC standard based on the ISA S88 / S95 standard.

Weaknesses. Since the main activity of the communities is strictly based on the distribution of water for irrigation, they are not directly involved in **communication plans** with the farmers, and these tasks are left to third parties, such as the cooperatives. The communication within the portal of the comuneros system is very sporadic and individual, they only contact each other when there is a problem of rupture or operation of the system, and the channel of information is very limited. In addition, it should be mentioned that they carry out just two annual meetings but they do not develop as many initiatives of training on new technologies related with the telecontrol.

Adding the fact that the average age of the community members is 55 years, of which the majority are within a low socioeconomic level, characteristics that make it more **difficult for some users to accept the integration** of new practices and technologies.

Opportunities. Inside the regulating opportunities, it's considered the **integration of new hydrants** expanding the network in an open, unlimited and totally intuitive way, at the same point it can integrate other data parameters such as zoning mapping as an approach to water management within the Precision Agriculture (PA) that is just a part of the more complex system of the so called Agriculture 4.0. An opportunity with which the company can

integrate more information technology to ensure that the crops and soil receive exactly the amount of resources needed, based on the crops' irrigation cycles.

At the level of provisioning it is also taken as an opportunity for the continuous **development plans** that have been carried out within the region, a local reality that can affect the way telecontrol is seen.

From the part of the cultural opportunities, regarding the communication and knowledge it can be possible to **improve the technical capacities** of around 1,500 comuneros that are part of the community and requalifying the irrigation sector.

From the other part the implementation can **encourage the cultivation of the uncultivated areas,** which currently correspond to 30% within the irrigable area, managing to highlight the value of water for the plegueros that goes beyond the eco-productive. Coming to have a symbolic meaning with socioeconomic benefits and see it as a strategic element.

Threats. For the main threats for Comunidad de Regantes we have to analyze the **external factors, attributed to the environment** in which the company operates, first as the region of Murcia has a semi-arid climate with low precipitation, the average daily temperature is 30 °C and in the hot season, the expected rise in temperature is a factor that must be taken into account mainly for the drought issue.

The last thear is related with the investment for new improvements, since smaller scale farmers see more investments as something unsustainable and unnecessary preferring to leave the systems as they are **reducing the possibility of an individual investment** in improving remote control systems.

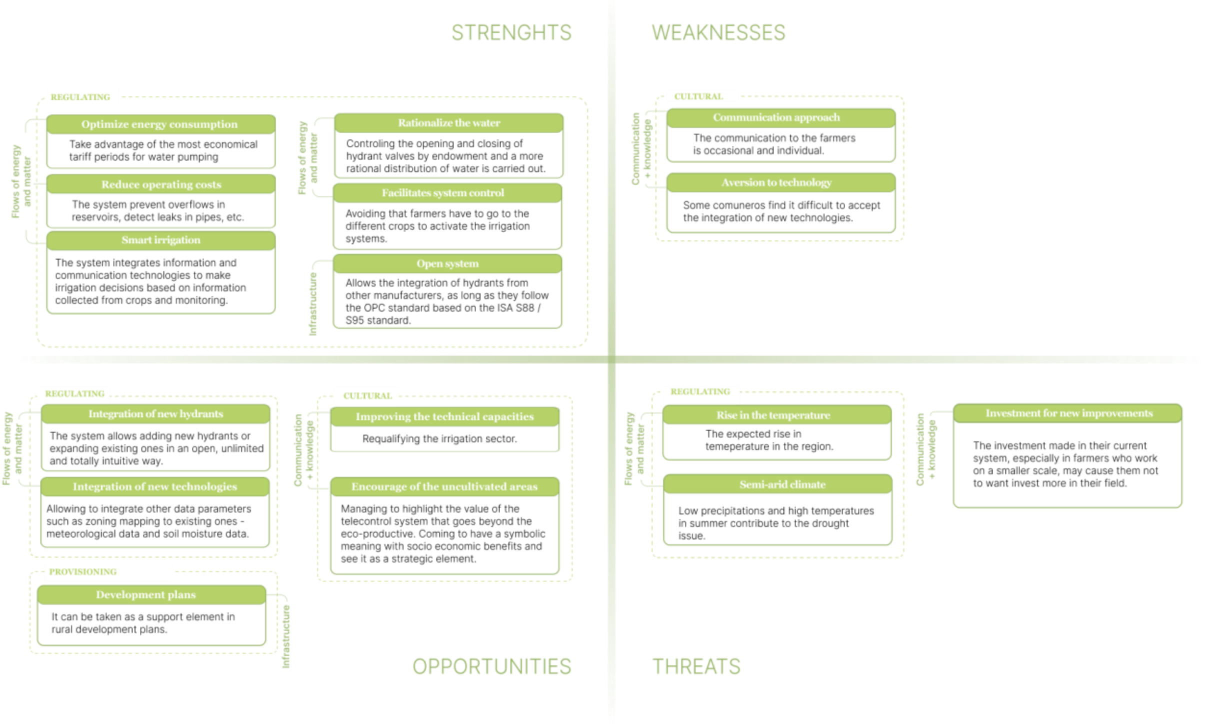


Figura 15. SWOT, analysis and its category of impact

2. The system

2.1 Control and Management Application for Irrigation Community - Irrigest

The IrriGEST Suite is made up of a set of client and fully customized software tools depending on the characteristics of each Irrigation Community, which are executed on a common database, totally open and connected with the field elements, in the case of the Irrigation Community of Pliego, as was mentioned above, this integrates the information from the meteorological stations and humidity sensors distributed on the land and together with other databases or irrigation management systems. This suite also has the following modules, which the company uses:

IrriCONTROL: Supervision and control of hydrants.

IrriADMIN: Billing and management of bank effects.

IrriWEB: Web server for user consultation.

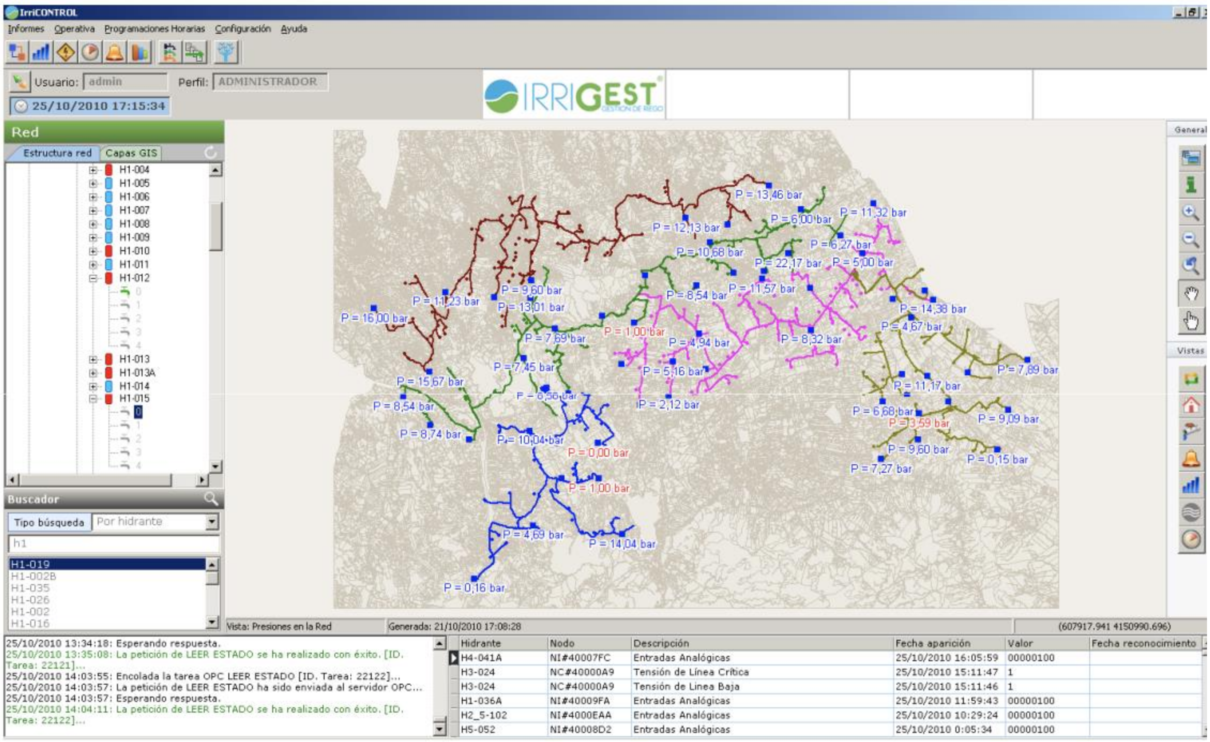
IrriINFORM: Generation of reports defined by the user.

This system allows adding new hydrants or expanding existing ones in an open, unlimited way, it also allows the integration of new hydrants from other manufacturers, as long as they follow the OPC standard based on the ISA S88 / S95 standard.

2.1.1 IrriCONTROL

It is a bundled application to monitor and control the irrigation system. It is based on communication with remote control systems via OPC link and storage of historical data based on SQLserver data.

This has functions such as: the supervision and control of hydrant meters and valves, geographic information system (GIS), control and feeding of the nodes, the programming of the irrigation schedules taking into account the optimization of the flows that are supported by the hydraulic network of the community. As well as the presentation of trend curves and reports for preventive maintenance.

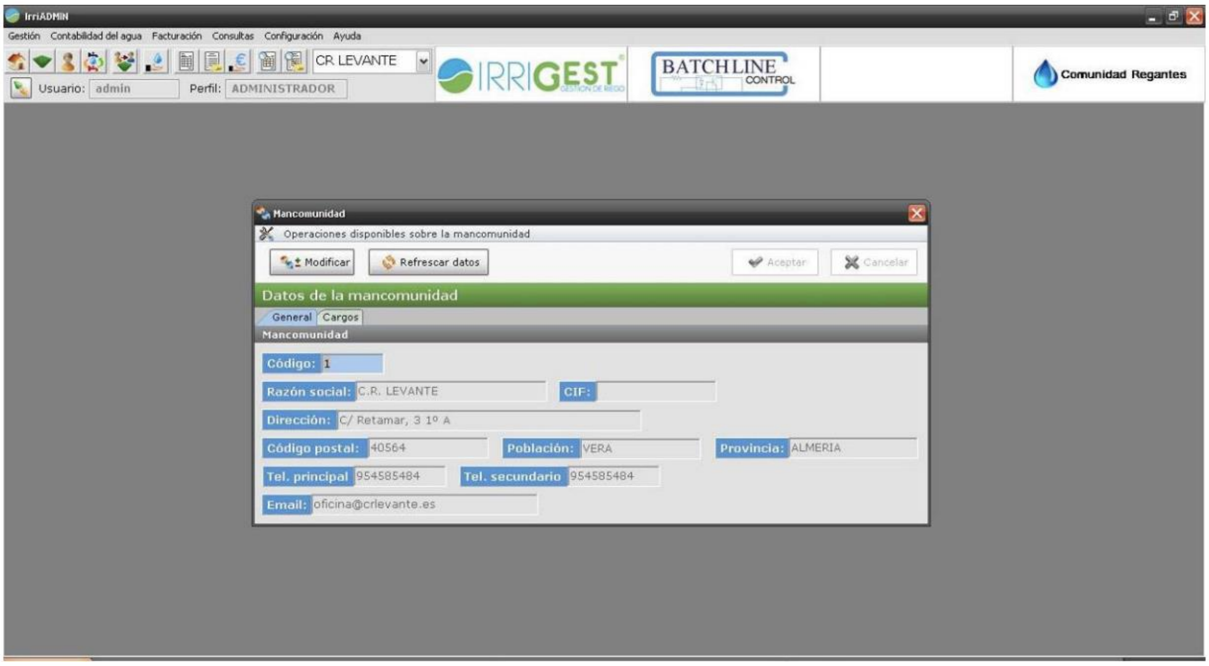


2.1.2 IrriADMIN

It allows to manage and control the data of the Irrigation Communities, as well as the consumption bills read from the remote control systems. It has functions such as the data management of Commonwealths and the management of plots.

It allows the assignment of irrigation units, plots and irrigators, and manages the consumption and accounting of water.

The system allows billing and generation of bank statements, as well as communication with accounting applications.



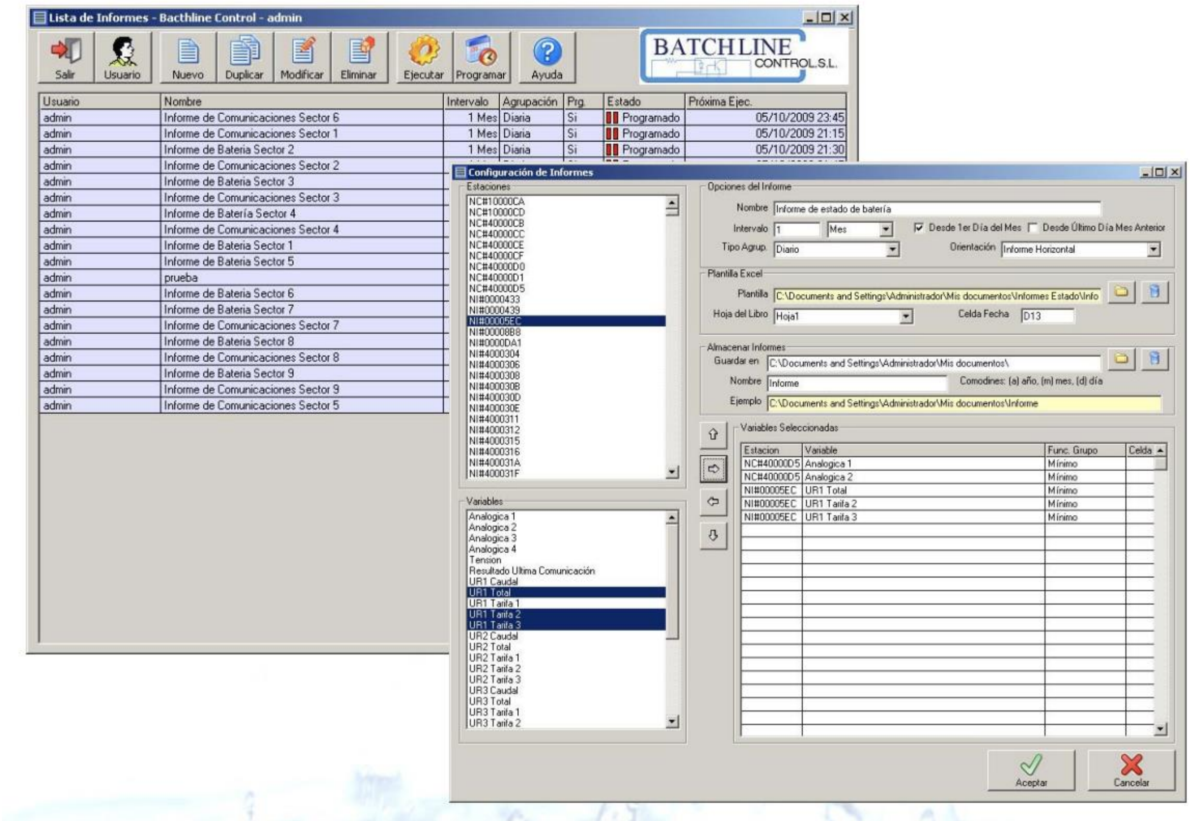
2.1.3 IrriWEB

It is the service for consultation and programming of irrigation systems that can be viewed by both users and administrators, in this case the IC of Pliego. This also has historical data storage and also has functions such as, the hourly programming of irrigation units, manual operations on the intake, consumption history query, query of latest billings, all this through remote access of the users / administrator via Internet.

It offers secure access to user data through a login with a staff for each of the users, having continuous access to systems and billing data.

2.1.4 IrriINFORM

It allows generation of personalized reports in XLS format on the data collected by the Telecontrol system. This has the control of reports by the user, the design of XLS reports by selecting variables from the remote control system and the programming of report generation automatically.



Summing up, Figura 16 depicts the Irrigest system applied in the Irrigation Community of Pliego which includes the application of the four main tools.

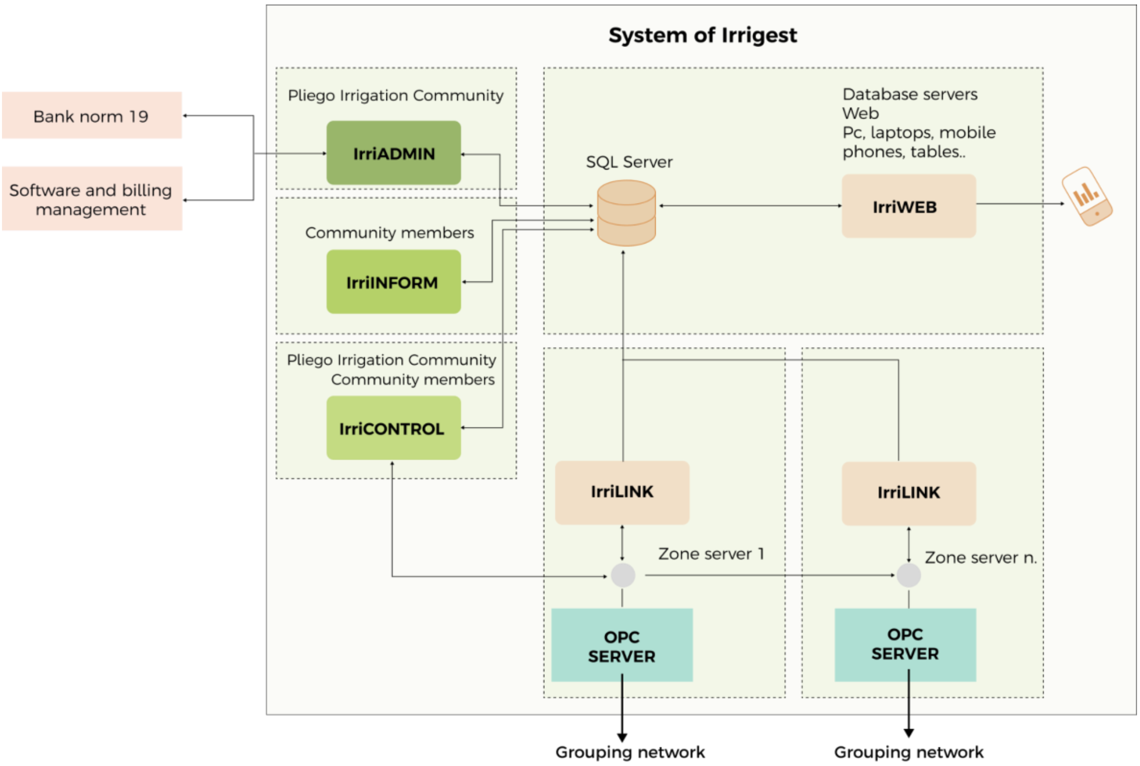


Figura 16 Irrigest system applied in the Irrigation Community of Pliego

2.2 Calculation of system integration

2.2.1. Evaluation on the solution

Concept	Year 2021	Year 2020	Year 2019	Year 2018	Year 2017	Year 2016
	m3	m3	m3-hours	m3-hours	m3-hours	m3-hours
SECTOR 2						
Subsector - Las Anguilas	240.669,50	331.374,00	317.591,60	294.057,00	346.688,00	283.278,00
SECTOR 1						
Subsector - El Cherrro	224.330,20	264.166,20	276.317,80	282.721,00	247.347,00	339.630,00
Supplies to works			25	10.996,100		
Traditional irrigation S1	0 h	0 h	25,50 h	25,50 h	66,50 h	191,50 h
	0,00	0,00	3.213,00	8.379	7.623	
Relief irrigation	26.923,00	26.232,00	32.329,00	53.976	56.182,00	50.148,00
Traditional irrigation S2	0 h	0 h	694 h	2.270,25 h	1.484,25 h	2.600 h
	0,00	0,00	87.444,00	286.051,50	187.015,50	327.600,00
Drip irrigation	275.495,00	337.229,90	196.606,60			
Total liters /m3	767.417,70	959.002,10	913.527	936.180,50	844.855,50	327.600,00
Total revenues	214.876 €	268.520 €	274.058 €	280.854,15€	253.456,65€	301.245,30 €

Tabla 1 Amount of water provided annually in the community from 2016 to 2021

On the table above, we have the info on the water use for the crops that are irrigated with water from Comunidad de Regantes de Pliego.

We have divided the years by color, so that we can see the differences before and after the modernization plan, which started in 2020.

So, the data we see from 2016 until 2019, are before the Mod.Plan, meaning the years before the sensors were applied.

As we can see, for these years, the amount of water used for irrigation was much higher, compared to 2020 and 2021 (after the Mod.Plan).

Thanks to changes in the irrigation system, the company contributed to both energy and water savings, and in this way it has been possible to increase crops in the territory, especially in Huerta Baja and that's what led the company to reduce the price for the consumer from 0.28 /m3 to 0.30 cents/m3, after the modernization plan.

We can see that in the first year, after the Mod.Plan, the cost is decreasing gradually. Although, it's only been 2 years since the Mod.Plan, and we don't have much data, we already can see a pattern forming, on the decrease of the cost and the water use, which helps us realize that the use of modern technologies, actually has a positive outcome, both for the company and the farmers.

In conclusion to the data above, we believe that if the company keeps on using modern technologies for irrigation, the cost for the farmers and the water use can decrease more in the next few years.

2.3 Integration of more technologies to improve the telecontrol system data

Due to the data we have received, as we saw on the table above, after the Mod.Plan, we can realize that modern technologies have a positive effect on the company and the farmers.

Taking that into account, we suggest a few more additions on the technologies, to improve the telecontrol systems, so that the precision of the data can increase as well.

With that, we believe that the data the company will receive from the sensors will be more precise and as a result of that, the water will be used more efficiently and also, the cost might also decrease as well.

2.3.1. New Technologies

GIS Technology. Geographic Information Systems operate with object details and location data to create maps, including digital ones. For dividing the farm into separate zones, remote sensing is needed. All zones have their characteristics, the analysis of which requires GIS and GPS use. Traditionally, these zones are divided according to a soil type, nutrient availability, soil moisture content, pH rate, and pest infestation.

GIS in precision agriculture permits farmers to view records, such as soil survey maps and plant characteristics traditionally grown in the region. Satellite images and aerial photographs provide additional information. Another handy feature of GIS is analyzing multiple farm management options by comparing and manipulating data layers.

Satellite Remote Sensing. This technology allows growers to observe the yield health using satellite images. They provide up-to-date information on moisture stress, disease, structural anomalies, and nutrient levels. Modern precision agriculture satellite imagery has a high spectral resolution, allowing growers to get the most accurate data.

It is most effective to combine scouting with satellite remote sensing: growers can determine the cause of deviations from the norm. Also, they can use satellite imagery for planning plant treatments and selecting agricultural chemicals.

An essential benefit of this method compared to GPS and UAVs is the absence of additional fuel and labor costs.

VRT In Precision Agriculture. VRT technology allows growers to apply fertilizer, chemicals, seeds, etc. to different parts of a field depending on their needs.Also, farmers can test the soil for nutrients, such as nitrogen, and feed only those areas that lack certain nutrients.

With variable rate application, precision agriculture requires a differential global positioning system (DGPS) and specialized software. There are several VRT types. The map-based VRT corrects the number of applied fertilizers, pesticides, and other products according to the previously generated area map. The sensor-based VRT examines the soil with sensors in real-time and can help determine nitrogen deficiency. Then the control system estimates the required number of inputs.

As a precision agriculture software, EOS Crop Monitoring provides the ability to zone any field based on vegetation indices. A zoned field map can be integrated with VRT to vary the amount of water, fertilizer, seeds, or chemicals on different parts of the field. So, thanks to VRT, farmers can care about plants more effectively, use as many additional resources as needed, save their money, and positively impact the environment, as there is no fertilizer run-off.

Figura 17 A corn field at the early season divided into three zones: yellow zones (Zone 2) requires a standard amount of fertilizer, green zones (Higher vegetation) reduced, red zones (Lower vegetation) increased.

2.3.2. Benefits from the point of view of CE

The contribution that technological development has given to the irrigation sector in Pliego in recent years appears to be decisive for the correct management of water resources and agriculture.

The value of the digital control system is widely recognized in all sectors, including agriculture. Technology in irrigation management is becoming crucial for the survival of businesses for both industrial farmers and smallhold landers .

Since the implementation of new technologies, the data received from the sensors have been more precise, which allows the irrigation to happen without wasting water more than the crops actually need.

As to the circular economy point of view, the reduction of water waste is the main point.

The new technologies make farming more sustainable, on the part of irrigation, which will have a long-term benefit on the environment, since the water sources of the region are extremely low in quantity.

To sum up, the use of even more technologies, as the ones suggested in the previous chapter, will have an even greater impact on the precision of the data and therefore the better and more efficient use of water for the irrigation of the crops.

2.3.3. Outcomes overview

Social. As a social outcome from the circular economy and the new technologies, we have the creation of job openings for professionals in the field, who have experience in similar fields and will be the ones who will collect, analyze and manage the data. Also, it's an opportunity for job openings for locals working in an agricultural field, since it will be even more efficient to have people who are familiar with the agricultural area and the local territory of the region.

Economic. As we mentioned in a previous chapter, the economic benefits come from the reduction of water waste, meaning less water equals lower cost in water production. Also, due to the reduction of water use and then the reduction of the price, the increase of crops is possible, since it will be more affordable for farmers to go through. Moreover, there's also the reduction in costs and risks associated to maintenance and energy operations and the reduced costs from unexpected water main breaks

Environmental. The reduction of energy use and water use, are the most important outcomes, when contemplating circular economy and new technologies. Both, the circular economy and the new technologies, make the whole procedure more sustainable, since water use and energy reduction are two main pillars concerning climate change. Also, the minimal contamination and maximized conservation of water resources can be ensured.

Operational.

- Efficient data analysis and processing
- Predictive Maintenance
- Reduced number of emergencies callouts
- Reduced downtown of critical assets
- Regulatory Compliance
- Reduced failures and overflows

Long-Term Resiliency.

Increased resilience

- Improved operational flexibility
- Workforce development
- Improved cross-department collaboration
- Reduced safety risks
- Brand and innovation

- Elevates utility brand and engagement in the water industry

Cultural. As a cultural outcome, we can assume that in the future, locals will be even more familiar with agriculture and even younger people will develop an interest in this field of work, helping the region to grow and evolve throughout the following years. That's due to the more interesting aspect of agriculture, since contemplating new technologies and not just the old classic ways of crop management, farming, etc. Many more different types of tasks with an even bigger career future.

2.3.4. Impact on Ecosystem services

To evaluate the impact, the Ecosystem Services method was taken into account, identifying the direct or indirect contributions to human well-being, integrating the four categories; **Provisioning services**, regarding the impacts on food, raw materials, fresh water and medicinal resources; **Regulation services**, regarding air quality regulation, climate regulation, water regulation, erosion regulation, water purification and waste treatment, disease and pest regulation, pollination and moderation of extreme events; **Support Services**, regarding soil formation, photosynthesis and nutrient cycling; finally with **Cultural Services** containing spiritual and religion values, aesthetic values, recreation and ecotourism and mental and physical health.

The potential impacts on the ecosystem services related to the use of telecontrol systems within irrigation management linked to the local agriculture of the municipality of Pliego are detailed below.

Provisioning services

Food and Raw materials. Within this category we see that the proposal has a positive impact on food, since by improving crop conditions, these will benefit in terms of productivity (quantity) and product quality, for both those dedicated to self-consumption agriculture that represents the 80% and the industrial farmers that represent the 20%. This industrial production has current cultivation figures of 30% represented by apricot, 5 - 10% of production of olives and almonds, 10-15% of citrus fruits. The rest corresponds to vegetables, which have been cultivated for 4 or 5 years after the modernization plan.

Greater crop diversification is created, with the implementation of the strategy, since by making a more efficient use of water, there will be a greater amount of water available for new types of crops. Having as a reference the different cycles depending on the type of crop and the different zones identified within the irrigable area; the project can also minimizes the cost of materials and resources that must be available such as water, seeds, energy and use of fertilizers, leaving irrigators with a higher quality of water available to be used in their crops.

Fresh water. The system conditions given by the implementation of the strategy represent positive effects in terms of quality and healthiness of the water that irrigates the fields, since an efficient management of resources often implies less consumption and use of fertilizers and pesticides.

Regulating services

Water regulation. Checking supplied irrigation volumes by using processed satellite images, it is possible to identify a classified map of crop growth trends and verify that the growth curve is linked to the established water supply; applying the strategies in which differential irrigation is integrated, this technique allows water savings that can represent up to 10% while maintaining crop yields at competitive levels. Based on the application of different amounts, shifts and times, even within the same field, according to homogeneous management areas identified based on soil variability.

Water purification and waste treatment; disease and pest regulation. Strategy implementation can also include monitoring wet soil conditions, by having more information on when to irrigate they can prevent the 20% of the actual excessive water use in irrigation and avoid runoff. At the same time, reducing the generation of conditions that can lead to favorable environments for bacteria or pests developed by the same humidity conditions. It could also maintain soil conditions by reducing the amount of pesticides needed.

Supporting service

Nutrient cycling. Since the crops conditions are improved and the wet soil controlled, the percentage of nutrients received increases and the genetic potential of the crops is maximized.

Photosynthesis. Implementing new agricultural techniques that allow other positive effects to be obtained, such as the increase in agricultural production (10-15%), since the reflected light increases photosynthesis.

Cultural service

Bearing in mind that the local knowledge linked to water is territorially contextualized, due to the cultural norms of water distribution, which have been regulated by the Irrigation Community since 1992. This, together with the reference people in the community, are aspects that are integrated into the network of actors and knowledge, empowering cultural identity and sense of belonging, both with the irrigation community and in their role as farmers. Improving the technical capacities of around 1,500 comuneros that are part of the community and requalifying the irrigation sector, developing totally local know-how.

Being able to encourage the cultivation of the uncultivated areas, which currently correspond to 30% within the irrigable area, managing to highlight the value of water for the plegueros that goes beyond the eco-productive. Coming to have a symbolic meaning with socioeconomic benefits and see it as a strategic element.

Mental and physical health. Just as water is essential for people, it is also essential for plants. And in the same way that having quality water is beneficial for our health, watering plants with efficient use of water can lead to better crops and therefore the nutrients they contain, leaving higher quality products that bring greater benefits to its consumers.

Aesthetic values. The landscapes of the crops, the route of the water and of the infrastructure form a mosaic in which irrigated crops and the zoning of vegetation are intermingled. As well as the integration of architectural and engineering elements that are integrated into the cultural landscape of great value, for the efficiency of the irrigation system.

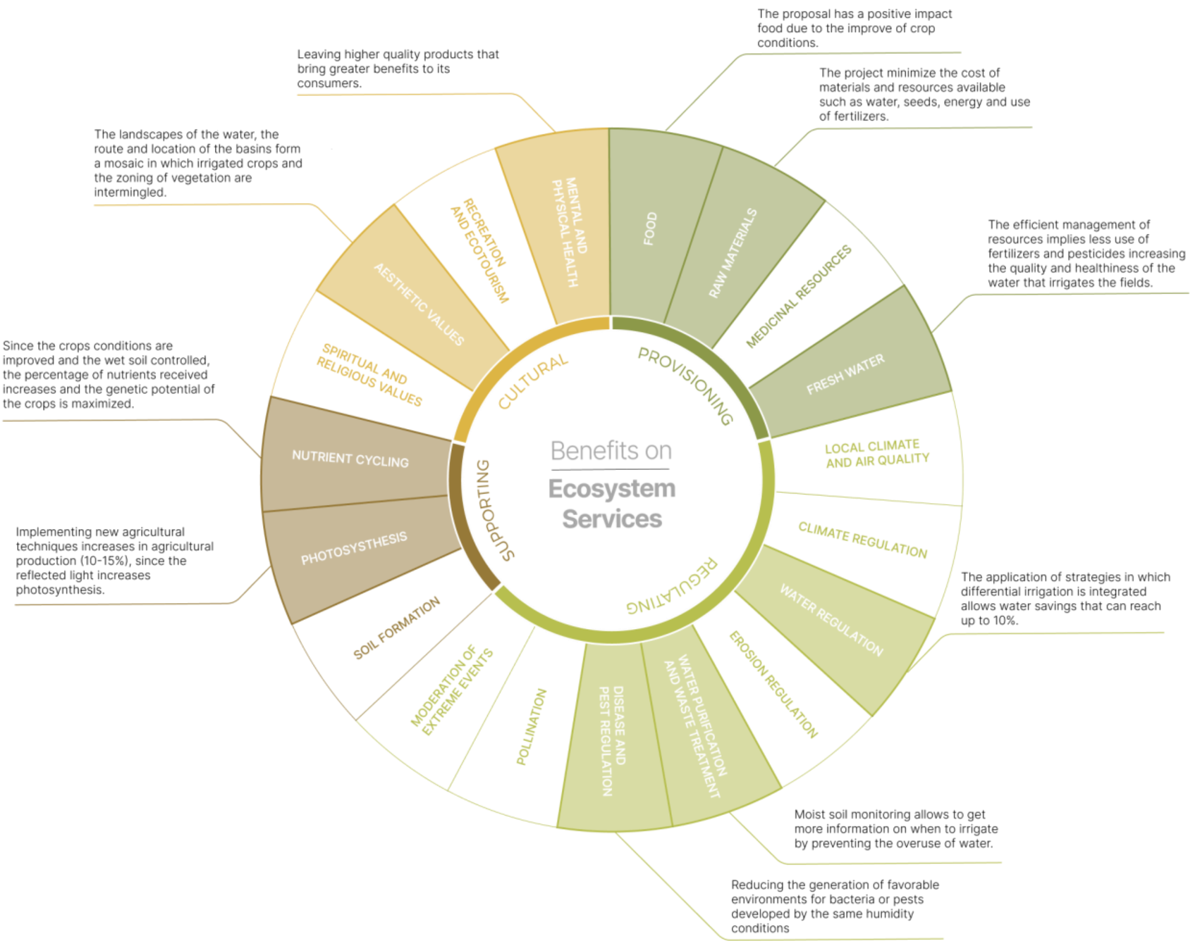


Figura 18 Impact on the ecosystem services

3. Investment cost and profitability analysis

3.1 Cost of the solution

The financing of the works carried out (including remote control) was financed 100% by the Administration:

- 63% charged to the European agricultural fund for rural development (EAFRD)
- 11.10% by the Ministry of Agriculture, Food and Environment of the Government of Spain.
- The remaining 25.90% by the regional administration (Region of Murcia).

The base cost of remote control and automation of the Huerta Alta, corresponding to sector I and Huerta Baja corresponding to sector II system was distributed as follows.

Remote control and automation sector I	Total budget of material execution sector I	% of RC and automatization within the total material execution of sector I	Remote control and automation sector II	Total budget of material execution sector II	% of RC and automatization within the total material execution of sector II
390.544,90 €	3.444.381,51€	3.91%	**550.341,65 €**	6.299.096,36 €	**8,74%**

Tabla 2 Cost of the Telecontrol system and automatization

The integration of the remote control system and the automation of the system for Sector I corresponding to Huerta Alta has a cost of 390.544,90 €, which is equivalent to 3.91% of the total budget of material execution for the project in sector I. Meanwhile the adjustments carried out in sector II corresponding to Huerta Baja represent a value of 550.341,65 €, which represents the 8,74% of the budget of material execution of sector II.

The total amount of the telecontrol system and automatization integrating Huerta Alta and Huerta baja sectors is **940.886,55 €**. The data on installations and other expenses related to the installations of the system are not specified within the documents, for this reason the previously mentioned value is taken as the total value, taken from bidding base budget the C.R of Pliego.

3.2 Benefit of the solution

Regarding the benefits, these are identified, on one hand, as direct benefits for farmers in terms of the reduction of operating expenses that involve labor and transportation to travel to the fields to manually irrigate their crops, in addition as it has been mentioned previously. a reduction in the cost of water supply per cubic meter, going from paying 0.30 cents to 0.28.

On the company side, the costs that the community must assume in order to supply the service to irrigators in the area are taken into account, showing what were the benefits that the implementation of the system brought with it.

Concept	CCAA 2019	CCAA 2020	CCAA 2021
Net amount of turnover	637.517,92 €	526.288,76 €	543.579,79 €
Allocation of non-financial fixed asset subsidies and others	438.471,38 €	876.942,75 €	876.942,75 €
A.1) Operating Income	**47.434,54 €**	**- 3.478,21 €**	**17.841,12 €**
Financial income	34.247,81 €	27.489,75 €	26.418,11 €
Financial Expenses	-23.169,40 €	19.666,87 €	-15.717,56 €
A.2) Financial results	**11.078,41 €**	**7.822,88 €**	**28.541,67 €**
A.3) Income before taxes	**58.512,95 €**	**4.344,67 €**	**28.541,67 €**
A.4) Profit for the year from continuing operations	**58.512,96 €**	**4.344,68 €**	**28.541,68 €**
A.5) Net result of the year	**58.512,97 €**	**4.344,69 €**	**28.541,69 €**

Tabla 3 Net result from 2019 - 2021 CR of Pliego

The following table shows the final result for the year. From here we must highlight that the highest income during the years 2020 and 2021 is given through the national and regional contributions that the community received during these periods for an amount of 876.942,75 € to improve the efficiency of the system. Although the year 2020 has such a low value compared to the previous year, it must be taken into account that it was the period in which all the changes in the system were made. In the year 2021 the net income corresponds to 28.541,69 € with an increased provision in the following years.

3.2.1. Direct Costs

These costs are directly related to the service that the company of C.R oF Pliego offers, in this case the supply of water for irrigation. The main reduction on the cost is reflected in the voice of suppliers, which refers to the cost of water and the energy that the company must assume.

In 2019 prior to the implementation of the system the suppliers had a total cost of 113.073,44€ the next year when the system was implemented the cost for suppliers decreased reaching a total cost of 95.976,91 €, a decrease in energy and water costs.

In the first year after the implementation, in 2021 the cost of suppliers increased again, but this growth does not mean that the system is not being more efficient.

There is a **20% increase in the use of materials** that, according to the information provided by the community, is linked to the growth of crops in the area. Here we also take into account the diversification of crops since the quantity of resources needed will depend on the type of crop.

The needs of a vegetable or vegetable crop are not going to be the same water needs of crops such as almonds and olive trees, which need a minimum amount compared to vegetables. This is why, although there is an increase in the use of materials, it is not reflected as inefficiency in the use of resources, but rather a change, an increase related to crop growth.

Concept	CCAA 2019	CCAA 2020	CCAA 2021
Suppliers	113.073,44 €	95.976,91 €	113.445,89 €

Tabla 4 Cost of Suppliers C.R of Pliego 2019-2021

The other benefit is reflected in the maintenance expenses that lead to other operating expenses, here there is evidence of an increase in 2020 of 36,843 € compared to 2019, taking into account that this was the year in which the changes were completed. in the system, which implied an increase in maintenance, however in the following year the cost of operating expenses decreased, taking into account that the system allows the reduction of costs and risks associated with maintenance and operations and the reduction by unexpected breaks.

Concept	CCAA 2019	CCAA 2020	CCAA 2021
Other operating expenses	369.537,71 €	406.380,34 €	376.908,33 €

Tabla 5 Cost of other operating expenses C.R of Pliego 2019-2021

3.2.3. Net present value

The NPV is determined by applying a ‘discount rate’ to the identified costs and benefits. The NPV is calculated as follows:

$$NPV = -I0 + \sum_{t=1}^{n} (Bt - Ct)/(1+r)t \text{ or}$$

$$NPV = -I0 + \sum_{t=1}^{n} (CFt)/(1+r)t$$

Where:

I0 is the investment cost; - ***940886,55 EUR***

Bt is the benefit at time t;

Ct is the cost at time t; - ***95976,91 EUR***

CFt is the cash flow at time t; - ***4344,67 EUR***

n is the expected exploration time of the project;

r is the discount rate - ***5%***

3.2.4. Payback period

The payback period is the amount of time it will take to recoup the initial cost of an investment https://www.youtube.com/watch?v=FJjGi7gsK3A

3.2.5. Internal Return Rate

Internal Rate of Return is the interest rate that makes the Net Present Value Zero:

$$NPV = -I0 + \sum_{t=1}^{n} (CFt)/(1+IRR)t = 0$$

4. Conclusion

It is clear that the impact of the digital telecontrol systems used by the company in water production and irrigation, is positive, with lots of opportunities for the company to make a positive change in the environmental crisis and the demand of the region in water sources. In the first chapter of the report, the company's telecontrol system is introduced along with the objective of the project. EU Policies on Agriculture and Circular Economy are also mentioned, along with the integration of Circular Economy in the project particularly. Also there are the details of how the system works, how telecontrol systems improve irrigation and some case studies based on telecontrol systems used in irrigation. In the second chapter, the system Irrigest is explained, along with information on how and why the chosen solution works. The technologies send out precise data on the amount of water, soil moisture, temperature, etc. (and other factors when needed) that is necessary for the irrigation of crops. There are also suggestions on more technologies that could be implemented in the system and maybe improve it, and also a general overview of the benefits. At the same time, with the implementation of even more digital control systems and technologies and the help of more trained professionals of a similar work experience background, the company can receive even more precise data and therefore manage to achieve a larger reduction in water and energy use and an even lower price per m3, throughout the following years.

In the third chapter, is the economic analysis based on the data from the company. At the end, according to the info gathered before and after the implementation of the modernization plan and comparing all the data, we have evidence on the success of the irrigation modernization program.

Only by using technologies similar to the ones mentioned in the research, can this positive impact be achieved.

5. References

1. Aiscosolutions. (s.f.). General information of the project. https://www.aiscosolutions.com/icontrol-irrigation-control-technology-at-its-best/
2. Aquarson. (s.f.). General information of the project. https://aquarson.com/
3. Campo García, A. (2014). Spanish Irrigators Communities and its Nationals Federations, Madrid, España. http://www.geoscopio.net/empresas/ fenaco-reweb/Libro%20regantes%20 FENACORE.pdf
4. Centro Regional de Estadístico de Murcia - CREM. (2022, 15 June). 1. Distribución general de la tierra.. https://econet.carm.es/inicio/-/crem/sicrem/PU_datosBasicos/sec48.html
5. Clm, R. (2017). El automatismo de gestión de riego "Irrigest 2" premio a la novedad tecnológica en Fercam. Interempresas. https://www.interempresas.net/Agricola/Articulos/190124-automatismo-gestion-riego-Irrigest-2-gana-premio-novedad-tecnologica-Fercam.html
6. Comunidad de Regantes de Pliego. (2022). Proceso de unificación de las Comunidades de Regantes de la Huerta de Pliego. https://crpliego.es/
7. CR-ARGOS Comunidad de Regantes de las Aguas Reguladas por el Embalse del Argos. (2022). Guía rápida IrriGest. Telecontrol CR-ARGOS. https://crargos.org/index.php/guia-rapida-irrigest/
8. Kamoun, A., Ksontini, M., & Ghorbel, Z. (2006). Remote-control and supervision of irrigation systems: an attempt to better water management. Journal of Applied Sciences, 6: 425-434. https://scialert.net/fulltext/?doi=jas.2006.425.434
9. Las obras de mejora de la Comunidad de Regantes de Pliego mejorarán la dotación de agua - (2018). Retema, Revista Técnica de Medio Ambiente. https://www.retema.es/noticia/las-obras-de-mejora-de-la-comunidad-de-regantes-de-pliego-mejoraran-la-dotacion-de-ag-7NVjd
10. Logitek: Creatin Smart Cities. (2014). Smart irrigation in Barcelona: introducing the new system. https://www.creatingsmartcities.es/blog/en/smart-irrigation-barcelona-smartcity/
11. Plantae. (2021). Productos. https://plantae.garden/products/
12. Precision Agriculture: Technology To Boost Crop Farming. (2022). Earth Observing System. https://eos.com/blog/precision-agriculture/
13. Santos, M. (2020, 4 mayo). El telecontrol del riego ya se ha implantado en más de un millón de hectáreas. El Ágora Diario de Agua https://www.elagoradiario.com/agua/espana-lider-mundial-telecontrol-riego/#:%7E:text=La%20Federaci%C3%B3n%20Nacional%20de%20Comunidades,sobre%20Superficies%20y%20Rendimientos%20de

14. Subsecretaría de Agricultura, Pesca y Alimentación, Subdirección General de Análisis, Coordinación y Estadística. (2020). Encuesta sobre Superficies y Rendimientos de cultivo, Informe sobre los regadíos en España. Ministerio de Agricultura, Pesca y Alimentación. https://www.mapa.gob.es/es/estadistica/temas/estadisticas-agrarias/agricultura/esyrce/
15. Wecoop. (2022). EU Policies & Regulations. https://wecoop.eu/regional-knowledge-centre/eu-policies-regulations/
16. New Challenges towards Smart Systems' Efficiency by Digital Twin in Water Distribution Networks. (2022). Helena M. Ramos, Morani M.C., Carravetta A., Fecarrotta O., Adeyeye K., P. Amparo López-Jiménez, Pérez-Sánchez M. file:///C:/Users/pc/Downloads/water-14-01304.pdf

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