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Reducing the Carbon Footprint of the Water-Energy Binomial through Governance and ICT. A Case Study

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Abstract: This paper reveals reductions of up to 485 t CO_2 eq (CO_2 equivalent) of greenhouse gas (GHG) emissions of energy origin associated with the water-energy binomial which can be achieved after modernizing and automating a Water User Association (WUA) of over 1780 users with microplots in a total area of 775 ha in southeastern Spain. This case study aims to show how the latest advances in information and communication technologies (ICTs) for precision agriculture are being applied efficiently with the implementation of a Smart Agri system, capable of making improvements through the use of renewable energies (64.49% of the total CO_2e- avoided), automation in irrigation water management, by applying adequate governance, use of ICTs (731,014 m^3 per water footprint reduction with 20.41% of total CO_2 eq of associated electrical origin), hydraulic improvements (283,995 m^3 per water footprint reduction, 13.77% of the total CO_2 eq of associated electrical origin) and reduction of evaporation in reservoirs (26,022 m^3 of water by water footprint reduction with 1.33% of the total CO_2 eq electrical origin avoided) that act as batteries to accumulate the daily solar energy and enable watering at night, when irrigation is most efficient. It is important to consider the valuable contribution of these artificial green lungs, not only in terms of food for the European Union, but also as a CO_2 eq sink that supports the planet's GHGs. As shown in this study, this is made possible by the joint governance led by the Water Users Association (WUA) and co-led by different management organizations with the support of ICT.

Keywords: water footprint; photovoltaic; reclaimed water; irrigation modernization; reservoirs

1. Introduction

The first reports of water governance in Murcia date back to the time of Alfonso X 'El Sabio', in the thirteenth century [1]. The rules for the use of water for agricultural use came from Muslim settlements. The Muslim people passed on the knowledge learned from the East [2], using the energy of the moving water to elevate it to lands above river level, adding value to the land dedicated to dry crops thanks to others with irrigation. In doing so, they understood the need to seek renewable energy sources. Farmers in the Region of Murcia (Spain), in the Segura basin, have maintained, improved and preserved the hydraulic facilities they inherited, while striving to produce the best fruits and vegetables in Europe.

The water and energy binomial applied to farms, using pressurized water systems, is a consequence of the water stress to which temperate areas of the Mediterranean area are subjected. The decrease in water availability, due to climate change, is forcing Murcian farmers to develop sustainable water energy systems to make their farms viable and reduce the water footprint by reducing their water consumption, taking advantage of the torrential rains captured by storm/environment tanks [3], using recovered water [4] and increasing the efficiency of its distribution systems. In addition, alternative energies are required to reduce emissions costs and production [5–7], together with the carbon footprint associated with the required energy consumption (based on real-time ICT governance and management [8–10]).

This study is based on the different energy audit systems used in Eastern Spain [11–13]. To this end, a scheme has been established that may be applicable to other water systems, which analyses the emissions generated, both avoidable and non-avoidable. Figure 1 shows a diagram that evaluates different actions based on their relevance and effectiveness. In a first phase, the total water unit system (irrigation system) should be examined and localized energy component consumption evaluated [14], considering both water reduction and carbon footprint. To achieve a global result, energy turnover has been studied in recent years along with water consumption by existing sectors. The diagram shows the role of water governance (Figure 1, purple zone), which is similar to a remote control management system. A maximum demand per hectare should be established because new crops should not be planted in certain sectors so as not to collapse the system. As for water problems (Figure 1, blue zone), this study examined how to sectorize the irrigator community by grouping sectors by similar manometric height levels, because excess pressure can cause leaks at irrigation points [15]. In addition, different scenarios are studied that are able to supply water according to demand by combining various sources (i.e., wells, transfers, regenerated water), without compromising viability. It is also necessary to locate any leakage to repair them or determine the abnormal operation of the hydraulic elements, complementing this with the use of regenerated water [16], just as astronauts do [17–19]. These processes are achieved through an energy balance where water intakes and CO_2 eq emissions are well established. Once these steps are completed, it is necessary to study the parts of the system that consume energy (Figure 1, orange zone) and generate emissions [20]. The energy consumption needed to replace them with renewable energies should be analyzed [21] or reduce consumption by applying smart measures and systems. In addition, water losses due to evaporation should be examined because, in this case, the losses caused are significant and lead to energy waste and avoidable emissions. Additionally, this study sought to visualize the sequestration of CO_2 eq by agricultural plantations (the artificial lungs of southern Europe), [22]. Several publications have been revised and used as a method of calculation, CO_2 eq sequestration by green mass has been differentiated from cultivation and soil depending on crop type and area, as well as its emissions during breathing in the night phase and emissions produced by fertilization. With these values, a balance of the CO_2 eq sequestered a WUA has been calculated.

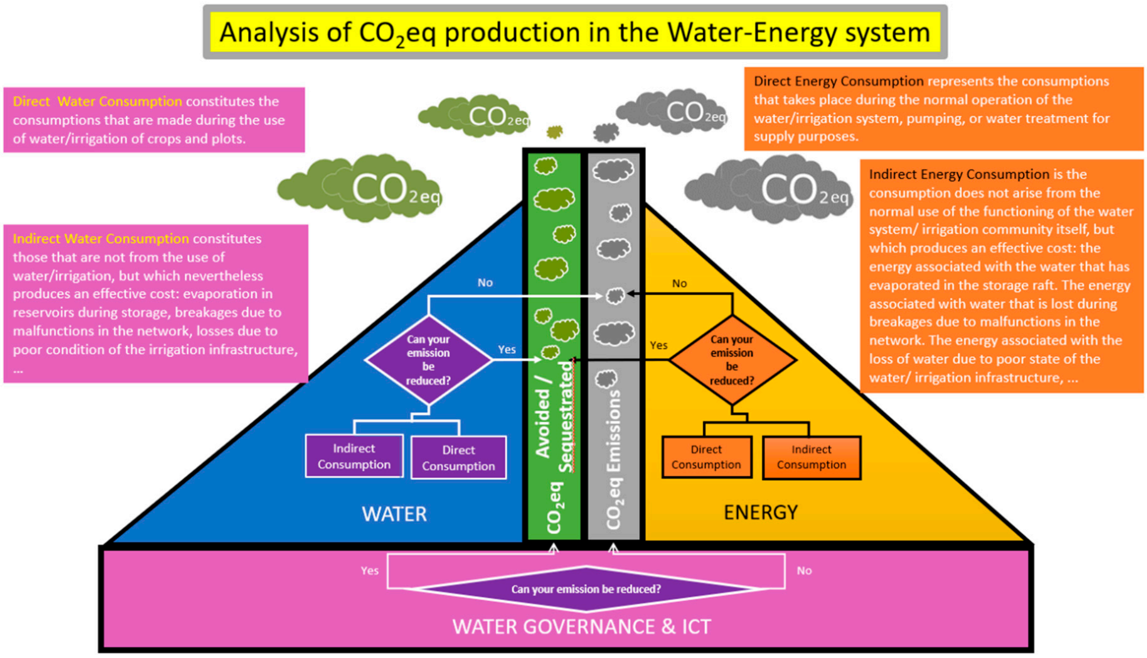


Figure 1. CO_2 eq analysis production in a Water-Energy system. Source: Own elaboration.

2. Materials and Methods

This study analyzed the monthly consumption of all consumption points in the Water Users Association (WUA) over the last 10 years (about 216,360 records). This data was processed in Excel to determine energy turnover for the year 2016 (considered the baseline year). In addition, all inputs and water consumption during 2016 were collected to determine a real kWh value of the energy associated with each m^3 of water consumed. With the kWh/m^3 obtained annually, the CO_2 eq t values associated with energy consumption were calculated, to determine the carbon footprint generated by an WUA (later with this kWh/m^3 value, and after applying ICTs, governance measures and consumption reductions), it is possible to calculate how much energy is being wasted, also, avoided CO_2 eq emissions are calculated. Subsequently, to show the benefits of crop management, a study was carried out on the evolution of crops over 10 years in the two municipal terms associated with this WUA, basing this work on the studies by CEDEX (Center for Studies and Experimentation and Public Works in Spain) on sequestered CO_2 eq by these crops, according to their species, the sequestered CO_2 eq was determined.

The applied methodology has been included in several publications. A general aspect about the evaluation of the nexus food, energy and water is cited by Sadegh et al. in 2020 [23]. This was located in USA. Another publication is about the determination of water footprint and primary demand for rice systems in China [24]. This paper includes the calculation of carbon footprint (CF), nitrogen footprint (NF), and primary energy demand (PED) of different rice production systems. Another case study was located in Spain [25]. The study was developing the reduction of water footprint and energy consumption (in the pumps that pressurize the grid, such as in the optimization of the proposed solution, by using batteries that communicate in low radiation of electric and magnetic alternating fields (LoRad), General Packet Radio Service (GPRS), or narrowband IoT (NB-IoT), or clean energy). The case study was about irrigation systems. Some aspects about energy balances and greenhouse gas emissions in agricultural zone in China [26] is cited in other paper. In this study, the objective was to evaluate the difference of crop and livestock products regarding energy balances, greenhouse gas (GHG) emissions, carbon economic efficiency and water use efficiency using a life cycle assessment (LCA) methodology on farms in three sub-oases within the Shihezi Oasis of China. Moreover, some authors of this article included an additional study about the reduction of carbon footprint in a water user's association in Spain [27]. In this case, the use of photovoltaic generation for the contribution in the reduction of greenhouse gas (GHG) emissions is analyzed. Additionally, the water and energy footprint for this system is presented. These methodologies have been included in the present paper.

2.1. Field Data

The Water Users Association (WUA) of the area under study is located in the Region of Murcia (Spain). The irrigable area is 799.71 ha: SECTOR I "HUERTA ALTA" (373.58 ha) and SECTOR II "HUERTA BAJA" (426.03 ha). This WUA is a combination of different irrigation groups and associations with over 1400 farmers. This WUA is fortunate to be able to choose three sources of water from different sources (regenerated water from the wastewater treatment plant (WWTP) in the village of the case study, water from the Tajo–Segura Transfer (TST), and a well on the property). The associated costs are proportional to the energy needed to pump the water and transport it to the plots that require the water and to lift it to the height applicable to the crops. Water governance and planning plays a fundamental role in achieving long-term life cycle analysis (LCA) objectives (our case study LCA gate to gate). Actions in agriculture are not instantaneous; they require a medium term to be effective and achieve significant objectives. The use of energy is associated with a carbon footprint which must be reduced to achieve the sustainable development goals (SDGs) and reduce the impact on the environment. Furthermore, the water footprint is associated with water governance, either by reducing its losses by improving distribution pipelines, improving management through automated systems that identify leaks and ultimately optimizing irrigation systems.

2.1.1. Agroclimatic Characteristics

It is important to consider the key agroclimatic characteristics of this WUA in relation to our study: a characteristic warm or semi-warm Mediterranean subtropical climate, with high temperatures during the summer determined by its latitude, reaching values of 32–34 °C, scarce rainfall (200–300 mm per year), although intense in years of flooding (e.g., torrential rains may occur, surpassing 350 mm). For these reasons water supply capacity must be guaranteed during the driest months, in the years of most rainfall.

2.1.2. Available Resources and Water Demand

To determine the true needs of the WUA, the operating regimes of the different sources available were analyzed and a reference year was used, which was most suited to the average consumption over the last 10 years. These data (Figure 2) provided a snapshot of the needs per month. As these needs are seasonal (that is, supply varies with the months of the year, depending on the weather and the state of storage of the transferring Tagus basin), this requires the collaboration of the reservoirs that are in service and the different available resources. The annual amount of available water is 3,629,361 m^3 which guarantees the survival of the crops. Using these values as a starting point, it is important to analyze and propose actions to compare and quantify the potential associated improvements. To do so, an initial scenario must be established, with specific data that can later be evaluated. This study considered 2016 as the baseline year.

2.2. Equivalent CO_2 eq Flow to the Atmosphere

If the quantity of consumed kWh for irrigation water supply is analyzed, the total amount for 2016 was 2,032,471 kWh. To calculate the carbon footprint generated it is important to know the transformation rate of this value. The fork values of the studies investigated range from 0.0413 $kgCO_2eq/kWh$ in a study conducted in Brazil according to Cardozo et al. [28], up to 0.947 $kgCO_2eq/kWh$ recorded by China in the two studies investigated by Li Cheng et al. [29] and Wan et al. [30] reached a value of 0.780, 0.608 and 0.166 $kgCO_2eq/kWh$ in Iran [31,32] and in Spain [33], respectively.

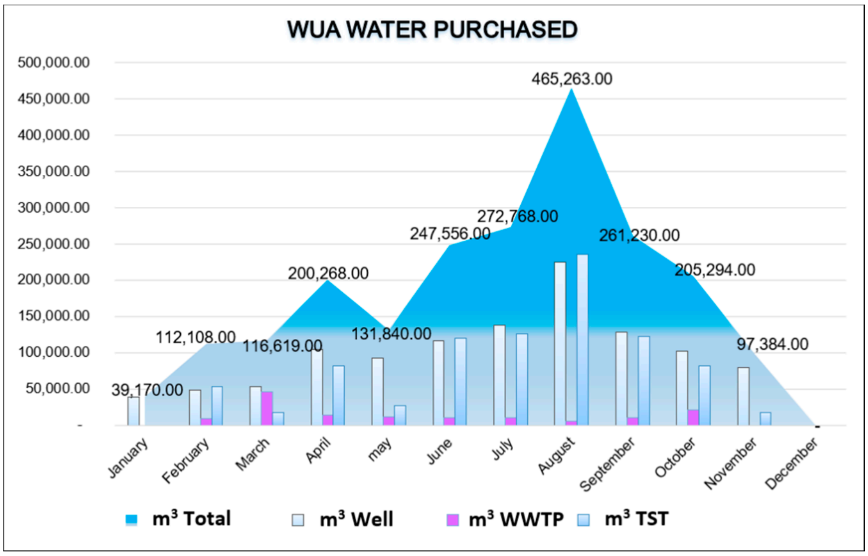


Figure 2. Monthly water purchased, according to the water supply source. Source: Own elaboration.

The values used in this study were based on the annual transformation rates called "electric mix factor (kgCO_2eq/kWh)", determined by the National Commission on Markets and Competition (CNMC, www.gdo.cnmc.es). The last 5 years were considered in order to calculate the average value (Figure 3).

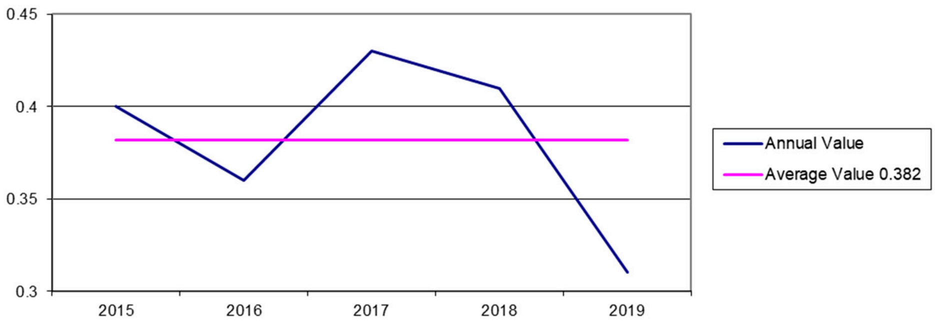
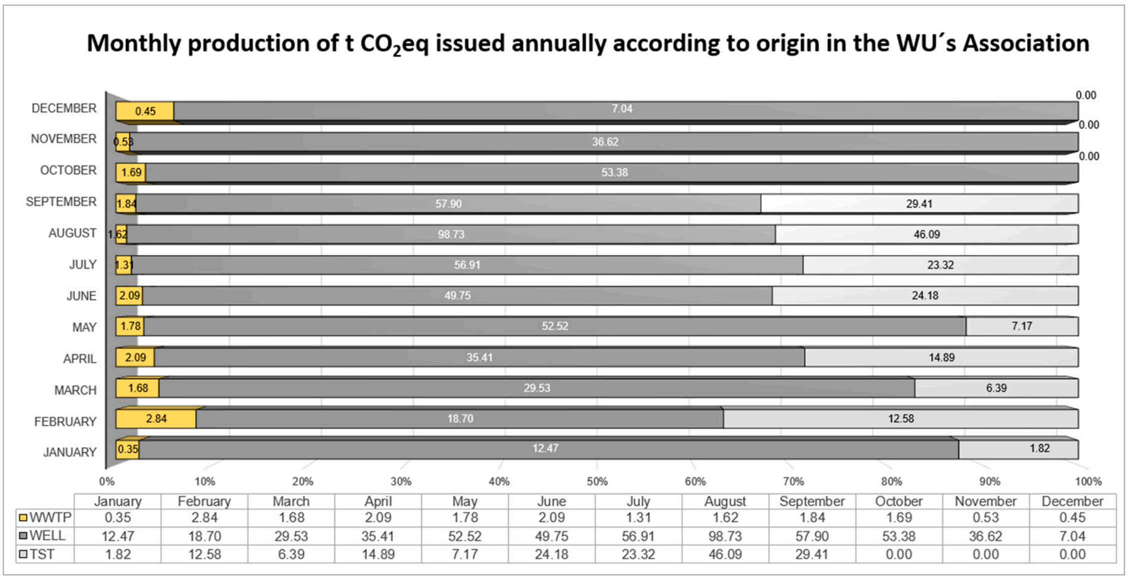


Figure 3. Evolution of the transformation index for electric energy in Spain (kgCO_2eq/kWh) 2015–2019. Source: Own elaboration, based in official CNMC data (Spain) (www.gdo.cnmc.es).

In the case of electrical energy, the rate of transformation varied between 0.041 and 0.947 kgCO_2eq/kWh, due to the generation mix used in each study area. This has been a key factor in calculating GHG emissions from water management in irrigation, and consequently it is important to deepen this aspect, analyzing and considering variations in the rate of transformation of electricity, to more accurately calculate the generated GHG emissions.

In total, 74 gCO_2eq/kWh was deducted from the cost of emissions involved in the generation and installation of photovoltaic plates according to data obtained from table 8 of study by Huld et al. [34] resulting in the 0.308 kgCO_2eq/kWh of this study which fits with the values set out above (taking into account the relation: 1 kWh corresponds to 0.308 kg of CO_2 eq) equaled a total amount of 626 t CO_2 eq (Figure 4).



	January	February	March	April	May	June	July	August	September	October	November	December
WWTP	0.35	2.84	1.68	2.09	1.78	2.09	1.31	1.62	1.84	1.69	0.53	0.45
WELL	12.47	18.70	29.53	35.41	52.52	49.75	56.91	98.73	57.90	53.38	36.62	7.04
TST	1.82	12.58	6.39	14.89	7.17	24.18	23.32	46.09	29.41	0.00	0.00	0.00

Figure 4. % t CO_2 eq flow rate to the atmosphere. 2016. Source: Own elaboration.

2.3. *Adopted Measures for Reduction of the Carbon Footprint*

After analyzing the system, framed decisions must be applied within the scope of water governance, in order to eliminate any limitations of the system and improve its exploitation by taking advantage of the available resources and considering weak points. These could refer to reservoirs where the exploitation does not contribute significantly to the system and leads to water loss via evaporation. To take advantage of the surface, photovoltaic plants (or other viable plants) could be introduced to generate clean energies.

2.3.1. Minimization of the Energy

The objectives of the European Climate Law proposal by the European Parliament endorsed the EU's goal of achieving net greenhouse gas emissions by 2050 in its resolution of 14 March 2019 on climate change 4 [35,36]. It is necessary to act on the WUA's energy consumption sources. After analyzing the relevant bills, the points of greatest consumption are the catchment pump systems, in this case there are three (Figure 5).

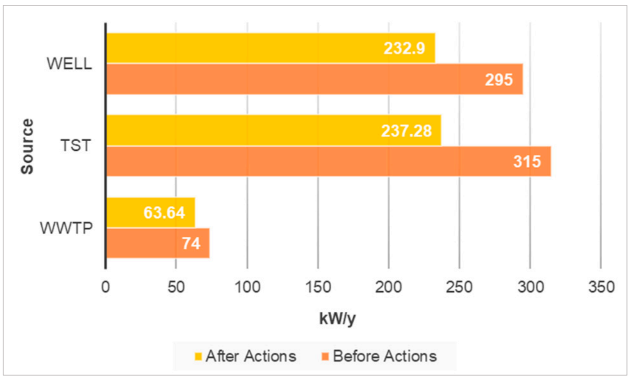


Figure 5. Annual consumption by source (kW). Source: Own elaboration.

The first goal towards the reduction greenhouse gas emissions was to improve the efficiency of lifting the water. For this reason, a study of the operating status of the pumps was carried out, comparing this with the optimal requirements of the equipment for use in real conditions. This revealed that all pumps had to be replaced and frequency inverters were required (Table 1). The second goal was to replace the use of conventional energy with renewable energy. This enables the reduction of consumption, together with associated emissions.

Table 1. Pumping equipment power comparison. Source: Own elaboration.

	Current Pump Power (kW)	Future Pump Power (kW)
Well	295	232.9
TST	315	237.28
WWTP	74	63.64

2.3.2. Analysis of the Available Technologies

After a detailed analysis of the different technologies available, photovoltaic generation was identified as the optimal option. This was due to the maturity of the technology, the availability of areas, the elevated irradiation in the area and the close proximity between the zones of generation and consumption. Other considered and rejected options were:

- Wind energy: after examination and according to the wind maps, the main conclusion was that insufficient available power. It would be necessary to complement the same with other alternative and safe energy sources, in order to avoid periods without energy supply.
- Water energy: the irrigation network design takes advantage of the existent overpressures at several points of the system in order to generate electric energy. After a technical study, the incorporation of this technology was evaluated. The solution was the incorporation of two micro turbines linked to the existing pressure reduction valves. Moreover, the installed powers were 10 and 7.5 kW. This option was discarded because of the low power available. Additionally, the large distance between energy generation and the nearest consumption (nearly three kms distance to the filtering system) can generate major losses due to the energy used during transportation.

2.4. Solar Photovoltaic System

To calculate the energy generated in each of the photovoltaic systems, the Database of the Satellite Application Facility on Climate Monitoring (CM SAF), belonging to the European Organization for the Exploitation of Meteorological Satellites, was used, and as a calculation tool, the PVGIS was used (Photovoltaic Geographical Information System) [37,38] and PVWatts [39,40] provided solar radiation databases on the web for calculating photovoltaic potential in various countries. This software uses all the climatic values (irradiation, temperature, among others) and geographical values of the area. This enables the energy generated by each of the photovoltaic plants was obtained. To design the system, the separation between rows and modules and the optimal inclination of the panels as a function of latitude were considered.

The system is designed to use accumulation reservoirs to meet instantaneous demands, thus avoiding the use of batteries that must be renewed and ultimately generating a carbon footprint during production and subsequent disposal. Pumping will be fed from the photovoltaic field, programming the inverters according to the levels in the existing reservoirs and the required production level.

The photovoltaic plants were calculated using the PVGIS software from the CM SAF database, obtaining the daily and annual electricity production supplied by each of the calculated plants [27,41] (see Table 2). Optimization of solar panels was designed considering their position, inclination and orientation.

Table 2. Summary of the calculation of the solar photovoltaic installations. Source: Own elaboration.

Photovoltaic Installation	Projected Power (kW)	Annual Generated Energy (kWh)	Units of 250 Wp, c/u
Pumping Well	232.9	543,200	1400
Pumping TST	237.3	360,971	1400
Pumping WWTP	63.64	108,640	280,000

It is important to consider that the monthly operation periods of the pump must adapt to the monthly generation curve of a photovoltaic installation, redistributing the peak consumption in the consecutive months and taking advantage of the existence of reservoirs for regulation and the quota that functions as systems for the accumulation of potential energy, thus, the installation of batteries of capacitors is ignored, equaling a significant saving for increasing the efficiency of the solar installations (Figure 6).

Figure 6. Reservoirs and Solar installations. Source: Own.

2.5. Water Footprint

Once the actions of the electrical component of the system have been calculated, the value of the water footprint must be studied, by analyzing the balance sheets of the water purchased for irrigation and the real cost of the same for farmers (Figure 7). The difference equals the losses in the system and conforms the water footprint, divided as follows: (1) the losses due to evaporation during storage in the reservoirs and (2) the losses due to the state of the hydraulic network.

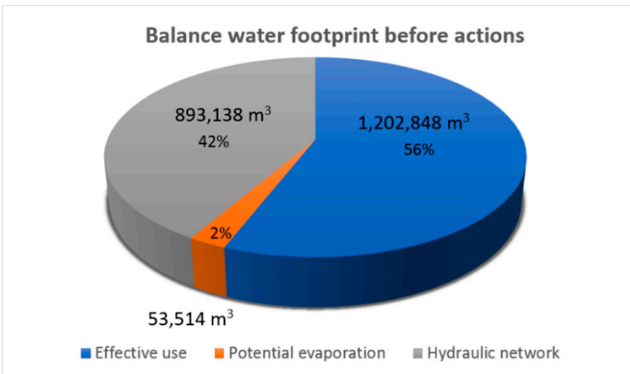


Figure 7. Balance water footprint before actions. Source: Own elaboration.

2.5.1. Direct Consumption Reduction by Governance

After evaluating these losses, several actions can be taken to reduce the water footprint. First, the system is analyzed, based on principles of efficient water governance (see blue area of the diagram, Figure 1). To this end, the farmers must be advised regarding the permissible crops, as well as the maximum endowments per plot, and the shifts established that are linked to the manometric heights of the plots in both sectors. To make this viable, it is necessary to use the ICTs that provide us information in real time such as enabling the possibility of changing the irrigation programs depending on the data provided by the meteorological stations (see article quote), or adjusting of water supplied to the plot, applying the data of the weighing lysimeter (see reference) (audio-slide can be added of the operation of the weighing lysimeter), and completing this with the information provided by the soil moisture sensors (see article quote) (Figure 8).

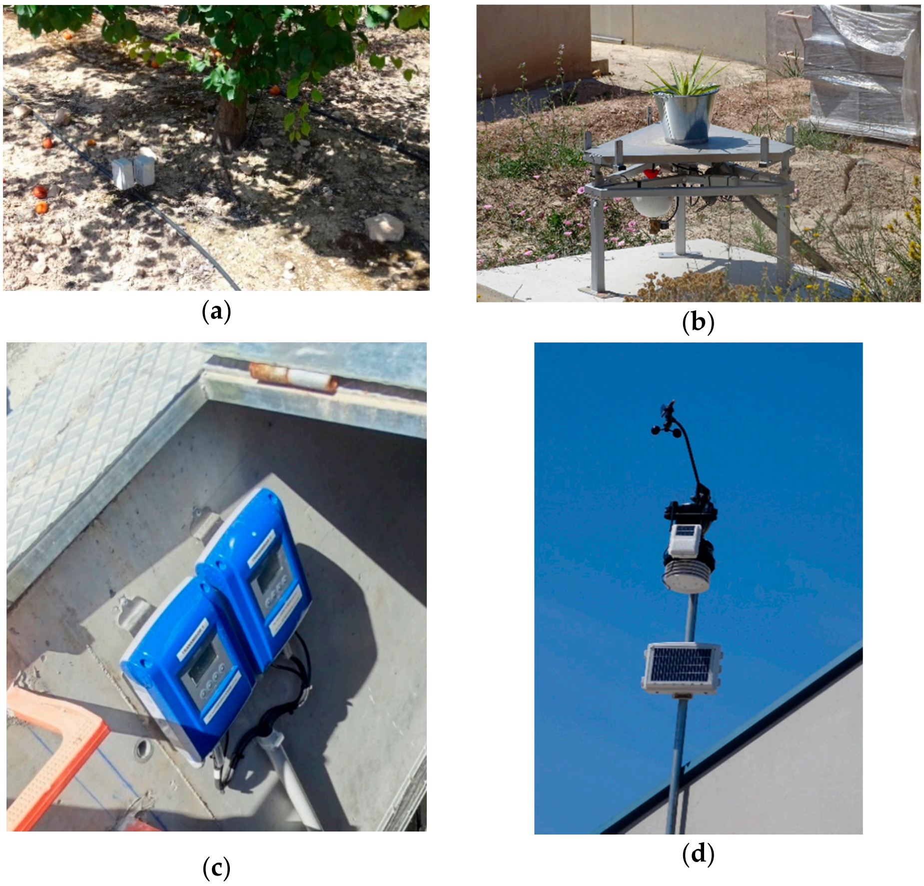


Figure 8. (**a**) Capacitive soil sensor, (**b**) Weighing lysimeter, (**c**) Water quality analyzer, and (**d**) Agrometeorological station. Source: Own.

It is also possible to program the irrigation to stop if certain moisture values are delimited in the terrain. All these actions lead to a savings regarding the direct consumption of water (which, in our case, equaled approximately between five to 10% of the actual consumed water). This saving is quantified by not wasting water that does not benefit the crop. In turn, this leads to a loss of indirect energy associated with water, which requires energy from the system to extract, distribute, and use the water in a plot, albeit with the minimum pressure, in order for the localized irrigation systems to work (see article quote). Furthermore, it is important evaluate and quantify the effect on the carbon footprint. The efficiency in the application represents the water that is used by the crops, compared to that applied to the plot. This will depend on the irrigation system used and the losses caused by deep percolation, runoff and lack of uniformity. The evaluation was carried out for the whole community of irrigators, establishing the weighted average, based on the proportional distribution of the irrigation systems used by surface, and considering the following values (Table 3) (values obtained from the efficiencies in the irrigated areas considered in ORDER ARM/2656/2008, of 10th September, approving the hydrological planning instruction [42]).

Table 3. Efficiency of water use according to the type of Irrigation System. Source: Ministry of the Environment, and Rural and Marine Affairs (Spain).

Type of Irrigation System Value	% of Efficiency
Irrigation by surface with total coverage (blanket), with good management	60
Irrigation by surface with partial coverage (by furrows), with good management	60–90
Irrigation by sprinkling, with good management	80
Irrigation by dripping on the surface, with good management	90
Irrigation by underground drip, with good management	95

The current network has a surface irrigation system with total coverage (blanket irrigation) from the endowments from ditches. This provides a value of efficiency in the application of 60% or, in some cases with drip irrigation on the surface and good management the efficiency is set at 90%. This means that the reduction by indirect consumption amounts to, at least 35% of the water actually consumed (1,020,848.10 m^3).

2.5.2. Indirect Consumption Reduction (ICR)

The reduction of the water footprint by losses via direct consumption has been differentiated into two sections:

- ICR by evaporation potential: losses due to evaporation on the surface of the ponds during storage (these represents the losses associated with the insulation received by the water sheet surfaces of the ponds and whose value has been estimated at 0.5 m^3/m^2) [43]. To estimate this, the initial losses must first be evaluated with the rafts that are available before applying the reductive actions. After applying these actions, the new exposed surfaces are calculated. The rafts and two others have been covered with a TPO polypropylene sheet reinforced with polyester mesh inside, which is estimated to be reduced by 95%. With the difference in volume of evaporated water W_{eBA} = 53,514 m^3 before and after the corrective actions W_{eAA} = 27,492 m^3, the water footprint that is generated has been quantified, obtaining a value of W_{eR} = 26,022 m^3 representing the volume of water annually saved by covering rafts and the reduction of surface exposed to insolation, by eliminating two of the rafts and transforming these into photovoltaic plants (Table 4).

Table 4. Summary of potential water evaporation. Source: Own elaboration.

By Evaporation Reduction								
				Before Actions (W_{eBA})		After Actions (W_{eAA})		
	Surface (m^2)	Volume (m^3)	Manometric Eight (m.c.a.)	Annual Evaporation m^3 (0.5 m^3/m^2)	Source	Annual Evaporation m^3	Source	Actions
Raft 1 "Cota" San Quintin Well	7534	45,000	440	3767	Well	75	Well, TST, WWTP	
Raft 2 Anguilas Cherro 1	7667	24,000	415	3834	Well, TST	-		Solar sector 1
Raft 3 Anguilas Cherro 2	6731	26,400	410	3366	Well, TST	-		Solar Well
Raft 4 Regulation Huerta Baja	30,878	237,675	411	15,439	Well, TST	309	Well, TST, WWTP	
Raft 5 Regulation Huerta Alta	45,929	317,380	413.55	22,965	Well, TST	22,965	Well, TST, WWTP	
Raft 6 La Esperanza	5761	12,000	424	-		-		Eliminated
Raft 7 WWTP Pliego	8285	39,464	372	4143	WWTP	4143	Well, TST	
Total Potential Water Evaporation				53,514			27,492	

- ICR for water improvements: The new improvement introduced in the system as the doubling of the pipes enabled a more adequate exploitation and the distribution in open ducts has been eliminated in front of pressurized pipes while remote control systems with controlled solenoid valves have been installed. Solenoids and counters in the irrigation head enable a balance of water inlets and outlets which helps clarify which sectors and networks suffer from water loss and require repair. This type of improvement reduces the total volume of losses (V_{ls} = 946,651.90 m^3)

by approximately 30%, which in turn reduces the water footprint for water improvements of the system (V_{IsR} = 283,995.57 m^3). Finally, the value of the reduction of the water footprint is based on the reduction by direct consumption (by governance and ICT) and indirect consumption (by evaporation and by hydraulic actions) (Figure 9), equaling a total amount of 731,014.41 m^3, disaggregated according to the summary displayed in Table 5.

Figure 9. Waterproof sheet in reservoir to reduce evaporation. Source: Own.

Table 5. Summary of water footprint reduction after actions. Source: Own elaboration.

Origin of the Consumption		Water Footprint Reduction after Actions (m^3)
Direct consumption	By governance & ITC	420,996.84
Indirect consumption	By evaporation	26,022.00
	By hydraulic actions	283,995.57
Total		731,014.41 m^3

3. Results

3.1. Reduction of Carbon Footprint by Water Footprint

In this study, by using data from electricity bills, the total energy consumption by origin has been calculated. Thanks to this financial data, the total volume of water that has moved within the system has also been determined. This clarifies the carbon footprint that generates the water footprint required to obtain a kWh/m^3 ratio (IE-W). This ratio will change annually and, if there is an adequate monitoring of the movements of the water when it is operating, the telecontrol scale can be determined with greater accuracy and value. In this study, it is used the average value of the three ratios according to origin and divided this by the total water purchased. The final value obtained was (IE-W) 0.62 kWh/m^3 and, considering that the volume of water reduced by water footprint is 731,014.41 m^3, a reduction of CO_2 eq emissions is obtained (0.382 kgCO_2eq/kWh), equivalent to 139 t CO_2eq/y (Figure 10) (it should be noted that for our study, only emissions associated with energy consumption, water handling for irrigation, have been considered, it is actually superior because the reduction of water in the water footprint is associated with a lower consumption of fertilizers that would increase this value by about a third).

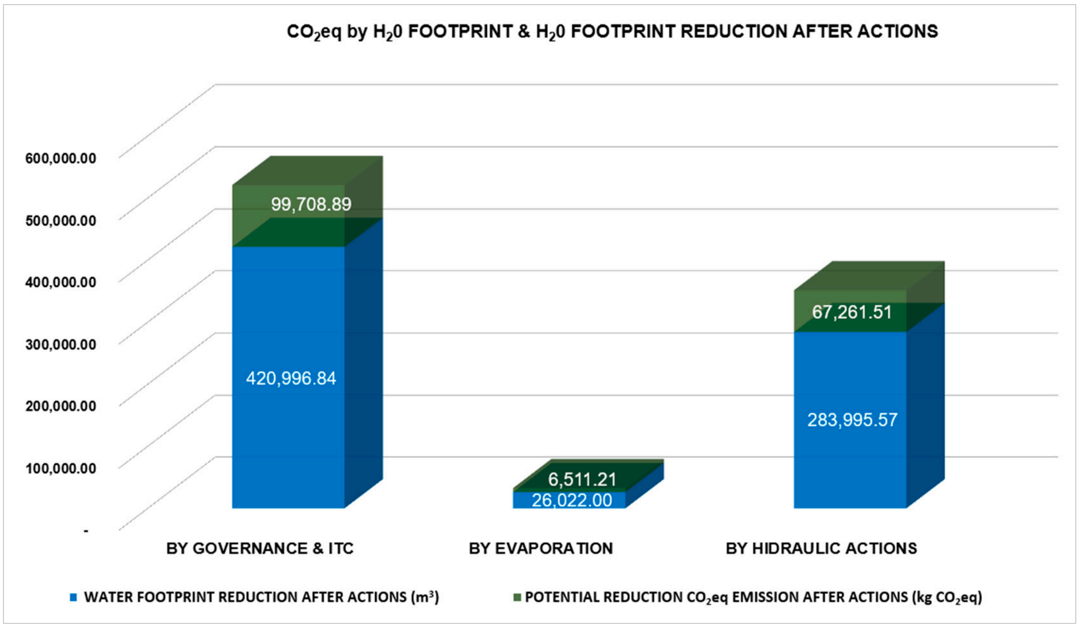


Figure 10. CO_2 eq reduction by water footprint after actions. Source: Own elaboration.

3.2. Sequestration of CO_2 eq by Crops

Given that the purpose of a WUA is the production of food based on growing crops, determining the amount of CO_2 eq sequestered by this community of farmers is sought. Consequently, this work is based on the study of the typology of the existing crops and irrigation varieties in the area, as well as their evolution over the last 10 years, both in the municipality of Pliego and in the municipality of Mula. See Annex 6 for the agronomic report of the project for the adaptation of Sector I "Huerta Alta" of the community of irrigators of Pliego (Murcia, Spain) [44].

This study shows the slight regression of irrigated land cultivated in the municipality of Pliego, as well as the low diversification of existing crops. Based on this data, the distribution of crop units by area differing from the plant, from the farmland has been estimated and the annual carbon values abducted in accordance with the study of Carvajal et al. [45] for the carbon accumulated in the plant have been applied. These values have discounted the CO_2 eq generated during the existence of the plant, since half the day is spent purifying CO_2 eq by day, transforming it into Carbon, emitting an approximate third of CO_2 eq at night [46]. For the purposes of the farmland more than accumulated on the land (approx. 6% of the total abducted) taking as reference values the contents in the publication of Visconti et al. [47]. As displayed, the annual CO_2 eq reduction for crops (Table 6) of a WUA is high, with 7007 t CO_2 eq sequestrated from the atmosphere.

Table 6. Summary of the footprint of CO_2 eq sequestration by crops. Source: Based on [44–47].

Cultivation	Surface (%)	Surface Area (ha) [44]	Annual Estimate Sequestrated kgCO_2eq/ha		Annual Estimate of Emissions kgCO_2eq/ha		Captured tCO_2eq/y	Emission tCO_2eq/y	Sequestrated tCO_2 eq
			Plant [45]	Field [47]	Plant [46]	Field [47]			
Citric trees	25	199.90							1696
Lemon	19	151.93	16,040	590	4812	520	2527	810	1717
Orange half session	2	15.99	9869	565	2961	515	167	56	111
Orange total session	4	31.98	6220	565	1866	515	217	76	141
Fruit trees	71	567.73	-						4940
Apricot tree	16	127.94	8450	825	2535	740	1187	419	768
Peach tree	37	295.86	14,463	835	4339	740	4526	1503	3023
Almond tree	18	143.93	11,356	475	3407	445	1703	554	1149
Vegetables	4	31.98	-						98
Lettuces and similar	4	31.98	4225	830	1268	735	162	64	98
Total	100	799.61							7007

3.3. Total CO_2 eq Balance of Our W-E SYSTEM in a WUA

The total balance of our water-energy system provides us with many benefits, as shown in Figure 11.

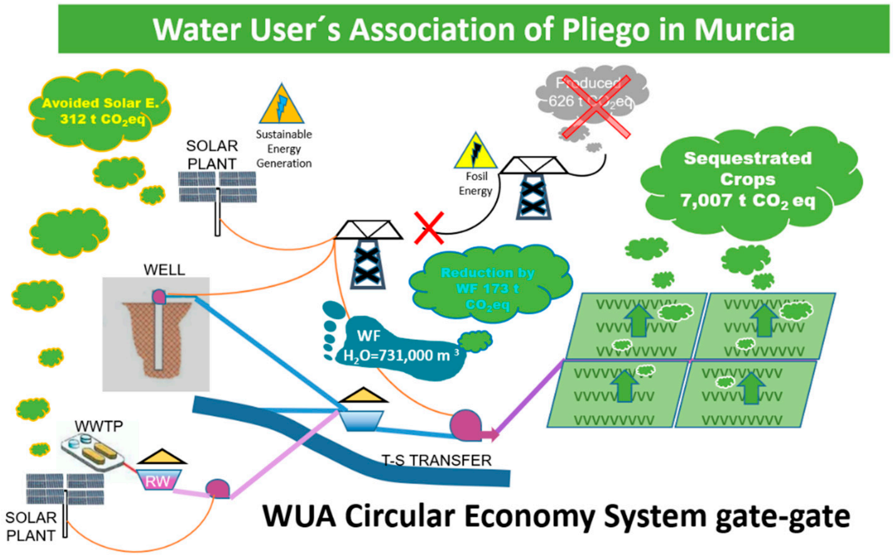


Figure 11. Summary of the environmental effects generated in the WUA. Source: Own elaboration.

Note that there are savings in annual CO_2 eq emissions after the implementation of these three photovoltaic installations, as follows:

- 111.18 t CO_2 eq for the TST pumping.
- 167.31 t CO_2 eq for pumping Well.
- 33.46 t CO_2 eq for pumping WWTP.

These three actions significantly improve the energy capacity of the Community of Irrigators and will they reduce annual maintenance costs once the break-even point has been reached for the installation, as well being totally unconnected with the Electric Fee factor. Furthermore, it is important to highlight the reduction of the water footprint (731,014.41 m^3) that contributes to reducing CO_2 eq emissions by 173 t per year. However, the key piece of agriculture in Murcia is the sink of CO_2 eq that must be preserved by reducing, in this case, up to 7492.08 t CO_2 eq per year which, in the authors' opinion, is a magnificent contribution to the environment (Figure 12).

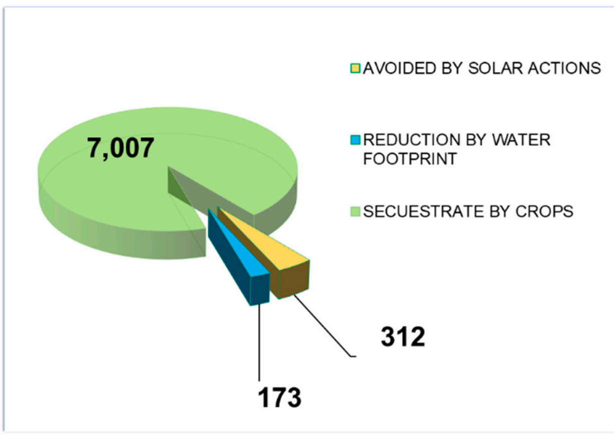


Figure 12. Summary new future reduction t CO_2eq/y after actions. Source: Own elaboration.

4. Discussion

After consulting the literature, the GHG indices and emissions during irrigation water management have been summarized, applicable to this case study, (Table 7) the values are in the range of 0.166 in Spain [33] with surface source water used in localized irrigation, at 0.341 $kgCO_2eq/kWh$, in China [48] where the water used for winter wheat irrigation came from underground, passing through the sum of 0.062 $kgCO_2eq/kWh$ of electrical origin plus 0.732 $kgCO_2eq/L$ of fossil fuel consumption in Pakistan [49], also of underground origin. The starting data were annual consumption of 2,149,500 m^3 and 2,032,471 kWh in 2016, resulting in an emission index of 0.361 $kgCO_2eq/kWh$ per m^3, before carrying out the improvement actions described in this article. After the actions, there is a consumption of 1,012,811 kWh/y of photovoltaic renewable origin, a reduction due to an improvement in the performance of the pumping equipment equivalent to 1,019,660 kWh/y and a water consumption of 1,418,485 m^3 per year after reducing more than 34% its water footprint. Given that the emissions are from renewable energy, it is possible to affirm that the emissions index by electrical origin associated with the water-energy binomial has been reduced to zero "0".

Table 7. Review of published values for emissions per m^3 of irrigation water.

Authors	Country	Source Energy Supply	Irrigation Type	Water Source	GHG Emissions
[49]	Pakistán	Electricity-Diesel		Underground	0.732 $kgCO_2eq/L$ 0.062 $kgCO_2eq/kWh$
[33]	Spain	Electricity	Located	Surface	0.166 $kgCO_2eq/kWh$
[48]	China	Electricity		Underground	0.341 $kgCO_2eq/kWh$

Additionally, the carbon footprint sequestered thanks to the crops of this WUA (7000.7 t CO_2eq/y) provides a value of 8.7 t C/ha per year against the threat of desertification and abandonment of farmland must be weighed. Due to the great contribution that this makes to mitigating climate change, Pinus pinaster forests are capable of sequestering 1.58 t C/ha, compared to Eucalyptus globulus forests, which are capable of sequestering up to 5.14 t C/ha [50], providing an idea of the great value of the vegetation cover provided by agriculture in the southeast of Spain.

Agriculture is the basis of our development, we cannot eat electronic chips or consume digital food. The evolution of the digital society and globalization are a reality that must be compensated in a manner that does not unbalance the ecosystems in which we operate. Developing countries should not lose control of the agricultural production that feeds their citizens. Thus, new technologies help us to control the quality of our food, how it is produced, where it is produced, when it is produced, who produces it and under what phytosanitary conditions. Most importantly, a footprint is produced in nature during the generation of these foods. Governance as a management tool is capable of articulating the reduction of GHG, starting from the allocation of certain water resources, to certain lands, and promoting the use of green energy during production. This article shows how farmers in eastern Spain, inspired by the astronauts living in space stations, are able to reuse reclaimed water from WWTPs, optimize and reduce energy consumption in their fields as much as possible, and take advantage of the energy resources generated. Nature provides resources (in this case solar energy), for improving their irrigation system and taking advantage of the advances in ICT to be able to maintain the artificial forests (fruit orchards) of the Mediterranean countries that serve as a lung to renew CO_2 eq in southern Europe while acting as a barrier to the threat of desertification as a consequence of climate change. Currently, as the global COVID-19 pandemic has drastically restricted people's mobility, the importance of having locally grown products has been highlighted, to avoid possible shortages affecting local markets.

5. Conclusions

Agriculture maintains the forests of fruit trees and vegetable plantations, allowing us to breathe cleaner air. It also avoids the abandonment of arable land and translates into a socio-economic redistribution that offers a niche market for women. This is thanks to the governance of the different administrations that must plan the availability of resources, the allocation of endowments for crops and the ICTs that optimize management and control of these resources. It should be noted that in semi-arid areas of the Mediterranean, fruit/agricultural plantations should be considered not only as the main means of production, but also as an ecological method of protection against climate change, concretely, against desertification.

In summary, and after appreciating the data presented in Section 4 discussion, this study seeks to collaborate in the fulfillment of the three objectives of European policy within the Climate and Energy Framework for 2030:

- reduction of at least 40% of greenhouse gas emissions (relative to 1990 levels).
- increase of at least 27% in the share of renewable energies.
- improve energy efficiency by at least 27%.

It also contributes to the fulfillment of the following SDGs:

- SDG 6 (sections 6.3 and 6a), the use of reclaimed water using alternative energies and ICTs is promoted, as well as actions to cover reservoirs that produce a better efficient use of the water resources of this WUA.
- SDG 7 (sections 7.2 and 7.3), the increase in the proportion of renewable energy in our system is evidenced).
- SDG 12 (sections 12.2 and 12.4), the set of actions described produces sustainable management and an improvement in the efficient use of natural resources, in our case water. All the actions described in this paper are aimed at reducing emissions to the atmosphere.
- SDG 15 (section 15.3), the lands included in this study and during its preparation (last 4 years) have been affected, by periods of drought and floods, which, if it were not for the aid articulated by the European Union, would be led to abandonment and subsequent desertification.

Thus, primary production methods, such as agriculture, must be integrated into sustainable technological development, serving as an example of development to other semi-arid regions that need accessible solutions. The need to import energy from other countries must also be reduced and create new opportunities for sustainable growth through the use of renewable energies.

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