Prepared by:

REDAWN – Reducing Energy Dependency in Atlantic area Water Networks

PROJECT REPORT

Environmental Impact Assessment

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REDAWN Reducing Energy Dependency in Atlantic Area Water Networks
Interreg Atlantic Area European Regional Development Fund
EUROPEAN UNION

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1. Introduction

Water consumption and energy production are two closely related activities. Large amounts of water are needed for energy production and an important energy consumption is required for water treatment and transport. The role of both has a high effect on productivity, health, climate change and food security.

These considerations are more important, if possible, taking into account the growth forecasts of the world's population, estimated (at) around +33% by 2050. This growth will impose greater water needs, so it is expected that in 2050 water consumption will be 40% higher than the current one. Climate change intensifies these needs even more.

To address the growing demand for energy and water at affordable costs and in an environmentally sustainable manner, it is necessary to know the availability of both resources and develop technologies to reduce their consumption and to make sustainable their use.

In this sense, EU policies are directed to:

- Reduce energy consumption in water management systems (supply, purification, sanitation) through improved energy and hydraulic efficiency.
- Recover energy from water flows in hydraulic infrastructures by means of small hydroelectric solutions.
- Reduce water consumption in energy production.

Regarding the first challenge, the processes linked to the integral water management seem far from reaching the top limit in energy and hydraulic efficiency. Energy consumption for water treatment processes can represent up to 5% of a country's total electricity consumption. On the other hand, leaks in water networks still reach significant values (20-25%).

Detail of a water leak

Regarding the second challenge, a possible solution could be the installation of micro-hydro generators in these infrastructures. These devices can produce electricity from water energy (kinetic and potential). This fact presents three perspectives, allows to reduce the power consumption of these plants through self-consumption solutions; facilitates distributed generation and greater use of renewable sources in electrical systems, contributing to reduce GHG emissions in the energy sector; allows to give access to the electrical network in remote or non-viable places, facilitating the installation of monitoring systems that improve hydraulic efficiency, one of the key points of the first challenge.

Regarding the third challenge, the introduction of micro-hydro devices will cause a shorter operating time of traditional thermal power plants and with it a downward adjustment of water consumption in electricity production processes.

A thermal power plant

Note: Hydroelectric generators produce electricity from water energy. Micro-hydro devices have a rated power lower than 100 kW.

The main objective of the REDAWN Project focuses on the second challenge, trying to consolidate a new water-energy management model more sustainable, and promoting the installation of micro-hydro devices in hydraulic infrastructures of the European countries in the Atlantic area.

The present study is divided into three parts. The first part is a summary of the analysis of the energy potential in the main hydraulic infrastructures located in countries in the Atlantic Area, including an identification of optimal sites to install micro-hydro devices. Those infrastructures are:

- Urban and industrial wastewater networks, including sewage treatment plants.
- Drinking water supply networks, including water potabilization plants.
- Irrigation infrastructures.

The second part is an evaluation of possible environmental impacts that could take place in these hydraulic infrastructures during its operation.

The third part is an evaluation of potential environmental benefits that could result from the integration of micro-hydro devices in those hydraulic infrastructures. The analysis includes commissioning and operative phases.

Although an exhaustive analysis will be done in the following sections, some positive effects can be now identified:

- GHG emissions from electrical production will be reduced. This has a direct impact in global warming and climate change.
- Generation of polluting waste will be avoided while the system is working.
- Once the new equipment has been introduced, the circulating water properties won´t be altered.
- It fits in a smaller space than the traditional hydroelectric plants, what means a smaller civil work and a reduction of the environmental impact.

The aim of this study it is not just to get a general vision of the environmental effects, but also be a reference document for potential project developers while they will be making their own environmental assessments.

2. Potential water resources and water network components database in AA

2.1. Ireland

Table 1 summarises the data collected on MHP potential in water networks in Ireland, including the number of existing sites identified, an estimate of their power potential and an extrapolation of that potential, in terms of energy, to the entire AA region of Ireland. Extrapolated data was conducted on the basis of the relationship between population and energy production estimations from the existing sites. These extrapolations are subject to significant uncertainties.

Table 1. MHP potential in Ireland measured and estimated in the REDAWN project

Data Description	Drinking Water	Irrigation	Wastewater	Industry	Total
Number of sites identified	44	0	535	22	601
Theoretical Power Potential (kW)	668	0	219	212	1099
Extrapolated Energy* (GWh)	13.7-40.0	0	1.8	2.3	17.8-44.1

*Annual potential

The drinking water sector in Ireland was estimated to hold an annual potential between 13.7 and 40.0 GWh of available energy for MHP installations. This estimate is on the basis of extrapolation of data from 7775 sites in the countries included in the area of interest and a ratio of energy potential to population serverd based on different assumptions, including the average and the median for the individual ratios of all countries with data, and the individual ratio for Ireland of 0.35 kW/1000 people.

No irrigation potential was identified in Ireland as such infrastructure is not common or not required in this climate.

Data on 535 wastewater treatment plants was collected and an estimate 1.8 GWh was determined for the full country as annual energy recovery potential in this sector.

Data was collected from a limited number of large industrial water users with a potential for MHP of 212 kW. Extrapolation was then carried out based on information about wastewater discharges for industries in Spain, and the gross domestic product related to the industrial activity for each country, estimating an annual energy potential for Ireland around 2.3 GWh.

A turbine in a water treatment plant near Dublin

2.2. United Kingdom

Table 2 summarises the data collected on MHP potential in water networks in the UK, including the number of existing sites identified, an estimate of their power potential and an extrapolation of that potential, in terms of energy, to the entire region of the UK. Extrapolated data was conducted on the basis of the relationship between population and energy production estimations from the existing sites. These extrapolations are subject to significant uncertainties.

Table 2. MHP potential in the UK measured and estimated in the REDAWN project

Data Description	Drinking Water	Irrigation	Wastewater	Industry	Total
Number of sites identified	7684	0	0	0	7684
Theoretical Power Potential (kW)	24637	0	0	0	24637
Extrapolated Energy (GWh)	191.7-689.1	0	25.7	15.2	232.6-730.0

*Annual potential

The drinking water sector in the UK was estimated to hold an annual potential between 191.7 and 689.1 GWh of available energy for MHP installations. This estimate is on the basis of extrapolation of data from 7775 sites in the countries included in the area of interest and a ratio of energy potential to population served based on different assumptions, including the average and the median for the individual ratios of all countries with data, and the individual ratios for Scotland (4.28 kW/1000 people), Wales (0.25 kW/1000 people) and Northern Ireland (0.47 kW/1000 people). No individual ratio was obtained for England as no information about potential sites was collected for this country.

No irrigation potential was identified in the UK as such infrastructure is not common or not required in this climate.

The waste water sector in the UK was estimated to hold the potential for annual MHP energy recovery of 25.7 GWh. This was estimated using a linear correlation between the power potential for MHP and the population served based on information about wastewater discharges for Irish and Spanish plants.

The extrapolation for the industry sector, based on data about the industrial wastewater discharges in Spain, amounted to a total energy potential of 15.2 GWh for the UK. This extrapolation was based on information about wastewater discharges for industries in Spain, and the gross domestic product related to the industrial activity for each country.

Turbine installation in UK water treatment works

2.3. France

Table 3 summarises the data collected on MHP potential in water networks in France, including the number of existing sites identified, an estimate of their power potential and an extrapolation of that potential, in terms of energy, to the entire region of France. Extrapolated data was conducted on the basis of the relationship between population and energy production estimations from the existing sites. These extrapolations are subject to significant uncertainties.

Table 3. MHP potential in France measured and estimated in the REDAWN project

Data Description	Drinking Water	Irrigation	Wastewater	Industry	Total
Number of sites identified	2	0	0	0	2
Theoretical Power Potential (kW)	0	0	0	0	0
Extrapolated Energy (GWh)	188.6-548.8	0	25.3	14.4	228.4-588.6

*Annual potential

The 2 potential sites identified for the drinking water sector in France did not presented enough power to be considered viable (minimum of 2 kW), being not included in the total. For that reason, the estimations for this country, for the diferent sectors, were based on the relation found between the energy potential and population served in countries in which data was available, following different assumptions. Thus, a total annual energy recovery potential between 188.6 and 548.8 GWh was estimated for the drinking water sector.

The estimation for the irrigation sector was not finally included for France, as no information about the surface with similar irrigation networks to those included in the analysis of the 18 pressurized irrigation networks for Southern Portugal and Spain was found.

The estimations for the wastewater sector were based on the correlation between the power potential and population served extracted from the Irish and Spanish treatment plants, accounting to a total of 25.3 GWh for France.

For the private industry sector a total of 14.4 GWh of potential energy recoverable throughout the year was estimated, based on wastewater discharges licenses of private industries included in the database analysed for Spain.

2.4. Spain

Table 4 summarises the data collected on MHP potential in water networks in Spain, including the number of existing sites identified, an estimate of their power potential and an extrapolation of that potential, in terms of energy, to the entire region of Spain. Extrapolated data was conducted on the basis of the relationship between population and energy production from the existing sites. These extrapolations are subject to significant uncertainties.

Table 4. MHP potential in Spain measured and estimated in the REDAWN project

Data Description	Drinking Water	Irrigation	Wastewater	Industry	Total
Number of sites identified	34	173	343	87	637
Theoretical Power Potential (kW)	95	2946	982	1403	5426
Extrapolated Energy (GWh)	135.7-396.1	221.4	18.2	12.3	387.7-648.1

*Annual potential

The drinking water sector in Spain was estimated to hold an annual potential between 135.7 and 396.1 GWh of available energy for MHP installations. This estimate is on the basis of extrapolation of data from 7775 sites in the countries included in the area of interest and a ratio of energy potential to population served based on different assumptions, including the average ratio and the median for the individual ratios of all countries, and the individual ratio for Spain of 0.09 kW/1000 people.

The irrigation sector extrapolations were based on the potential found for the pressurised irrigation networks analysed in the south of Portugal and Spain, as well as the information about the localised irrigation surface and the ratio between the surface water and total water used for irrigation. The total extrapolation reached 221.4 GWh for energy recovery potential for irrigation in Spain.

Data of the discharge licenses for 343 wastewater treatment plants were collected in Spain, and together with the Irish data, a linear correlation between the power potential and the population served was found. This correlation determined a total energy recovery potential for the wastewater sector in Spain of 18.2 GWh.

The industry sector was examined considering the annual wastewater discharge volumes for the set of industries included in the database of wastewater licenses of the country, amounting to a total annual energy recovery potential of 12.3 GWh.

A turbine in a water supply network in Asturias (Spain)

2.5. Portugal

Table 5 summarises the data collected on MHP potential in water networks in Portugal, including the number of existing sites identified, an estimate of their power potential and an extrapolation of that potential, in terms of energy, to the entire region of Portugal. Extrapolated data was conducted on the basis of the relationship between population and energy production estimations from the existing sites. These extrapolations are subject to significant uncertainties.

Table 5. MHP potential in Portugal measured and estimated in the REDAWN project

Data Description	Drinking Water	Irrigation	Wastewater	Industry	Total
Number of sites identified	11	4	0	1	16
Theoretical Power Potential (kW)	34	49	0	10	93
Extrapolated Energy (GWh)	29.6-86.4	23.9	4.0	2.6	60.1-116.9

*Annual potential

The drinking water sector in Portugal was estimated to hold a potential between 29.6 and 86.4 GWh of available energy for MHP installations. This estimate is on the basis of extrapolation of data from 7775 sites identified in the countries included in the area of interest and a ratio of energy potential to population served based on different assumptions, including the average ratio and the median for the individual ratios of all countries, and the individual ratio for Portugal of 0.31 kW/1000 people.

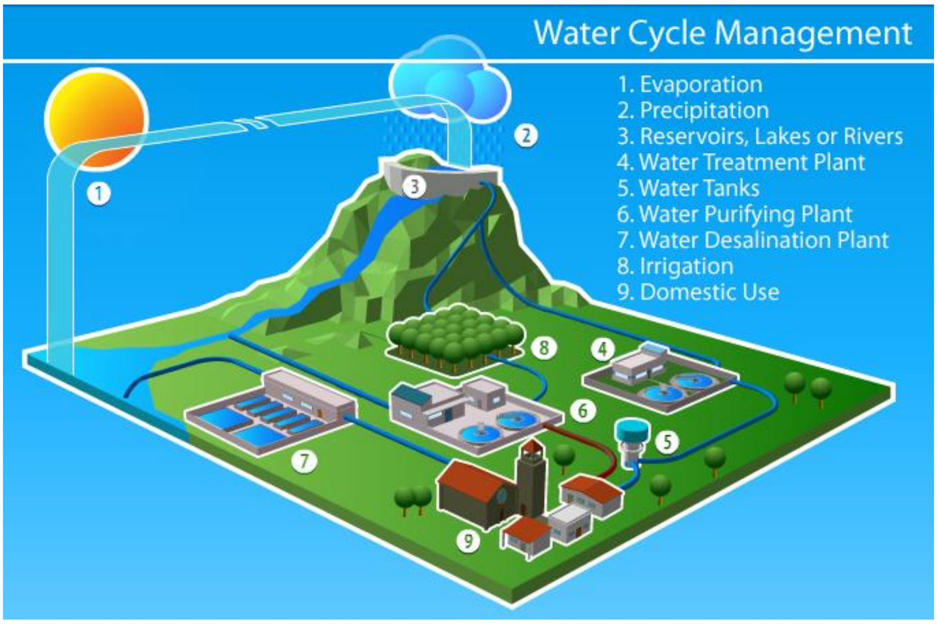
Irrigation potential extrapolation was based on the potential found for the pressurised irrigation networks analysed in the south of Portugal and Spain, as well as the information about the total surface in the region with similar irrigation networks. 4 sites were found in the assessment of the Aboro network. The extrapolated energy potential for Portugal was then identified as 23.9 GWh.

The waste water sector in Portugal was estimated to hold the potential for 4 GWh of energy throughout the year. This was estimated on the basis on the population and the linear correlation found between the potential for MHP in the wastewater treatment plants analysed and the population served in Ireland and Spain.

Data was collected for the industry sector in Portugal from the pilot plant at Renova S.A. Extrapolation was then carried out based on information about industrial wastewater discharges in Spain, estimating an annual energy potential for Portugal around 2.6 GWh.

3. Environmental impact of water sectors

Hydraulic infrastructures related to the integral cycle of water management (catchment, purification, distribution, sewage, filtration, reuse) and those used for irrigation have environmental impacts arising from its operation and maintenance. It must be borne in mind that the average age of these infrastructures in the European countries of the Atlantic Arc are approaching the 50 years.



Water cycle management

In general, in water networks, the main activities that can cause environmental impacts during operation and maintenance are:

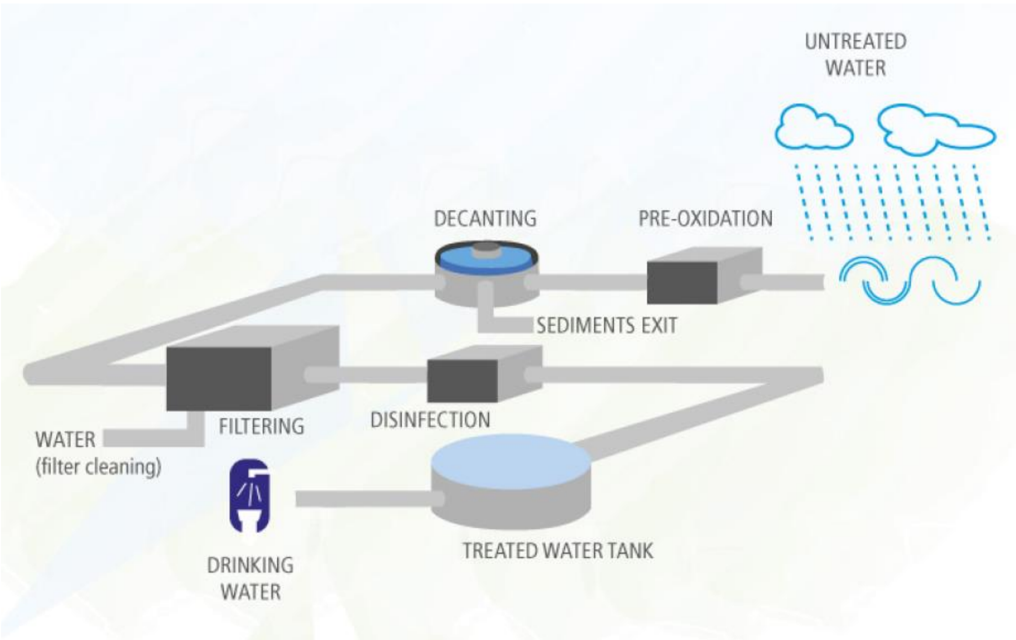
- Electrical energy consumption. The environmental effects considered are the emissions of CO2 and other greenhouse gases associated with the production and transport of the electrical energy consumed in these systems; electromagnetic pollution and the risks of electrocution of birds caused by the networks of distribution and transport coming to these systems.
- Maintenance and upkeep of the equipment. The environmental effects considered are risks of contamination of soil and water by accidental spills of chemicals or inadequate waste management.
- Breakage of pipes. The environmental effects considered are the modification of the conditions of soils and groundwater by water saturation.

Additionally, in the stages of purification of water and treatment of waste water (urban and industrial), there are other activities linked to the operation of Drinking Water Treatment Plant (DWTP) and Sewage Treatment Plant (STP) with high potential to generate environmental impacts. Among them, we can distinguish:

- Addition of chemical reactives. The environmental effects considered are the risks of pollution of soils, water and air by accidental spills of chemicals or gaseous pollutants derived.
- Removal of sludge and other waste. The environmental effects considered are risks of contamination of soil and water by inadequate waste management.

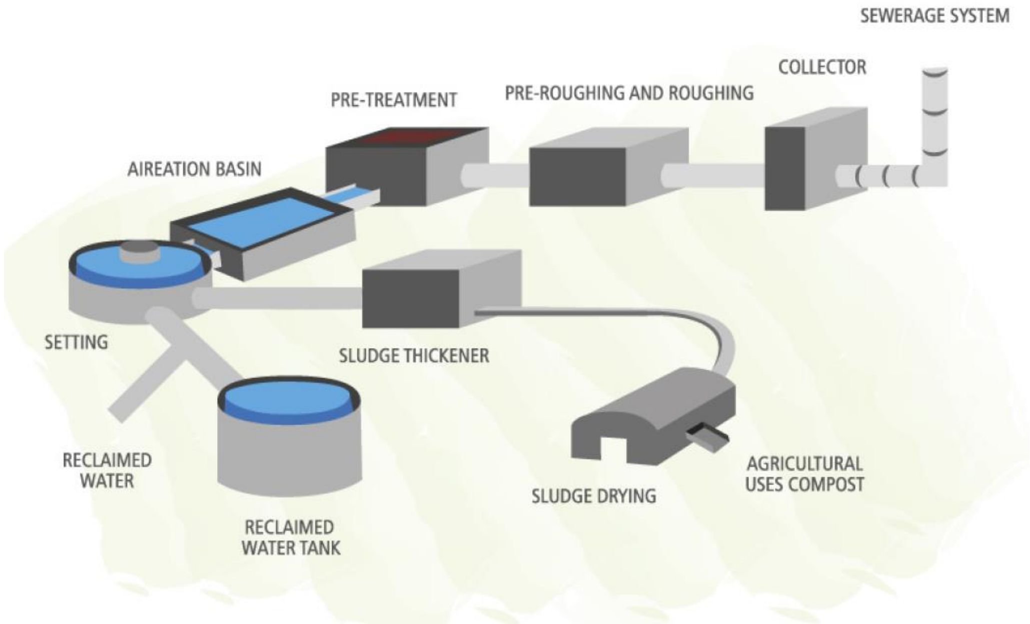
Therefore, it is observed that the most important environmental impact is the associated to energy consumption since the rest are due to accidental or extraordinary situations.

It should be noted that during the past years there has been a significant increase in the consumption of energy in water treatment processes. In the DWTP natural water is subjected to processes of treatment with high demand of electricity to make it suitable for human consumption. These processes are, generally, coagulation, flocculation, decantation, filtration and disinfection. In the last generation plants, where are used innovative purification systems to achieve higher quality water, energy consumption soar in processes such as ozonation. The development of new analytical methods more sophisticated that allow detection of elements at trace level also contributes to higher rates of energy consumption on this type of plants.



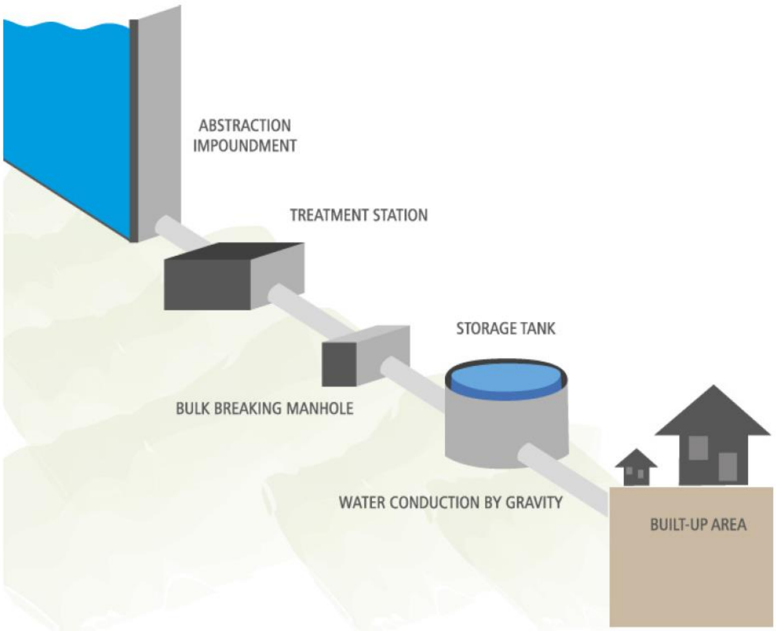
Process scheme of a drinking water treatment plant

In the STP is residual water from the circuits of sewage or industrial activities so that it can be returned to the natural cycle without affecting the environment. For this purpose, different physical, chemical and biological processes such as mechanical removal, flotation, neutralization, homogenization, biological treatment to remove organic matter, advanced treatments are used to remove heavy metals, treatment of sludge (dehydration, centrifugation, stabilization, packaging for transportation). All of these processes require a significant amount of electrical energy.



Process scheme of a sewage treatment plant

In supply networks and irrigation infrastructures, electrical consumption is due to the presence of equipment such as actuation of valves or pumping systems.



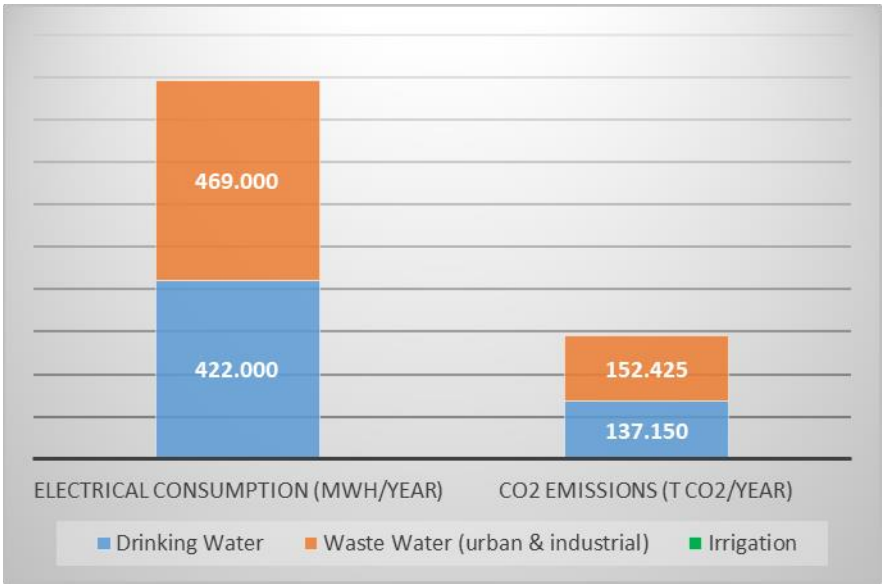
General outline of a drinking water supply system

To measure the environmental impact of these consumption is to quantify the CO2 emissions associated with the energy consumption of these activities in each of the European countries of the Atlantic Arc.

Detail of an irrigation system

3.1. Ireland

The carbon footprint, valued in the form of CO2 emissions, caused by the electrical consumption of the hydraulic infrastructure of Ireland is shown in the figure below.



Electrical consumption and CO2 emissions in water networks of Ireland by infrastructure type

The sources of the electrical consumption and water volume data have been mainly the Sustainable Energy Authority of Ireland (SEAI) and Irish Water.

According to the data provided by the Department of Communications, Climate Action and the Environment of the Government of Ireland, the factor of CO2 emissions associated with the generation of the electrical system of Ireland reached an average value of 0,325 t CO2/MWh in 2017.

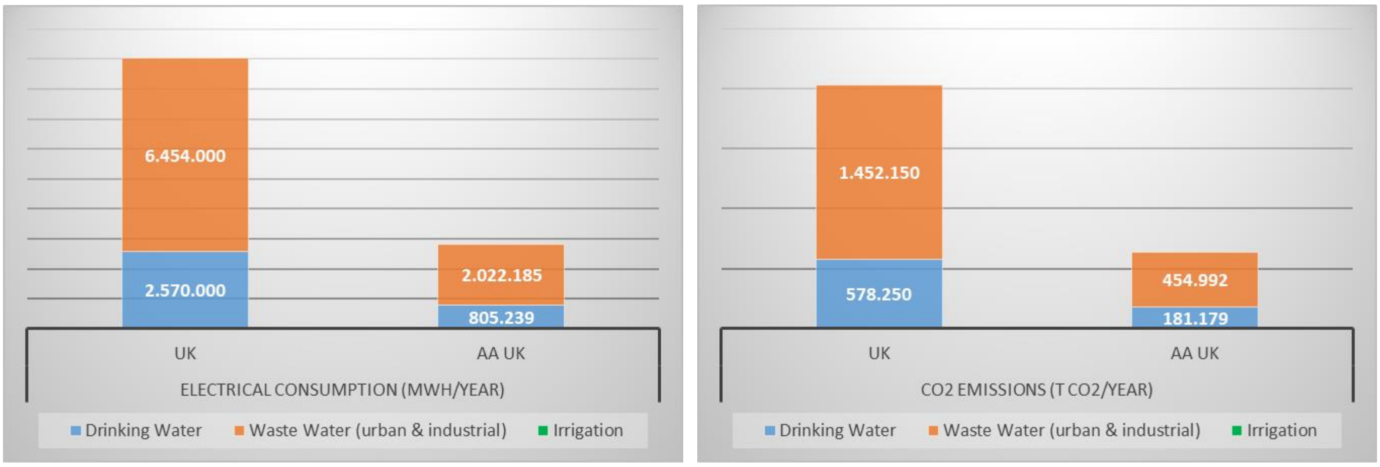
Considering this factor of CO_2 emission for the energy, the emissions associated to the water consumption will be the following:

	kWh/m3	kg CO2/m3
Drinking water	0,72	0,235
Waste water (urban and industrial)	0,80	0,261
Irrigation	0	0
TOTAL WATER SECTOR	**0,76**	**0,248**

In Ireland, the highest consumption takes place in wastewater networks. The country's climatic conditions make irrigation of crops unnecessary.

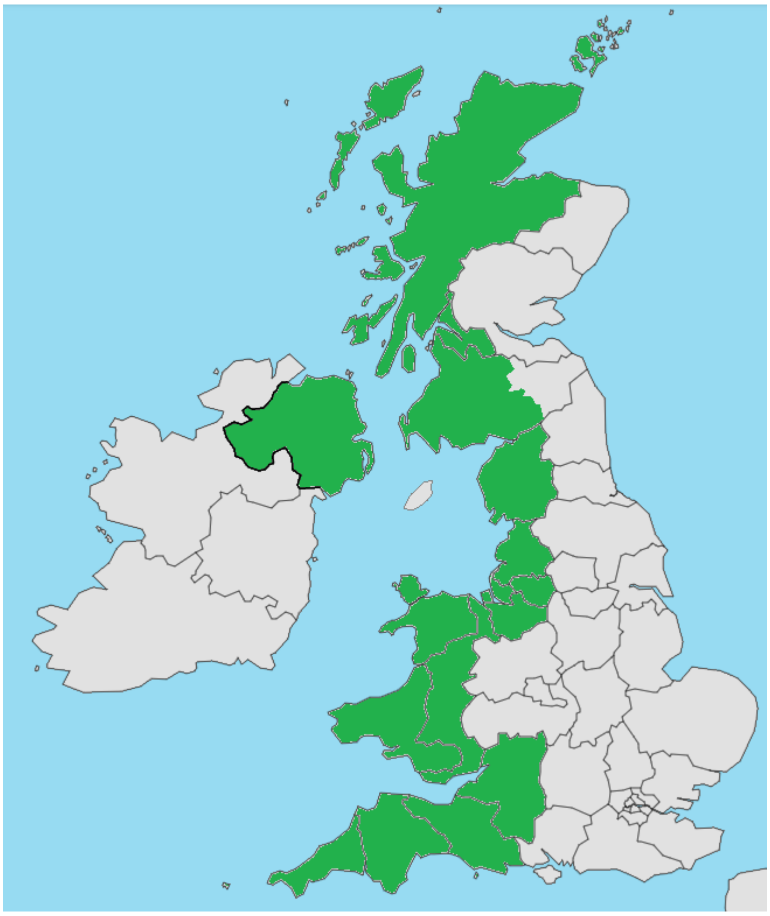
3.2. United Kingdom

Is then analyzed the carbon footprint, valued in the form of CO2 emissions, caused by the electrical consumption of the hydraulic infrastructure of United Kingdom and particularly in the AA regions of UK.



Electrical consumption and CO2 emissions in water networks of UK and AA UK by infrastructure type

The Atlantic Area in UK includes entire North Ireland and Wales and the following departments of England and Scotland (according to Eurostat NUTS-2): Cornwall and Isles of Scilly; Devon; Dorset and Somerset; Gloucestershire, Wiltshire and Bristol/Bath Area; Cheshire; Greater Manchester; Merseyside; Lancashire; Cumbria; Highlands and Islands; West Central Scotland and Southern Scotland (excluding Scottish Borders).



Atlantic Area in UK (green)

The sources of the electrical consumption and water volume data have been mainly the Office for National Statistics (ONS) and Water UK. The AA consumption data have been estimated from available population figures (national and regional) obtained from Eurostat and ONS.

According to the data provided by the Department for Business, Energy and Industrial Strategy of the Government of UK, the factor of CO2 emissions associated with the generation of the electrical system of the United Kingdom reached an average value of 0,225 t CO2/MWh in 2017.

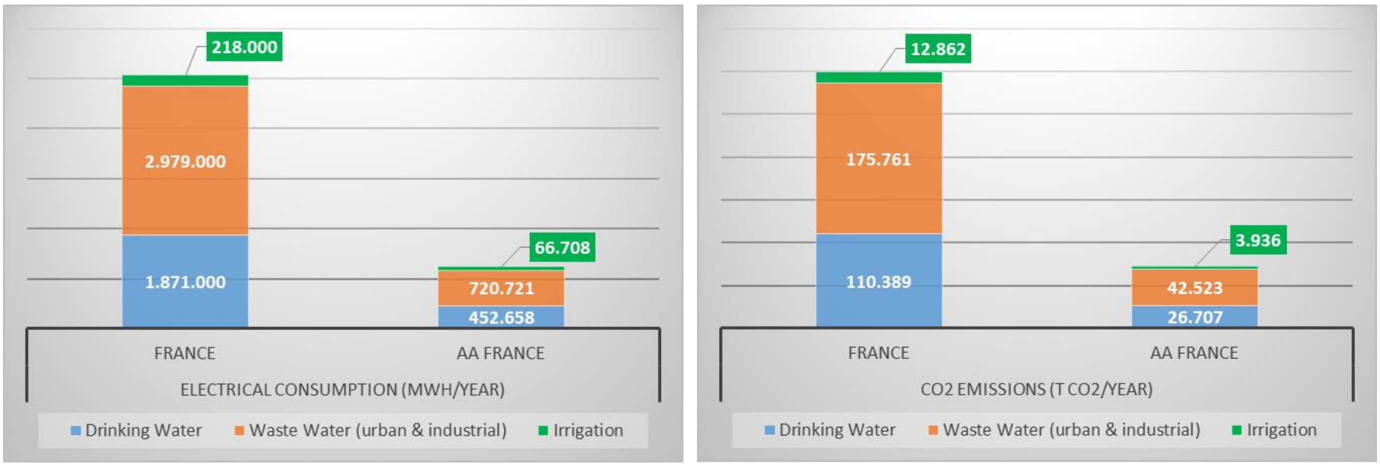
Considering this factor of CO_2 emission for the energy, the emissions associated to the water consumption will be the following:

	kWh/m3	kg CO2/m3
Drinking water	0,46	0,103
Waste water (urban and industrial)	0,87	0,195
Irrigation	0	0
TOTAL WATER SECTOR	**0,69**	**0,156**

In the AA of UK, the highest consumption takes place in wastewater networks. The country's climatic conditions make irrigation of crops unnecessary.

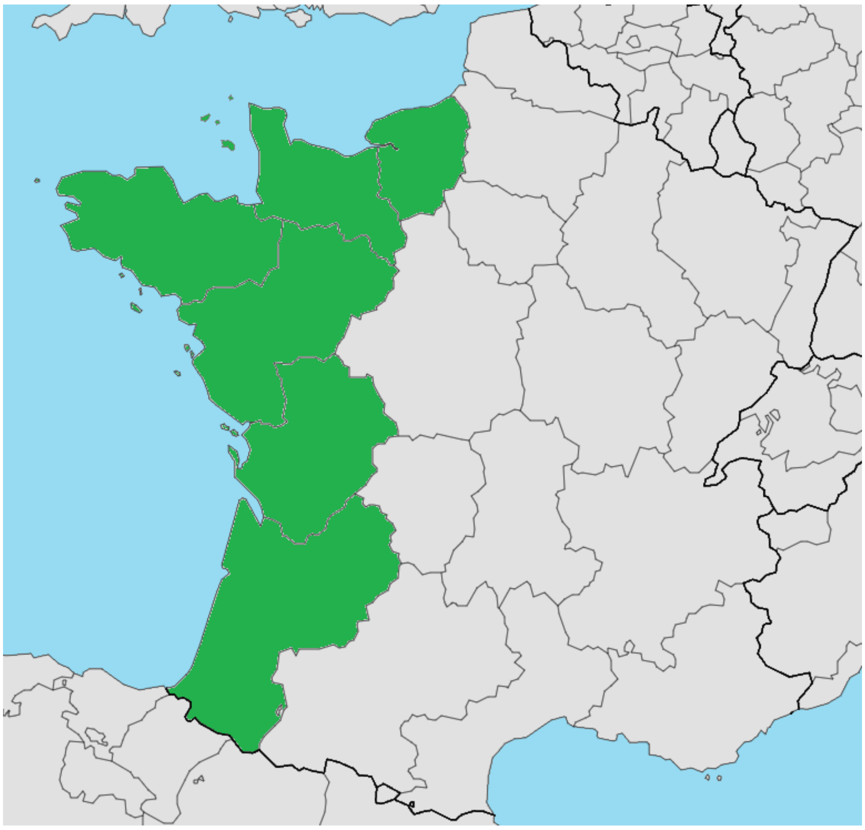
3.3. France

Is then analyzed the carbon footprint, valued in the form of CO_2 emissions, caused by the electrical consumption of the hydraulic infrastructure of France and particularly in the AA regions of France.



Electrical consumption and CO2 emissions in water networks of France and AA France by infrastructure type

The Atlantic Area in France includes the following departments (according to Eurostat NUTS-2): Aquitaine, Poitou-Charentes, Pays de la Loire, Bretagne, Basse Normandie and Haute Normandie.



Atlantic Area in France (green)

The source of the electrical consumption and water volume data has been mainly Eurostat. The AA consumption data have been estimated from available population figures (national and regional) obtained from Eurostat and L'Institut National de la Statistique et des Études Économiques (drinking water and wastewater). In the case of irrigation systems, the reference has been the irrigated agricultural area (source: Eurostat).

According to the data of the European Environment Agency, factor of CO2 emissions associated with the generation of the electrical system of France reached an average value of 0,059 t CO2/MWh in 2016.

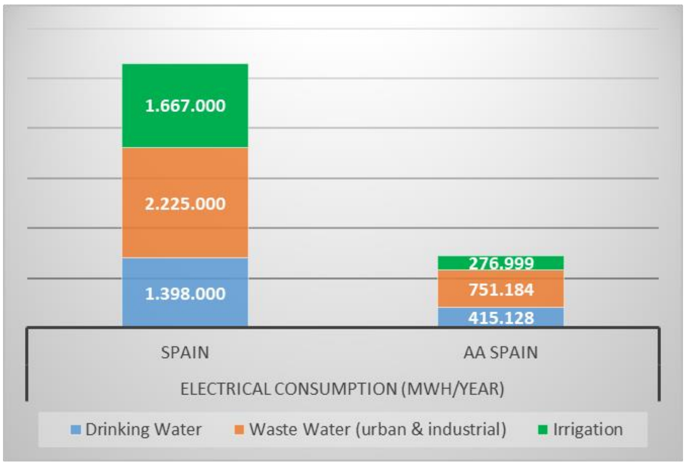
Considering this factor of CO_2 emission for the energy, the emissions associated to the water consumption will be the following:

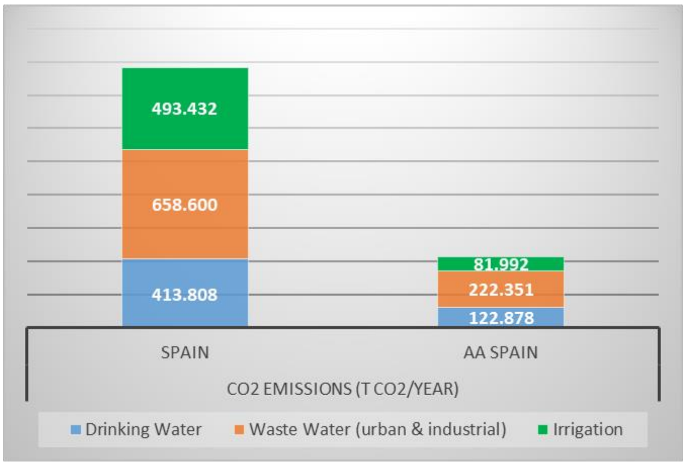
	kWh/m3	kg CO2/m3
Drinking water	0,55	0,033
Waste water (urban and industrial)	0,60	0,035
Irrigation	0,11	0,007
TOTAL WATER SECTOR	**0,47**	**0,028**

In the AA of France, the highest consumption takes place in wastewater networks.

3.4. Spain

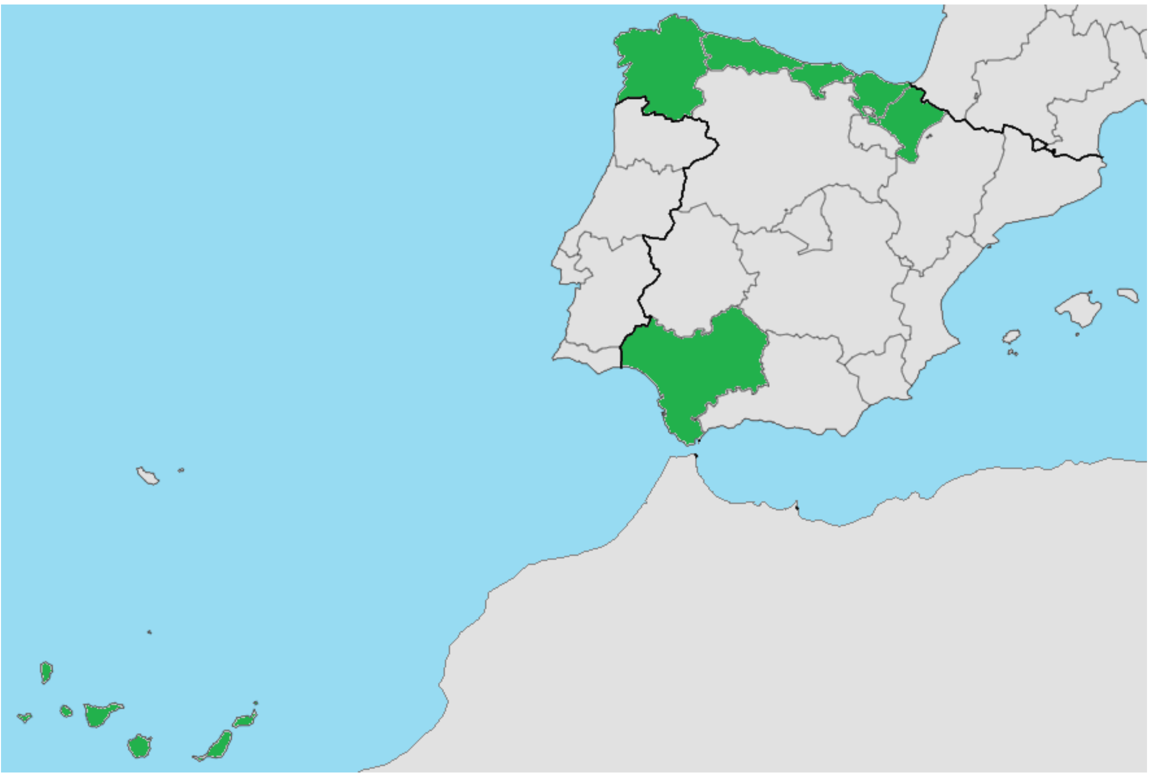
Is then analyzed the carbon footprint, valued in the form of CO2 emissions, caused by the electrical consumption of the hydraulic infrastructure of Spain and particularly in the AA regions of Spain.





Electrical consumption and CO2 emissions in water networks of Spain and AA Spain by infrastructure type

The Atlantic Area in Spain includes the following departments (according to Eurostat NUTS-2): Galicia, Principado de Asturias, Cantabria, País Vasco, Comunidad Foral de Navarra, Canarias and Andalucía (only Huelva, Sevilla, Cádiz and Córdoba provinces).



Atlantic Area in Spain (green)

The sources of the electrical consumption and water volume data have been mainly Instituto Nacional de Estadística (INE), Instituto para la Diversificación y Ahorro de la Energía (IDAE) and Universidad de Córdoba. The AA consumption data have been estimated from water consumption figures in regional drinking water, wastewater and irrigation systems obtained from INE.

According to data from the National Commission of Markets and Competition from Spain, CNMC, energy consumption for processes of water treatment in urban areas in Spain is around 8% of the total power consumption of the country.

According to data of Red Eléctrica de España (REE), the factor of CO2 emissions associated with the generation of the electrical system of Spain reached an average value of 0,296 t CO2/MWh in 2017.

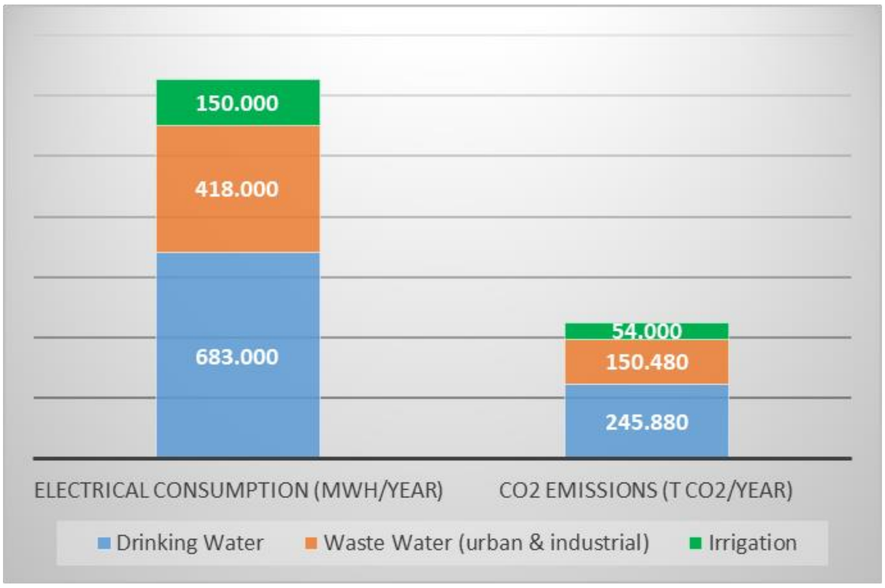
Considering this factor of CO_2 emission for the energy, the emissions associated to the water consumption will be the following:

	kWh/m3	kg CO2/m3
Drinking water	0,44	0,129
Waste water (urban and industrial)	0,47	0,139
Irrigation	0,14	0,043
TOTAL WATER SECTOR	**0,32**	**0,096**

In the AA of Spain, the highest consumption takes place in wastewater networks.

3.5. Portugal

Is then analyzed the carbon footprint, valued in the form of CO2 emissions, caused by the electrical consumption of the hydraulic infrastructure of Portugal.



Electrical consumption and CO2 emissions in water networks of Portugal by infrastructure type

The sources of the electrical consumption and water volume data have been mainly Entidade Reguladora dos Serviços de Águas e Resíduos (ERSAR) and Eurostat.

According to the data provided by Redes Energéticas Nacionais (REN), the factor of CO2 emissions associated with the generation of the electrical system of Portugal reached an average value of 0,360 t CO2/MWh in 2017.

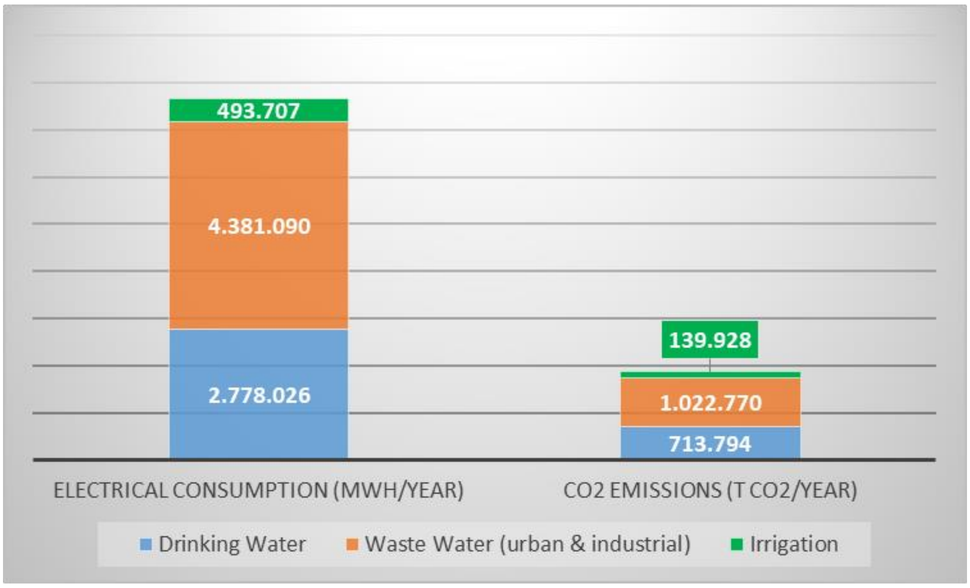
Considering this factor of CO_2 emission for the energy, the emissions associated to the water consumption will be the following:

	kWh/m3	kg CO2/m3
Drinking water	1,10	0,395
Waste water (urban and industrial)	0,45	0,163
Irrigation	0,08	0,029
TOTAL WATER SECTOR	**0,37**	**0,132**

In Portugal, the highest consumption, both total and partial, takes place in drinking water networks. It is remarkable the high consumption ratio of this sector.

3.6. Atlantic Area

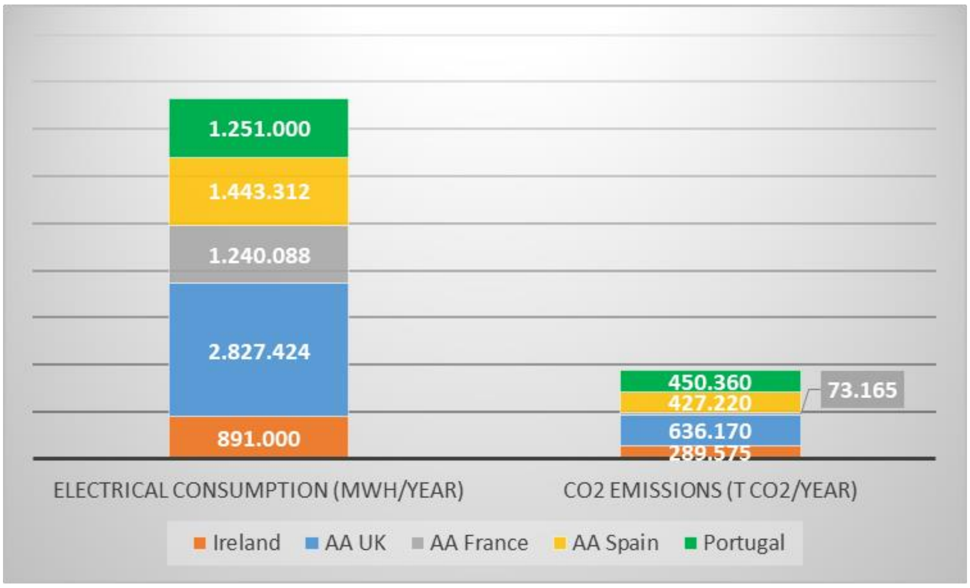
As a compendium of the data presented above, it is included the following graphics with the CO2 emissions caused by the electrical consumption of the hydraulic infrastructure in the regions of the Atlantic Area.



Electrical consumption and CO2 emissions in water networks of Atlantic Area by infrastructure type

In the Atlantic Area, the highest consumption takes place in wastewater networks. In general, the consumption (and emissions) ratio of irrigation is substantially lower than in other sectors.

According to the figure, the highest emissions take place in wastewater networks (54%) because these systems have the greatest electrical consumption.



Electrical consumption and CO2 emissions in water networks of Atlantic Area by country

The Atlantic Area of UK is the region with the highest value of emissions (34%) due to the significant consumption in wastewater facilities. Contrary, the Atlantic Area of France is the region with the lowest value of emissions (4%) due to the small ratio of CO2 emissions of its electricity system, dominated by nuclear power.

4. Environmental benefits of MHP plants in water sectors. Potential in AA

The introduction of MHP devices in water infrastructures in operation reports significantly environmental benefits.

First of all, it's a system of renewable electricity generation. Unlike fossil fuels, renewable energies do not emit GHG into the atmosphere, causing climate change

Secondly, according to various studies of IDAE, hydroelectric generation is the energy system of electricity production that produces lower impacts on the environment per kWh generated, including renewable sources. Its main environmental benefits are as follows:

- Non-consumptive use of water, since the water used is not consumed, being returned to the natural environment without alteration of their characteristics, once energy is used.
- Local character, by reducing the environmental impacts of any type of transport.
- Do not produce polluting waste, except in the construction phase, which preventive and corrective measures must always be followed.
- Use equipment whose manufacture involves the use of a smaller volume of hazardous substances and waste generation compared to other technologies.
- Endless, thanks to the natural hydrological cycle.

Thirdly, the MHP micro plants character provides them with a number of advantages over traditional hydroelectric plants. Traditional hydroelectric plants occupy large spaces causing relatively significant social and environmental impacts. A key point is the smaller volume of civil work required for the start-up.

In general, the setting up or construction phase in a traditional hydro plant includes the following actions:

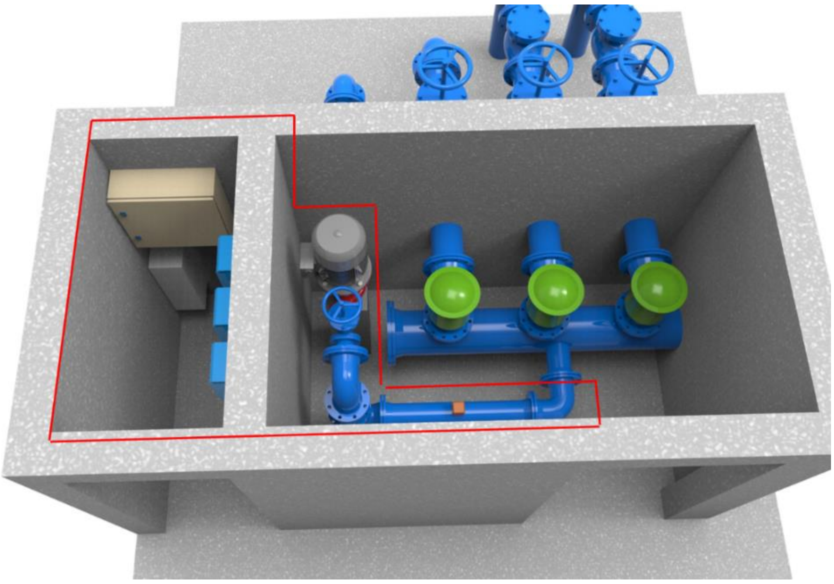
1. Conditioning of roads.
2. Mulching and earthworks (depending on work size).
3. Placement of pipes and construction of manholes.
4. Laying of electrical line.
5. Filling of excavation holes.
6. Construction of buildings to house electromechanical equipment.
7. Transport, storage and assembly of electromechanical equipment.

This work lead to a number of environmental impacts. The main potential effects are the following:

- Release of substances, energy or noise (accidental release of chemicals in the construction machinery or in maintenance works; emission of noise and vibrations by use of machinery in construction).

- Ground, air and water pollution (loss of air quality by the emission of gases of combustion and dust of the construction machinery, water pollution and soil by accidental spills).
- Destruction of vegetation, landscapes, habitats and fauna (higher erosive capacity of the water channel and alteration of aquatic ecosystems by variations in flow, deposition materials, tranquil waters, water barrier effects of dams, erosion and degradation of soil and loss of vegetation cover by earthworks and excavations; loss of habitat of species by disappearance of the vegetation and flood of margins after the construction of dams; movement of susceptible species caused by noise; visual impact due to changes in the landscape due to the presence of new infrastructures).

The integration of a MHP plant in any hydraulic infrastructure requires only steps 3 to 7 above and in a much smaller size, which affects a lower incidence of environmental effects during the installation phase. The impacts are minimized as a result of a smaller volume of excavation and land, and less use of heavy machinery movement. Because it is not be located in a natural channel does not cause alteration of the natural environment. It prevents problems of disruption of stream water or the barrier effect for the construction of dams or weirs. Also is avoided, in the same way, the loss of habitat due to the flooding of large areas.



3D model of a MHP in an irrigation system

However, it has to be taken into account during the operation of a plant MHP typical environmental impacts of any hydro-power plant, they may occur, even though on a smaller scale because of a smaller installation. The main environmental impacts that could occur in this phase of operation are:

- Release of energy or noise (emission of noise and vibrations by the turbine in operation; emission of electromagnetic radiation in power lines).

- Ground and water pollution (pollution of water and soil for accidental release of chemicals in maintenance). In the particular case of MCH plants integrated in water supply networks is adding the risk of loss of drinking water because of possible dilution of toxic substances. To eliminate this risk, it has to be ensured that the elements in contact with the water should have the treatments indicated by legislation and that the lubrication circuits of moving parts in contact with water do not produce leaks.

In regards to the environmental improvement of the hydraulic infrastructure, the introduction of such devices offers the possibility of reducing external electrical consumption through self-supply and the use of a wasted resource, the flow water. This fact not only reduces operating costs but it also helps to reduce the carbon footprint of the installation.

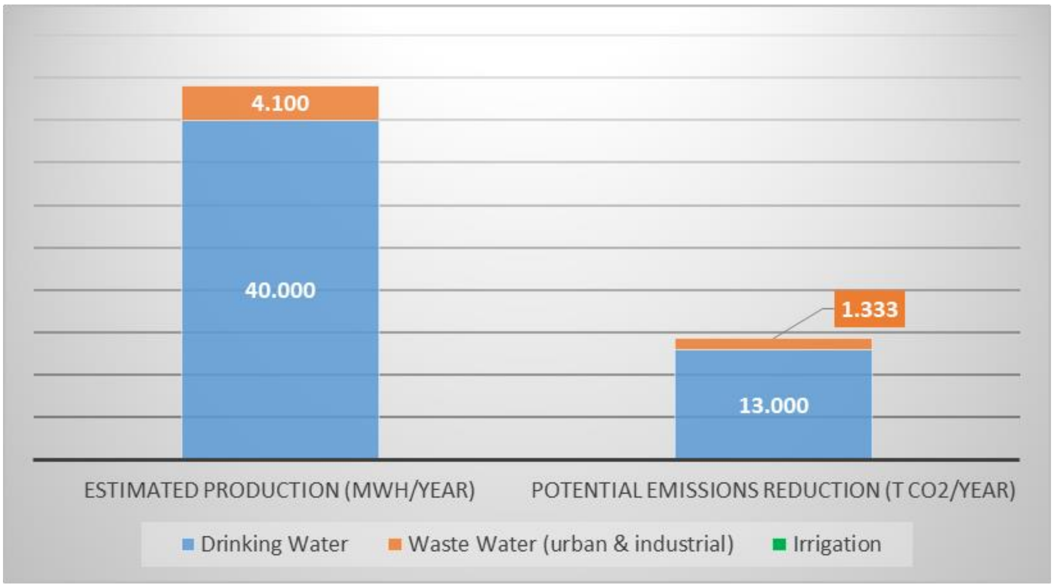
An irrigation system

Another positive environmental effect is the reduction of the risk of saturation of the ground due to breakage of pipes since MHP devices act as pressure-reducing elements. It also has an economic outlet for developers due to the reduction of investment costs in broken valves and similar equipment.

Below it is evaluated the reduction of the carbon footprint that would cause the MHP potential use identified in paragraph 2. For its calculation it has been considered that the MHP plants produce electricity without emitting greenhouse gases, so it is considered a reduction of CO2 emissions equivalent to the electrical energy generated according to the electrical mix of each country.

4.1. Ireland

According to the data provided by the Department of Communications, Climate Action and the Environment of the Government of Ireland, the factor of CO2 emissions associated with the generation of the electrical system of Ireland reached an average value of 0,325 t CO2/MWh in 2017.

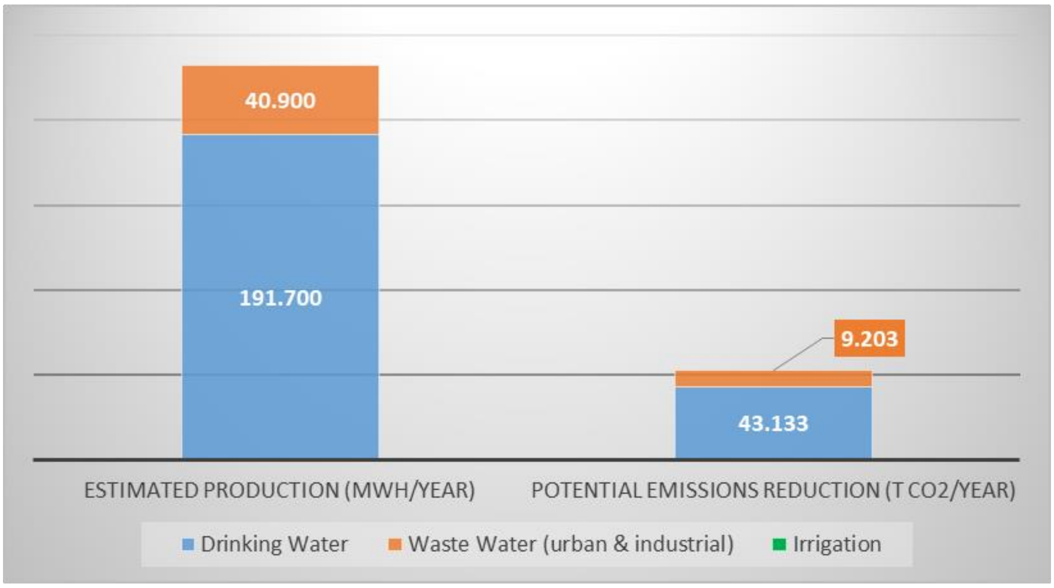


Estimated potential for electrical production and for emissions reduction as consequence of the installation of MHP in water networks of Ireland (by infrastructure type)

This potential for emissions reduction means -9,5% in DW and -0,9% in WW. In Ireland, the greatest potential for emissions reduction clearly lies in the installation of MHP in drinking water facilities.

4.2. United Kingdom

According to the data provided by the Department for Business, Energy and Industrial Strategy of the Government of UK, the factor of CO_2 emissions associated with the generation of the electrical system of the United Kingdom reached an average value of 0,225 t CO_2/MWh in 2017.

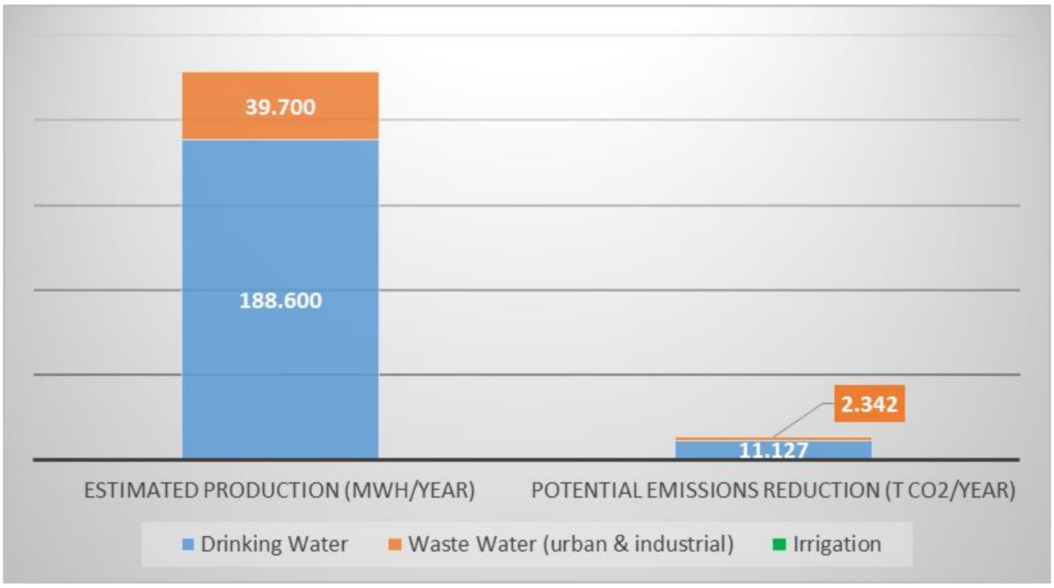


Estimated potential for electrical production and for emissions reduction as consequence of the installation of MHP in water networks of AA UK (by infrastructure type)

This potential for emissions reduction means -23,8% in DW and -2,0% in WW. In the AA of UK, the greatest potential for emissions reduction clearly lies in the installation of MHP in drinking water facilities.

4.3. France

According to the data of the European Environment Agency, factor of CO2 emissions associated with the generation of the electrical system of France reached an average value of 0,059 t CO2/MWh in 2016.



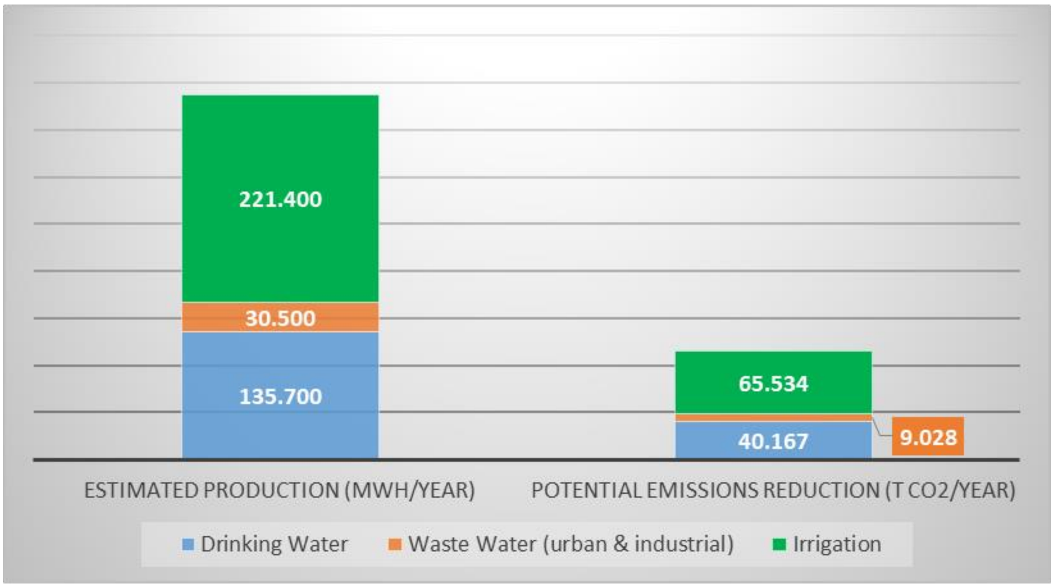
Estimated potential for electrical production and for emissions reduction as consequence of the installation of MHP in water networks of AA France (by infrastructure type)

According to what was commented in section 2, the estimation for the irrigation sector was not finally included for France.

This potential for emissions reduction means -41,7% in DW and -5,5% in WW. In the AA of France, the greatest potential for emissions reduction clearly lies in the installation of MHP in drinking water facilities.

4.4. Spain

According to data provided by Red Eléctrica de España (REE), the factor of CO2 emissions associated with the generation of the electrical system of Spain reached an average value of 0,296 t CO2/MWh in 2017.

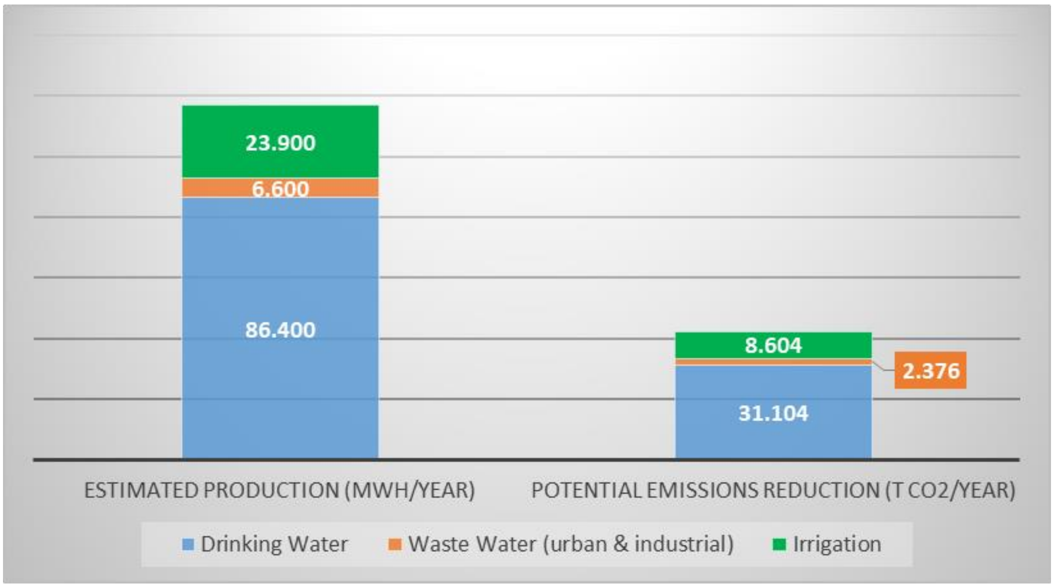


Estimated potential for electrical production and for emissions reduction as consequence of the installation of MHP in water networks of AA Spain (by infrastructure type)

This potential for emissions reduction means -32,7% in DW, -4,1% in WW and -79,9% in irrigation. In the AA of Spain, the greatest potential for emissions reduction lies in the installation of MHP in irrigation facilities, mainly concentrated in the region of Andalucía, although drinking water systems also have a significant potential.

4.5. Portugal

According to the data provided by Redes Energéticas Nacionais (REN), the factor of CO_2 emissions associated with the generation of the electrical system of Portugal reached an average value of 0,360 t CO_2/MWh in 2017.

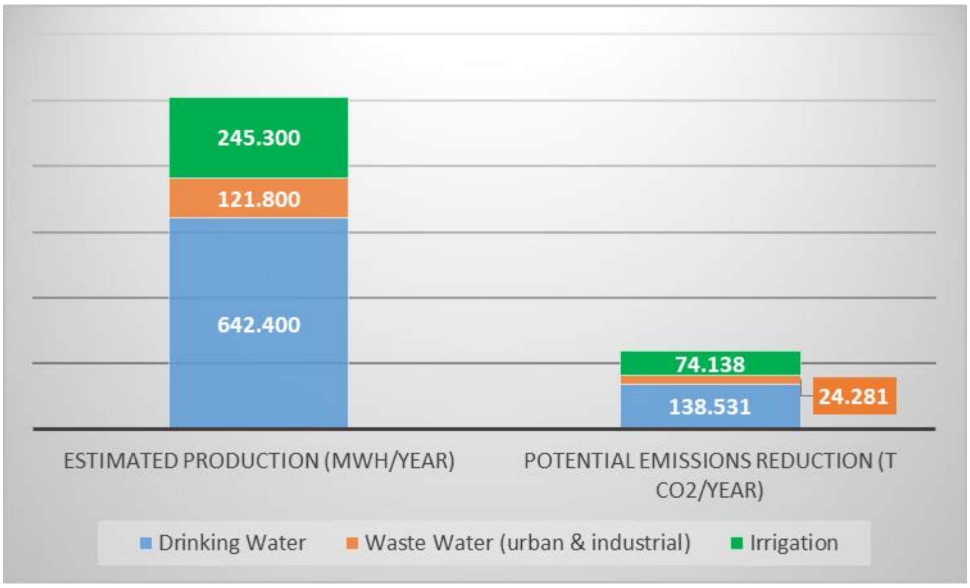


Estimated potential for electrical production and for emissions reduction as consequence of the installation of MHP in water networks of Portugal (by infrastructure type)

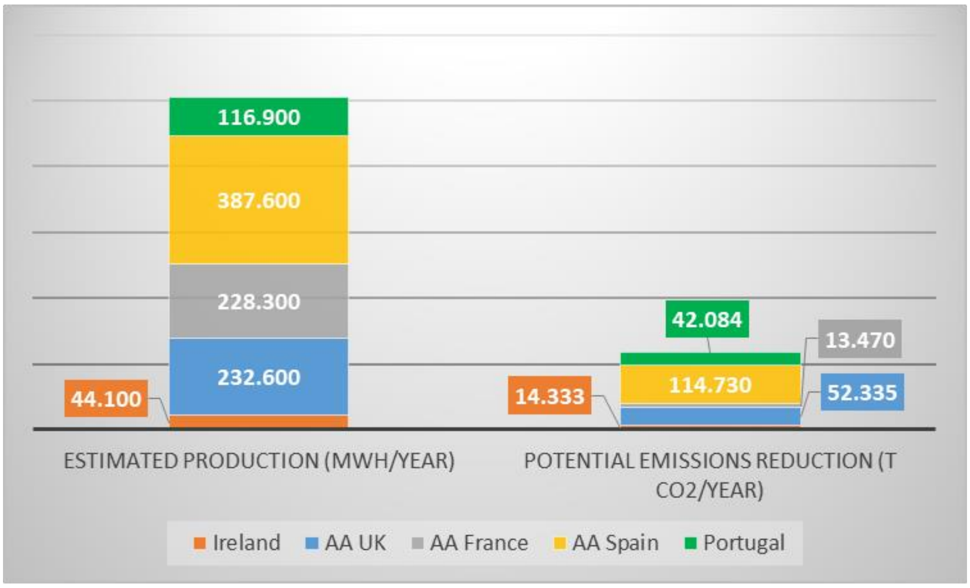
This potential for emissions reduction means -12,7% in DW, -1,6% in WW and -15,9% in irrigation. In Portugal, the greatest potential for emissions reduction lies in the installation of MHP in drinking water facilities, although irrigation systems also have a significant potential.

4.6. Atlantic Area

Picture overview with the compilation of the data obtained for the 5 countries of the Atlantic Area:



Estimated potential for electrical production and for emissions reduction as consequence of the installation of MHP in water networks of Atlantic Area (by infrastructure type)



Estimated potential for electrical production and for emissions reduction as consequence of the installation of MHP in water networks of Atlantic Area (by country)

It is estimated a potential of total emission reduction resulting from the implementation of MHP in the identified sites of the water networks (section 3) in the Atlantic Area of -12,6%. By water sectors, the higest potential of reduction is identified in the irrigation sector (-53,2%) and there are interesting potentials in the drinking water networks (19,3%) and in the waste water networks (2,3%). By countries, the higest potential of reduction is identified in Spain (-26,9%) and the lowest potential in Ireland (-4,8%).

MHP in an irrigation system (Córdoba, Spain)

5. Conclusions

The implementation of MHP in hydraulic networks in operation promotes the achievement of the objectives set by the EU as to promote the recovery of energy contained in the water of anthropogenic systems and reducing energy consumption in the water management.

Like all human activities, water management has its impact on the environment. The main impact arising from the operation and maintenance of networks comes from its power consumption. Hence arises the installation of MHP in hydraulic networks which, in a self-supply modality, contributes to reduce this environmental effect of hydraulic networks and, in grid retail modality, favors the decarbonisation of the power sector.

The characteristics of the water networks (supply, wastewater treatment, industrial water and irrigation) in the regions of the Atlantic Area have an estimated energy use potential of 1.009,5 GWh/year. The country where the greatest potential is identified is Spain (387,6 GWh/year). UK is the country with the greatest potential in supply networks (191,7 GWh/year) and wastewater networks (40,9 GWh/year) and Spain in irrigation (221,4 GWh/year).

Having in mind that the MHP, according to studies by specialized agencies, are electrical power generation systems which have a lower environmental impact, considering all the associated industrial chain, it is intended the use of the potential identified in hydraulic networks of the Atlantic Area. Given the above data, exploiting this potential will be an environmental benefit to the Atlantic Area, considering only the reduction of CO2 emissions, of 236.951 tCO2/year which are not emitted what represents approximately 12,6% of the water sector emissions.

In the Atlantic Area, the greatest potential for emissions reduction lies in the installation of MHP in drinking water facilities. In percentual terms, the largest potential is detected in irrigations systems (53% of their emissions).

The Atlantic Area of Spain is the region with the largest potential for emissions reduction due to the significant MHP potential in irrigation facilities. In percentual terms, the largest potential is also detected in the AA of Spain (27% of their emissions). Contrary, Ireland is the country with the smallest potential.

Also, must be considered that the energy that is produced with water, is not necessary to generate it using other technologies, which would, therefore, reduce electricity production of large thermal power stations, reversing a reduction of water consumption in energy production processes.

REDAWN – Reducing Energy Dependency in Atlantic area Water Networks

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