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REDAWN – Reducing Energy Dependency in Atlantic area Water Networks

PROJECT REPORT

Sector Level
Economic Impact Analysis

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REDAWN
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Interreg
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EUROPEAN UNION

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1. Introduction

The objective of the REDAWN project is to reduce the energy dependence of water networks in the Atlantic area (AA), improving the energy efficiency of water networks through the use of micro hydropower (MHP) technology. The energy consumption linked to the water industry is such that it is responsible for significant contributions to climate change, thus, some measures are needed to transform the sector into a more sustainable system. Potential energy recovery from Micro-hydropower plants (MHP), using small-scale traditional turbines and pump as turbines (PATs), present an option to reduce this energy consumption. These are being assessed in the REDAWN project across public drinking water networks, private industrial water networks, waste water networks, and irrigation networks are investigated.

The introduction of MHP in water networks will have an economic impact in the water activity. This effect not only suppose a potential reduction of costs due to a self-consumption of the electricity generated but also a potential increase in the competitiveness of the management of the network thanks to the access to electricity in isolated areas where could be used electrical devices to improve the management of the grid. The content of this report tries to give some indications to the owners and managers of the water networks related to the benefits that the installation of MHPs could have for the water companies.

More specifically, this report, Sector Level Economic Impact Analysis, will comprise 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.
- Irrigation infrastructures.

A sewage treatment plant (UK)

The second part is an assessment related to the current situation of the water networks in the Atlantic Area.

The third part is an evaluation of the potential benefits for the water networks of the exploitation of the available sites identified.

Detail of an irrigation system

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)	13.7-30.4	0	1.8	2.3	17.8-34.4

*Annual potential

The drinking water sector in Ireland was estimated to hold an annual potential between 13.7 and 30.4 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)	191.2-508.9	0	25.7	15.2	232.0-549.8

*Annual potential

The drinking water sector in the UK was estimated to hold an annual potential between 191.2 and 508.9 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 (2.89 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)	188.0-416.0	0	25.3	14.4	227.6-455.7

*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 188.0 and 416.0 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)	135.7-300.3	221.4	18.2	12.3	387.6-552.2

*Annual potential

The drinking water sector in Spain was estimated to hold an annual potential between 135.7 and 300.3 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)	29.6-65.5	23.9	4.0	2.6	60.1-96.0

*Annual potential

The drinking water sector in Portugal was estimated to hold a potential between 29.6 and 65.5 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.

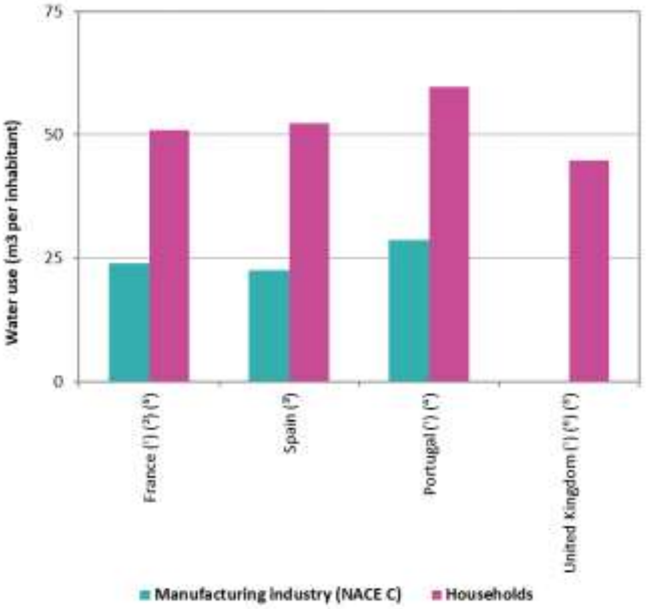
The waste water sector in Portugal was estimated to hold the potential for 4 GWh of energy throughout the year. This was estimated on the basis on the population and the linear correlation found between the potential for MHP in the wastewater treatment plants analysed and the population served in Ireland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

3.1. Drinking water network

At the European scale, the households and the manufacturing industry are both important users of water. However, their relative share varies a lot among European countries: In France, Spain and Portugal, water use by the households is about 2 times the industry demand of water, reflecting the dominance of the service sector in the economy of these countries (Figure 1).



Note: no data available for Ireland. (1) households: only public water supply
(2) NACE C: only self and other supply; (3) 2014

Figure 1 - Water use by households and the manufacturing industry, from public water supply and self and other supply, 2015 (m^3 per inhabitant) (source Eurostat, 2017).

Table 6 provides further information on the use of water from public water supply, analysed by economic sector, confirming that the main users of water from public supply are households.

Table 6 - Water use by economic sector — public water supply in 2015 (million m³) (source Eurostat, 2017)

GEO/Sector	All NACE activities and households	of which:				
		Agriculture, forestry and fishing	Industry and construction	of which: Manufacturing	Services	Households
Ireland	669.0	:	:	:	:	:
Spain	3 669.3	25.5	403.6	353.7	812.2	2 428.1
France	3 622.0	:	:	:	:	3 388.0
Portugal	:	:	:	:	:	:
United Kingdom	3 968.0	120.0	345.0	263.0	601.0	2 902.0

Additionally, Table 7 reports values for water use by the building or domestic sector (services and households) between 2005 and 2014. A strong increase was recorded in France, i.e. +122 % from 2008–2013, without considering public water supply for services (source Eurostat, 2017).

Table 7 - Use of water by the domestic sector (households and services) between 2005–2014 (m³ per inhabitant) (source Eurostat, 2017)

GEO/year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Ireland	:	:	:	:	:	:	:	:	:	:
Spain	*79.1*	*76.0*	*81.7*	*80.0*	*76.7*	*72.7*	*73.3*	*73.6*	*71.2*	71.0
France (¹)	:	:	:	64.6	64.1	114.4	120.2	140.6	143.7	:
Portugal (²)	47.3	50.0	53.4	57.0	59.7	:	:	:	:	:
United Kingdom (²)	:	:	:	:	:	:	55.6	:	:	:

(¹) Public water supply for services: not available

(²) Public water supply only.

Another important indicator is the water productivity, where it indicates how much economic output is produced per cubic meter of fresh water abstracted (Table 8). It serves as a measure of the efficiency of water use. For this interpretation it should be taken into account that water productivity is strongly influenced by the economic structure and the proportion of water intensive industries (Eurostat 2019). A lower water productivity primarily means that the economic and industrial structure of the country is water use intensive. A less water-consuming economy would show a relatively high water productivity. The change in water productivity is influenced by both ‘real’ productivity improvements and deteriorations, as well as by changes in economic and industry structure.

Table 8 - Water productivity (Euro per m3) (source Eurostat, 2017).

GEO/Year	2010	2011	2012	2013	2014	2015	2016	2017
Ireland	:	:	:	:	:	:	:	:
Spain	30,4	30,3	30,1	31,5	31,3	33,9	35,3	:
France	70,4	72	68,2	73,9	76,7	74,7	80	:
Portugal	28	30	31	32	33	34	35	37,3
United Kingdom	223,9	244,8	232,3	:	275,2	:	:	:

Table 9 presents the water abstracted by economic units destinated to collection, purification and distribution of water (including desalting of sea water to produce water as the principal product of interest) and water that is used to absorb and remove heat in the course of processes for the generation of electricity.

Table 9 - Water abstraction for public water (Millions m3) (source Eurostat, 2017)

GEO/Year	2010	2011	2012	2013	2014	2015	2016	2017
Ireland	532	530	527	518	540	526	526	508
Spain	3 460	3 098,199	3 004,22	3 018,165	3 055,032	3 140	3 250	:
France	1 772,97	1 750,24	1 952	1 701,142	1 555,51	1 720,688	1 740,404	:
Portugal	:	:	554,706	546,666	534,446	557,305	557,883	549,952
United Kingdom	4 227,3	4 074	4 144	:	3 558	:	:	:

Aditionally to this data of use of water, other important value for defining the water sector is the energy consumption for the managment and treatment of water. Taking as reference the data from the Sustainable Energy Authority of Ireland (SEAI), the Office for National Statistics (ONS), Eurostat, Instituto para la Diversificación y Ahorro de la Energía (IDAE), University of Córdoba and Entidade Reguladora dos Serviços de Águas e Resíduos (ERSAR), in the table 10 are included figures of energy consumption in drinking water networks from 2017:

Table 10 – Electrical consumption in drinking water networks (GWh/year) (several sources, 2017)

GEO/Sector	Drinking water
Ireland	422
Spain	1 398
France	1 871
Portugal	683
United Kingdom	2 570

3.2. Irrigation network

In this section are presented the main figures of the irrigation sector in the Atlantic Area. In this way, Tables 11 shows the overall water use from public water in irrigation sector, available for Portugal, Spain and United Kingdom. In the case of Table 12, it is presented water abstraction for agriculture in Spain, France, Portugal and United kingdom.

Table 11 - Water use from public water in irrigation (Millions m3) (source Eurostat, 2017)

GEO/Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Spain	61,3	58,6	54,1	37,325	34,077	22,816	25,458	23,089	20,72	:
Portugal	1,1	0,7	:	:	:	:	:	:	:	:
United Kingdom	:	:	:	120	:	:	:	:	:	:

Table 12 - Water abstraction for irrigation (Millions m3) (source Eurostat, 2017)

GEO/Year	2010	2011	2012	2013	2014	2015	2016	2017
Ireland	:	:	:	:	:	:	:	:
Spain	18 560	19 299,733	18 349,97	16 908,404	17 331,061	16 098	15 722	:
France	1 831,48	1 820	1 879,6	1 745,992	1 327,103	1 885,518	1 935,77	:
Portugal	:	:	:	:	:	:	:	1 862,6
United Kingdom	982,2	782,4	893	:	848	:	:	:

Related to the energy consumption, taking into consideration the same sources than in the section 3.1, the data are the following:

Table 13 – Electrical consumption in irrigation networks (GWh/year) (several sources, 2017)

GEO/Sector	Irrigation
Ireland	0
Spain	1 667
France	218
Portugal	150
United Kingdom	0

3.3. Waste water treatment network

In the case of the waste water treatment networks the main indicators are shown in the following tables. In theTable 14 is presented the generation and discharge of wastewater in volume in Portugal and Spain, in the rest of countries data are not available.

Table 14 - Generation of wastewater – supply points – total (million m³) (source Eurostat, 2017)

GEO/Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Spain	9 585,4	9 189,1	7 158	6 579,5	3 417,4	3 446,1	3 416,1	3 456,702	3 442,3
Portugal	501,6	527,4	:	:	:	:	:	:	:

Related to the energy consumption, taking into consideration the same sources than in the section 3.1, the data are the following:

Table 15 – Electrical consumption in waste water networks (GWh/year) (several sources, 2017)

GEO/Sector	Waste water
Ireland	469
Spain	2 225
France	2 979
Portugal	418
United Kingdom	6 454

3.4. Industrial water network

For the industrial network in the Atlantic Area, self and other water supply is the main source of water for the industrial sector (Table 16).

Table 16: Water use in industry by supply category, 2005–15 (million m³) (source Eurostat, 2017)

GEO/Year	Public water supply					
	2005	2007	2009	2011	2013	2015
Ireland	:	:	:	:	:	:
Spain	485.4	446.2	384.6	359.1	355.6	360,889
France	:	:	:	:	:	:
Portugal	8.1	8.7	17.1	:	:	:
United Kingdom	:	:	:	263.0	:	:
Geo/Year	**Self and other water supply**					
	2005	**2007**	**2009**	**2011**	**2013**	**2015**
Ireland	:	:	:	:	:	:
Spain	1 208.7	993.2	794.2	723.4	703.2	648,97
France	:	:	1 819.0	1 805.0	1 589.0	:
Portugal	:	:	280.6	:	:	:
United Kingdom	:	:	:	:	:	:

Regarding the total amount of water abstraction for industry, Table 17 shows the evolution in the 5 countries.

Table 17 - Water abstraction for industry (Millions m3) (source Eurostat, 2017)

GEO/Year	2010	2011	2012	2013	2014	2015	2016	2017
Ireland	:	:	:	:	:	:	:	:
Spain	331	326,086	312,782	311,677	310,314	292	275	:
France	1 612,17	1 828,45	1 520,318	1 491,705	1 450,586	1 565,817	1 387,054	:
Portugal	:	:	:	:	:	:	:	92,741
United Kingdom	695,9	483,5	950	:	680,1	:	:	:

There are not available specific data of energy consumption from industrial water networks in the Atlantic Area. It is considered that these data are included in the energy consumption of the wastewater networks.

3.5. Summary

Considering the indicators aforementioned , in the Figures 2 and 3 are shown the use of water in water networks in the Atlantic Area by sector (Figure 2) and by country (Figure 3)

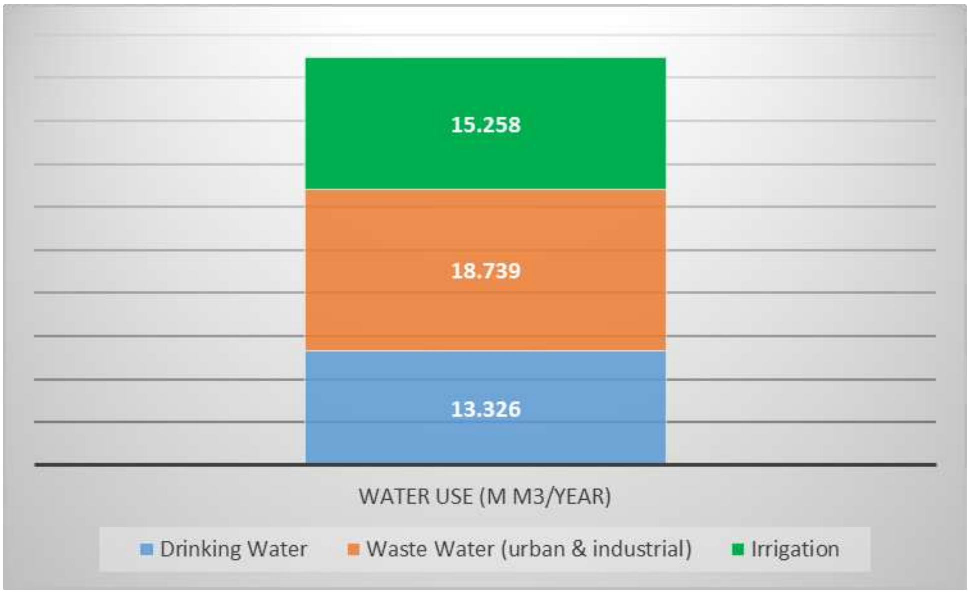


Figure 2 – Water use in water networks of Atlantic Area by infrastructure type (million cubic meters per year) (several sources, 2017)

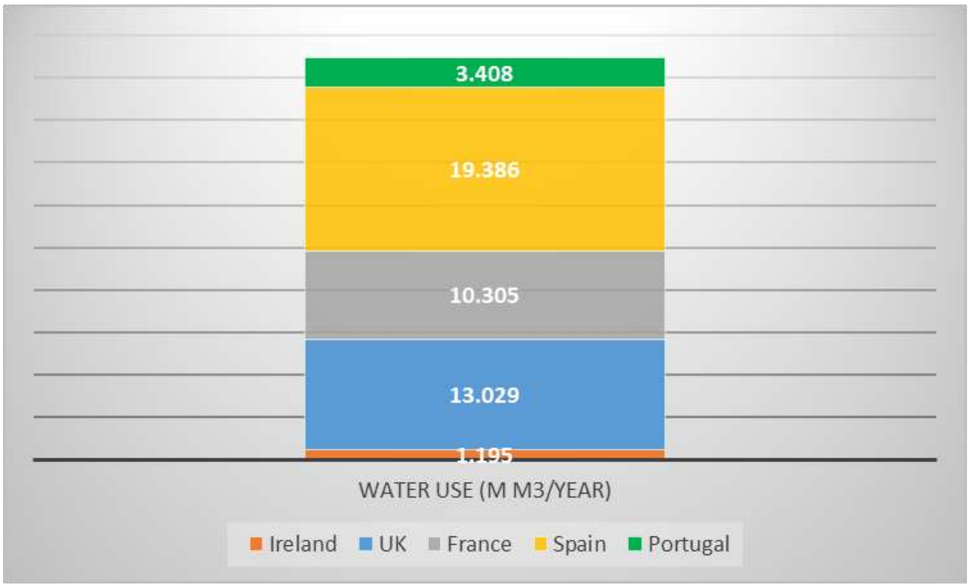


Figure 3 – Water use in water networks of Atlantic Area by country (million cubic meters per year) (several sources, 2017)

The total volume of water used in the five countries of the Atlantic Area is higer than 47.000 M m3/year. The sector that use the highest volume of water is the waste water (40%), mainly due to the high activity if the sector in UK. By other side, drinking waters is the sector that use the lowest volume of water. By countries, Spain is the main consumer of water, mainly due to the consumption in irrigation. The country with the lowest consumption is Ireland

Related to the energy consumption, the global results of the Atlantic Area are shown by sector in the Figure 4 and by country in the Figure 5:

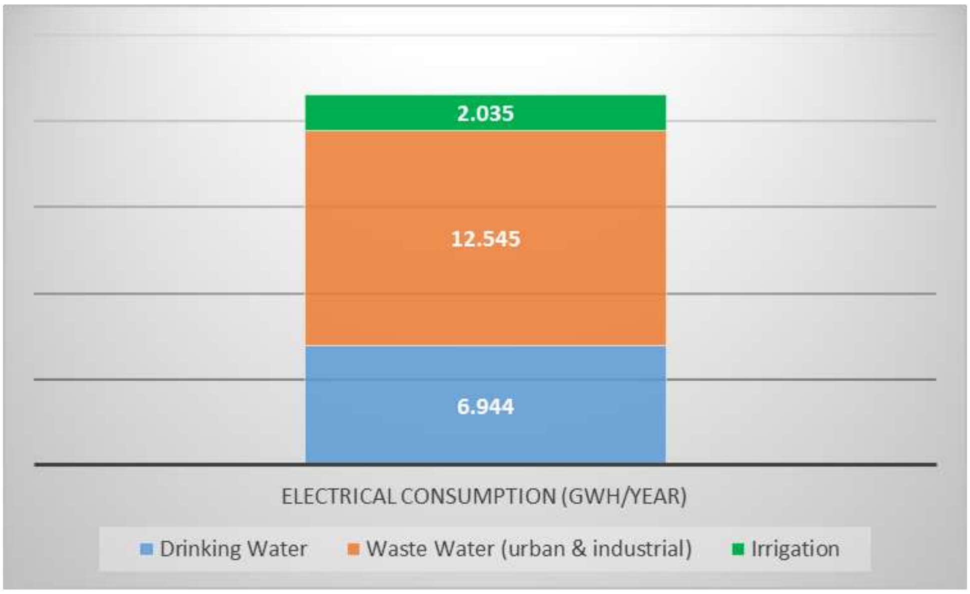


Figure 4 – Electrical consumption in water networks of Atlantic Area by infrastructure type (gigawatt-hour per year) (several sources, 2017)

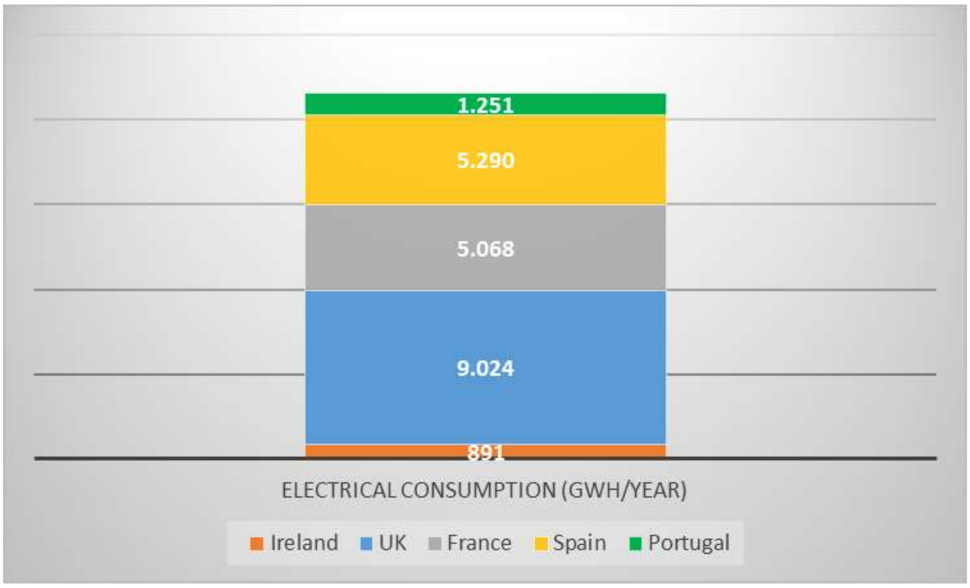


Figure 5 – Electrical consumption in water networks of Atlantic Area by country (gigawatt-hour per year) (several sources, 2017)

The total energy consumption in the water sector of the five countries is higher than 21.000 GWh/year. The sector with the highest energy consumption is the waste waster sector (58%) and the sector with the lowest energy consumption is the irrigation sector (9%). By countries, UK is the country with a higher energy demand in the water sector meanwhile Ireland is the country with the lowest energy consumption.

As additional information, the water use for energy production in hidroelectric facilities in each country is shown in the Table 18. This water comes not only from water networks but also for rivers.

Table 18 - Water abstraction for production of electricity (Millions m3) (source Eurostat, 2017)

GEO/Year	2010	2011	2012	2013	2014	2015	2016	2017
Ireland	:	:	:	:	:	:	:	:
Spain	6 300	6 150	6 100	5 950	5 870	5 650	5 580	:
France	17 139,25	17 009,26	18 832,4	17 016,41	17 213,356	17 024,005	15 704,588	:
Portugal	:	:	:	:	:	:	:	264,518
U. Kingdom	188	165,9	:	:	131,6	:	:	:

The importance of the production of electricity by hydroelectric facilities in the five countries is shown in the Figure 6. In France and Portugal is the most important renewable energy technology, although its importance is decreasing due to the raising of the share of wind farms and photovoltaic plants.

Figure 6 displays information on the distribution of renewable energy technologies within a country in relation to renewable hydropower energy generation.

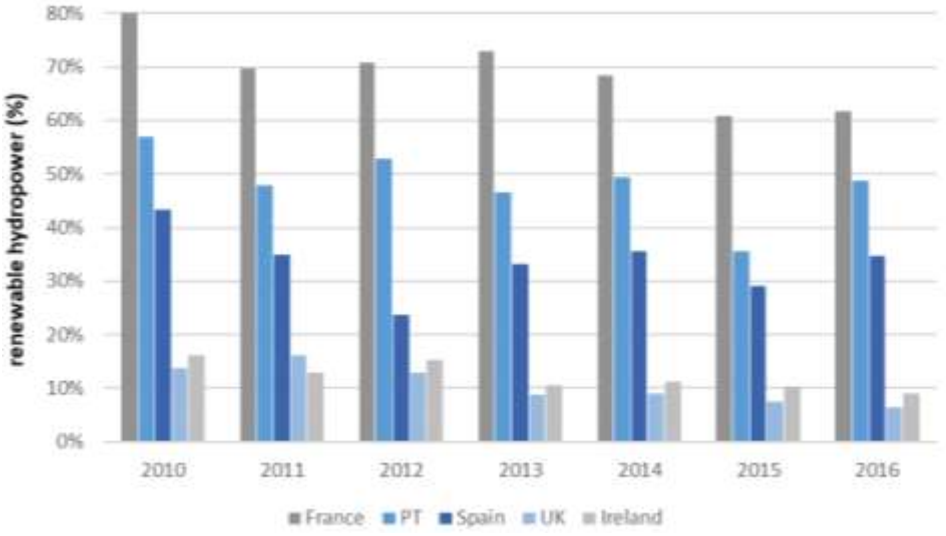


Figure 6 – Renewable energy generation through hydropower. Based on data available in IRENA

4. Sector level analysis of the potential impact of MHP

The installation of MHP in the operating water networks of the Atlantic Area brings several benefits to the water sectors and to the energy sector

1. Economic benefits described in the report “Economic Feasibility Assessment” carried out in the framework of REDAWN project.
2. Environmental benefits described in the report “Environmental Impact Assessment”carried out in the framework of the REDAWN project.
3. Reduction in the need of supply of electricity for the grid and access to the energy in isolated areas, in the water networks.
4. Benefits due to the electrification of the water networks that allows modernization of equipment, improvement in the management of the network, reduction of leakages and improvement in the water quality.
5. Contribution to the implementation of a new energy model based on a descentralized generation with a important share of renewable energies (including hydro), aligned with the energy objectives of the UE in 2030.
6. Allows the implementation of the energy transition, digital water and smart water grids in the water sector with several benefits associated.

As former mentioned, in other reports of the REDAWN project it has been estimated the environmental and economic benefits through the reduction of CO2 emissions and the reduction of energy costs due to the use of MHP in water networks.

Related to the reduction in the need of supply of electricity, considering the potential identified of implementation of MHP in the water networks of the Atlantic Area in other studies carried out in the framework of the REDAWN project, it is possible to estimate the potential production of electricity. If we consider that this total production is used as self-consumption in the water networks, it is possible to achieve a reduction in the consumption of electricity of around 1000 GWh/year. Considering the energy consumption showed in figures 4 and 5, this electricity is the 5% of the total energy demand of the water networks . The results obtained are shown in the figures 7 and 8.

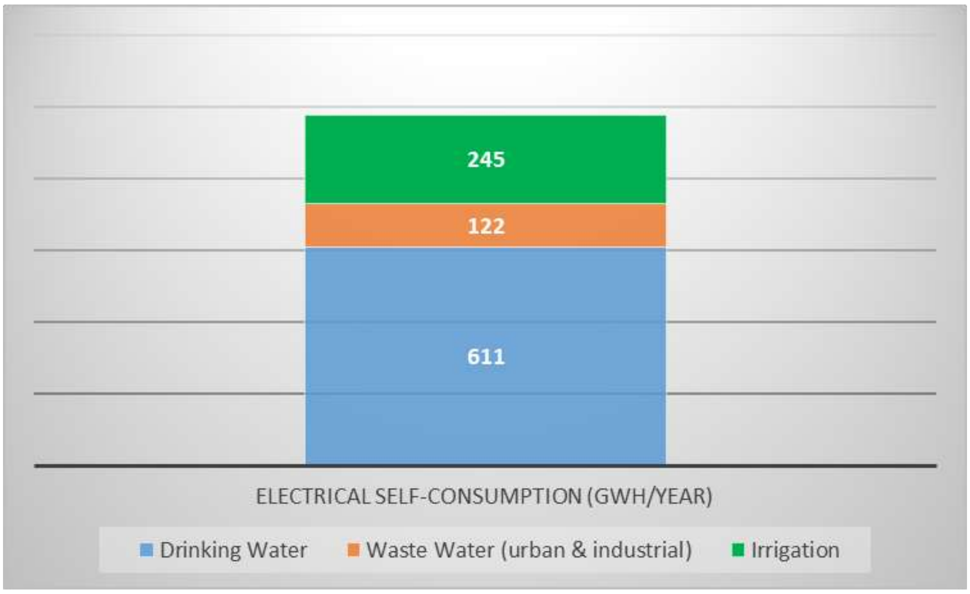


Figure 7 – Estimated potential for electrical production as consequence of the installation of MHP in water networks of Atlantic Area (by infrastructure type) (gigawatt-hour per year) (own sources, 2017)

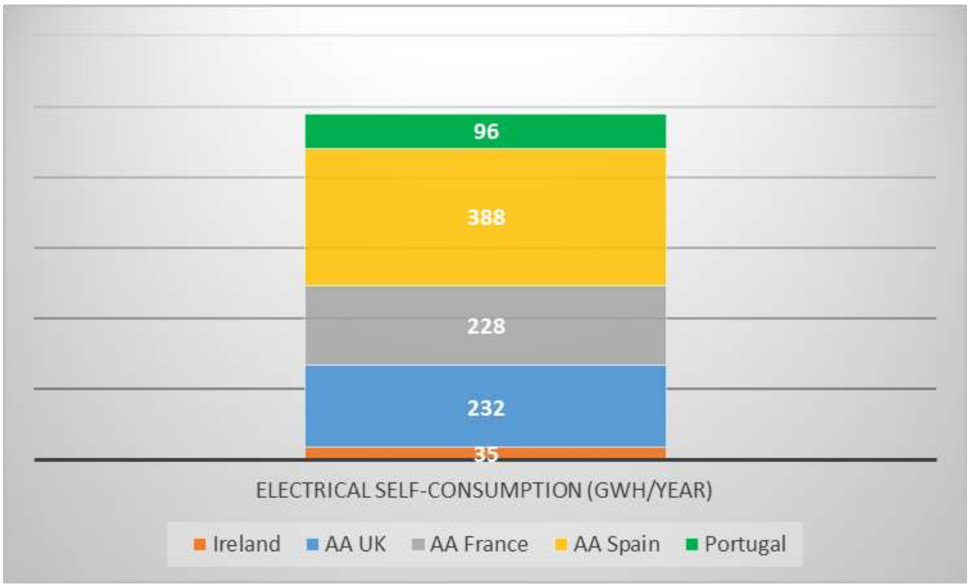


Figure 8 – Estimated potential for electrical production as consequence of the installation of MHP in water networks of Atlantic Area (by country) (gigawatt-hour per year) (own sources, 2017)

The irrigation sector is the activity where it is identified the highest potential of reduction (-12%). By countries, Portugal is the country whith the highest potential (-8%). It must be taken into account that the identified potentital is for Ireland, Portugal and the Atlantic area of UK, France and Spain, what means that for these last three countries the indicators of production at a national level would be higer.

With the use of this self-consumed electricity, it is possible to increase the security of supply, the quality of the electricity (important for some electrical devices) and the use of electrical systems (water chlorination, quality control, warning alarms,…) in isolated areas.

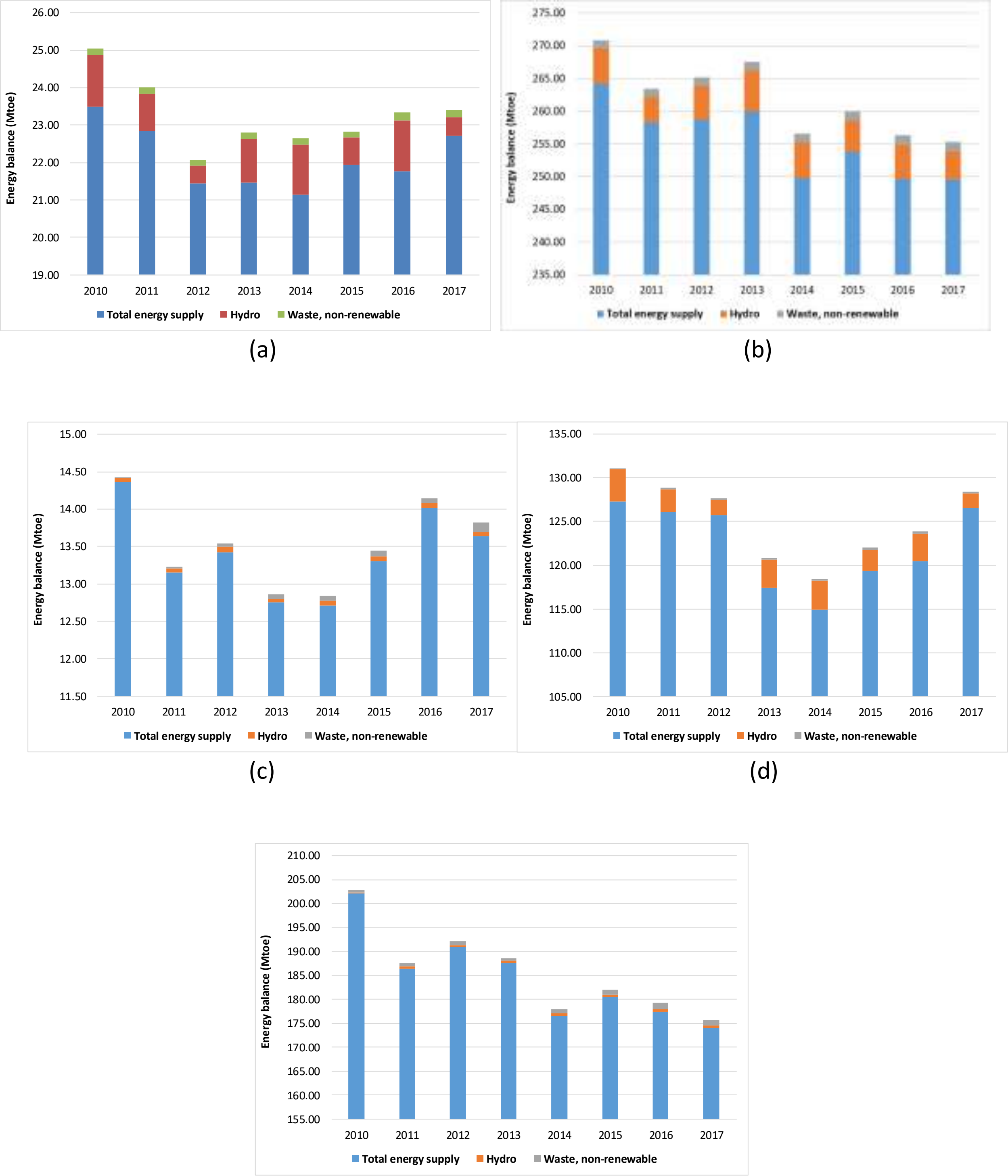
The electrification of the water networks allows not only the acces of electricity in isolated areas but also the installation in key points of the network of devices for the control of the quality of the water and an optimization in the consumption of water. Some of the services that could be provided by these devices are leak detection, monitoring of hydraulic parameters, pressure regulation, demand measurement, reading of water quality parameters (chlorine, PH), water chlorination… This allows to improve the control strategy by quickly identifying network failures, evaluating their causes, offering an immediate resolution and preventing future problems before they can happen. The optimization in the operation of the network means a reduction in the consumption of water and in the maintenance tasks what will mean a reduction in the energy demand. Taking into account the results of other best practices, these benefits could be estimated in 3-5% reduction in consumption of water and 15-20% reduction in energy consumption (source: EFINET project).

Finally, related to the contribution of the water networks to the new energy model, it is clear that the installation in the water networks of MHP in different sites will contribute to a more descentralized production system and to incrase the share of renewable energies in the supply of electricity. Related to this, it is clear the rise tendency in the last years in the production with renewable energies, with a key role played by the hydroelectric energy. Table 19 summarizes the total supply, transformation and consumption of renewables and wastes.

Table 19 - Supply, transformation and consumption of renewables and wastes (terajoule) (source Eurostat, 2017)

GEO/Year	2010	2011	2012	2013	2014	2015	2016	2017
Spain	670,000	703,000	738,000	758,000	789,000	789,000	789,000	789,000
France	7308,644	9611,545	10126,311	12728,450	12252,126	12704,693	13989,609	17355,858
Portugal	7560,000	8091,000	5652,000	7551,000	7889,000	7829,000	6602,000	8329,235
U. Kingdom	33,000	33,000	33,000	33,000	33,000	33,000	33,000	33,000

From the available information, it was possible to observe the total energy balanced between 2010-2016, identifying the total energy supplied by hydro and total amount of waste, non-renewable (Figure 9).



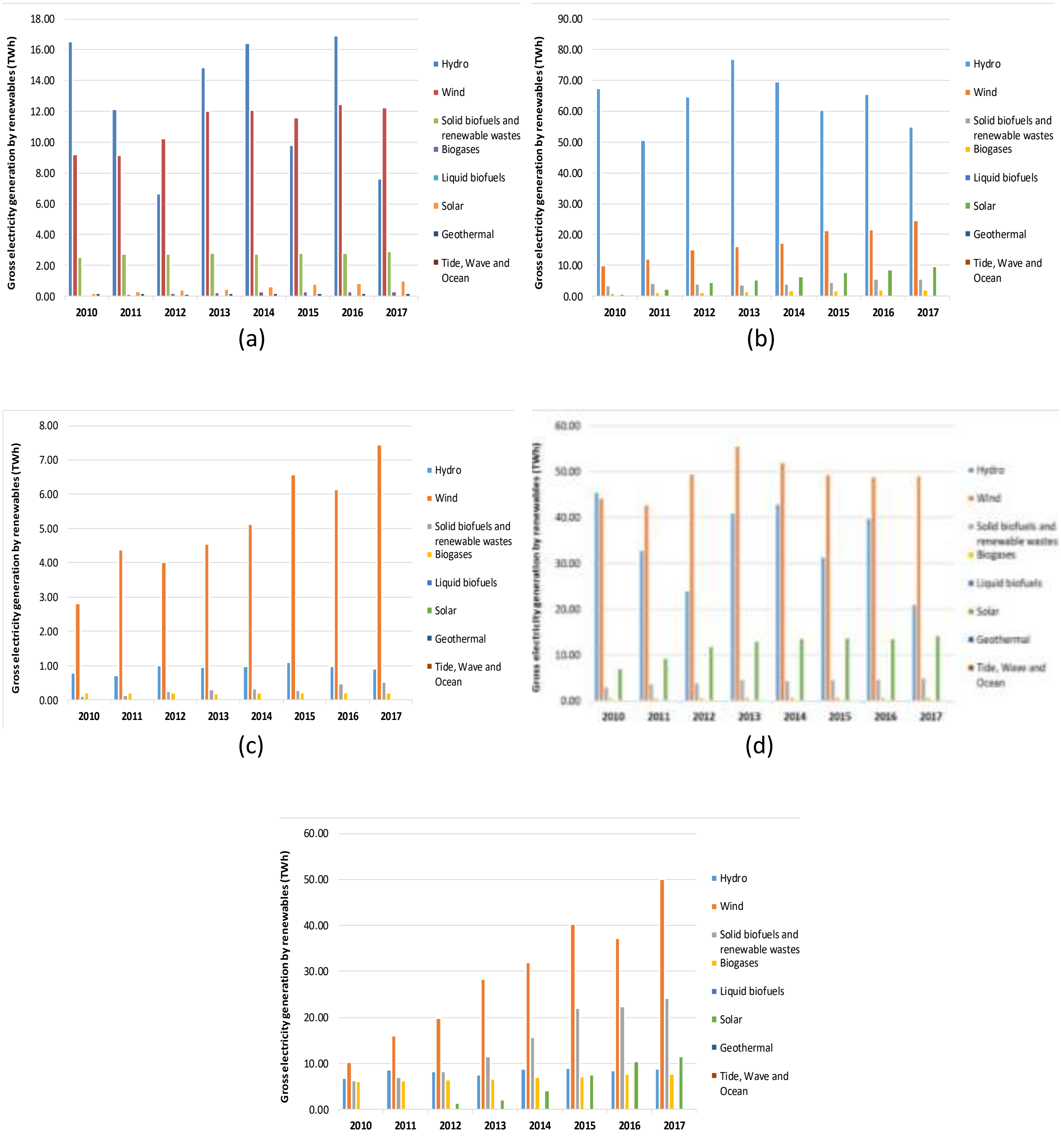
(a) (b)

(c) (d)

(e)

Figure 9 – Energy balance between 2010-2016: (a) Portugal; (b) France; (c) Ireland; (d) Spain; (e) United Kingdom (source Eurostat, 2017).

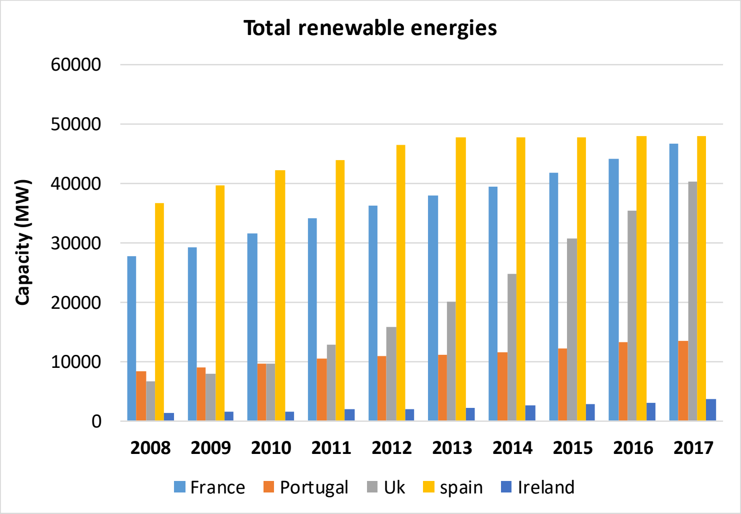
Figure 10 presents the gross energy generation by each type of renewables identified for each country between 2010-2017.



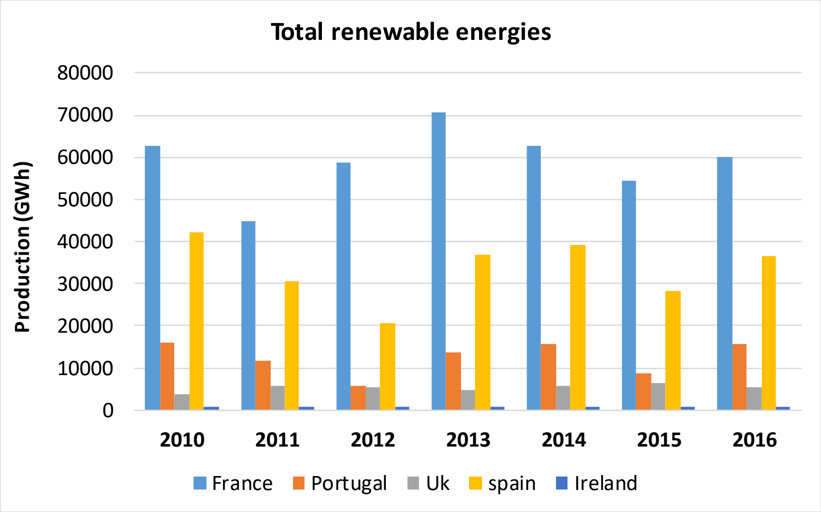
(a) (b) (c) (d) (e)

Figure 10 – Gross electricity generation by renewables: (a) Portugal; (b) France; (c) Ireland; (d) Spain; (e) UK (source EEA, 2019).

Additionally, Figure 11 presents the capacity and energy production through the addition of renewable energies since 2010. It is possible to observe an increase of the capacity since adopting renewables.



(a)



(b)

Figure 11 – Total renewable energies: (a) capacity; (b) production (source Eurostat, 2017).

In this framework, the implementation of MHP in water networks is aligned with the new energy European objectives. The target of clean energy transition should result in a system in which the largest share of the EU's primary energy supply comes from renewable energy sources, thereby improving the security of supply and fostering domestic jobs, as well as reducing emissions. The EU has agreed a renewables target of 32% by 2030.

If we focus in a Atlantic country like Portugal, the emissions trajectory of the energy system (including emissions from industrial processes) shows that without any specific GHG mitigation target, a reduction of -21% is achieved in 2030 and of 26% in 2050 compared to 1990, well below the mitigation trend necessary to achieve the objectives to which Portugal is committed (APREN 2018). To this end, three scenarios were developed from 2015 to 2050, through a holistic approach of the Portuguese energy system. These three scenarios are presented in Figure 12.

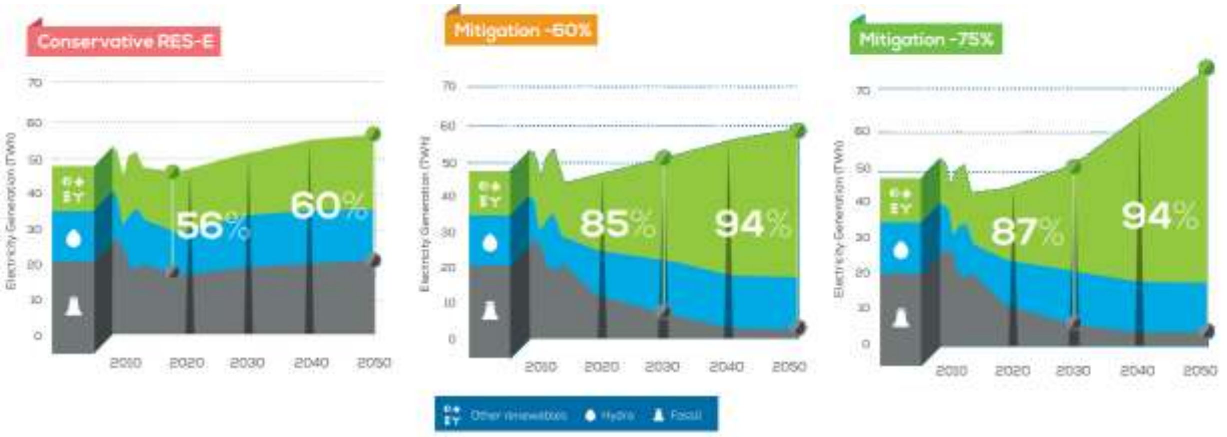


Figure 12 – Portugal's Scenarios for decarbonization by 2050 (based on APREN 2018).

To achieve the required decarbonisation levels, the contribution of renewable electricity should be 85% by 2030 and 94% by 2050 (without including cogeneration). In all 3 scenarios, onshore wind could account for around 39% of the electricity generated in 2050 in the Mitigation scenarios (Seixas, et al 2015).

In the Conservative RES-E scenario, the reduction is due to the implementation of more efficient technologies with higher potential for energy efficiency. In the Mitigation scenarios -60% and -75%, the reduction is more significant, due to a greater share of the electricity demand in several end-use technologies, generally more efficient than former fossil fuels based technologies. The mitigation scenarios ensure a reduction in primary energy consumption of 38%, when compared to the current consumption (Seixas, et al 2012). This is due, among other factors, to the larger share of high efficient end-use electric technologies.

Figure 13 – Primary energy vs. renewable energy for the 3 scenarios (APREN 2018).

This approach was applied to the remained Atlantic countries to estimate the total amount of renewable hydro energy production until 2050.

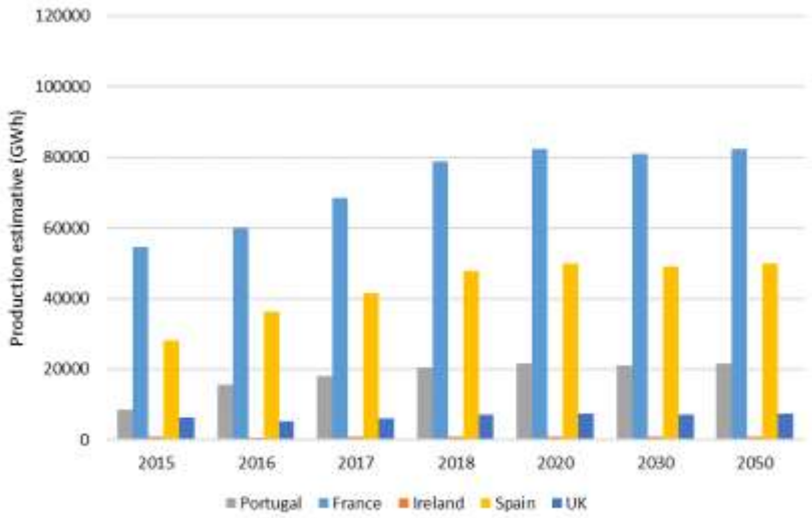
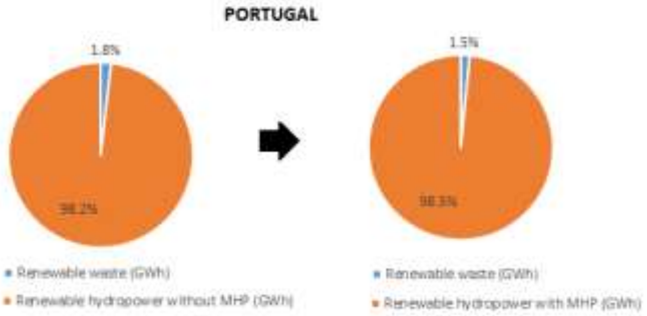
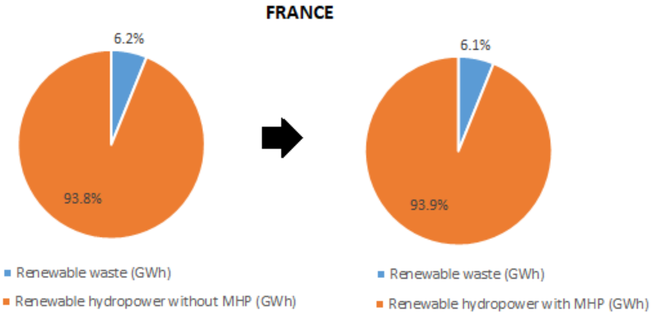


Figure 14 – Renewable hydro production estimative according to scenario 3.

Considerable progress has already been made with benefits in the energy sector (renewable hydropower) by introducing MHP in water networks.





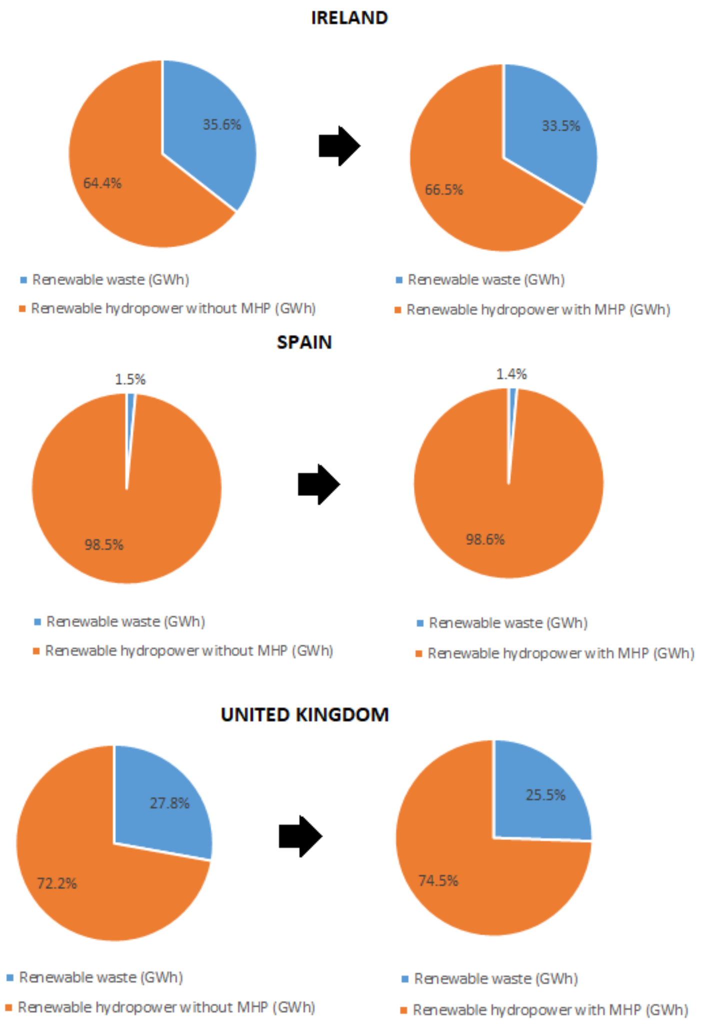


Figure 15 – Renewable energy generation through MHP.

From Figure 14 and Figure 15, by the end of 2050, additional trends can be expected in renewable energy using MHP (Figure 16) for each country.

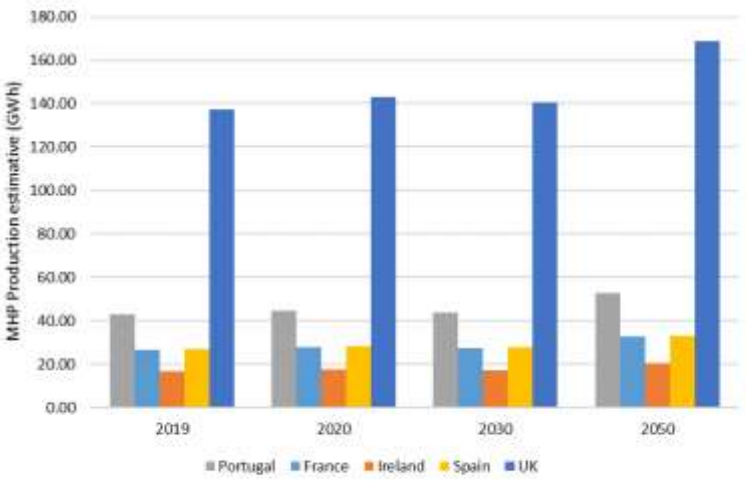


Figure 16 – Renewable energy generation through MHP.

Moreover, this trends can also be divided according to each sector for the 5 countries of the Atlantic Area (Table 20):

Table 20 – Renewable energy generation estimative through MHP.

YEAR	GEO/Prod	Drinking	Irrigation	Waste water	Total
2030	France	0.00	26.51	0.89	27.40
	Ireland	15.00	0.00	2.13	17.13
	Portugal	34.02	9.13	0.74	43.89
	Spain	0.00	26.06	1.59	27.65
	UK	138.29	0.00	2.46	140.74
2050	France	0.00	31.81	1.07	32.88
	Ireland	18.00	0.00	2.56	20.56
	Portugal	40.82	10.96	0.88	52.66
	Spain	0.00	31.27	1.90	33.17
	UK	165.94	0.00	2.95	168.89

The REmap (renewable energy roadmap) Atlantic Area (Figure 17) based on IRENA (2019), shows that the accelerated deployment of renewables, combined with deep electrification and increased energy efficiency, can achieve over 70% of the energy-related CO2 emissions reductions needed by 2050. Electrification with renewables is the key, together making up 75% of the mitigation potential.

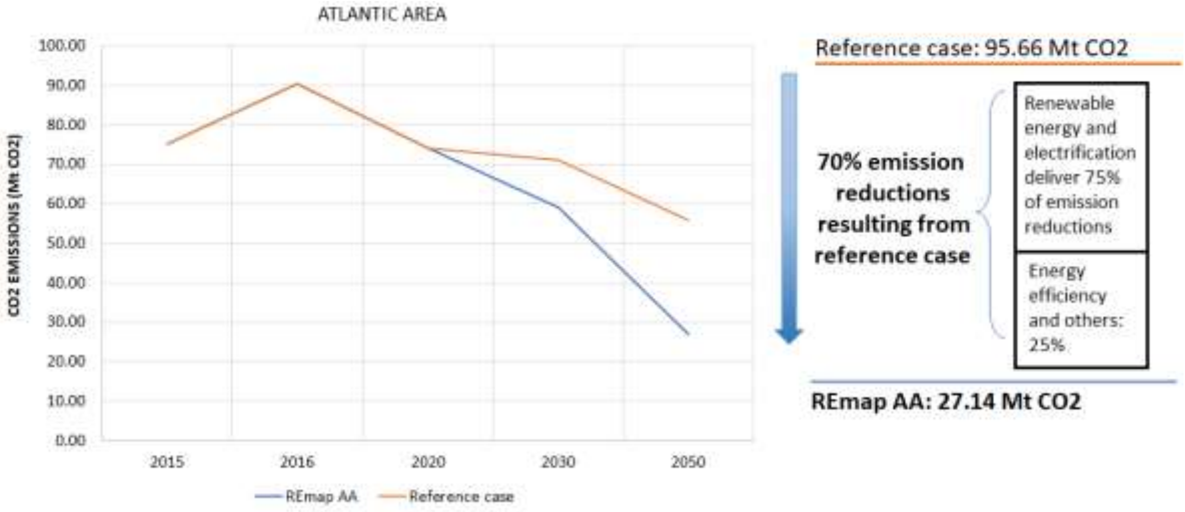


Figure 17 – Renewable energy and energy efficiency can provide over 70% of the necessary reductions in energy-related CO2 emissions.

5. Conclusions

A significant effort would be required to reduce carbon emissions generated by industrial processes and by land use to less than zero by 2050. The water sectors must contribute to this ambitious challenge in the framework of these activities.

The water sector in the Atlantic Area has an important activity and a high associated energy consumption that must be descarbonized. The implementation of MHP in the water networks could contribute to this objective and, additionally, it supposes other benefits. In this way, it is possible the reduction of energy costs by the use of the produced electricity as self-consumption; the reduction in the need of supply of electricity; the access to the energy in isolated areas that allows the use of electric devices; and the electrification of the network that allows to improve its management system.

But the benefits there are not only for the water sector but also for the energy sector. To take advantage of the excess of energy in the water networks will contribute in the implementation of a new energy model based on a descentralized generation with an important share of renewable energies.

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