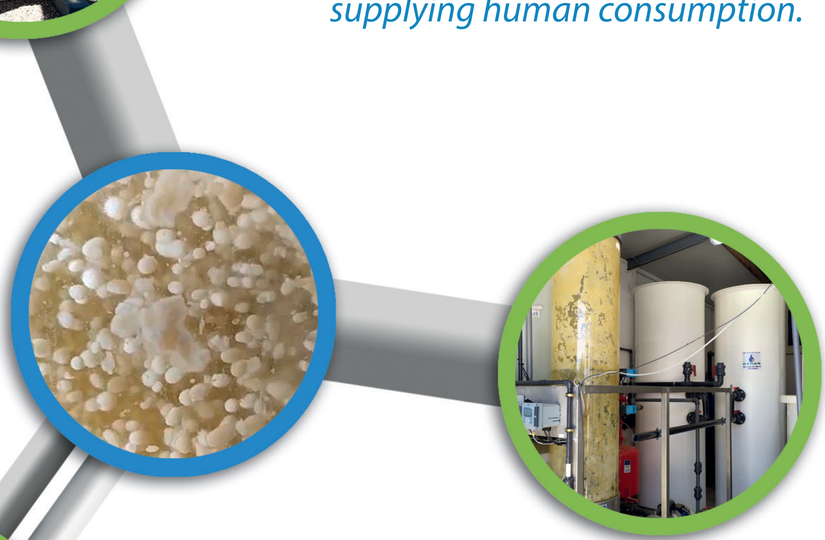
(LIFE16 ENV/ES/196)

Project co-funded by the EU LIFE Programme.

LAYMAN'S REPORT

Innovative technology *based on biological methods to* ***remove nitrates, pesticides and other pollutants*** *from groundwater supplying human consumption.*



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Project data:

LIFE16/ENV/ES/196 ECOGRANULARWATER

Call: 2016.

Priority Area: Environment and Resource Efficiency.

Topic: Drinking water.

Beneficiaries: Provincial Council of Granada, University of Granada, Aalto University (Finland), Construcciones Otero S.L. and Gedar S.L.

Dates: 1 September 2017 to 30 September 2021.

Approved budget: € 995,000

EU financial contribution: € 546,113

1.CONTEXT AND ENVIRONMENTAL PROBLEM

Water pollution stemming from nitrates of agricultural origin constitutes a widespread environmental problem throughout the world. The development of intensive agriculture and the introduction of new cultivation techniques have led to the use of large quantities of fertilizers (mainly nitrates and phosphates) and other agrochemicals, causing the accumulation of these organic and inorganic chemicals in the soil. Nitrates and phosphates are mobile forms of nitrogen and phosphorus in the soil owing to their high solubility, and are liable to be borne by irrigation and rainwater through the various soil horizons to the aquifers below.

In the European Union, groundwater is an essential resource for urban water supply. The role played by aquifers is even greater in Southeastern Europe, where groundwater is a strategic resource, especially during periods of drought.

EU Directive 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human consumption requires member states to take the necessary steps to ensure the healthiness and cleanliness of water intended for human consumption. Among the minimum requirements water must meet in order to be fit for human consumption, it establishes a nitrate concentration limit of 50 mg/l.

$[NO_3^-] > 50$ mg/l → WATER UNFIT FOR HUMAN CONSUMPTION

The municipality of Torre Cardela in the province of Granada has, in the past, had **nitrate concentration values in groundwater intended for human consumption above 50 mg/l.**

As a solution to the problem of nitrate pollution, reverse osmosis systems have mainly been used. This is an effective but economically costly solution for small municipalities and involves higher consumption of water, a scarce commodity in the territory in question.

The LIFE ecoGRANULARWATER project, in response to the LIFE 2016 call for proposals, put forward an innovative project based on a biological method **using aerobic granular technology for the removal of nitrates and other pollutants present in water intended for human consumption**. The project is coordinated by the provincial council of Granada and has involved the participation of the University of Granada, the University of Aalto in Finland and Granada-based companies Construcciones Otero SL and Gedar SL, as beneficiary partners. The project began in September 2017 and has been extended to September 2021. It had a budget of €995,000, €546,113 of which was provided by the European Union's LIFE Programme.

2. OBJECTIVES

The **main objective** of Life ecoGRANULARWATER was to demonstrate the effectiveness of an innovative technology based on biological methods for the elimination of nitrates, pesticides and other compounds present in groundwater intended for human consumption in small populations.

The following were established as **specific goals** for the effectiveness of the biological system proposed for the treatment of drinking water:

- The elimination of organic and inorganic nutrients from water intended for drinking water supply in small towns, complying with the requirements established in the legislation related to the quality of water for human consumption.

- Energy self-sufficiency of biological plants, ensuring that the process of rendering the water potable had a carbon footprint of close to zero and ensuring the release of nitrogen as nitrogen gas back into the atmosphere.

- The selection of the best combination of microorganisms, carbon source and plant operating conditions, ensuring the elimination of 90% of nutrients and avoiding the generation of residues such as brine.

- The production of drinking water under conditions of biosecurity.

- The reduction of water treatment costs compared to other systems, reducing energy consumption by 70%, maintenance costs by 50% and waste treatment by 100%.

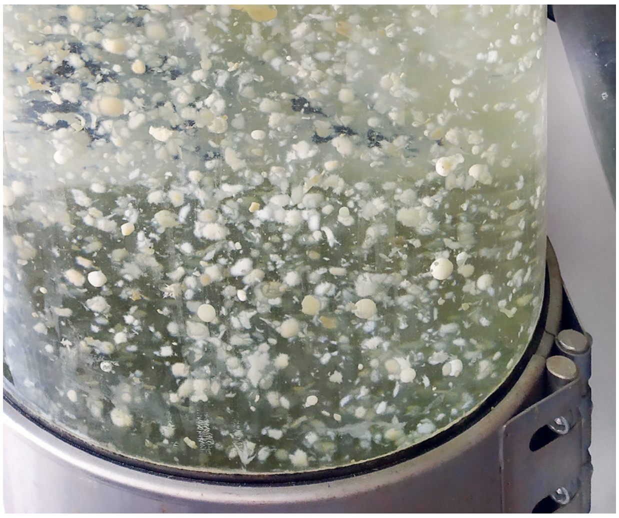
- The drawing up of a business plan and distribution of the technology throughout Europe, for the installation of the water treatment plants in other territories with the same environmental problem.

Location of Torre Cardela, Granada (Spain).

3.METHODOLOGY

LifeecoGRANULARWATER has designed, manufactured and installed a pilot drinking water treatment plant consisting of three SBR (sequential biological reactors) bioreactors, which were inoculated with granules formed in the laboratory from wastewater treatment plant sludge, in Torre Cardela, a municipality of the province of Granada with 813 inhabitants *(INE 2016)*.

The treated water then passes through a sand filter in which any organic matter that may have left the bioreactor is retained. To reduce any risk of biological contamination, the water leaving the sand filter undergoes a prior disinfection process before passing to the main tank of the drinking water treatment plant (DWTP), where the disinfection process takes place by means of chlorination.



Granules formed by denitrifying microorganisms.

The system operates sequentially in **four phases**: filling, aeration, decanting and emptying, with the aeration phase being the longest of the four. In each cycle, 65% of the bioreactor volume is emptied, to be replaced at the beginning of the next cycle with raw catchment water.

Sand filter.

The sand filter is subject to periodic backwashing, with the backwash water passed to an artificial wetland for treatment prior to discharge.

In order for biological denitrification to occur, a carbon source must be added to the groundwater. From the tests carried out, the nutrient with the highest yield was food-grade sodium acetate, added at a concentration of 100 mg/l. Salts such as potassium chloride, magnesium sulfate and dipotassium hydrogen phosphate, among others, are also added.

The operating conditions were optimised during the monitoring phase of the project, reaching 2-hour cycles, making a total of 12 cycles per day.

The dimensions of the bioreactors were limited by the height of the facility in which they were located. The volume of water treated per day thus depends on the size of the bioreactors and the number of bioreactors installed.

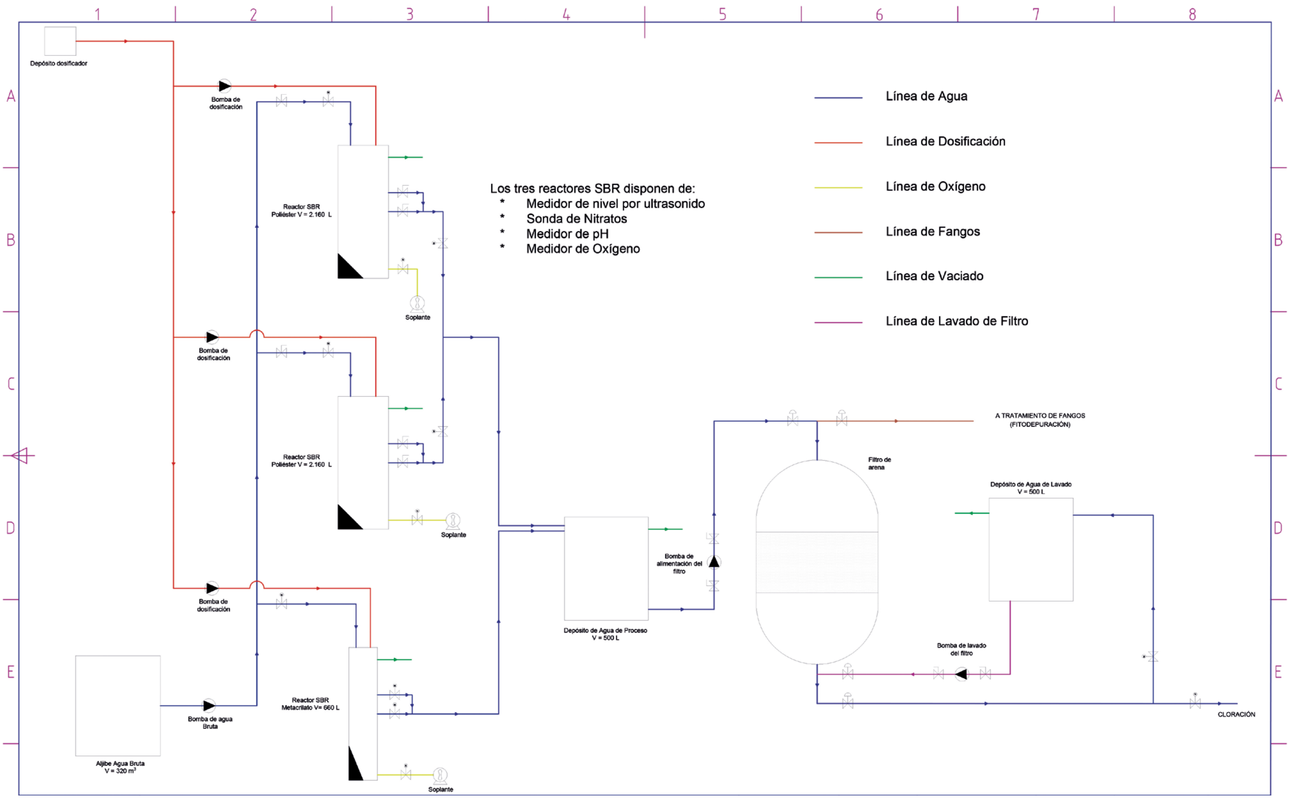
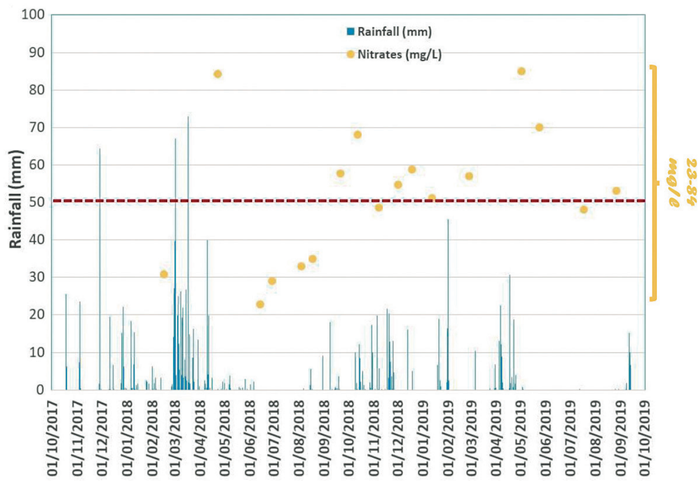


Diagram of the biological plant.

4.RESULTS

Throughout the four years that the project has been running, impacted by the COVID-19 pandemic, a series of milestones have been recorded, among which the following are noteworthy:

- **Characterisation of the aquifer** from which the municipality is supplied, ascertaining how the concentration of nitrates varies over time.



Graph of nitrate concentration in the groundwater and rainfall.

- Selection of the best **combination of bacteria, carbon source and the aerobic granular system operating conditions** for nitrate removal under laboratory conditions.

- Design, construction and installation of a **full-scale pilot drinking water treatment plant** consisting of three SBR bioreactors inoculated with granules. Plant operating in four phases: filling, aeration, decanting and emptying.

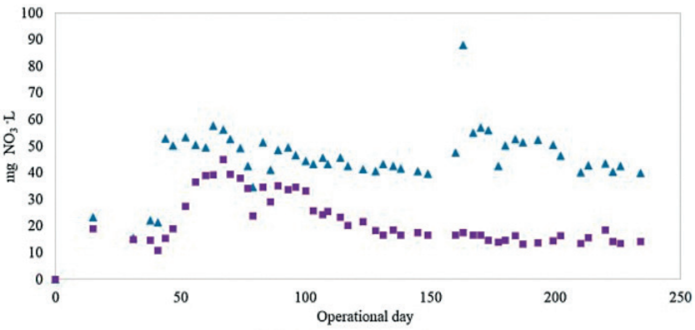
- Installation of **solar panels and batteries** to supply the necessary energy.

- Construction of a small **artificial wetland** for the treatment of the sand filter backwash water.

Artificial wetland for the treatment of the sand filter backwash water.

Plant monitoring, correction of errors detected, adjustment of the operating cycles to 2 hours and of the optimal amount of nutrients added to the system.

Efficiency of around 60% in the **removal of nitrates** from groundwater and above 90% in the **removal of organic matter**.

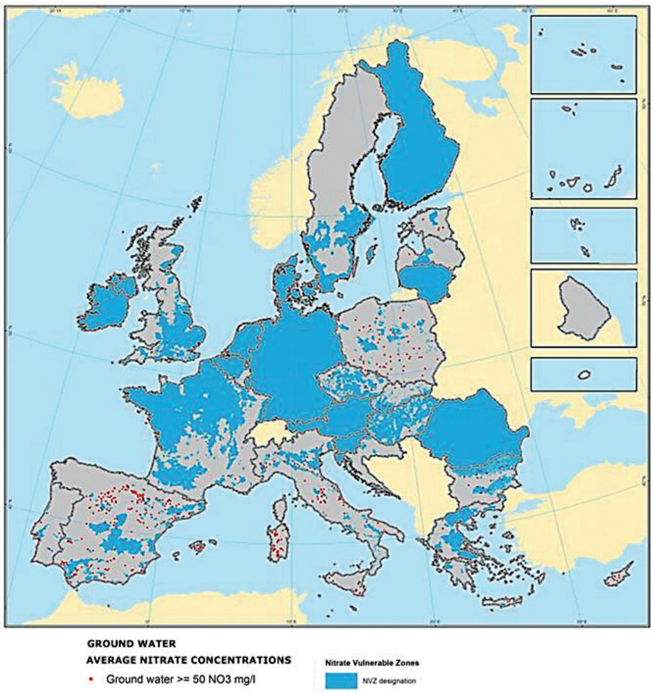


Nitrate concentration of the intake water.

Nitrate concentration on leaving the biological system.

Removal of nitrates for groundwater with the biological system graph.

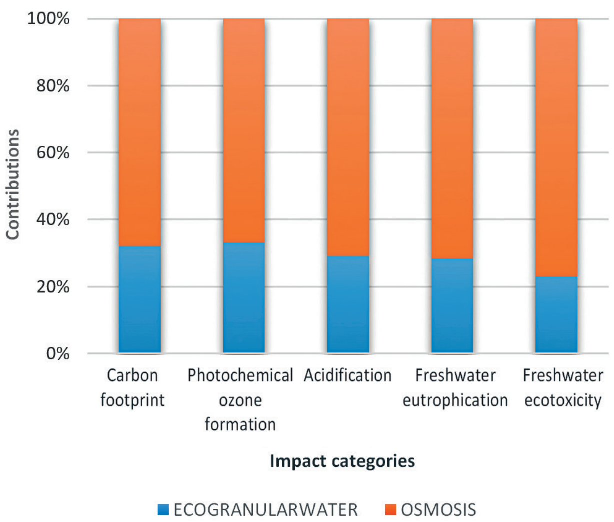
Identification of areas affected by nitrate contamination at the European level, as well as the main economic sectors, in addition to municipal supplies, that could benefit from the technology.



Nitrates Directive EU-28. Area designated as nitrates vulnerable zone and groundwater monitoring stations with average nitrates concentrations above 50mg/L outside NVZ, period 2012-2015.
Source: Report from the Commission to the Council and the European Parliament on the implementation of Council Directive 91/676/EEC.

Life Cycle Analysis of the potabilisation of 1 cubic metre of water, using both the reverse osmosis system and the biological system, as well as the economic cost of both systems. It has been shown that the carbon footprint of the biological system is 2.5 times less than the carbon footprint of reverse osmosis and, furthermore, the purification of 1 cubic metre of water with the biological system is carried out at a cost that is 45% lower.

Technical Workshop held in October 2019 for the LIFE ECOGRANULARWATER project.

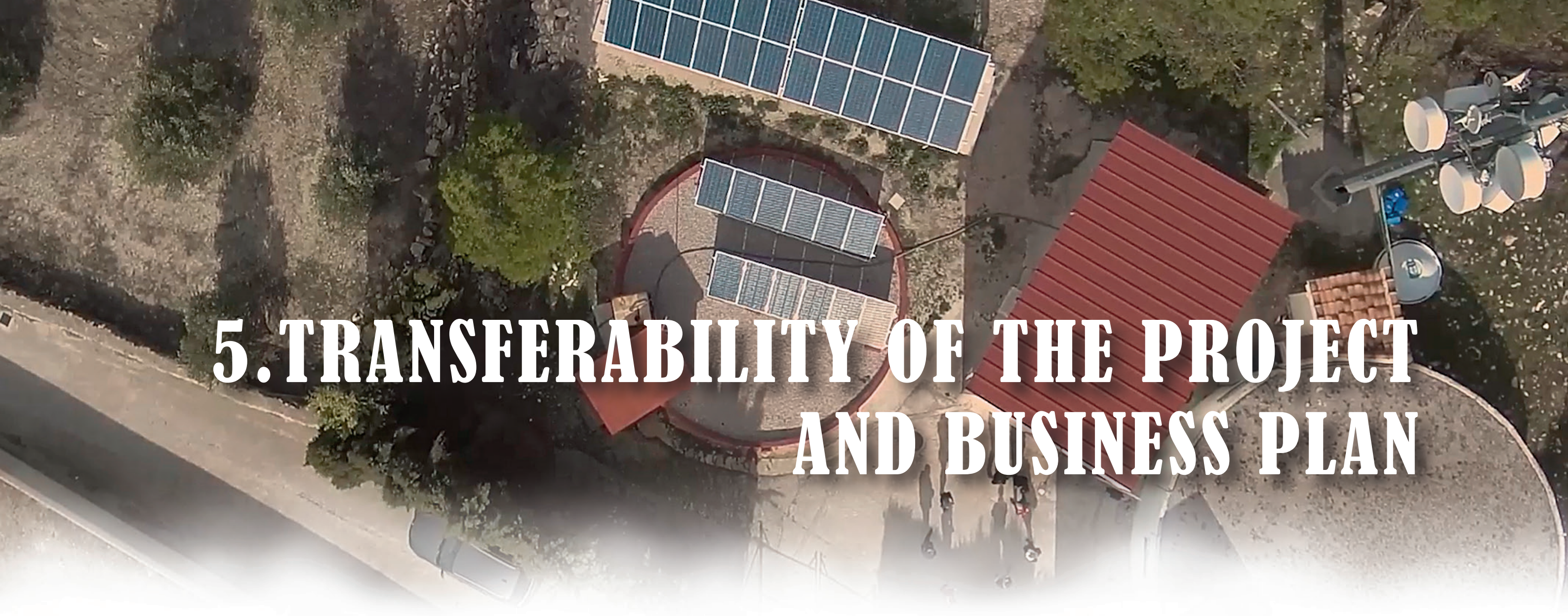


Environmental footprint. Comparison between both systems.

Dissemination of information on project results in newsletters, audiovisual media, specialised conferences and contacts through local sustainability networks.

Informative leaflet of the project.

Drawing up of a **business plan** to promote the use of this biological technology in other European territories.

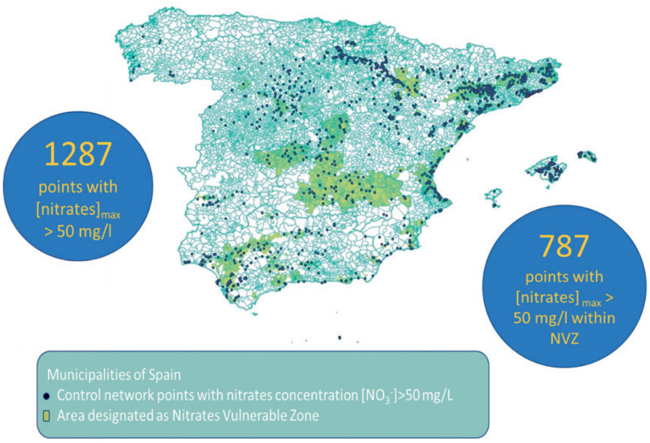


5.TRANSFERABILITY OF THE PROJECT AND BUSINESS PLAN

With the aim of being able to transfer and replicate this innovative technology in other territories, a **business plan** has been drawn up in which the **potential market** in Southern European countries has been analysed. To this end, the areas with the highest levels of nitrate contamination of groundwater were identified, broken down by municipalities or counties.

In Spain alone, more than 150 municipalities have been identified as having severe nitrate pollution problems, which require the supply of more than 260 million m3 of drinking water per year to supply a total population of nearly 4 million people. Turning to other Mediterranean countries, it is estimated that in the areas most polluted by nitrates there are around 18 million inhabitants who require a water supply of 1.4 billion m3 per year.

In addition to the municipal drinking water supply market, Ecogranularwater technology has the potential to be marketed to **industrial and service companies** as an individual solution for obtaining nitrate-free water for use in their production processes. In this regard, a study has been conducted into the business activities that require the greatest consumption of drinking water for their output.



Map of areas affected by nitrate contamination in Spain.

The branches of activity with the highest water consumption in Southern European countries are principally the “food and beverage”, “chemical, rubber and plastics” and “metallurgy and metal products” industries, which together account for almost 40% of the water used in all productive activities. In the services sector, “Accommodation and hospitality”, “Health care”, “Retail” and “Arts, recreation and other services” are prominent activities, accounting for almost 33% of the water required by companies. Therefore, in addition to households, the major beneficiaries of Ecogranularwater technology include these business activities, which constitute an additional potential market to be tapped.

Branches of activity	Andalusia	Spain	Italy, Greece and Malta
Food, beverage and tobacco industry	19.8	13.5	18.6
Chemical and transformation of rubber and plastic materials	14.6	18.0	15.2
Accommodation services	7.4	8.8	9.2
Food and beverage services	9.2	7.7	6.1
Health activities, assistance in residential establishments and veterinary activities	6.3	6.8	5.5
Retail trade	6.8	4.9	5.2
Metallurgy and manufacture of metal products	5.0	5.6	6.2
Artistic, recreational activities and other services	3.7	4.5	4.5
Rest of productive activities	27.2	30.2	29.4

Distribution in percentage of business activities with the highest water consumption.

The business plan also contains an analysis of the general and specific environment that will undoubtedly affect the marketing of Ecogranularwater technology, and concludes with a SWOT analysis (Strengths, Weaknesses, Opportunities and Threats).

Among the **opportunities**, it is worth highlighting the possibilities of attracting resources from the European Union, both from the Next Generation funds, as well as from the Multiannual Financial Framework 2021-2027, aimed at financing projects that promote the ecological and digital transition as promoted by the Ecogranularwater project. Moreover, this technology could be used in other areas, not only in the phase of rendering water potable, but also in the purification phase, to treat the effluents generated by certain industries, thereby preventing the discharge of water with high nitrate concentrations into the environment.

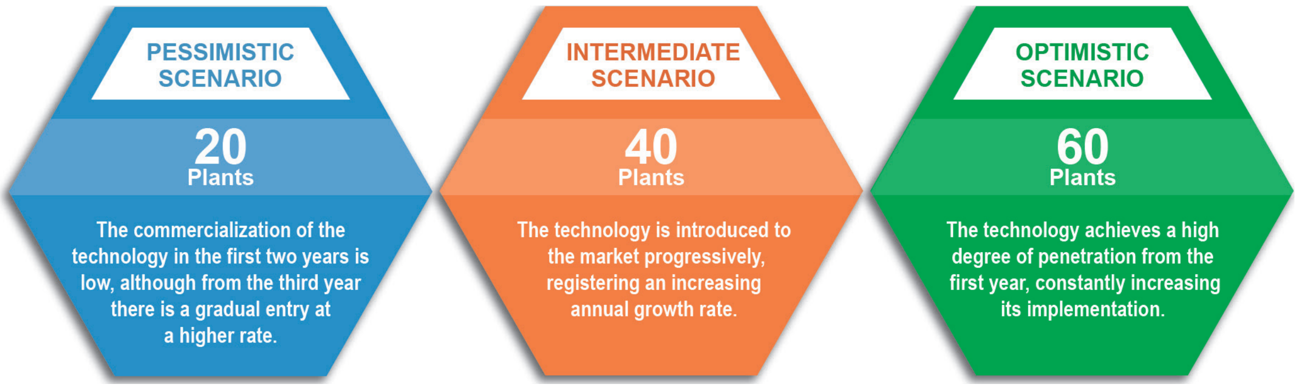
In addition to the above analyses, a **strategic plan** has been drawn up to ensure the success and continuity of the company marketing the technology in the medium and long-term. Among the main strategies to be pursued, it is recommended that investment be made in human capital and R&D, to continue innovating in the improvement and study of new uses for Ecogranularwater technology, and in the development of other clean technologies, to ensure the sustained growth of the company in the future. It has also been recommended that the company implement a comprehensive quality system, promote collaboration and the establishment of alliances with other companies to reach more markets, seek leadership in environmentally sustainable development and contribute to the social welfare of the population through its activities.

In order to achieve the proposed economic objectives, a **marketing plan** has also been drawn up that includes the strategies and actions to be carried out in order to sell Ecogranularwater technology in the marketplace. **Three stages** have been designed for marketing,

in accordance with the established target market. The first stage, which coincides with the technology introduction phase, covers the first three years, and has the Andalusia region as its target market, owing to the proximity to the Torre Cardela pilot plant and the possibility of exploiting the demonstration effect in other municipalities. In a second stage, which will last from 4 to 6 years, we will seek to grow in the rest of Spain and Portugal. Finally, in the long term (7-10 years), we expect to open up new markets in other EU Mediterranean countries. However, although marketing actions will be directed at these priority markets in each of the planned stages, demand from any area of the EU will be met from the outset.

From the economic and financial point of view, the **business viability** of this project has been studied in **three** different demand **scenarios**, for a time horizon of 5 years. In an intermediate scenario, a total of 40 water treatment plants using Ecogranularwater technology are expected to be installed during this period. In the worst-case demand scenario, a sales target of 20 plants is estimated for the 5-year period, while in the most optimistic scenario, a total of 60 plants would be reached.

The results of the economic and financial feasibility study for this project are very positive. Assuming that the marketing of this technology is carried out by an industrial company specialising in water treatment and purification systems and of medium size, with between 20 and 50 workers, it has been estimated that this company could obtain an average profitability, after five years, of between 12% and 20% of the initial investment, depending on the demand scenario. In other words, the company would be able to double its turnover after five years and recover the initial investment.



Business viability of the project.

6. BENEFITS AND IMPACTS

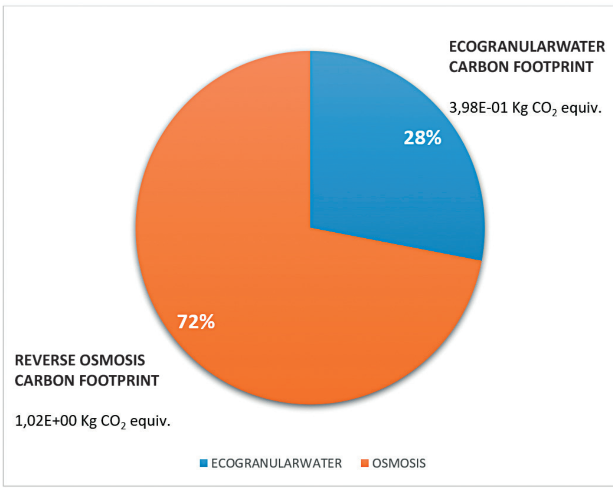
Throughout the life of the project, comparative analyses have been carried out, both environmental and economic, of the water purification technology currently existing in the municipality concerned, consisting of a reverse osmosis plant, and the technology developed in the project, based on biological treatment. Several **positive aspects of the new biological** technology can be highlighted from these analyses.

ENVIRONMENTAL BENEFITS

The environmental comparative analysis was carried out using the **Life Cycle Analysis** methodology. The scope of the analysis considered the <u>construction phase</u>, including the main construction materials for both plants and the transportation of these materials from the place of purchase to the location of the plants in Torre Cardela, and the <u>production phase</u>. The dismantling phase was not taken into account, as it is not significant.

Initially, in the results obtained from the infrastructure analysis, the plant developed by the ECOGRANULARWATER project proved to have greater impact than reverse osmosis, owing mainly to the larger volume of materials used during construction. To sum up, we can say that having greater mass incurs more impact, since the products used are similar.

However, the weight of infrastructure on the total impact over the useful lifetime of the plants represents only 1.61% in the case of the ECOGRANULARWATER plant and 0.01% in the case of osmosis. This indicates that the construction phase in both plants is not really significant in the overall impact generated, with the production phase being the dominant phase in terms of impact.



Carbon footprint of the purification of 1 m^3 of water. Comparison between both systems.

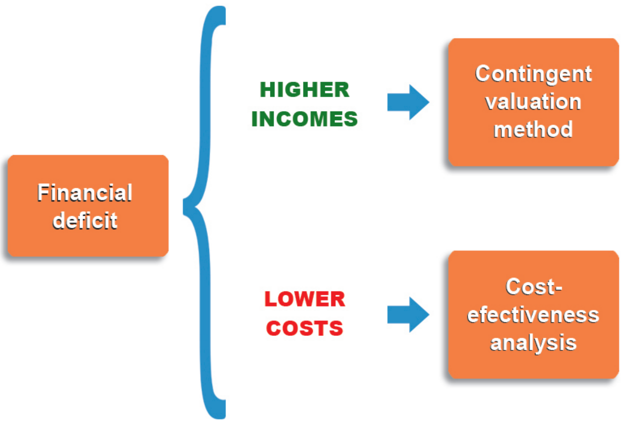
When comparing the Life Cycle Assessment impacts of both drinking water production processes, we observe that the impact of the ECOGRANULARWATER plant equates to 28% compared to 72% for reverse osmosis.

To sum up, in the ECOGRANULARWATER plant, the main inputs with an impact on its Carbon Footprint are organic salts in first place followed by electricity consumption, with these results being replicated in the various impact categories of the Environmental Footprint. In the case of reverse osmosis, the main impact-generating input is electricity, which represents 93% of the impact on the Carbon Footprint and is also replicated in the Environmental Footprint for the selected impact categories.

Bearing the above comparison in mind in addition to the impact generated by the infrastructure, practically the same result is obtained: 28% for the ECOGRANULARWATER plant compared to 72% for the reverse osmosis plant. As initially stated, the impact of infrastructure on the overall impact in the life cycle analysis is virtually insignificant. Therefore, an **average reduction of 60% in both carbon footprint and environmental footprint is obtained with the treatment carried out by the ECOGRANULARWATER plant**. It is estimated that there is still room for improvement, since the comparison was made based on a pilot model that has the potential for greater efficiency.

ECONOMIC BENEFITS

Urban water supply services are often deficient in small municipalities where it is not possible to take advantage of the existing economies of scale in the sector. In these cases, the cost recovery rate remains at low levels, which gives an idea of the economic burden that the provision of this basic service represents for the municipality itself.



One option to ensure that the user pays for the service would be to raise the price of water. In the case analysed in this project, this could be achieved with a linear increase of 60% on all tariff items. But a contingent evaluation analysis shows that only 40% of the population would be willing to pay more for their water.

Moreover, this 40% of the population would, on average, only accept tariff increases well below the 60% required to achieve full cost recovery. Indeed, in a municipality where the main economic activity is rain-fed agriculture, in which families have an average net income of 8,569 euros, most of the people who stated that they were not willing to pay more for water cited their budget constraints as the reason.

In this context, such high tariff increases to comply with the cost recovery principle could jeopardise the affordability of the service for many families, so in these cases, without foregoing more moderate water price increases, the best possible option is to adopt strategies to **reduce production costs.**

The use of Ecogranularwater biological technology for the treatment of water contaminated by nitrates has been shown to have a lower economic cost than reverse osmosis, the system with which it has been compared. Specifically, taking the current reverse osmosis plant as a reference, **the cost of making 1 cubic metre of water drinkable is 45% lower** with the biological system. In addition, the system maintains the same levels of technical and economic viability, operating with photovoltaic solar energy.

As a result of the reduction in costs thanks to the biological plant, the gap between revenue and costs for the water supply service could be reduced. A larger part of the water service costs would be covered by tariff and non-tariff revenue, which would free up resources from the municipal budget for initiatives other than the water service.

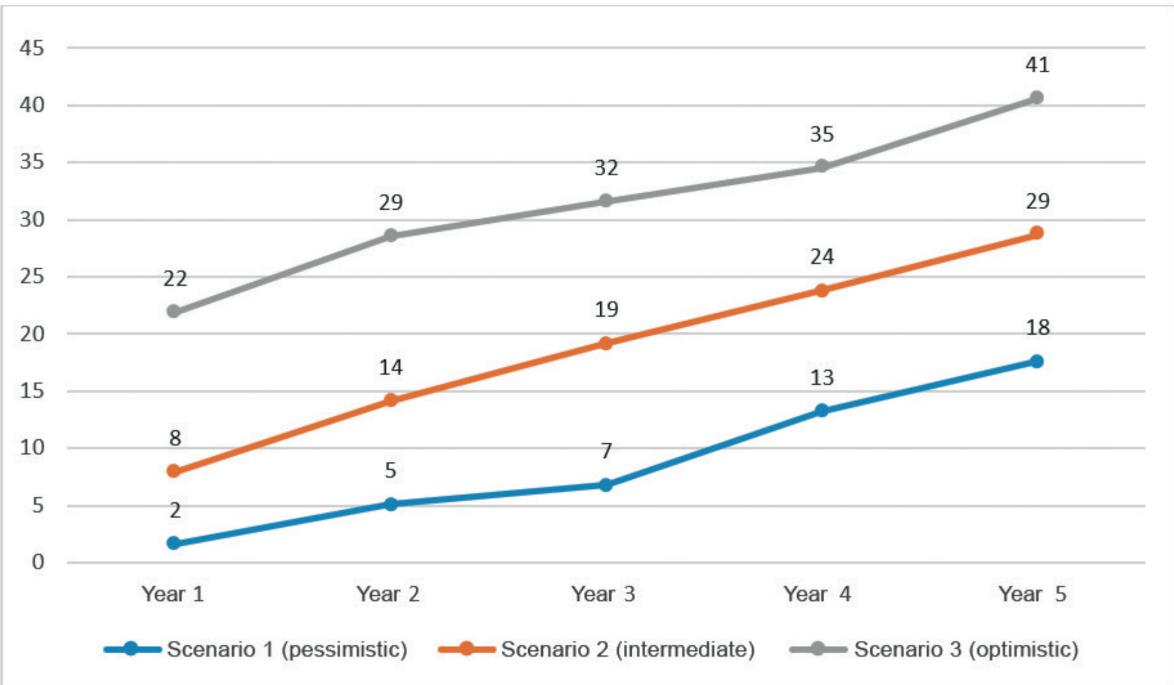
A direct consequence of the above is a closer approximation to compliance with the **cost recovery principle** established in the Water Framework Directive 2000/60/EC.

INCOMES = COST OF SERVICE

SOCIAL BENEFITS

From the social point of view, the marketing of Ecogranularwater technology will **generate** direct and indirect **employment**. Depending on the evolution of demand, it is estimated that, in the fifth year, around 30 new full-time jobs will have been created in the intermediate scenario, of which 20 would be direct and 10 indirect. In addition, an average of 19 jobs would be created annually during the first five years.

In the best-case demand scenario, jobs created in the fifth year would rise to more than 40, while in the worst-case scenario, they would fall to 18 jobs in the last year. The average annual number of direct and indirect jobs in the first five years would amount to 31 in the most favorable demand scenario and nine in the pessimistic scenario.



Scenarios	1 (pessimistic)	2 (intermediate)	3 (optimistic)
Average employment	9	19	31

Estimated number of full-time jobs, direct and indirect, in each demand scenario.

7. CONCLUSIONS

Nitrate contamination of water is a widespread problem at the European level, sometimes affecting the supply of drinking water. In order to meet the requirements of drinking water quality legislation, water supply managers need to use techniques to remove nitrates from the water.

The Life ECOGRANULARWATER project has demonstrated the **efficiency of biological technology for the removal of nitrates** from water intended for human consumption, at a lower cost and with a lesser environmental footprint than other currently more widely-used systems such as reverse osmosis.

The system **generates no waste and reduces water consumption** compared to other systems such as reverse osmosis, where about 40% of the volume of treated water is rejected as brine. There is also a very significant reduction in energy consumption by the biological system.

The system has been demonstrated to supply a population of 500, but is **easily scalable** to other population sizes by increasing the height of the bioreactors and the number of these.

The elimination of nitrates using biological methods is carried out under **conditions of complete biosecurity**, with no eco-toxicity detected at any stage of the process.

Given the effectiveness and the **environmental, social and economic benefits** of this technology, the business plan developed foresees that, in a time horizon of five years, in an intermediate scenario, 40 plants could be installed and generate around 30 new full-time jobs.

Within the framework of the project, it has been demonstrated that the **ECOGRANULARWATER technology is a competitive alternative** to existing technologies for the removal of nitrates from drinking water.

Drinking water at consumer's tap.

LIFE ECOGRANULARWATER

(LIFE16 ENV/ES/196)

More Information:

www.lifeecogranularwater.com
ecogranularwater@dipgra.es

Integral Water Cycle Service.
Provincial Council of Granada.
C/ Periodista Barrios Talavera, 1. 18014 Granada
958 24 73 46

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