PPP FOR CITIES CASE STUDY

AUGUST 2021

END-TO-END WATER CYCLE MANAGEMENT IN THE CITY OF ALMERÍA (ANDALUSIA, SPAIN)

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PPP for CITIES
Specialist Centre on PPP in Smart and Sustainable Cities

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The Specialist Centre on PPPs in Smart and Sustainable Cities (PPP for Cities) is a research, innovation and advisory center that aims to provide public authorities throughout the world with support in the organization, management and execution of projects involving collaboration between the public and private sector in the field of smart cities.

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This document has been prepared with information provided by Aqualia and forms part of a series of case studies on public-private partnerships (PPP) carried out for the CAF – Investment Bank.

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List of Acronyms and Abbreviations

BioSol: Bio-Solar Water Recycling

BSP: Bio-Solar Purification

Capex: capital expenditure

CETIM: Multisectoral Research Technology Centre

COD: chemical oxygen demand

CPI: consumer price index

DAF: dissolved air flotation

DI: ductile iron

EC: European Commission

EPC: engineering, procurement, and construction

ESP: peseta (currency used in Spain from 1868 to 1999)

EU: European Union

EUR: euro

FC: fiber cement

FCC: Fomento de Construcciones y Contratas (a Spanish construction company)

GDP: gross domestic product

GIS: geographic information system

IECA: Institute of Statistics and Cartography of Andalusia

INCOVER: Innovative Eco-Technologies for Resource Recovery from Wastewater

INE: Instituto Nacional de Estadística (National Institute of Statistics)

IO: input-output

O&M: operations and maintenance

OMT: operate, maintain, and transfer

PE: polyethylene

People-First PPP: People-First Public-Private Partnership

PHOENIX: Perfluorinated Compounds Holistic Environmental Interinstitutional Experience

PITA: Almería Science and Technology Park

PPP: public-private partnership

PVC: polyvinyl chloride

R&D: research and development

SABANA: Sustainable Algae Biorefinery for Agriculture and Aquaculture

SCADA: supervisory control and data acquisition

SDP: seawater desalination plant

ULISES: Upgrading Wastewater Treatment Plants by Low-Cost Innovative Technologies for Energy Self-Sufficiency and Full Recycling

UN: United Nations

UNECE: United Nations Economic Commission for Europe

UTE: unión temporal de empresas (temporary business alliance)

WWPS: wastewater pumping station

WWTP: wastewater treatment plant

Overview

The City of Almería is located in the southeast of the Iberian Peninsula, which is one of the driest regions in Spain due to its sub-desert climate and low levels of rainfall. The climate has historically posed a major challenge to the economic development of both the city and the region but has also provided a strong incentive for the implementation of measures aimed at efficient water management. Such measures have enabled the region to develop an economy driven by the horticulture sector and tourism and made the city a center of regional economic development and a magnet for population.

Efficient management of the end-to-end water cycle (production, supply, distribution, sanitation, and treatment), modernization of infrastructure and facilities, and the establishment of appropriate incentives that encourage residents to consume this scarce resource more responsibly have made it possible to meet growing water consumption demands in the region while maintaining environmental sustainability.

Aqualia is the company that currently manages all the plants involved in this process in Almería (except for the desalination plant), under an administrative concession contract with the City Council of Almería that dates to 1993. The infrastructure managed by the company includes:

- Eight aquifer wells (Bernal wells)
- 100,000 m^3 regulation tank
- Chlorination facility (to treat water from wells for drinking)
- 19 tanks of different capacities in the high supply network
- 788 km of supply networks
- Sewerage networks with 642 km of sewers
- Cabo de Gata wastewater treatment plant (WWTP; in the Cabo de Gata-Níjar Natural Park)
- El Bobar WWTP (the metropolitan area where 85% of the wastewater generated in the municipality is concentrated)
- El Toyo WWTP (which serves the Retamar-El Toyo zone to reduce the pollutant load produced by the El Bobar WWTP)

Bringing in a private concessionaire to manage publicly owned infrastructure facilitated pending investments to upgrade and expand existing facilities, brought in the knowledge and experience of a multinational company, and enabled the transfer of construction and operations and maintenance (O&M) risks from the public to the private sector.

The investments made led to a significant increase in the efficiency of the network and a marked reduction in energy consumption, thus minimizing its environmental impact.

Several research projects have also been carried out at the El Toyo WWTP, including the Sustainable Algae Biorefinery for Agriculture and Aquaculture (SABANA), Innovative Eco-Technologies for Resource Recovery from Wastewater (INCOVER), and Bio-Solar Water Recycling (BioSol). The first two are part of the EU's Horizon 2020 program.[1] The BioSol project, which is part of the LIFE program,[2] uses innovative technology based on microalgae to obtain treated water suitable for reuse in the irrigation of green areas and golf courses. It boosts economic activity in the region as well as generating by-products with high added value, such as fertilizers.

Another LIFE project—Perfluorinated Compounds Holistic Environmental Interinstitutional Experience, also known as PHOENIX—is also being implemented and will run until 2024. This project focuses on study and analysis of cutting-edge systems for the regeneration and reuse of wastewater and ways to eliminate microplastics and other pollutants.

[1] Horizon 2020, the financial instrument used to implement innovation policies in the European Union (EU), was aimed at ensuring Europe's global competitiveness over a seven-year period (2014-2020).

[2] The Environment and Climate Action Program (LIFE), launched in 1992, is the EU's funding mechanism for environment and climate action.

In the case of the El Bobar WWTP, a circular economy project known as LIFE Upgrading Wastewater Treatment Plants by Low-Cost Innovative Technologies for Energy Self-Sufficiency and Full Recycling (ULISES) is being carried out. The project, which is being applied at full scale, involves purification and enrichment of biogas to produce biofuel for vehicles and agricultural biofertilizers, and the treatment of wastewater to obtain water suitable for reuse.

The operation of the concession has led to steady progress in meeting some of the UN Sustainable Development Goals (SDGs), in particular: SDG 3, Good Health and Well-Being; SDG 6, Clean Water and Sanitation; SDG 8, Decent Work and Economic Growth; SDG 9, Industry, Innovation and Infrastructure; SDG 13, Climate Action; SDG 14, Life Below Water; and SDG 17, Partnership for the Goals.

In this study, we estimate the economic impact of Aqualia's direct and indirect investment at €191.49 million, equivalent to 0.11% of the regional gross domestic product (GDP) in 2019.

The project has made Almería a benchmark for efficient water use and an example of how smart technologies can be used in the sector. Such technologies have made it possible to overcome the strict constraints imposed by the local climate and foster sustainable economic development in the region, which undoubtedly has a direct positive impact on its population.

Location: Almería, Andalusia (Spain).

Characteristics of the PPP Contract

Project type: Greenfield.[1]

Mode of delivery: Concession.

Total private investment by period:[2]

- 1993-2005: Investment[3] of €21,512,3584[4] in infrastructure improvement and an upfront concession fee of €7,012,890. Total investment in the period: €28,525,248.
- 2006-2020: Investment of €41,883,920 for modernization and improvement of infrastructure; payment of €14,341,862 in annual fees.[5] Total investment in the period: €56,225,782.

Total private investment (1993-2020): €84,751,030.

General conditions of contract: June 18, 1992.

Submission of bids: July 17, 1992.

Opening of sealed bids: August 11, 1992.

Signing of the contract: November 9, 1992.

Contract start date: December 4, 1992.

Start of operations: January 1, 1993.

Duration of the contract: 20 years, plus a 20-year extension (1993-2032).

End of operations: December 31, 2032, following the extension of the contract in 2006 (linked to new investment in infrastructure).

Method of payment to the concessionaire: From the tariff paid by customers, in accordance with the municipal ordinance. Initially, the remuneration paid to the concessionaire was based on the unit price tendered (which we will refer to as the "tariff"[6]), which was adjusted annually by applying a polynomial formula.

Subsequently, because of the economic crisis, a new remuneration system was established. The new scheme was based on the tariff specified in the municipal ordinance, which was indexed to 90% of the annual consumer price index (CPI).

Contracting authority: City Council of Almería.

[1] A project involving new construction or infrastructure renewal that requires significant capital expenditure (capex) and entails construction risk.
[2] The contract was signed in 1993, for a period of 20 years, and extended in 2006 to meet additional needs for infrastructure investment.
[3] The contract was tendered in pesetas, the Spanish currency in use in 1992. The euro was adopted seven years later, in 1999, with an exchange rate of 166.386 pesetas per euro, though the new currency did not come into circulation until 2002. For simplicity, amounts are expressed in euros at the exchange rate in effect in 1999 and adjusted for inflation as of December 2020 (the closing year of this case). See https://www.ine.es/calcula/calcula.do.
[4] This included an initial investment and an annual financial allocation for infrastructure.
[5] From 2010 on, a system for payments by the concessionaire to the City Council of Almería was adopted. The concessionaire paid a fixed fee plus a variable fee that depended on the amount of water billed.
[6] Though the unit price and the tariff are not equivalent, we will use the term "tariff" in both cases for the sake of simplicity. The company bid for the contract by offering a unit price, while tariffs are specified in the municipal ordinance.

Bidding Process

Winning company: Sociedad de Gestión de Servicios Urbanos (Sogesur), now Aqualia Gestión Integral del Agua, S.A. (Aqualia).

Financing: Entirely with capital from the parent company, Aqualia.

1. Project Background

We will now contextualize the project by describing its location, the stages of the water cycle, and the tariff framework that applies.

1.1. Project Location and Environment

The project is located in the City of Almería (capital of the province of the same name), which is situated in the autonomous community of Andalusia (Spain),[1] in the southeast of the Iberian Peninsula (see **Figure 1**). In 2019, the city had a population of 198,533,[2] in a municipal district that covers 298.42 km^2 and is home to 28% of the total population of the province. (In 2019, the total provincial population was 719,820.)

Figure 1. Project Location

Source: Almería (April 18, 2021). Based on the Wikipedia file: "Archivo:EspañaLoc-Almería.svg," Wikipedia, last modified June 26, 2010, https://es.wikipedia.org/wi.

Due to its geographical and hydrographical characteristics, Almería is one of the driest regions in Spain.[3] However, this challenging climate has not prevented the province from achieving economic growth above the average rate for Spain in recent decades. In 2018, Almería ranked 34th among Spain's 54 provinces in GDP per capita[4] despite having been one of the country's most impoverished regions in 1960.[5] This strong economic growth has been driven by intensive agriculture, centering on horticultural products[6] and related industry, and by a significant upturn in tourism, especially in recent years.

In 2017, the province's agricultural sector accounted for 17% of Andalusia's GDP and employed 90,000 people.

The economic development of both the province and the city has been made possible in part by efficient water management. Public bodies and private companies involved in water management have worked together to carry out investments and implement innovative technologies, modernize irrigation systems,[7] and ensure efficient provision of this resource. Actions taken include:

- Combining seawater desalination with use of water from aquifers.
- Use of smart water networks to minimize losses.
- Reuse of treated water to irrigate golf courses, gardens, and public spaces.

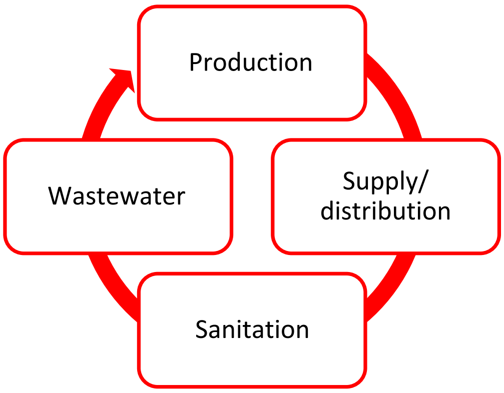
[1] In 2018, Andalusia ranked 227th out of 312 in the ranking of European regions (Nomenclature of Territorial Units for Statistics [NUTS 2]) in GDP per capita.
[2] Instituto Nacional de Estadística (2020a).
[3] Downward, S. R. and Taylor, R. (2007).
[4] Instituto Nacional de Estadística (2020b).
[5] Buchs, A. (2010).
[6] Molina Herrera, J. (2005).
[7] García-Valiñas, M. A. (2019).

As a result of this public-private collaboration, Almería is now one of the most efficient provinces in the world when it comes to water management.[8,9]

1.2. End-to-end Water Cycle Management

In this section, we describe the various components of end-to-end water cycle management in the Almería concession. The stages are presented in "downstream" order; that is, from the beginning of the cycle to the end and back to the beginning (see **Figure 2**). The cycle starts with water production (including drinking water treatment and storage), which is followed by the distribution of drinking water, sanitation (sewerage) and wastewater treatment.

Figure 2. End-to-end Water Cycle



Source: Prepared by the authors.

1.2.1. Production

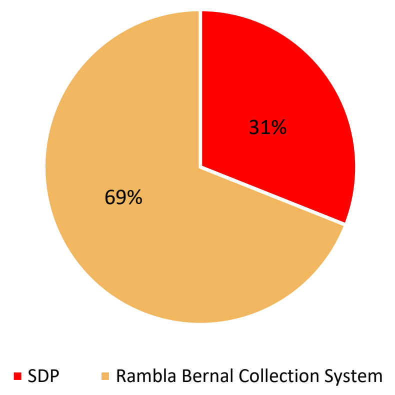
The water that supplies the city comes from two sources (see **Figure 3**):

- The Rambla Bernal aquifer[10] in the municipality of El Ejido, where the water comes mainly from melting of snow accumulated on the far side of the Sierra Nevada mountain range (elevation 3,479 m) and reaches the aquifer through subsurface filtration. To make this water fit for human consumption, it is only necessary to add sodium hypochlorite (NaClO) at the chlorination facility. This aquifer is composed of eight wells, which produce 69% of the water distributed in the City of Almería.

- From the Almería seawater desalination plant (SDP). The plant started to operate in 2006 and is intended to support the production of water from Rambla Bernal and prevent overexploitation of the wells, which could seriously damage the ecosystem. The plant uses reverse osmosis technology and has a capacity of 50,000 m^3/day, supplying drinking water to an average of 200,000 people. In 2019, this form of production accounted for 31% of the drinking water supplied to the city.

[8] Grindlay, A. L. et al. (2011).
[9] Fernández, A. (July 19, 2019).
[10] Rambla Bernal discharges water through eight perforations into a 1,000 mm diameter pipe. The water is conveyed through this pipe to the main regulation tank, which has a capacity of 100,000 m^3. Once it has been treated and is fit for human consumption, the drinking water is conveyed through the Aguadulce Canal to the City of Almería. Water is collected at an average depth of 265 m.

Figure 3. Sources of Water Consumed in the City of Almería, in Cubic Meters (2019)



Source: Aqualia. Document provided by the company.

1.2.2. Supply

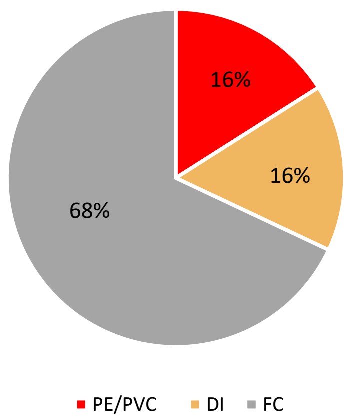
Supply-related activities include abstraction, conveyance of raw water, conveyance to tanks; and management of regulation tanks, the city's general distribution networks, and the electromechanical elements used to lift water.

The water supply network comprises 19 tanks, as well as distribution pipes and a series of pumping stations, all of which are managed by Aqualia (except for the storage tank at the Pipa Alta desalination plant). These linked elements distribute drinking water to the city's interconnected networks, from the Castell del Rey housing development to the Cabo de Gata district. Tank capacities range from 200 m^3 in the case of the one in Cuevas de los Medina to 100,000 m^3 for the one located in the town of Aguadulce.

Water is supplied to the city from tanks distributed throughout the municipal district to end user delivery points, either by gravity or using pumping systems. Pumping systems and tanks are integrated in a remote-control system connected to a monitoring center that provides real-time information on the status of the pumps and the water level in each tank. This system can also be used to obtain historical data on the facilities.

The drinking water distribution system in the City of Almería consists of a 788-km network that extends over about 10 large areas, which are in turn divided into 76 water distribution sectors (usually named after the neighborhoods they supply), with flowmeters that incorporate a system of data loggers to monitor consumption. In each of the water sectors, there are large-diameter flowmeters for the drinking water. The demand in each sector can therefore be checked at any time. All this information is collected at a central point by a remote-control system. As a result, real-time data on demand in a particular sector and any demand anomalies in the various zones (which can occur due to overdemand caused by breaks in water networks downstream from flowmeters) is always available. The network has a total of 37,107 supply connections, 7,789 shut-off valves, 1,242 watering nozzles, and 1,160 fire hydrants. As shown in **Figure 4** below, 68% of the pipes in the distribution network are made of fiber cement (FC); 16%, ductile iron (DI); and 16%, polyethylene (PE) or polyvinyl chloride (PVC).

Figure 4. Composition of Distribution Network Pipes



Source: Aqualia (2020). Data obtained from https://www.aqualia.com/es/web/aqualia-almeria/ciclo-del-agua/abastecimiento.

1.2.3. Sanitation

Sanitation activities include management of the municipal sewerage network, pumping stations and land-based outfall sewers.

Sewerage networks channel the wastewater produced in the city (by gravity or via pumping stations) to the WWTPs. Up until 2019, this network had 642 km of sewers, 29,646 household connections units, and 17,588 scuppers and drains for channeling rainwater.

As for the sewerage network in the urban core, the main facility is a trunk line that conveys all wastewater from the main urban core to the El Bobar WWTP by gravity. Before reaching the trunk line, the water passes through several wastewater pumping stations (WWPS), which collect the water and lift it from the coastal zone to the main sewer line. Wastewater from outlying population centers—La Cañada de San Urbano, El Alquián, Costacabana and Retamar-El Toyo—is transported through several WWPSs to the El Toyo WWTP. All the WWPSs are connected to a remote-control system, which, like the supply system, provides real-time information on pumps, flow rates, temperature, etc.

1.2.4. Wastewater Treatment

The wastewater treatment process is the final stage of the water cycle. The City of Almería has had a wastewater treatment system since 1981, when the Costacabana WWTP came into operation. In 1995, this facility was replaced by the El Bobar WWTP, which has a treatment capacity of 48,000 m^3/day.

A European R&D project known as LIFE ULISES is currently in the construction and implementation phase at the El Bobar WWTP. The project focuses on purifying and enriching biogas to produce biofuel from wastewater.

In 1995, the Cabo de Gata WWTP was also put into operation (to treat wastewater from the San Miguel district). At present, it also handles wastewater generated in the neighboring towns of Ruescas and Pujaire. The facility was designed to treat up to 750 m^3 of wastewater a day, and its capacity was recently expanded to 1,000 m^3/day, which enables the plant to adapt to variation in the flow of wastewater from these towns due to tourism-related activity.

Wastewater from the outlying population centers mentioned above (Costacabana, Retamar-El Toyo, El Alquián and La Cañada de San Urbano) is treated at the El Toyo WWTP, which was built in 2004 and has a capacity of 13,000 m^3/day (see **Table 1**). The plant also has a tertiary treatment system that produces water of suitable quality for reuse in the irrigation of golf courses and public gardens.

In 2018, three European R&D projects based on microalgae technology (INCOVER,[11] BioSol[12] and SABANA) were implemented at the El Toyo WWTP. Another known as LIFE PHOENIX, which focuses on reuse and regeneration of urban wastewater for agricultural uses and the elimination of emerging pollutants and microplastics, will get underway shortly. This initiative is one of Aqualia's R&D milestones (see **Appendix A**).

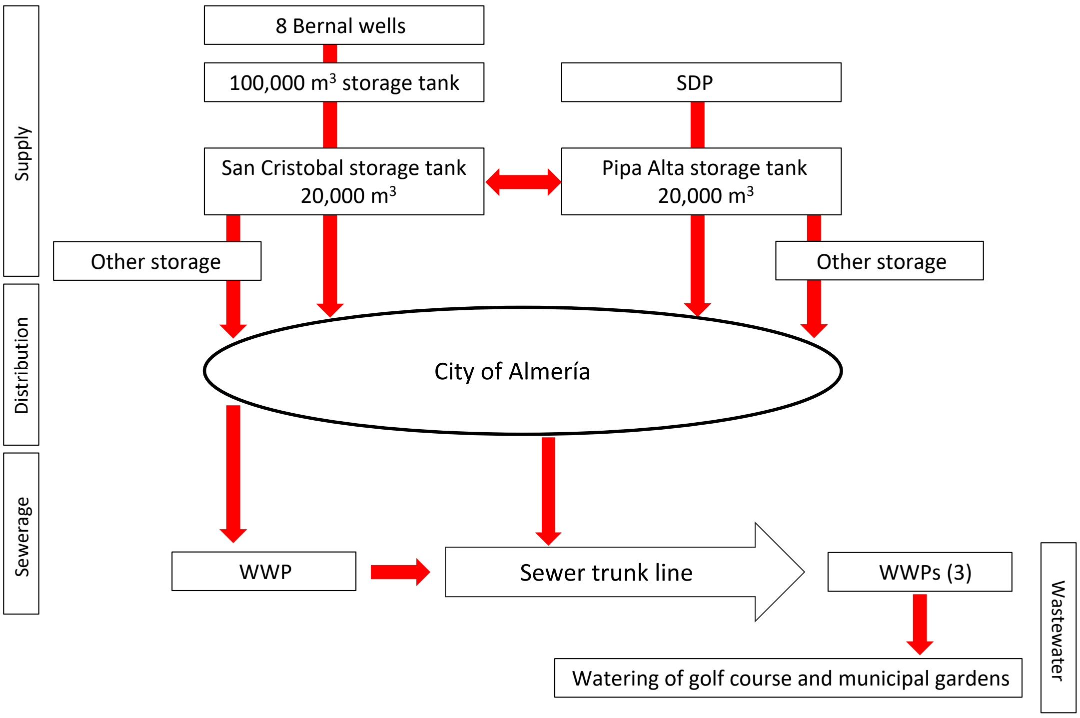
Table 1. Wastewater Treatment Plants

Year	WWTP	Percentage of total volume treated	Capacity
1995-present	El Bobar	85%	48,000 m³/day
1995-present	Cabo de Gata	2%	1,000 m³/day
2004-present	El Toyo	13%	13,000 m³/day

Source: Aqualia (2018b). Data provided by the company.

Figure 5 shows the end-to-end water cycle management system for the City of Almería, from the production of water drawn from wells to its subsequent distribution, and finally its return to the environment and/or reuse.

Figure 5. End-to-end Water Cycle



Source: Prepared by the authors.

1.3. Tariff Framework: Flow of Payments

The Spanish regulatory framework provides that local governments must guarantee water and sanitation services to residents.[13] Local governments may administer this service themselves or outsource it to a publicly owned, private or mixed company.[14] In the case of Almería, there is currently an administrative concession to manage the end-to-end water cycle for the city, and the concessionaire is the private company Aqualia.

[11] The idea behind the INCOVER project is to transform sanitation technology, shifting it towards a bioproduct recovery industry and a source of water that can be reused. https://incover-project.eu/.
[12] The main aim of the BioSol project is to develop and validate a new wastewater treatment system that is efficient and competitive, based on an environmentally friendly process called bio-solar purification (BSP). http://www.life-biosol.eu/.
[13] Pursuant to Law 7/1985, of April 2, 1985, which regulates the system of local government.
[14] Garcia-Valiñas, M. A. (2019).

The tariffs that the concessionaire charges customers for the water supply and sanitation service are approved by the City Council and the Andalusian government before they are applied. Broadly speaking, the revenue the concessionaire derives from these tariffs must cover the cost of providing the service and enable the company to recover its investments so that the concession can be kept in economic balance.

Over the life of the contract, the concessionaire's total revenue should cover the following items:

- The concession fee paid to the municipality
- New infrastructure and investments in upgrading and replacing infrastructure (e.g., pipes, pumps, water meters, etc.)
- O&M costs
- The concessionaire's profit

The initial 1993 contract for the concession of the water service for the City of Almería was based on an agreement specifying the remuneration to be paid to the concessionaire, based on the tariff offered in the bidding process (see Section 3.3.), in which the winning bidder was the one that offered the lowest operating tariff.[15] **Table 2** shows how the amounts collected for the service were distributed according to the remuneration system established in 1993, which remained in effect until 2010.

Table 2. Distribution of Tariff Revenues

Tariff (paid by users)	Remuneration paid to the concessionaire	Concession fee
		Investment in infrastructure
		O&M costs
		Concessionaire's profit

Source: Prepared by the authors.

[15] From 2010 on, the tariff was indexed to 90% of the CPI.

2. Tendering of the Project

In 1992, Almería had very poor water quality, low distribution efficiency because of high-water losses (due in turn to the age of its distribution networks), and a high percentage of households without water meters. The entry into force of Decree 120/1991, of June 11, approving the Domestic Water Supply Regulations (which required that Almería households be provided with water meters so that consumption could be monitored, and tariffs could be set accordingly[16]), was still very recent. As a result, the regulations were applied only to a limited extent in the city.

Faced with this situation, in July of the same year, with the goal of granting a private company the concession for managing water and sanitation and making the investments needed, the City Council of Almería published a call for tenders for the administrative concession of the municipal public service of drinking water supply and distribution and sanitation services for the city.

2.1. Call for Tenders

The company awarded the tender would be the one that met all the technical requirements and submitted the best economic offer.

Bidders had to submit an offer specifying the tariff for the supply and sanitation service (euros/m^3 of water billed), which needed to cover the costs indicated in the table below.

Table 3. Costs to Be Covered by the Tariff Bid

Fixed	Variable
Personnel	Purchase of water
Maintenance and conservation	Electric power
Miscellaneous expenses	Reagents
Amortization of investments	Overhead costs and concessionaire’s profit
Overhead costs and concessionaire’s profit	Other
Financial expenses incurred by the City Council	

Source: Administrative contract for the operation of the municipal public service of drinking water supply and distribution and sanitation services under an administrative concession, City Council of Almería, December 1992.

The concessionaire’s total revenue would be determined by the tariff it had offered in the bidding process (adjusted annually according to the polynomial formula) multiplied by the volume of water billed (in cubic meters).

Bidders also had to specify the following figures in their tenders:

- The average tariff, calculated based on the anticipated volume of water to be billed. The volume of water billed would also determine the profit or loss generated by the service provided.
- The volume of investment in service-related works and facilities (to be recovered through the concessionaire’s remuneration, included in the unit price).
- The minimum upfront concession fee of approximately €3 million[17] paid at the start of the contract. (Bidders could offer additional sums.)

[16] Decree 120/1991 established that the water supplier was responsible for providing meters to the population to monitor consumption, maintaining pressure and flow within permitted limits, and suspending the service if necessary. Consumption, as determined by meter readings, was used to set tariffs, and apply bill payment methods.
[17] 260 million pesetas (€2,908,056.29).

- An annual financial allocation for the expansion, renewal and upgrading of water service works and facilities, generally as a matter of urgency, which required the prior authorization of the City Council. This financial allocation was initially set at €671,089.[18]

- The supply, without charge, of 10% of the volume of water billed to municipal services.

Bidders also had to provide a security of €357,000[19] and furnish two bonds:

- A bid bond in the amount of €2,236.92,[20] which all bidders were required to post to participate in the tender procedure.

- A performance bond in the amount of €4,473.84,[21] provided by the company awarded the contract, to be returned upon completion of the contract.

The documentation, including the following items, had to be submitted in three envelopes:

- Administrative documentation

- Reference documentation establishing the bidder's capacity to provide the service

- Economic offer

Following the opening of the first and second envelopes, all bidders who did not meet the requirements or who had submitted incomplete documentation were excluded from the process. The contract award committee then opened the third envelope containing the economic offer, which was sent to the municipal council's technical team for analysis. The award criteria were as follows:

- Best proposed organizational framework to deliver the service

- Greatest financial solvency

- Best economic offer

- Highest level of provision without charge for municipal consumption

- Best price for consumption more than that level

- Discretionary power of the City Council

- Higher volume of investments made at the concessionaire's expense

- Best financial conditions for planned investments

- Submission of certificates from the city councils of localities with a population of at least 300,000 (double the estimated population of Almería) where domestic drinking water distribution services had been provided by the bidder

Five bids were submitted, and the envelopes were opened in August 1992. The bidders were three temporary business alliances and two individual entities:

1. Ferrovial and Cadagua

2. Gestión y Técnicas del Agua, S. A. (Gestagua) and Société d'Aménagement Urbain et Rural (Saur)

3. Sociedad de Gestión de Servicios Urbanos, S. A. (Sogesur), now Aqualia

4. Construcciones Lain, S. A., Servicio Omicron, S. A. and Elsamex, S. A.

5. Aquagest

[18] 60,000,000 pesetas a year in 1993. This amount has been adjusted periodically (initially by applying the polynomial formula). In December 2020, it was approximately €723,000 a year
[19] 332,000,000 pesetas in 1993 (€357,913).
[20] 200,000 pesetas in 1993 (€2,236).
[21] 400,000 pesetas in 1993 (€4,473).

Of the five bids, Sogesur presented the most advantageous proposal for the supply, distribution, and water sanitation service for the City of Almería. The results of the tender process are summarized in **Table 4**.

Table 4. Results of the Tender Process

Bidders	Position
Sogesur	1
Aguagest	2
Gestagua-Saur	3
Lain-Omicron-Elsamex	4
Ferrovial-Cadagua	5

Source: Almería Water Supply, Distribution and Sanitation Service Contract (December 4, 1992).

2.2. Winning Bid

The winning bid, submitted by the company Sogesur, included:

- An average tariff of 103 ESP/m^3 for the supply and sanitation service.
- An average current tariff of 119.24 ESP/m^3.
- The upfront concession fee of €2,900,000 (to be paid to the City Council upon the signing of the contract) plus an additional sum of €4,104,833.75 (on top of the minimum stipulated in the tender specifications).[22] In total, the company's bid included the payment of €7,012,890.[23]
- The provision without charge of 10% of the volume of water billed for use in municipal services.
- A budget of €13,400,000[24] for infrastructure investments, to be carried out over four years (1993-1996), for refurbishment works and improvements.
- An annual allocation of €671,089[25] for infrastructure. Subject to the prior approval of the City Council, this allocation was to be used to cover the cost of renewing infrastructure at the end of its useful life (generally as a matter of urgency). This amount was adjusted in the same proportion or percentage applied to adjust the tariff.

In addition to the above, the company deposited the security and the two bonds required.

[22] 367 million pesetas (€4,104,833.75).
[23] 627 million pesetas (€7,012,890.04).
[24] 1,264,080 pesetas (€13,397.03).
[25] Initially, 60,000 pesetas a year.

3. The Contract: Investments, Operation and Remuneration

In this section, we set out the details of the contract entered by the concessionaire and the City Council to carry out the end-to-end water cycle management project in the City of Almería.

3.1. Investments

The current concession came into effect in 1993, when Sogesur (acquired by Aqualia in 2003) won the tender to supply and distribute water to the city for a period of 20 years.[26]

The contract, which remains in force, has been executed in two stages:

1. 1993-2005

During this stage, the following actions were carried out:

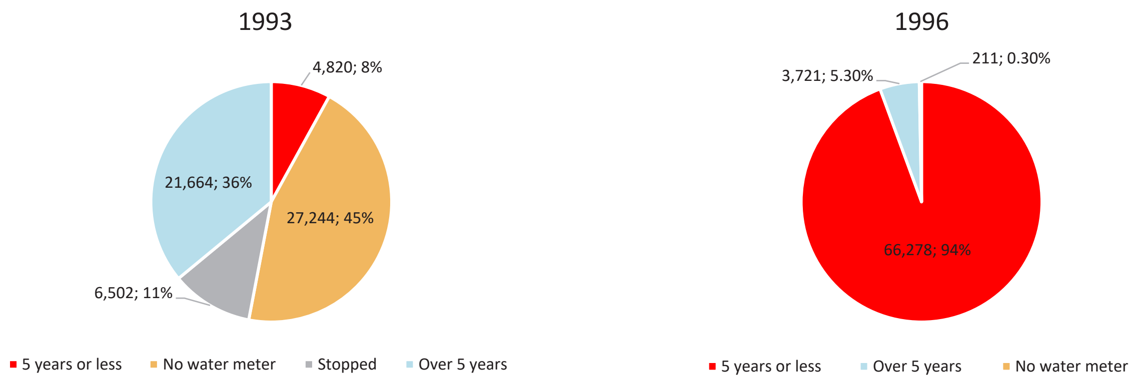
- Infrastructure investments amounting to €21,512,358
- Payment of the upfront concession fee of €7,012,890[27] (to be used for investment in infrastructure)

Investment executed during this period totaled €28,525,248.

During the first four years of the concession contract (1993-1996), the focus was on locating and remedying infrastructure malfunctions and water losses, analyzing municipal consumption, and identifying households without meters or with poorly functioning meters.

Aqualia installed a total of 70,000 water meters for consumers, reaching a micro-metering coverage of 94% of the city's population in 1996, just three years after winning the concession (see **Figure 6**). The concessionaire also identified and mapped all the city's supply networks to facilitate optimal service planning.

Figure 6. Evolution of the Number of Meters and Percentage of Total (1993-1996)



Source: Documents provided by the company. Information presented at the Water, Agriculture, and Sustainability summer course offered by the University of Almería in 2019.

[26] Sogesur started providing services to the municipality of Almería back in the 1980s, when it was awarded a contract for the operation and maintenance of the Costacabana WWTP.
[27] The contract also established an upfront concession fee that Aqualia would pay to the City Council of Almería, based on its expected profit from the operation of the plant. The fee was not to be modified if the tariffs or the unit price did not vary, and the City Council was required to reinvest this amount in maintaining and upgrading infrastructure.

This initial stage of heavy investment led to significant savings in water consumption by reducing losses (through the replacement of deteriorated networks) and because the new meters installed encouraged residents to save water.

During the second stage of the first contract, from 1997 to 2005, the concessionaire focused on optimizing infrastructure management and improving systems. The following new investments were also carried out:

- Leak detection equipment, such as leak correlators
- Electromagnetic and insertion flowmeters
- SMS data loggers
- Replacement and installation of new valves for sector control
- Extensions of the existing transport network, among others

Over these years, maps of the territory were also updated and introduced into Aqualia's new geographic information system (GIS) platform (see **Figure 7**), which allows for optimal planning and operation based on georeferenced data. Sector meters for volume control were also installed during the second stage.

Figure 7. Aqualia's GIS Network

Source: Aqualia (2018a). Retrieved on November 12, 2019, from "Aplicación de las nuevas tecnologías en la gestión diaria de la red de abastecimiento de Almería" [Application of new technologies in the day-to-day management of Almería's supply network].

2. 2006-2020

In 2006, the company's contract was extended for another 20 years (until 2032). In 2004, the City Council had detected infrastructure improvement needs with an estimated cost of €82,800,000, so the extension was subject to a commitment on the part of the concessionaire to make new investments.

For the 2006-2020 period, the new contract for the renewal, expansion and improvement of infrastructure included the following items:

- Investment in infrastructure of €41,883,920. The concessionaire also contributed €7,300,000 of financing, at no additional financial cost, to start up the desalination plant.
- Aqualia would pay up to €200,000 towards annual maintenance costs generated by two large new facilities: the Almería Science and Technology Park (PITA) and the El Bobar WWTP expansion.
- An increase in the performance bond to €666,930.48.

In addition, in 2012 (with retroactive effect from 2010), the parties agreed a system that entailed the payment of an annual fee (fixed and variable) to the City Council by the concessionaire:

- Fixed fee:
    - €0 (2010)
    - €750,000 (2011)
    - €1,100,000 (2012)
    - €1,300,000 (2013)
    - €1,500,000 (2014 on)

From 2015, the concessionaire would also pay a variable fee calculated as 10% of year-on-year revenue growth (the difference in the amount billed for water volume from one fiscal year to the next).

Annual fees paid over the period totaled €14,341,862.

During this period, new techniques were introduced to detect water leaks, 19 pressure modulation systems were installed, and a new supervisory control and data acquisition (SCADA) system was installed for data reception and management of loggers and GPRS pressure modulation equipment. Internet of Things (IoT) tools were also introduced, enabling more efficient management by facilitating the detection, quantification and management of water losses, analysis of significant flows, management of telemetry failures, early detection of leaks in the network, and monitoring of water quality (see details in **Appendix A.1.**).

Since 2014, Aqualia (the concessionaire) has also focused on incorporating innovative data management technologies to develop a smart network management system. Intelligent network management software was also introduced in 2014 (see **Appendix A.2.**). In combination with the other methods adopted, the software facilitated better monitoring, management of events in real time, automatic alerts, more efficient short- and long-term planning, etc. In addition, innovative teams and technological equipment have been introduced for the detection of leaks using tracer gas.

The total amount invested from the start of the project in 1993 to the present day is shown in **Table 5**.

Table 5. Investment Plan (1993-2020)

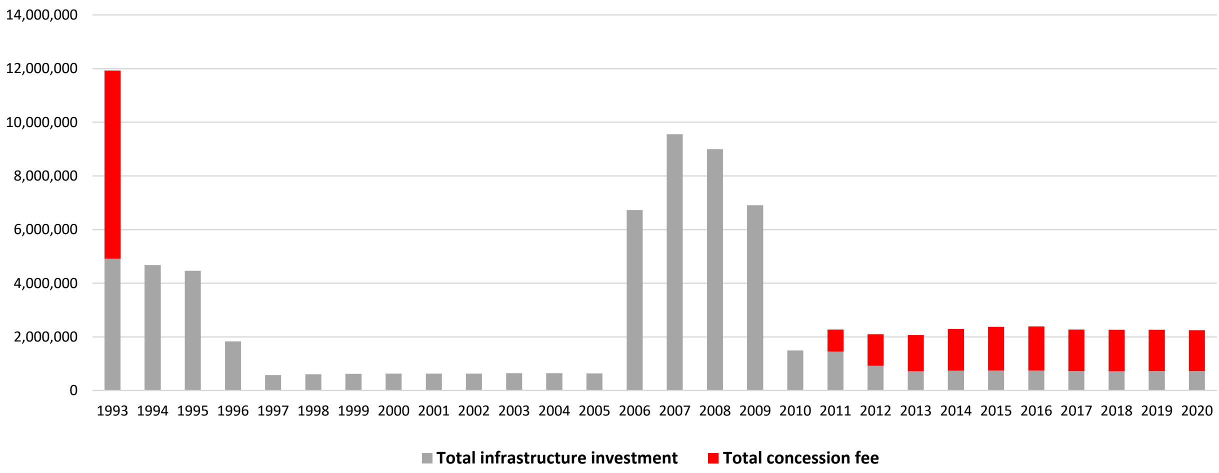
Investment plan (1993-2006)	Adjusted amounts (2020)
Infrastructure investment	€21,512,358
Upfront concession fee	€7,012,890
Subtotal	€28,525,248
Investment plan (2006-2020)	
Infrastructure investment	€41,883,920
Annual fee	€14,341,862
Subtotal	€56,225,782
TOTAL	€84,751,030

Note: Adjusted amounts (in euros) were obtained by applying inflation over the period using the INE application (https://www.ine.es/calcula/).

Source: Documents provided by the company.

Total investment in infrastructure from 1993, when Aqualia started managing the water network, until 2020 amounted to €84,751,030 (inflation-adjusted). These investments were fully financed through the contribution of capital by the concessionaire (see **Figure 8**).

Figure 8. Total Concession Investments in Almería (in Euros, 1993-2020)

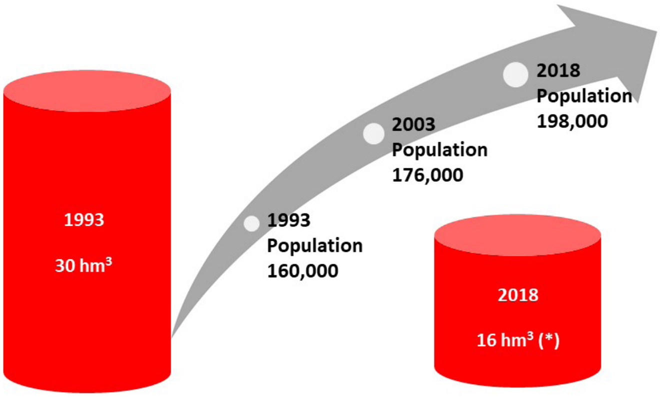


Source: Documents provided by the company.

3.2. Operation

The investments outlined above have led to an increase in water consumption efficiency (see **Figure 9**), reflected in a reduction in water use of around 50% (from 30 hm^3 in 1993 to 16 hm^3 in 2018), despite a population increase of about 22% over the same period (from 160,000 in 1993 to 198,533 in 2019).

Figure 9. Water Consumption and Population Growth in Almería (1993, 2003, 2018)



(*) 15 Almería + 1 Bajo Andarax

Source: Documents provided by the company. Presented at the Water, Agriculture, and Sustainability summer course offered by the University of Almería in 2019.

Table 6 below presents a series of indicators that show the evolution of water management from 1993 to the present day.

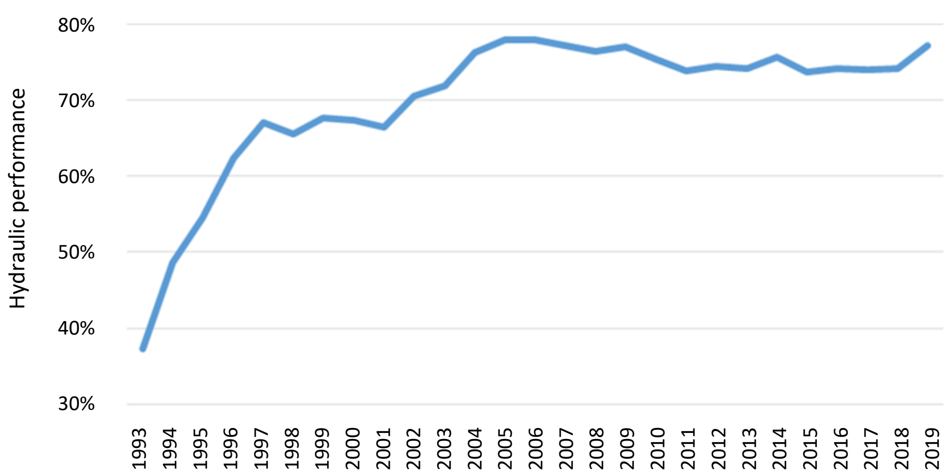
Table 6. Evolution of Water Services (1993 vs. 2019)

	1993	2019	Percentage change
Population served	162,316	199,650	23.00%
Volume of water supplied (millions of m³/year)	29.10	16.05	-44.85%
Total registered volume (millions of m³/year)	10.5	12.7	20.95%
Municipal supply (m³/year)	957,853	1.24 m	29.46%
Water network efficiency (%)	45.44	75.2	65.49%
Number of water sectors	16	75	368.75%
Water meters (units)	42,848	103,444	141.42%
Supply connections (to the network; in units)	25,200	37,107	35.61%
Length of supply network (km)	442	788	78.28%
Energy consumption (million kWh/year)	18	14	-22.22%

Source: Document provided by the company.

These data show the improvement in the technical performance of the water network in Almería, which achieved a hydraulic efficiency of nearly 75%, an optimal result considering the age of the network and the main materials used in infrastructure (see **Figure 4**). This efficiency gain represents a 65% improvement over the initial stage of the contract (see **Figure 10**). The improvements in water management have made more water available, thus supporting the sustainable demographic and economic growth of the city.

Figure 10. Technical Performance of Almería's Water Network Infrastructure (1993-2019)



Source: Document provided by the company.

3.3. Concessionaire's Revenue

The concessionaire's revenue was calculated by applying two formulas in two distinct stages: 1993-2010 and from 2010[28] on. Changes in revenue were due to a drastic reduction in water consumption caused by the severe economic crisis that Spain went through from 2008 on.

In the first stage (1993-2010), the operator's revenue was based on the tariff offered in its tender:

Concessionaire's revenue = tariff offered in tender multiplied by the volume of water billed

As indicated in Section 1.3, this revenue was intended to cover the upfront concession fee and new investments, improvement and expansion of infrastructure, the operator's O&M costs, and its profit.

If the remuneration was insufficient due to lower-than-expected volumes consumed, the private entity could also receive subsidies to achieve economic balance in its operation of the concession. According to the bidding conditions for the concession, the operator was not required to assume losses generated in such circumstances.

The tariff could be indexed after at least one year had passed from the contract award date or when the cumulative indexation adjustment was greater than 2.5%. The amount of the increase was to be calculated using the polynomial formula established in the contract, which considers variations in the cost of various elements.

The following polynomial formula was used to calculate the indexation of the average tariff:

$$Kt = a\frac{Ht}{Ho} + b\frac{Et}{Eo} - c\frac{Qt}{Qo} + d\frac{It}{Io} + e$$

where:

kt = adjustment factor at time *t.*

a, b, c, d = weight, as a decimal fraction of one, of each of the five items that comprise total expenses (*a + b + c + d + e* = 1.00).

e = weight, as a decimal fraction of one, of amortization and financing with respect to total expenses.

Ht = labor cost index (at the provincial level), at the time of adjustment, *t.*

Ho = labor cost index (at the provincial level), on the date when the initial study was prepared, *o.*

Et = energy cost index, at the time of adjustment, *t.*

Eo = energy cost index, on the date of the initial study, *o*.

Qt = weighted average price per m^3 of water purchased, at the time of adjustment, *t.*

Qo = weighted average price per m^3 of water purchased, on the date of the initial study, *o*.

It = CPI at the time of the adjustment, *t.*

Io = CPI on the date of the initial study, *o.*

The average rate could also be modified if the concessionaire had undertaken investments for unforeseen expansions or improvements, subject to the prior approval of the City Council.

The 1993 formula for calculating the concessionaire's remuneration (based on the tariff offered and indexed by applying the polynomial formula) did not adapt well to the abrupt and sustained drops in demand that occurred from 2009 on. As a result, there were significant shortfalls in coverage of the concessionaire's operating costs.

Consequently, given that the tariff was intended to cover all service costs as well as investments, from 2012 on, the tariff in effect at the time, which had not been adjusted for several years, was taken as a baseline; it was agreed that differences owing would be paid over the fiscal years 2012, 2013 and 2014, and that a process of automatic adjustment (indexed to 90% of the rate of inflation) would be introduced.

The new fixed concession fee was applied from 2011 and gradually rose from €750,000 to €1,500,000 a year in 2015. A variable fee—calculated as 10% of year-on-year revenue growth (the difference in the amount billed for water volume from one year to the next)—was also introduced, with 10,000,000 m^3 as the baseline volume (see Section 3.1.).

[28] Although the contractual amendments were made in 2012, they were applied retroactively, with effect from 2010.

4. Concessionaire

Aqualia began to operate in 1980 and is currently owned by the Fomento de Construcciones y Contratas (FCC) Group (which holds a 51% interest)—whose main business areas focus on the environment, water, and infrastructure—and IFM Investors, a multinational pension fund manager specializing in infrastructure investments (49% interest).

Aqualia is the leading company in end-to-end water cycle management in Spain, fourth in Europe, and ninth in the world. It operates in 17 countries and serves nearly 30 million people in over 1,100 municipalities. In 2020, the company reported approximately €1.2 billion in revenue.

In addition to providing services at the municipal level, Aqualia has significant multinational experience and a strong track record in engineering, procurement, and construction (EPC) and O&M. The company has successfully executed more than 700 projects related to these sectors in Europe, Latin America, the Middle East, and North Africa.

5. Risk: Management and Mitigation

As with any public-private partnership (PPP) project, proper risk assessment is critical to the success of the service. In the literature on the subject, it is often said that the risk involved in such projects should be transferred to the party best able to deal with it.[29] **Table 7** shows how the various risks associated with the Almería project were allocated by category.

Table 7. Risk Allocation Between the Company and the City Council

Risk	Allocation
Land and space	City Council
Environment	Aqualia
Design and construction	Aqualia
Financing	Aqualia
Demand	Aqualia/City Council
Inflation	Aqualia/City Council
Interest rate	Aqualia
O&M	Aqualia
Political	Aqualia

Source: Prepared by the authors.

Land and space risk: The City Council of Almería was responsible for acquiring land and making the space required for the construction, modernization, and expansion of facilities available to the concessionaire.

Environmental risk: The city's governing body was responsible for transferring the facilities to Aqualia with all appropriate environmental safeguards at the start of the concession and ultimately responsible for any problems in this area. However, the company had to assume responsibility for compliance with environmental regulations during the period of operation of the infrastructure. It was directly responsible for the facilities and subject to penalties if it failed to fulfill its duties.

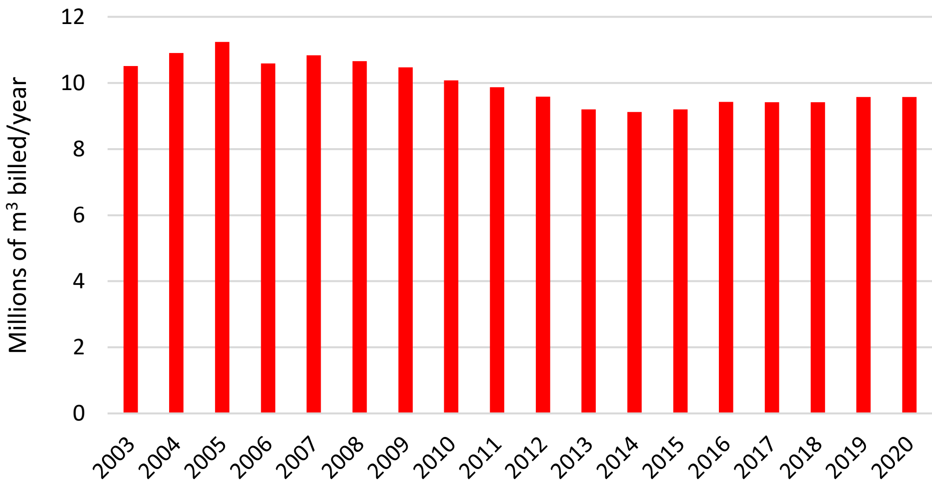
Design and construction risk: The private company was responsible for infrastructure expansion and improvement processes for the duration of the contract and therefore assumed any risks of this kind.

Financial risk: Aqualia was solely responsible for carrying out the investment plan to improve and expand infrastructure (both in the initial contract and its renewal in 2006). This risk therefore had no impact on the liabilities of the City Council. All the investments made by the company during the term of the contract were financed with its own capital, and the parent company assumed all financial risks.

Demand risk: This risk was partially borne by the company. In the 1993-2010 period, the total remuneration paid to the concessionaire depended on the total volume of water billed and the unit price tendered. However, some of the operating costs were fixed and therefore independent of the volume billed; variability in consumption was a factor over which the company had no control. The concessionaire therefore had to adjust its operating costs according to the volume of water distributed and assume any risks associated with abrupt changes in consumption. In 2009, there was a significant drop in the amount of water billed due to the severe economic crisis the country was going through. Given the system for calculating remuneration, this had a considerable impact on the company's revenue. These developments led to the remuneration conditions being changed in 2012 to ensure that the operation of the concession would not generate losses. The City Council thus assumed part of the risk: if there were losses that could not be covered by the approved tariff, Aqualia would be compensated, or restructuring measures would be taken if economic balance could not be achieved.

[29] Berrone, P. et al (2018).

Figure 11. Evolution of Water Demand (2003-2020)



Source: Aqualia (2020). Document provided by the company.

Inflation risk: This risk was assumed mainly by the local authority in the first stage (via the polynomial formula for adjusting the unit tariff, and in the second stage (from 2012 on), through the adjustment of remuneration at a rate equivalent to 90% of the CPI. However, it is important to note that adjustments to remuneration were not fully in line with inflation; the evolution of O&M costs could differ from the inflation rate reflected in the CPI; and adjustments were made at the end of the year, which meant that the concessionaire had to incur financing costs.

Interest rate risk: This risk was assumed by Aqualia, which had to finance infrastructure improvement and expansion works, as well as the upfront concession fee paid at the start of the contract. The company's financial solvency and assets would determine the interest rate at which it could borrow.

O&M risk: This risk was assumed solely and exclusively by the concessionaire.

Political risk: This risk was borne by Aqualia, which faced the risk that its public-sector partner might cancel the concession or fail to comply with the terms and conditions of the initial contract, even though if the public authority were to make such unilateral changes, the concessionaire would be paid compensation equivalent to the amount of the resulting economic loss. However, while Spain's legal and institutional system reduces political risks related to discretionary actions taken by public authorities, it does not completely eliminate them. Negotiations between the City Council and Aqualia to resolve tariff issues resulting from the drop in consumption dragged on for three years (from 2010 to 2012). During this period, the concessionaire continued to provide the service to the population on the same terms.

6. Governance

In this type of concession (as in any medium- or long-term contract involving various political and economic actors with different priorities), project governance is one of the keys to success. Over the life of a project, unexpected situations may arise, forcing the parties to reach agreements on issues that were not addressed at the outset. Given that uncertainty increases over time, the longer a contract runs, the greater the extent to which it is considered incomplete. If good governance mechanisms are in place, it will be possible to ensure that a project's progresses smoothly over time.[30]

Although no formal institutions for settling disputes were established in the contract in this case, the agreement does stipulate that there should be constant, regular, and fluid dialogue between the parties, with the common goal of offering citizens uninterrupted and adequate service in a service as essential as water supply.

In the event that agreement cannot be reached to resolve disputes that arise between the parties, they must be settled as established in Law 39/2015, of October 1, 2015, on the Common Administrative Procedure of Public Administrations,[31] and in the Regulations on Local Government Services.[32] The law establishes that when a dispute occurs, the public authority concerned is responsible for appointing an inspector and a secretary, who will request any necessary evidence, set formal requirements, and formulate a statement of objections to deliver to the concessionaire, which has eight days to respond. The statement of objections and the concessionaire's response are sent to the public authority, which issues a final decision on the matter.

If the concessionaire is found to have breached the contract, it must pay a fine, the amount of which varies according to the nature of the breach. The City Council may also temporarily suspend the operation of the service, in which case operations are taken over by the public body if this is deemed necessary. Very serious breaches may even lead to termination of the concession contract. Although none of these situations have occurred in the case studied, we believe it is important to mention the powers that the local authority has with respect to supervision of the concession.

In the case under study, from the start of the contract, the main obstacle that the concession had to overcome was triggered by the deep economic crisis Spain went through from 2008 on, which significantly reduced water consumption. This challenging situation arose because the system for calculating the concessionaire's remuneration could not adapt sufficiently to significant changes in demand. The system worked well while variations in consumption were moderate but ceased to function as intended when there were sharp drops in demand. This resulted in a significant economic loss for the concessionaire and put the economic balance of its management activity at risk.

Faced with this situation, and for the benefit of all parties, the City Council proposed an amendment to the contract (described in previous sections), which included an investment plan financed by the company in the medium term (see Section 3.3. for more details).

[30] Grossman, S, J. and Hart, O. D. (1986); Hart, O. D. and Moore, J. (1990).

[31] When the first contract was signed, the regulation in force was the Law on Administrative Procedure (of July 17, 1958). This law has undergone various amendments over the years. The version currently in force is the one approved on October 1, 2015: Law 39/2015, of October 1, on the Common Administrative Procedure of Public Administrations.

[32] Decree of June 17, 1955, approving the Regulations on Local Government Services.

7. Economic Impact[33]

In this section, we estimate the macroeconomic impact of the investments made by the concessionaire on the output of the Andalusian and the Almerian economy. The analysis focuses on the output (sales) generated in the short term for the project, considering the investment made under the 1993 and 2006 investment plans. To perform this analysis, we use the input-output (IO) method.[34]

Using the IO matrix, we can calculate final demand multipliers in terms of output. These multipliers express the degree of linkage between industries and make it possible to estimate the total effect that a specific one (in this case, water infrastructure) has on the economy. Consequently, this method has been widely used to quantify the economic impact of an increase in final demand in each industry.

Multipliers capture two kinds of effects that result from a change in economic activity: direct and indirect effects. The intuition behind the multiplier concept is that the initial increase in final demand in each industry (in this case, water supply and sanitation) will multiply demand in that industry (direct effect) and all related industries (indirect effect). For example, initial investment in water infrastructure will affect final demand in the construction sector, leading to an increase in consumption of concrete, which in turn will translate into higher consumption of mining products and an increase in hiring in the sector, leading to higher employment and household spending.

To calculate economic impact, we considered the investment plan carried out between 1993 and 2006. Values for investments in the first year (presented in pesetas) were converted to 2020 adjusted euros. Data (for both 1993 and 2006) were then converted to their 2020 equivalents[35] using the inflation rates published by the National Institute of Statistics (INE).[36]

The multipliers used were obtained from the IO tables (dated 2016[37]) published by the Institute of Statistics and Cartography of Andalusia (IECA).[38] Regional GDP data for 2019 (the most recent year for which data have been published)[39] were also obtained from IECA.

[33] It is important to keep in mind that the input-output method requires that certain assumptions hold true, which can constrain the interpretation of results. Furthermore, the use of regional macroeconomic data makes the results imprecise if the goal is to gain a deeper understanding of the impact on the economy (as in the case of the City of Almería). Despite these limitations, the model can be used as a good approximation at the regional level, though readers are advised to interpret the results with caution.

[34] The IO framework is based on certain input and output matrices, constructed using observed economic data for a specific geographic region (e.g., a metropolitan area, state, country, etc.), which reflect the activity of a group of industries that produce certain goods (outputs) and consume goods produced by other industries (inputs) in their own production processes (Miller and Blair 2009). This approach allows for intersectoral analysis of the economy.

[35] The year 2018 is used as a variable because at the time of this study it was the most recent year for which IECA had published regional accounts. https://www.juntadeandalucia.es/institutodeestadisticaycartografia.

[36] Adjustment of income according to the general CPI (2016 CPI base) for full annual periods. https://www.ine.es/calcula/calcula.do.

[37] The most recent year of publication for the IO tables.

[38] http://www.juntadeandalucia.es/institutodeestadisticaycartografia/mioan/.

[39] See http://www.juntadeandalucia.es/institutodeestadisticaycartografia/craa/index.htm.

The application of direct and indirect multipliers[40] to plant investment yielded the results shown in **Table 8**.

Table 8. Summary of Economic Data

GDP (Andalusia, 2019)	€173,373.13 m
GDP (Almería, 2019)	€16,234.77 m
Project infrastructure investment (1993-2020)	€84.75 m
Estimated project impact (1993-2020)	€191.49 m
Economic impact per euro invested	€2.26/€1
Economic output generated in relation to Andalusia's annual GDP (2019)	0.11%
Economic output generated in relation to Almería's annual GDP (2019)	1.18%
Direct jobs generated by the project	147 jobs in 2019

Source: Prepared by the authors.

This study estimates that the €84,751,030 invested between 1993 and 2020 contributed to increasing the total output of the Andalusian economy through direct and indirect effects quantified at €191.49 million, which represented 0.11% of the regional GDP in 2019 and is equivalent to approximately 1.18% of the GDP of the province of Almería for the same year. Operation and maintenance of the service directly generated 147 jobs in the period up to 2019. The economic impact was €2.26 for every euro invested.

[40] The 2016 regional IO tables published by IECA were used. https://www.juntadeandalucia.es/institutodeestadisticaycartografia.

8. Impact of the Project on Stakeholders

The water cycle management project has had an impact on four specific areas, which are discussed in the following sections: the local authority, residents, the environment, and the concessionaire.

8.1. Local Authority

The concession of the water supply and sanitation service in the City of Almería allowed the local authority to benefit from the most advanced water management technologies, the operational know-how of a company with extensive international experience, and the investment capacity Aqualia could provide, as well as transferring O&M risks to the private sector (see Section 5 for more details). The transfer of responsibilities to the private operator provided strong incentives for the concessionaire to manage the service efficiently in addition to ensuring that it was run effectively.

Investment in improving and expanding infrastructure over the term of the contract was made with capital provided by the concessionaire, which allowed the city to improve its public capital stock without any direct impact on municipal finances. Investments focused on key infrastructure such as extension of the length of the network and the ramping up of water meter installation.

Finally, the city has gained international recognition in the field of water treatment (by hosting and being the main implementation site for major European R&D projects, as mentioned above) and in the use of technology.

8.2. Residents

The City of Almería is located in an arid area with low rainfall. It is therefore especially important to make good use of the scarce water resources available, which can be used to support sustainable economic development.

Optimal use of this asset—thanks to better infrastructure and increased operational efficiency—has facilitated development of the horticulture industry and tourism, resulting in a positive impact in terms of creation of added value and employment.

Residents have also benefited directly from the generation of local jobs over the entire life of the project, peaking at 169 jobs in 2006. This is an important factor to bear in mind given that the area is particularly affected by unemployment.[41]

The average price[42] paid by consumers for water supply (supply and sanitation without VAT) in the City of Almería in 2019[43] was €28.85. In this context, it should be noted that Almería is the only provincial capital with desalinated water supply, which has a much higher cost than any other source.

In Jaén, for example, the average price paid by consumers in 2019 was €30.43, while in other Andalusian cities with public operators' prices were generally higher (Seville, €36.27; Huelva, €37.50; Granada, €31.40; and Córdoba, €28.48).

Finally, in terms of service improvements for users, it is worth mentioning other innovations introduced, such as automated payment machines in customer service offices to facilitate bill payment and offer a better quality of service.

[41] According to INE data, in the third quarter of 2020, the average unemployment rate in Spain was 16.3%, while the rate for the province of Almería was 26.5%.
[42] The average price for consumption of between 10 m^3 and 20 m^3 with an individual 13 mm.
[43] According to the consumer association Federación de Asociaciones de Consumidores y Usuarios de Andalucía–Consumidores en Acción (2019).

8.3. Environment

The management system implemented, and infrastructure improvements have generated an environmental benefit due to greater efficiency in the use of this natural resource, reflected in a lower volume of drinking water distributed (a reduction of approximately 50% from 1993 to 2017), which has made it possible to serve a higher percentage of the population (up 22% from 1993 to 2017). Improved infrastructure use and the application of new smart technologies have also made it easier to reduce and control water leaks before they occur, helping to address the significant and growing problem of water scarcity in the area. This in turn has a direct positive impact in improving the sustainability of aquifer wells.

Also, given the complexity of water treatment, new methods for water reuse represent major innovations in the sector. Although this process still accounts for a small proportion of total water consumption, it is very important in terms of economic and environmental sustainability.

Finally, the R&D projects being carried out in the Almería region have enormous potential when it comes to environmental preservation. Key objectives include the study of new ways of using sludge from wastewater treatment and innovation in technologies aimed at reducing energy consumption.

8.4. Concessionaire

One of the main benefits for Aqualia is the international recognition it has gained as the company responsible for managing the water cycle in Almería, which has been achieved thanks to the activity it has carried out over the last few decades.

In addition, the city's location has allowed the company to participate as a strategic partner in several EU projects, playing a leadership role not only in the provision of water services, but also in innovation in this field. Cooperation with international companies, as well as the City of Almería and the University of Almería, has also enabled Aqualia to become one of the entities that have put Almería on the path to becoming a smart city and an example of leadership in drinking water supply and end-to-end water cycle management.

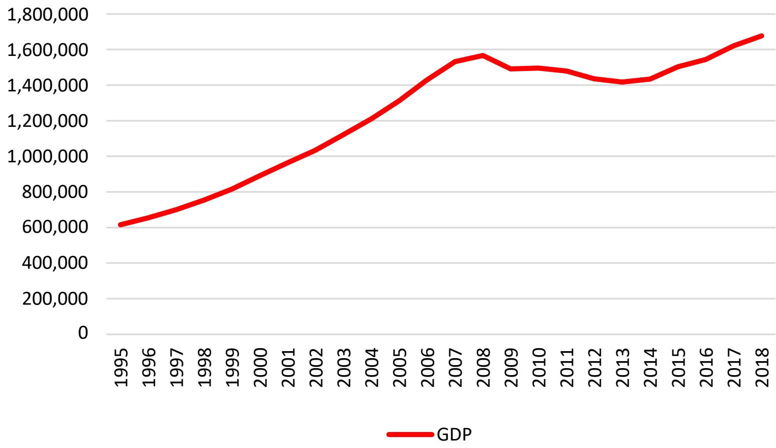
9. External Project Characteristics

The main external factors affecting the end-to-end water cycle management project in Almería are described in the following sections, which focus on the economic, legal/administrative, and environmental conditions that have affected the project.

9.1. Economic Conditions

The contract was awarded in 1992, during an economic downturn following the Universal Exhibition of Seville and the Barcelona Olympic Games. The Spanish economy, and the Andalusian economy in particular, began to recover two years later, in 1994. As **Figure 12** shows, this marked the start of a long period of growth that continued until 2008, when the economic crisis triggered by the bursting of the real estate bubble began. In 2014, a new phase of growth began, continuing until March 2020, when it was interrupted by the COVID-19 health crisis.

Figure 12. GDP of Andalusia (1995-2018)

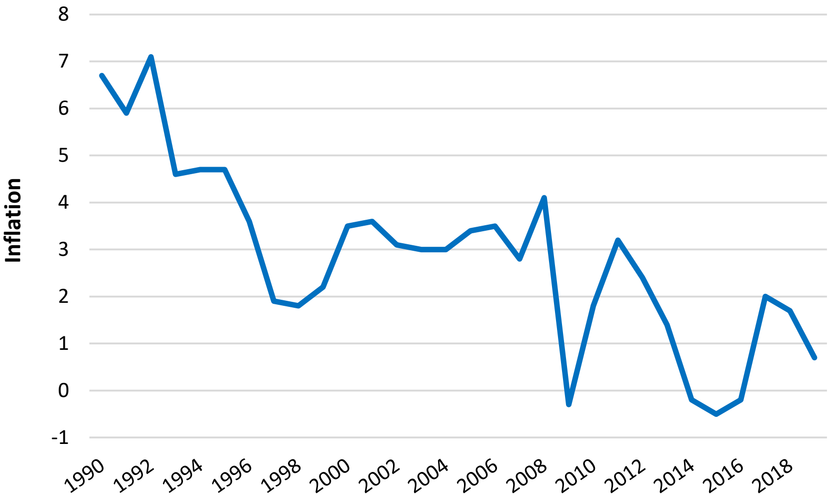


Note: Figures in millions of euros.

Source: Prepared by the authors based on tables from the Institute of Statistics and Cartography of Andalusia. www.juntadeyalucia.es/institutodeestadisticaycartografia/temas/est/tema_cuentas.htm.

From 1993 to 1996, the inflation rate remained high because of the devaluation processes affecting the peseta, which had been undertaken with the aim of counteracting the deep economic crisis the country was immersed in. However, with Spain's entry into the eurozone, price increases stabilized at rates compatible with strong economic expansion (see **Figure 13**).

Figure 13. Average Annual Inflation Rate in Spain (1990-2018)



Source: Prepared by the authors based on IMF data (2021) Inflation Rate, Average Consumer Prices [Data Map]. https://www.imf.org/external/datamapper/datasets/WEO.

In 2018, the GDP of the province of Almería represented 9.4% of the Andalusian economy. Agriculture accounted for a significant and growing share of the province's GDP (12.7% in 2008, rising to 17.2% in 2017), followed by wholesale and retail activities (15% in 2017), and a notable contribution by the construction sector, which lost steam after 2008.

9.2. Legal/Legislative Conditions

In Spain, local authorities are responsible for the provision of urban drinking water service (pursuant to Law 7/1985, of April 2,1985, which regulates the system of local government). Local authorities can opt for internal provision, through the city council itself, or outsource the service to a publicly-owned private or mixed company.

In addition, the Domestic Water Supply Regulations for Andalusia (approved by Decree 120/1991, of June 11) govern the relationship between the local authority and the entity that provides the drinking water supply service to households and its customers, stipulating the basic rights and obligations of each party.

9.3. Environmental Conditions

As previously mentioned, the province of Almería is one of the most arid areas on the Iberian Peninsula. It also has high average solar radiation and rainfall is infrequent. This climate is ideal for the growth of microalgae, which as photosynthetic organisms require solar radiation. The same environmental conditions have also been conducive to carrying out projects such as SABANA and LIFE ULISES.[44] However, given the deterioration that natural water sources have undergone over the years, these conditions also pose environmental challenges. Demand for water for domestic and agricultural use has exceeded nature's capacity to balance withdrawals through the recharge of reservoirs and aquifers.[45]

Table 9 shows percentages of consumption for the main activities. As these figures make clear, irrigation for horticultural activities consumes around 80% of the region's water resources, which is causing a deficit in water supply that is unsustainable in the long term.[46]

[44] The LIFE ULISES project aims to revolutionize conventional wastewater treatment processes by applying a set of innovative technologies to produce valuable resources such as vehicle biofuel, agricultural biofertilizers, and water suitable for reuse—all from wastewater.
[45] Downward, S. R. and Taylor, R. (2007).
[47] Downward and Taylor, 2007, García-Caparrós et al., 2017.

An array of measures and actions have been pursued to address this situation, ranging from the use of alternative water resources (including desalinated water from reverse osmosis desalination plants; see **Table 10**) to water reuse (particularly for golf course irrigation) and integrated management of water resources based on the use of new technologies for water supply and irrigation that aim to increase water use efficiency.[47]

Authorities in the region undoubtedly face major challenges when it comes to water needs. Efforts are ongoing and infrastructure investment has been steadily increasing in recent years to address and meet existing needs.

Table 9. Water Consumption by Activity (in Percentages)

River basins	Urban	Irrigation	Livestock	Golf courses	Industry
Adra River Basin and Dalías aquifer	20.0%	79.2%	0.0%	0.7%	0.0%
Andarax	8.9%	88.4%	0.2%	0.0%	2.5%
Campo de Níjar	4.8%	93.9%	0.2%	1.0%	0.1%
Carboneras and Aguas River Basins	27.0%	68.2%	0.2%	4.1%	0.5%
Almanzora	9.0%	88.6%	0.8%	0.7%	0.9%

Note: Percentages are calculated as total annual freshwater withdrawals for consumption divided by average annual freshwater resources.

Source: García-Caparrós et al. (2017).

Table 10. Capacity of Seawater Reverse Osmosis Desalination Plants in Almería

Desalination plant	Water capacity (hm^3/year)
Lower Almanzora	20
Palomares	9-10
Carboneras	42
Rambla Morales	22
Almería	20
Campo de Dalías	30

Source: Prepared by the authors based on data from the Andalusian Ministry of Agriculture, Fisheries and Sustainable Development (2015). Annex 3, Usos y demandas, in *Demarcación Hidrográfica de las Cuencas Mediterráneas Andaluzas*. https://www.juntadeandalucia.es/medioambiente/portal_web/agencia_andaluza_del_agua/nueva_organizacion_gestion_integral_agua/planificacion/planes_aprobados_consejo_gobierno/dh_mediterraneo_aprobado/Anejos_memoria/Anejo_III/ANEJO_III.pdf.

[47] García-Caparrós et al. (2017).

10. Evaluation

We will now evaluate and analyze the end-to-end water cycle management project for the City of Almería, considering various parameters, from the perspective of the PPP methodology, in relation to the SDGs, and in terms of the city's strategy.

10.1. PPP Methodology

Table 11 presents the data for the project carried out by Aqualia for the City Council of Almería.

Table 11. PPP Methodology

	PPP Methodology	Yes/No	Project details. Water supply and sanitation in Almería
1. Procurement method and bidding process			
1.1.	Value-for-money or cost-benefit analysis	No	Concession contract including construction and financing.
1.2.	Real competition for the contract	Yes	Yes, five bidders.
1.3.	Tender evaluation committee	Yes	Procurement committee.
2. Contractual issues and incentives			
2.1.	Construction	Yes	Including engineering, O&M, expansion, and improvement of existing infrastructure.
2.2.	Quality verifiable	Yes	Minimum water quality required by law, reduction of losses, reduction of consumption and improved efficiency.
2.3.	Externalities	Yes	Positive impact on environment, economic development, and research.
2.4.	Duration		20 years plus a 20-year contract extension.
3. Risk, financing and payments			
3.1.	Construction and operational risk	Aqualia	Engineering, expansion, and improvement of facilities.
3.2.	Financing risk	Aqualia	Operation and maintenance of facilities.
3.3.	Operational risk	Aqualia	Operation and maintenance of facilities.
3.4.	Demand risk	Partially transferred	
3.5.	Payment mechanism	User tariff set by municipal ordinance. Initially adjusted annually by applying a polynomial formula; from 2010, indexed to 90% of CPI.	
3.6.	Special purpose vehicle (SPV)	No	The parent company is liable for the contract.
4. Governance			
4.1.	Transparency	Yes	Tariffs according to contract, approved annually by municipal ordinance.
4.2.	Participatory decision-making process	Yes	Ongoing communication between concessionaire and City Council.
4.3.	External monitoring	No	The municipality has the obligation to monitor and control the concessionaire's compliance with its obligations.
4.4.	Specific legal framework	Yes	Stable.
5. Construction process			
5.1.	Cost overruns	No	
5.2.	Delayed deadlines	No	

6. Potential benefits			
6.1.	Possible price certainty	Yes	Municipal tariffs.
6.2.	Transfer of responsibilities to the private sector	Yes, almost completely	
6.3.	Incentives for innovation	Yes	Efficiency in water management, minimization of environmental impact, and incentives for cost reduction.
6.4.	Savings on public payments	Yes	Investment is borne by the private company.
6.5.	Life-cycle approach	Yes	O&M contract and transfer of responsibilities.
6.6.	Incentive to complete on time	Yes	Completion of the infrastructure work maximizes efficiency gains.

Source: Prepared by the authors.

10.2. Sustainable Development Goals

The SDGs, part of the United Nations 2030 Agenda, aim to achieve a better and more sustainable future for the world's population.

In the case of the end-to-end water cycle management concession for the city of Almería, we can identify two levels of impact in terms of achieving the SDGs: high and moderate (see **Table 12**).

A high level of impact has been achieved for the following SDGs:

- 3: Good Health and Well-Being
- 6: Clean Water and Sanitation
- 8: Decent Work and Economic Growth
- 9: Industry, Innovation and Infrastructure
- 13: Climate Action
- 14: Life Below Water
- 17: Partnerships to Achieve Goals, a key aspect of the agreement between public and private sector actors for the provision of an essential service

The infrastructure delivered has facilitated consumption of drinking water and treatment of wastewater, thus improving conditions that affect public health and well-being in the city. The investment made has also led to a reduction in consumption of this resource, more efficient water management, lower energy consumption, and participation in international research projects, thereby supporting ecosystem sustainability. Together, these actions have reduced pressure on the environment and increased water availability, which has facilitated the development of industries, fostering economic growth and stable employment. In addition to generating cost savings for the company, improved energy efficiency has reduced pollutant emissions.

The project has also had a moderate impact on one SDG:

- 11: Sustainable Cities and Communities

Ensuring a good quality water supply and an adequate sanitation system has direct benefits for people's health. In addition, reduced per capita consumption and water reuse have made more water resources available for irrigation of green areas and facilities and for the agricultural sector, which plays an important role in the regional economy.

Table 12. UN Sustainable Development Goals

	SDG	Water supply and sanitation in Almería	
		High impact	Moderate impact
1.	No Poverty		
2.	Zero Hunger		
3.	Good Health and Well-Being	✓	
4.	Quality Education		
5.	Gender Equality		
6.	Clean Water and Sanitation	✓	
7.	Affordable and Clean Energy		
8.	Decent Work and Economic Growth	✓	
9.	Industry, Innovation and Infrastructure	✓	
10.	Reduced Inequalities		
11.	Sustainable Cities and Communities		✓
12.	Responsible Consumption and Production		
13.	Climate Action	✓	
14.	Life Below Water	✓	
15.	Life on Land		
16.	Peace, Justice and Strong Institutions		
17.	Partnerships for the Goals	✓	

Source: Prepared by the authors.

In parallel, the United Nations Economic Commission for Europe[48] (UNECE) has developed the concept of "People-First Public Private Partnership" (People-First PPP) that, in simple terms, this means PPP projects that go beyond just meeting service provision objectives by improving the well-being of people, especially the most disadvantaged. People-First PPP projects must meet the following conditions:

- Increase access to essential services (with no restrictions), especially for the most vulnerable, and promote equity.
- Develop infrastructure in an economically efficient and fiscally sustainable manner that promotes economic growth and job creation.
- Be environmentally sustainable, contributing to the protection and preservation of the planet.
- Be replicable and scalable, to allow the development of further projects.
- Involve all stakeholders.

Based on the information presented in the previous sections, the project for the concession of Almería's end-to-end water cycle to Aqualia is aligned with the People-First PPP principles defined by UNECE and can be considered a project of this kind.

[48] UNECE (2021).

10.3. City Strategy

Based on studies carried out by the Specialist Centre on PPPs in Smart and Sustainable Cities (PPP for Cities), led by the IESE Business School, five indicators have been selected (see **Table 13**) to define the characteristics that projects must have, and which PPPs can foster, to help make cities more hospitable, functional, and sustainable places in which to live and work.[49]

Table 13. Five Key Principles for the Development of PPPs in Cities

Identify the needs of citizens through consultation processes in which they are involved.	✓
Leverage the benefits of using big data.	✓
Capture synergies and collective gains by involving different stakeholders in the decision-making process.	✓
Share know-how and innovation. Private companies are specialized areas in which they can provide the latest available technology and expertise.	✓
Mobilize financial resources. Public budgets are subject to increasingly tight constraints, particularly at the municipal level. Inviting private companies to participate in financing can make it possible to fund certain projects that could not otherwise be carried out.	✓

Source: Prepared by the authors.

In the case of the end-to-end water cycle management concession for the urban center of Almería, in the context of the city, the following points are particularly significant:

- The project is clearly justified by the need to meet the water consumption demands of a growing population in an arid environment. Improved infrastructure and more efficient management, combined with incentives for water savings, have made it possible to reduce water losses and ensure environmental sustainability.
- The development of project infrastructure contributes directly to the economic development of the urban center.
- The concession has facilitated knowledge transfer from the private to the public sector, the transfer of construction and operational risk, and a financial contribution by the private sector, easing the strain on municipal budgets. Thanks to the concession arrangement, the public sector has been able to draw on the experience of the private sector without losing control over the project; ownership reverts to the public authority when the concession period expires.

[49] Berrone, P. et al. (2017).

11. Conclusions

Historically, low water availability in the city of Almería had limited its capacity for economic and demographic development at both the city and provincial level.

During the 1980s, the problem of water scarcity was exacerbated by excessive per capita consumption due to a lack of meters in most of the city's households and outdated infrastructure, which resulted in constant water losses.

Faced with this situation, the local authority tendered a concession contract under which the private company Aqualia would undertake the investment required to modernize the existing infrastructure (including installation of meters in homes and distribution networks) with the aim of improving operational efficiency and reducing water losses. The project has led to more efficient water use, which was critical given the importance of this resource as a driver of the city's sustainable development.

Using a PPP procurement approach, the private concessionaire was selected through a bidding process carried out in accordance with international standards and good practices. The winning company would be responsible for carrying out engineering work, construction and improvement of infrastructure, financing the project, and operating and maintaining the water network. It would also assume the risk associated with all these aspects of the project. By taking this approach, the public authority reduced the risks to which it was exposed when providing this essential public service.

The investments made by Aqualia amounted to €84.7 million and the direct and indirect economic effects are estimated at €191.4 million, equivalent to approximately 1.18% of the GDP of the province of Almería (in 2019). The economic impact was therefore €2.26 for every euro invested, and the project had generated 147 direct jobs up to 2019.

The following key figures underscore the scope and impact of the infrastructure improvements and operational changes made since 1993: (1) water consumption in the city has been cut by half, despite a 22% increase in population; (2) the efficiency of the water network has increased to 81.03%; (3) water meters have been installed and subsequently maintained and replaced as necessary, with almost 100% micro-metering coverage; and (4) energy consumption has been reduced by 30%.

When the project got underway, the system for paying the concessionaire was based on the tariff bid, which was adjusted by applying a polynomial formula. However, since 2010, payments have been based on the tariff approved by the City Council, which is indexed to 90% of the CPI.

It should also be noted that the price of water[50] in Almería in 2019[51] is lower than in other Andalusian provincial capitals, such as Granada, Huelva, and Seville, which have public operators, despite the fact that Almería is the only capital where desalinated water is a source of supply.

In addition to managing the water network, Aqualia has pursued various European R&D projects within the framework of the concession—such as SABANA, INCOVER and BioSol—with the aim of promoting water reuse in the irrigation of green areas and golf courses. The LIFE PHOENIX and ULISES circular economy projects (aimed at enriching biogas from wastewater) have also been carried out.

Together, the actions undertaken have increased the availability of water, thus supporting the development of agriculture and the horticulture industry in the region, leading to job creation while also ensuring the environmental sustainability of the city.

Investment in the end-to-end water cycle in Almería has also made a significant contribution to meeting the following UN Sustainable Development Goals: SDG 3, Good Health and Well-Being; SDG 6, Clean Water and Sanitation; SDG 8, Decent Work and Economic Growth; SDG 9, Industry, Innovation and Infrastructure; SDG 13, Climate Action; SDG 14, Life Below Water; and SDG 17, Partnership for the Goals.

[50] For consumption of between 10 m^3 and 20 m^3 with an individual 13 mm meter.

[51] According to the consumer association Federación de Asociaciones de Consumidores y Usuarios de Andalucía–Consumidores en Acción (2019).

The Almería project is also in line with the principles defined in the EU taxonomy for sustainable activities[52] a classification system for environmentally sustainable economic activities, which is intended to support the scaling up of sustainable investment and implementation of the European Green Deal. Economic activities must meet four overarching conditions to qualify as environmentally sustainable. The classification system, establishes six environmental objectives:

1. Climate change mitigation
2. Climate change adaptation
3. Sustainable use and protection of water and marine resources
4. Transition to a circular economy
5. Pollution prevention and control
6. Protection and restoration of biodiversity and ecosystems.

En In the case of the concession in Almería, the project meets five of these objectives: 2, 3, 4, 5 and 6.

In conclusion, the project has improved the quality of life of Almería residents by guaranteeing the provision of an essential good, and preventing public health problems, ensuring the sustainability of current water sources, generating and boosting economic growth, and creating stable jobs. In addition to these positive effects, the management of the end-to-end water cycle is aligned with some of the United Nations SDGs and with UNECE's People-First PPP initiative. It also meets the conditions set out in the EU taxonomy for sustainable activities and is in line with the principles that underpin the system.

[52] European Commission (2020).

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Appendix A: R&D Innovation

Throughout the life of the project, Aqualia has implemented various R&D innovations, pioneering the use of new techniques for the treatment and purification of wastewater, its reuse, and the production of biofertilizers. In addition, intelligent network management systems have significantly improved water use efficiency. Both areas of innovation are described in this appendix.

A.1. Intelligent Network Management System

In 2014, intelligent network management software was implemented. The software uses the SCADA system to centralize network pressure and flow readings with hourly frequency. It also integrates a GIS system (based on network maps) and Internet connectivity, which allows the information to be uploaded to servers.

Using advanced mathematical and statistical algorithms, the software can translate the raw data collected into useful information and create a model of network planning operations for each day, considering temporal and spatial correlations and variation. Variations in monitored quantities are interpreted by the software, which identifies and classifies events for display to the administrator. The reliability of predictions and of the event classifier is underpinned by dozens of patented algorithms.

The software is a good example of how new technologies can leverage IoT and data science to:

- Detect, quantify, and manage water losses.
- Analyze significant flows.
- Study flow trends.
- Manage telemetry failures (sensors, communications, etc.).
- Warn of pressure anomalies.
- Identify break events by sector.
- Monitor water quality.
- Identify leakage areas within sectors (through hydraulic modeling and analysis of existing pressures).

The software also makes it possible to optimize service to consumers by efficiently managing network intervention work orders (generated or pending) and by providing demand information and forecasts.[53]

[53] Aqualia (2018a).

A.2. R&D: WWTP

The WWTP, located at the El Toyo WWTP, is an innovative facility that harnesses these microorganisms, which grow by photosynthesis (using sunlight) and consume nutrients present in the aquatic environment. The use of this technology in the purification process enables high levels of elimination of chemical oxygen demand (COD), nitrogen and phosphorus, yielding two end products: treated water suitable for reuse in irrigation and an algal biomass with excellent properties as a biofertilizer. The project was developed around two European R&D initiatives in which Aqualia participated as a strategic partner:

- INCOVER: Supported by the European Commission (EC) through the Horizon 2020 program, the largest European R&D funding program. Given the current global water shortage and the O&M cost of wastewater treatment, the idea behind INCOVER is to transform sanitation technology, shifting it towards a bioproduct recovery industry and a source of water that can be reused. The main objective was to transform wastewater from urban agglomerations into a source of energy (biomethane) while also generating valuable products such as bioplastics and biofertilizers and obtaining good quality water for reuse—all using photobioreactors in which microalgae are cultivated.

- LIFE BioSol Water Recycling: Developed with EC funding within the framework of the LIFE program, the main objective of this project was to develop and validate a new system for reusing wastewater. Like INCOVER, the project was based on microalgae technology, with a particular focus on its use in small cities. In this system, biological processes and solar technology were harnessed to enable the reuse of up to 80% of treated water while also recovering and valorizing the organic waste generated in this process. The second stage of the project consisted of the construction and operation of the El Toyo WWTP.

The following technologies were developed at the plant:

- Treatment of wastewater via industrial-scale cultivation of microalgae in a 3,000 m^2 high-efficiency, low-energy pond, using a system patented by Aqualia (which enables this process to be carried out in accordance with Council Directive 91/271/EEC, concerning urban wastewater treatment). The system also eliminates nutrients thanks to the symbiosis between algae and bacteria. In addition to achieving high efficiency in the elimination of pollutants, thanks to the oxygen released by microalgae, this process reduced energy and operating costs by 50% compared to conventional facilities.

- Production of biofertilizers by means of a system of microalgae collection and effluent clarification was carried out at the El Toyo WWTP, where a dissolved air flotation (DAF) system developed by the company was used. Subsequent dewatering was carried out using a horizontal centrifugal decanter.

- Reuse of wastewater (in compliance with Royal Decree 1620/2007, of December 7, which establishes the legal system for reuse of treated water) for agricultural crops and irrigation of golf courses and housing developments through the application of two new technologies:

    1. A system for solar disinfection of effluent from the microalgae cultivation pond, which uses an anodic oxidation process, without consuming any external energy or using chemical reagents; implemented by AUTARCON GmbH (Germany).

    2. A smart irrigation system from the company Future Intelligence (Greece), which optimizes water consumption by using local sensors in fields and data processing over the Internet.

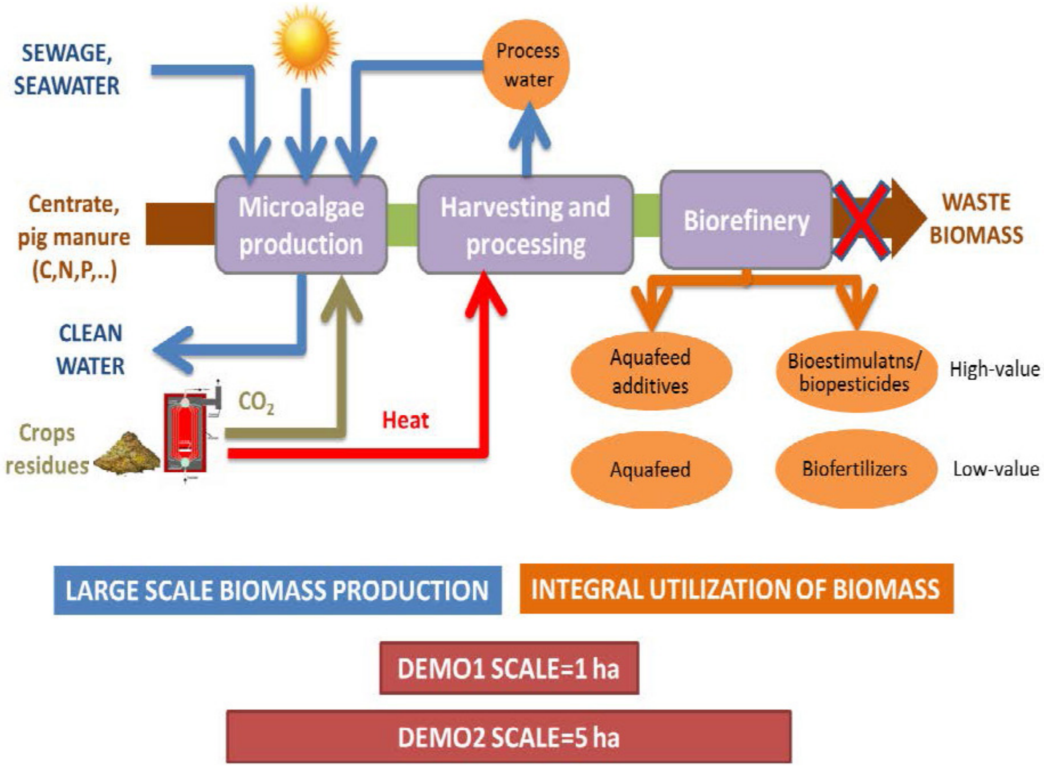
- Nutrient recovery in vertical wetlands, designed by the Center for Recirkulering–Recirku (Denmark), based on research on different types of plants for optimizing recovery of nutrients from wastewater.

The WWTP started operating in July 2018 and was used to treat 200 m^3/day of wastewater. To evaluate the stability of the purification system, the data obtained and results from the various measuring stations were closely tracked. Microbiological aspects of the process were also monitored through microscopic identification of the species of microalgae involved in the process. In addition, a collaborative relationship was maintained with the University of Almería. Each month, researchers were sent samples of the harvested biomass, and specific bioassays were performed to determine its agronomic properties as a biofertilizer.[54]

ABoth initiatives came to an end in September 2019 and achieved good results, demonstrating the viability of the technology used.

Like INCOVER, this project is part of the EU's Horizon 2020 program. With a budget of over €10 million, the project aims to demonstrate, at full scale, how a series of products—including biostimulants, biopesticides, food additives and biofertilizers—can be derived from microalgae cultivated with different nutrient sources, such as sludge and municipal wastewater. The aim is to achieve a water purification process with zero waste at a demonstration scale of up to five hectares of cultivation area, thus taking the concept of a "biorefinery" from theory to practice. The treatment process is outlined in **Figure A1**.

Figure A1. General Structure of the SABANA Project



Source: Aqualia (2019)[55]. Document provided by the company.

[54] Aqualia (2018b). Document provided by the company.
[55] Aqualia (2019).

A.3. WWTPs as Urban Biorefineries: A New Model

The latest milestone in the development of novel technologies is the launch of another LIFE project called ULISES. Based on a new wastewater treatment model, the project aims to transform WWTPs into urban biorefineries through energy self-sufficiency and full recovery of waste, sludge, and water, which are used to produce biofuels, fertilizers, and quality water for irrigation.[56]

EThe initiative, co-financed by the EC under the LIFE program, was awarded to several entities: Aqualia (the project leader), EnergyLab Technology Centre, the University of Almería, and the Multisectoral Research Technology Centre (CETIM).

In the first stage, carried out in two pilot plants at El Bobar, the project has focused on minimizing energy demand a new anaerobic pre-treatment process and an aeration system, and on increasing biogas production and its use as a transport fuel. Thanks to these technologies, the plant will be energy self-sufficient in water treatment.

In the final stage, the project will be scaled up in a 600 m^2 crop field to demonstrate the effectiveness of this strategy for recycling waste and recovering nutrients for fertilizers.

[56] LIFE ULISES Project – Wastewater Treatment Plants as a New Model of Urban Biorefinery (September 20, 2019).