Almada, Portugal

Recovering energy from biogas produced in wastewater treatment plants

ICLEI Local Governments for Sustainability

Almada is paving the way towards a carbon efficient urban water cycle. As a coastal city, progressive water and wastewater management is a priority for the City Council of Almada. The construction of the Portinho da Costa Wastewater Treatment Plant, which recovers energy from biogas, represents integrated local action which progresses wastewater treatment, water resources management, and low emissions development.

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Summary

The City Council of Almada provides wastewater treatment service that accounts for almost 100 percent of wastewater within the city. This is a result of a municipal strategy which aims to achieve full coverage of the drainage networks and treatment systems within Almada's territory; a goal towards which the City Council has allocated considerable financial and human resources.

The Portinho da Costa Wastewater Treatment Plant (WWTP), the subject of this case study, demonstrates the City Council of Almada's commitment to ensuring that water circulates within closed loops in the municipality. A closed loop water cycle not only allows for repeated use of water resources, it also contributes to the preservation of biodiversity in the Tagus estuary, which provides numerous ecological functions and is habitat for numerous species of fish, bivalves, molluscs and birds. Portinho da Costa WWTP is connected to one of the three municipal wastewater drainage systems, and serves approximately 80,000 inhabitants across the territories of Costa de Caparica, Trafaria and part of Caparica.

This case study documents the recovery of the biogas generated in the wastewater treatment process and highlights its importance within the framework of the Local Strategy for Climate Change of the Municipality of Almada.

Facts & Figures

Population / Land area
174 030 (2011) / 72 km²

Municipal budget
77,5 M€ (2015)

Greenhouse gas inventory
Yes, since 2003

Introduction: the importance of biogas recovery

Anaerobic digestion is being increasingly used in wastewater treatment systems. The main goal of this process is the stabilisation of the primary and secondary sludge resulting from the treatment, rather than the production and use of biogas. Typically, the biogas produced in this process is burned off, when it could alternatively be considered a useful energy by-product that can be harnessed.

This business-as-usual practice detrimental to global energy efficiency: it is estimated that if all the worlds organic waste which is processed through anaerobic digestion were converted into methane and used as fuel with even only 50 percent efficiency, the result would be the savings of approximately 5 percent of global fossil energy.

The potential energy recovery with this technique is considerable and can be utilized in any WWTP equipped with anaerobic digesters for the treatment of sludge. However, considering biogas conservation during the project planning phase provides greater opportunity to create a cost effective and energy efficient design.

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Almada has been a member of ICLEI since 2001

Photo 1: A cogeneration engine at Portinho da Costa WWTP

Biogas is suitable for use within energy conversion equipment such as power units (motor + generator), cogeneration units for heat (thermal energy) and electricity output, and even boilers for hot water and/or steam production. The possibility of producing and internally using biogas in the WWTP as a "free" fuel, which also serves to reduce GHG emissions, proved to be enough evidence to justify the technical, human and financial effort that Almada's Water and Sanitation Municipal Services (SMAS) have invested in the design and construction of the Portinho da Costa WWTP.

Almada: between land and sea

Located on the south bank of the Tagus River across from Lisbon, Almada is one of the 18 municipalities within the Lisbon Metropolitan Area. The municipality has 175,000 full-time residents and an estimated 8,000,000 visitors per year. It occupies a surface of 72 km^2, 40 percent of which is built up urban area and 24.2 percent is a lush forested area of great natural richness. Almada's boundaries are almost entirely waterfront: to the east and north lay the Tagus River, while to the west lays the Atlantic Ocean. Almada's Atlantic Ocean beachfront, Costa de Caparica, extends for approximately 13 km and is a popular summertime destination for Lisbon residents as well as foreign visitors.

The Almada City Council has long been developing policies and strategies towards a more sustainable city. The Local Strategy for Climate Change of the Municipality of Almada contains a number of actions targeted at reducing the energy consumption in the different activity sectors in Almada and, complementarily, at fostering the use of endogenous energy resources to generate heat and electricity. These efforts have been technically supported by the Local Energy Management Agency of Almada, AGENEAL. To ease the implementation of energy efficiency measures in municipal operations, Almada has created "Almada Less Carbon", a carbon fund which finances sustainble investemnts within the municipality.

Along these lines, the City Council of Almada has been a signatory of the Covenant of Mayors since its inception, and has embraced the challenge of reducing its energy consumption and GHG emissions by 20 percent as a contribution to the EU common 3x20 objectives.

Most recently, Almada subscribed to the Paris City Hall Declaration during the COP 21 and embraced the ambitious commitment of reducing its emissions 80 percent by 2050.

Table 1: Almada's Strategic Plan targets for 2017/2033

Performance indicators and targets	2011	2017	2033
Misconnections and groundwater infiltration (m^3/km)	6600	6000	2000
Sewer rehabilitation (% of total)	0.1%	0.5%	2%
Energy optimization in pumping stations (kWh/m^3 100m)	0.65	0.45	0.35
Reclaimed wastewater (%)	2.36%	3.5%	10%
Regulation compliance (%)	89%	100%	100%

Planning in Ten Year Intervals

Every 10 years, the Municipality of Almada approves an updated local development strategy, and water and wastewater management have factored heavily in many of these plans:

- **1960's** - First Plans made for the wastewater drainage network and water supply network.
- **1980's** – Plan & construction of the wastewater drainage network; construction and renovation of the water supply network
- **1990's** – Plan & construction of wastewater treatment plants
- **2000's** – 100% urban water cycle coveraage
- **2010's** – Ensuring quality service; asset management; eco-efficiency; and adapting water and wastewater systems to climate change.

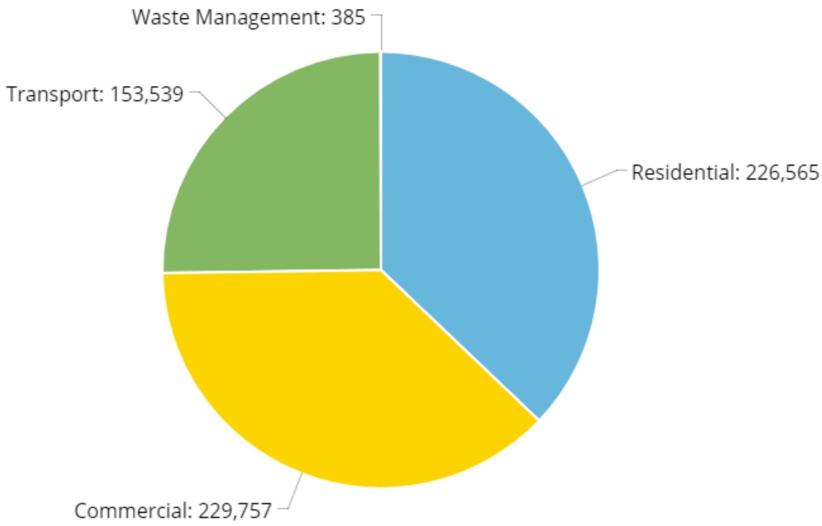
Almada's Strategic Plan also includes guidelines and actions for its wastewater drainage and treatment systems, namely:

- Pollution prevention and assets management, with the use of technology for intensive measuring and monitoring – in parallel with sewer rehabilitation – to address drainage misconnections and ground water infiltration
- Pollution reduction, through adaptation of older WWTP's to current EU regulations
- Sludge valorization, through biogas energy recovery and re-application to agricultural lands
- Energy efficiency, in wastewater pumping stations and WWTP
- Reclaimed wastewater, through effective long-term planning

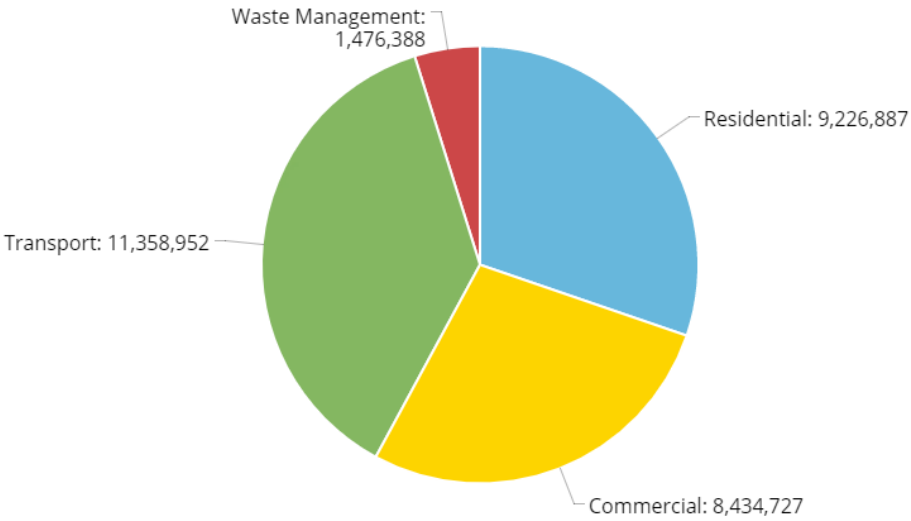
Almada's Strategic Plan also sets specific targets for the wastewater drainage and treatment System within the municipality, as indicated in Table 1. The plan also includes targets for the development of sustainable urban drainage solutions, including harvest and retention of rainwater.

Measures towards the 2033 targets have already been implemented to address the water energy nexus, including: low energy intensity treatment technology (trickling filters with natural aeration), soft starters and variable speed drivers in pumps, and energy efficiency measures in buildings (passive solar building design, energy saving air conditioning systems, double glass windows, lighting efficient electronic ballasts) to minimize energy consumption. Biogas recovery through cogeneration has been implemented to maximize energy production and minimize external energy dependence. Physical-chemical treatment plus biological treatments ensure process flexibility and reliability.

Graph 1: Annual community energy use in Almada as of 2012 by sector (MJ/year)



Graph 2: Annual community emissions in Almada as of 2012 by sector (tonnes CO_{2eq})



Further additional measures are already being explored, including maximizing use of renewable resources through installation of solar panels and photovoltaic panels, as well as WWTP 8-year energy auditing programs to reduce electric energy consumption. These programs will incorporate the use of efficient pump engines, efficient outdoor lighting, energy management tools and professional training.

Explaining the Initiative:

Energy in Portinho da Costa WWTP

Portinho da Costa WWTP produces energy which corresponds to that which is used in the treatment of the sludge and electricity consumed it the various processes. Since its inception, the project foresaw the potential of supplying these energy needs by installing a cogeneration system powered by the biogas produced within the same WWTP.

Biogas stems from the digestion of the sludge originated in the primary and secondary treatment of wastewater. Sludge, which is mainly formed by the organic matter of the initial sewage, is the ideal substrate for the application of a treatment process known as anaerobic digestion (biological degradation in the absence of oxygen). This process results in the production of biogas, a form of renewable energy, essentially consisting of methane (CH4) and carbon dioxide (CO_2), which may be used as fuel.

Biogas from Portinho da Costa WWTP: a noble renewable energy

Among different forms of renewable energy, the methods that allow for recovering waste should be considered in all cases, as they combine energy generation with an immediate positive environmental effect. If used for energy production, biogas which originated in a WWTP or in landfills belongs to this group.

The importance of biogas as an energy resource is due to its main constituent, methane. This compound has a high heating value, which makes it a very valuable utility for the cogeneration of thermal energy and electricity. However, its direct release to the atmosphere is harmful, since methane has a global warming potential approximately 21 times higher than that of carbon dioxide.

Biogas composition varies according to the waste characteristics and operating conditions of the digestion process. On average, it is 60 percent methane (CH4) and 40 percent carbon dioxide (CO_2). Other gases such as nitrogen (N2) and hydrogen sulphide (H2S) are also present in the composition, but only in trace amounts. The laboratory analysis of the biogas produced at the Portinho da Costa WWTP displays a percentage of over 65 percent methane.

Figure 1: Energy equivalence of biogas with 70% methane

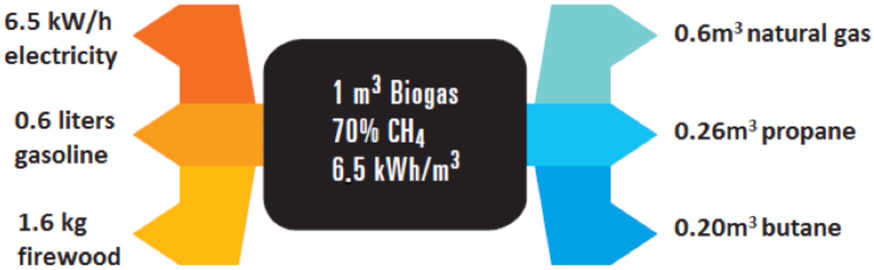
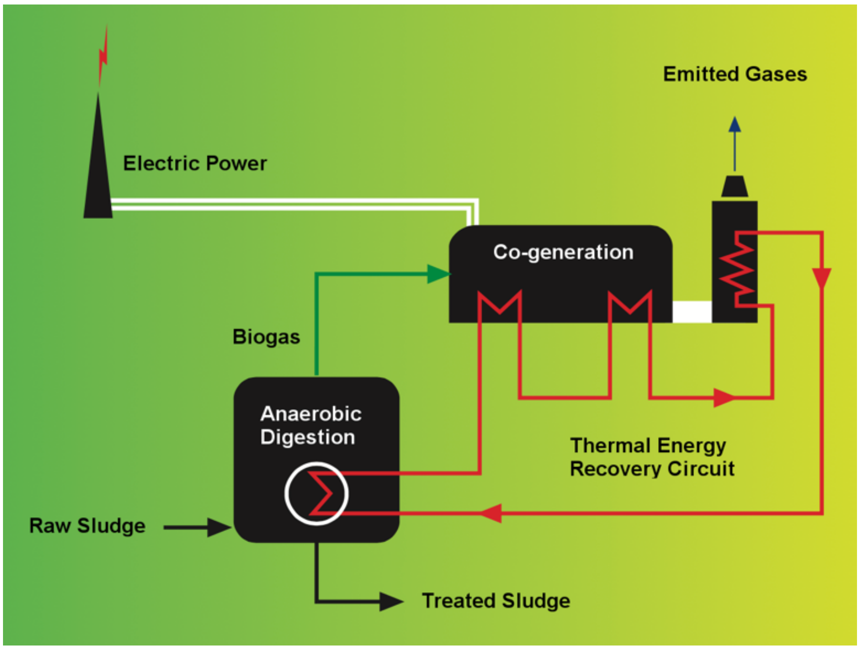


Figure 2: Diagram of the Portinho da Costa WWTP cogeneration system



While, in absolute terms, biogas energy is a lower grade of energy than most of the gases normally used as fuel (low grade reflecting the difficulty of converting it into other forms), the fact that it is both a by-product and renewable makes its use environmentally very efficient. Moreover, regardless of the way in which biogas is used, it is always possible to produce at least one form of energy, be it electrical, thermal or mechanical.

The cogeneration system of Portinho da Costa WWTP

The cogeneration system of Portinho da Costa WWTP consists of two power units (motors and alternators) that feed on the biogas stored in two double membrane floating gasometers (2 x 200 m3).

The power units (2 x 250 kW) allow for converting approximately 33 percent of the energy contained in the biogas into electricity. About 60 percent of its energy is recovered in the form of heat (steam and hot water) using heat exchangers to profit from the thermal energy present in the exhaust gases and engine cooling circuits. The loss of energy in the co-generation process amounts to just 7 percent.

Photo 2: Primary treatment of sludge at Portinho da Costa WWTP

The wastewater treatment process of Portinho da Costa WWTP

Portinho da Costa WWTP receives a daily average rate of around 9 500 m^3 (3 467 500 m^3/year). The treatment encompasses a solid phase process and a liquid phase process. The liquid phase treatment starts with a first stage of filtering the sewage, followed by an advanced physical-chemical treatment (the primary treatment). This is followed by biological treatment (the secondary treatment) of the effluent through biofilters. Reclaimed water is further treated with ultra violet (UV) light disinfection). The treatment effluent is then discharged under-sea with diffusers which are situated 25m deep and 150m from the bank of the Tagus River.

In the solid phase, the sludge resulting from the primary and secondary treatment of the wastewater is thickened by gravity. In the next step, this thickened sludge undergoes a digestion in a mesophilic regime (35°C temperature), using the heat generated by the cogeneration engines to maintain an operating temperature that maximizes the generation of methane.

The digested sludge is then dehydrated by centrifugation, stored in silos and used in agriculture. This is a technologically advanced and environmentally efficient treatment plant: it achieves high treatment efficiency (removal of organic matter higher than 96%), produces biogas, repurposes the sludge as agricultural fertilizer, and reuses the treated wastewater for washing and watering green spaces.

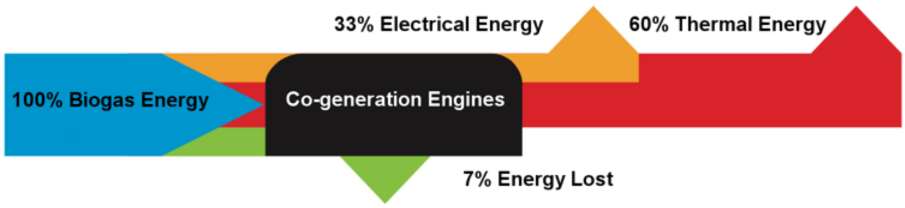


Figure 3: Energy balance of the Portino da Costa cogeneration plant

Portinho da Costa WWTP: an ecological WWTP that turns waste into energy

The co-generation system of Portinho da Costa covers about 40 percent of the energy needs of the facility, equivalent to about 550 MWh per year. In environmental terms, these energy savings translate into a decrease of 40 percent of GHG emissions, which in absolute terms represents a reduction of 180 tons of CO_2. In addition to the reduction of emissions due to the displacement of the use of natural gas and electricity, this measure also decreases the amount of carbon dioxide equivalent that would otherwise be released from the disposal of sludge in a landfill, where the capture of methane is less effective.

This is, therefore, a significant contribution from the Almada SMAS to the ongoing joint effort to contain and reduce GHG emissions which originate within the municipality.

The construction of the Portinho da Costa WWTP ensures the additional treatment of 24 percent of the wastewater in the Municipality of Almada without increasing emissions from the waste sector. This performance is due to the fact that the design of this facility provided for a cogeneration system to convert biogas into thermal and electric energy.

Portinho da Costa WWTP design parameters	
Project lifetime [3]	2020
Population served [3]	140.000 inhabitants equivalent
Tratment capacity [3]	22.400 m^3/day
Liquid phase treatment efficiency [1]	Biochemical Oxygen Demand 5-days (BOD5): 96% Chemical Oxygen Demand (COD): 97% Total Suspended Solids (TSS): 97%
Anaerobic digestion design parameters	
Biogas storage capacity	2x200 m^3
Cogeneration design parameters	
Electricity production capacity	2 x 250 kW
Climate change mitigation	
Potential greenhouse gas emissions reduction	687 t CO_2/year

Table 3: Technical characteristics of the Portinho da Costa WWTP

Energy carrier	Consumption prior to cogeneration (MWh/year)	Consumption with co-generation (projections for 2020) (MWh/year)	Energy savings (MWh/year)	Energy savings (%)
Electricity	1,778	967	811	46
Natural gas	1,282	51	1,231	96
Total	3,060	1,018	2,042	67

Table 4: Projected potential energy savings enabled by the cogeneration plant when fully operational (2020)

Lessons Learned

- Municipalities should consider energy recapture and cogeneration at the draft stage of constructing new facilities in order to ease their physical integration in the wastewater treatment plant and its operation.
- Highlighting the environmental, social, and financial benefits of the project can help generate enthusiasm from City Council: Biogas recovery increases the efficiency of these facilities, creating tangible value and intangible benefits in the local community associated with this measure.
- The role of the "in-house" technical capacity is invaluable. Internal experts identified the possibility of harnessing the biogas energy generated in the anaerobic digestion process, and included this as a requirement in the public procurement procedure to select the design of the treatment plant.
- Process control, close monitoring, and planned maintenance can help to ensure continued good performance of the system and delivery of expected savings and benefits. Team goals and targets as well as team dedication and endeavour are also essential.

Policy	• Long-term municipal strategy and action plan for water and wastewater, and a long-standing committment to fighting climate change
Finance	• Funding was provided through grants
Organizational arrangements and capacity	• Technical support was provided by Local Energy Management Agency of Almada, AGENEAL, and Almada's Water and Sanitation Municipal Services, (SMAS Almada)
Stakeholder engagement	• Harnessing of energy from the biogas was included as a requirement in the public procurement procedure to award the design of the treatment plant
Technology	• Anaerobic digestion for biogas production coupled with electricity and heat cogeneration

Table 5: Key features of Almada's approach to the Portinho da Costa WWTP

Replication

The technology used in the Portinho da Costa WWTP is all commercially available and poses no obstacles to use. Existing WWTP's that already have anaerobic digestion in place to treat sludge, but which are not yet harnessing the energy potential of biogas, can potentially replicate elements of the Almada model.

The key issue to bear in mind in the implementation of such a project is that the capacity to integrate different technical disciplines must be in place. The presence of in-house expert knowledge and expertise allows for identifying the needs and opportunities for energy recovery of waste, or a by-product of the wastewater treatment process.

Harnessing biogas reduces operating costs with the acquisition of energy while it also avoids GHG emissions. The major costs towards such a WWTP are those associated with the acquisition and installation of equipment, which are recoverable within its life span, and are thus not a financial burden. This visible return on investment further supports making the financial case towards sustainable action.

Costs and Funding

The investment in Portinho da Costa WWTP was approximately 10 million Euros. Funding was secured through grants from the European Investment Bank (EIB) and EEA Grants.

The use of biogas for cogeneration enables operational cost savings through the displacement of natural gas and grid electricity consumption, which in 2011 amounted to 55,322 Euros. With the increase of the base tariff as well as of the applicable VAT (changed from 6% to 23%), the savings associated with energy amount to at least 60.000€/year.

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