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Reducing Urban Water System's Carbon Footprint and Reservoir Water Balance Study in Ceuta, Spain

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Hydropower Development
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Abstract

This study seeks to reduce the energy consumed by the water company in Ceuta by implementing two type of developments: hydropower and solar photovoltaic project. It will be necessary to design both schemes and determine the benefits provided by each one to decide whether the benefits outweigh the costs or, on the contrary, the projects are not viable.

Key words: Water Sources, Energy generation, Hydropower, Turbine, Bypass, Floating Solar Panels, Evaporation

Resumen

Este estudio tiene como objetivo reducir la energía consumida por la compañía de aguas de Ceuta implementando dos tipos de proyectos: hidroeléctrico y solar fotovoltaico. Será necesario diseñar ambos y determinar los beneficios obtenidos de cada uno para decidir si los beneficios superan a los costes o si, por el contrario, el proyecto no es viable.

Palabras clave: Recursos Hídricos, Generación de Energía, Hidroeléctrico, Turbina, Bypass, Paneles Solares Flotantes, Evaporación

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1. INTRODUCTION

This Master Thesis has been written as final requirement to complete the MSc of Hydropower Development at the NTNU in Trondheim, Norway.

During these pages, the current characteristics of the water supply and energy supply system in Ceuta will be described, showing the deficiencies they present and the improvements studied in this project. The objective will be to reduce the carbon footprint of Ceuta by reducing the energy consumption of the local water company through the development of renewable energy projects. It will finish with a conclusion regarding the feasibility of the different options.

There are two different parts in the project: hydropower development and solar energy development.

The part related to hydropower will consist on studying the feasibility of installing a turbine to generate energy in the outlet of the pipe which transports the water from the reservoir to the pumping station.

The solar PV part of this work is related to solar energy. There are two reservoirs in the city of Ceuta, one of them used for water consumption and recreational use and the other is only used for reinforcing the water supply in some periods. The feasibility of installing floating solar panels will be analysed. The implementation of this system includes an additional benefit, because the area where the solar panels are located will have less evaporation. Therefore, there is more volume of water to use for consumption.

2. GENERAL CHARACTERISTICS OF THE AUTONOMOUS CITY OF CEUTA

2.1 GEOGRAPHICAL SITUATION

Ceuta is a Spanish city located in the North of Africa. Its population is around 85.000 habitants. The city conforms the border between Europe and Morocco. It presents a strategic situation in the Strait of Gibraltar due to the communications between Mediterranean Sea and Atlantic Ocean.

2.2 HYDROGRAPHIC DEMARCATION OF CEUTA

The Hydrographic Demarcation of Ceuta comprises the territory of the autonomous city of Ceuta, located in the south of the Strait of Gibraltar. The peninsula where the demarcation is located has an area of 20 km^2 and a perimeter of 28 km, eight of them being the border with Morocco. The maximum height within the area is 349 meters.

Considered traditionally as the division between the Mediterranean Sea and the Atlantic Ocean, Ceuta is surrounded by the sea forming two bays, North Bay facing the Iberian Peninsula and South Bay, looking to Morocco. (Confederación Hidrográfica del Guadalquivir, 2016)

2.3 GEOLOGICAL CHARACTERISTICS

The geology of Ceuta is extremely complex because it is located in the centre of a very intricate geological formation such as the Andalusian – Riffean system, and it is also the confluence between the Eurasian and African tectonic plates.

In general, the terrain is rolling, and moderate to steep slopes with values of 30% are common. This affects the configuration of the hydrographic network, which is comprised of numerous streams with short length and an accused torrential character.

The climate is Mediterranean type, characterized by mild temperatures and irregular precipitations. However, it is tempered by two important factors, the terrain and the surrounding sea. (Confederación Hidrográfica del Guadalquivir, 2016)

Map 1. Territorial scope of Hydrographic Demarcation of Ceuta. (Confederación Hidrográfica del Guadalquivir, 2016, p. 7)

2.4 HYDROLOGY

This territory is characterized by an absence of streams with permanent water, represented by only a few brooks and several gullies and ravines where the water from precipitations circulates. Thus, their nature is seasonal.

The hydrology in the subsurface is mostly determined by the permeability of the materials and the terrain. Hence, the Monte Hacho area, with its steep slopes and the proximity to the sea, has a strong runoff with a consequent reduced water infiltration.

On the other hand, the zones with layers of sandstones and limestones have a higher water infiltration and water storage. The hydrographic network of the city of Ceuta is compound by small entity streams, being most of them brooks and gullies with a discontinuous regime, dependent on the season. The average width of these streams is less than 5 meters. The gullies are originated by the erosion process of the water from precipitations during the wet season.

The most representative streams in the area of study are the next creeks:

- Benzú
- Calamocarro
- Renegado
- Infierno
- Bombas

Benzú Creek has a winding layout and a dendritic ramification, presenting steeper slopes in the outside of the curves of the stream. It flows into the Atlantic Ocean near the neighbour called like the gorge.

The Calamocarro Creek has also a dendritic ramification.

The Renegado and Infierno streams are regulated by dams in order to reinforce the water sources of the city of Ceuta. They also have served as regulating reservoirs for the water from the Bombas Brook, which has no regulation because it is bordering with Morocco.

Both dams (Infierno and Renegado) are rock fill dam type. The reservoirs have a volume of 1.65 hm^3 (Renegado) and 0.65 hm^3 (Infierno).

Besides these streams, along the coast between Benítez and Benzú, there are several seasonal creeks originated by erosion in steep slopes, such as Central Gully, San José Creek, Parrón Glen, Altaba'cal Glen, etc.

In terms of subsurface hydrology, in the project developed by the Geological and Mining Institute of Spain (IGME), called "Hydrogeological works in the plans of management, planning and control of aquifers and studies about contamination of aquifers", made by the Spanish Ministry of Industry and Energy in 1995, the aquifers located in the area present the characteristics described below.

2.4.1. ALLUVIAL AQUIFER

This aquifer is composed of alluvial deposits associated with Benzú, Calamocarro and Bombas creeks. Benzú creek is limited in its sides and its bed by schistose materials, which are watertight.

The exploitation of the aquifer has two problems: the scarcity of resources during the dry season due to its reduced dimension (it has a basin area of 1 km^2), and the salinity caused by the sea intrusion.

This aquifer has a maximum width of 15 meters and a length of 600 meters. The thickness of the alluvial materials is around 4 meters.

Regarding Bombas creek, the alluvial aquifer has a thickness between 5 and 7 meters and it is compound by sand, gravel and clay. (Prointec, n.d., pp. 8-10)

2.4.2. BENZÚ AQUIFER

It is a limestone outcrop located in Benzú, with a high level of permeability. (Prointec, n.d., pp. 8-10)

2.5. SOURCES OF WATER

2.5.1. SUBSURFACE MASS OF WATER

In the Hydrographic Demarcation of Ceuta it has been identified a subsurface mass of water called Alpujárride – Maláguide Aquifer, also known as Occidente Ceutí Aquifer. This subsurface mass of water does not count with a high exploitation rate. The main refilling source of this aquifer is the water from precipitation, which is directly related to the infiltration capacity of the terrain.

As it has been described before, Ceuta does not count with streams of importance from the point of view of the flow. Every streams present seasonal flows.

To sum up, there are 42 streams, 11 in the area of Monte Hacho and the rest of them in the continental zone. The natural resources can be evaluated as 2.93 hm^3 per year from runoff, distributed as shown below.

Map 2. Aquifer of Occidente Ceutí. (Confederación Hidrográfica del Guadalquivir, 2016, p. 9)

Due to the water tightness of the terrain and its rolling character, the subsurface resources are scarce. However, there is a volume of subsurface water concentrated in the fissures of the material, in the limestone outcrops and in the alluvial deposits.

Other water resources available in the region are outlined below.

2.5.2. DESALINATION

The city of Ceuta has a desalination plant which is capable of producing 30,000 m^3 of drinking water per day.

Map 3. Desalination plant location. (Google Earth Pro, 2016)

2.5.3. RECYCLING

Ceuta has a new waste water plant to treat the water used in the city. The regeneration of the waste water by using a tertiary water treatment represents a potential source to different uses such as irrigation, industrial uses and street cleaning. Between 5 and 10% of the water treated is currently used for these purposes.

Map 4. Waste water plant location. (Google Earth Pro, 2016)

2.5.4. BELIONEX SPRINGS

They are located outside of the Spanish territory, but their water discharge into Benzú aquifer and Infierno reservoir, so they are a source of water for the city.

Nowadays the water coming from these springs is seasonal type and the volume used oscillates between 2,000 and 7,000 m^3 per day. (Confederación Hidrográfica del Guadalquivir, 2016)

2.5.5. WATER TANKER

Before the desalination plant was built, the water supply to the city had to be performed by ship. This was because the reservoirs have not enough water to meet the city demand.

There is a supply infrastructure to transport the water from the ship to the water deposits. This infrastructure is still operative to use in case of failure or malfunction of the desalination plant.

The problem with this system is that it has a very high cost and it depends on the weather conditions. In case of bad conditions no ship can cross the Strait of Gibraltar.

3. CURRENT WATER SUPPLY SYSTEM

As it can be inferred from the previous description, Ceuta is an island regarding water supply. It has two small reservoirs which provide usually less than half of water demand volume. With the objective of solving this problem, a desalination plant was constructed in 1996, with a capacity of 16,000 m^3 per day, and two years after the capacity of the plant was increased to 20,000 m^3 per day. In 2015 a new plant was built beside the old one, with a capacity of 10,000 m^3 per day. Therefore, the current total capacity is around 30,000 m^3 per day.

Before its construction, the water demand was met by using the water from the reservoirs, and when it was not enough, it was necessary to bring water by ship from the Iberian Peninsula.

The current water supply system has four elements:

3.1 RENEGADO RESERVOIR

It has a volume of 1.65 Hm^3 and its height over the sea is 82.10 meters. The dam is rock fill dam type. There is a pipe which takes the water from the reservoir and transport it to the pumping station, where the water is treated before pumping it to the city. The length of the pipe is 286 meters.

Map 5. Renegado reservoir. (Google Earth Pro, 2016)

To define better the reservoir, an elevation – volume curve is shown below, obtained from the next table of water levels and the corresponding area and volume.

M.A.S.L.	VOLUME (m^3)	VARIATION (m^3)	AREA (m^2)
43	39,800	39,800	9,100
45	40,950	1,150	10,200
50	59,280	18,330	11,250
55	72,627	178	17,400
60	190,685	308	33,972
65	394,197	467	40,100
70	645,831	616	53,100
75	991,170	1,559	72,500
80	1,424,773	958	79,600
82	1,633,364	1,024	87,600

Table 1. Volume and area variation depending on the water level in Renegado reservoir. (Aguas de Ceuta S.A. (ACEMSA), 2016). (Instituto Geográfico Nacional, 2016)

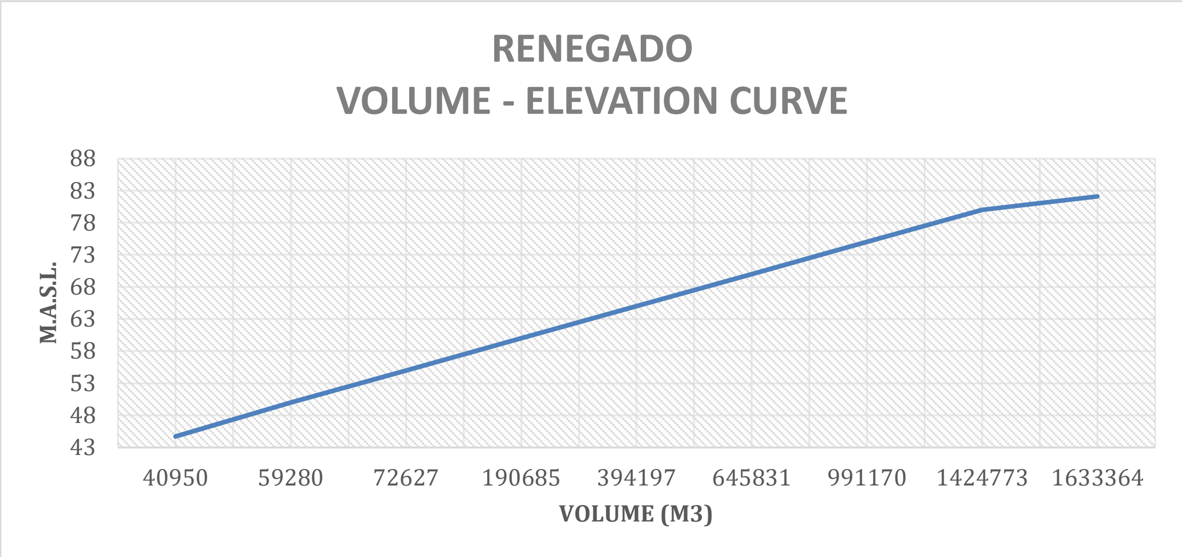
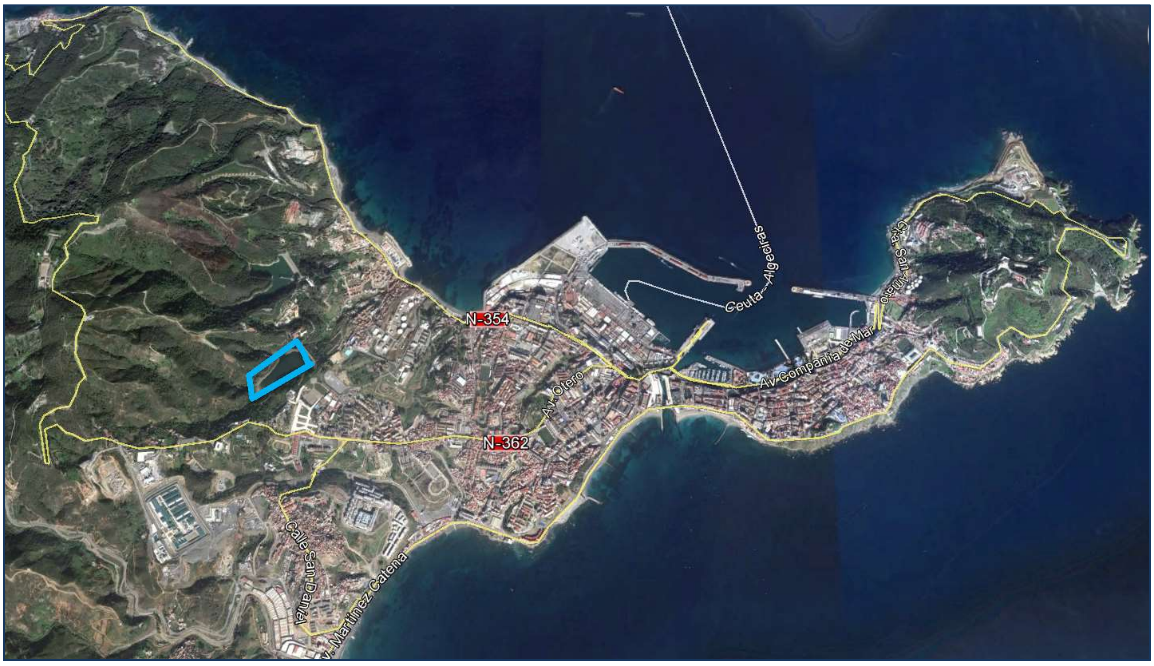


Figure 1. Renegado volume – elevation curve.

The highest water level is 82.1 meters above the sea level, corresponding to 1.65 Hm^3 and an area of 87,600 m^2. The lowest water level is in line with the level of the lowest outlet, located at 43 m.a.s.l., and the corresponding volume is the dead storage water volume of this reservoir.

3.2 INFIERNO RESERVOIR

Its volume is 0.65 Hm^3 and the height over the sea level is 60 meters. The dam is also rock fill dam type. This reservoir has direct connection to the pumping station through a curved syphon pipe, which goes from the reservoir to the desalination plant following the road, and from the desalination plant to the pumping station. It needs to save the difference of height between the desalination plant and the pumping station, which is 35 meters, and that is the reason of the pipe type.



Map 6. Infierno reservoir. (Google Earth Pro, 2016)

Next table shows the area and volume variation depending on the water level. This is the basis for drawing the area – volume graph of the Infierno reservoir.

M.A.S.L.	VOLUME (m^3)	VARIATION (m^3)	AREA (m^2)
42.5	15,313	15,313	10,447
45	44,215	28,902	30,500
50	16,1695	117,480	35,300
55	360,705	199,010	52,100
60	654,266	293,561	63,100

Table 2. Variation of area and volume according to Infierno water level. (Aguas de Ceuta S.A. (ACEMSA), 2016). (Instituto Geográfico Nacional, 2016)

The maximum water level of this reservoir is 60 meters above the sea level, which corresponds to a volume of 0.65 Hm^3 and an area of 63100 m^2. The lowest regulated water level is 45 meters above the sea level, corresponding to a volume of 28,902 m^3 and an area of 30,500 m^2. This minimum level is related to the lowest outlet of the reservoir.

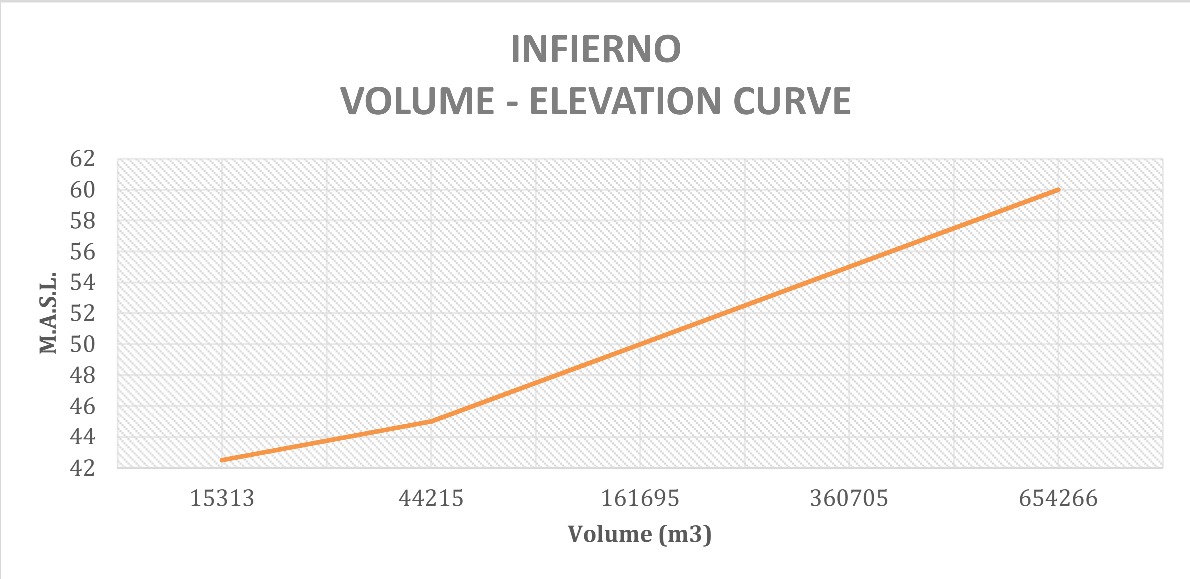


Figure 2. Volume – Elevation Curve. Infierno Reservoir.

3.3 DESALINATION PLANT

It has a capacity of 30,000 m^3 per day, and it is located 5 meters over the sea level. It was built in 1996 with a capacity of 16,000 m^3 per day and after some years it was updated to improve the capacity.

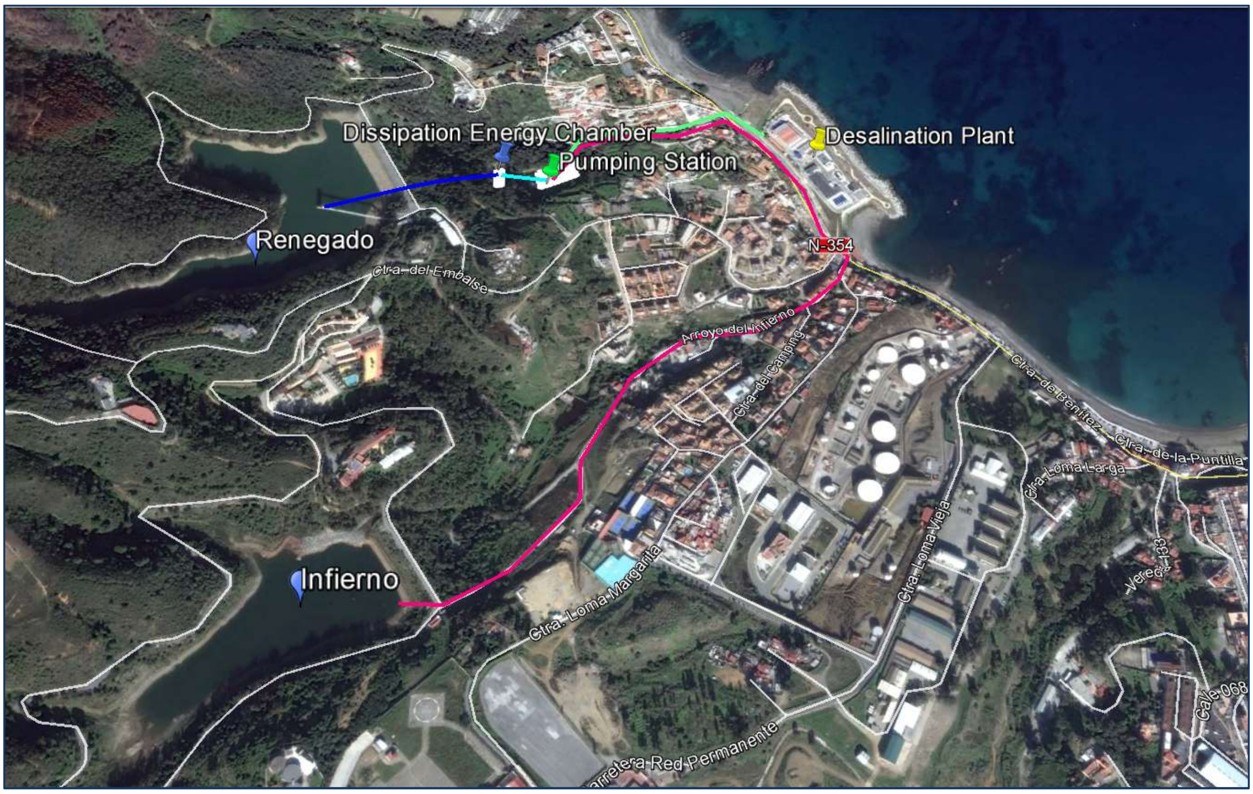
Nowadays the water demand is around 22,000 m^3 per day, so the desalination plant can supply the city demand without difficulties.

The location can be seen on Map 3, attached in previous pages.

3.4 PUMPING STATION

The pumping station distributes the water to all the city. It means that it is the point where the water from the different sources converge.

The water coming from the different sources will depend on the period and the type of year (wet or dry). In general, the principal source is the desalination plant, but the reservoirs can provide all the water demand during wet periods.



Map 7. Pipe system between reservoirs, desalination plant and pumping station. (Google Earth Pro, 2016)

3.5. CURRENT SYSTEM

The next table shows data about volume used from different sources to meet the demand. The values are total volume for each year since 2010 until 2015, the population of each year and the consumption per capita in litres per day.

YEAR	SURFACE WATER (m^3)		IDAM (m^3)	TOTAL WATER CONSUMPTION (m^3)	POPULATION	CONSUMPTION PER CAPITA (l/day)
	INFIERNO	RENEGADO				
2010	828,970	2,074,193	7,205,409	10,108,572	80,579	344
2011	775,460	2,929,034	4,447,413	8,151,907	82,376	271
2012	58,039	1,277,051	6,582,950	7,918,040	84,018	258
2013	480,062	2,502,205	4,877,510	7,859,777	84,180	256
2014	66,600	976,780	7,025,403	8,068,783	84,524	262
2015	321,663	1,732,078	6,281,473	8,335,214	85,244	268
AVERAGE	421,799	1,915,224	6,070,026	8,407,049	83,487	276

Table 3. Data from current supply system. (Instituto Nacional de Estadística, 2016) (Aguas de Ceuta S.A. (ACEMSA), 2016)

The table shows the trends of the different variables involved in this project and it can help in defining the characteristics of the design.

In percentage, the Infierno reservoir provides a 5% and the Reservado reservoir a 22.8 %,

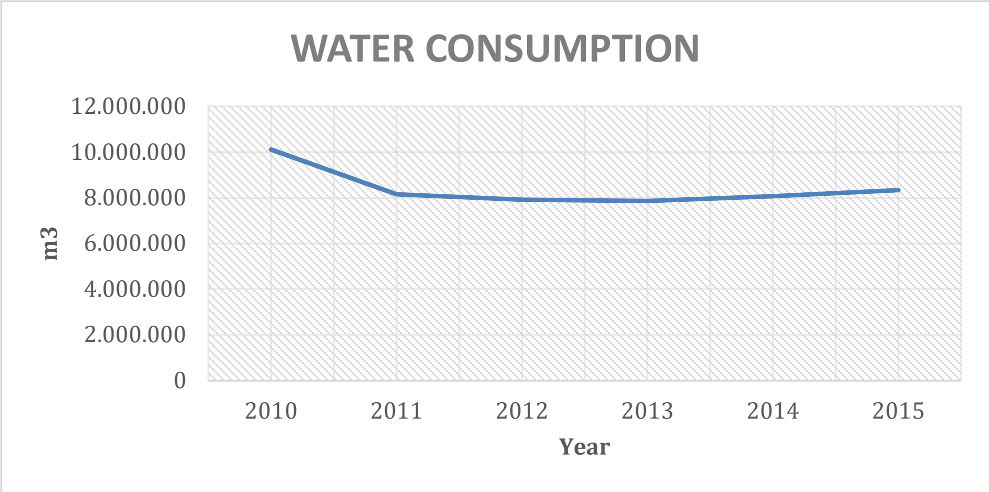


Figure 3. Evolution of water consumption during the past six years in Ceuta.

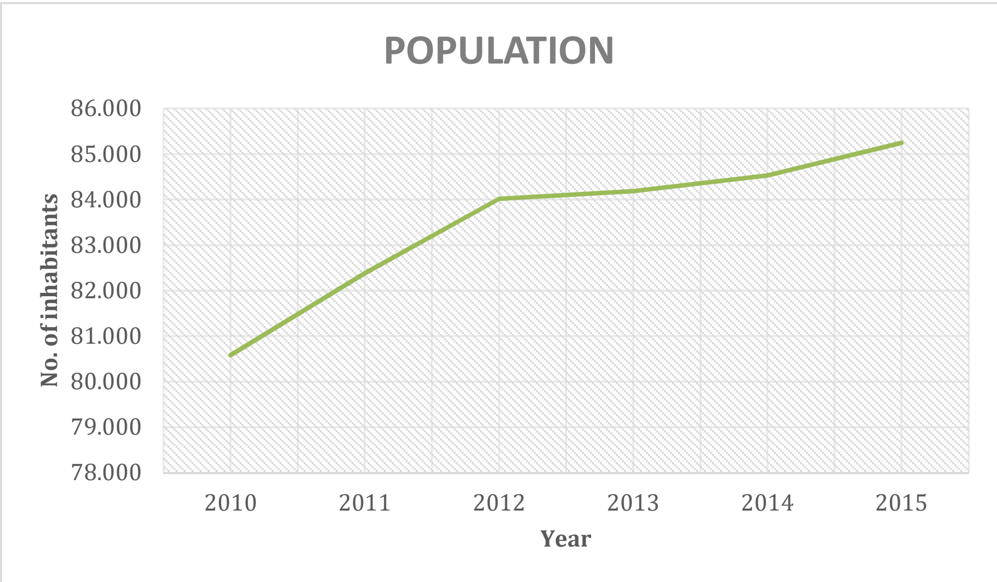


Figure 4. Evolution of Ceuta's population during the past six years.

Before drawing any conclusions, it is important to point some details. Since 2010 the water company has been developing a plan for reduction of leakages. ACEMSA has accomplished a reduction of around 10,000 m^3 per day since the plan started. This plan is still being performed, but the improvement is just slightly increasing. Then, the data collected during the first years is not reliable, and the data which can be more exact to show the trend is the collected since 2013.

YEAR	SURFACE WATER (m³)		IDAM (m³)	TOTAL WATER CONSUMPTION (m³)	POPULATION	CONSUMPTION PER CAPITA (l/day)
	INFIERNO	RENEGADO				
2013	480,062	2,502,205	4,877 510	7,859,777	84,180	256
2014	66,600	976,780	7,025,403	8,068,783	84,524	260
2015	321,663	1,732,078	6,281,473	8,335,214	85,244	271
AVERAGE	**289,442**	**1,737,021**	**6 061 462**	**8 087,925**	**84,649**	**262**

Table 4. Current supply system.

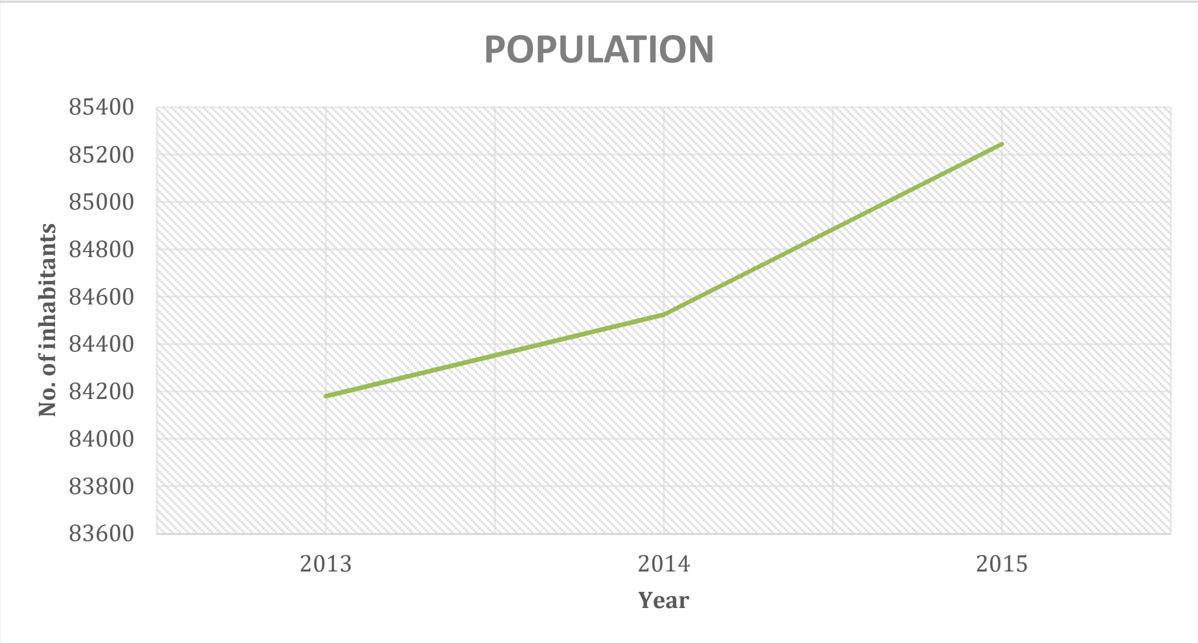


Figure 5. Population evolution since 2013.

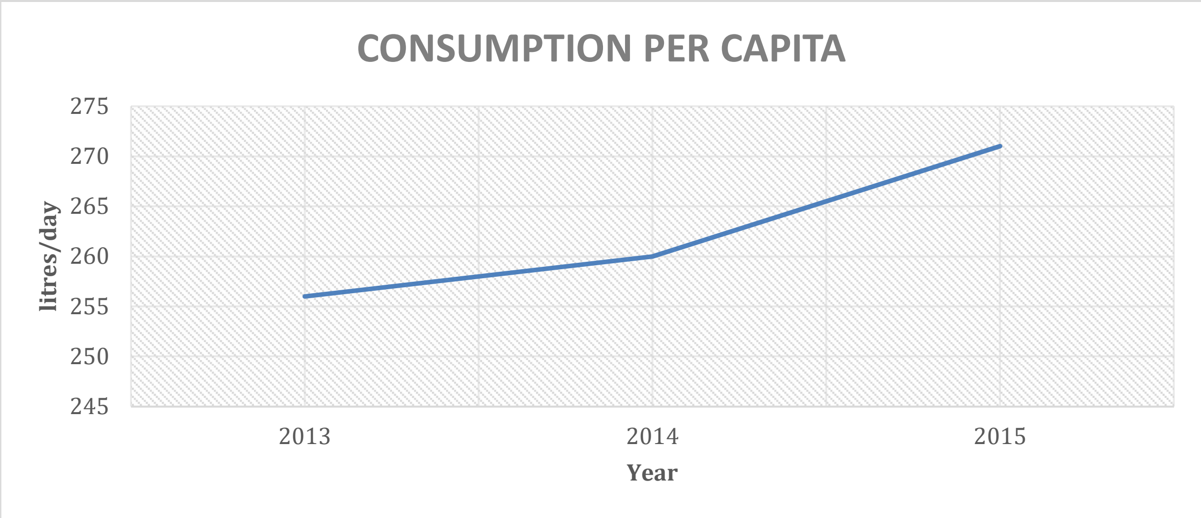


Figure 6. Litres per day consumed per inhabitant since 2013

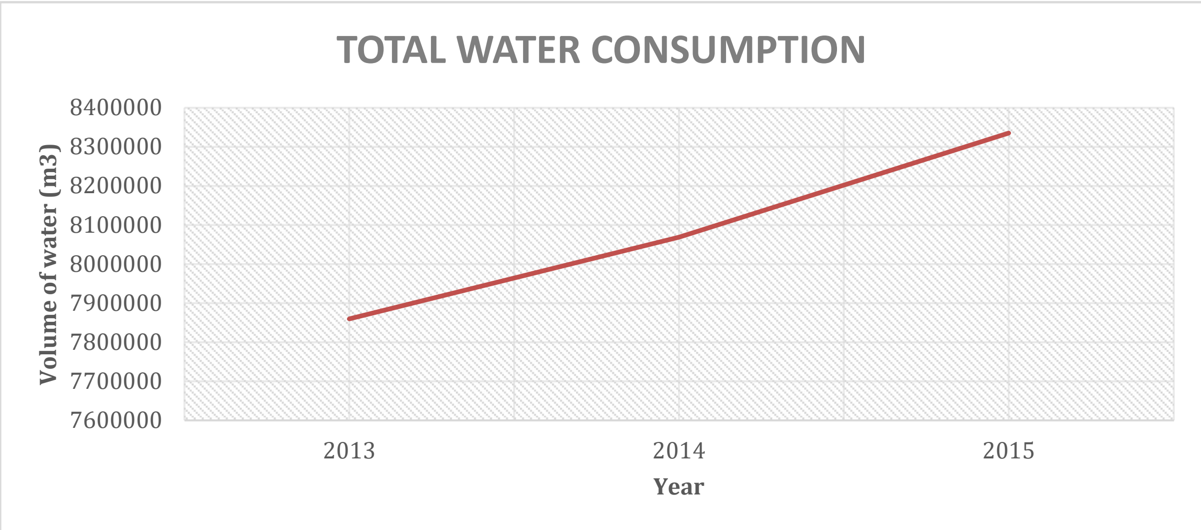


Figure 7. Total volume of water consumed per year since 2013.

In view of the above, a future prediction for 2020 should considerate a higher population and a higher total volume of water consumption. According to the data, the consumption per capita is also increasing, but if the reduction of leakage plan is taken into account, this is not a trend. Therefore, the future consumption per capita assumed will be an average of the data collected since 2013.

The volume of water extracted from the reservoirs will not change in the future because no changes are expected regarding water inflow. Thus, in further calculations the volume used will be the average of the water abstracted from the reservoirs during the past three years.

The volume from the desalination plant, on the contrary, will change due to the increase of population and total consumption in the future.

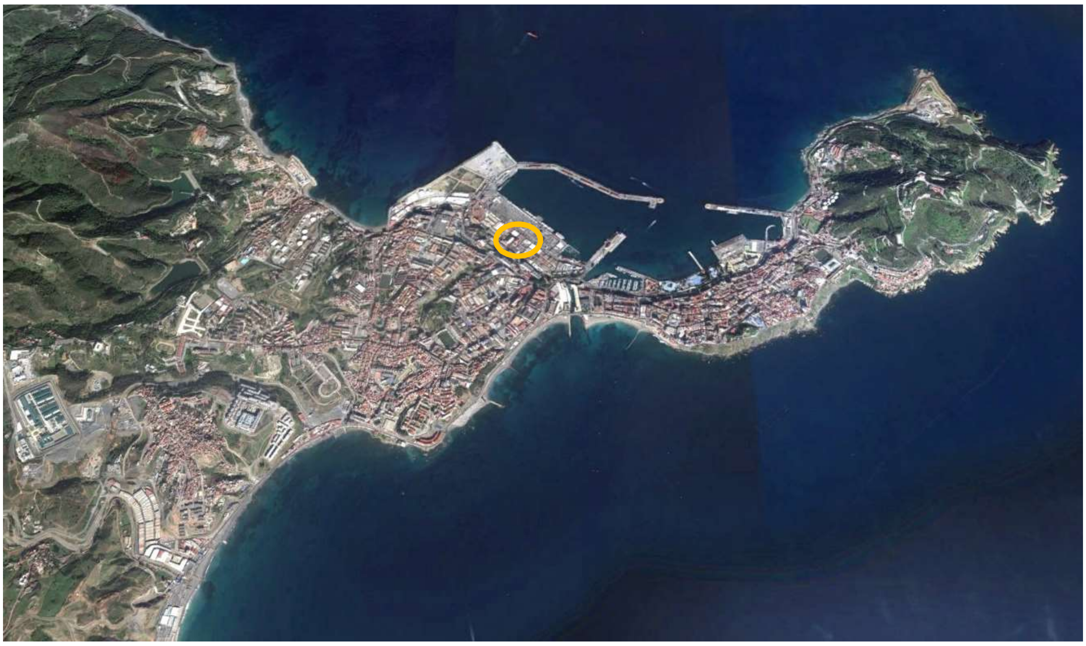
Assuming that the population will increase until 86 000 habitants and expecting 265 litres per day of consumption per capita, the water consumption expected and provided by the desalination plant is shown below.

<table>
<tr><th rowspan="2"></th><th colspan="2">SURFACE WATER (m^3)</th><th rowspan="2">IDAM (m^3)</th><th rowspan="2">TOTAL WATER CONSUMPTION (m^3)</th><th rowspan="2">POPULA TION</th><th rowspan="2">CONSUMPTION PER CAPITA (l/day)</th></tr>
<tr><th>INFIERNO</th><th>RENEGADO</th></tr>
<tr><td>EXPECTED</td><td>289,442</td><td>1,737,021</td><td>6,291,887</td><td>8,318,350</td><td>86,000</td><td>265</td></tr>
<tr><td>PERCENTAGE</td><td>3%</td><td>21%</td><td>76%</td><td>100%</td><td></td><td></td></tr>
</table>

Table 5. Expected values of water consumption and population in Ceuta.

4. ENERGY SUPPLY SYSTEM

As with the water supply, Ceuta is an island regarding energy supply. It is not connected to the Iberian Peninsula or to Morocco, but it is supplied by a thermal plant fed with fuel.



Map 8. Location of thermal plant. (Google Earth Pro, 2016)

The diesel plant of Ceuta was inaugurated in 1980. Since then, it is the only centre of energy production of the city. This plant, which is property of Endesa, has an installed capacity of 97.7 MW. It is located near the port of Ceuta.

At the present, the plant is composed of ten generators, nine of them powered by diesel motors and one powered by gas turbine. The fuel used is fuel-oil BIA. Additionally, diesel is used as auxiliary fuel for start and stop of the diesel generators, and automotive gas-oil for the gas turbine. (Pedrosa, 2015, p. 5)

The power plant supplies electricity to the city following an “island system”, where the production depends almost instantaneously on the demand, and the electric energy distribution starts directly from the plant.

THERMAL PLANT ANNUAL PRODUCTION (MWh)	
YEAR	**MWh/year**
2010	234,253
2011	222,514
2012	232,455
2013	220,642
2014	231,064
2015	225,843
AVERAGE ANNUAL PRODUCTION	**227,795 MWh/year**

Table 6. Thermal plant annual production. (Pedrosa, 2015, p. 20)

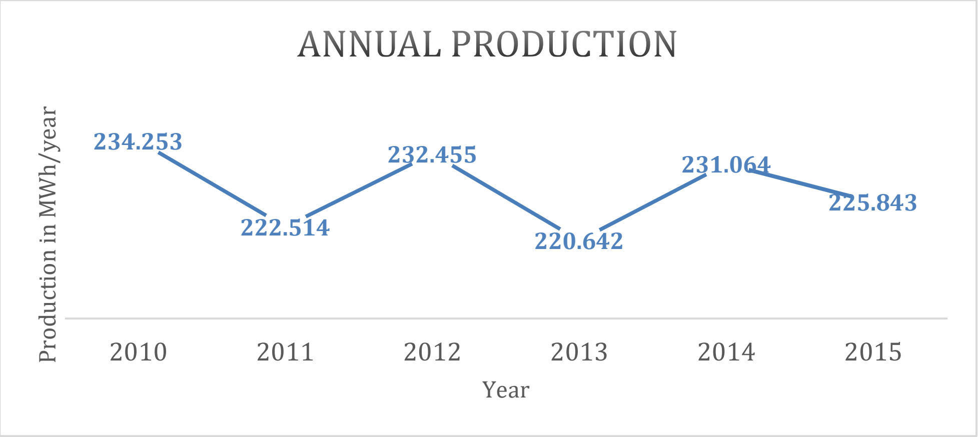


Figure 8. Annual production. (Pedrosa, 2015, p. 20)

The production is strongly influenced by the desalination plant due to the high quantity of energy that this plant needs to desalinate the water. Thus, it is related to the character wet or dry of the period. It can be deduced then that the production during the next years will not be increased because, as it has been said before, the water consumption is decreasing.

5. PROPOSED PROJECTS

The purpose of this master thesis is to reduce the carbon footprint of the water system of Ceuta. This idea will be developed from the point of view of ACEMSA, with the objective of reducing the cost of energy and water to the company.

Two different projects will be studied for this purpose:

- Hydropower Project
- Solar Photovoltaic Project

And, of course, the combination of both.

5.1. HYDROPOWER PROJECT

As it has been said before, part of the water used for consumption in the city of Ceuta comes from the Renegado Reservoir. The current system consists of a pipe which takes the water from the intake tower and drives it to a chamber where the energy is dissipated. After that, the water goes to the treatment plant to be pumped to the rest of the city.

Map 9. Pipe from intake tower to dissipation chamber.

This project focus on utilize the difference of height to create energy by installing a turbine instead of just dissipating the energy. The viability of the project will be studied by making the necessary calculations of energy produced, and the corresponding economic analysis will be performed in order to determine the feasibility of the development.

5.1.1. AVAILABLE HEAD

The dissipation chamber is located at a height of 40 meters above the sea level, and the maximum head of the Renegado reservoir is 82.1 meters. But this difference of height cannot be used to generate energy. It will be necessary to take into account the average water level and the head loss to know the actual head.

The daily values of water level during the past three years (included in Appendix 1) have been used for calculating the average head. The next graphs and table present the information obtained about the water level. (Aguas de Ceuta S.A. (ACEMSA), 2016)

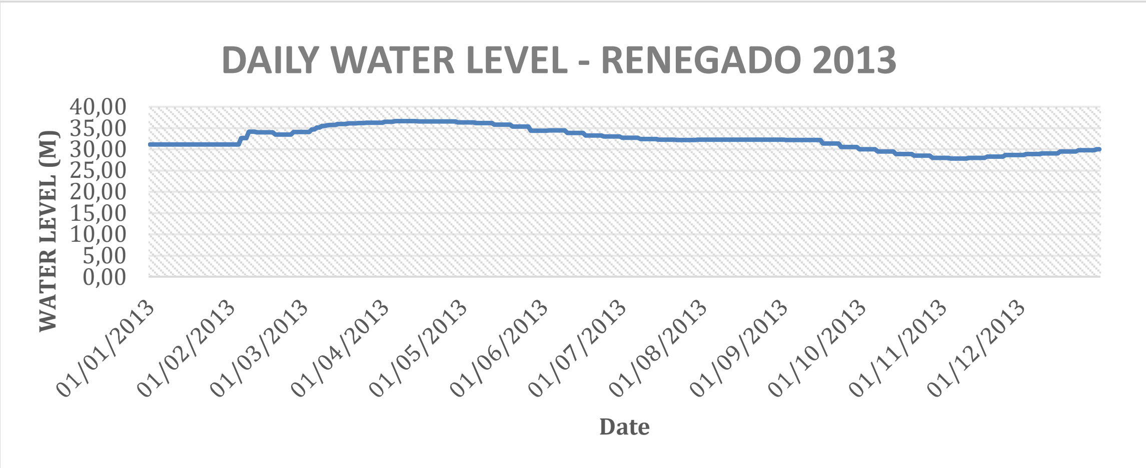


Figure 9. Daily water level in 2013. (Aguas de Ceuta S.A. (ACEMSA), 2016)

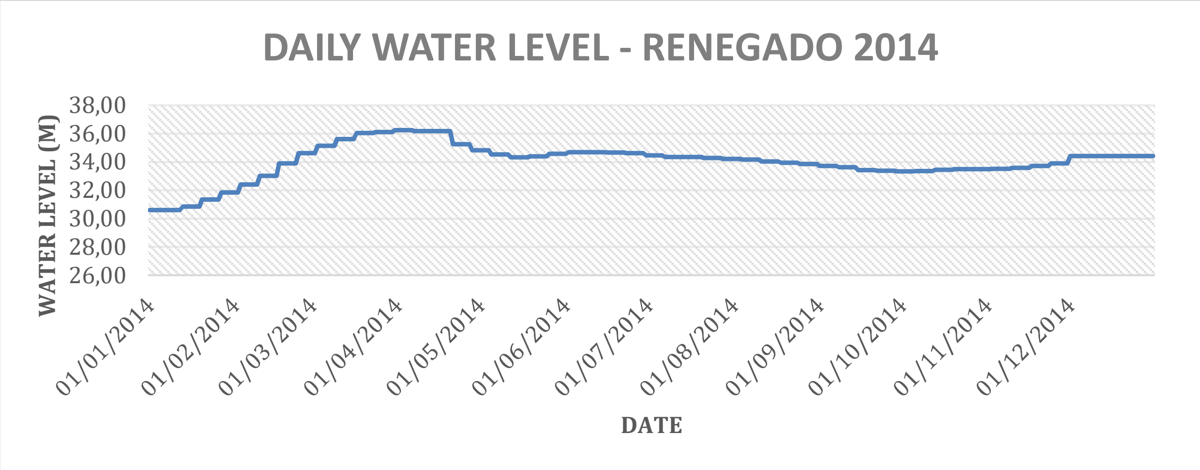


Figure 10. Daily water level in 2014. (Aguas de Ceuta S.A. (ACEMSA), 2016)

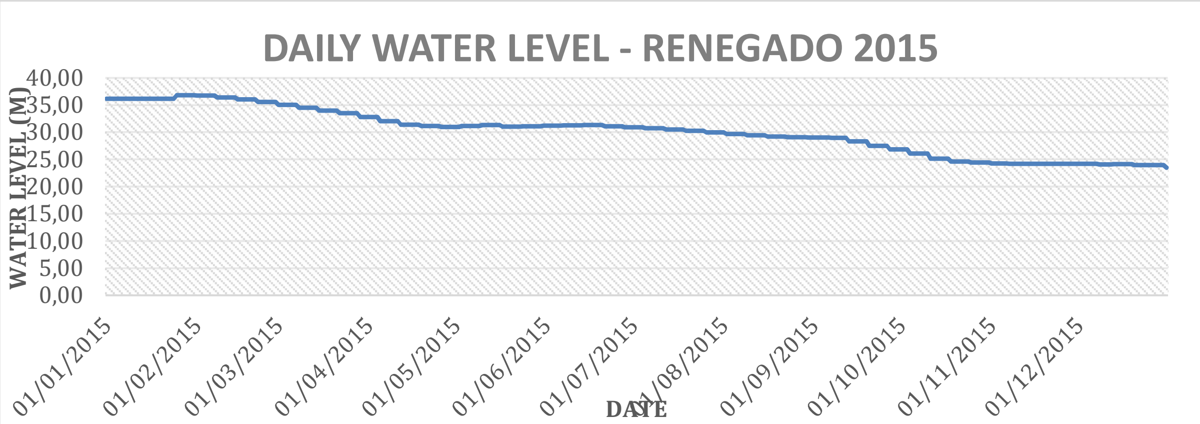


Figure 11. Daily water level in 2015. (Aguas de Ceuta S.A. (ACEMSA), 2016)

YEAR	AV. WATER LEVEL (m)	M.A.S.L.
2013	32,38	77,11
2014	34,03	78,76
2015	30,13	74,86
Hgross	32,18	**76,91**

Table 7. Average water level. (Aguas de Ceuta S.A. (ACEMSA), 2016)

For further calculations, the water level used will be the average water level from the past three years.

Then, the gross head can be calculated as the difference between the height above the sea level of the average water level and the height of the dissipation chamber. Thus, the gross head is 36.91 meters.

Besides the head, it is essential to know the discharge. ACEMSA has provided information about the maximum and minimum discharge available.

Qmax	0.24 m3/s
Qmin	0.03 m3/s

Table 8. Maximum and minimum discharge (Aguas de Ceuta S.A. (ACEMSA), 2016)

With this data, and knowing that the pipe is ductile iron pipe, with a length of 286 meters and its diameter is 0.6 meters, the head loss can be calculated by using the Manning formula. The Manning coefficient used is:

$$n = 0.012$$

Figure 12. Manning Coefficient for ductile iron pipe.

Therefore, the net head available is 36.54 meters (Appendix 2).

5.1.2. AVAILABE FLOW

Another important data is the available flow from the reservoir. The water company regulates the flow taken from the reservoir during the year depending on several factors, such as the period of the year (dry or wet), the level of water both in the Renegado and Infierno reservoirs, etc.

ACEMSA collect the daily discharge from the reservoir since 2010, but due to the leakage during the first years and the reduction of water consumption because of the repair plan

(3.5. CURRENT SYSTEM), it is more accurate to use the last three year to find the average flow horizon. The daily data is attached in the Appendix 2.

YEAR	AV. FLOW (m^3)
2013	2,502,205
2014	976,780
2015	1,732,078
AVERAGE FLOW	**1,737,021**

Table 9. Average flow of the reservoir. (Aguas de Ceuta S.A. (ACEMSA), 2016)

The average flow will be used to calculate the potential energy available. As a first approximation, an efficiency of 90% of the turbine has been used to calculate the energy that can be generated with the flow and head available. The result obtained is 147,006.42 kWh per year.

It is also possible to calculate the turbine capacity at maximum discharge approximately, getting a result of 88.42 kW.

5.1.3. TURBINE OPTIMIZATION

The type of turbine is chosen regarding two factors: discharge and head. With the maximum discharge and the head obtained for this project, the best option is the Francis turbine.

However, due to this type of flow, which is not constant and it will be released when it is necessary for consumption, it would be better to choose a Pelton turbine. This is because this type of turbine works at a high efficiency even with low flows, as opposed to the Francis turbine, which needs to work with high flows to obtain a high efficiency. It even can be damaged as a result of working with low flows for a long time.

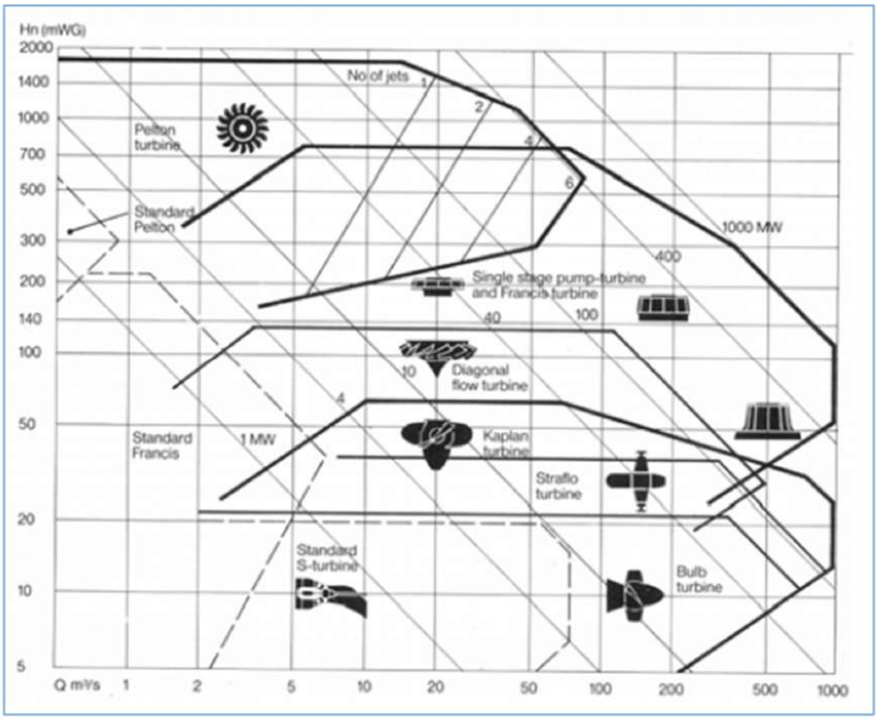


Figure 13. Turbine type operational range.

Another option is to use two Francis turbines with a 50% of capacity each one. This scheme gets more flexibility regarding low flows and efficiency.

The difference of efficiency between the three options (one Francis turbine, one Pelton turbine or two Francis turbines) is shown in the next charts.

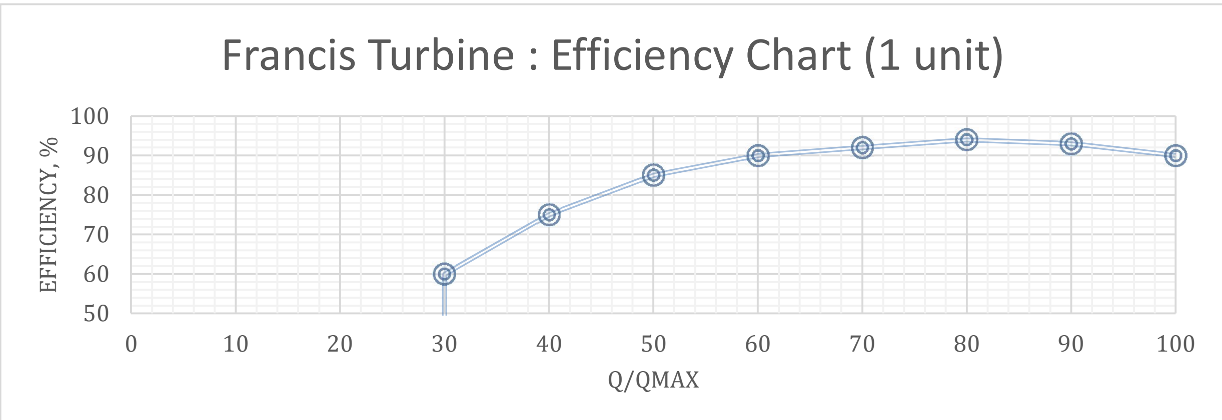


Figure 14. Efficiency of one Francis turbine.

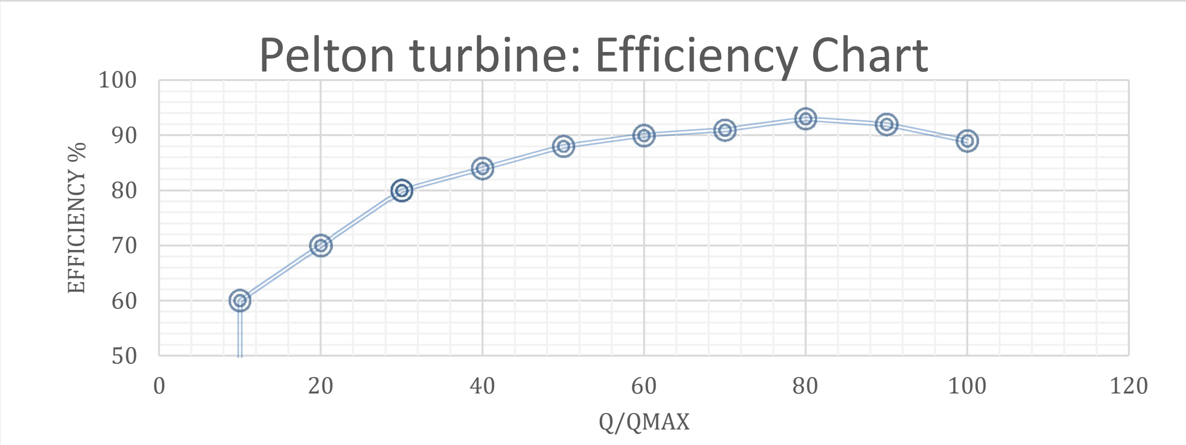


Figure 15. Efficiency of one Pelton turbine.

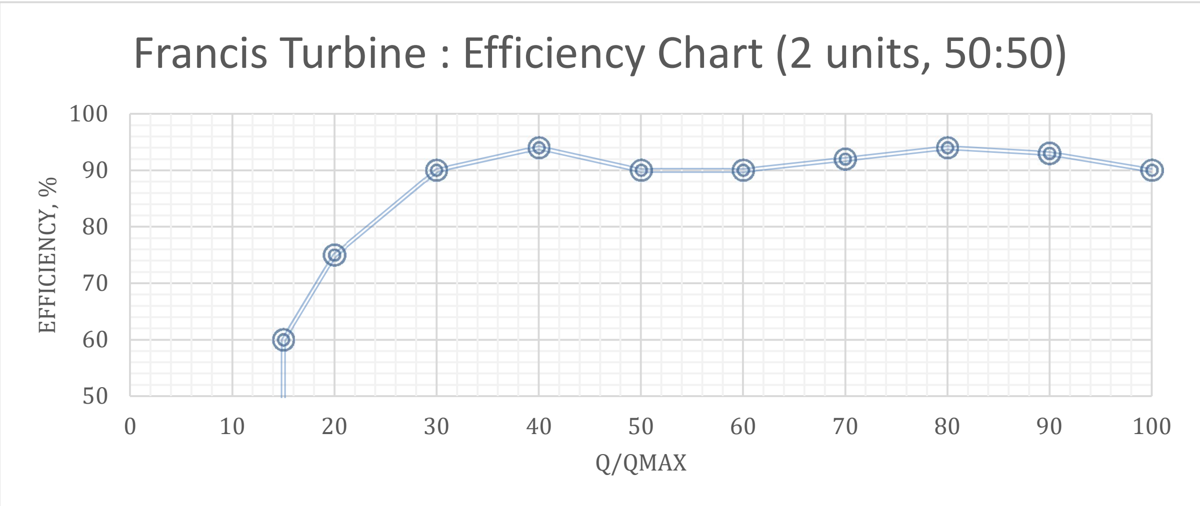


Figure 16. Efficiency of two Francis turbines.

In order to determine which scheme is the most feasible, it is necessary to calculate the costs per kWh. This unit will allow the comparison between the options.

5.1.4. PROJECT COMPONENTS

This project is a micro hydropower type, so the costs cannot be too high to have a viable project.

Due to the characteristics of the scheme, some of the necessary elements, such as the pipe or the intake, are already built.

The main element to build is a bypass near the dissipation chamber. This component aims to drive the water flow to the turbine, which will be placed near the bypass inside of a small power plant. In case of failure or technical stop of the turbine, the bypass allows to divert the water to the dissipation chamber and to the treatment plant.

The bypass designed is made of ductile iron pipe. It will be necessary to install a pipe of 20 meters and a throttle valve with electric drive in each connection between the new pipe and the old one. These valves permit to control the water way. The design also include the joints and bends required for a correct operation.

Regarding the power plant, it will be a small building made to accommodate both the turbine and the rest of components.

5.1.5. DETAILED COST CALCULATIONS

Detailed cost calculations have been made for each scheme, and they are shown below. The construction costs were computed based on data provided by Saint Gobain (Spanish company which make pipes and accessories), Multiconsult ASA, which helped with the turbine costs and “Cost Base for Hydropower Plants with a generating capacity of more than 10 000 kW” (SWECO AS Norge, 2012), also a help in finding the turbines cost.

FRANCIS TURBINE: 1 UNIT				
ELEMENT	**UNIT**	**QANTITY**	**UNIT RATE (Eur/unit)**	**COST (Euros)**
Design Discharge	m^3/s	0,24		
Gross Head	m	36,91		
Net Head	m	36,65		

A. CIVIL WORKS				
1	**Bypass**			
Diameter	mm	600		
Length	m	20	268	5,353
Type	FD			
Bend	no.	2	2,423	4,845
Throttle valve with electric drive	no.	2	2,547	5,094
Universal joints	no.	4	146	584
Special piece (connection with existing pipe)	m	5	88	438
2	**Power house**			
Type	Surface			
Installed capacity	kW	75		
Cost	Eur	15,000		15,000
Total Cost of Civil Works				**31,314**
B. ELECTRO-MECHANICAL EQUIPMENT				
Installed Capacity	kW	75		
1	**Turbine and electro mechanical equipment**			
Cost	Eur/kW	75	1,148	86,463
Total cost of Electro-mechanical Equipment				86,463
Civil Works +Electro-mechanical Equipment				117,777
40% Contigency				47,111
Total Cost (Eur)				**164,888**
Total Energy Generation (GWh/Year)				**0,15**
Unit Cost of Energy (Eur/kWh)				**1,10**

Table 10. Detailed cost calculations for one Francis turbine scheme. (Multiconsult ASA, 2016) (Saint Gobain S.A., 2016) (SWECO AS Norge, 2012)

PELTON TURBINE				
ELEMENT	**UNIT**	**QANTITY**	**UNIT RATE (Eur/unit)**	**COST (Euros)**
Design Discharge	m^3/s	0,24		
Gross Head	m	36,91		
Net Head	m	36,65		
A. CIVIL WORKS				

1	**Bypass**			
Diameter	mm	600		
Length	m	20	268	5,353
Type	FD			
Bend	no.	2	2,423	4,845
Throttle valve with electric drive	no.	2	2,547	5,094
Universal joints	no.	4	146	584
Special piece (connection with existing pipe)	m	5	88	438
2	**Power house**			
Type	Surface			
Installed capacity	kW	85		
Cost	Eur	15,000		15,000
Total Cost of Civil Works				**31,314**
B. ELECTRO-MECHANICAL EQUIPMENT				
Installed Capacity	kW	85		
1	**Turbine and electro mechanical equipment**			
Cost	Eur/kW	85	2,067	174,878
Total cost of Electro-mechanical Equipment				174,878
Civil Works +Electro-mechanical Equipment				206,193
40% Contigency				82,477
Total Cost (Eur)				**288,670**
Total Energy Generation (GWh/Year)				**0,15**
Unit Cost of Energy (Eur/kWh)				**1,92**

Table 11. Detailed cost calculation for one Pelton turbine scheme. (Multiconsult ASA, 2016) (Saint Gobain S.A., 2016) (Saint Gobain S.A., 2016)

FRANCIS TURBINE: 2 UNITS				
ELEMENT	**UNIT**	**QANTITY**	**UNIT RATE (Eur/unit)**	**COST (Euros)**
Design Discharge	m^3/s	0,24		
Gross Head	m	36,91		
Net Head	m	36,65		
A. CIVIL WORKS				
1	**Bypass**			
Diameter	mm	600		

Length	m	20	268	5,353
Type	FD			
Bend	no.	2	2,423	4,845
Throttle valve with electric drive	no.	2	2,547	5,094
Universal joints	no.	4	146	584
Special piece (connection with existing pipe)	m	5	88	438
2	**Power house**			
Type	Surface			
Installed capacity	kW	88		
Cost	Eur	18,000		18,000
Total Cost of Civil Works				**34,314**
B. ELECTRO-MECHANICAL EQUIPMENT				
Installed Capacity	kW	88		
1	**Turbine and electro mechanical equipment**			
Cost	Eur/kW	88	1,378	121,836
Total cost of Electro-mechanical Equipment				121,836
Civil Works +Electro-mechanical Equipment				156,150
40% Contigency				62,460
Total Cost (Eur)				**218,611**
Total Energy Generation (GWh/Year)				**0,15**
Unit Cost of Energy (Eur/kWh)				**1,46**

Table 12. Detailed cost calculation for two Francis turbines scheme. (Multiconsult ASA, 2016) (SWECO AS Norge, 2012) (Saint Gobain S.A., 2016)

The benefits of developing this project are related to the electric energy saved by the water company. The price paid by ACEMSA for each kWh is 0.12 Eur. Then, it is possible to know and compare the benefits obtained with each one of the options studied.

BENEFITS-COSTS COMPARISON			
Benefits	1Francis	2Francis (50:50)	1Pelton
Power, kW	75	88	85
Energy Production, GWh	0,13	0,16	0,15
Energy Value, EUR	15,887	18,656	17,852
Costs			
Civil Works	31,314	34,314	31,314
Turbine Cost, EUR/kW	1,148	1,378	2,067

Turbine Cost, EUR	86,463	121,837	174,876
Sub Total Cost EUR	117,777	156,152	206,190
Unforeseen Cost, EUR	47,111	62,461	82,476
Total Cost, EUR	164,888	218,613	288,666
Total Cost/Energy, EUR/kWh	1,25	1,41	1,94

Table 13. Benefit – Cost comparison between the three schemes.

5.1.6. ECONOMIC ANALYSIS

In previous calculations, one of the options arises as the cheapest one. However, economic analysis of all of the options will be developed in order to be able to compare them more properly.

Discounted cash flow method has been utilized to determine the feasibility of the projects. It consists in determining the Net Present Value (NPV), the Interest Rate of Return and the Benefit-Cost Ratio. The viability of the projects will depend on the results of these three values.

There are some aspects to consider in order to perform an economic analysis. These aspects are common for the three features (i.e. one Francis turbine, two Francis turbines, one Pelton turbine).

- The discount rate is 7%.
- The period of preconstruction, construction and testing will last three years, starting in 2017.
- The operation and maintenance cost has been stablished as 1% of the total costs.
- The project lifetime is 40 years.

OPTION 1. POWER PLANT WITH ONE FRANCIS TURBINE

The next diagram shows the cash flow. Calculations made to develop the graph are detailed in Appendix 4.

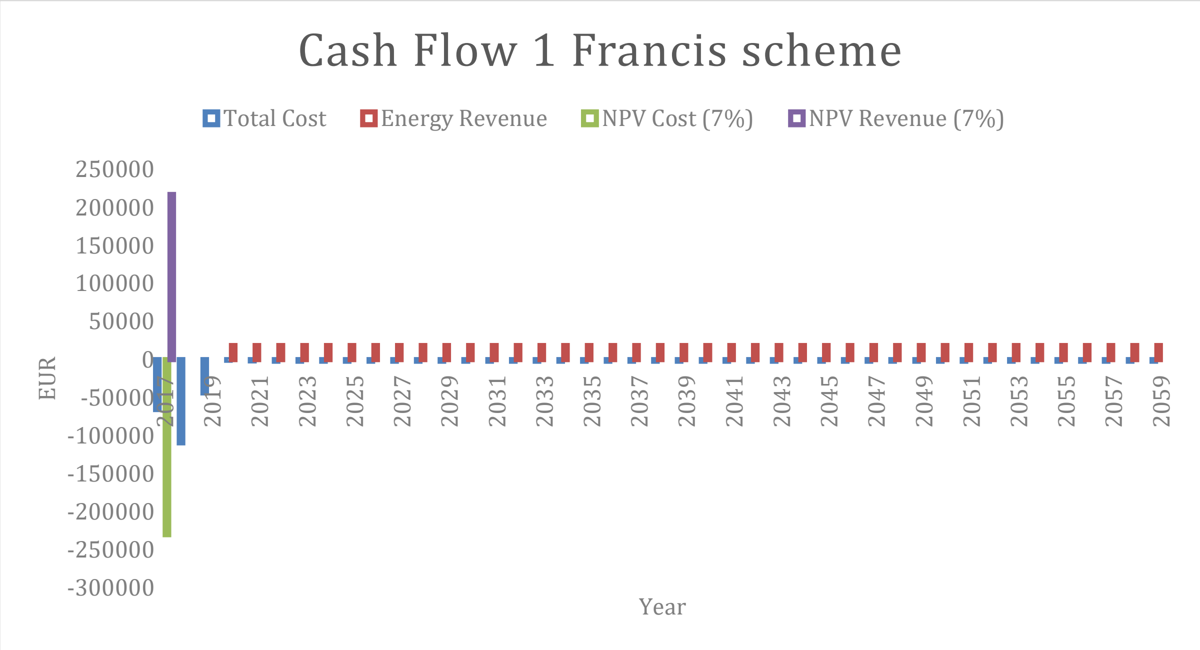


Figure 17. Cash flow graph for one Francis turbine scheme.

The results obtained from the economic analysis regarding Net Present Value, Interest Rate of Return and Benefit – Cost Ratio for one Francis turbine are shown below:

OPTION 1: HYDROPOWER PLANT WITH ONE FRANCIS TURBINE		
APPROACH	**VALUE**	**MEANING**
NET PRESENT VALUE	11,673.41	>0 Feasible
INTEREST RATE OF RETURN	7.59 %	>NPV Feasible
BENEFIT – COST RATIO	1.1	>1 Feasible

Table 14. Economic analysis results for Option 1.

Calculations are shown in Appendix 4.

OPTION 2. POWER PLANT WITH ONE PELTON TURBINE

The cash flow diagram, in addition to results for NPV, IRR and B-C ratio for this scheme are attached below. Calculations are demonstrated in Appendix 5.

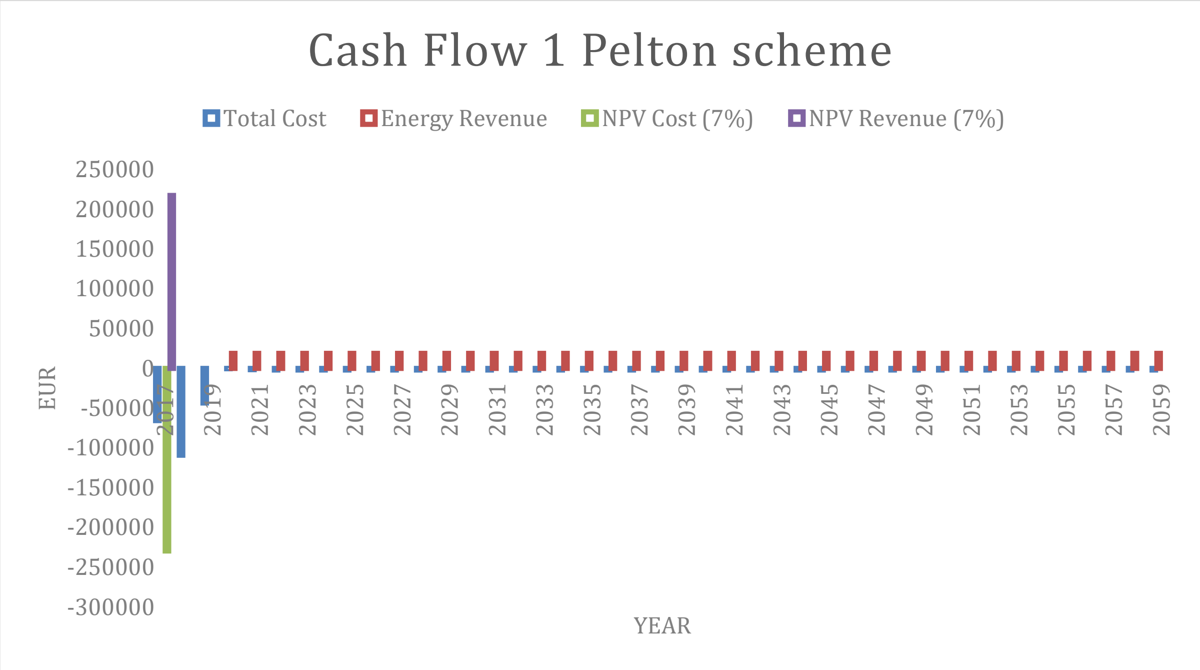


Figure 18. Cash flow graph for one Pelton turbine scheme.

OPTION 2: HYDROPOWER PLANT WITH ONE PELTON TURBINE		
APPROACH	VALUE	MEANING
NET PRESENT VALUE	-95,566.10	<0 **NOT** Feasible
INTEREST RATE OF RETURN	3.94 %	<NPV **NOT** Feasible
BENEFIT – COST RATIO	0.7	<1 **NOT** Feasible

Table 15. Economic analysis results for option 2.

OPTION 3. HYDROPOWER PLANT WITH TWO FRANCIS TURBINES

The calculations of this option have been performed for two identical Francis turbines with an efficiency equivalent to half of the efficiency reached with one Francis turbine scheme. Calculations are shown in Appendix 6.

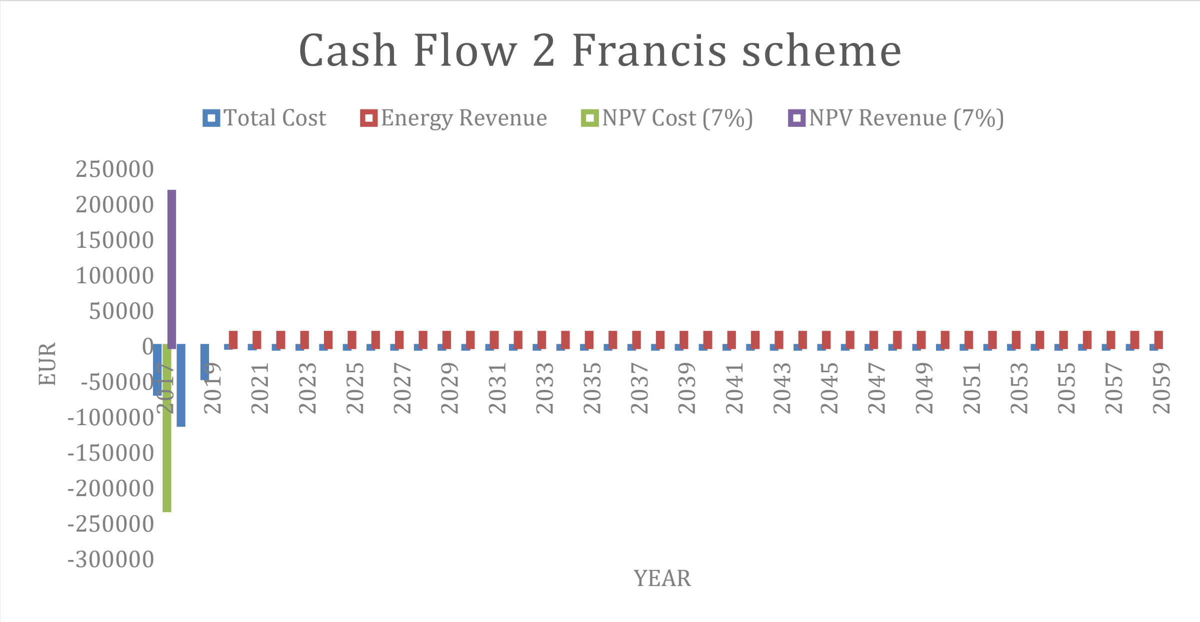


Figure 19. Cash flow graph for two identical Francis turbines.

OPTION 3: HYDROPOWER PLANT WITH TWO FRANCIS TURBINES		
APPROACH	**VALUE**	**MEANING**
NET PRESENT VALUE	-12,559.55	<0 **NOT** Feasible
INTEREST RATE OF RETURN	6.51 %	<NPV **NOT** Feasible
BENEFIT – COST RATIO	0.9	<1 **NOT** Feasible

Table 16. Economic analysis result for option 3.

5.1.7. CONCLUSIONS

In Chapter 5 of this thesis it has been studied the possibility of installing a hydropower plant in Renegado Reservoir. The objective is to make use of the available head and the flow taken from the reservoir for water consumption, and thereby to achieve a reduction of ACEMSA's energy costs.

Three systems have been studied, where the difference between the number and / or the type of turbine influences not only the efficiency and the energy generated, but also the installation costs.

After performing a detailing cost calculation for each system, and the corresponding economic analysis, it has been obtained that the only viable scheme is Option 1, the one with only one Francis turbine. Yet, it can be deducted from the results that the benefits obtained with the implementation of the power plant are reduced.

However, there is a detail which has not been taken into account in previous calculations.

The European Union promote this kind of projects, to what they call I+D+i projects. Therefore, the initial construction costs could be subsidised up to 50% of the total construction costs. On the other hand, the Spanish Industry and Energy Ministry also seeks to promote this type of installations, thus the financing construction costs of this project would be largely covered by public funds.

Knowing this, and with the results of the economic analysis, the recommendation is to develop the construction project of a hydropower plant with a Francis turbine scheme in Renegado Reservoir, in the city of Ceuta.

5.2. SOLAR PHOTOVOLTAIC PROJECT

The purpose of this work is to reduce the carbon footprint of Ceuta by reducing the energy consumption of the water company ACEMSA.

Besides the hydropower project, it is going to be studied the possibility of developing a solar photovoltaic project.

The problem arises when the terrain and the available area of the city are observed. Ceuta is located in a small peninsula with steep terrain and an area of 20 km^2. Then, it is difficult to find a zone wide enough to build this kind of project.

Because all of this, it has been determined that the best option for this city is to install a floating solar photovoltaic project.

There exist two possible locations: Renegado and Infierno reservoirs. Renegado is used for water consumption and for recreational uses. Infierno is used for water consumption, but it is not used for other uses. Therefore, the best location for this type of project is Infierno reservoir.

5.2.1. INFIERNO RESERVOIR

This reservoir has a capacity of 0.65 Hm^3, an average water level of 11.67 meters and the area of the water surface at the average water level is 49,300 m^2.

In order to determine the area that can be occupied by the floating solar panels, it is necessary to take into account that the floating panels only can occupy the area of the reservoir at its minimum water level.

Down below the relation between water level, volume and area of the water surface of Infierno reservoir is shown.

HEIGTH m	M.A.S.L.	VOLUME m^3	VARIATION m^3	AREA m^2
2.50	45.00	44,215	149	30,500
7.50	50.00	161,695	117,480	35,300
12.50	55.00	360,705	199,010	52,100
17.50	60.00	654,266	293,561	63,100

Table 17. Area and volume of Infierno Reservoir according to water level. (Aguas de Ceuta S.A. (ACEMSA), 2016)

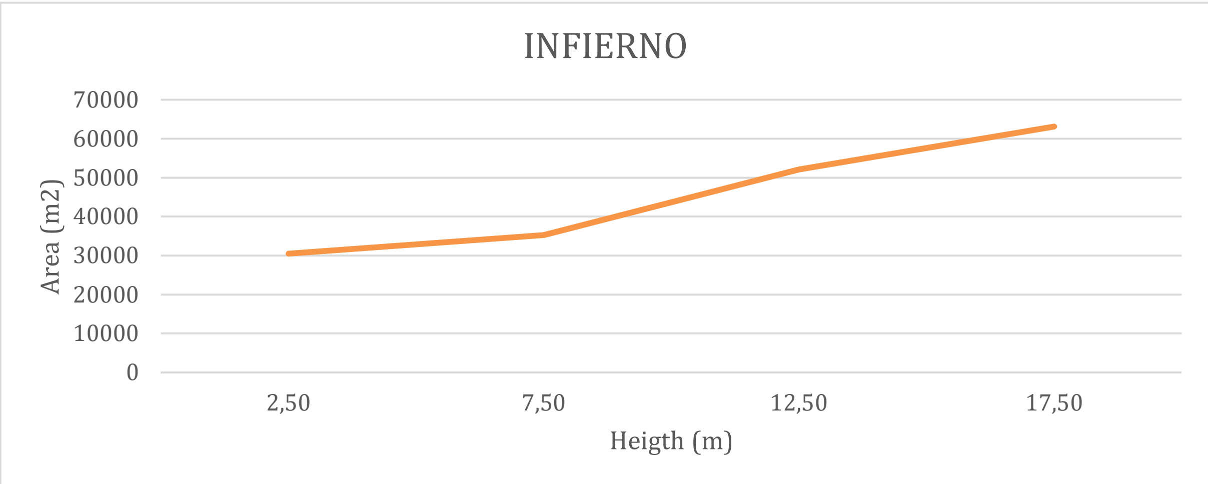


Figure 20. Area – Volume curve.

The minimum water level is 2.50 meters, equivalent to a minimum area of 30,500 m^2. Next figure shows the shape of this area.

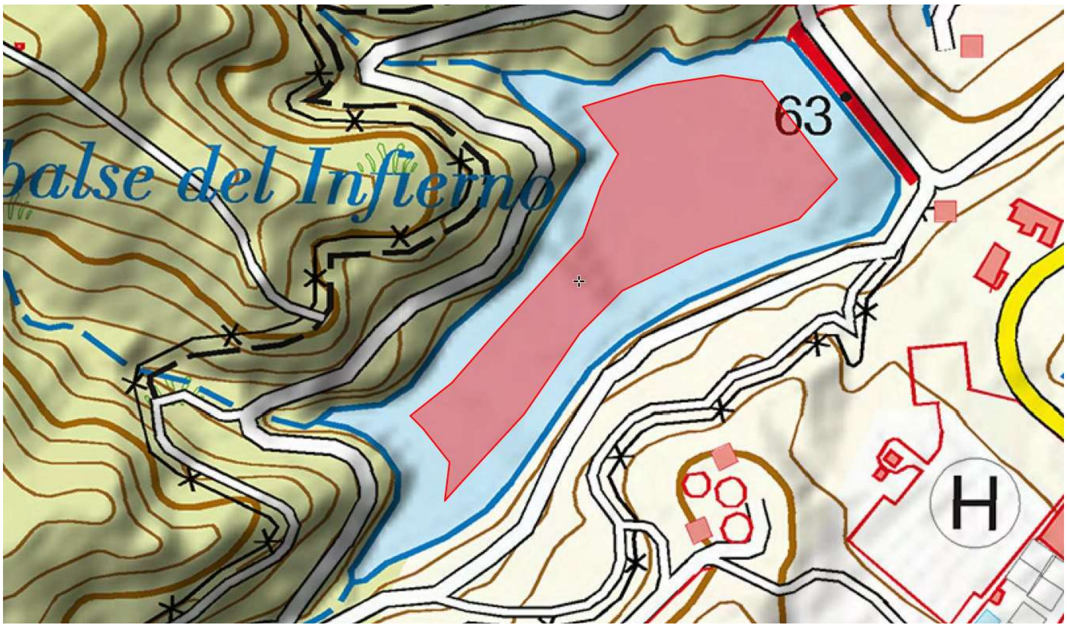
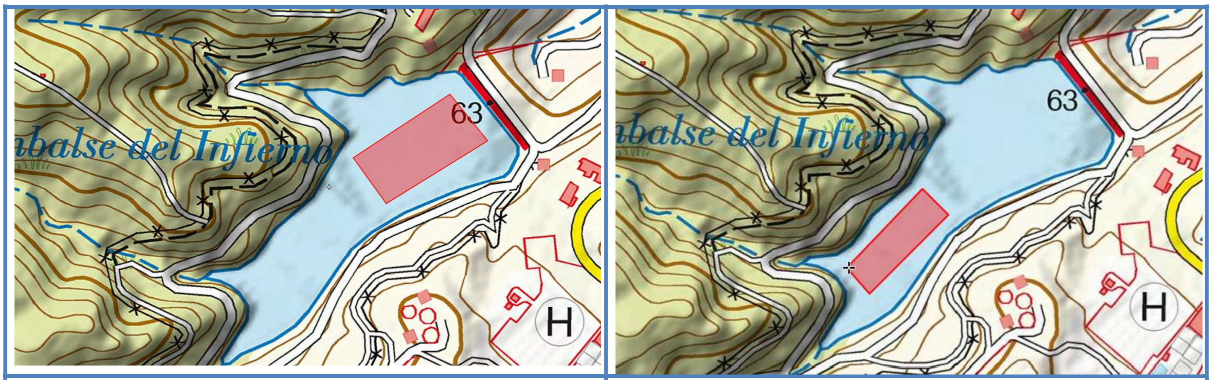


Figure 21. Minimum area available for installing floating solar panels. (Instituto Geográfico Nacional, 2016)

Now, in the image can be seen that in the reservoir there is a protuberance at the bottom of the reservoir. Because of that, it will be necessary to divide the areas where the solar panels can be installed in two parts.

This solution prevents the solar panels collide with the reservoir bottom when the water level is minimum.

Therefore, the available area for installing the floating solar panels are the ones shown below.



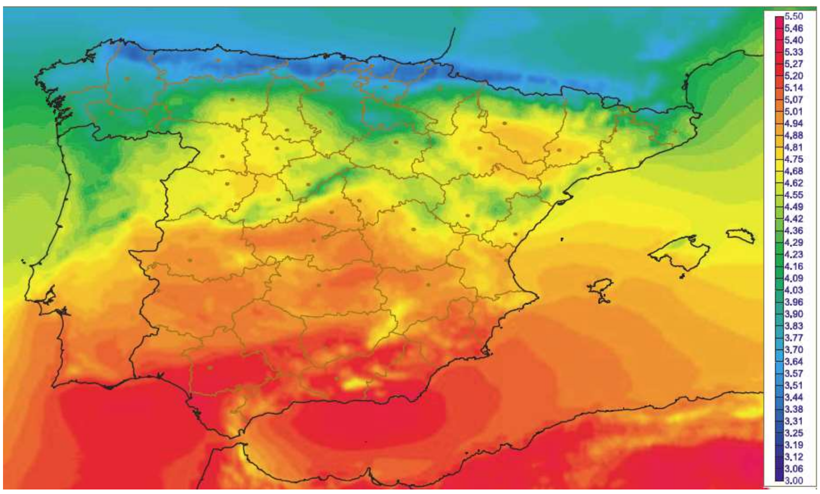
Area = 13500 m²	Area = 7900 m²
TOTAL AREA = 21400 m²	

Figure 22. Floating solar panels area. (Instituto Geográfico Nacional, 2016)

In addition to the area, there are other important factors to consider during the design phase.

Due to the disposition of the areas and the steepness of the terrain surrounding the reservoir, which can generate shadows, the orientation chosen for the solar panels is 45 degrees west.

The average global irradiation for this location is 4.91 kWh/m^2 per day. (Agencia Estatal de Meteorología, 2006)



Map 10. Average global irradiation in Spain. (Agencia Estatal de Meteorología, 2006)

5.1.2. SIMULATION

Thanks to Multiconsult ASA it has been possible to simulate the designed floating solar PV system, and the results of the simulation are shown below.

FLOATING SOLAR PV PROJECT	
System type	Grid - connected
Azimuth	45⁰
Number of modules	8680
Pnom total	2,257 kWp
Pnom total	2,000 kW ac
Produced Energy	3,645 MWh/year
Specific production	1,615 kWh/kWp/year
Performance Ratio	83.6 %

Table 18. Results of simulating the PV system. (Multiconsult ASA, 2016)

Another orientation which can provide a high efficiency for this kind of project is east – west. If this orientation would have chosen, the efficiency would increase, but the number of panels would decrease. Therefore, there is not a clear benefit of using an east – west orientation. There is another possibility, which is to orientate the panels to the south. This scheme could increase the efficiency of the system.

The performance ratio of the project is high. There are two factors that influence this value. One the one hand, the global irradiation value for this location is high. On the other hand, although Ceuta is located in the south of Spain, its mild climate reduces the loss of efficiency due to heat.

The total monthly production obtained for an average year is shown in the next graph.

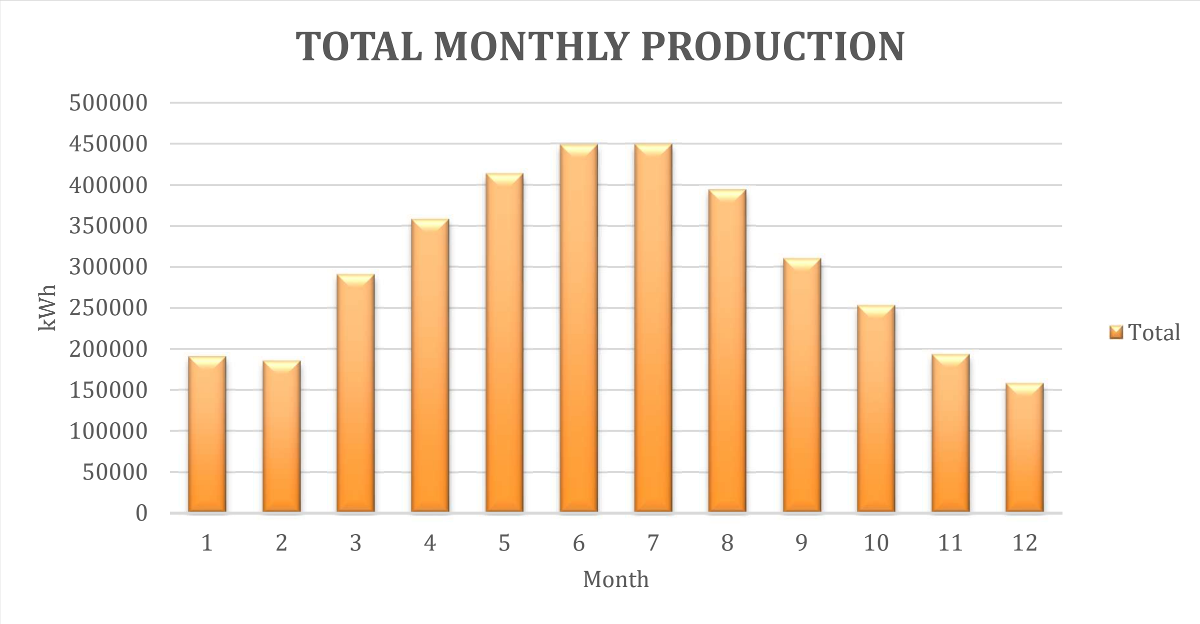


Figure 23. Total monthly production in kWh. (Multiconsult ASA, 2016)

In the next figure it can be seen the variation of production depending on the season of the year and the time of the day.

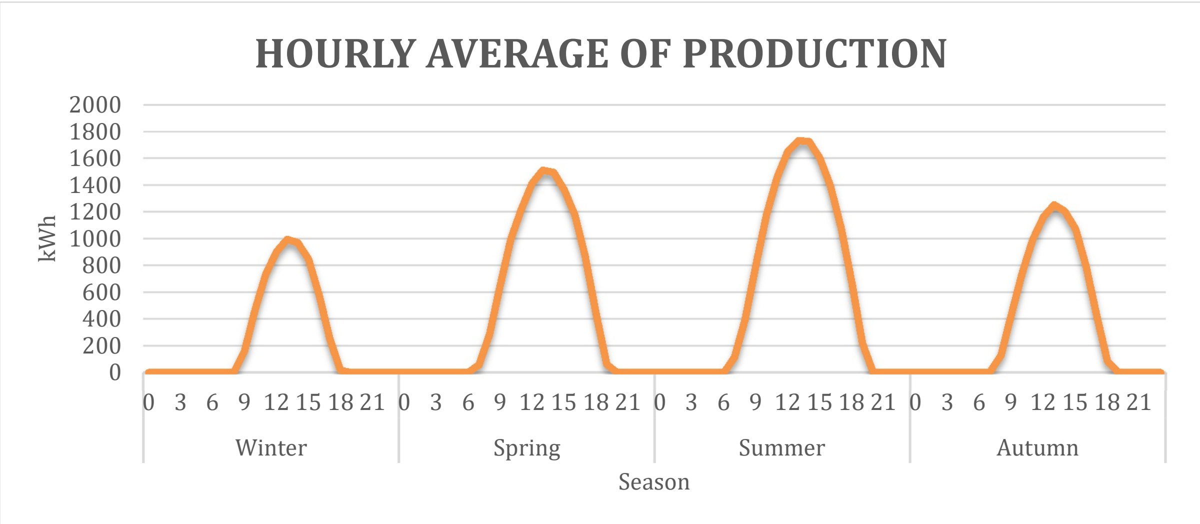


Figure 24. Hourly average of production in kWh. (Multiconsult ASA, 2016)

5.1.3. PROJECT COSTS

Nowadays this type of projects is not very extended yet, thus it is not easy to find information about the elements which conform the system.

Therefore, to calculate the cost it has been used the information obtained thanks to Multiconsult ASA, which indicate that the cost of a floating solar PV project can be calculated by using the relation 1Wp = 1,7 USD . As this project is located in Spain, the currency used is euros, then 1Wp = 1,496 EUR.

Henceforth, the costs of this Project are:

Costs		
Production	2,257	kWp
Value	1,496	Eur/Wp
Total Cost	**3,376,472.00**	**Euros**

5.1.4. PROJECT BENEFITS

The development of the floating solar PV project can generate different benefits.

On the one hand, the cost that ACEMSA will save by generating its own energy instead of buying it to the energy company. This benefit is calculated by using the energy price that ACEMSA is currently paying, which is 0.12 eur/kWh.

Benefits		
Production	3,645	MWh/year
Energy cost	0.12	Eur/kWh
Energy benefit	**437,400.00**	**Eur/year**

On the other hand, when the reservoir is covered by the solar panels structure, the evaporation will decrease. Then, there will be more volume of water for consumption purposes, and henceforth ACEMSA will reduce the water bought to the desalination plant.

The benefit of the reduction of evaporation can be calculated by knowing how much ACEMSA pays for 1 m^3 of desalinated water to the desalination plant. They are currently paying 0.5 eur/ m^3 for it.

It is also necessary to know the evaporation in the reservoir. For this purpose, Thornthwaite Formula for evapotranspiration has been used, since the Spanish State Weather Agency does not provide enough information to calculate the actual evaporation.

According to this formula, the value of the evapotranspiration is 782.42 mm per year (Amorox, 2010), but this result is lower than expected. The value for this area is around 1100 mm per year (Agencia Estatal de Meteorología, 2016), therefore despite the value obtained with the Thornthwaite formula, it will be used the one corresponding to 1100 mm per year because it is more accurate. Calculations are shown in Appendix 7. (Amorox, 2010)

The evaporation and the benefit of covering the reservoir with solar panels can be seen below.

EVAPORATION (mm/year)	EVAPORATION (m3/ha.month)	EVAPORATION INFIERNO (m3)	EVAPORATION INFIERNO WITH PV (m3)	VOLUME SAVED WITH PV (m3)	BENEFIT (EUR)
1,100.00	11,000.00	511,500.00	276,100.00	235,400.00	**117,700.00**

Table 19. Benefit obtained by installing floating PV and therefore reducing the evaporation. (Aguas de Ceuta S.A. (ACEMSA), 2016)

5.1.5. ECONOMIC ANALYSIS

After the cost and benefit calculations are done, next step is to know if the Project is feasible or not. For that purpose, an economic analysis has been performed. As in previous chapters, three different indices will help to determine the viability: NPV, IRR and B-C ratio.

The aspects considered for the economic analysis are:

- The discount rate is 7%.
- The period of preconstruction, construction and testing will last one year, starting in 2017.
- The operation and maintenance cost has been stablished as 2% of the total costs.
- The project lifetime is 25 years.

The summary of costs and benefits is shown in the table below.

Costs		
Production	2,257	kWp
Value	1,496	Eur/Wp
Total cost	**3,376,472.00**	**Euros**
Benefits		
Production	3,645	MWh/year
Energy cost	0.12	Eur/kWh
Energy benefit	437,400.00	Eur/year
Evap benefit	117,700.00	Eur/year
Total benefit	**555,100.00**	**Eur/year**

Table 20. Costs and benefits of the floating solar PV project.

Cash flow diagram is shown below. Calculations done can be seen in Appendix 9.

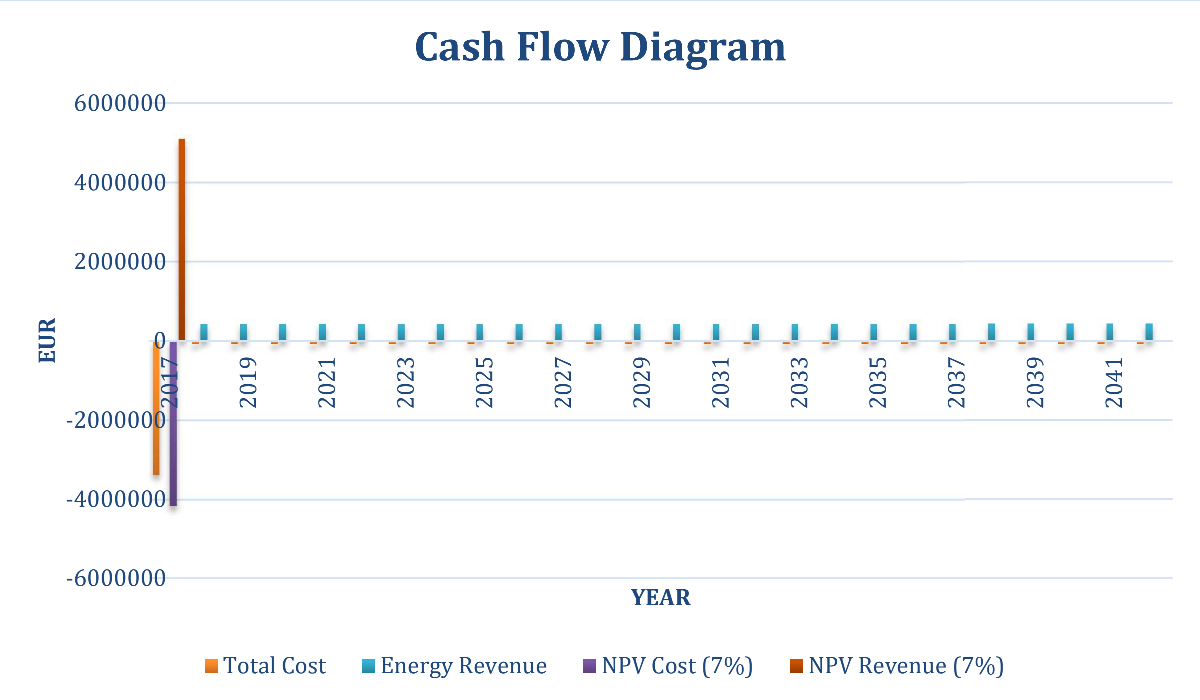


Figure 25. Cash flow diagram.

FLOATING SOLAR PHOTOVOLTAIC PROJECT		
APPROACH	**VALUE**	**MEANING**
NET PRESENT VALUE	933,845.34	>0 Feasible
INTEREST RATE OF RETURN	9.93 %	>NPV Feasible
BENEFIT – COST RATIO	1.2	>1 Feasible

Table 21. Values of NPV, IRR and B-C Ratio for the project.

5.1.6. CONCLUSIONS

After calculating the detailed costs of this project and the benefits obtained, and after the economic analysis, it can be determined that this project is viable, and its construction is strongly recommended.

In this way ACEMSA will increase its independence from both the desalination plant and the energy company. It also will reduce its costs, promoting the reduction of the carbon footprint in Ceuta.

Additionally to the economic analysis performed, it has to be taken to account that this kind of project, like the hydropower project, is likely to be subsidised by the European Union. Thus, the construction costs could reduce up to 50%.

5.3. HYDROPOWER PROJECT + FLOATING SOLAR PV PROJECT

This chapter seeks to summarize the costs and benefits that could have a project which integrates both approaches, hydropower and floating solar photovoltaic projects.

Regarding hydropower project, it has been chosen the most viable scheme, which is the one with one Francis turbine.

Project	HYDROPOWER	FLOATING SOLAR PV	TOTAL
Costs (EUR)	164,887.92	3,376,472.00	**3,541,359.92**
Benefits (EUR)	15,887.48	555,100.00	**570,987.48**
Energy generated (MWh/year)	132,40	3,645.00	**3,777.40**

Table 22. Summary of costs and benefits for all the projects.

6. FINAL CONCLUSION

This study started from the hypothesis of it is possible to reduce the carbon footprint. Although the results are not spectacular, they reflect that it is feasible to improve the conditions of a complex urban water system by implementing new renewable sources of energy and technologies such as floating solar panels or high efficient turbines for small flows.

The final recommendation seeks to encourage the local companies to involve and develop this type of projects, since it has been demonstrated that they provide not only economic but also important environmental benefits.

In particular, after studying the hydropower project and the PV project, it can be concluded that the development of the PV project can generate up to 28 times more energy than the hydropower project. Therefore, it is recommended to build up the floating solar panels project because the benefit/cost ratio is higher than the obtained from the other option. The sensitivity analysis also shows a positive response to changes in energy prices.

However, the development of the hydropower project it is also recommended since allthoug the amount of generated energy is much lower, the benefits related are important. On the one hand, the carbon footprint of the city will be reduced with the implementation of the project, and on the other hand, the energy produced will be used to pump the water from the pumping station to the city. Then, the water company will reduce its energy costs with this project.

Thus, there exists a wide field of work for improving the current energy system by using renewable energy sources and, consequently, for reducing the carbon footprint.

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DATE	WATER LEVEL RENEGADO (m)	DATE	WATER LEVEL RENEGADO (m)	DATE	WATER LEVEL RENEGADO (m)
01/01/2013	31,14	01/01/2014	30,60	01/01/2015	36,16
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04/01/2013	31,14	04/01/2014	30,60	04/01/2015	36,16
05/01/2013	31,14	05/01/2014	30,60	05/01/2015	36,16
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31/01/2013	31,14	31/01/2014	31,85	31/01/2015	36,82
01/02/2013	31,14	01/02/2014	31,85	01/02/2015	36,76
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23/05/2013	35,33	23/05/2014	34,40	23/05/2015	31,05
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19/08/2013	32,27	19/08/2014	33,95	19/08/2015	29,20
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21/08/2013	32,27	21/08/2014	33,95	21/08/2015	29,20
22/08/2013	32,27	22/08/2014	33,95	22/08/2015	29,20
23/08/2013	32,27	23/08/2014	33,95	23/08/2015	29,10
24/08/2013	32,27	24/08/2014	33,95	24/08/2015	29,10
25/08/2013	32,27	25/08/2014	33,86	25/08/2015	29,10
26/08/2013	32,28	26/08/2014	33,86	26/08/2015	29,10
27/08/2013	32,28	27/08/2014	33,86	27/08/2015	29,10
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29/08/2013	32,28	29/08/2014	33,86	29/08/2015	29,10
30/08/2013	32,28	30/08/2014	33,86	30/08/2015	29,02
31/08/2013	32,28	31/08/2014	33,86	31/08/2015	29,02
01/09/2013	32,28	01/09/2014	33,72	01/09/2015	29,02
02/09/2013	32,22	02/09/2014	33,72	02/09/2015	29,02
03/09/2013	32,22	03/09/2014	33,72	03/09/2015	29,02
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05/09/2013	32,22	05/09/2014	33,72	05/09/2015	29,02
06/09/2013	32,22	06/09/2014	33,72	06/09/2015	29,02
07/09/2013	32,22	07/09/2014	33,72	07/09/2015	28,98
08/09/2013	32,22	08/09/2014	33,62	08/09/2015	28,98

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16/09/2013	31,36	16/09/2014	33,42	16/09/2015	28,30
17/09/2013	31,36	17/09/2014	33,42	17/09/2015	28,30
18/09/2013	31,36	18/09/2014	33,42	18/09/2015	28,30
19/09/2013	31,36	19/09/2014	33,42	19/09/2015	28,30
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22/09/2013	31,36	22/09/2014	33,38	22/09/2015	27,50
23/09/2013	30,54	23/09/2014	33,38	23/09/2015	27,50
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26/09/2013	30,54	26/09/2014	33,38	26/09/2015	27,50
27/09/2013	30,54	27/09/2014	33,38	27/09/2015	26,82
28/09/2013	30,54	28/09/2014	33,38	28/09/2015	26,82
29/09/2013	30,54	29/09/2014	33,33	29/09/2015	26,82
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14/10/2013	28,90	14/10/2014	33,45	14/10/2015	25,15
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17/10/2013	28,90	17/10/2014	33,45	17/10/2015	25,15
18/10/2013	28,90	18/10/2014	33,45	18/10/2015	24,58
19/10/2013	28,90	19/10/2014	33,45	19/10/2015	24,58
20/10/2013	28,90	20/10/2014	33,50	20/10/2015	24,58
21/10/2013	28,49	21/10/2014	33,50	21/10/2015	24,58
22/10/2013	28,49	22/10/2014	33,50	22/10/2015	24,58
23/10/2013	28,49	23/10/2014	33,50	23/10/2015	24,58
24/10/2013	28,49	24/10/2014	33,50	24/10/2015	24,58
25/10/2013	28,49	25/10/2014	33,50	25/10/2015	24,40
26/10/2013	28,49	26/10/2014	33,50	26/10/2015	24,40
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03/11/2013	27,95	03/11/2014	33,52	03/11/2015	24,24
04/11/2013	27,84	04/11/2014	33,52	04/11/2015	24,24
05/11/2013	27,84	05/11/2014	33,52	05/11/2015	24,24
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07/11/2013	27,84	07/11/2014	33,52	07/11/2015	24,22
08/11/2013	27,84	08/11/2014	33,52	08/11/2015	24,22
09/11/2013	27,84	09/11/2014	33,52	09/11/2015	24,22
10/11/2013	27,84	10/11/2014	33,58	10/11/2015	24,22
11/11/2013	27,98	11/11/2014	33,58	11/11/2015	24,22
12/11/2013	27,98	12/11/2014	33,58	12/11/2015	24,22
13/11/2013	27,98	13/11/2014	33,58	13/11/2015	24,22
14/11/2013	27,98	14/11/2014	33,58	14/11/2015	24,22
15/11/2013	27,98	15/11/2014	33,58	15/11/2015	24,20
16/11/2013	27,98	16/11/2014	33,58	16/11/2015	24,20
17/11/2013	27,98	17/11/2014	33,72	17/11/2015	24,20
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19/11/2013	28,30	19/11/2014	33,72	19/11/2015	24,20
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21/11/2013	28,30	21/11/2014	33,72	21/11/2015	24,20

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23/11/2013	28,30	23/11/2014	33,72	23/11/2015	24,20
24/11/2013	28,30	24/11/2014	33,90	24/11/2015	24,20
25/11/2013	28,62	25/11/2014	33,90	25/11/2015	24,20
26/11/2013	28,62	26/11/2014	33,90	26/11/2015	24,20
27/11/2013	28,62	27/11/2014	33,90	27/11/2015	24,20
28/11/2013	28,62	28/11/2014	33,90	28/11/2015	24,20
29/11/2013	28,62	29/11/2014	33,90	29/11/2015	24,20
30/11/2013	28,62	30/11/2014	33,90	30/11/2015	24,20
01/12/2013	28,62	01/12/2014	34,42	01/12/2015	24,20
02/12/2013	28,62	02/12/2014	34,42	02/12/2015	24,20
03/12/2013	28,86	03/12/2014	34,42	03/12/2015	24,20
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06/12/2013	28,86	06/12/2014	34,42	06/12/2015	24,20
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11/12/2013	29,05	11/12/2014	34,42	11/12/2015	24,10
12/12/2013	29,05	12/12/2014	34,42	12/12/2015	24,10
13/12/2013	29,05	13/12/2014	34,42	13/12/2015	24,12
14/12/2013	29,05	14/12/2014	34,42	14/12/2015	24,12
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17/12/2013	29,46	17/12/2014	34,42	17/12/2015	24,12
18/12/2013	29,46	18/12/2014	34,42	18/12/2015	24,12
19/12/2013	29,46	19/12/2014	34,42	19/12/2015	24,12
20/12/2013	29,46	20/12/2014	34,42	20/12/2015	23,98
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22/12/2013	29,46	22/12/2014	34,42	22/12/2015	23,98
23/12/2013	29,78	23/12/2014	34,42	23/12/2015	23,98
24/12/2013	29,78	24/12/2014	34,42	24/12/2015	23,98
25/12/2013	29,78	25/12/2014	34,42	25/12/2015	23,98
26/12/2013	29,78	26/12/2014	34,42	26/12/2015	23,98
27/12/2013	29,78	27/12/2014	34,42	27/12/2015	23,98
28/12/2013	29,78	28/12/2014	34,42	28/12/2015	23,98

29/12/2013	29,78	29/12/2014	34,42	29/12/2015	23,98
30/12/2013	30,02	30/12/2014	34,42	30/12/2015	23,98
31/12/2013	30,02	31/12/2014	34,42	31/12/2015	23,51

APPENDIX 2. WATER FLOW FROM THE RESERVOIRS AND THE DESALINATION PLANT

	2.013				2.014				2.015			
	INFIERNO	RENEGADO	DESALINATION PRODUCTION	TOTAL WATER PUMPED	INFIERNO	RENEGADO	DESALINATION PRODUCTION	TOTAL WATER PUMPED	INFIERNO	RENEGADO	DESALINATION PRODUCTION	TOTAL WATER PUMPED
01-ene	0	3.901	16.310	20.211	0	43	18.107	18.150	0	0	20.377	20.377
02-ene	0	5.785	15.476	21.261	0	149	19.689	19.838	0	0	19.480	19.480
03-ene	0	5.846	15.506	21.352	110	3.558	16.138	19.806	0	417	20.264	20.681
04-ene	0	6.483	15.591	22.074	0	910	16.219	17.129	0	52	20.002	20.054
05-ene	0	6.875	15.847	22.722	0	491	17.364	17.855	0	164	21.340	21.504
06-ene	0	5.332	15.682	21.014	0	287	20.355	20.642	0	199	20.098	20.297
07-ene	0	6.586	15.875	22.461	0	115	21.123	21.238	0	4.980	18.397	23.377
08-ene	0	6.672	16.136	22.808	0	2.063	18.765	20.828	0	528	21.330	21.858
09-ene	0	7.286	16.137	23.423	0	281	20.257	20.538	0	1.466	20.140	21.606
10-ene	0	6.772	16.223	22.995	80	7	20.163	20.250	0	425	20.526	20.951
11-ene	0	6.607	16.145	22.752	0	2.515	17.321	19.836	0	12	21.472	21.484
12-ene	0	4.844	16.066	20.910	0	228	19.142	19.370	0	842	21.242	22.084
13-ene	0	4.781	16.055	20.836	0	437	20.188	20.625	0	1.407	21.327	22.734
14-ene	0	6.893	15.935	22.828	0	118	21.085	21.203	0	736	21.505	22.241
15-ene	0	6.124	16.179	22.303	0	4.406	17.111	21.517	0	2.886	19.181	22.067
16-ene	0	6.768	16.250	23.018	0	3.585	15.850	19.435	0	6	21.018	21.024
17-ene	0	5.870	16.255	22.125	0	3.377	16.078	19.455	0	309	21.599	21.908
18-ene	0	7.154	14.912	22.066	0	726	18.171	18.897	0	188	20.330	20.518
19-ene	0	2.309	18.400	20.709	0	474	21.157	21.631	0	1.537	21.046	22.583
20-ene	0	2.271	18.800	21.071	0	455	20.269	20.724	0	10	21.606	21.616
21-ene	0	2.551	18.619	21.170	0	319	20.439	20.758	0	1.374	21.533	22.907
22-ene	0	5.374	17.123	22.497	0	963	20.593	21.556	0	2.931	18.412	21.343
23-ene	0	5.708	16.867	22.575	310	3.130	16.801	20.241	0	525	21.250	21.775
24-ene	0	5.099	15.877	20.976	0	4.183	16.105	20.288	0	90	20.580	20.670
25-ene	3.720	1.979	16.096	21.795	0	149	19.762	19.911	0	176	21.057	21.233
26-ene	4.080	2.010	15.480	21.570	0	692	19.355	20.047	0	3.774	21.960	25.734
27-ene	3.130	2.368	16.053	21.551	0	86	20.997	21.083	0	4.484	18.574	23.058
28-ene	3.940	3.822	15.679	23.441	0	383	20.156	20.539	0	276	18.287	18.563

29-ene	6.880	15.608	0	22.488	0	159	20.425	20.584	0	8.421	15.538	23.959
30-ene	1.270	12.450	9.068	22.788	80	527	20.523	21.130	0	9.475	11.621	21.096
31-ene	0	11.477	10.822	22.299	0	3.113	16.730	19.843	0	10.430	10.404	20.834
01-feb	0	11.120	10.680	21.800	0	48	18.744	18.792	0	10.270	10.355	20.625
02-feb	0	10.710	10.885	21.595	0	94	20.615	20.709	0	11.472	10.602	22.074
03-feb	0	10.940	10.929	21.869	0	137	20.505	20.642	0	10.667	10.655	21.322
04-feb	0	11.536	11.009	22.545	0	1.298	21.443	22.741	0	10.707	10.616	21.323
05-feb	0	11.083	10.924	22.007	0	462	20.418	20.880	0	11.223	10.741	21.964
06-feb	220	12.846	9.052	22.118	40	1.143	21.350	22.533	0	10.282	10.911	21.193
07-feb	0	11.615	10.764	22.379	0	4.507	16.705	21.212	0	9.185	10.827	20.012
08-feb	0	10.521	10.719	21.240	0	729	20.104	20.833	0	10.215	10.616	20.831
09-feb	0	10.711	10.258	20.969	0	162	19.113	19.275	0	12.102	10.444	22.546
10-feb	0	4.592	10.526	15.118	0	805	21.385	22.190	0	11.004	10.342	21.346
11-feb	0	15.840	10.440	26.280	0	6.626	16.819	23.445	0	11.349	10.245	21.594
12-feb	2.630	12.063	5.514	20.207	0	555	20.997	21.552	0	11.515	10.300	21.815
13-feb	4.060	14.587	5.410	24.057	0	150	21.018	21.168	0	11.218	10.356	21.574
14-feb	3.400	15.891	2.397	21.688	0	8.095	16.530	24.625	0	11.215	10.345	21.560
15-feb	3.430	16.328	3.033	22.791	80	106	19.411	19.597	0	10.427	10.056	20.483
16-feb	3.480	14.224	4.580	22.284	0	93	19.461	19.554	0	12.728	10.162	22.890
17-feb	3.460	11.714	3.935	19.109	0	860	21.428	22.288	0	9.505	10.934	20.439
18-feb	3.400	13.739	4.810	21.949	0	349	21.589	21.938	0	12.693	10.842	23.535
19-feb	0	10.606	9.938	20.544	0	430	16.546	16.976	0	9.274	10.579	19.853
20-feb	350	12.458	10.297	23.105	0	5.140	21.361	26.501	0	9.072	9.549	18.621
21-feb	180	10.915	10.061	21.156	0	2.362	18.377	20.739	0	14.381	9.928	24.309
22-feb	0	11.174	10.621	21.795	0	148	21.203	21.351	0	11.467	9.894	21.361
23-feb	0	9.085	10.770	19.855	0	255	20.656	20.911	0	12.691	9.993	22.684
24-feb	0	8.638	10.820	19.458	0	321	20.759	21.080	0	12.901	9.971	22.872
25-feb	0	11.357	10.798	22.155	0	191	21.638	21.829	0	13.318	10.029	23.347
26-feb	0	11.408	10.825	22.233	0	386	21.650	22.036	0	12.862	9.852	22.714
27-feb	0	11.730	10.987	22.717	0	1.517	21.444	22.961	0	12.327	9.964	22.291

28-feb	0	7.302	10.616	17.918	0	6.820	16.823	23.643	0	11.402	9.846	21.248
29-feb	0	12.189	10.558	22.747	0	131	18.533	18.664	0	11.741	9.978	21.719
01-mar	0	10.211	10.885	21.096	0	4.704	19.571	24.275	0	13.685	9.867	23.552
02-mar	0	8.590	10.865	19.455	0	1.804	21.461	23.265	0	13.227	10.003	23.230
03-mar	0	9.907	10.800	20.707	0	5.437	18.457	23.894	0	14.033	9.782	23.815
04-mar	0	11.276	10.279	21.555	0	1.482	21.023	22.505	0	15.074	9.873	24.947
05-mar	0	12.025	10.867	22.892	0	854	21.556	22.410	0	13.188	9.897	23.085
06-mar	4.210	10.186	6.123	20.519	0	22	21.501	21.523	0	11.665	9.818	21.483
07-mar	4.900	11.046	5.311	21.257	0	1.138	19.019	20.157	0	11.886	9.796	21.682
08-mar	7.000	6.214	5.340	18.554	0	164	21.397	21.561	0	13.325	9.913	23.238
09-mar	8.690	4.860	5.356	18.906	0	173	17.437	17.610	1.110	10.938	9.706	21.754
10-mar	6.460	12.387	5.377	24.224	0	709	19.557	20.266	0	13.766	9.684	23.450
11-mar	8.830	6.638	2.490	17.958	0	1.365	21.586	22.951	0	13.576	8.753	22.329
12-mar	11.170	11.557	0	22.727	0	3.413	21.563	24.976	0	13.018	9.994	23.012
13-mar	11.510	8.735	0	20.245	0	671	19.358	20.029	0	11.319	9.913	21.232
14-mar	10.550	10.798	0	21.348	0	76	20.454	20.530	0	11.756	9.947	21.703
15-mar	10.240	9.704	0	19.944	0	168	21.127	21.295	0	12.808	10.352	23.160
16-mar	9.490	14.455	0	23.945	0	768	21.306	22.074	0	11.123	10.537	21.660
17-mar	8.830	11.378	0	20.208	4.920	24	16.784	21.728	0	11.840	10.319	22.159
18-mar	10.950	10.787	0	21.737	0	10.280	11.543	21.823	0	11.480	10.627	22.107
19-mar	9.580	11.540	0	21.120	0	5.887	15.936	21.823	0	11.081	10.361	21.442
20-mar	8.630	12.813	0	21.443	0	5.825	15.945	21.770	0	11.478	10.185	21.663
21-mar	8.870	11.575	0	20.445	0	4.474	16.062	20.536	0	11.207	10.208	21.415
22-mar	10.180	8.525	0	18.705	0	4.412	15.932	20.344	0	12.906	10.290	23.196
23-mar	10.410	9.282	0	19.692	0	5.795	16.072	21.867	3.360	8.513	10.485	22.358
24-mar	8.320	14.750	0	23.070	0	6.490	16.138	22.628	3.480	7.918	10.437	21.835
25-mar	9.220	11.191	0	20.411	0	6.217	16.168	22.385	3.450	8.731	9.742	21.923
26-mar	10.600	9.345	0	19.945	0	5.807	16.147	21.954	3.190	8.814	10.248	22.252
27-mar	9.300	11.254	0	20.554	0	4.458	16.238	20.696	2.350	9.138	9.593	21.081
28-mar	9.120	10.941	0	20.061	0	2.543	16.402	18.945	1.220	9.617	10.106	20.943

29-mar	8.220	8.540	0	16.760	0	5.860	15.675	21.535	1.600	11.664	10.032	23.296
30-mar	9.690	9.007	0	18.697	0	5.544	16.501	22.045	3.630	8.620	9.542	21.792
31-mar	9.800	14.153	0	23.953	0	5.742	16.408	22.150	3.270	8.427	10.167	21.864
01-abr	10.640	7.872	0	18.512	820	4.065	16.119	21.004	2.730	7.117	10.082	19.929
02-abr	12.300	9.811	0	22.111	930	8.373	11.432	20.735	1.830	9.157	9.935	20.922
03-abr	10.930	10.393	0	21.323	5.140	5.966	10.755	21.861	1.540	8.851	9.936	20.327
04-abr	11.900	9.251	0	21.151	5.590	9.175	6.011	20.776	1.660	8.919	9.870	20.449
05-abr	1.126	2.343	14.400	17.869	5.540	8.920	5.434	19.894	2.820	9.688	9.965	22.473
06-abr	6.380	4.931	9.248	20.559	9.670	5.991	5.592	21.253	730	12.607	9.894	23.231
07-abr	6.320	6.108	7.754	20.182	3.620	13.031	5.996	22.647	0	12.115	9.856	21.971
08-abr	1.200	12.580	6.013	19.793	2.410	13.670	5.467	21.547	0	11.263	9.856	21.119
09-abr	0	16.759	5.276	22.035	2.350	14.165	5.502	22.017	0	12.194	9.929	22.123
10-abr	5.200	5.352	5.367	15.919	2.340	13.866	5.563	21.769	0	10.474	9.888	20.362
11-abr	1.830	21.141	5.214	28.185	1.950	13.142	5.040	20.132	0	11.277	9.905	21.182
12-abr	320	14.741	5.081	20.142	1.110	13.743	5.551	20.404	0	8.393	13.373	21.766
13-abr	0	15.401	5.274	20.675	920	15.391	5.445	21.756	0	5.894	15.244	21.138
14-abr	0	17.748	5.326	23.074	1.870	14.152	5.554	21.576	0	7.776	15.408	23.184
15-abr	0	13.183	9.484	22.667	3.340	12.717	5.457	21.514	0	6.928	15.238	22.166
16-abr	0	10.531	9.888	20.419	270	14.477	5.290	20.037	0	8.072	15.408	23.480
17-abr	0	11.466	10.703	22.169	0	10.369	10.254	20.623	0	6.957	14.495	21.452
18-abr	0	10.868	10.707	21.575	0	8.509	10.735	19.244	0	6.299	15.060	21.359
19-abr	0	8.266	10.701	18.967	0	10.565	10.798	21.363	0	7.319	15.283	22.602
20-abr	0	8.803	10.675	19.478	0	10.539	10.741	21.280	0	6.568	15.154	21.722
21-abr	0	12.914	10.760	23.674	0	11.417	10.812	22.229	0	6.846	15.365	22.211
22-abr	0	18.189	10.719	28.908	0	11.677	10.795	22.472	0	6.739	15.404	22.143
23-abr	1.210	7.093	8.797	17.100	0	11.199	10.861	22.060	0	5.819	15.726	21.545
24-abr	370	11.395	10.664	22.429	0	10.760	10.729	21.489	0	5.345	15.650	20.995
25-abr	0	17.246	10.016	27.262	0	10.367	10.898	21.265	0	5.325	15.719	21.044
26-abr	0	9.735	10.585	20.320	0	10.938	10.758	21.696	0	3.697	18.525	22.222
27-abr	0	10.144	10.558	20.702	0	12.625	10.724	23.349	0	992	21.196	22.188

28-abr	0	11.032	10.436	21.468	0	12.328	10.805	23.133	4.070	5.998	12.383	22.451
29-abr	0	10.441	10.173	20.614	0	12.810	10.754	23.564	0	747	20.916	21.663
30-abr	0	10.770	10.557	21.327	0	10.074	10.890	20.964	0	1.513	21.004	22.517
01-may	0	12.020	10.535	22.555	0	11.056	10.801	21.857	0	71	19.014	19.085
02-may	0	9.949	10.651	20.600	0	9.562	10.859	20.421	0	535	21.010	21.545
03-may	0	9.596	10.584	20.180	0	10.147	10.783	20.930	2.590	2.169	21.067	25.826
04-may	0	10.306	10.627	20.933	0	11.640	10.896	22.536	2.700	2.953	15.743	21.396
05-may	10	7.933	10.559	18.502	0	6.623	15.586	22.209	300	782	17.536	18.618
06-may	2.190	13.565	10.558	26.313	0	6.177	16.320	22.497	0	6.398	21.207	27.605
07-may	390	10.820	10.613	21.823	0	7.438	15.819	23.257	0	23	20.118	20.141
08-may	0	12.553	10.582	23.135	0	6.110	16.033	22.143	0	2.217	18.356	20.573
09-may	0	12.068	10.453	22.521	0	719	21.087	21.806	0	175	20.670	20.845
10-may	260	9.985	10.292	20.537	0	465	21.466	21.931	0	3.157	21.195	24.352
11-may	6.630	13.441	0	20.071	0	1.302	21.601	22.903	0	4.464	17.049	21.513
12-may	6.630	15.926	0	22.556	0	887	21.845	22.732	1.440	7.952	14.452	23.844
13-may	1.530	12.225	8.528	22.283	0	4.381	17.893	22.274	6.710	10.783	5.423	22.916
14-may	370	11.362	10.578	22.310	0	1.226	21.535	22.761	0	2.011	19.121	21.132
15-may	2.360	8.662	10.160	21.182	0	2.097	20.032	22.129	2.680	2.366	15.445	20.491
16-may	960	8.553	10.667	20.180	0	116	21.342	21.458	0	171	20.250	20.421
17-may	2.490	6.877	9.965	19.332	0	118	21.722	21.840	0	1.059	21.248	22.307
18-may	1.220	9.316	10.899	21.435	0	596	21.680	22.276	0	2.429	21.405	23.834
19-may	1.090	9.020	10.639	20.749	0	1.000	21.847	22.847	0	831	21.313	22.144
20-may	1.870	9.193	10.583	21.646	0	-530	21.830	21.300	0	4.558	18.936	23.494
21-may	1.090	9.951	10.803	21.844	0	3.712	18.544	22.256	0	1.088	21.320	22.408
22-may	2.370	10.375	9.673	22.418	0	1.075	21.773	22.848	0	34	20.994	21.028
23-may	3.490	7.393	10.647	21.530	0	-116	21.830	21.714	0		20.297	20.297
24-may	70	10.838	9.839	20.747	0	104	21.780	21.884	0	1.700	20.166	21.866
25-may	0	9.503	10.472	19.975	0	691	21.781	22.472	0	903	21.226	22.129
26-may	0	11.605	10.496	22.101	0	1.524	21.649	23.173	0	1.734	21.240	22.974
27-may	0	12.601	9.317	21.918	0	842	21.701	22.543	0	4.147	18.405	22.552

28-may	130	11.715	10.224	22.069	0	5.067	19.346	24.413	0	1.947	21.159	23.106
29-may	100	14.752	10.471	25.323	0	1.250	21.337	22.587	0	913	21.560	22.473
30-may	80	8.484	10.432	18.996	0	1.411	20.861	22.272	0	646	21.182	21.828
31-may	110	10.808	10.230	21.148	0	803	21.259	22.062	0	2.024	21.625	23.649
01-jun	0	11.351	10.632	21.983	0	2.256	21.707	23.963	0	1.390	21.427	22.817
02-jun	0	11.738	10.550	22.288	0	1.694	20.985	22.679	0	1.177	21.270	22.447
03-jun	420	13.931	9.747	24.098	0	3.007	21.457	24.464	0	4.522	18.290	22.812
04-jun	950	11.193	10.651	22.794	0	1.866	21.466	23.332	0	1.864	20.576	22.440
05-jun	2.440	10.584	10.575	23.599	0	3.377	19.261	22.638	0	391	20.377	20.768
06-jun	880	9.521	10.745	21.146	0	929	21.503	22.432	0	517	21.433	21.950
07-jun	180	10.604	10.739	21.523	0	874	21.537	22.411	0	2.004	20.625	22.629
08-jun	190	10.000	11.036	21.226	0	2.400	21.634	24.034	0	1.044	21.445	22.489
09-jun	0	12.248	10.376	22.624	0	2.421	21.343	23.764	0	1.615	21.509	23.124
10-jun	0	12.326	10.591	22.917	0	1.524	21.610	23.134	0	3.723	19.411	23.134
11-jun	160	12.054	10.662	22.876	0	3.635	20.443	24.078	0	1.148	21.589	22.737
12-jun	120	11.675	10.533	22.328	0	3.175	19.652	22.827	0	75	20.377	20.452
13-jun	120	11.647	10.712	22.479	0	440	21.570	22.010	0	376	20.519	20.895
14-jun	0	10.716	10.773	21.489	0	711	21.725	22.436	0	611	21.132	21.743
15-jun	360	10.682	11.285	22.327	0	2.305	21.689	23.994	0	1.560	21.262	22.822
16-jun	0	11.324	10.699	22.023	0	3.322	21.050	24.372	0	607	18.502	19.109
17-jun	60	8.221	15.153	23.434	0	1.620	21.707	23.327	0	11.433	19.245	30.678
18-jun	0	7.181	16.106	23.287	0	1.879	21.769	23.648	0	1.349	21.409	22.758
19-jun	0	6.933	16.153	23.086	0	2.087	21.490	23.577	0	600	21.358	21.958
20-jun	0	7.128	15.424	22.552	0	1.072	21.727	22.799	0	696	21.472	22.168
21-jun	70	4.422	16.368	20.860	0	1.032	21.718	22.750	0	1.222	19.468	20.690
22-jun	0	6.940	15.844	22.784	0	5	21.717	21.722	0	4.130	21.290	25.420
23-jun	0	6.330	16.170	22.500	1.800	180	20.382	22.362	0	2.284	21.428	23.712
24-jun	0	5.158	16.116	21.274	0	18.929	3.738	22.667	0	5.674	17.499	23.173
25-jun	0	6.366	15.983	22.349	0	2.301	20.015	22.316	250	3.845	19.041	23.136
26-jun	80	6.243	16.104	22.427	0	1.156	21.630	22.786	0	578	21.597	22.175

27-jun	230	5.301	16.281	21.812	0	748	21.689	22.437	0	1.626	21.452	23.078
28-jun	0	5.162	16.281	21.443	0	522	21.202	21.724	0	2.606	21.469	24.075
29-jun	0	5.602	16.227	21.829	0	2.751	21.357	24.108	0	1.647	21.900	23.547
30-jun	0	5.684	16.152	21.836	0	1.244	19.728	20.972	300	1.893	21.162	23.355
01-jul	0	6.772	16.116	22.888	0	1.833	21.392	23.225	210	3.922	20.388	24.520
02-jul	310	7.554	14.448	22.312	0	2.414	21.624	24.038	0	1.820	22.045	23.865
03-jul	220	7.356	15.254	22.830	0	1.643	20.348	21.991	0	19.184	2.579	21.763
04-jul	70	6.135	16.021	22.226	0	2.065	20.434	22.499	0	1.791	22.033	23.824
05-jul	210	4.789	15.742	20.741	0	47	21.870	21.917	0	3.713	21.255	24.968
06-jul	80	5.073	16.329	21.482	0	300	21.814	22.114	0	1.840	21.807	23.647
07-jul	0	2.985	16.003	18.988	0	2.083	21.591	23.674	0	2.817	21.859	24.676
08-jul	0	12.396	16.041	28.437	0	724	20.992	21.716	0	3.423	21.427	24.850
09-jul	120	10.554	16.146	26.820	0	581	20.557	21.138	0	2.707	20.924	23.631
10-jul	30	705	20.097	20.832	0	2.796	19.810	22.606	0	2.158	21.784	23.942
11-jul	40	10.600	11.150	21.790	0	224	21.825	22.049	0	794	21.811	22.605
12-jul	90	5.150	16.152	21.392	0	3.585	21.615	25.200	0	3.909	21.613	25.522
13-jul	1.980	2.978	15.786	20.744	0	55	21.312	21.367	0	2.608	21.491	24.099
14-jul	4.300	1.774	16.103	22.177	0	1.491	21.828	23.319	0	6.690	21.129	27.819
15-jul	210	1.884	20.002	22.096	0	2.339	20.426	22.765	0	521	21.361	21.882
16-jul	0	2.198	21.177	23.375	0	670	21.718	22.388	0	2.975	21.221	24.196
17-jul	0	903	21.236	22.139	0	2.886	19.360	22.246	0	1.332	21.330	22.662
18-jul	0	1.873	19.857	21.730	0	328	22.192	22.520	0	1.675	21.253	22.928
19-jul	0	178	20.268	20.446	0	109	21.129	21.238	0	3.416	21.455	24.871
20-jul	0	145	20.510	20.655	0	3.410	21.650	25.060	0	3.333	21.388	24.721
21-jul	0	2.147	21.055	23.202	0	2.051	21.755	23.806	0	3.489	21.202	24.691
22-jul	0	4.862	18.294	23.156	0	934	19.775	20.709	0	3.442	21.189	24.631
23-jul	120	2.557	19.590	22.267	0	1.174	21.670	22.844	0	2.723	21.628	24.351
24-jul	100	1.189	21.297	22.586	0	5.023	18.842	23.865	0	2.940	21.349	24.289
25-jul	0	2	21.028	21.030	0	871	21.819	22.690	0	2.067	20.925	22.992
26-jul	140	155	19.336	19.631	0	185	21.072	21.257	0	4.826	21.208	26.034

27-jul	0	872	21.159	22.031	0	2.214	21.727	23.941	0	3.852	21.330	25.182
28-jul	0	1.114	21.155	22.269	0	696	20.087	20.783	0	3.513	21.287	24.800
29-jul	0	3.174	19.199	22.373	0	1.255	21.973	23.228	0	4.284	21.276	25.560
30-jul	0	474	20.956	21.430	0	1.019	21.780	22.799	0	3.349	21.268	24.617
31-jul	0	1.975	21.182	23.157	0	5.047	18.545	23.592	0	2.590	21.406	23.996
01-ago	0	1.567	21.228	22.795	0	499	21.822	22.321	0	3.126	21.075	24.201
02-ago	0	1.894	21.283	23.177	0	491	21.850	22.341	0	3.503	21.186	24.689
03-ago	0	2.510	20.964	23.474	0	2.145	21.495	23.640	0	3.837	21.318	25.155
04-ago	0	177	19.391	19.568	0	1.086	21.673	22.759	0	2.753	21.355	24.108
05-ago	100	1.129	21.229	22.458	0	1.355	21.875	23.230	0	2.973	21.781	24.754
06-ago	0	4.348	19.049	23.397	0	2.146	21.855	24.001	0	4.210	21.441	25.651
07-ago	0	2.353	21.407	23.760	0	4.096	19.006	23.102	0	2.652	21.102	23.754
08-ago	0	335	18.482	18.817	0	111	21.415	21.526	0	2.005	21.180	23.185
09-ago	0	3	21.000	21.003	0	409	20.767	21.176	0	3.932	21.465	25.397
10-ago	0	135	21.237	21.372	0	1.597	21.473	23.070	0	4.147	21.356	25.503
11-ago	0	1.901	21.267	23.168	0	2.959	21.887	24.846	0	2.253	21.490	23.743
12-ago	100	3.179	18.579	21.858	0	1.464	21.162	22.626	0	3.941	21.775	25.716
13-ago	0	1.572	21.232	22.804	0	2.003	21.745	23.748	0	1.951	21.592	23.543
14-ago	0	1.742	19.652	21.394	2	2.767	19.098	21.867	0	406	22.113	22.519
15-ago	0	783	21.132	21.915	2	998	21.584	22.584	0	383	22.335	22.718
16-ago	0	419	20.409	20.828	0	308	21.039	21.347	0	2.902	21.646	24.548
17-ago	0	441	21.288	21.729	0	2.083	21.646	23.729	0	2.243	22.098	24.341
18-ago	0	1.388	21.196	22.584	0	1.632	21.548	23.180	0	2.352	22.091	24.443
19-ago	0	3.632	18.390	22.022	0	1.630	21.630	23.260	0	1.688	22.053	23.741
20-ago	0	1.080	21.187	22.267	0	1.636	22.065	23.701	0	2.696	21.967	24.663
21-ago	0	2.115	21.032	23.147	0	2.764	20.045	22.809	0	936	22.175	23.111
22-ago	0	2.617	21.262	23.879	0	8.172	20.449	28.621	0	591	21.122	21.713
23-ago	80	203	21.028	21.311	0	585	18.919	19.504	0	2.573	21.957	24.530
24-ago	0	589	21.170	21.759	0	2.127	21.695	23.822	0	2.600	21.904	24.504
25-ago	0	2.169	21.329	23.498	0	1.972	21.814	23.786	0	2.784	21.896	24.680

26-ago	0	2.354	18.539	20.893	50	2.935	21.833	24.818	0	2.762	22.039	24.801
27-ago	0	3.196	21.234	24.430	2.870	6	21.007	23.883	0	2.006	21.862	23.868
28-ago	0	600	21.370	21.970	0	11.052	12.629	23.681	0	657	21.754	22.411
29-ago	0	2.092	20.306	22.398	0	1.697	21.094	22.791	0	974	21.634	22.608
30-ago	0	757	20.313	21.070	0	1.279	21.670	22.949	0	2.136	21.779	23.915
31-ago	0	644	20.328	20.972	0	2.437	21.806	24.243	0	3.223	21.786	25.009
01-sep	0	2.092	21.121	23.213	0	2.288	21.733	24.021	0	2.928	21.844	24.772
02-sep	0	4.167	18.431	22.598	0	2.309	21.158	23.467	0	2.084	22.072	24.156
03-sep	80	2.115	20.234	22.429	0	2.238	21.850	24.088	0	1.672	21.849	23.521
04-sep	0	2.829	19.541	22.370	0	3.942	20.223	24.165	0	1.066	22.040	23.106
05-sep	0	995	21.142	22.137	0	1.626	20.407	22.033	0	1.378	21.777	23.155
06-sep	0	130	20.015	20.145	0	1.395	21.896	23.291	0	2.471	22.042	24.513
07-sep	0	380	21.132	21.512	460	2.459	21.787	24.706	0	3.873	21.638	25.511
08-sep	0	1.371	21.077	22.448	460	3.261	19.292	23.013	0	7.613	17.332	24.945
09-sep	1.110	10.734	10.866	22.710	0	6.750	18.518	25.268	1.150	12.509	11.206	24.865
10-sep	1.220	10.571	10.348	22.139	0	177	21.700	21.877	2.470	10.863	10.775	24.108
11-sep	1.940	9.948	10.454	22.342	0	4.137	19.403	23.540	3.700	7.480	10.714	21.894
12-sep	1.240	9.768	10.466	21.474	0	1.857	21.422	23.279	1.080	9.635	12.773	23.488
13-sep	2.170	9.095	9.865	21.130	0	1.162	21.643	22.805	1.000	7.135	16.600	24.735
14-sep	1.700	9.168	10.475	21.343	0	2.839	21.498	24.337	5.270	7.743	11.775	24.788
15-sep	1.540	10.588	10.528	22.656	0	2.238	21.580	23.818	5.660	7.640	10.654	23.954
16-sep	1.530	10.667	10.387	22.584	0	2.004	21.401	23.405	3.460	10.108	10.796	24.364
17-sep	1.530	10.959	10.512	23.001	0	2.240	21.598	23.838	3.244	17.267	0	20.511
18-sep	450	7.986	14.326	22.762	0	3.766	19.415	23.181	3.506	569	21.417	25.492
19-sep	0	6.158	15.868	22.026	0	1.610	20.926	22.536	3.330	8.467	10.592	22.389
20-sep	2.140	7.389	10.971	20.500	0	1	21.554	21.555	3.340	10.654	10.577	24.571
21-sep	2.250	8.425	10.517	21.192	0	2.485	21.661	24.146	750	7.596	15.219	23.565
22-sep	1.680	9.810	10.462	21.952	0	1.609	21.649	23.258	0	7.240	16.450	23.690
23-sep	1.480	11.478	10.420	23.378	0	1.972	21.000	22.972	0	7.639	16.390	24.029
24-sep	1.890	9.918	10.333	22.141	0	1.273	21.680	22.953	0	6.349	16.472	22.821

25-sep	1.660	10.533	10.302	22.495	0	2.222	19.986	22.208	0	5.962	16.495	22.457
26-sep	1.820	9.431	10.383	21.634	0	194	20.501	20.695	0	6.717	15.827	22.544
27-sep	1.810	7.885	10.341	20.036	0	569	21.773	22.342	360	7.728	15.912	24.000
28-sep	1.820	8.148	10.565	20.533	0	2.537	21.775	24.312	0	9.314	16.294	25.608
29-sep	1.110	10.242	10.459	21.811	0	222	21.855	22.077	0	9.079	15.584	24.663
30-sep	840	10.346	10.432	21.618	0	1.167	21.513	22.680	0	9.789	15.808	25.597
01-oct	1.420	9.011	10.381	20.812	0	1.582	21.023	22.605	0	9.538	15.705	25.243
02-oct	1.430	10.513	10.598	22.541	0	2.369	19.400	21.769	0	6.046	15.843	21.889
03-oct	1.440	10.415	10.626	22.481	0	192	20.801	20.993	0	8.033	15.668	23.701
04-oct	2.060	7.756	10.592	20.408	0	725	21.003	21.728	0	5.506	15.939	21.445
05-oct	2.650	7.847	10.474	20.971	0	29	20.920	20.949	0	8.647	15.700	24.347
06-oct	1.620	9.792	10.523	21.935	0	1.266	21.050	22.316	0	7.883	15.916	23.799
07-oct	1.970	8.034	10.436	20.440	0	4.200	18.318	22.518	0	8.527	15.752	24.279
08-oct	2.560	6.216	10.401	19.177	0	3.025	19.995	23.020	0	7.869	15.746	23.615
09-oct	1.370	10.390	10.325	22.085	0	1.783	19.634	21.417	0	6.060	15.754	21.814
10-oct	1.320	10.127	10.130	21.577	0	69	21.073	21.142	0	5.888	15.614	21.502
11-oct	1.480	7.893	10.459	19.832	0	164	19.599	19.763	0	6.350	15.944	22.294
12-oct	1.490	7.824	10.431	19.745	0	400	21.821	22.221	0	7.756	15.860	23.616
13-oct	1.390	10.754	10.283	22.427	0	809	21.685	22.494	0	7.906	15.769	23.675
14-oct	1.410	8.533	9.900	19.843	0	1.485	21.687	23.172	0	8.106	15.758	23.864
15-oct	1.390	9.635	10.023	21.048	0	3.865	19.904	23.769	0	7.525	15.850	23.375
16-oct	1.750	7.413	10.324	19.487	0	2.150	20.285	22.435	50	6.737	15.353	22.140
17-oct	1.620	7.904	10.253	19.777	0	869	21.236	22.105	0	6.811	15.590	22.401
18-oct	1.600	8.388	10.488	20.476	0	131	21.485	21.616	0	8.381	15.343	23.724
19-oct	170	8.429	10.601	19.200	0	1.848	21.814	23.662	0	2.905	20.516	23.421
20-oct	1.240	10.049	10.460	21.749	0	1.856	21.604	23.460	0	2.692	21.408	24.100
21-oct	1.720	9.009	10.470	21.199	0	663	21.933	22.596	0	4.439	19.725	24.164
22-oct	2.350	8.478	10.398	21.226	0	707	21.581	22.288	0	1.249	21.361	22.610
23-oct	2.260	8.099	10.331	20.690	0	3.871	19.343	23.214	0	1.030	22.309	23.339
24-oct	1.610	8.364	10.418	20.392	0	529	21.499	22.028	0	472	21.354	21.826

25-oct	1.440	7.391	10.222	19.053	0	402	22.384	22.786	0	2.425	21.431	23.856
26-oct	1.470	8.673	10.764	20.907	0	1.975	21.506	23.481	0	2.106	21.430	23.536
27-oct	1.520	9.727	10.093	21.340	0	265	21.450	21.715	0	3.913	20.020	23.933
28-oct	240	6.079	14.575	20.894	0	2.097	21.127	23.224	0	1.912	21.533	23.445
29-oct	586	5.906	14.106	20.598	0	848	21.644	22.492	0	1.910	20.540	22.450
30-oct	0	5.166	15.814	20.980	0	2.392	19.695	22.087	0	1.996	20.423	22.419
31-oct	90	2.782	16.009	18.881	0	599	20.316	20.915	0	296	21.584	21.880
01-nov	0	3.970	15.756	19.726	0	78	21.753	21.831	0	742	20.724	21.466
02-nov	0	3.811	15.848	19.659	0	1.837	21.482	23.319	0	2.843	21.280	24.123
03-nov	70	5.772	15.682	21.524	0	7	19.702	19.709	710	2.099	20.942	23.751
04-nov	0	698	20.470	21.168	0	9.477	16.886	26.363	3.120	1.563	18.451	23.134
05-nov	0	1.110	21.230	22.340	0	4.202	17.939	22.141	4.530	820	17.742	23.092
06-nov	0	1.022	20.402	21.424	0	146	21.473	21.619	4.790	1.913	15.835	22.538
07-nov	0	71	19.458	19.529	0	9	21.257	21.266	0	23.111	0	23.111
08-nov	0	877	21.018	21.895	0	1.815	21.373	23.188	6.720	1.846	15.908	24.474
09-nov	0	261	20.546	20.807	0	1.434	21.329	22.763	8.000	145	15.832	23.977
10-nov	0	567	21.119	21.686	6	800	21.371	22.177	6.380	959	16.021	23.360
11-nov	0	1.002	21.189	22.191	0	1.527	21.547	23.074	7.240	1.984	15.617	24.841
12-nov	0	323	20.836	21.159	0	1.566	21.242	22.808	7.230	70	15.473	22.773
13-nov	0	862	20.877	21.739	0	552	18.854	19.406	6.220	1.379	15.469	23.068
14-nov	190	1.655	18.855	20.700	0	2.266	20.796	23.062	6.510	569	15.011	22.090
15-nov	0	1.010	18.940	19.950	0	37	21.601	21.638	7.050	1.643	15.163	23.856
16-nov	0	298	20.232	20.530	0	5.087	21.713	26.800	6.990	1.806	15.419	24.215
17-nov	0	239	20.150	20.389	4.310	174	18.137	22.621	6.890	512	15.742	23.144
18-nov	0	1.026	21.028	22.054	3.150	718	16.963	20.831	6.950	1.500	15.556	24.006
19-nov	0	2.195	20.992	23.187	0	2.363	18.129	20.492	7.110	70	15.729	22.909
20-nov	0	450	21.308	21.758	0	712	20.626	21.338	6.070	342	15.543	21.955
21-nov	0	2.477	18.440	20.917	0	5	20.432	20.437	6.100	779	15.772	22.651
22-nov	0	427	19.487	19.914	0	689	20.284	20.973	6.270	1.427	15.811	23.508
23-nov	0	376	20.313	20.689	0	667	21.224	21.891	6.920	349	15.952	23.221

24-nov	0	345	21.327	21.672	0	569	21.327	21.896	6.730	857	15.370	22.957
25-nov	0	418	21.310	21.728	0	200	21.038	21.238	6.720	466	15.690	22.876
26-nov	0	49	21.086	21.135	0	751	20.892	21.643	7.010	977	15.526	23.513
27-nov	0	527	19.267	19.794	0	1.456	18.853	20.309	6.650	471	15.704	22.825
28-nov	0	2.477	18.723	21.200	0	178	20.675	20.853	6.010	10	15.055	21.075
29-nov	0	2.810	18.221	21.031	0	406	18.617	19.023	7.430	1.570	15.742	24.742
30-nov	0	174	19.063	19.237	0	572	20.513	21.085	7.370	620	15.618	23.608
01-dic	0	1.957	21.268	23.225	0	20	21.550	21.570	8.240	69	15.080	23.389
02-dic	0	306	21.203	21.509	0	879	21.295	22.174	6.900	506	15.715	23.121
03-dic	0	1.403	21.175	22.578	0	515	21.801	22.316	7.250	64	15.018	22.332
04-dic	0	140	21.022	21.162	0	2.966	18.491	21.457	6.260	85	15.002	21.347
05-dic	0	66	18.425	18.491	0	713	20.488	21.201	4.140	1.002	15.540	20.682
06-dic	0	1.096	17.254	18.350	0	734	18.653	19.387	5.110	99	15.311	20.520
07-dic	0	148	20.891	21.039	0	414	18.364	18.778	5.980	112	15.496	21.588
08-dic	0	179	20.108	20.287	0	2.322	21.672	23.994	820	1.648	20.151	22.619
09-dic	0	3.311	17.490	20.801	0	60	21.502	21.562	0	1.339	21.407	22.746
10-dic	0	486	20.978	21.464	0	2.051	21.237	23.288	0	1.870	21.216	23.086
11-dic	0	599	20.489	21.088	0	2.213	19.697	21.910	0	729	21.344	22.073
12-dic	0	733	20.040	20.773	0	425	20.300	20.725	0	1.775	20.602	22.377
13-dic	0	1.157	18.689	19.846	0	253	20.697	20.950	1.880	79	20.933	22.892
14-dic	0	17.726	2.401	20.127	0	562	21.655	22.217	2.280	26	21.027	23.333
15-dic	0	46	20.035	20.081	0	656	21.419	22.075	0	3.023	20.180	23.203
16-dic	0	2.544	18.600	21.144	0	1.542	21.301	22.843	0	1.270	21.555	22.825
17-dic	0	602	21.450	22.052	0	609	21.667	22.276	0	1.503	21.604	23.107
18-dic	0	485	19.100	19.585	0	3.127	18.853	21.980	0	1.563	21.694	23.257
19-dic	0	1.159	20.145	21.304	0	195	20.376	20.571	0	560	20.310	20.870
20-dic	0	1.006	18.777	19.783	0	551	19.570	20.121	0	1.618	21.330	22.948
21-dic	0	260	18.078	18.338	0	710	20.327	21.037	1.823	69	20.194	22.086
22-dic	0	223	20.332	20.555	0	55	21.302	21.357	1.650	296	20.174	22.120
23-dic	0	680	19.228	19.908	0	1.637	20.972	22.609	0	788	21.208	21.996

24-dic	0	96	18.055	18.151	0	320	19.408	19.728	0	97	21.265	21.362
25-dic	0	2.343	18.045	20.388	0	527	21.316	21.843	0	28	21.001	21.029
26-dic	0	2.627	16.093	18.720	0	1.349	18.921	20.270	0	683	20.088	20.771
27-dic	0	1.738	16.252	17.990	0	394	19.316	19.710	0	1.071	21.135	22.206
28-dic	0	843	17.163	18.006	0	704	21.060	21.764	190	795	21.287	22.272
29-dic	0	1.676	20.357	22.033	0	377	20.988	21.365	1.390	338	20.413	22.141
30-dic	0	537	20.570	21.107	0	608	21.197	21.805	440	1.959	21.525	23.924
31-dic	0	0	21.107	21.107		654	21.152	21.806	0	2.702	21.223	23.925
	480.062	**2.502.205**	**4.877.510**	**7.859.777**	**66.600**	**976.780**	**7.025.403**	**8.068.783**	**321.663**	**1.732.078**	**6.281.473**	**8.335.214**

APPENDIX 3. GROSS AND NET HEAD. HEAD LOSSES.

HEAD LOSSES	**Manning Formula** $h = 10{,}3 * n^2 * (Q^2/D^{5{,}33}) * L$			
L	286,00	M		
Q	0,24	M3/S	AH	0,37 m
D	0,60	M		
n	0,012	Ductile iron pipe		

Hnet = Hgross	-	Head loss = 36,54 m
Hmax =Hmax gross	-	Head loss = 41,73 m

Turbine capacity (Qmax) – First approximation	
88,42	kW
Avge. Annual flow*90%Efficiency*Net head*9.81/3600= 155.653,86	KWh
kWh / 1.000.000 = 0,16	GWh

APPENDIX 4. CASH FLOW, NPV, IRR, B-C RATIO FOR ONE FRANCIS TURBINE SCHEME

INITIAL DATA

Total capital costs =	164888	Eur
Total Energy Generation =	132396	kWh/year
Energy Benefits =	15887	eur/year

CASH FLOW

	Fiscal Year	Capital Cost	O&M	Total Cost	NPV Cost (7%)	Energy Revenue	NPV Revenue (7%)
		Eur	Eur	Eur	Eur	Eur	Eur
	Total	**-164888**	**-31494**	**-229359**	**-173327**	**635499**	**185001**
	2017	-49466		-49466	-49466		
	2018	-82444		-82444	-77050		
	2019	-32978		-32978	-28804		
1	2020		-495	-495	-404	15887	12969
2	2021		-1319	-1319	-1006	15887	12120
3	2022		-1649	-1649	-1176	15887	11328
4	2023		-1649	-1649	-1099	15887	10586
5	2024		-1649	-1649	-1027	15887	9894
6	2025		-1649	-1649	-960	15887	9247
7	2026		-1649	-1649	-897	15887	8642
8	2027		-1649	-1649	-838	15887	8076
9	2028		-1649	-1649	-783	15887	7548
10	2029		-1649	-1649	-732	15887	7054
11	2030		-1649	-1649	-684	15887	6593
12	2031		-1649	-1649	-639	15887	6161
13	2032		-1649	-1649	-598	15887	5758
14	2033		-1649	-1649	-559	15887	5382
15	2034		-1649	-1649	-522	15887	5030
16	2035		-1649	-1649	-488	15887	4701
17	2036		-1649	-1649	-456	15887	4393
18	2037		-1649	-1649	-426	15887	4106
19	2038		-1649	-1649	-398	15887	3837
20	2039		-1649	-1649	-372	15887	3586
21	2040		-1649	-1649	-348	15887	3351
22	2041		-1649	-1649	-325	15887	3132

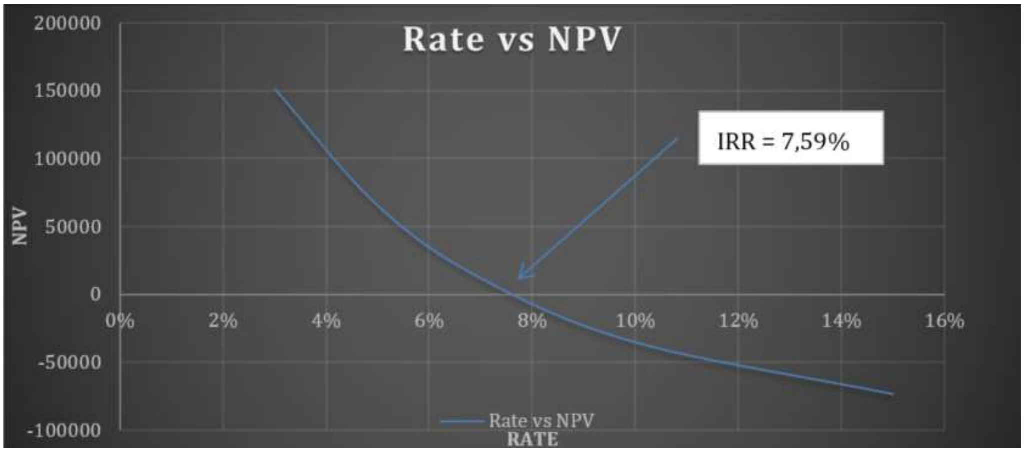
23	2042		-1649	-1649	-304	15887	2927
24	2043		-1649	-1649	-284	15887	2736
25	2044		-1649	-1649	-265	15887	2557
26	2045		-1649	-1649	-248	15887	2390
27	2046		-1649	-1649	-232	15887	2233
28	2047		-1649	-1649	-217	15887	2087
29	2048		-1649	-1649	-202	15887	1951
30	2049		-1649	-1649	-189	15887	1823
31	2050		-1649	-1649	-177	15887	1704
32	2051		-1649	-1649	-165	15887	1592
33	2052		-1649	-1649	-154	15887	1488
34	2053		-1649	-1649	-144	15887	1391
35	2054		-1649	-1649	-135	15887	1300
36	2055		-1649	-1649	-126	15887	1215
37	2056		-1649	-1649	-118	15887	1135
38	2057		-1649	-1649	-110	15887	1061
39	2058		-1649	-1649	-103	15887	992
40	2059		-1649	-1649	-96	15887	927

NPV

Year	Capital Cost	O&M	Total Cost	NPV Cost (7%)	Energy Revenue	NPV Revenue (7%)	Net NPV (7%)
	Eur	Eur	Eur	Eur	Eur	Eur	Eur
Total	-164888	-31494	-229359	-173327	635499	185001	11673

INTEREST RATE OF RETURN

Rate	NPV (Eur)
3%	150985
5%	64979
7%	11673
10%	-35503
15%	-73637



BENEFIT – COST RATIO

$$\mathbf{BCR} = \frac{\mathbf{PV_{benefits}}}{\mathbf{PV_{costs}}}$$

where:

$\mathbf{PV_{benefits}}$ = present value of benefits

$\mathbf{PV_{costs}}$ = present value of costs

B-C Ratio =	1,1

APPENDIX 5. SENSITIVITY ANALYSIS. ONE FRANCIS TURBINE

Discount rate varying from 5% to 12%
Price of energy from 0.06 to 0.15 EUR/kWh

					0,06	0,15
	Fiscal Year	**Capital Cost**	**O&M**	**Total Cost**	**Energy Revenue**	**Energy Revenue**
		Eur	**Eur**	**Eur**	**Eur**	**Eur**
	Total	**164888**	**-64471**	**-229359**	**317750**	**794374**
	2017	-49466		-49466		
	2018	-82444		-82444		
	2019	-32978		-32978		
1	2020		-495	-495	7944	19859
2	2021		-1319	-1319	7944	19859
3	2022		-1649	-1649	7944	19859
4	2023		-1649	-1649	7944	19859
5	2024		-1649	-1649	7944	19859
6	2025		-1649	-1649	7944	19859
7	2026		-1649	-1649	7944	19859
8	2027		-1649	-1649	7944	19859
9	2028		-1649	-1649	7944	19859
10	2029		-1649	-1649	7944	19859
11	2030		-1649	-1649	7944	19859
12	2031		-1649	-1649	7944	19859
13	2032		-1649	-1649	7944	19859
14	2033		-1649	-1649	7944	19859
15	2034		-1649	-1649	7944	19859
16	2035		-1649	-1649	7944	19859
17	2036		-1649	-1649	7944	19859
18	2037		-1649	-1649	7944	19859
19	2038		-1649	-1649	7944	19859
20	2039		-1649	-1649	7944	19859
21	2040		-1649	-1649	7944	19859
22	2041		-1649	-1649	7944	19859
23	2042		-1649	-1649	7944	19859
24	2043		-1649	-1649	7944	19859
25	2044		-1649	-1649	7944	19859

26	2045		-1649	-1649	7944	19859
27	2046		-1649	-1649	7944	19859
28	2047		-1649	-1649	7944	19859
29	2048		-1649	-1649	7944	19859
30	2049		-1649	-1649	7944	19859
31	2050		-1649	-1649	7944	19859
32	2051		-1649	-1649	7944	19859
33	2052		-1649	-1649	7944	19859
34	2053		-1649	-1649	7944	19859
35	2054		-1649	-1649	7944	19859
36	2055		-1649	-1649	7944	19859
37	2056		-1649	-1649	7944	19859
38	2057		-1649	-1649	7944	19859
39	2058		-1649	-1649	7944	19859
40	2059		-1649	-1649	7944	19859

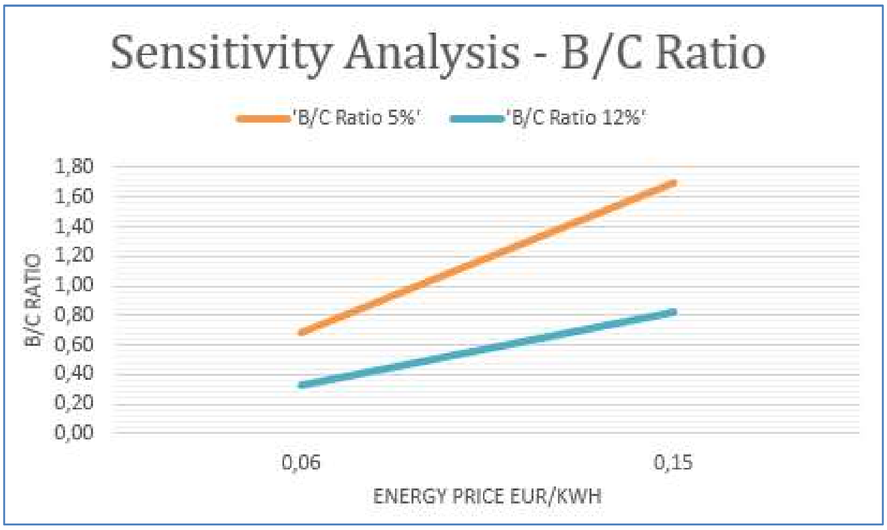
0.06 eur/kWh			
Rate	5%	Rate	12%
NPV	-58655,81	NPV	-106966,35
PV COST	**PV Benefits**	**PV COST**	**PV Benefits**
Eur	**Eur**	**Eur**	**Eur**
-182291	**123635**	**-159172**	**52205**
-49466	0	-49466	0
-78518	0	-73611	0
-29912	0	-26290	0
-427	6862	-352	5654
-1085	6535	-838	5048
-1292	6224	-936	4507
-1230	5928	-835	4025
-1172	5645	-746	3593
-1116	5377	-666	3208
-1063	5121	-595	2865
-1012	4877	-531	2558
-964	4645	-474	2284
-918	4423	-423	2039
-874	4213	-378	1820
-833	4012	-337	1625
-793	3821	-301	1451
-755	3639	-269	1296

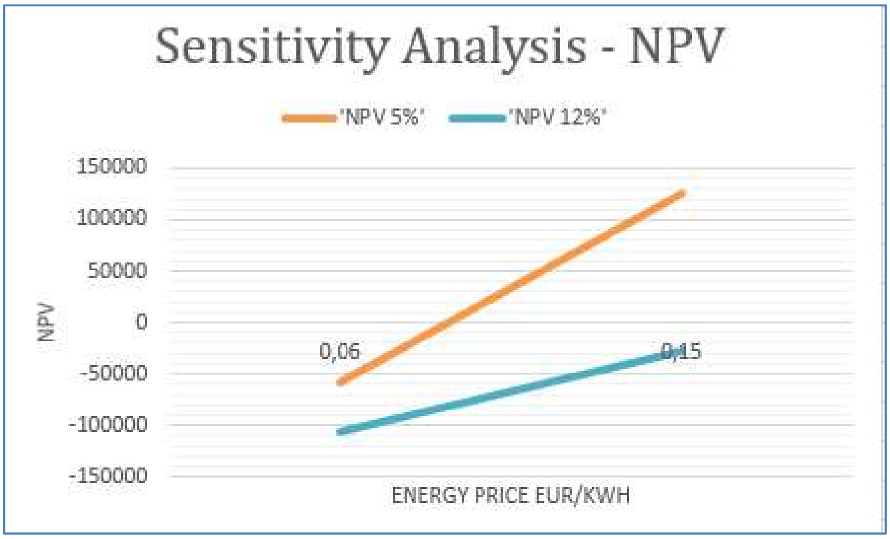
0.15 eur/kWh			
Rate	5%	Rate	12%
NPV	126796,27	NPV	-28658,31
PV COST	**PV Benefits**	**PV COST**	**PV Benefits**
Eur	**Eur**	**Eur**	**Eur**
-182291	**309087**	**-159172**	**130513**
-49466	0	-49466	0
-78518	0	-73611	0
-29912	0	-26290	0
-427	17155	-352	14135
-1085	16338	-838	12621
-1292	15560	-936	11269
-1230	14819	-835	10061
-1172	14114	-746	8983
-1116	13442	-666	8021
-1063	12802	-595	7161
-1012	12192	-531	6394
-964	11611	-474	5709
-918	11058	-423	5097
-874	10532	-378	4551
-833	10030	-337	4064
-793	9553	-301	3628
-755	9098	-269	3239

-719	3466	-240	1157
-685	3301	-214	1033
-653	3144	-191	922
-621	2994	-171	824
-592	2851	-153	735
-564	2716	-136	656
-537	2586	-122	586
-511	2463	-109	523
-487	2346	-97	467
-464	2234	-87	417
-442	2128	-77	373
-421	2026	-69	333
-401	1930	-62	297
-382	1838	-55	265
-363	1750	-49	237
-346	1667	-44	211
-330	1588	-39	189
-314	1512	-35	169
-299	1440	-31	150
-285	1372	-28	134
-271	1306	-25	120
-258	1244	-22	107
-246	1185	-20	96
-234	1128	-18	85
-223	1075	-16	76
-212	1023	-14	68

-719	8665	-240	2892
-685	8252	-214	2583
-653	7859	-191	2306
-621	7485	-171	2059
-592	7128	-153	1838
-564	6789	-136	1641
-537	6466	-122	1465
-511	6158	-109	1308
-487	5865	-97	1168
-464	5585	-87	1043
-442	5319	-77	931
-421	5066	-69	831
-401	4825	-62	742
-382	4595	-55	663
-363	4376	-49	592
-346	4168	-44	528
-330	3969	-39	472
-314	3780	-35	421
-299	3600	-31	376
-285	3429	-28	336
-271	3266	-25	300
-258	3110	-22	268
-246	2962	-20	239
-234	2821	-18	213
-223	2687	-16	191
-212	2559	-14	170

	0,06	Eur/kWh	NPV	B/C Ratio	**0,15**	Eur/kWh	NPV	B/C Ratio
Discount rate	PV Costs	PV Benefits			PV Costs	PV Benefits		
5%	-182291	123635	-58656	0,68	-182291	309087	126796	1,70
12%	-159172	52205	-106966	0,33	-159172	130513	-28658	0,82


Sensitivity Analysis - B/C Ratio
'B/C Ratio 5%'
'B/C Ratio 12%'
B/C RATIO
1,80
1,60
1,40
1,20
1,00
0,80
0,60
0,40
0,20
0,00
0,06
0,15
ENERGY PRICE EUR/KWH


Sensitivity Analysis - NPV
'NPV 5%'
'NPV 12%'
NPV
150000
100000
50000
0
-50000
-100000
-150000
0,06
0,15
ENERGY PRICE EUR/KWH

APPENDIX 6. CASH FLOW, NPV, IRR, B-C RATIO FOR ONE PELTON TURBINE SCHEME

INITIAL DATA

Total capital costs =	288666	Eur
Total Energy Generation =	148765	kWh/year
Energy Benefits =	17852	eur/year

CASH FLOW

	Fiscal Year	Capital Cost	O&M	Total Cost	NPV Cost (7%)	Energy Revenue	NPV Revenue (7%)
		Eur	Eur	Eur	Eur	Eur	Eur
	Total	**-288666**	**-55135**	**-401535**	**-303441**	**714074**	**207875**
	2017	-86600		-86600	-86600		
	2018	-144333		-144333	-134891		
	2019	-57733		-57733	-50426		
1	2020		-866	-866	-707	17852	14572
2	2021		-2309	-2309	-1762	17852	13619
3	2022		-2887	-2887	-2058	17852	12728
4	2023		-2887	-2887	-1924	17852	11895
5	2024		-2887	-2887	-1798	17852	11117
6	2025		-2887	-2887	-1680	17852	10390
7	2026		-2887	-2887	-1570	17852	9710
8	2027		-2887	-2887	-1467	17852	9075
9	2028		-2887	-2887	-1371	17852	8481
10	2029		-2887	-2887	-1282	17852	7926
11	2030		-2887	-2887	-1198	17852	7408
12	2031		-2887	-2887	-1119	17852	6923
13	2032		-2887	-2887	-1046	17852	6470
14	2033		-2887	-2887	-978	17852	6047
15	2034		-2887	-2887	-914	17852	5651
16	2035		-2887	-2887	-854	17852	5282
17	2036		-2887	-2887	-798	17852	4936
18	2037		-2887	-2887	-746	17852	4613
19	2038		-2887	-2887	-697	17852	4311
20	2039		-2887	-2887	-652	17852	4029
21	2040		-2887	-2887	-609	17852	3766
22	2041		-2887	-2887	-569	17852	3519

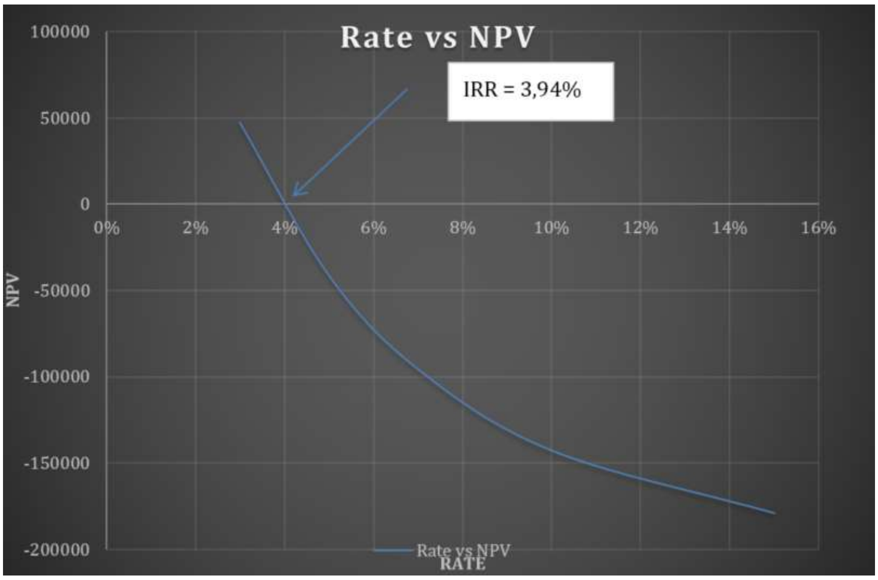
23	2042		-2887	-2887	-532	17852	3289
24	2043		-2887	-2887	-497	17852	3074
25	2044		-2887	-2887	-465	17852	2873
26	2045		-2887	-2887	-434	17852	2685
27	2046		-2887	-2887	-406	17852	2509
28	2047		-2887	-2887	-379	17852	2345
29	2048		-2887	-2887	-354	17852	2192
30	2049		-2887	-2887	-331	17852	2048
31	2050		-2887	-2887	-310	17852	1914
32	2051		-2887	-2887	-289	17852	1789
33	2052		-2887	-2887	-270	17852	1672
34	2053		-2887	-2887	-253	17852	1563
35	2054		-2887	-2887	-236	17852	1460
36	2055		-2887	-2887	-221	17852	1365
37	2056		-2887	-2887	-206	17852	1276
38	2057		-2887	-2887	-193	17852	1192
39	2058		-2887	-2887	-180	17852	1114
40	2059		-2887	-2887	-168	17852	1041

NPV

Year	Capital Cost	O&M	Total Cost	NPV Cost (7%)	Energy Revenue	NPV Revenue (7%)	Net NPV (7%)
	Eur	Eur	Eur	Eur	Eur	Eur	Eur
Total	-288666	-55135	-401535	-303441	714074	207875	-95566

INTEREST RATE OF RETURN

Rate	NPV (Eur)
3%	47274
5%	-41290
7%	-95566
10%	-142666
15%	-178946



BENEFIT – COST RATIO

$$BCR = \frac{PV_{benefits}}{PV_{costs}}$$

where:

$PV_{benefits}$ = present value of benefits

PV_{costs} = present value of costs

B-C Ratio =	0.7

APPENDIX 7. SENSITIVITY ANALYSIS. ONE PELTON TURBINE

Discount rate varying from 5% to 12%
Price of energy from 0.06 to 0.15 EUR/kWh

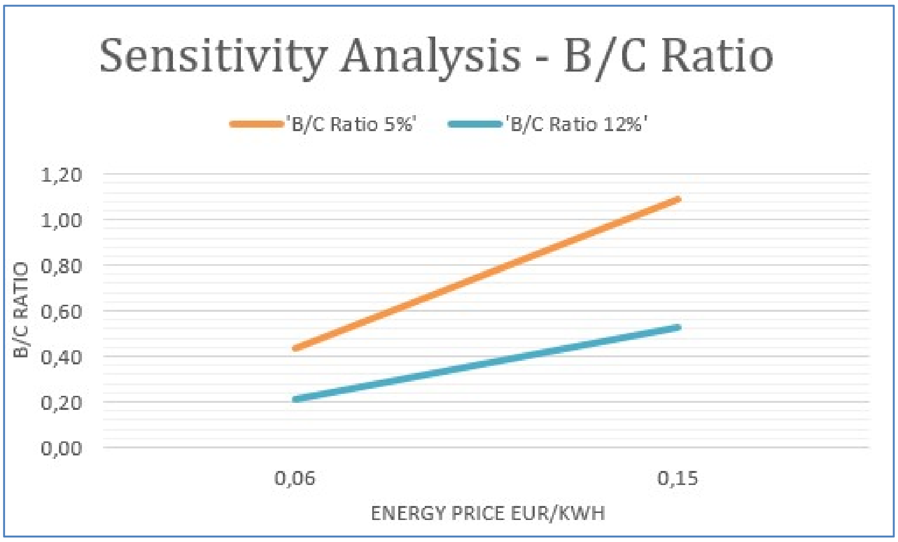
					0,06	0,15
	Fiscal Year	**Capital Cost**	**O&M**	**Total Cost**	**Energy Revenue**	**Energy Revenue**
		Eur	**Eur**	**Eur**	**Eur**	**Eur**
	Total	**288666**	**-112868**	**-401535**	**357037**	**892592**
	2017	-86600		-86600		
	2018	-144333		-144333		
	2019	-57733		-57733		
1	2020		-866	-866	8926	22315
2	2021		-2309	-2309	8926	22315
3	2022		-2887	-2887	8926	22315
4	2023		-2887	-2887	8926	22315
5	2024		-2887	-2887	8926	22315
6	2025		-2887	-2887	8926	22315
7	2026		-2887	-2887	8926	22315
8	2027		-2887	-2887	8926	22315
9	2028		-2887	-2887	8926	22315
10	2029		-2887	-2887	8926	22315
11	2030		-2887	-2887	8926	22315
12	2031		-2887	-2887	8926	22315
13	2032		-2887	-2887	8926	22315
14	2033		-2887	-2887	8926	22315
15	2034		-2887	-2887	8926	22315
16	2035		-2887	-2887	8926	22315
17	2036		-2887	-2887	8926	22315
18	2037		-2887	-2887	8926	22315
19	2038		-2887	-2887	8926	22315
20	2039		-2887	-2887	8926	22315
21	2040		-2887	-2887	8926	22315
22	2041		-2887	-2887	8926	22315
23	2042		-2887	-2887	8926	22315
24	2043		-2887	-2887	8926	22315
25	2044		-2887	-2887	8926	22315

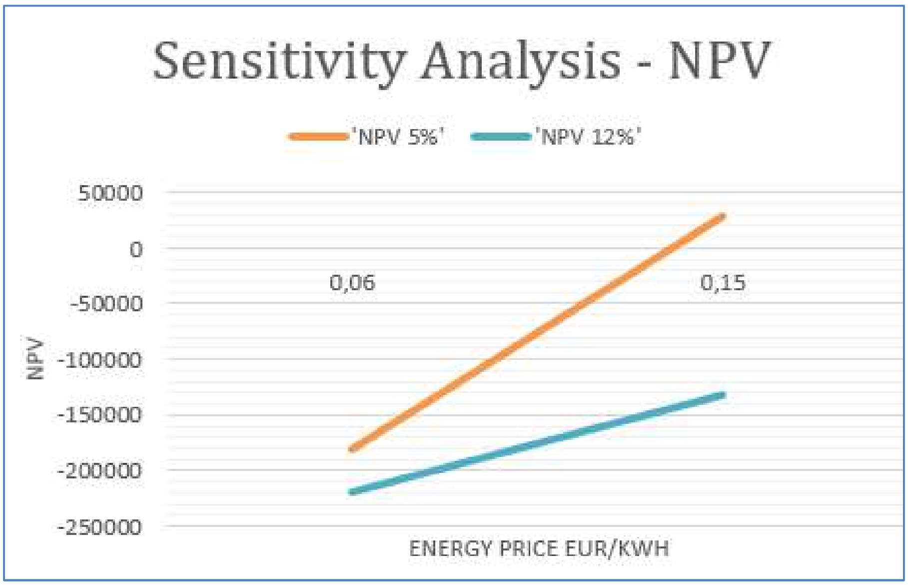
26	2045		-2887	-2887	8926	22315
27	2046		-2887	-2887	8926	22315
28	2047		-2887	-2887	8926	22315
29	2048		-2887	-2887	8926	22315
30	2049		-2887	-2887	8926	22315
31	2050		-2887	-2887	8926	22315
32	2051		-2887	-2887	8926	22315
33	2052		-2887	-2887	8926	22315
34	2053		-2887	-2887	8926	22315
35	2054		-2887	-2887	8926	22315
36	2055		-2887	-2887	8926	22315
37	2056		-2887	-2887	8926	22315
38	2057		-2887	-2887	8926	22315
39	2058		-2887	-2887	8926	22315
40	2059		-2887	-2887	8926	22315

0.06 eur/kWh				0.15 eur/kWh			
Rate	5%	Rate	12%	Rate	5%	Rate	12%
NPV	-180211,37	NPV	-219998,75	**NPV**	28170,48	NPV	-132008,51
PV COST	**PV Benefits**	**PV COST**	**PV Benefits**	**PV COST**	**PV Benefits**	**PV COST**	**PV Benefits**
Eur	**Eur**	**Eur**	**Eur**	**Eur**	**Eur**	**Eur**	**Eur**
-319133	**138921**	**-278659**	**58660**	**-319133**	**347303**	**-278659**	**146650**
-86600	0	-86600	0	-86600	0	-86600	0
-137460	0	-128869	0	-137460	0	-128869	0
-52366	0	-46025	0	-52366	0	-46025	0
-748	7711	-616	6353	-748	19276	-616	15883
-1900	7343	-1468	5673	-1900	18358	-1468	14181
-2262	6994	-1638	5065	-2262	17484	-1638	12662
-2154	6661	-1462	4522	-2154	16652	-1462	11305
-2051	6343	-1306	4038	-2051	15859	-1306	10094
-1954	6041	-1166	3605	-1954	15104	-1166	9013
-1861	5754	-1041	3219	-1861	14384	-1041	8047
-1772	5480	-929	2874	-1772	13699	-929	7185
-1688	5219	-830	2566	-1688	13047	-830	6415
-1607	4970	-741	2291	-1607	12426	-741	5728
-1531	4734	-662	2046	-1531	11834	-662	5114
-1458	4508	-591	1826	-1458	11270	-591	4566
-1389	4294	-527	1631	-1389	10734	-527	4077
-1322	4089	-471	1456	-1322	10223	-471	3640

-1259	3894	-420	1300	-1259	9736	-420	3250
-1199	3709	-375	1161	-1199	9272	-375	2902
-1142	3532	-335	1036	-1142	8831	-335	2591
-1088	3364	-299	925	-1088	8410	-299	2313
-1036	3204	-267	826	-1036	8010	-267	2065
-987	3051	-239	738	-987	7628	-239	1844
-940	2906	-213	659	-940	7265	-213	1647
-895	2768	-190	588	-895	6919	-190	1470
-852	2636	-170	525	-852	6590	-170	1313
-812	2510	-152	469	-812	6276	-152	1172
-773	2391	-135	419	-773	5977	-135	1046
-736	2277	-121	374	-736	5692	-121	934
-701	2169	-108	334	-701	5421	-108	834
-668	2065	-96	298	-668	5163	-96	745
-636	1967	-86	266	-636	4917	-86	665
-606	1873	-77	238	-606	4683	-77	594
-577	1784	-69	212	-577	4460	-69	530
-549	1699	-61	189	-549	4248	-61	473
-523	1618	-55	169	-523	4045	-55	423
-498	1541	-49	151	-498	3853	-49	377
-475	1468	-44	135	-475	3669	-44	337
-452	1398	-39	120	-452	3495	-39	301
-431	1331	-35	107	-431	3328	-35	269
-410	1268	-31	96	-410	3170	-31	240
-391	1208	-28	86	-391	3019	-28	214
-372	1150	-25	76	-372	2875	-25	191

	0,06	Eur/kWh	NPV	B/C Ratio	**0,15**	Eur/kWh	NPV	B/C Ratio
Discount rate	PV Costs	PV Benefits			PV Costs	PV Benefits		
5%	-319133	138921	-180211	0,44	-319133	347303	28170	1,09
12%	-278659	58660	-219999	0,21	-278659	146650	-132009	0,53


Sensitivity Analysis - B/C Ratio
'B/C Ratio 5%'
'B/C Ratio 12%'
B/C RATIO
1,20
1,00
0,80
0,60
0,40
0,20
0,00
0,06
0,15
ENERGY PRICE EUR/KWH


Sensitivity Analysis - NPV
'NPV 5%'
'NPV 12%'
NPV
50000
0
-50000
-100000
-150000
-200000
-250000
0,06
0,15
ENERGY PRICE EUR/KWH

APPENDIX 8. CASH FLOW, NPV, IRR, B-C RATIO FOR TWO FRANCIS TURBINES SCHEME

INITIAL DATA

Total capital costs =	218613	Eur
Total Energy Generation =	155469	kWh/year
Energy Benefits =	18656	eur/year

CASH FLOW

	Fiscal Year	Capital Cost	O&M	Total Cost	NPV Cost (7%)	Energy Revenue	NPV Revenue (7%)
		Eur	Eur	Eur	Eur	Eur	Eur
	Total	**-218613**	**-41755**	**-304090**	**-229802**	**746252**	**217242**
	2017	-65584		-65584	-65584		
	2018	-109306		-109306	-102155		
	2019	-43723		-43723	-38189		
1	2020		-656	-656	-535	18656	15229
2	2021		-1749	-1749	-1334	18656	14233
3	2022		-2186	-2186	-1559	18656	13302
4	2023		-2186	-2186	-1457	18656	12431
5	2024		-2186	-2186	-1361	18656	11618
6	2025		-2186	-2186	-1272	18656	10858
7	2026		-2186	-2186	-1189	18656	10148
8	2027		-2186	-2186	-1111	18656	9484
9	2028		-2186	-2186	-1039	18656	8863
10	2029		-2186	-2186	-971	18656	8284
11	2030		-2186	-2186	-907	18656	7742
12	2031		-2186	-2186	-848	18656	7235
13	2032		-2186	-2186	-792	18656	6762
14	2033		-2186	-2186	-741	18656	6320
15	2034		-2186	-2186	-692	18656	5906
16	2035		-2186	-2186	-647	18656	5520
17	2036		-2186	-2186	-604	18656	5159
18	2037		-2186	-2186	-565	18656	4821
19	2038		-2186	-2186	-528	18656	4506
20	2039		-2186	-2186	-493	18656	4211
21	2040		-2186	-2186	-461	18656	3935
22	2041		-2186	-2186	-431	18656	3678

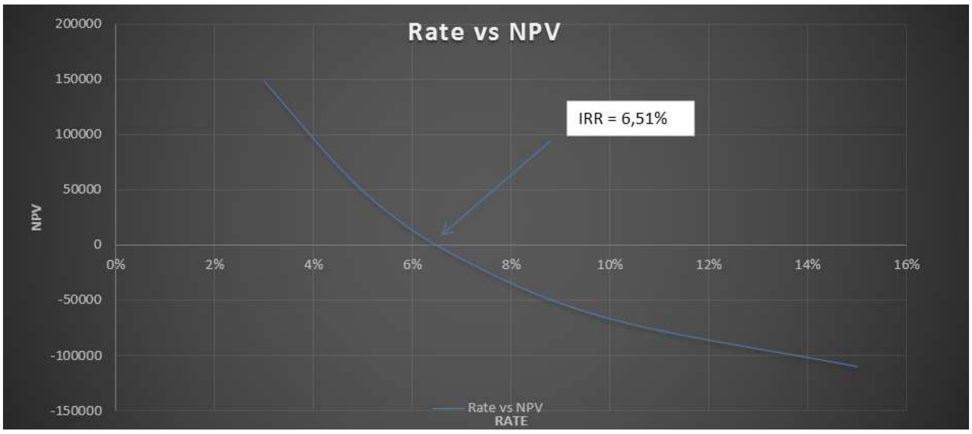
23	2042		-2186	-2186	-403	18656	3437
24	2043		-2186	-2186	-376	18656	3213
25	2044		-2186	-2186	-352	18656	3002
26	2045		-2186	-2186	-329	18656	2806
27	2046		-2186	-2186	-307	18656	2622
28	2047		-2186	-2186	-287	18656	2451
29	2048		-2186	-2186	-268	18656	2290
30	2049		-2186	-2186	-251	18656	2141
31	2050		-2186	-2186	-234	18656	2001
32	2051		-2186	-2186	-219	18656	1870
33	2052		-2186	-2186	-205	18656	1747
34	2053		-2186	-2186	-191	18656	1633
35	2054		-2186	-2186	-179	18656	1526
36	2055		-2186	-2186	-167	18656	1426
37	2056		-2186	-2186	-156	18656	1333
38	2057		-2186	-2186	-146	18656	1246
39	2058		-2186	-2186	-136	18656	1164
40	2059		-2186	-2186	-128	18656	1088

NPV

Year	Capital Cost	O&M	Total Cost	NPV Cost (7%)	Energy Revenue	NPV Revenue (7%)	Net NPV (7%)
	Eur	Eur	Eur	Eur	Eur	Eur	Eur
Total	-218613	-41755	-304090	-229802	746252	217242	-12560

INTEREST RATE OF RETURN

Rate	NPV (Eur)
3%	147720
5%	48678
7%	-12560
10%	-66529
15%	-109722



BENEFIT – COST RATIO

$$\mathrm{BCR} = \frac{\mathrm{PV}_{\mathrm{benefits}}}{\mathrm{PV}_{\mathrm{costs}}}$$

where:

$\mathrm{PV}_{\mathrm{benefits}}$ = present value of benefits

$\mathrm{PV}_{\mathrm{costs}}$ = present value of costs

B-C Ratio = 0.9

APPENDIX 9. SENSITIVITY ANALYSIS. TWO FRANCIS TURBINES

Discount rate varying from 5% to 12%
Price of energy from 0.06 to 0.15 EUR/kWh

					0,06	0,15
	Fiscal Year	Capital Cost	O&M	Total Cost	Energy Revenue	Energy Revenue
		Eur	Eur	Eur	Eur	Eur
	Total	**218613**	**-85477**	**-304090**	**373126**	**932815**
	2017	-65584		-65584		
	2018	-109306		-109306		
	2019	-43723		-43723		
1	2020		-656	-656	9328	23320
2	2021		-1749	-1749	9328	23320
3	2022		-2186	-2186	9328	23320
4	2023		-2186	-2186	9328	23320
5	2024		-2186	-2186	9328	23320
6	2025		-2186	-2186	9328	23320
7	2026		-2186	-2186	9328	23320
8	2027		-2186	-2186	9328	23320
9	2028		-2186	-2186	9328	23320
10	2029		-2186	-2186	9328	23320
11	2030		-2186	-2186	9328	23320
12	2031		-2186	-2186	9328	23320
13	2032		-2186	-2186	9328	23320
14	2033		-2186	-2186	9328	23320
15	2034		-2186	-2186	9328	23320
16	2035		-2186	-2186	9328	23320
17	2036		-2186	-2186	9328	23320
18	2037		-2186	-2186	9328	23320
19	2038		-2186	-2186	9328	23320
20	2039		-2186	-2186	9328	23320
21	2040		-2186	-2186	9328	23320
22	2041		-2186	-2186	9328	23320
23	2042		-2186	-2186	9328	23320
24	2043		-2186	-2186	9328	23320
25	2044		-2186	-2186	9328	23320

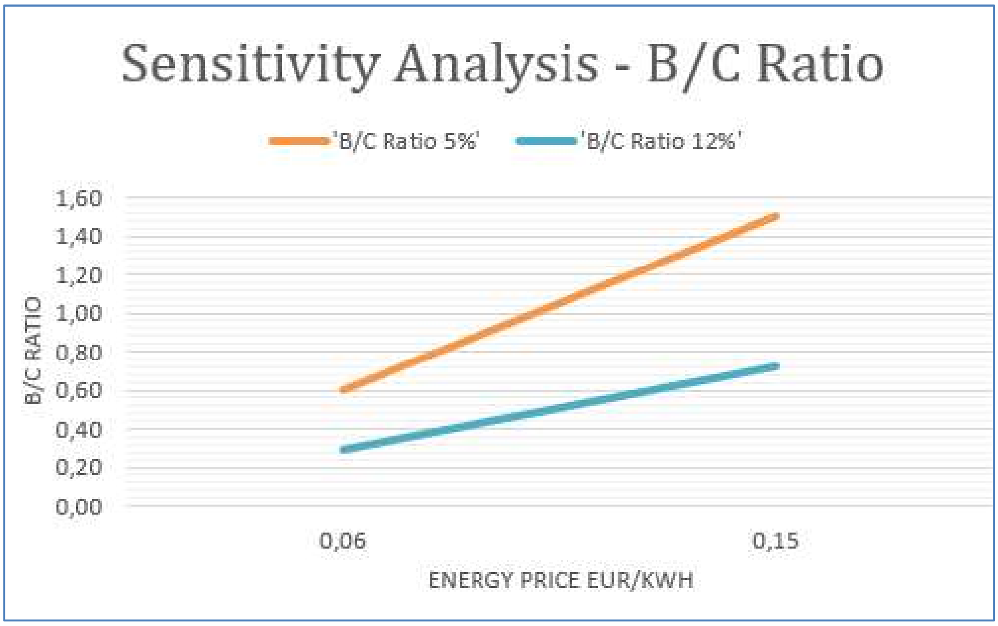
26	2045		-2186	-2186	9328	23320
27	2046		-2186	-2186	9328	23320
28	2047		-2186	-2186	9328	23320
29	2048		-2186	-2186	9328	23320
30	2049		-2186	-2186	9328	23320
31	2050		-2186	-2186	9328	23320
32	2051		-2186	-2186	9328	23320
33	2052		-2186	-2186	9328	23320
34	2053		-2186	-2186	9328	23320
35	2054		-2186	-2186	9328	23320
36	2055		-2186	-2186	9328	23320
37	2056		-2186	-2186	9328	23320
38	2057		-2186	-2186	9328	23320
39	2058		-2186	-2186	9328	23320
40	2059		-2186	-2186	9328	23320

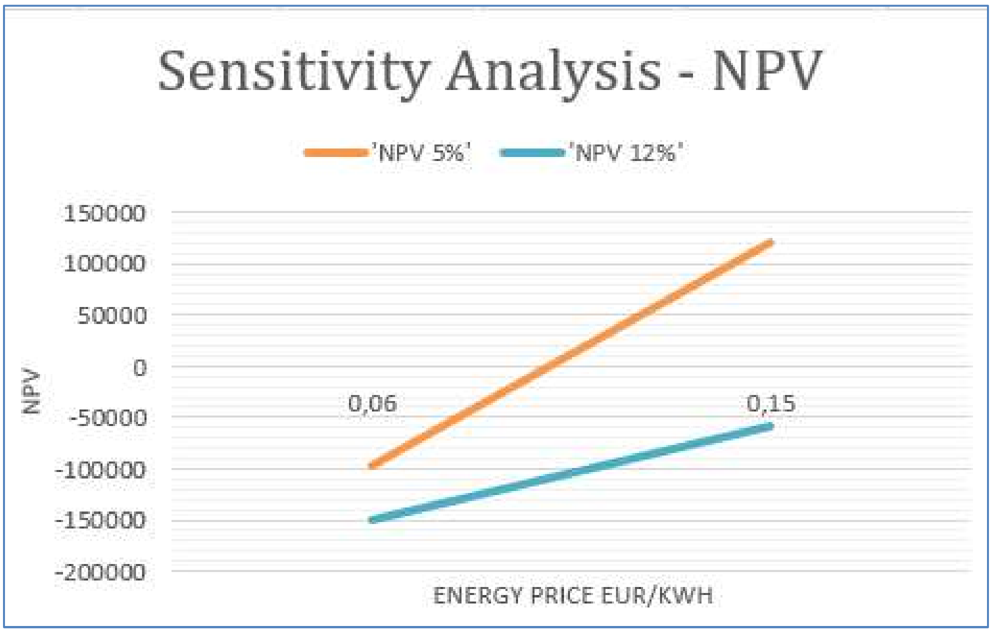
0.06 eur/kWh				0.15 eur/kWh			
Rate	5%	Rate	12%	Rate	5%	Rate	12%
NPV	-96503,92	NPV	-149730,27	**NPV**	121268,22	NPV	-57774,94
PV COST	**PV Benefits**	**PV COST**	**PV Benefits**	**PV COST**	**PV Benefits**	**PV COST**	**PV Benefits**
Eur	**Eur**	**Eur**	**Eur**	**Eur**	**Eur**	**Eur**	**Eur**
-241685	**145181**	**-211034**	**61304**	**-241685**	**362954**	**-211034**	**153259**
-65584	0	-65584	0	-65584	0	-65584	0
-104101	0	-97595	0	-104101	0	-97595	0
-39658	0	-34855	0	-39658	0	-34855	0
-567	8058	-467	6640	-567	20145	-467	16599
-1439	7674	-1111	5928	-1439	19186	-1111	14821
-1713	7309	-1240	5293	-1713	18272	-1240	13233
-1631	6961	-1108	4726	-1631	17402	-1108	11815
-1554	6629	-989	4220	-1554	16573	-989	10549
-1480	6314	-883	3767	-1480	15784	-883	9419
-1409	6013	-788	3364	-1409	15033	-788	8410
-1342	5727	-704	3003	-1342	14317	-704	7509
-1278	5454	-628	2682	-1278	13635	-628	6704
-1217	5194	-561	2394	-1217	12986	-561	5986
-1159	4947	-501	2138	-1159	12367	-501	5344
-1104	4711	-447	1909	-1104	11778	-447	4772
-1052	4487	-399	1704	-1052	11217	-399	4261
-1001	4273	-357	1522	-1001	10683	-357	3804

-954	4070	-318	1359
-908	3876	-284	1213
-865	3691	-254	1083
-824	3516	-227	967
-785	3348	-202	863
-747	3189	-181	771
-712	3037	-161	688
-678	2892	-144	615
-646	2755	-129	549
-615	2623	-115	490
-586	2499	-103	437
-558	2380	-92	391
-531	2266	-82	349
-506	2158	-73	311
-482	2056	-65	278
-459	1958	-58	248
-437	1864	-52	222
-416	1776	-46	198
-396	1691	-41	177
-377	1611	-37	158
-359	1534	-33	141
-342	1461	-29	126
-326	1391	-26	112
-311	1325	-23	100
-296	1262	-21	90
-282	1202	-19	80

-954	10175	-318	3396
-908	9690	-284	3033
-865	9229	-254	2708
-824	8789	-227	2418
-785	8371	-202	2159
-747	7972	-181	1927
-712	7592	-161	1721
-678	7231	-144	1536
-646	6887	-129	1372
-615	6559	-115	1225
-586	6246	-103	1094
-558	5949	-92	976
-531	5666	-82	872
-506	5396	-73	778
-482	5139	-65	695
-459	4894	-58	621
-437	4661	-52	554
-416	4439	-46	495
-396	4228	-41	442
-377	4026	-37	394
-359	3835	-33	352
-342	3652	-29	314
-326	3478	-26	281
-311	3313	-23	251
-296	3155	-21	224
-282	3005	-19	200

	0,06	Eur/kWh	NPV	B/C Ratio	**0,15**	Eur/kWh	NPV	B/C Ratio
Discount rate	PV Costs	PV Benefits			PV Costs	PV Benefits		
5%	-241685	145181	-96504	0,60	-241685	362954	121268	1,50
12%	-211034	61304	-149730	0,29	-211034	153259	-57775	0,73


Sensitivity Analysis - B/C Ratio
'B/C Ratio 5%'
'B/C Ratio 12%'
B/C RATIO
1,60
1,40
1,20
1,00
0,80
0,60
0,40
0,20
0,00
0,06
0,15
ENERGY PRICE EUR/KWH


Sensitivity Analysis - NPV
'NPV 5%'
'NPV 12%'
NPV
150000
100000
50000
0
-50000
-100000
-150000
-200000
0,06
0,15
ENERGY PRICE EUR/KWH

APPENDIX 10. EVAPOTRANSPIRATION

MONTH	AVG. TEMP.	MONTHLY HEAT INDEX	e (mm/month)	L	ETPtho (mm/month)	ETPtho (m3/ha.month)
JANUARY	11,5	3,53	34,38	0,87	29,91	299,09
FEBRUARY	11,7	3,62	35,36	0,85	30,05	300,53
MARCH	12,6	4,05	39,89	1,03	41,09	410,87
APRIL	13,8	4,65	46,26	1,09	50,42	504,21
MAY	16,4	6,04	61,27	1,21	74,13	741,34
JUNE	19	7,55	77,85	1,21	94,20	942,02
JULY	21,7	9,23	96,65	1,23	118,88	1.188,85
AUGUST	22,2	9,55	100,31	1,16	116,35	1.163,55
SEPTEMBER	20,3	8,34	86,71	1,03	89,31	893,11
OCTOBER	17,4	6,61	67,46	0,97	65,44	654,41
NOVEMBER	14,2	4,86	48,46	0,86	41,68	416,76
DECEMBER	12	3,86	36,84	0,84	30,95	309,49
TOTAL		71,89			782,42	7.824,22

Evaporation Infierno (m3)	Evaporation Renegado	Evaporation Infierno PV
13.907,59	22.745,64	7.507,11
13.974,69	22.855,38	7.543,33
19.105,44	31.246,64	10.312,83
23.445,87	38.345,34	12.655,73
34.472,10	56.378,57	18.607,52
43.803,91	71.640,59	23.644,69
55.281,29	90.411,67	29.840,01
54.104,98	88.487,83	29.205,06
41.529,57	67.920,94	22.417,04
30.430,04	49.767,84	16.425,68
19.379,41	31.694,71	10.460,71
14.391,40	23.536,90	7.768,26
363.826,30	**595.032,05**	**196.387,96**

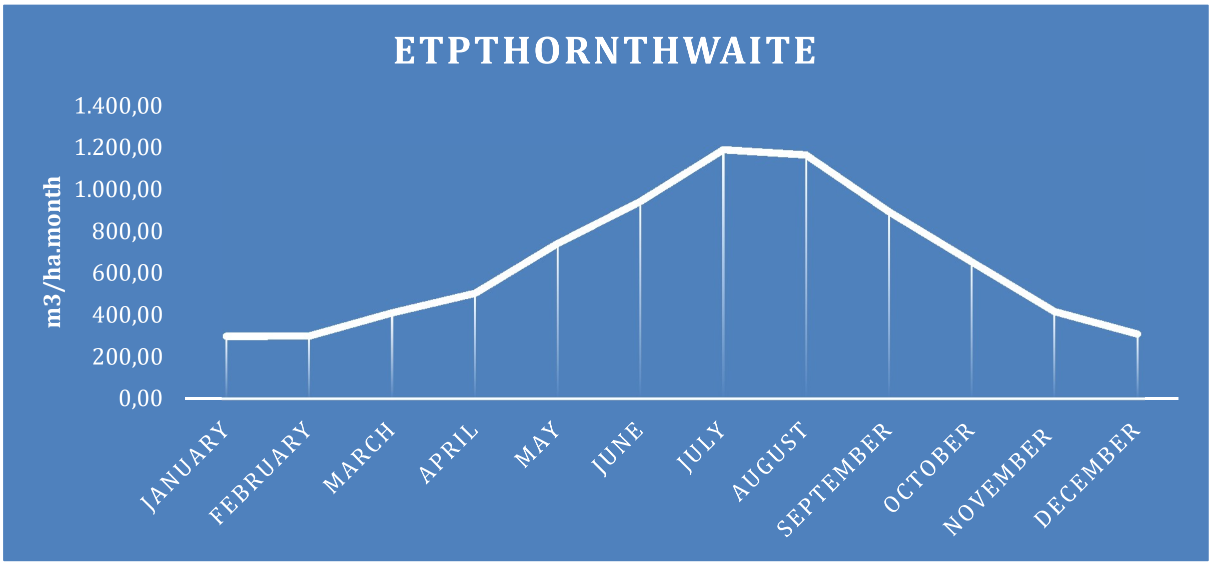


Tabla. Índice de calor mensual en función de la temperatura. Se obtiene a partir de una temperatura determinada, entrando con el valor entero por el eje vertical y con el decimal por el horizontal.

tm(ºC)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0	0	0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.07
1	0.09	0.1	0.12	0.13	0.15	0.16	0.18	0.2	0.21	0.23
2	0.25	0.27	0.29	0.31	0.33	0.35	0.37	0.39	0.42	0.44
3	0.46	0.48	0.51	0.53	0.56	0.58	0.61	0.63	0.66	0.69
4	0.71	0.74	0.77	0.8	0.82	0.85	0.88	0.91	0.94	0.97
5	1	1.03	1.06	1.09	1.12	1.16	1.19	1.22	1.25	1.28
6	1.32	1.35	1.38	1.42	1.45	1.49	1.52	1.56	1.59	1.63
7	1.66	1.7	1.74	1.77	1.81	1.85	1.88	1.92	1.96	2
8	2.04	2.08	2.11	2.15	2.19	2.23	2.27	2.31	2.35	2.39
9	2.43	2.48	2.52	2.56	2.6	2.64	2.68	2.73	2.77	2.81
10	2.86	2.9	2.94	2.99	3.03	3.07	3.12	3.16	3.21	3.25
11	3.3	3.34	3.39	3.44	3.48	3.53	3.58	3.62	3.67	3.72
12	3.76	3.81	3.86	3.91	3.96	4	4.05	4.1	4.15	4.2
13	4.25	4.3	4.35	4.4	4.45	4.5	4.55	4.6	4.65	4.7
14	4.75	4.8	4.86	4.91	4.96	5.01	5.07	5.12	5.17	5.22
15	5.28	5.33	5.38	5.44	5.49	5.55	5.6	5.65	5.71	5.76
16	5.82	5.87	5.93	5.98	6.04	6.1	6.15	6.21	6.26	6.32
17	6.38	6.43	6.49	6.55	6.61	6.66	6.72	6.78	6.84	6.9
18	6.95	7.01	7.07	7.13	7.19	7.25	7.31	7.37	7.43	7.49
19	7.55	7.61	7.67	7.73	7.79	7.85	7.91	7.97	8.03	8.1
20	8.16	8.22	8.28	8.34	8.41	8.47	8.53	8.59	8.66	8.72
21	8.78	8.85	8.91	8.97	9.04	9.1	9.16	9.23	9.29	9.36
22	9.42	9.49	9.55	9.62	9.68	9.75	9.81	9.88	9.95	10.01
23	10.08	10.15	10.21	10.28	10.35	10.41	10.48	10.55	10.61	10.68
24	10.75	10.82	10.89	10.95	11.02	11.09	11.16	11.23	11.3	11.37
25	11.44	11.5	11.57	11.64	11.71	11.78	11.85	11.92	11.99	12.06
26	12.13	12.21	12.28	12.35	12.42	12.49	12.56	12.63	12.7	12.78

(Amorox, 2010)

Tabla. Valor coeficiente "a". Se entra con el valor del índice de calor anual I y se lee directamente el valor de "a".

I	a	I	a	I	a	I	a
20	0.83	60	1.44	100	2.19	140	3.34
21	0.84	61	1.45	101	2.21	141	3.38
22	0.86	62	1.47	102	2.23	142	3.42
23	0.87	63	1.48	103	2.26	143	3.45
24	0.89	64	1.5	104	2.28	144	3.49
25	0.9	65	1.52	105	2.31	145	3.53
26	0.92	66	1.53	106	2.33	146	3.57
27	0.93	67	1.55	107	2.35	147	3.6
28	0.95	68	1.57	108	2.38	148	3.64
29	0.96	69	1.58	109	2.4	149	3.68
30	0.98	70	1.6	110	2.43	150	3.72
31	0.99	71	1.62	111	2.45	151	3.76
32	1.01	72	1.63	112	2.48	152	3.81
33	1.02	73	1.65	113	2.51	153	3.85
34	1.04	74	1.67	114	2.53	154	3.89
35	1.05	75	1.69	115	2.56	155	3.93
36	1.07	76	1.71	116	2.59	156	3.97
37	1.08	77	1.72	117	2.61	157	4.02
38	1.1	78	1.74	118	2.64	158	4.06

(Amorox, 2010)

39	1.11	79	1.76	119	2.67	159	4.11
40	1.13	80	1.78	120	2.7	160	4.15
41	1.14	81	1.8	121	2.73	161	4.2
42	1.16	82	1.82	122	2.76	162	4.24
43	1.17	83	1.83	123	2.79	163	4.29
44	1.19	84	1.85	124	2.82	164	4.33
45	1.2	85	1.87	125	2.85	165	4.38
46	1.22	86	1.89	126	2.88	166	4.43
47	1.23	87	1.91	127	2.91	167	4.48
48	1.25	88	1.93	128	2.94	168	4.53
49	1.26	89	1.95	129	2.97	169	4.58
50	1.28	90	1.97	130	3	170	4.63
51	1.3	91	1.99	131	3.03	171	4.68
52	1.31	92	2.01	132	3.07	172	4.73
53	1.33	93	2.04	133	3.1	173	4.78
54	1.34	94	2.06	134	3.13	174	4.83
55	1.36	95	2.08	135	3.17	175	4.88
56	1.37	96	2.1	136	3.2	176	4.94
57	1.39	97	2.12	137	3.24	177	4.99
58	1.4	98	2.14	138	3.27	178	5.05
59	1.42	99	2.17	139	3.31	179	5.1

(Amorox, 2010)

Tabla. Valor L del método de Thornthwaite. Coeficientes para la corrección de la ETP debida a la duración media de la luz solar para un determinado mes y latitud.

LAT. N.	E	F	M	A	M	J	J	A	S	O	N	D
27	0,92	0,88	1,03	1,07	1,16	1,15	1,18	1,13	1,02	0,99	0,90	0,90
28	0,91	0,88	1,03	1,07	1,16	1,16	1,18	1,13	1,02	0,98	0,90	0,90
29	0,91	0,87	1,03	1,07	1,17	1,16	1,19	1,13	1,03	0,98	0,90	0,89
30	0,90	0,87	1,03	1,08	1,18	1,17	1,20	1,14	1,03	0,98	0,89	0,88
35	0,87	0,85	1,03	1,09	1,21	1,21	1,23	1,16	1,03	0,97	0,86	0,85
36	0,87	0,85	1,03	1,10	1,21	1,22	1,24	1,16	1,03	0,97	0,86	0,84
37	0,86	0,84	1,03	1,10	1,22	1,23	1,25	1,17	1,03	0,97	0,85	0,83
38	0,85	0,84	1,03	1,10	1,23	1,24	1,25	1,17	1,04	0,96	0,84	0,83
39	0,85	0,84	1,03	1,11	1,23	1,24	1,26	1,18	1,04	0,96	0,84	0,82
40	0,84	0,83	1,03	1,11	1,24	1,25	1,27	1,18	1,04	0,96	0,83	0,81
41	0,83	0,83	1,03	1,11	1,25	1,26	1,27	1,19	1,04	0,96	0,82	0,80
42	0,82	0,83	1,03	1,12	1,26	1,27	1,28	1,19	1,04	0,95	0,82	0,79
43	0,81	0,82	1,02	1,12	1,26	1,28	1,29	1,20	1,04	0,95	0,81	0,77
44	0,81	0,82	1,02	1,13	1,27	1,29	1,30	1,20	1,04	0,95	0,80	0,76

(Amorox, 2010)

Saved
167.438,34 m3/year
83.719,17 eur/year

APPENDIX 11. BENEFITS DUE TO REDUCTION OF EVAPORATION

EVAPORATION (mm/year)	EVAPORATION (m3/ha.month)	EVAPORATION INFIERNO (m3)	EVAPORATION INFIERNO WITH PV (m3)	VOLUME SAVED WITH PV	BENEFIT
1100	11000	511500	276100	235400	117700

APPENDIX 12. SIMULATION REPORT (MULTICONSULT ASA, 2016)

PVSYST V6.43	28/04/16	Page 1/4

Grid-Connected System: Simulation parameters

Project : **Cueta**

Geographical Site		**Cueta**	Country	**Spain**
Situation	Latitude	35.9°N	Longitude	5.3°W
Time defined as	Legal Time	Time zone UT+1	Altitude	73 m
	Albedo	0.20		
Meteo data:	**Cueta**	Meteonorm 7.1 (1993-2009), Sat=100% - Synthetic		

Simulation variant : **Floating fields 45 degrees west**

Simulation date 28/04/16 13h18

Simulation parameters

Collector Plane Orientation	Tilt	12°	Azimuth	45°
40 Sheds	Pitch	1.50 m	Collector width	1.00 m
Inactive band	Top	0.00 m	Bottom	0.00 m
Shading limit angle	Gamma	21.72 °	Occupation Ratio	66.7 %
Shadings electrical effect	Cell size	15.6cm	Strings in width	3
Models used	Transposition	Perez	Diffuse	Perez, Meteonorm
Horizon	Average Height	9.5°		
Near Shadings	Mutual shadings of sheds	Electrical effect		

PV Array Characteristics

PV module Si-poly	Model	**REC 260PE / PE-BLK**		
Original PVsyst database	Manufacturer	REC		
Number of PV modules	In series	14 modules	In parallel	620 strings
Total number of PV modules	Nb. modules	8680	Unit Nom. Power	260 Wp
Array global power	Nominal (STC)	**2257 kWp**	At operating cond.	2031 kWp (50°C)
Array operating characteristics (50°C)	U mpp	388 V	I mpp	5236 A
Total area	Module area	**14322 m²**	Cell area	12676 m²
Inverter	Model	**500 kWac inverter**		
Original PVsyst database	Manufacturer	Generic		
Characteristics	Operating Voltage	320-700 V	Unit Nom. Power	500 kWac
Inverter pack	Nb. of inverters	4 units	Total Power	2000 kWac

PV Array loss factors

Array Soiling Losses			Loss Fraction	1.0 %
Thermal Loss factor	Uc (const)	25.0 W/m²K	Uv (wind)	1.5 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	0.80 mOhm	Loss Fraction	1.0 % at STC
LID - Light Induced Degradation			Loss Fraction	1.5 %
Module Quality Loss			Loss Fraction	-0.5 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP

Incidence effect, user defined profile

0°	30°	50°	60°	70°	75°	80°	85°	90°
1.00	0.99	0.97	0.95	0.90	0.86	0.76	0.48	0.00

User's needs : Unlimited load (grid)

PVsyst Licensed to Multiconsult (Norway)

PVSYST V6.43	28/04/16	Page 2/4

Grid-Connected System: Horizon definition

Project : Cueta

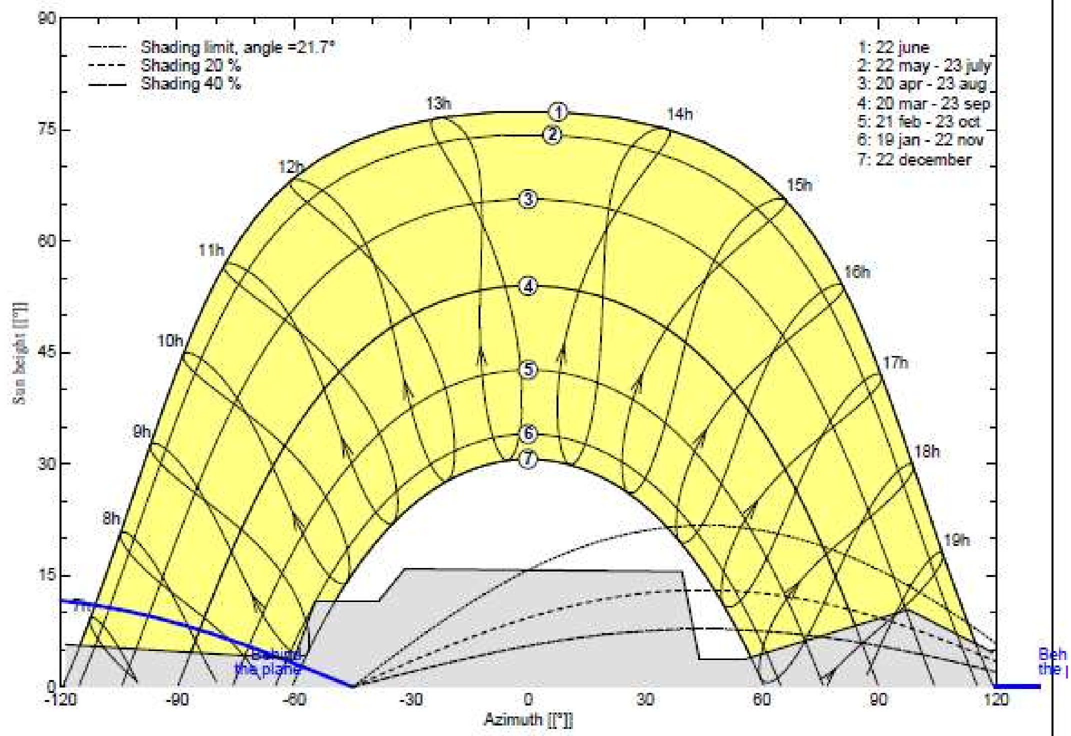
Simulation variant : **Floating fields 45 degrees west**

Main system parameters	System type	Grid-Connected		
Horizon	Average Height	9.5°		
PV Field Orientation	Sheds disposition, tilt	12°	azimuth	45°
PV modules	Model	REC 260PE / PE-BLK	Pnom	260 Wp
PV Array	Nb. of modules	8680	Pnom total	**2257 kWp**
Inverter	Model	500 kWac inverter	Pnom	500 kW ac
Inverter pack	Nb. of units	4.0	Pnom total	**2000 kW ac**
User's needs	Unlimited load (grid)			

Horizon	Average Height	9.5°	Diffuse Factor	0.96
	Albedo Factor	100 %	Albedo Fraction	0.48

Height [°]	5.7	3.8	11.6	11.6	15.9	15.5	3.8	3.8	10.4	4.6
Azimuth [°]	-119	-60	-55	-38	-32	40	44	56	98	119

Horizon linLegal Time



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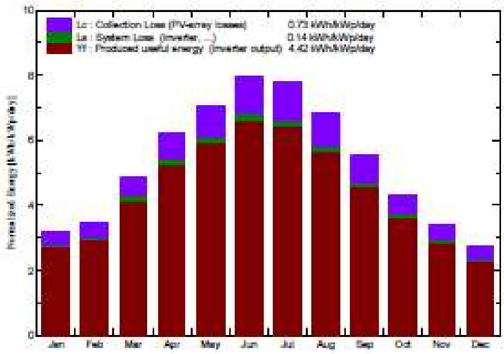
Grid-Connected System: Main results

Project : Cueta
Simulation variant : Floating fields 45 degrees west

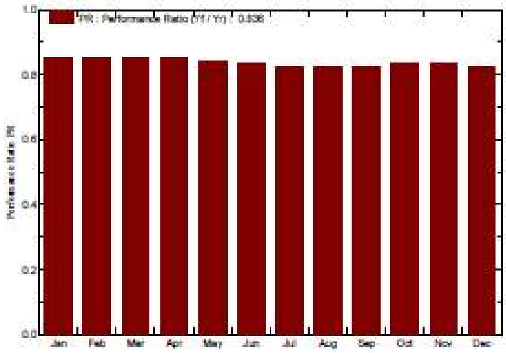
Main system parameters	System type	Grid-Connected		
Horizon	Average Height	9.5°		
PV Field Orientation	Sheds disposition, tilt	12°	azimuth	45°
PV modules	Model	REC 260PE / PE-BLK	Pnom	260 Wp
PV Array	Nb. of modules	8680	Pnom total	**2257 kWp**
Inverter	Model	500 kWac inverter	Pnom	500 kW ac
Inverter pack	Nb. of units	4.0	Pnom total	**2000 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	Produced Energy	3645 MWh/year	Specific prod.	1615 kWh/kWp/year
	Performance Ratio PR	83.6 %		

Normalized productions (per installed kWp): Nominal power 2257 kWp



Performance Ratio PR



Floating fields 45 degrees west

Balances and main results

	GlobHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	EffArrR %	EffSysR %
January	83.9	12.61	99.0	90.6	196.2	190.4	13.83	13.42
February	87.1	13.42	96.3	88.7	191.4	185.4	13.88	13.45
March	140.8	15.31	150.8	140.1	299.3	290.6	13.86	13.46
April	179.8	16.66	185.7	174.9	369.0	357.9	13.87	13.45
May	216.2	19.42	216.1	205.1	426.2	413.6	13.64	13.24
June	239.2	22.52	238.9	226.5	462.5	448.7	13.52	13.11
July	240.9	24.88	241.9	229.2	463.0	449.6	13.36	12.98
August	207.6	24.93	212.4	200.2	405.9	394.0	13.34	12.95
September	155.9	22.42	166.6	155.4	319.7	310.2	13.40	13.00
October	121.1	19.69	133.9	124.3	260.6	253.0	13.59	13.19
November	86.9	15.66	102.8	93.7	199.3	193.1	13.53	13.11
December	70.8	13.59	85.1	76.3	163.3	158.2	13.41	12.98
Year	1830.2	18.45	1931.6	1805.1	3756.3	3644.8	13.58	13.17

Legends:				
	GlobHor	Horizontal global irradiation	EArray	Effective energy at the output of the array
	T Amb	Ambient Temperature	E_Grid	Energy injected into grid
	GlobInc	Global incident in coll. plane	EffArrR	Effic. Eout array / rough area
	GlobEff	Effective Global, corr. for IAM and shadings	EffSysR	Effic. Eout system / rough area

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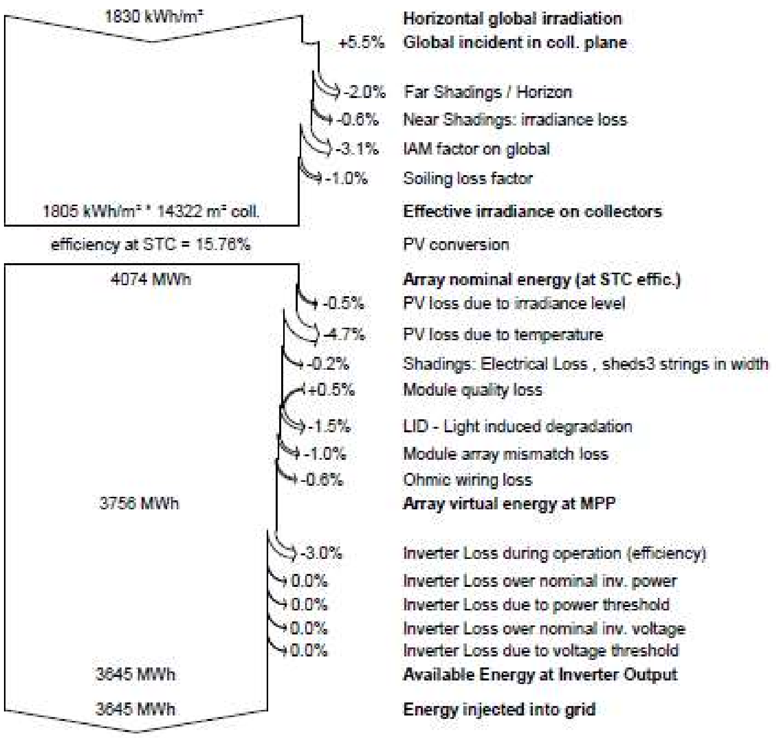
Grid-Connected System: Loss diagram

Project : Cueta

Simulation variant : Floating fields 45 degrees west

Main system parameters	System type	Grid-Connected		
Horizon	Average Height	9.5°		
PV Field Orientation	Sheds disposition, tilt	12°	azimuth	45°
PV modules	Model	REC 260PE / PE-BLK	Pnom	260 Wp
PV Array	Nb. of modules	8680	Pnom total	**2257 kWp**
Inverter	Model	500 kWac inverter	Pnom	500 kW ac
Inverter pack	Nb. of units	4.0	Pnom total	**2000 kW ac**
User's needs	Unlimited load (grid)			

Loss diagram over the whole year



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APPENDIX 13. ECONOMIC ANALYSIS OF FLOATING SOLAR PV PROJECT

INITIAL DATA

Total capital costs =	3.376.472,00	Eur
Total Energy Generation =	3.645.000,00	kWh/year
Energy Benefits =	555.100,00	eur/year

CASH FLOW

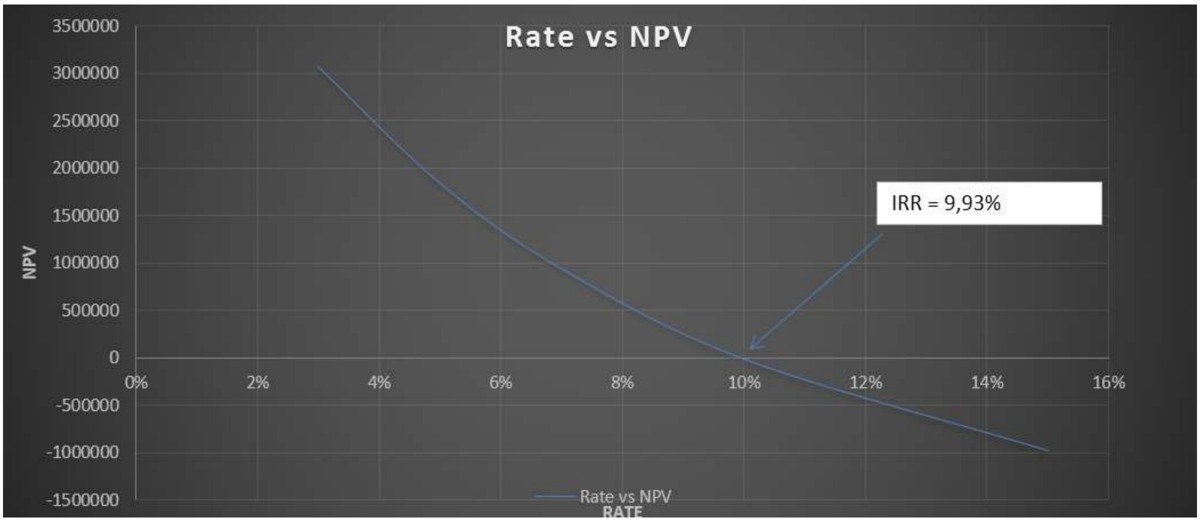
	Year	Capital Cost	O&M	Total Cost	NPV Cost (7%)	Energy Revenue	NPV Revenue (7%)
		Eur	Eur	Eur	Eur	Eur	Eur
	Total	**-3.376.472,00**	**-1.688.236,00**	**-5.064.708,00**	**-4.163.431,95**	**10.935.000,00**	**5.097.277,28**
	2017	-3376472,00		-3376472,00	-3376472,00		
1	2018		-67529,44	-67529,44	-63111,63	437400,00	408785,05
2	2019		-67529,44	-67529,44	-58982,83	437400,00	382042,10
3	2020		-67529,44	-67529,44	-55124,14	437400,00	357048,69
4	2021		-67529,44	-67529,44	-51517,89	437400,00	333690,37
5	2022		-67529,44	-67529,44	-48147,56	437400,00	311860,15
6	2023		-67529,44	-67529,44	-44997,72	437400,00	291458,09
7	2024		-67529,44	-67529,44	-42053,94	437400,00	272390,74
8	2025		-67529,44	-67529,44	-39302,75	437400,00	254570,78
9	2026		-67529,44	-67529,44	-36731,54	437400,00	237916,62
10	2027		-67529,44	-67529,44	-34328,54	437400,00	222351,98
11	2028		-67529,44	-67529,44	-32082,75	437400,00	207805,59
12	2029		-67529,44	-67529,44	-29983,88	437400,00	194210,83
13	2030		-67529,44	-67529,44	-28022,32	437400,00	181505,45
14	2031		-67529,44	-67529,44	-26189,08	437400,00	169631,26
15	2032		-67529,44	-67529,44	-24475,78	437400,00	158533,89
16	2033		-67529,44	-67529,44	-22874,56	437400,00	148162,51
17	2034		-67529,44	-67529,44	-21378,09	437400,00	138469,64
18	2035		-67529,44	-67529,44	-19979,52	437400,00	129410,88
19	2036		-67529,44	-67529,44	-18672,45	437400,00	120944,74
20	2037		-67529,44	-67529,44	-17450,89	437400,00	113032,47
21	2038		-67529,44	-67529,44	-16309,24	437400,00	105637,82
22	2039		-67529,44	-67529,44	-15242,28	437400,00	98726,94
23	2040		-67529,44	-67529,44	-14245,12	437400,00	92268,17
24	2041		-67529,44	-67529,44	-13313,20	437400,00	86231,93
25	2042		-67529,44	-67529,44	-12442,24	437400,00	80590,59

NPV

Year	Capital Cost	O&M	Total Cost	NPV Cost (7%)	Energy Revenue	NPV Revenue (7%)	Net NPV (7%)
	Eur	Eur	Eur	Eur	Eur	Eur	Eur
Total	-3.376.472,00	-1.688.236,00	-5.064.708,00	-4.163.431,95	10.935.000,00	5.097.277,28	933.845,34

INTEREST RATE OF RETURN

Rate	NPV (Eur)
3%	3064138,69
5%	1836463,17
7%	933845,34
10%	-19142,13
15%	-985573,56



BENEFIT – COST RATIO

$$BCR = \frac{PV_{benefits}}{PV_{costs}}$$

where:

$PV_{benefits}$ = present value of benefits

PV_{costs} = present value of costs

B-C Ratio =	1.2

APPENDIX 14. SENSITIVITY ANALYSIS FLOATING SOLAR PV SYSTEM

Discount rate varying from 3% to 10%

Price of energy from 0.06 Eur/kWh to 0.15 Eur/kWh

				0,06	0,15
Fiscal Year	**Capital Cost**	**O&M**	**Total Cost**	**Energy Revenue**	**Energy Revenue**
	Eur	**Eur**	**Eur**	**Eur**	**Eur**
Total	**3.376.472,00**	**-1.688.236,00**	**-5.064.708,00**	**5.467.500,00**	**13.668.750,00**
2017	-3.376.472,00		-3.376.472,00		
2018		-67.529,44	-67.529,44	218.700,00	546.750,00
2019		-67.529,44	-67.529,44	218.700,00	546.750,00
2020		-67.529,44	-67.529,44	218.700,00	546.750,00
2021		-67.529,44	-67.529,44	218.700,00	546.750,00
2022		-67.529,44	-67.529,44	218.700,00	546.750,00
2023		-67.529,44	-67.529,44	218.700,00	546.750,00
2024		-67.529,44	-67.529,44	218.700,00	546.750,00
2025		-67.529,44	-67.529,44	218.700,00	546.750,00
2026		-67.529,44	-67.529,44	218.700,00	546.750,00
2027		-67.529,44	-67.529,44	218.700,00	546.750,00
2028		-67.529,44	-67.529,44	218.700,00	546.750,00
2029		-67.529,44	-67.529,44	218.700,00	546.750,00
2030		-67.529,44	-67.529,44	218.700,00	546.750,00
2031		-67.529,44	-67.529,44	218.700,00	546.750,00
2032		-67.529,44	-67.529,44	218.700,00	546.750,00
2033		-67.529,44	-67.529,44	218.700,00	546.750,00
2034		-67.529,44	-67.529,44	218.700,00	546.750,00
2035		-67.529,44	-67.529,44	218.700,00	546.750,00
2036		-67.529,44	-67.529,44	218.700,00	546.750,00
2037		-67.529,44	-67.529,44	218.700,00	546.750,00
2038		-67.529,44	-67.529,44	218.700,00	546.750,00
2039		-67.529,44	-67.529,44	218.700,00	546.750,00
2040		-67.529,44	-67.529,44	218.700,00	546.750,00
2041		-67.529,44	-67.529,44	218.700,00	546.750,00
2042		-67.529,44	-67.529,44	218.700,00	546.750,00

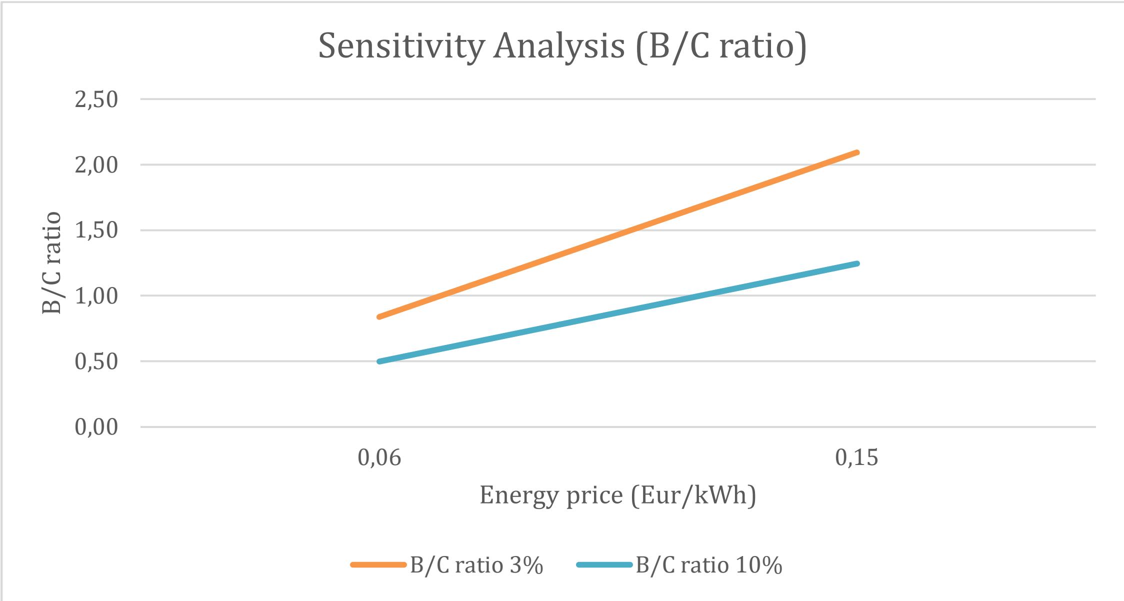
0.06 eur/kWh			
Rate	3%	Rate	10%
NPV	-744116,71	NPV	-2004290,78
PV COST	**PV Benefits**	**PV COST**	**PV Benefits**
Eur	**Eur**	**Eur**	**Eur**
-4.552.372,11	**3.808.255,40**	**-3.989.439,43**	**1.985.148,65**
-3.376.472,00	0,00	-3.376.472,00	0,00
-65.562,56	212.330,10	-61.390,40	198.818,18
-63.652,97	206.145,73	-55.809,45	180.743,80
-61.799,00	200.141,48	-50.735,87	164.312,55
-59.999,03	194.312,12	-46.123,52	149.375,04
-58.251,49	188.652,54	-41.930,47	135.795,49
-56.554,84	183.157,81	-38.118,61	123.450,45
-54.907,61	177.823,11	-34.653,28	112.227,68
-53.308,36	172.643,80	-31.502,98	102.025,16
-51.755,69	167.615,34	-28.639,07	92.750,15
-50.248,25	162.733,34	-26.035,52	84.318,32
-48.784,70	157.993,53	-23.668,66	76.653,02
-47.363,79	153.391,78	-21.516,96	69.684,56
-45.984,26	148.924,06	-19.560,87	63.349,60
-44.644,92	144.586,46	-17.782,61	57.590,55
-43.344,58	140.375,21	-16.166,01	52.355,04
-42.082,11	136.286,61	-14.696,37	47.595,49

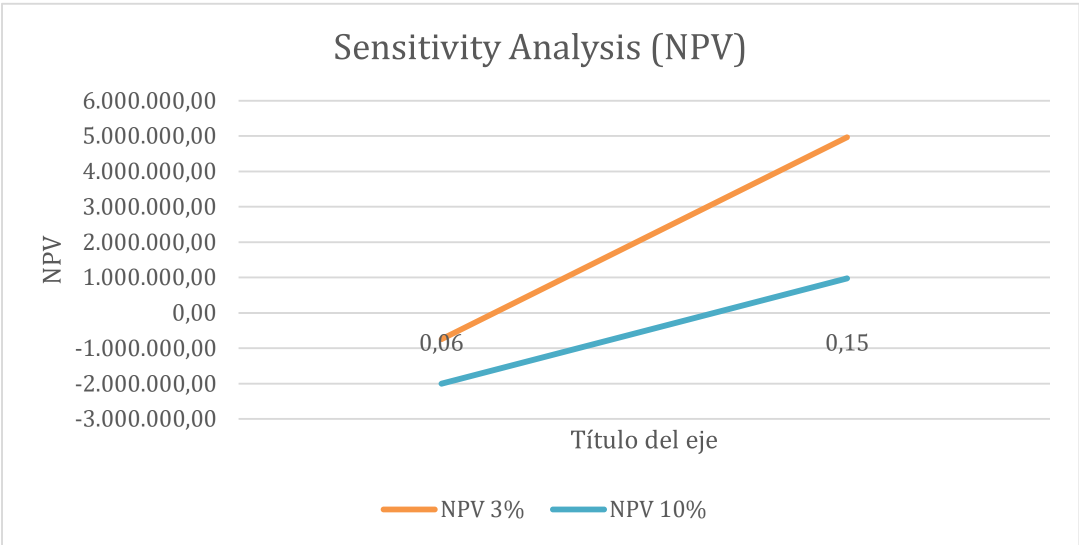
0.15 eur/kWh			
Rate	3%	Rate	10%
NPV	4968266,39	NPV	973432,20
PV COST	**PV Benefits**	**PV COST**	**PV Benefits**
Eur	**Eur**	**Eur**	**Eur**
-4.552.372,11	**9.520.638,50**	**-3.989.439,43**	**4.962.871,63**
-3.376.472,00	0,00	-3.376.472,00	0,00
-65.562,56	530.825,24	-61.390,40	497.045,45
-63.652,97	515.364,31	-55.809,45	451.859,50
-61.799,00	500.353,70	-50.735,87	410.781,37
-59.999,03	485.780,29	-46.123,52	373.437,61
-58.251,49	471.631,35	-41.930,47	339.488,73
-56.554,84	457.894,52	-38.118,61	308.626,12
-54.907,61	444.557,78	-34.653,28	280.569,20
-53.308,36	431.609,50	-31.502,98	255.062,91
-51.755,69	419.038,35	-28.639,07	231.875,37
-50.248,25	406.833,35	-26.035,52	210.795,79
-48.784,70	394.983,83	-23.668,66	191.632,54
-47.363,79	383.479,45	-21.516,96	174.211,40
-45.984,26	372.310,15	-19.560,87	158.374,00
-44.644,92	361.466,16	-17.782,61	143.976,36
-43.344,58	350.938,02	-16.166,01	130.887,60
-42.082,11	340.716,52	-14.696,37	118.988,73

-40.856,42	132.317,10	-13.360,34	43.268,63
-39.666,43	128.463,20	-12.145,76	39.335,12
-38.511,10	124.721,55	-11.041,60	35.759,20
-37.389,41	121.088,89	-10.037,82	32.508,36
-36.300,40	117.562,03	-9.125,29	29.553,06
-35.243,11	114.137,89	-8.295,72	26.866,41
-34.216,61	110.813,49	-7.541,56	24.424,01
-33.220,01	107.585,91	-6.855,97	22.203,65
-32.252,44	104.452,34	-6.232,70	20.185,13

-40.856,42	330.792,74	-13.360,34	108.171,57
-39.666,43	321.158,00	-12.145,76	98.337,79
-38.511,10	311.803,89	-11.041,60	89.397,99
-37.389,41	302.722,22	-10.037,82	81.270,90
-36.300,40	293.905,07	-9.125,29	73.882,64
-35.243,11	285.344,72	-8.295,72	67.166,04
-34.216,61	277.033,71	-7.541,56	61.060,03
-33.220,01	268.964,77	-6.855,97	55.509,12
-32.252,44	261.130,84	-6.232,70	50.462,84

	0,06	Eur/kWh			**0,15**	Eur/kWh		
Discount rate	PV Costs	PV Benefits	NPV	B/C Ratio	PV Costs	PV Benefits	NPV	B/C Ratio
3%	-4.552.372,11	3.808.255,40	-744.116,71	0,84	-4.552.372,11	9.520.638,50	4.968.266,39	2,09
10%	-3.989.439,43	1.985.148,65	-2.004.290,78	0,50	-3.989.439,43	4.962.871,63	973.432,20	1,24


Sensitivity Analysis (B/C ratio)
2,50
2,00
1,50
1,00
0,50
0,00
B/C ratio
0,06
0,15
Energy price (Eur/kWh)
B/C ratio 3%
B/C ratio 10%


Sensitivity Analysis (NPV)
6.000.000,00
5.000.000,00
4.000.000,00
3.000.000,00
2.000.000,00
1.000.000,00
0,00
-1.000.000,00
-2.000.000,00
-3.000.000,00
NPV
0,06
0,15
Título del eje
NPV 3%
NPV 10%