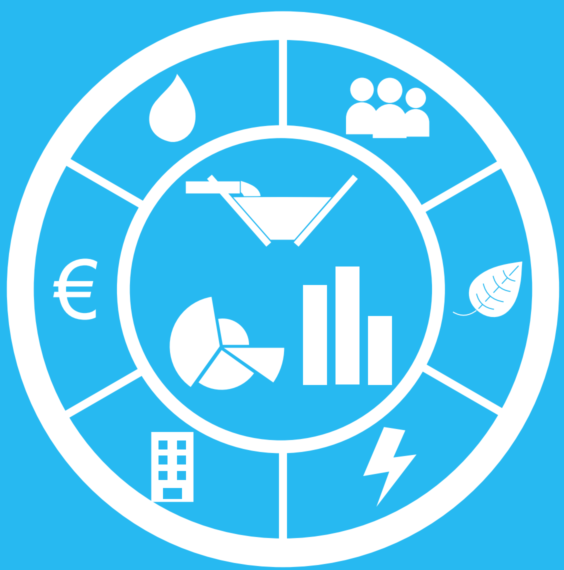
Application of the E^{2}STORMED Decision Support Tool in Benaguasil



E^{2}STORMED PROJECT
Improvement of energy efficiency in the water cycle by the use of innovative storm water management in smart Mediterranean cities
www.e2stormed.eu

Benaguasil
AJUNTAMENT

L'Europe en Méditerranée
Europe in the Mediterranean

Projet cofinancé par le Fonds Européen de Développement Régional (FEDER)
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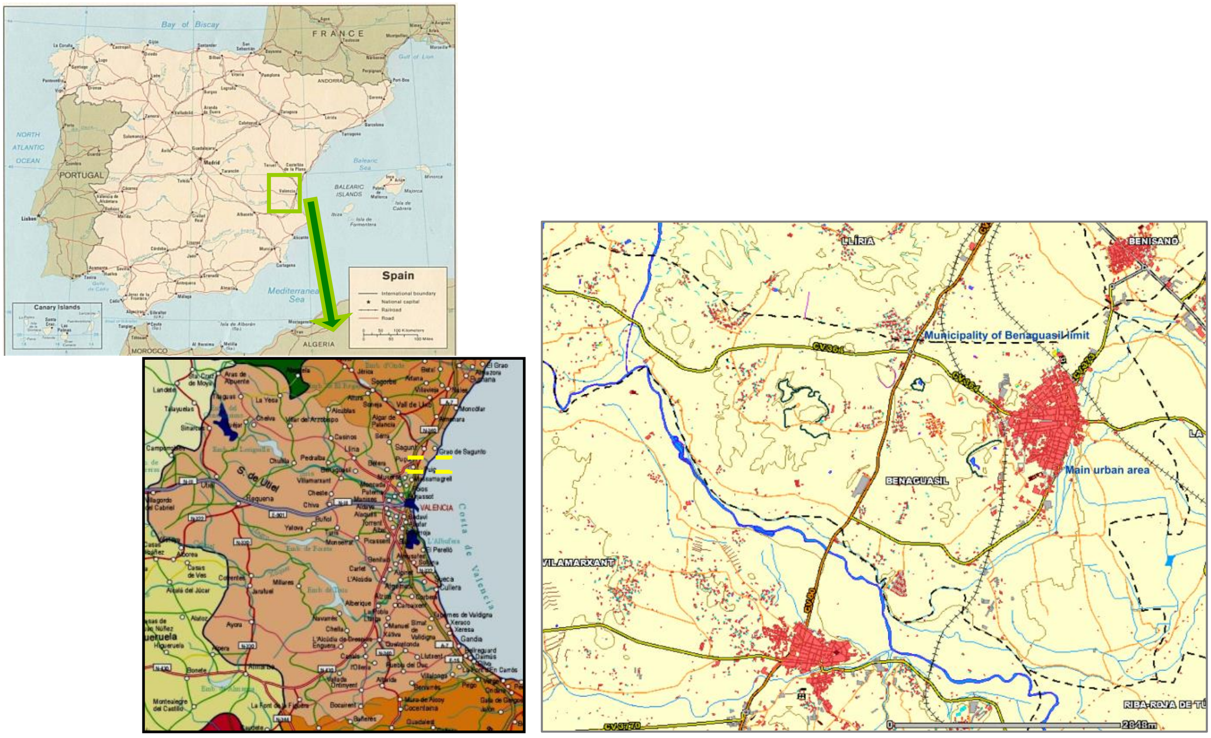
Date: June 2015

INDEX

1. PILOT CITY DESCRIPTION

1.1. GENERAL DESCRIPTION

Benaguasil (Spain) is located in the East of the Iberian Peninsula, in the Comunidad Valenciana region. This region is divided into three provinces. Benaguasil is located, within the province of Valencia, to the West of the city of Valencia, on the left bank side of the Turia River.



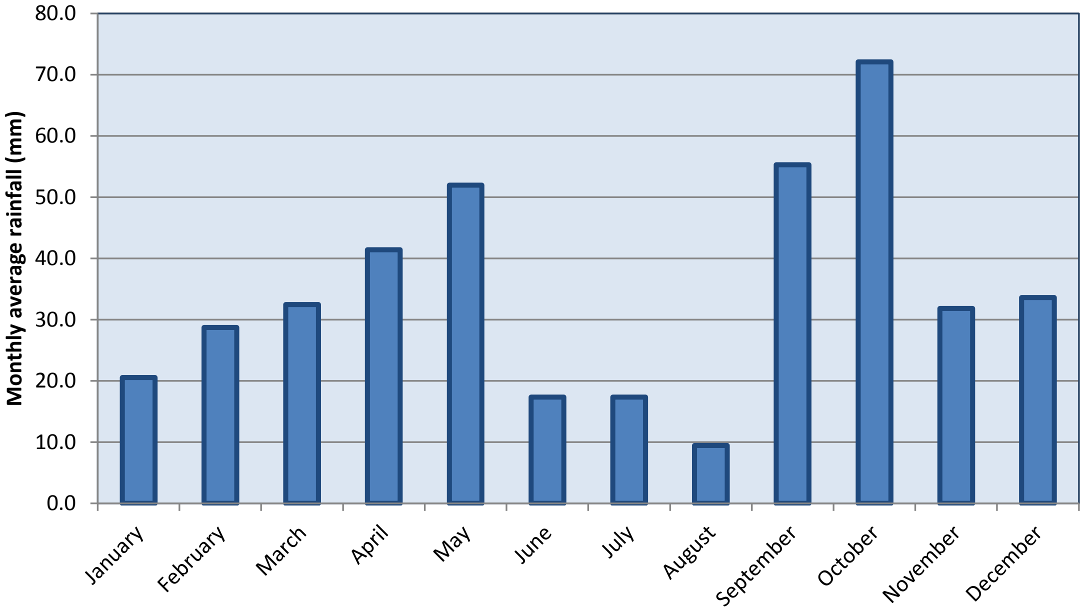
Benaguasil municipality includes the main Benaguasil urban area and some small urban developments and houses, as shown in the previous map. The main urban area is dense, most of the buildings have two to four floors and usually there is an apartment per floor, so there are about 3 or 4 families per building. The apartments are quite large and usually all the people in the same building are relatives. The quality of buildings is quite good. The construction materials are concrete and bricks; there are not houses of wood or shanty dwellings. Most of the population are the owners of their dwellings.

Population of the main urban area (2.38 km^2) is 11 298, which increases about 200 people during summer holidays, mainly from 20th August to 20th September, when the local festivities take place. Hence, population density in the city is 4 747 hab/Km^2.

1.2. CLIMATE

The proximity of the sea sets a Mediterranean-type climate, characterized by dry summers with mild maritime influence and high erratic rainfall. The sky turns out to be normally clear, with more than 125 days without clouds and only 30 totally covered ones. Temperatures are soft in winter (9 º - 10 º C in January) and hot in summer (26 º - 29 º C in August).

Annual average rainfall is 432 mm, and the wetter seasons are spring and autumn, as shown in the monthly average rainfall figure below.

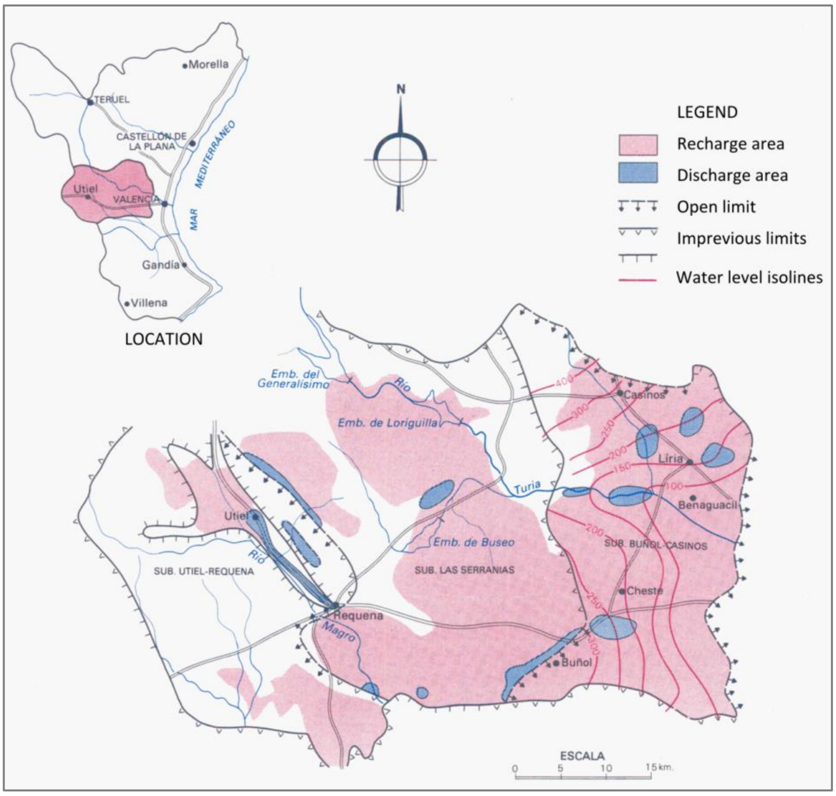


1.3. Water resources

From ancient times, this small size municipality has appreciated the value of water, being essential for its agricultural based economy. Benaguasil is in a continuous evolution process, adapting to a changing environment with the improvement of its infrastructure and public and social equipment, and providing a better quality of life to its neighbours.

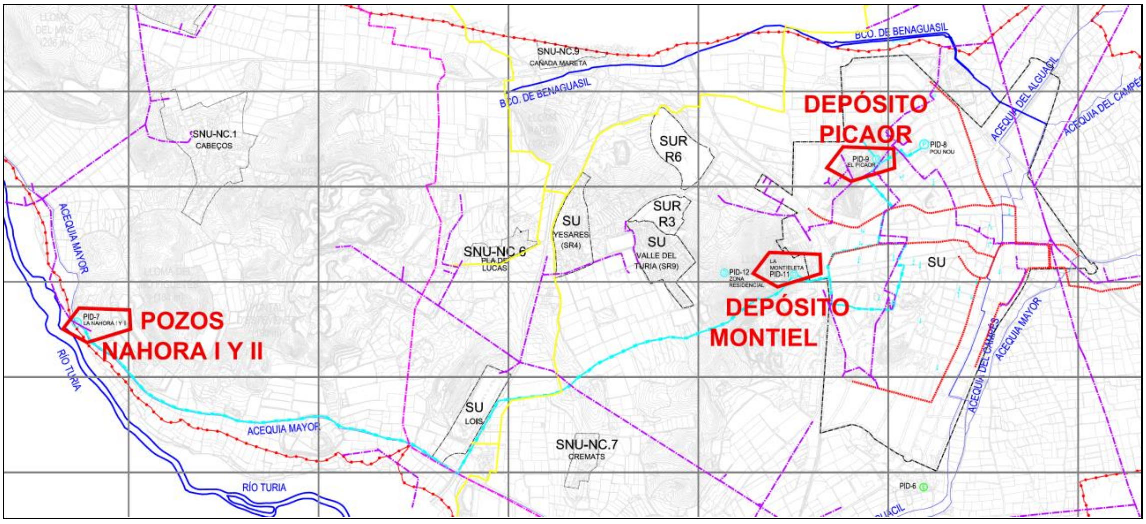
In Benaguasil, urban water demand is completely supplied from underground aquifers. This urban area is located in the aquifer Liria-Casinos, inside the province of Valencia. This unconfined aquifer, composed of Cretacic and Jurassic soils, has an extension of 812 km^2 and provides water for irrigation and some urban areas like Liria, Benaguasil, Casinos, Pobla de Vallbona and Marines. Benaguasil boreholes are located in a superficial layer of 80-370 meters depth formed by limestones and marls.

Water level of this aquifer has been quite constant during the last years. In general, about 86 hm^3 are pumped from this aquifer each year where as there is a recharge of 54 hm^3 per year from rainfall and 35 hm^3 from irrigation. As seen in the map below, Benaguasil is located within the recharge area of the aquifer (Map of Liria-Casinos aquifer. Source: Instituto Geológico y Minero de España).



1.4. Water management systems

In Benaguasil, urban water demand is completely supplied from underground aquifer. Water is extracted from the aquifer mainly through two wells, "La Nahora I y II", located near the river Turia and 5 km aprox. far away from the urban center. Water is pumped (using submerged pumps) alternating from one and the other wells. From the Wells, water is pumped using a Ø400 pipe to the Montiel water tank, where water is chlorinated and distributed by gravity to citizens. This implies high energy consumption.



In terms of sanitation, Benaguasil has a combined sewer network, so stormwater that enters the network is mixed with wastewater form households and industries. It is a conventional system, mainly composed of sewer pipes and culverts. It is mainly a gravity system; there is only one point where stormwater is pumped: the underground passage located at road CV-375 towards "La Pobla de Vallbona" when it crosses the tram line. This water is pumped to the nearby irrigation channel.

At the end of the combined network, there is a restriction on the flow that is directed to the Waste Water Treatment Plant. The remaining water overflows to one of the irrigation channels, which will end up at the Turia river. Additional overflow to irrigation channels points are marked in the map below in orange.

1.5. WATER RELATED ISSUES AND CHALLENGES

The main water-related problems in Benaguasil are due to floods produced by the torrential rain, very usual at the end of summer and the beginning of autumn. During heavy storms, the combined network is overloaded and runoff flows overland along the streets, flooding some dwellings. In some cases wastewater from the overloaded sewer backs up into houses through toilets and baths. These pluvial flooding events are quite common (about once each 2-3 years). Another issue is that supplied water does not fully comply with OMS's guidelines for potable water, as nitrate concentrations are often higher than 50 mg/l (around 65 mg/l), due to agricultural pollution.

In summary, main problems related to stormwater management in the city of Benaguasil are:

- Frequent pluvial flooding events.
- Combined Sewer Overflows to Turia River.
- High energy consumption in urban water management.

Local pluvial flooding (left) and pollution due to Combined Sewer Overflows (right) in Benaguasil.

Hence, main objectives considered in the case studies should be:

- Reducing urban flooding.
- Reducing Combined Sewer Overflows (CSOs).
- Protection of receiving water bodies.
- Reducing energy consumption and CO2 emissions in the urban water management.
- Landscaping integration of infrastructures.
- Aquifers recharge.
- Optimization of drinking water use.

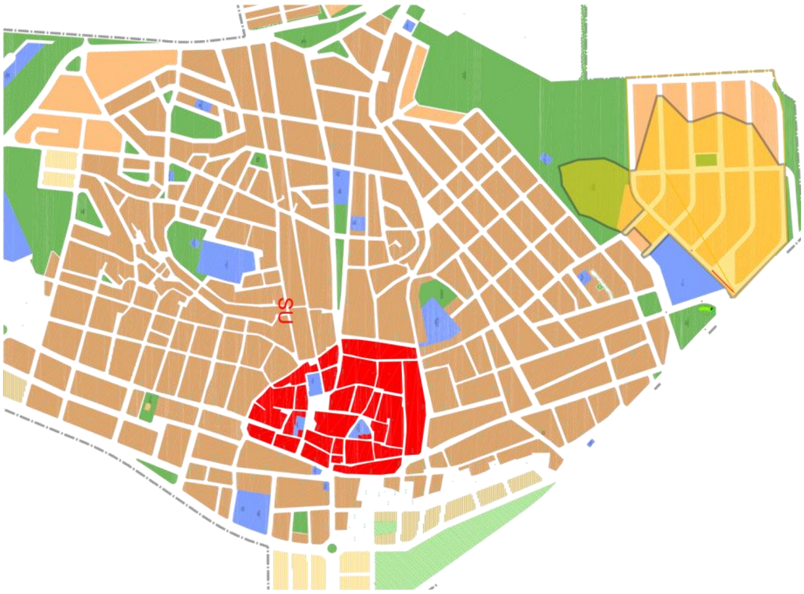
Take stormwater out of the combined sewer network (reducing urban flooding, CSOs and protecting receiving water bodies), and managing it with SuDS (integrated within the city landscape), promoting infiltration (aquifer recharge) and rainwater harvesting for future use (optimizations of drinking water use), looks like a promising solution to achieve the objectives and reducing energy consumption and CO_2 emissions.

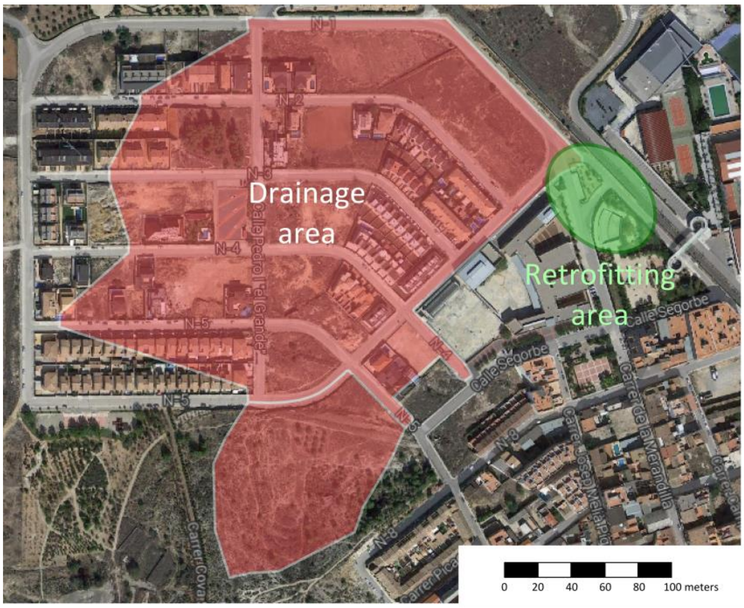
2. Pilot case 1: Developed area

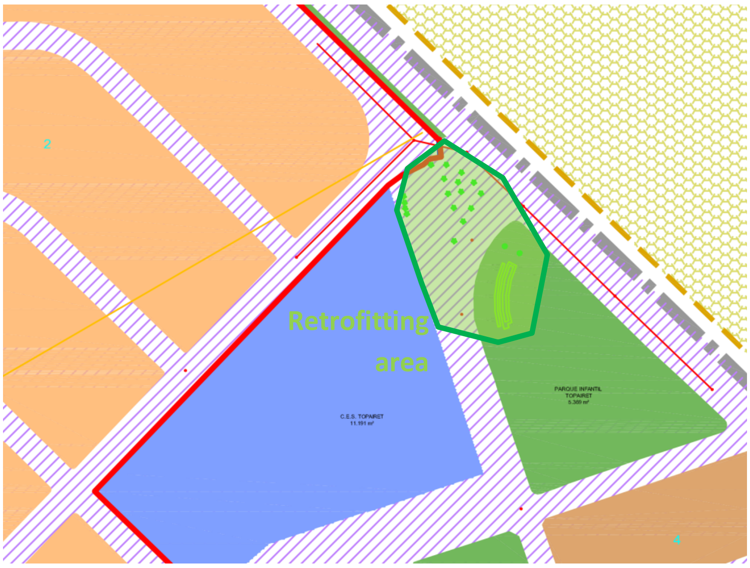
2.1. General description

Pilot case 1 is located to the North of Benaguasil urban area. Developed less than a decade ago, a big part of the so called sector SR-1, Topairet, is a residential zone still to be filled with dwellings. The existing ones, that cover approximately 20% of the area, are mainly two-floor-detached or attached houses, comprising around 150 inhabitants. When completely developed, this 123 000 m^2 site is expected to host around 750 inhabitants.

Sector SR-1 is served by a combined network, with gullies that collect runoff distributed along the streets. The sewer network is formed mainly by 400 diameter pipes, and only at the end of Pablo II el Ceremonioso street, at the lower part of the site, pipes increase diameter up to 1 000 mm. It is known that during medium-high intensity rainfall events water runs freely over the streets, and ponds in the lower corner of the sector, between a small traffic island and the park next to it (average slope is 3%). At the same time, ponded water is not able to enter the sewer, that is overloaded, and when it finally enters, a big portion of it will be discharged untreated to the irrigation channel at the West of the urban area, due to the restricted capacity of the sewer line that goes to the Waste Water Treatment Plant (WWTP) (a 800 mm diameter pipe). In the following figures, the location and characteristics of this drainage area can be observed:


SU


Drainage area
Retrofitting area
Calle Segorbe
0 20 40 60 80 100 meters


Retrofitting area

It is proposed that a drainage infrastructure is retrofitted in that lower area to partially alleviate flooding and combines sewer overflows issues. As depicted in the map above, the drainage area of that lower point is much bigger than the area to be retrofitted (11 ha in comparison to 0.2 ha), hence it is not expected to solve the problem with this small intervention, but every effort counts.

The aim is to build a retention structure that can safely storage runoff and release it at lower rates after the storm. In the case of the conventional option, stored runoff would be released into the sewer network to such a low rates that it is expected it reaches the WWTP once it has recover its operational capacity, hence, the main benefit is:

- Reduced CSOs (taking stormwater out of the sewers, although only temporarily), hence protection of receiving water bodies.

For the SuDS option, storage runoff would have been filtrated using vegetation, granular materials and geotextile fabric, and then released into the ground by infiltration. Hence, main benefits are:

- Reduced CSOs (taking stormwater out of the sewers), hence protection of receiving water bodies.
- Reduced runoff treatment energy consumption and CO_2 emissions.
- Landscaping integration of infrastructures and educational opportunities.
- Aquifers recharge.

In the decision making process, the following important issues need to be considered:

- Construction and maintenance cost of drainage infrastructures.
- Reduction in the volume of CSOs.
- Reduction in the number of CSOs events.
- Landscaping integration of infrastructures and educational opportunities.
- Cost and energy consumption in the Wastewater Treatment Plant.
- Aquifers recharge

2.2. GENERAL MODEL DATA

General model data used is as follows:

Country: Spain

Currency: Euros

Electricity price: 0.4278 €/kWh (obtained from an invoice received by the Municipality dated 27th June 2014).

Electricity emissions: 0.238 kgCO_2/kWh (obtained from Table 1.1 (IEA, 2012) of the "Report on energy in the water cycle"; Value for Spain in 2010). Default value for Spain.

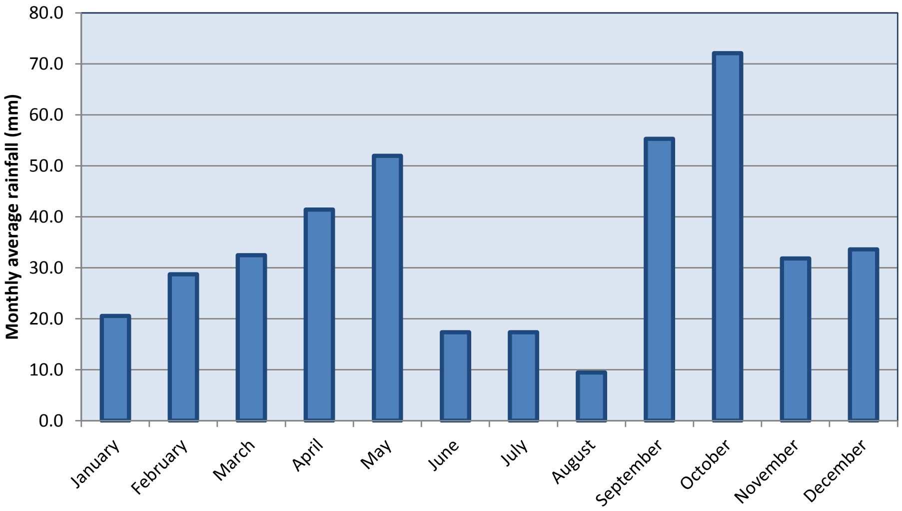
Period of analysis: It has been decided to use 50 years so it covers the life span expected for the infrastructures used.

Economic discount rate: Default value has been used (3%).

Define rainfall distribution:

Mean annual rainfall (period 1993-2010, from City Council rain gauge) = 432 mm/year

Mean Monthly Rainfall	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	30	29	24	42	49	21	11	24	57	72	32	41



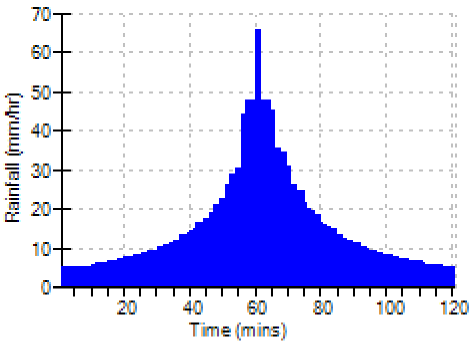
In addition, the following information has been obtained from a detail study of the Benaguasil City Council rain gauge (period 1993-2010):

- Average of 40 rainy days per year
- In the 80% of the rainy days, rainfall is lesser tan 16 mm. Hence, 80% rainfall volume is V_{80} = 16 mm. This is the rainfall that will have to be "managed" by drainage infrastructures to comply with the runoff reduction design criteria for Benaguasil.
- In the 90% of the rainy days, rainfall is lesser tan 26 mm. Hence, 90% rainfall volume is V_{90} = 26 mm. This is the rainfall that will have to be "managed" by drainage infrastructures to comply with the water quality design criteria for Benaguasil.
- In the 99% of the rainy days, rainfall is lesser tan 71 mm.

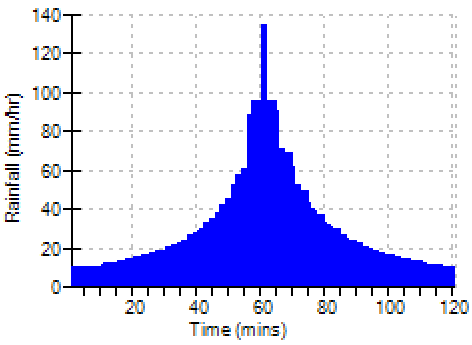
From that data, some design storms have been built, with the following main characteristics:

Name	Return period T (year)	Duration (h)	Peak intensity (mm/h)	Average intensity (mm/h)	Rainfall volume (mm)
DesignT2-2hr	2	2	66	16	32

DesignT2-24hr	2	24	36	2	48
DesignT15-2hr	15	2	135	32	64
DesignT15+CC-2hr	15 + 10%CC	2	149	35	70
DesignT100-6hr	100	6	169	23	138
DesignT100+CC-6hr	100 + 17%CC	6	198	27	162



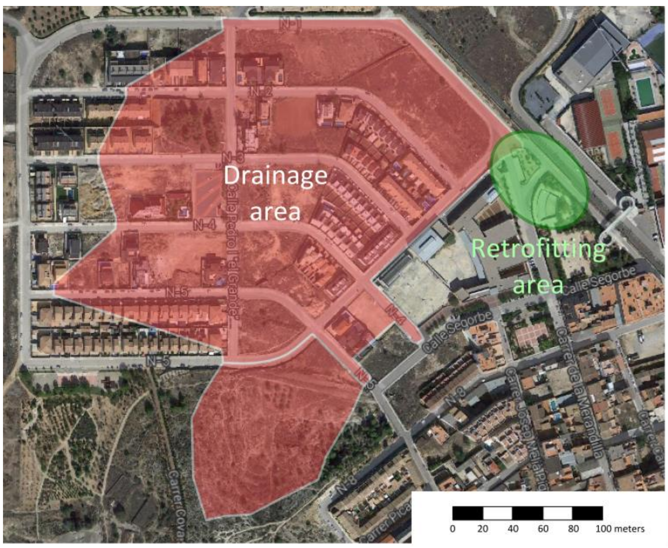
Design rainfall for T = 2 years



Design rainfall for T = 15 years

In addition, continuous analysis with rainfall data for the year 2013 (data obtained every 10 minutes at the new Benaguasil rain gauge) will be used in the stormwater runoff section. Year 2013 was a dry one, with a yearly total precipitation of only 238 mm. However, this is the only data available at the moment, as for previous years only daily data was taken in Benaguasil.

Being a retrofitted solution, a compromise has been reached between managing the largest possible amount of stormwater and space availability (with no major works involved that might result unaffordable). Catchment area of the proposed solutions (both conventional and SuDS based) is 11 ha, most of them currently remaining in nearly natural conditions, which would suppose an impermeable catchment area of around 3 ha.



As one can appreciate on the figure above, that catchment area is too big for the area that it is available for retrofitting. In addition, part of the runoff will enter the combined network before reaching the lower part of the site, and some will not be able to enter the retrofitted infrastructure due to connecting pipe flow restrictions. In order to obtain meaningful results, catchment area has been restricted, with the following argument:

- Option with more restrictions for water retention: SuDS solution (as storage provided within the existing amphitheater, as explained herein).
- Volume available: 80 m^3.
- Rainfall that has to be managed to comply with the runoff criteria (taking water out of the sewers): V_{80} = 16 mm.
- Impermeable area that can be properly managed within the proposed infrastructures: $A_i = 80\ m^3 / 0.016\ m = 5\,000\ m^2$.

Hence, impermeable catchment area to consider for the runoff calculations in both scenarios is 5 000 m^2.

Being a retrofitted solution with limited space available, the following criteria will be used for the modelling in both scenarios:

- Volume estimated using 2013 continuous (every 10 min) rainfall data.
- Peak flow estimated using “DesignT2-2hr” design storm.

Define temperature distribution: Not applicable, as not green roof are used in this case study.

Flood protection benefits have not been analysed. For the retrofitting case study, local flooding only causes minor inconveniences (traffic cuts).

2.3. Scenario 1: Conventional development

2.3.1. General description

The proposed conventional solution is building a shallow structural retention facility that can safely storage runoff and release it into the sewer network at lower rates during and after the storm, in such a way that it is expected it reaches the WWTP, hence, the main benefit is:

- Reduced CSOs (taking stormwater out of the sewers), hence protection of receiving water bodies.

In addition, runoff retention would allow reducing flooding problems in this area and downstream.

This facility would be located in the lowest part of this urban area, buried within the small traffic island. It has been complemented with a sedimentation manhole upstream of the detention structure, to easy maintenance tasks.

It would collect stormwater from two streets and storage it during some hours. Stored water will be released by gravity at a very low rates (maximum 0.5 l/s) to the combined network and then transported (also by gravity) to the Wastewater Treatment Plant.

General criteria that has guided the design:

- Tank dimensions to fit the available area, and runoff retention comparable with the proposed SuDS solution.
- Stored runoff to be released to the sewer network by gravity (to avoid pumping) at a very low rate.
- Pre-treatment chamber to trap floatables and big particulate sediments.

2.3.2. Drainage infrastructures included in the scenario

Only one structure has been included: a structural detention facility with a 100 m^2 base and 1 m deep. As the overflow control is located 0.8 m above the bottom of the tank, the storage-retention volume is 80 m^3. Design sketches, maps and design criteria are presented in the preceding section.

Summary of values included in the DST are presented in the following figure:

In order to estimate construction cost, a detailed budget considering local prices (used in recent projects constructed in Benaguasil) has been elaborated. Estimated total construction cost (including complementary works) is 54 800 €, with a unitary cost of 548 €/m^3.

To estimate maintenance costs, the following tasks have been considered:

- removing any trash/debris and sediment buildup in the sedimentation manhole and the underground tanks (twice a year)
- performing structural repairs to inlet and outlets when required (once every 5 years)

With local cost for personnel, machinery, and materials, estimated maintenance tasks amount 220 €/year, hence 2.2 €/m^3/year.

In terms of energy consumed during construction, DST default values have been used. For emissions during construction, a unitary value of 26 902 kgCO_2e/100 m^3 = 269.02 kgCO_2e/m^3 has been used.

For energy consumption and emissions of maintenance tasks, the corresponding total values for the 100 m^3 tank in the data sheet has been used.

2.3.3. Water reuse

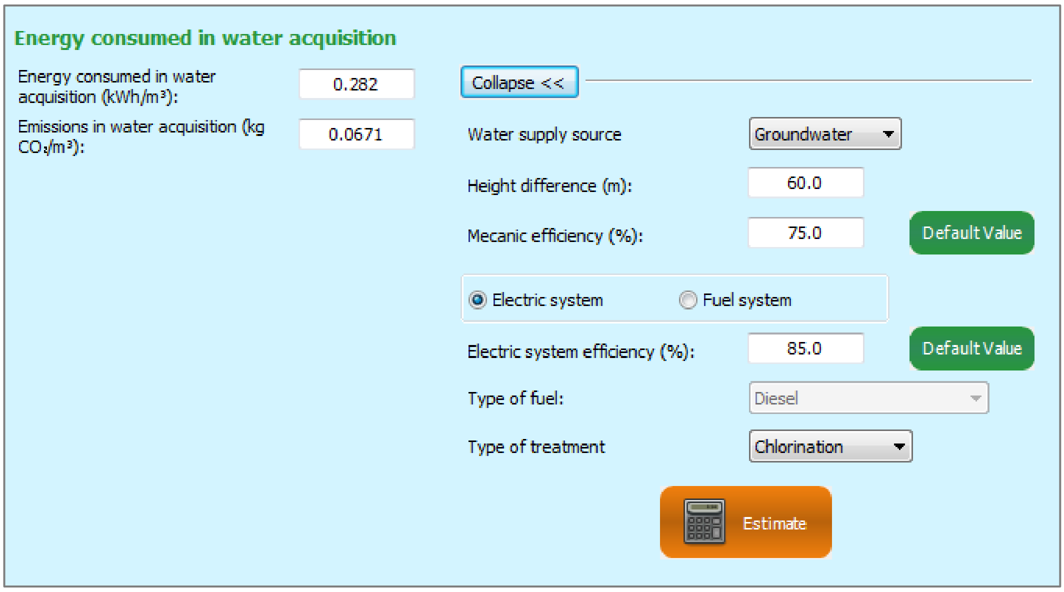
Values for water supply cost have been obtained from the municipality. Values depend on the consumption, as follows:

- Less than 10 m3: Cost = 0.236 €/m3.
- Between 10-15 m3: Cost = 0.333 €/m3.
- More than 15 m3: Cost = 0.474 €/m3.

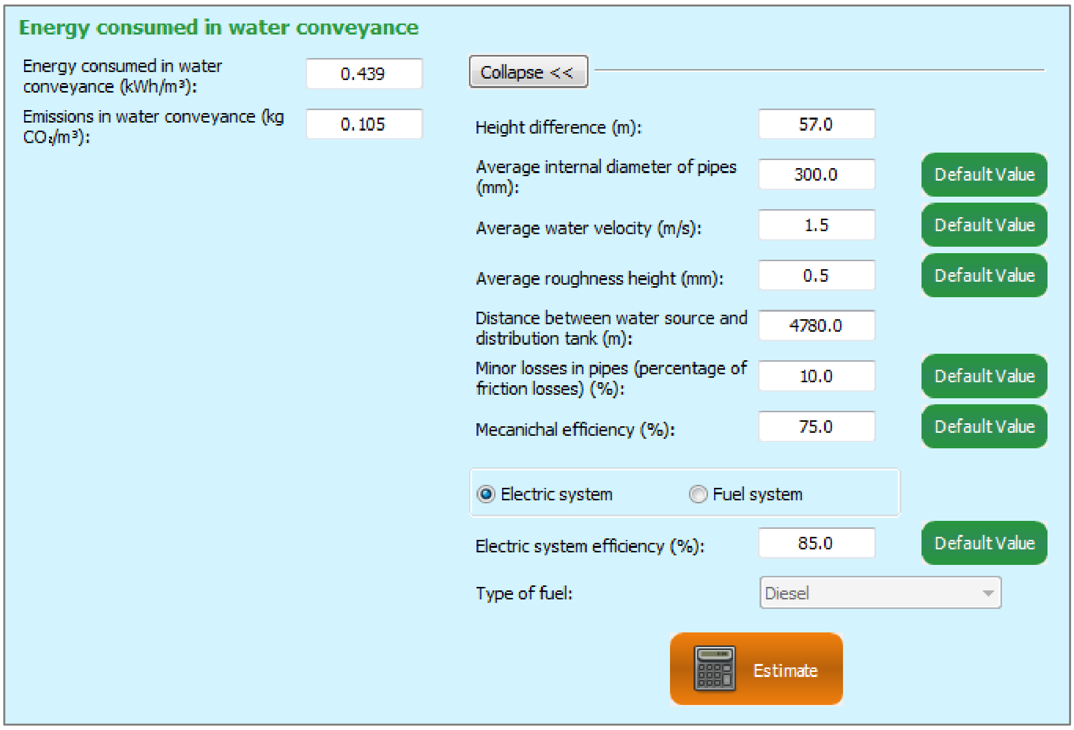
A value of 0.474 €/m^3 has been used for Pilot Case 1.

Water losses in network obtained from the municipality (difference between recorded extracted and supplied volumes), with a value of 37%.

Energy consumed in water acquisition estimated using DST tool, with data as follows (default values used for mechanic efficiency and electric system efficiency):



Energy consumed in water conveyance estimated using DST tool, with data as follows:

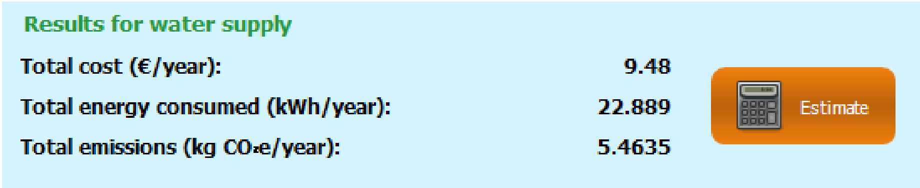


As it can be observed, default values have been used for average water velocity, minor losses in pipes and mechanical efficiency. For the average roughness height, a value within the bracket presented in table 2.9 of the guidelines for concrete pipes has been used (0.5 mm).

Being a gravity system, there is no energy consumption in water distribution.

Cleaning consumption has been estimated at 20 m^3/year (10 m^3 to clean a surface of 100 m^2, twice a year).

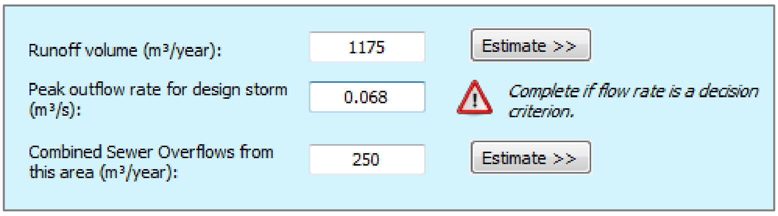
Results are as follows:



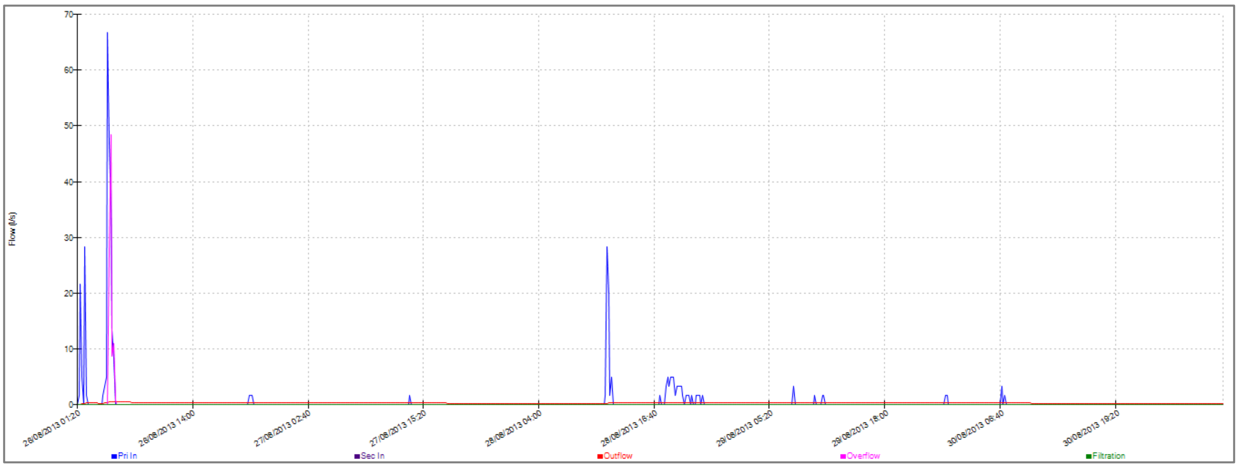
2.3.4. Stormwater runoff

Proprietary software from XPSolutions, called MicroDrainage (v2014.1.1), has been used for the hydraulic model to analyze runoff. Modelling is undertaken with the Wallingford Procedure, simulating using time/area full hydrograph methodology including energy and momentum equations for dynamic analysis. More information can be obtained from their website (http://xpsolutions.com/Software/MICRO-DRAINAGE/).

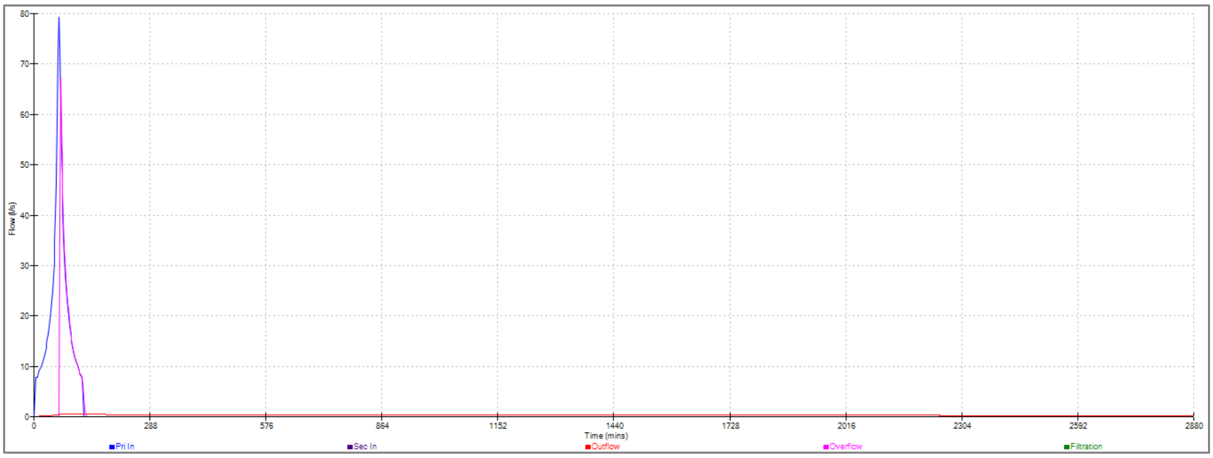
Rainfall data from year 2013 has been used for the volume calculations, and peak outflow estimated using "DesignT2-2hr" design storm. Results obtained are as follows:



Graphs below show inflows and outflows for the most critical storm in 2013 (26th August 2013) and for the design storm.

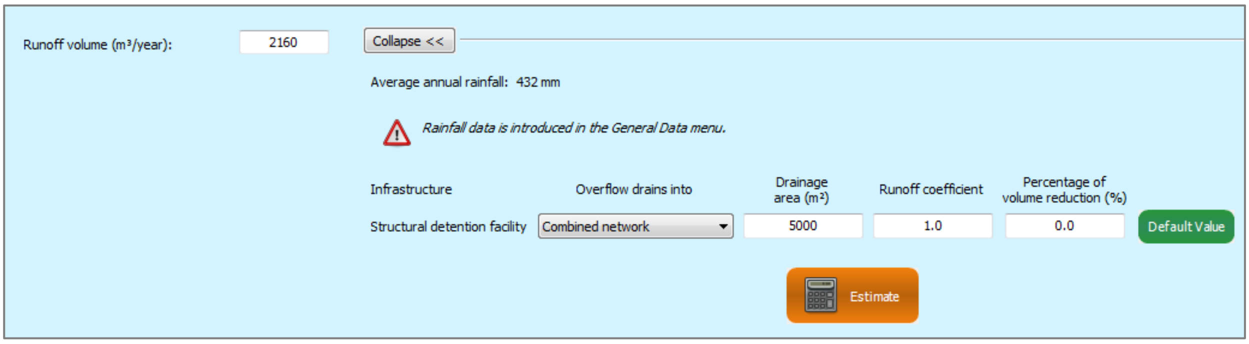


Inflow (blue) and outflow (magenta) for 26th August 2013 storm in Scenario 1: Conventional



Inflow (blue) and outflow (magenta) for DesignT2-2hr storm in Scenario 1: Conventional

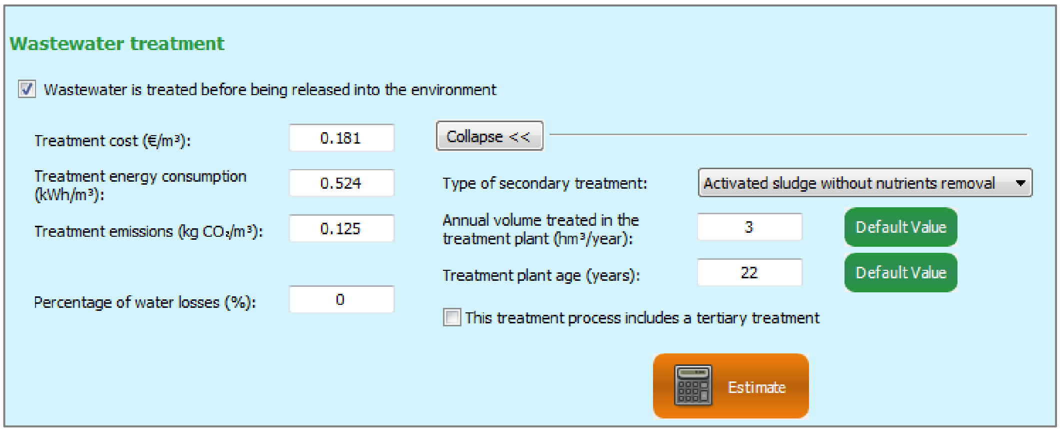
We have tried to use the Estimate tools for comparison, but the problem is that the average yearly rainfall data is used (432), instead of the one for 2013 (235 mm), so values are not comparable:



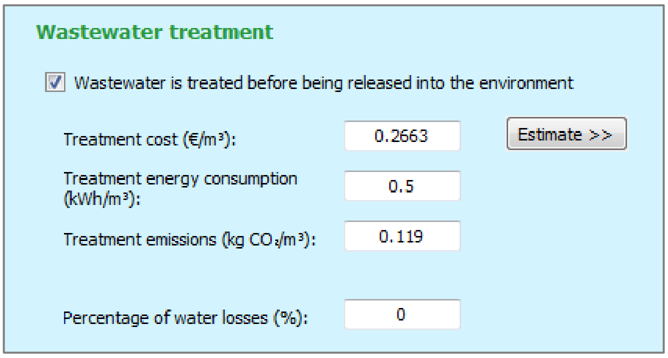
There is not data available to use the Estimate tool for CSOs. Data introduced in this field accounts for the amount of stormwater that overflows from the structure into the sewer system. As this usually happens when rainfall intensity is high, there is a good chance that the system cannot cope with it, producing CSOs. Stormwater retained in the tank, will be slowly discharged, hence with a good chance that it reaches the WWTP. In this case, that volume is estimated to be 925 m^3 for the year 2013.

2.3.5. Conveyance and treatment

Using the Estimate tool, we have obtained the following data:

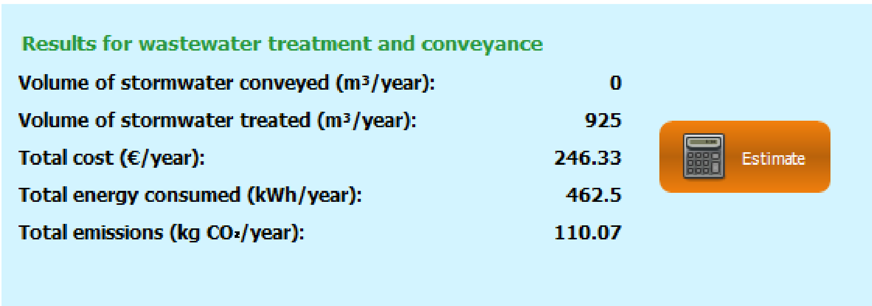


However, we have more data obtained from the local Wastewater treatment plant (WWTP), Camp de Turia I, provided by the operator; hence we have used the latest (using the national electricity emissions factor for 2010 to estimate treatment emissions), as shown:



In terms of % of water loses, we have used a null value, as we consider all stormwater discharged into the network after being retained in the tank will be able to reach the WWTP.

Hence, results are as follows:



2.3.6. Water quality

A qualitative evaluation of runoff water quality is not going to be used as a criterion in the decision-making process for this Pilot Case 1. In both scenarios runoff is discharged into a combined sewer after a similar treatment in both of them (being sedimentation the main pollutant removal mechanism).

2.3.7. Flood protection

Not applicable.

An evaluation of flood protection is not going to be used as a criterion in the decision-making process for this Pilot Case 1, as in both cases is very similar.

2.3.8. Building insulation

Not applicable.

2.3.9. Ecosystem services

No reduction in carbon dioxide. Very low global ecosystem services evaluation.

2.3.10. Summary

Results table:

Results

	Financial cost	Energy consumption	Emissions
Construction of infrastructures	54800 €	84929 kWh	26902 kg CO_2e
Maintenance of infrastructures	220 €/year	8.024 kWh/year	2.144 kg CO_2e/year
Infrastructure landtake	0 €	-	-
Potable water consumed and saved	9.48 €/year	22.889 kWh/year	5.4635 kg CO_2e/year
Wastewater conveyance and treatment	246.33 €/year	462.5 kWh/year	110.07 kg CO_2e/year
Flood protection	0 €/year	-	-
Building insulation	0 €/year	0 kWh/year	0 kg CO_2e/year
Carbon dioxide reduction	-	-	0 kg CO_2e/year
Other costs and benefits	0 €/year	0 kWh/year	0 kg CO_2e/year

Negative values indicate financial savings, energy savings and emissions avoided.

Other costs and benefits: Not considered

Energy consumed in the urban water cycle table:

Other costs and benefits

Add cost/benefit

Energy consumed in the urban water cycle

	Energy conssumption (kWh/m³)	Emissions (kg CO_2/m³)
Water supply acquisition	0.282	0.0671
Water supply conveyance	0.439	0.105
Water supply distribution	0	0
Wastewater conveyance	0	0
Wastewater treatment	0.5	0.119

Export table...

2.4. Scenario 2: Development with SuDS

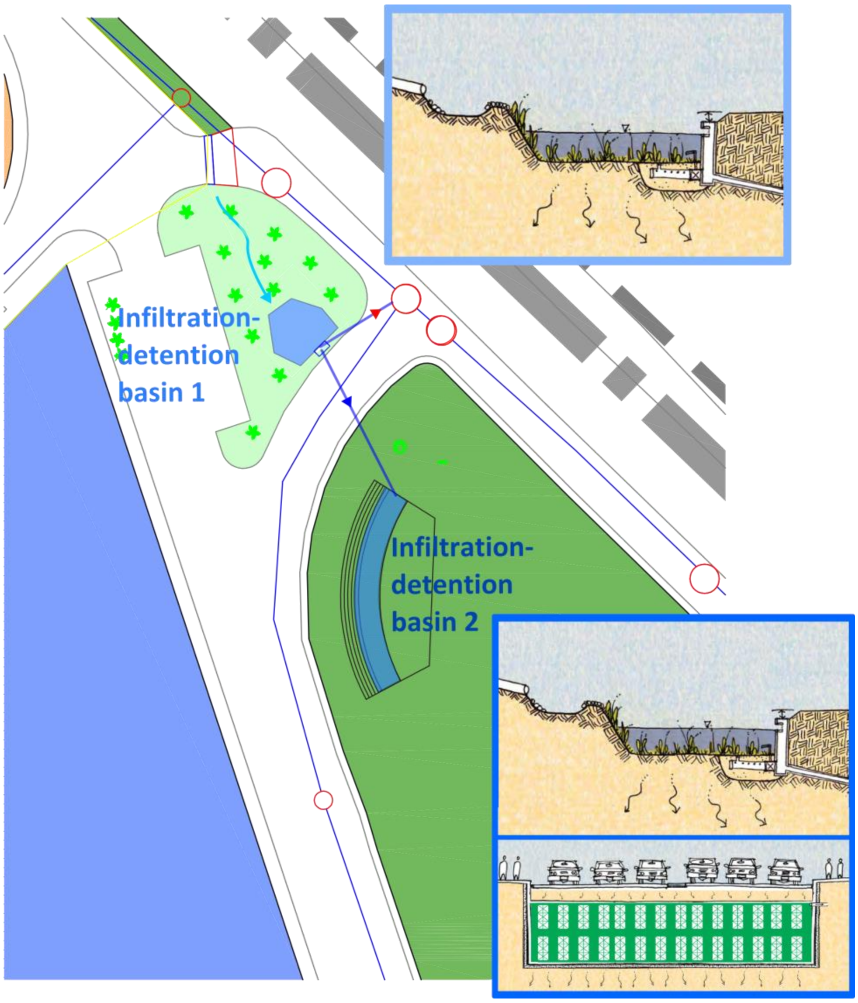
2.4.1. General description

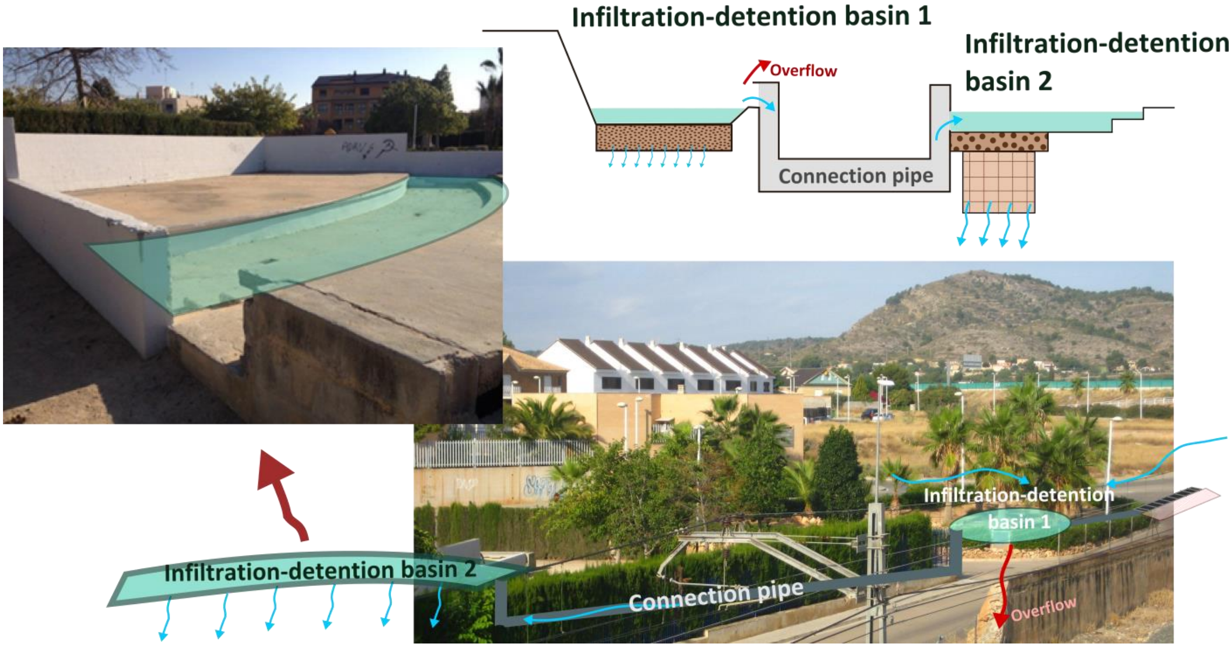
The proposed retrofit solution with SuDS provides local retention for runoff by making the most of landscape integration opportunities. The facility will be located in the lowest part of this urban area, making use of the small traffic island as well as of an existing amphitheater located at the park nearby.

The proposed solution is a combination of:

- Detention basin: Smaller basin to be retrofitted within the traffic island that collects water from two streets and serves as a pretreatment infrastructure (mainly sedimentation) before redirecting runoff to the second basin. Both basins will be connected by an underground pipe. It counts with an overflow to the combined sewer. Detention volume is 9.4 m^3.

- Infiltration-detention basin: The existing amphitheater would be retrofitted to increase retention volume by removing the bottom concrete slab, excavating the ground and placing modular plastic structures (geocellular system) wrapped with geotextile fabric and covered with gravel (underground retention volume is 23 m^3). Above ground retention volume is also provided by the shape of the amphitheater, with overflow structure preventing flooding of the stage (above ground retention volume is 57 m^3).





For this SuDS option, storage runoff would have been filtrated using vegetation (first basin), granular materials and geotextile fabric (second basin), and then released into the ground by infiltration. In addition, educational signs can be installed so citizens and visitors can learn about sustainable and energy efficient stormwater management when attending a performance or enjoying the park. Hence, main benefits are:

- Reduced CSOs (taking stormwater out of the sewers), hence protection of receiving water bodies.
- Reduced runoff treatment energy consumption and CO_2 emissions.
- Landscaping integration of infrastructures and educational opportunities.
- Aquifers recharge.

General criteria that has guided the design:

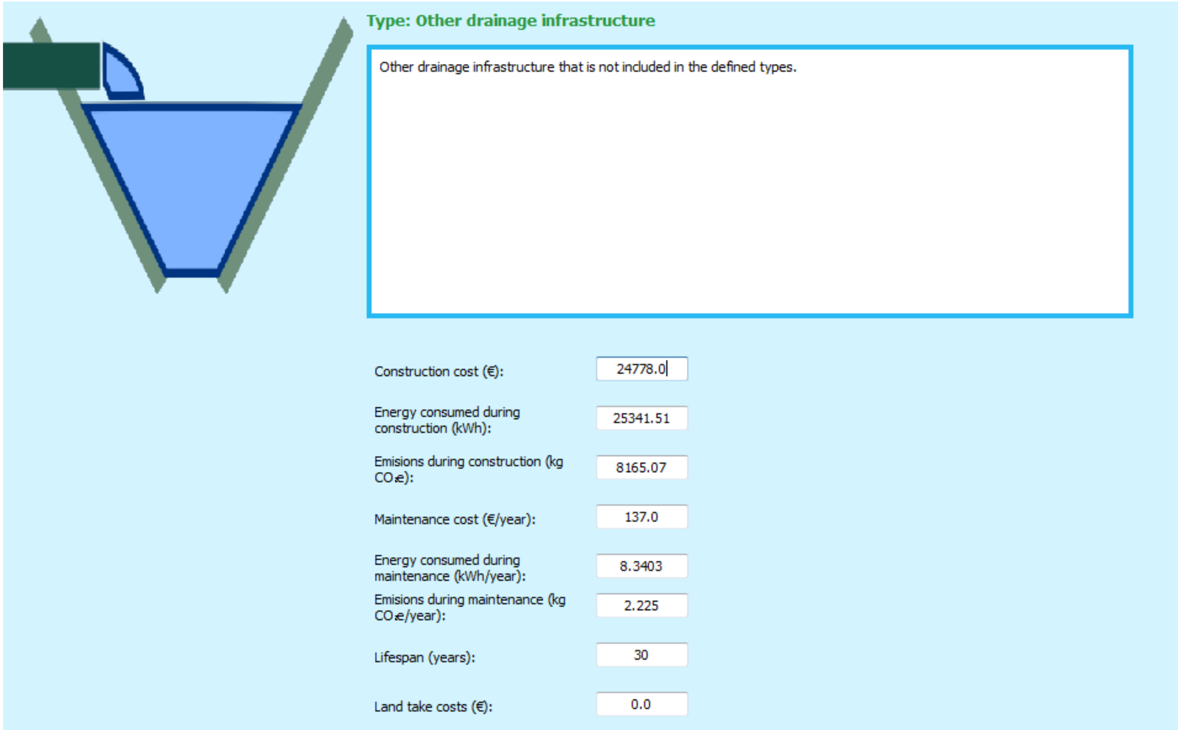
- Basin dimensions to fit the available area, and runoff retention comparable with the proposed conventional solution.
- Stored runoff to be released to the ground after filtration has occurred. Runoff retained above surface to infiltrate in less than 48 hours.
- Pre-treatment basin to facilitate sedimentation of big particles and to trap floatables.

2.4.2. Drainage infrastructures included in the scenario

Only one structure has been included. As explained above, it is a mixture of different types of drainage infrastructure; hence, the “other drainage infrastructure” type has been chosen.

In this case, the overflow is located 0.6 m from the base of the amphitheater base, being the storage-retention volume below that height of 80 m^3 (including the underground volume). Considering that the overflow structure is 0.2 m high, the total volume of the structure (before flooding occurs) is 104 m^3. Design sketches, maps and design criteria are presented in the preceding section.

Summary of values included in the DST are presented in the following figure:



In order to estimate construction cost, a detailed budget considering local prices (used in recent projects constructed in Benaguasil) has been elaborated. Estimated total construction cost (including complementary works) is 24 778 €, with a unitary cost of 238 €/m^3.

To estimate maintenance costs, the following tasks have been considered:

- Removing any trash/debris and sediment buildup in detention-infiltration basins (twice a year).
- Performing structural repairs to inlet, outlets and gravel base when required (once every 5 years).

With local cost for personnel, machinery, and materials, estimated maintenance tasks amount 137 €/year, hence 1.3 €/m^3/year.

In terms of energy consumed during construction, the default values contained in the DST for "geocellular system" (23 m^3) and "detention basin" (81 m^3) have been used and combined. Same procedure has been followed for calculating emissions during construction. In summary, and average emissions of 243.67 $kgCO_2e/m^3$ have been obtained.

For energy consumption and emissions of maintenance tasks, the same procedure have been followed, combining the two types of infrastructures. In addition, it has been considered that these infrastructures would be visited twice per year for maintenance. Average emissions for maintenance are 0.021 $kgCO_2e/m^3$.

Projet cofinancé par le Fonds Européen de Développement Régional (FEDER)
Project cofinanced by the European Regional Development Fund (ERDF)

2.4.3. Water reuse

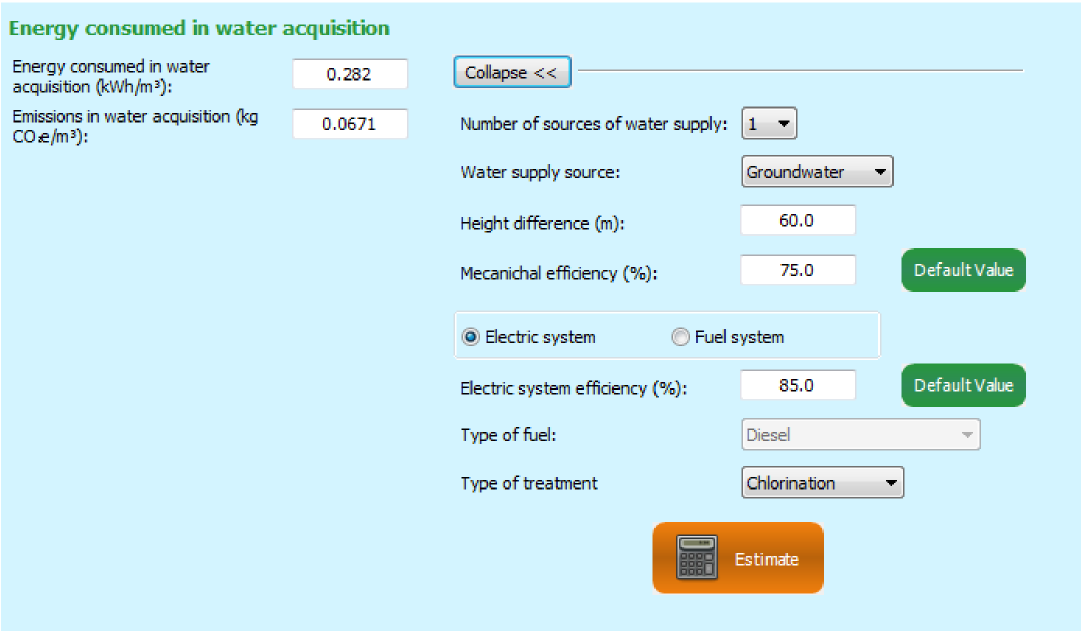
Values for water supply cost have been obtained from the municipality. Values depend on the consumption, as follows:

- Less than 10 m3: Cost = 0.236 €/m3.
- Between 10-15 m3: Cost = 0.333 €/m3.
- More than 15 m3: Cost = 0.474 €/m3.

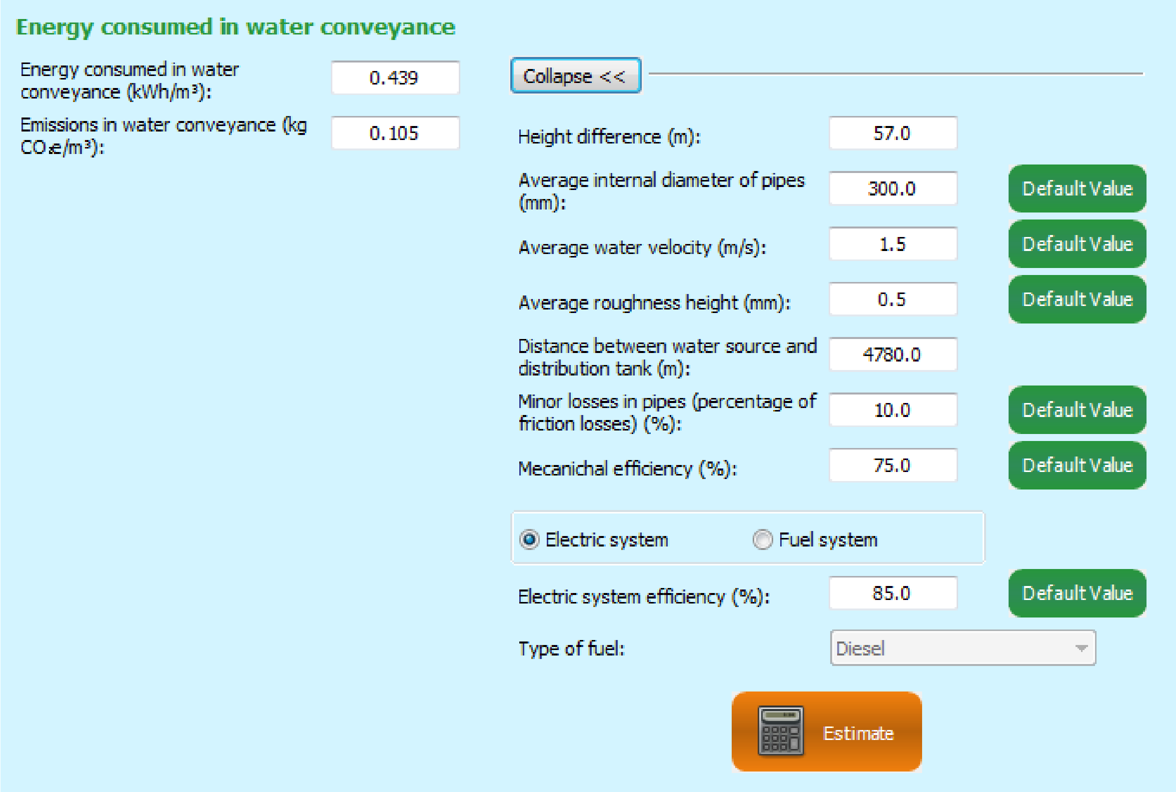
A value of 0.474 €/m^3 has been used for Pilot Case 1.

Water losses in network obtained from the municipality (difference between recorded extracted and supplied volumes), with a value of 37%.

Energy consumed in water acquisition estimated using DST tool, with data as follows (default values used for mechanic efficiency and electric system efficiency):



Energy consumed in water conveyance estimated using DST tool, with data as follows:

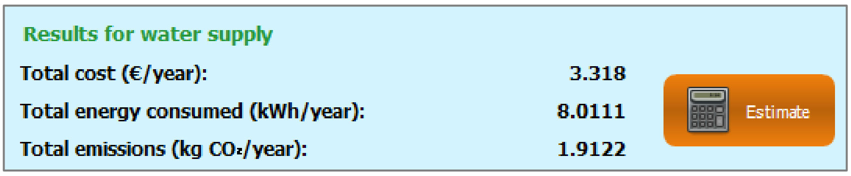


As it can be observed, default values have been used for average water velocity, minor losses in pipes and mechanical efficiency. For the average roughness height, a value within the bracket presented in table 2.9 of the guidelines for concrete pipes has been used (0.5 mm).

Being a gravity system, there is no energy consumption in water distribution.

Cleaning consumption has been estimated at 7 m^3/year (1 m^3 year for each one of the 7 palm trees that do not have to be removed in comparison to Scenario 1).

Results are as follows:



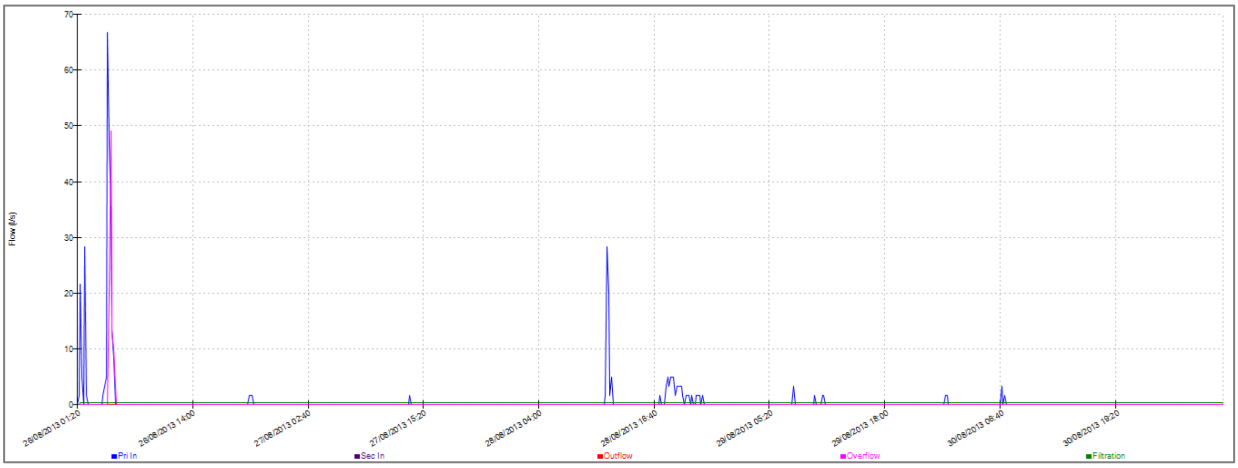
2.4.4. Stormwater runoff

Proprietary software from XPSolutions, called MicroDrainage (v2014.1.1), has been used for the hydraulic model to analyze runoff. Modelling is undertaken with the Wallingford Procedure, simulating using time/area full hydrograph methodology including energy and momentum equations for dynamic analysis. More information can be obtained from their website (http://xpsolutions.com/Software/MICRO-DRAINAGE/).

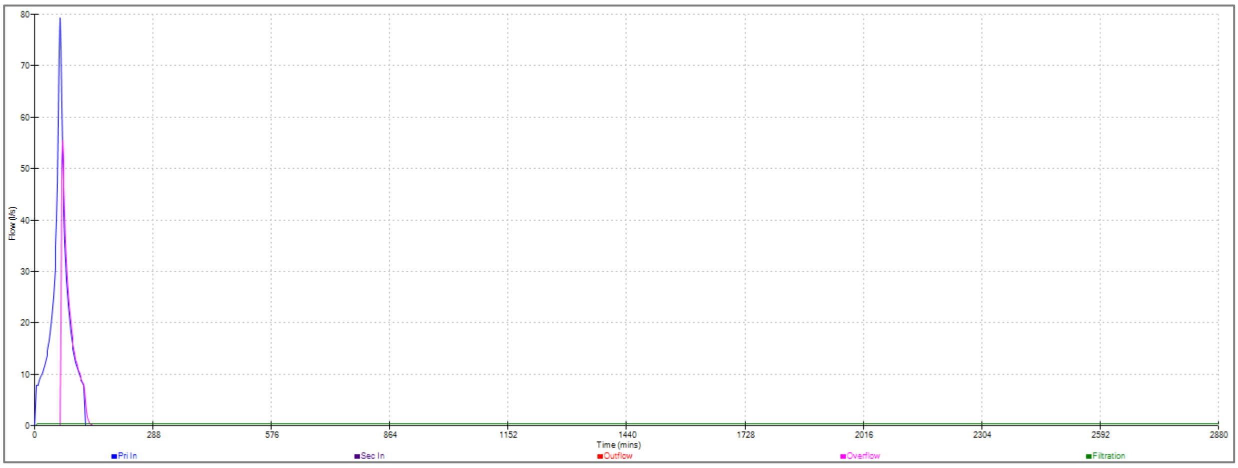
Rainfall data from year 2013 has been used for the volume calculations, and peak outflow estimated using “DesignT2-2hr” design storm. Results obtained are as follows:

Runoff volume (m³/year):	278	Estimate >>
Peak outflow rate for design storm (m³/s):	0.056	*Complete if flow rate is a decision criterion.*
Combined Sewer Overflows from this area (m³/year):	278.0	Estimate >>

Graphs below show inflows and outflows for the most critical storm in 2013 (26th August 2013) and for the design storm.

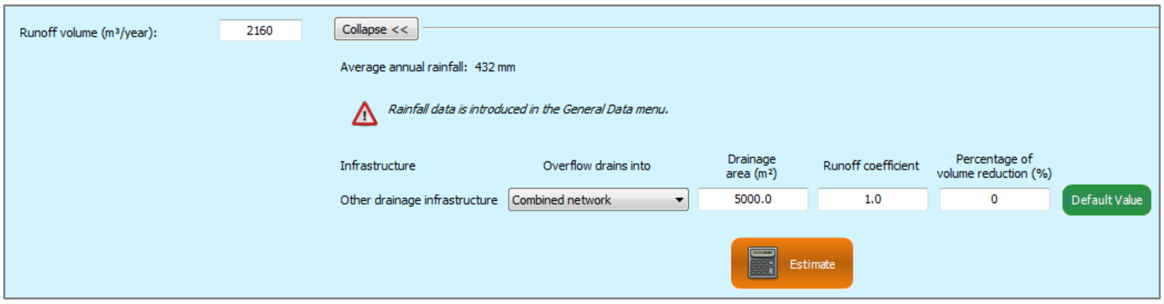


Inflow (blue) and outflow (magenta) for 26th August 2013 storm in Scenario 2: SuDS



Inflow (blue) and outflow (magenta) for DesignT2-2hr storm in Scenario 2: SuDS

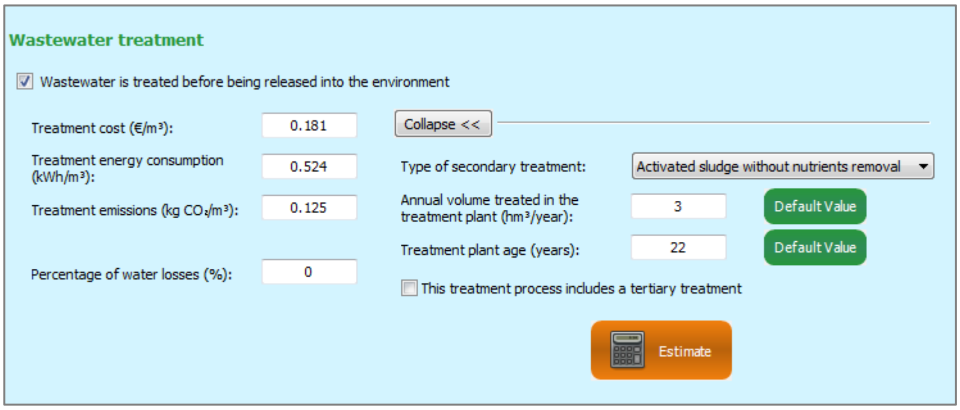
We have tried to us the Estimate tools for comparison, but the problem is that the average yearly rainfall data is used (432), instead of the one for 2013 (235 mm), so values are not comparable:



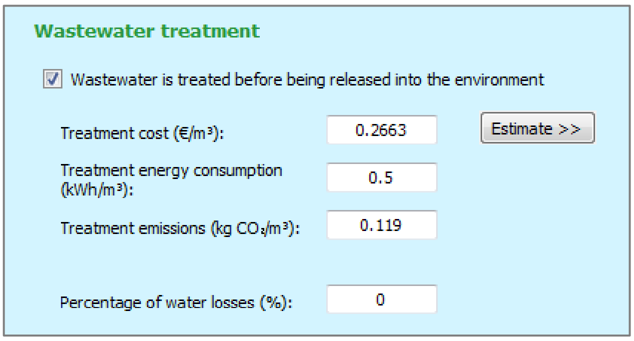
There is not data available to use the Estimate tool for CSOs. Data introduced in this field accounts for the amount of stormwater that overflows from the structure into the sewer system. As this usually happens when rainfall intensity is high, there is a good chance that the system cannot cope with it, producing CSOs. Stormwater retained in the infrastructure, will slowly infiltrate in the ground, hence not reaching the WWTP. In this case, infiltration volume is estimated to be 897 m^3 for the year 2013.

2.4.5. Conveyance and treatment

Using the Estimate tool, we have obtained the following data:

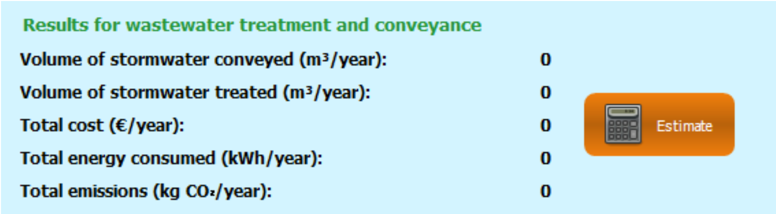


However, we have more data obtained from the local Wastewater treatment plant (WWTP), Camp de Turia I, provided by the operator; hence we have used the latest (using the national electricity emissions factor for 2010 to estimate treatment emissions), as shown:



In terms of % of water loses, we have used a null value, as we consider all stormwater discharged into the network after being retained in the tank will be able to reach the WWTP.

As runoff retained within the infrastructure is infiltrated into the ground, results are as follows:



2.4.6. Water quality

A qualitative evaluation of runoff water quality is not going to be used as a criterion in the decision-making process for this Pilot Case 1. In both scenarios runoff is discharged into a combined sewer after a similar treatment in both of them (being sedimentation the main pollutant removal mechanism).

2.4.7. Flood protection

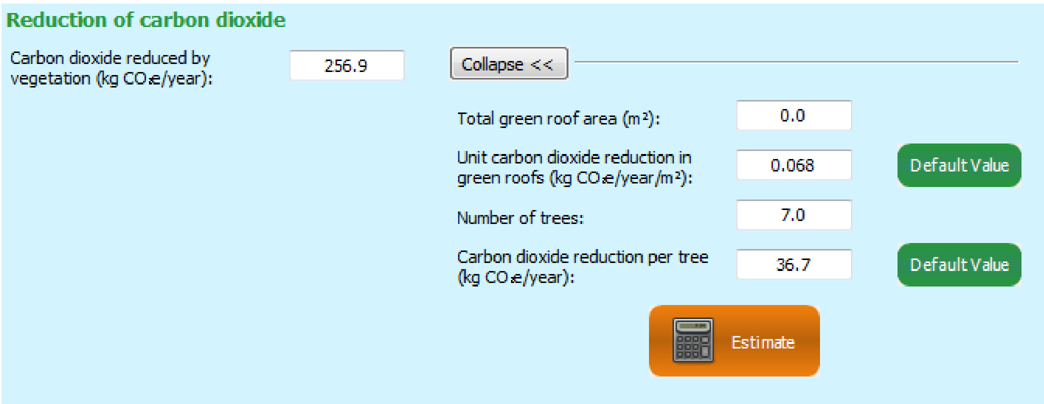
An evaluation of flood protection is not going to be used as a criterion in the decision-making process for this Pilot Case 1, as in both cases is very similar.

2.4.8. Building insulation

Not applicable.

2.4.9. Ecosystem services

For this scenario, 7 palm trees that will have to be removed in Scenario 1 will remain; hence, their benefits are computed, as follows (default value used for carbon dioxide reduction per tree value):



Being this one the only significant difference with Scenario 1, global ecosystem services has been evaluated as low.

Global evaluation of ecosystem services is not going to be used as a criterion in the decision-making process for this Pilot Case 1.

2.4.10. Summary

Results table:

Results

	Financial cost	Energy consumption	Emissions
Construction of infrastructures	24778 €	25342 kWh	8165.1 kg CO_2e
Maintenance of infrastructures	137 €/year	8.3403 kWh/year	2.225 kg CO_2e/year
Infrastructure landtake	0 €	-	-
Potable water consumed and saved	3.318 €/year	8.0111 kWh/year	1.9122 kg CO_2e/year
Wastewater conveyance and treatment	0 €/year	0 kWh/year	0 kg CO_2e/year
Flood protection	0 €/year	-	-
Building insulation	0 €/year	0 kWh/year	0 kg CO_2e/year
Carbon dioxide reduction	-	-	-256.9 kg CO_2e/year
Other costs and benefits	0 €/year	0 kWh/year	0 kg CO_2e/year

Negative values indicate financial savings, energy savings and emissions avoided.

Other costs and benefits: not considered

Energy consumed in the urban water cycle table:

Other costs and benefits

Add cost/benefit

Energy consumed in the urban water cycle

	Energy conssumption (kWh/m³)	Emissions (kg CO_2/m³)
Water supply acquisition	0.282	0.0671
Water supply conveyance	0.439	0.105
Water supply distribution	0	0
Wastewater conveyance	0	0
Wastewater treatment	0.5	0.119

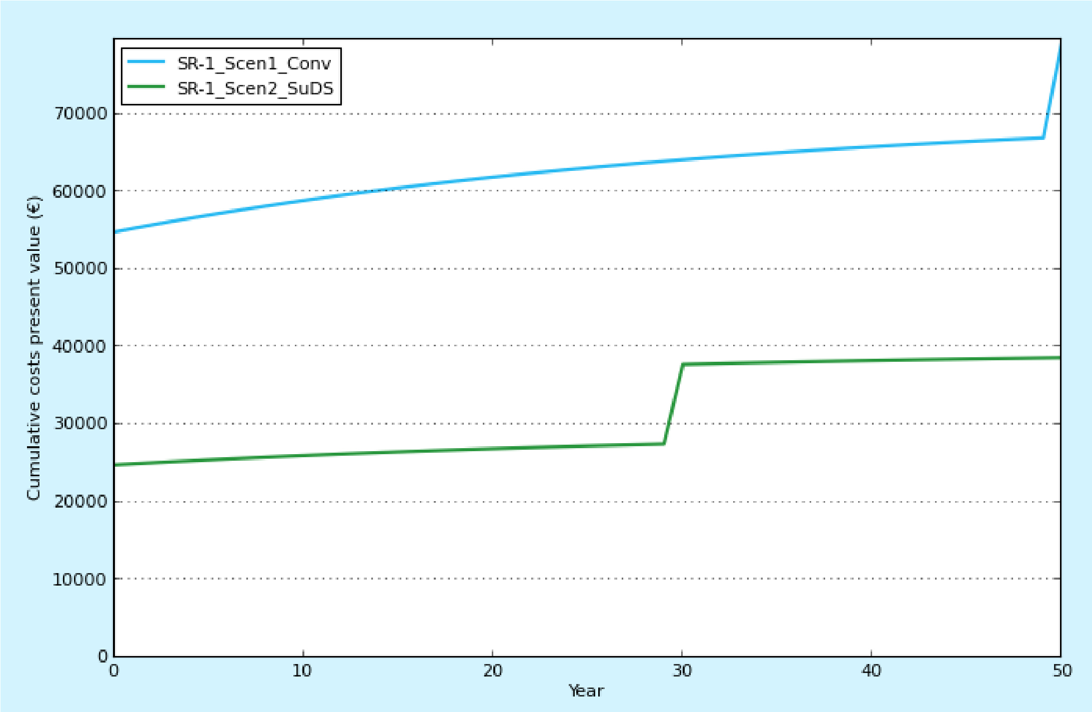
Export table...

2.5. Results

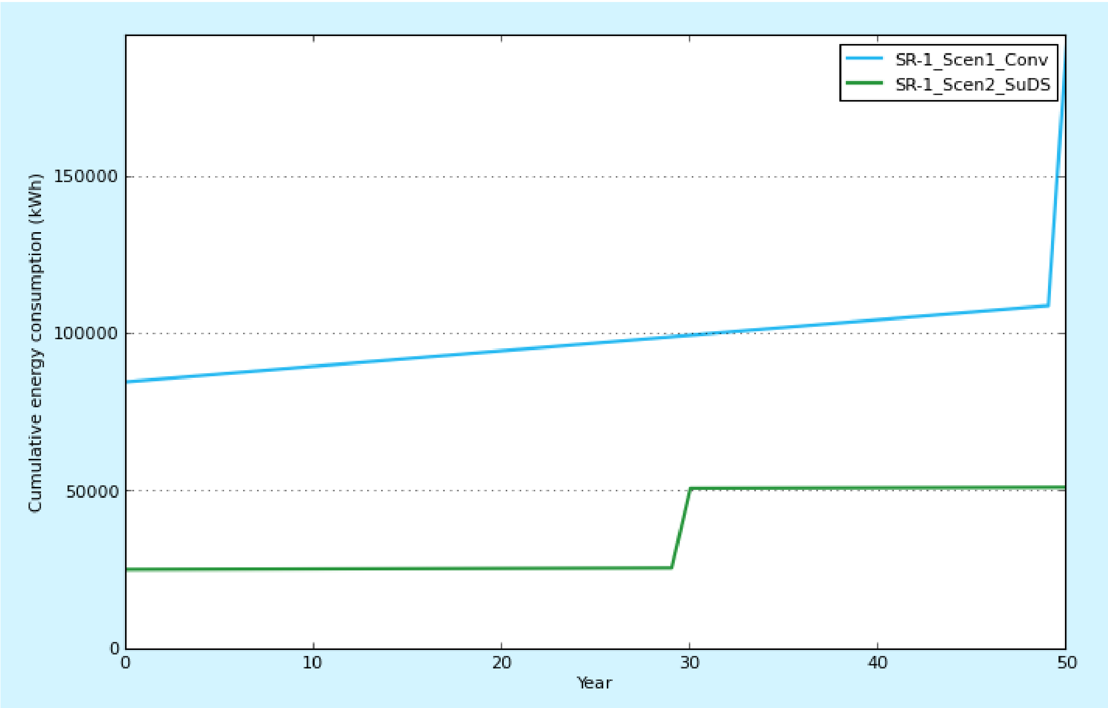
2.5.1. Time graphs

- Global time graphs obtained with the DST (graph and tables).

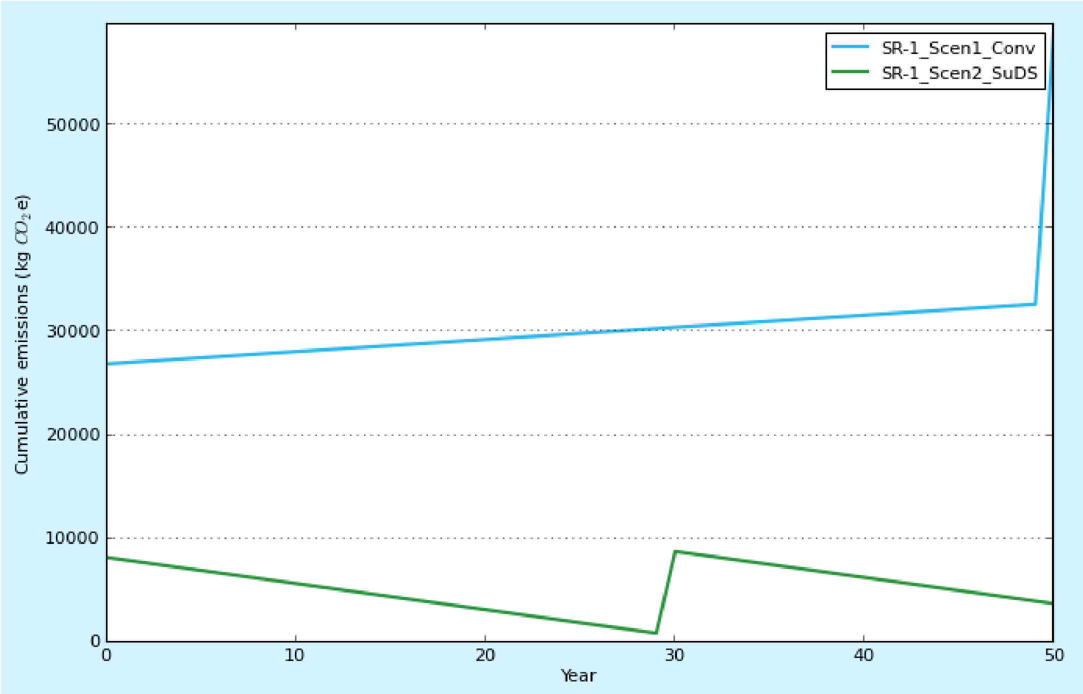
- Cost present value:



- Energy consumption:



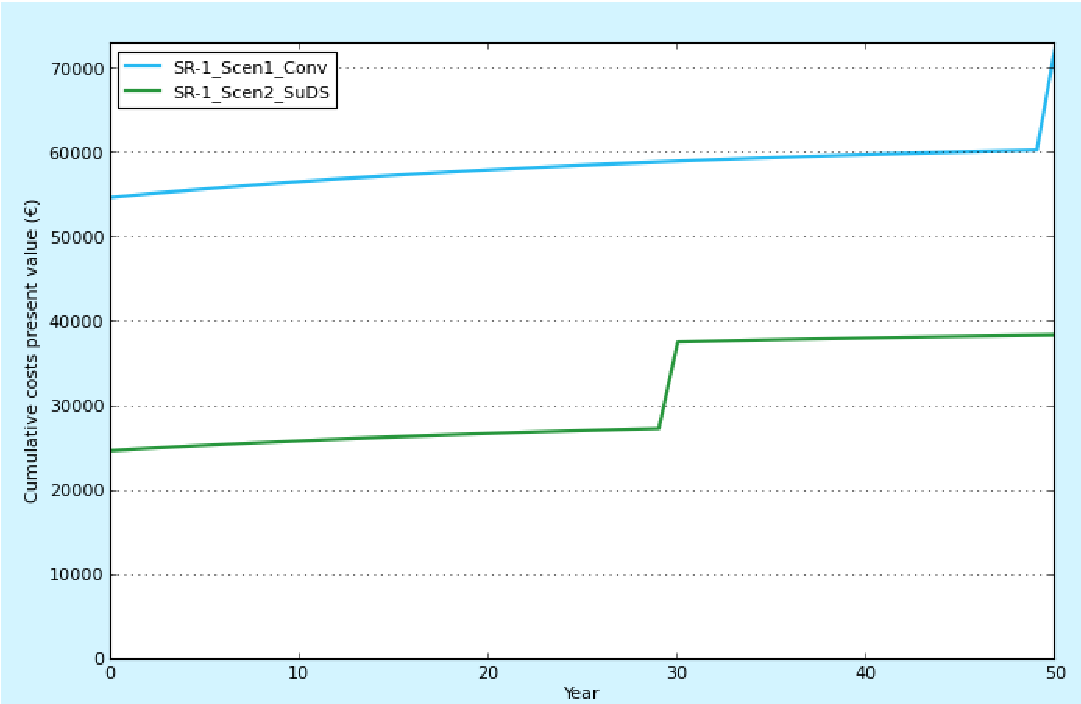
- CO_2 emissions:



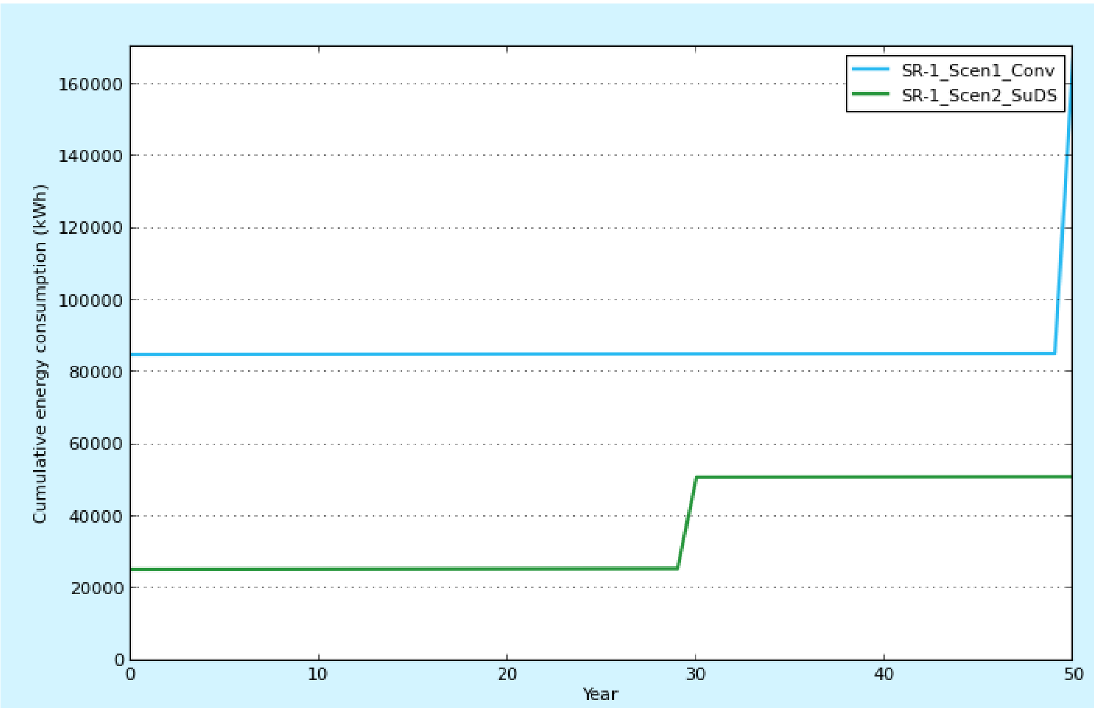
Year	Costs Present Value		Energy conssumption		CO2e Emissions	
	Scen1	Scen2	Scen1	Scen2	Scen1	Scen2
0	54800.00	24778.00	84929.00	25341.51	26902.00	8165.07
1	55261.95	24914.23	85422.41	25357.86	27019.68	7912.31
2	55710.44	25046.49	85915.83	25374.21	27137.36	7659.54
3	56145.87	25174.91	86409.24	25390.56	27255.05	7406.78
4	56568.62	25299.58	86902.65	25406.92	27372.73	7154.02
5	56979.06	25420.62	87396.06	25423.27	27490.41	6901.26
6	57377.54	25538.13	87889.48	25439.62	27608.09	6648.49
7	57764.42	25652.22	88382.89	25455.97	27725.78	6395.73
8	58140.02	25762.99	88876.30	25472.32	27843.46	6142.97
9	58504.69	25870.53	89369.72	25488.67	27961.14	5890.21
10	58858.73	25974.94	89863.13	25505.02	28078.82	5637.44
11	59202.47	26076.31	90356.54	25521.38	28196.51	5384.68
12	59536.19	26174.73	90849.95	25537.73	28314.19	5131.92
13	59860.19	26270.28	91343.37	25554.08	28431.87	4879.15
14	60174.76	26363.04	91836.78	25570.43	28549.55	4626.39
15	60480.16	26453.11	92330.19	25586.78	28667.24	4373.63
16	60776.67	26540.55	92823.61	25603.13	28784.92	4120.87
17	61064.54	26625.44	93317.02	25619.48	28902.60	3868.10
18	61344.02	26707.87	93810.43	25635.84	29020.28	3615.34
19	61615.37	26787.89	94303.84	25652.19	29137.97	3362.58
20	61878.81	26865.58	94797.26	25668.54	29255.65	3109.81
21	62134.58	26941.01	95290.67	25684.89	29373.33	2857.05
22	62382.90	27014.24	95784.08	25701.24	29491.01	2604.29
23	62623.99	27085.33	96277.50	25717.59	29608.70	2351.53
24	62858.06	27154.36	96770.91	25733.94	29726.38	2098.76
25	63085.31	27221.38	97264.32	25750.30	29844.06	1846.00
26	63305.94	27286.44	97757.74	25766.65	29961.74	1593.24
27	63520.14	27349.61	98251.15	25783.00	30079.43	1340.48
28	63728.10	27410.94	98744.56	25799.35	30197.11	1087.71
29	63930.01	27470.49	99237.97	25815.70	30314.79	834.95
30	64126.04	37736.50	99731.39	51173.56	30432.47	8747.26
31	64316.35	37792.63	100224.80	51189.91	30550.16	8494.49
32	64501.13	37847.12	100718.21	51206.27	30667.84	8241.73
33	64680.52	37900.02	101211.63	51222.62	30785.52	7988.97
34	64854.69	37951.38	101705.04	51238.97	30903.20	7736.21
35	65023.78	38001.25	102198.45	51255.32	31020.89	7483.44
36	65187.95	38049.67	102691.86	51271.67	31138.57	7230.68
37	65347.34	38096.67	103185.28	51288.02	31256.25	6977.92
38	65502.08	38142.31	103678.69	51304.37	31373.93	6725.15
39	65652.32	38186.61	104172.10	51320.73	31491.62	6472.39
40	65798.18	38229.63	104665.52	51337.08	31609.30	6219.63
41	65939.80	38271.39	105158.93	51353.43	31726.98	5966.87
42	66077.28	38311.94	105652.34	51369.78	31844.66	5714.10
43	66210.77	38351.30	106145.75	51386.13	31962.35	5461.34
44	66340.37	38389.52	106639.17	51402.48	32080.03	5208.58
45	66466.19	38426.62	107132.58	51418.83	32197.71	4955.82
46	66588.34	38462.65	107625.99	51435.18	32315.39	4703.05
47	66706.94	38497.62	108119.41	51451.54	32433.08	4450.29
48	66822.09	38531.58	108612.82	51467.89	32550.76	4197.53
49	66933.88	38564.55	109106.23	51484.24	32668.44	3944.76
50	79542.68	38596.56	194528.64	51500.59	59688.12	3692.00

- Time graphs obtained with only construction and maintenance.

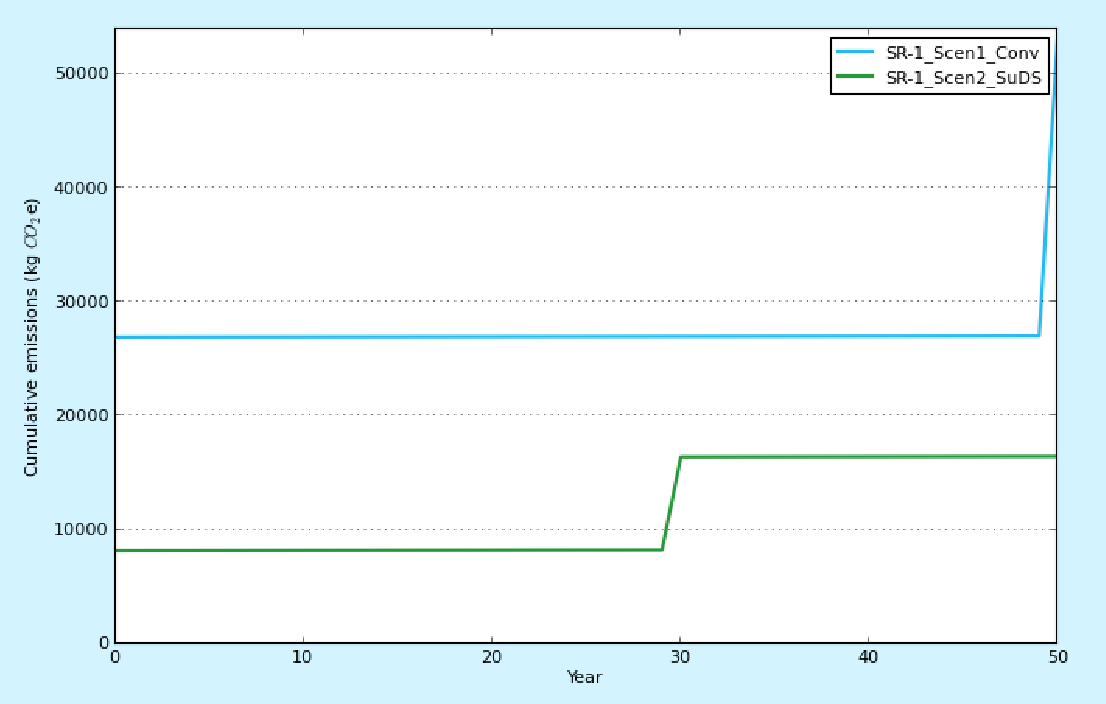
- Cost present value:



- Energy consumption:



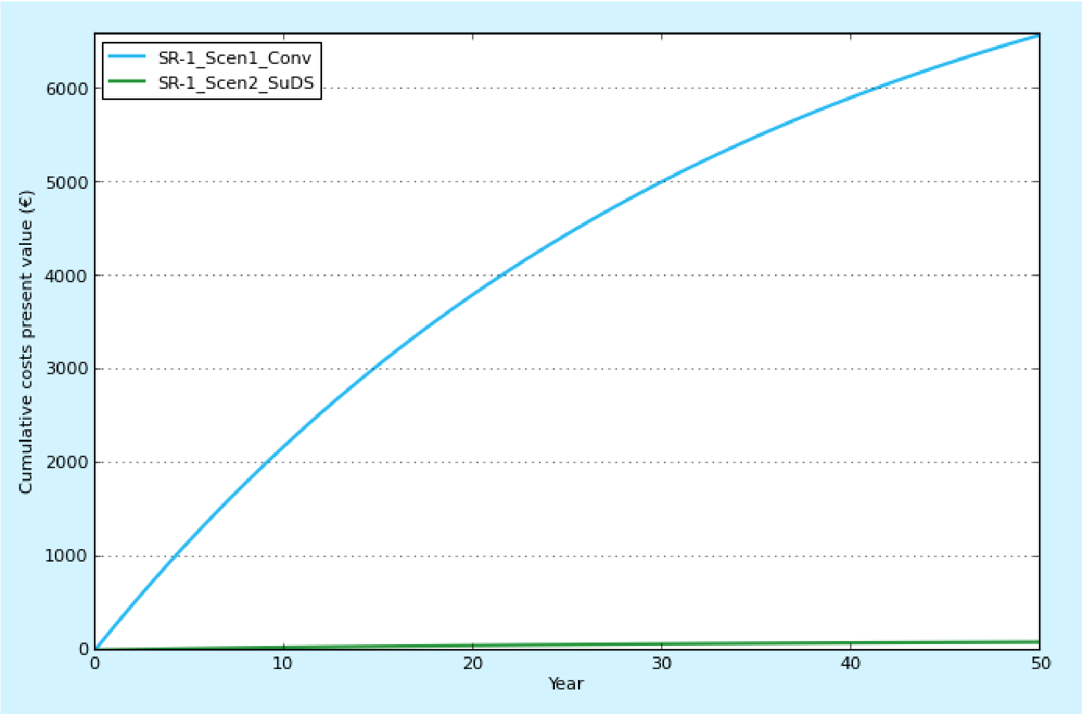
- CO_2 emissions:



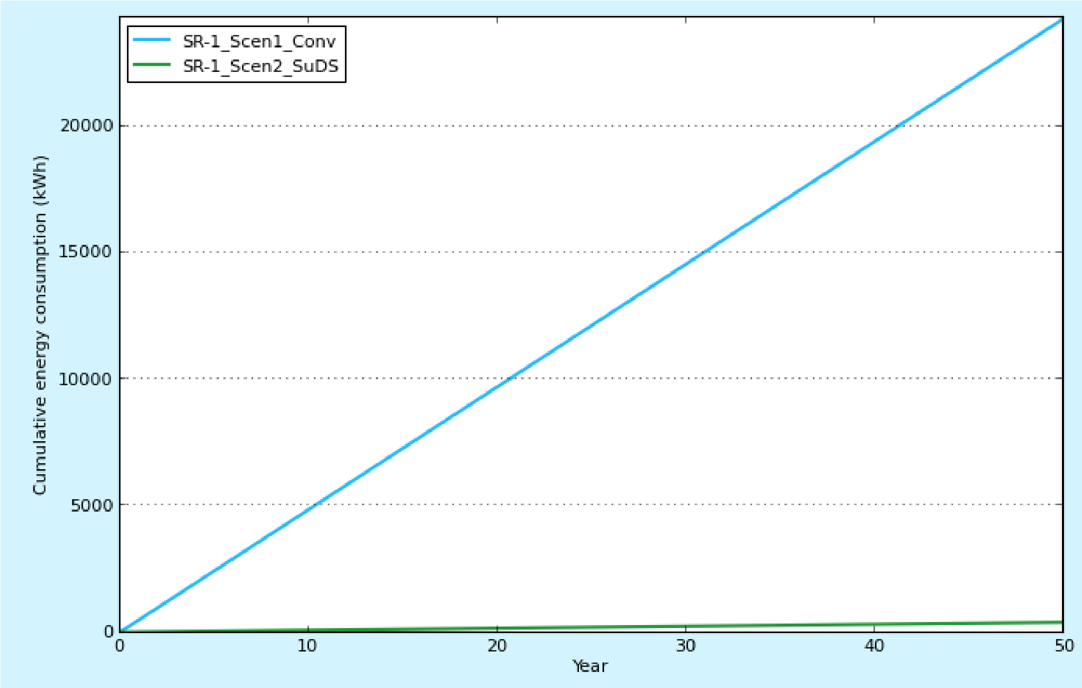
Year	Costs Present Value		Energy conssumption		CO2e Emissions	
	Scen1	Scen2	Scen1	Scen2	Scen1	Scen2
0	54800.00	24778.00	84929.00	25341.51	26902.00	8165.07
1	55013.59	24911.01	84937.02	25349.85	26904.14	8167.30
2	55220.96	25040.15	84945.05	25358.19	26906.29	8169.52
3	55422.29	25165.52	84953.07	25366.53	26908.43	8171.75
4	55617.76	25287.24	84961.10	25374.87	26910.58	8173.97
5	55807.54	25405.42	84969.12	25383.21	26912.72	8176.20
6	55991.78	25520.16	84977.14	25391.55	26914.86	8178.42
7	56170.66	25631.55	84985.17	25399.89	26917.01	8180.65
8	56344.33	25739.70	84993.19	25408.23	26919.15	8182.87
9	56512.94	25844.70	85001.22	25416.57	26921.30	8185.10
10	56676.64	25946.64	85009.24	25424.91	26923.44	8187.32
11	56835.58	26045.61	85017.26	25433.25	26925.58	8189.55
12	56989.88	26141.70	85025.29	25441.59	26927.73	8191.77
13	57139.69	26234.99	85033.31	25449.93	26929.87	8194.00
14	57285.14	26325.56	85041.34	25458.27	26932.02	8196.22
15	57426.35	26413.50	85049.36	25466.61	26934.16	8198.45
16	57563.44	26498.87	85057.38	25474.95	26936.30	8200.67
17	57696.55	26581.76	85065.41	25483.30	26938.45	8202.90
18	57825.77	26662.23	85073.43	25491.64	26940.59	8205.12
19	57951.24	26740.36	85081.46	25499.98	26942.74	8207.35
20	58073.04	26816.21	85089.48	25508.32	26944.88	8209.57
21	58191.31	26889.86	85097.50	25516.66	26947.02	8211.80
22	58306.12	26961.36	85105.53	25525.00	26949.17	8214.02
23	58417.59	27030.77	85113.55	25533.34	26951.31	8216.25
24	58525.82	27098.17	85121.58	25541.68	26953.46	8218.47
25	58630.89	27163.60	85129.60	25550.02	26955.60	8220.70
26	58732.91	27227.13	85137.62	25558.36	26957.74	8222.92
27	58831.95	27288.80	85145.65	25566.70	26959.89	8225.15
28	58928.10	27348.68	85153.67	25575.04	26962.03	8227.37
29	59021.46	27406.82	85161.70	25583.38	26964.18	8229.60
30	59112.10	37671.47	85169.72	50933.23	26966.32	16396.89
31	59200.09	37726.27	85177.74	50941.57	26968.46	16399.12
32	59285.53	37779.47	85185.77	50949.91	26970.61	16401.34
33	59368.47	37831.12	85193.79	50958.25	26972.75	16403.57
34	59449.00	37881.27	85201.82	50966.59	26974.90	16405.79
35	59527.19	37929.96	85209.84	50974.93	26977.04	16408.02
36	59603.10	37977.23	85217.86	50983.27	26979.18	16410.24
37	59676.79	38023.12	85225.89	50991.61	26981.33	16412.47
38	59748.34	38067.68	85233.91	50999.95	26983.47	16414.69
39	59817.81	38110.93	85241.94	51008.29	26985.62	16416.92
40	59885.25	38152.93	85249.96	51016.63	26987.76	16419.14
41	59950.73	38193.71	85257.98	51024.97	26989.90	16421.37
42	60014.30	38233.29	85266.01	51033.31	26992.05	16423.59
43	60076.02	38271.73	85274.03	51041.65	26994.19	16425.82
44	60135.94	38309.04	85282.06	51049.99	26996.34	16428.04
45	60194.12	38345.27	85290.08	51058.33	26998.48	16430.27
46	60250.60	38380.44	85298.10	51066.67	27000.62	16432.49
47	60305.44	38414.59	85306.13	51075.01	27002.77	16434.72
48	60358.68	38447.75	85314.15	51083.35	27004.91	16436.94
49	60410.36	38479.93	85322.18	51091.69	27007.06	16439.17
50	72960.82	38511.19	170259.20	51100.04	53911.20	16441.39

- Time graphs obtained without construction and maintenance.

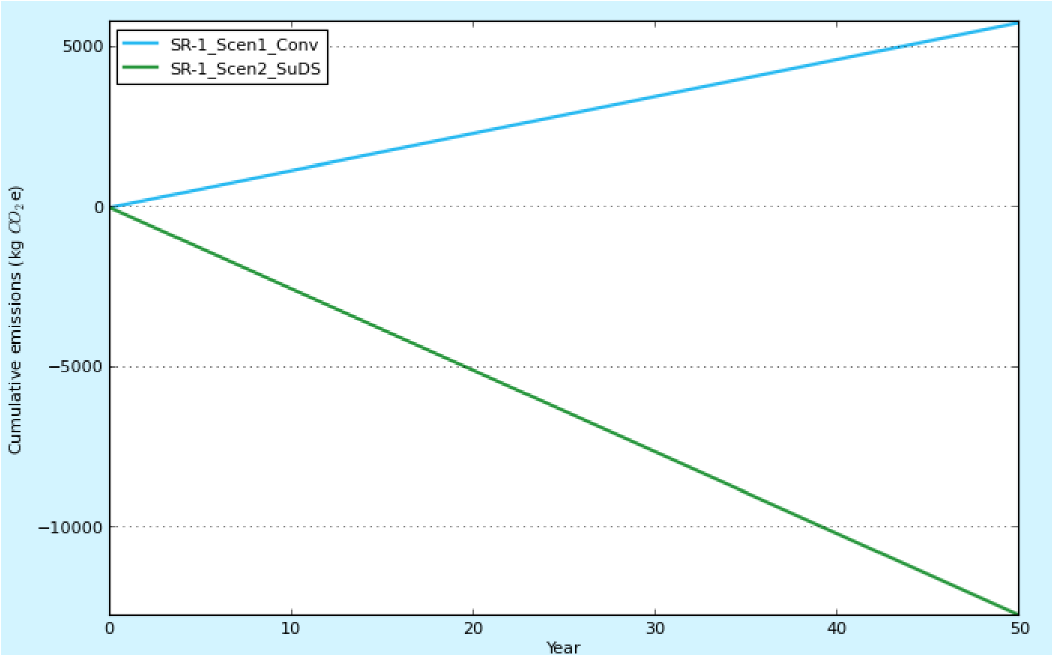
- Cost present value:



- Energy consumption:



- CO_2 emissions:



Year	Costs Present Value		Energy conssumption		CO2e Emissions	
	Scen1	Scen2	Scen1	Scen2	Scen1	Scen2
0	0.00	0.00	0.00	0.00	0.00	0.00
1	248.36	3.22	485.39	8.01	115.54	-254.99
2	489.48	6.35	970.78	16.02	231.08	-509.98
3	723.58	9.39	1456.17	24.03	346.62	-764.96
4	950.86	12.33	1941.56	32.04	462.15	-1019.95
5	1171.52	15.20	2426.94	40.06	577.69	-1274.94
6	1385.76	17.97	2912.33	48.07	693.23	-1529.93
7	1593.75	20.67	3397.72	56.08	808.77	-1784.91
8	1795.69	23.29	3883.11	64.09	924.31	-2039.90
9	1991.75	25.83	4368.50	72.10	1039.85	-2294.89
10	2182.09	28.30	4853.89	80.11	1155.38	-2549.88
11	2366.89	30.70	5339.28	88.12	1270.92	-2804.87
12	2546.31	33.03	5824.67	96.13	1386.46	-3059.85
13	2720.50	35.29	6310.06	104.14	1502.00	-3314.84
14	2889.62	37.48	6795.44	112.16	1617.54	-3569.83
15	3053.81	39.61	7280.83	120.17	1733.08	-3824.82
16	3213.22	41.68	7766.22	128.18	1848.62	-4079.80
17	3367.99	43.69	8251.61	136.19	1964.15	-4334.79
18	3518.25	45.63	8737.00	144.20	2079.69	-4589.78
19	3664.14	47.53	9222.39	152.21	2195.23	-4844.77
20	3805.77	49.36	9707.78	160.22	2310.77	-5099.76
21	3943.28	51.15	10193.17	168.23	2426.31	-5354.74
22	4076.78	52.88	10678.56	176.24	2541.85	-5609.73
23	4206.40	54.56	11163.94	184.26	2657.39	-5864.72
24	4332.24	56.19	11649.33	192.27	2772.92	-6119.71
25	4454.41	57.78	12134.72	200.28	2888.46	-6374.69
26	4573.03	59.32	12620.11	208.29	3004.00	-6629.68
27	4688.19	60.81	13105.50	216.30	3119.54	-6884.67
28	4800.00	62.26	13590.89	224.31	3235.08	-7139.66
29	4908.55	63.67	14076.28	232.32	3350.62	-7394.65
30	5013.94	65.03	14561.67	240.33	3466.15	-7649.63
31	5116.26	66.36	15047.06	248.34	3581.69	-7904.62
32	5215.60	67.65	15532.44	256.36	3697.23	-8159.61
33	5312.05	68.90	16017.83	264.37	3812.77	-8414.60
34	5405.68	70.12	16503.22	272.38	3928.31	-8669.58
35	5496.59	71.29	16988.61	280.39	4043.85	-8924.57
36	5584.85	72.44	17474.00	288.40	4159.39	-9179.56
37	5670.55	73.55	17959.39	296.41	4274.92	-9434.55
38	5753.74	74.63	18444.78	304.42	4390.46	-9689.54
39	5834.51	75.68	18930.17	312.43	4506.00	-9944.52
40	5912.93	76.69	19415.56	320.44	4621.54	-10199.51
41	5989.07	77.68	19900.94	328.46	4737.08	-10454.50
42	6062.99	78.64	20386.33	336.47	4852.62	-10709.49
43	6134.75	79.57	20871.72	344.48	4968.16	-10964.47
44	6204.43	80.48	21357.11	352.49	5083.69	-11219.46
45	6272.07	81.35	21842.50	360.50	5199.23	-11474.45
46	6337.75	82.20	22327.89	368.51	5314.77	-11729.44
47	6401.51	83.03	22813.28	376.52	5430.31	-11984.43
48	6463.41	83.83	23298.67	384.53	5545.85	-12239.41
49	6523.52	84.61	23784.06	392.54	5661.39	-12494.40
50	6581.87	85.37	24269.44	400.56	5776.92	-12749.39

- Explanation and justification of results.

As shown in the previous graphs and tables, the second option has lower costs, energy consumptions and emissions in all the period of analysis. This is mainly due to the lower costs and energy consumptions during construction and the reduction of the runoff volume that goes to the treatment plant.

2.5.2. Decision criteria

Benaguasil main objectives, as explained at the beginning of the document, are:

- Reducing urban flooding.
- Reducing Combined Sewer Overflows (CSOs).
- Protection of receiving water bodies.
- Reducing energy consumption and CO_2 emissions in the urban water management.
- Landscaping integration of infrastructures.
- Aquifers recharge.
- Optimization of drinking water use.

Decision criteria have been chosen in accordance to the above, in a way that comparison of how different options achieve them can be made, and including what the costs are, as this is going to dictate in a big proportion whether the retrofitted proposed action is feasible. They have been preliminary chosen by technicians carrying out the application of the DST, and later on reviewed and modified considering the opinion of decision makers and technical staff within the municipality. In addition, the criteria selected and their weights have been discussed in the meetings with the RWGEE.

Being a very small retrofit action, with both scenarios presenting a very similar retention volume, its impact on Reducing urban flooding, Reducing Combined Sewer Overflows (CSOs) and Protection of receiving water bodies, although present, are not relevant in comparative terms. Hence, selected decision criteria are as follows:

- **Cost of stormwater management** (total present value of stormwater management cost obtained adding costs of infrastructures construction and maintenance and runoff treatment and conveyance): Weight **60%**. Financial criteria.
- **Energy consumed by stormwater management** (total stormwater management energy consumed obtained adding energy consumed by infrastructures' construction and maintenance and runoff treatment and conveyance): Weight **15%**. Energy criteria.
- **Emissions of stormwater management** (total stormwater management CO_2 emissions obtained adding emissions of infrastructures construction and maintenance and runoff treatment and conveyance): Weight **5%**. Energy criteria.
- **Landscaping integration of infrastructures and educational opportunities**: Weight **10%**. Additional qualitative decision criterion (ecosystem services).
- **Aquifer recharge**: Weight **10%**. Additional quantitative decision criteria (ecosystem services).

Minimum and maximum values considered in each criterion are:

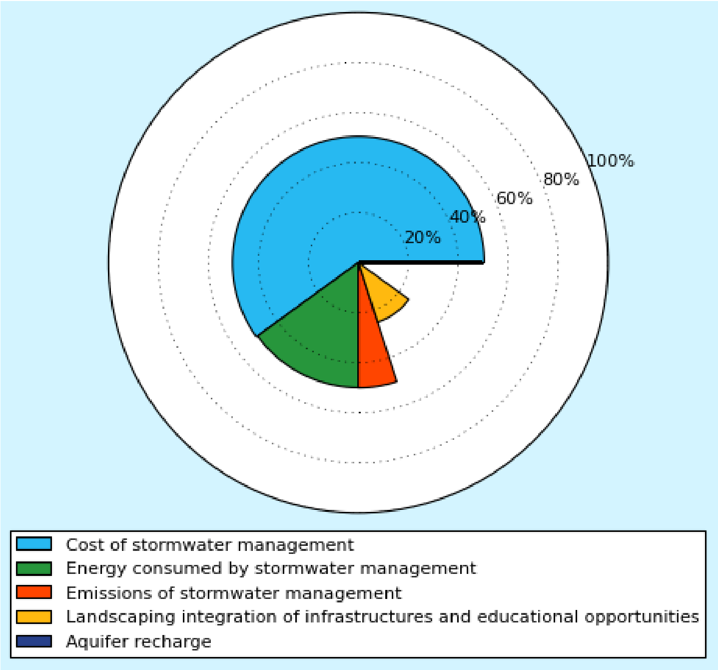
- Cost of stormwater management. Worst: 160 000 € (just above the double of max of both scenarios); Best: 0 €.

- Energy consumed by stormwater management. Worst: 103 000 kWh (double of max of both scenarios); Best: 0 kWh.
- Emissions of stormwater management. Worst: 118 830 kgCO_2e (double of max of both scenarios); Best: 0 kgCO_2e.
- Landscaping integration of infrastructures and educational opportunities. Additional qualitative decision criterion: Low for Scenario 1 and Very high for Scenario 2.
- Aquifer recharge. Additional quantitative decision criterion. Worst: 0 m^3/year; Best 1 175 m^3/year (max runoff generated in that area for the year of comparison, 2013). Values (m^3/year): 0 for Scenario 1 and 897 for Scenario 2.

2.5.3. Multi-criteria analysis results

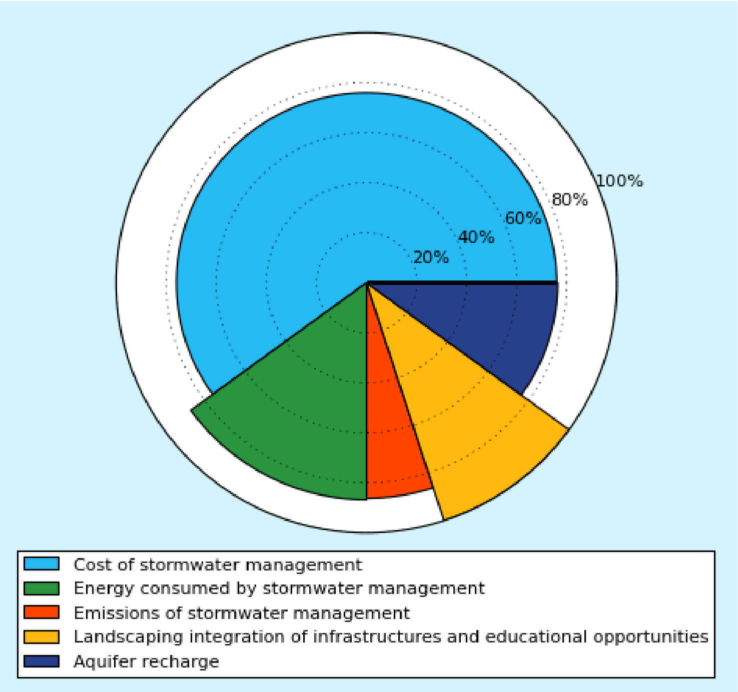
- Circular results per scenario (graphs and table).

- Scenario 1_Conventional:



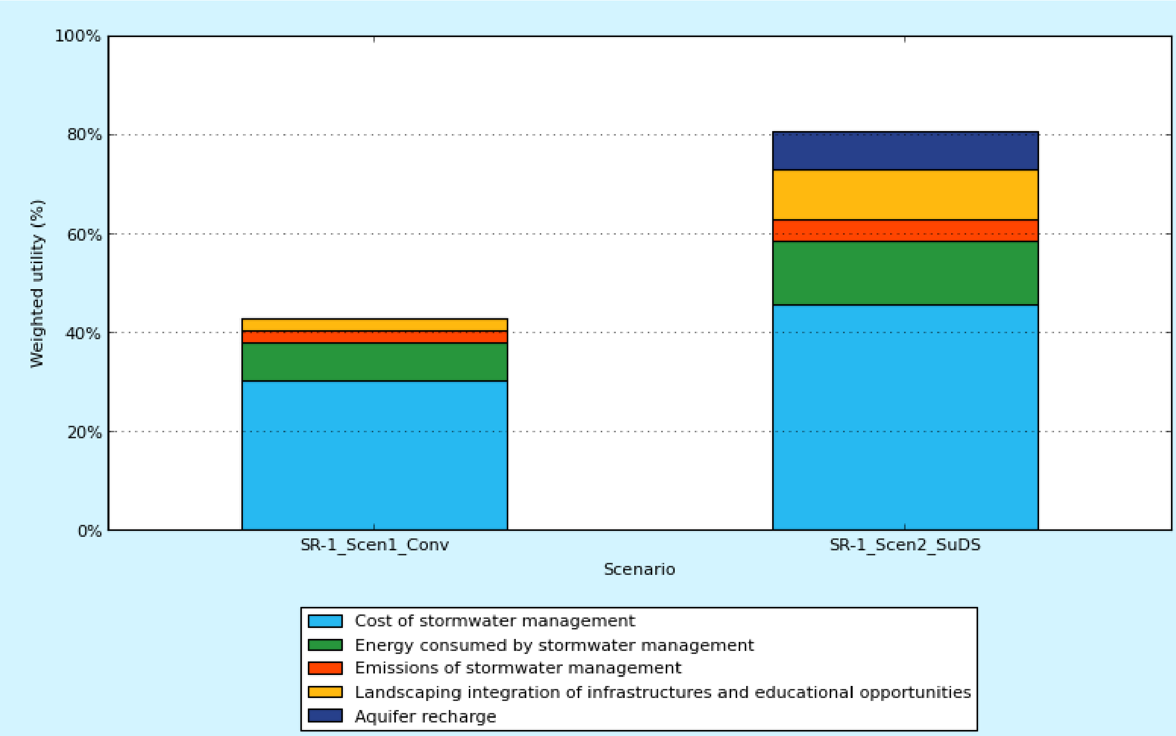
Criterion	Weight (%)	Utility (%)
Cost of stormwater management	60	50.44
Energy consumed by stormwater management	15	49.90
Emissions of stormwater management	5	50.00
Landscaping integration of infrastructures and educational opportunities	10	25.00
Aquifer recharge	10	0.00

- Scenario 2_SuDS:



Criterion	Weight (%)	Utility (%)
Cost of stormwater management	60	75.93
Energy consumed by stormwater management	15	86.76
Emissions of stormwater management	5	86.16
Landscaping integration of infrastructures and educational opportunities	10	100.00
Aquifer recharge	10	76.34

- Global results (graph and table).



Criterion	Weighted utility (%)	
	Scen1	Scen2
Cost of stormwater management	30.26	45.56
Energy consumed by stormwater management	7.49	13.01
Emissions of stormwater management	2.50	4.31
Landscaping integration of infrastructures and educational opportunities	2.50	10.00
Aquifer recharge	0.00	7.63
Total	**42.75**	**80.51**

- Explanation and justification of results.

Relative results of the utility are highly dependent on best and worse values chosen in each criterion. For this reason, when worse value was not clear, a value double of the worse value of the two scenarios has been chosen.

In any case, independently of the worst and best values chosen, the second scenario's utility is higher than the utility of the first scenario, since it scores better in all the criteria.

2.6. CONCLUSIONS

In the presented scenarios the infrastructures needed to reduce Combined Sewer Overflows in a small urban area in Benaguasil are defined following two different approaches: Conventional and SuDS. Specifically, a small underground detention facility is being compared with a detention-infiltration facility integrated in an existing park. The actions implemented are not going to solve the complete problem of CSO and flooding in this urban area but they will help reducing the peaks of the runoff produced. In order to achieve a fair comparison, these two options have been defined with a very similar detention volume and similar performance in the runoff peaks reduction. The main difference is that with the conventional option retained runoff volume goes back into the system (an into the WWTP) whereas within the SuDS option it is infiltrated.

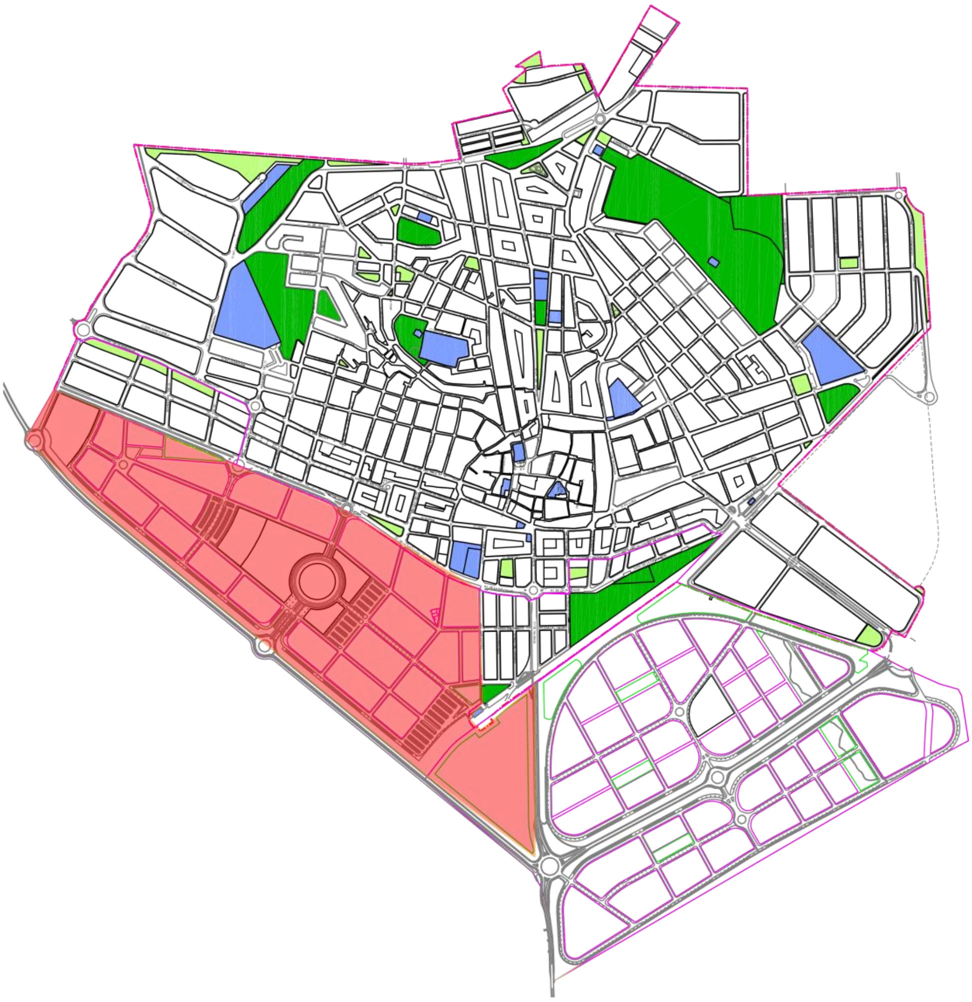
The conclusions obtained with the multi-criteria analysis show that the second option (SuDS) should be selected since it has betters scores in all the criteria selected for the comparison. This result highlights that small retrofitting SuDS action can be very useful within the urban area to improve stormwater management. Therefore, SuDS can be combined with the existing drainage infrastructure for a better and more energy-efficient stormwater management. Many small actions like this one in the urban area will reduce stormwater problems noticeably and at a lower cost than only conventional approaches. In addition, the SuDS solution produces additional benefits:

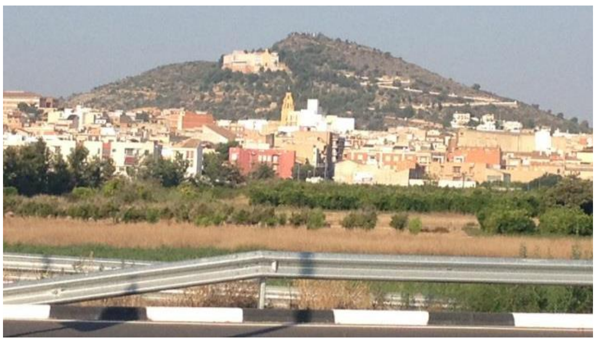
- Lower energy consumptions in stormwater management, especially in the construction and water treatment.
- Lower CO_2 emissions.
- Better integration of stormwater infrastructure in the urban landscape. Combining stormwater management with educational and recreational uses maximizes the benefits of drainage infrastructures.
- Higher aquifer recharge.

3. Pilot case 2: New development area

3.1. General description

Pilot case 2 is part of the urban development of the so called SR-10, which is included in the Urban Plan of the municipality. This area of 387 741 m² is currently used for agricultural purposes (see figures and pictures below).





This urban development will include households (expected population: 1 840 inhabitants) and public buildings with small green areas, with a separated system for stormwater management. The main objective of the drainage systems will be preserving drainage patterns (quantity and quality) to protect receiving water bodies. Therefore, this new development should not increment runoff peaks and pollutants load downstream.

In the absence of a formal water course in the surrounding area, irrigation channels (ultimately linked to the Turia river) are the preferred option to discharge runoff from new development areas (which will have to use a drainage system completely independent from the foul system). As explained above, the existing combined network frequently overflows to the main irrigation channel, called "Acequia Mayor"; hence, runoff should be directed to other irrigation channels. Other options studied few years ago comprised the construction of a big and long sewer to connect the new development areas directly to the Turia river, but they were discarded due to the high economic cost and other implications.

The small irrigation channel known as "Roll d'Alginet" has been identified as a suitable discharge point for runoff from the part of the SR-10 new development considered herein, and it is the one used for this pilot case. There are other two additional irrigation channels that could be also considered in a more detailed design phase: "Roll del Mentirós" and "Roll del Fondo". However, their capacity is limited. Available data estimates "Roll d'Alginet" full capacity to be 1.3 m^3/s, and to be in the safe side, a maximum flow of 650 l/s has been considered for the new development runoff directed to it. This is the main "anchor point" to compare both scenarios: two drainage solutions that have a proper performance for the design storm (without surface floods) and a maximum outflow of 650 l/s.

Expected energy benefits with SuDS option are:

- As explained in the following sections, the proposed detention facility in the conventional option needs a pump to introduce water in the irrigation channel, but the detention-infiltration basin does not need the pump, so less energy would be needed.

- Bioretention areas, permeable parking lots, vegetated swales and rain gardens distributed around the site, together with the end-op-pipe infiltration basin will improve runoff water quality, what produces better water quality in the Turia River; therefore less treatment to improve river water quality would be needed.

- On-site rainwater harvesting systems located under the porous car parks will harvest stormwater for irrigation and other uses, so less drinking water would be consumed and less energy for water acquisition and transport would be consumed.

Main objectives considered in the case studies should be:

- Protection of receiving water bodies.
- Reducing energy consumption and CO_2 emissions in the urban water management cycle.
- Landscaping integration of infrastructures and educational opportunities.
- Aquifers recharge.
- Optimization of drinking water use.

In the decision making process, the following important issues need to be considered:

- Construction and maintenance cost of drainage infrastructures.
- Volume of stormwater reused.
- CO_2 emissions in the urban water management cycle.
- Runoff: water quality.
- Runoff: peak flow.
- Aquifers recharge
- Landscaping integration of infrastructures and educational opportunities.

3.2. GENERAL MODEL DATA

General model data used is as follows:

Country: Spain

Currency: Euros

Electricity price: 0.4278 €/kWh (obtained from an invoice received by the Municipality dated 27th June 2014).

Electricity emissions: 0.238 kgCO_2/kWh (obtained from Table 1.1 (IEA, 2012) of the "Report on energy in the water cycle"; Value for Spain in 2010). Default value for Spain.

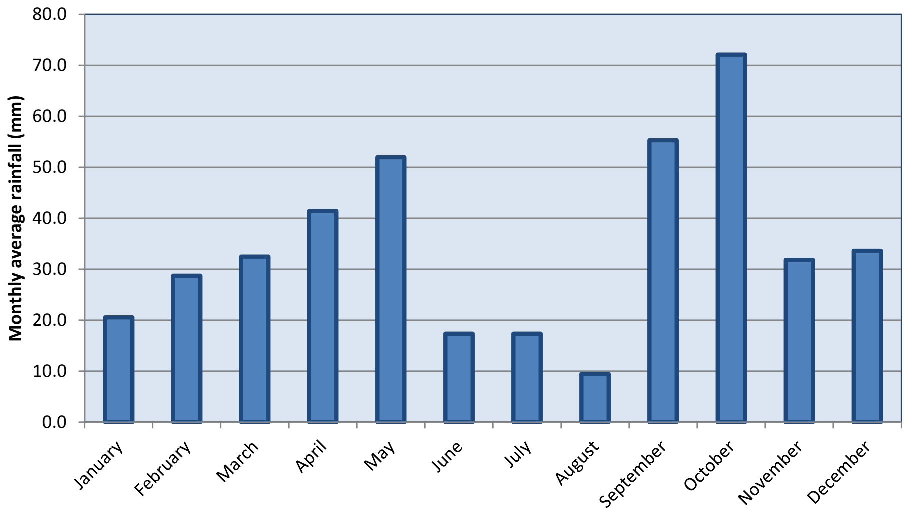
Period of analysis: It has been decided to use 50 years so it covers the life span expected for the infrastructures used.

Economic discount rate: Default value has been used (3%).

Define rainfall distribution:

Mean annual rainfall (period 1993-2010, from City Council rain gauge) = 432 mm/year

Mean Monthly Rainfall	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	30	29	24	42	49	21	11	24	57	72	32	41



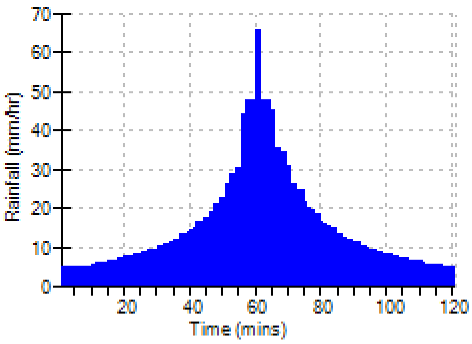
In addition, the following information has been obtained from a detail study of the Benaguasil City Council rain gauge (period 1993-2010):

- Average of 40 rainy days per year
- In the 80% of the rainy days, rainfall is lesser tan 16 mm. Hence, 80% rainfall volume is V_{80} = 16 mm.
- In the 90% of the rainy days, rainfall is lesser tan 26 mm. Hence, 90% rainfall volume is V_{80} = 26 mm.
- In the 99% of the rainy days, rainfall is lesser tan 71 mm.

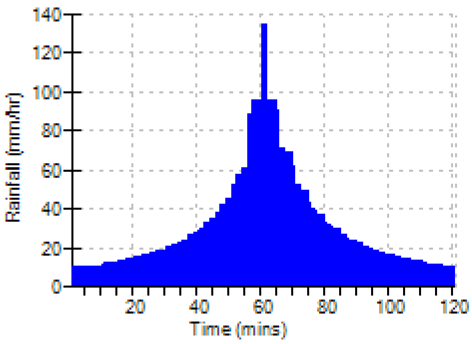
From that data, some design storms have been built, with the following main characteristics:

Name	Return period T (year)	Duration (h)	Peak intensity (mm/h)	Average intensity (mm/h)	Rainfall volume (mm)
DesignT2-2hr	2	2	66	16	32
DesignT2-24hr	2	24	36	2	48
DesignT15-2hr	15	2	135	32	64
DesignT15+CC-2hr	15 + 10%CC	2	149	35	70
DesignT100-6hr	100	6	169	23	138
DesignT100+CC-6hr	100 + 17%CC	6	198	27	162

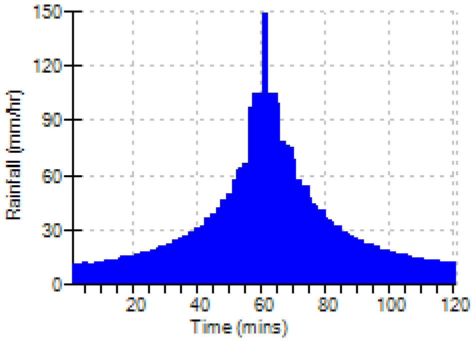
The storm used for the design and testing of the drainage scenarios is the storm with a return period of 15 years, 2 hours of duration and considering the effect of climate change (increment of 10% in return period). This storm has a peak intensity of 149 mm/h.



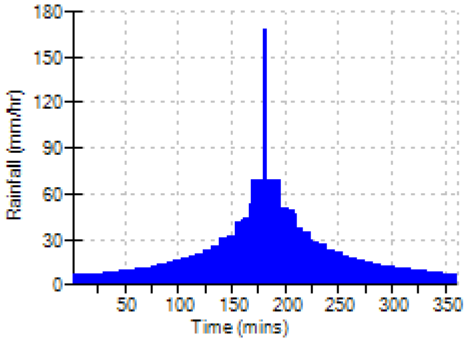
Design rainfall for T = 2 years



Design rainfall for T = 15 years



Design rainfall for T = 15 years + 10%CC



Design rainfall for T = 100 years

In addition, continuous analysis with rainfall data for the year 2013 (data obtained every 10 minutes at the new Benaguasil rain gauge) will be used in the stormwater runoff section. Year 2013 was a dry one, with a yearly total precipitation of only 238 mm. However, this is the only data available at the moment, as for previous years only daily data was taken in Benaguasil.

Define temperature distribution: There is not a good record of local temperatures and the ones freely available at the Spanish Meteorological office (AEMET) corresponding to Valencia Airport have been used. For the final DST application, temperatures registered at the Social Centre roof (E^2STORMED) could be used to compare how they influence the results.

Mean monthly temperature (period 1971-2000, from AEMET-Valencia Airport:

Mean Monthly Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	10.2	11.5	13.1	15.0	18.2	22.0	24.9	25.4	22.8	18.4	13.9	11.2

Average day temperatures winter/summer (to be changed when Social Centre roof temperature monitoring data is available):

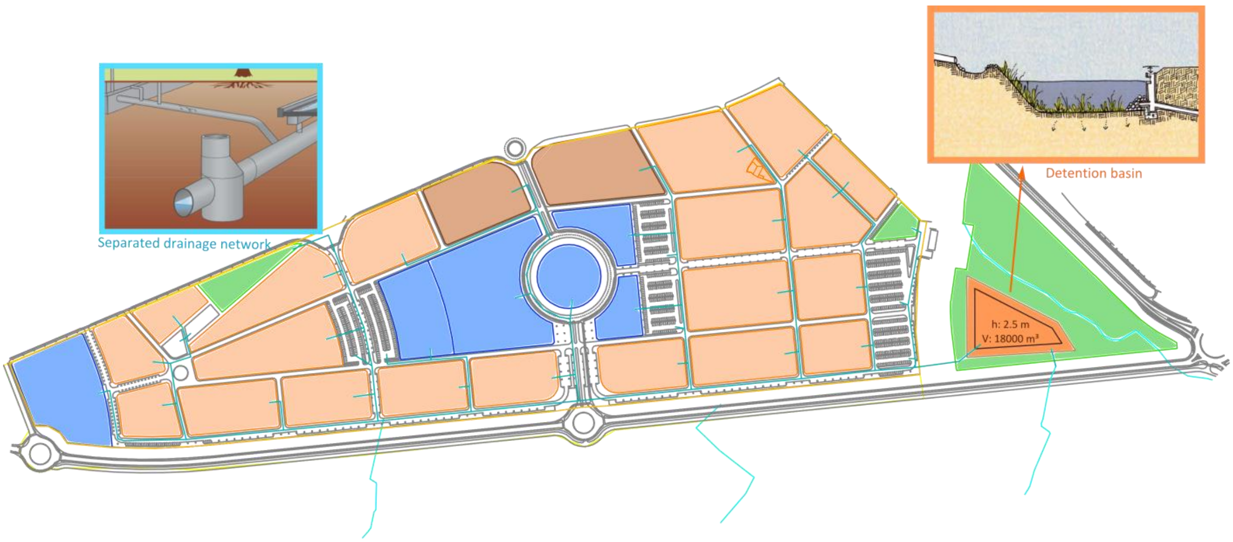
Hour	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-0
Winter temperature (ºC)	8	6	5	5	8	10	12	12	11	10	10	9
Summer temperature (ºC)	20	20	18	20	25	30	34	33	31	28	25	22

Flood protection benefits have not been analysed. For the new development case study, flood protection is a design requirement in both scenarios, since they do not produce surface floods for the design storm.

3.3. Scenario 1: Conventional development

3.3.1. General description

In this case, buildings would use conventional roofing and parking areas will be impermeable. A conventional drainage network is proposed with pipes, curbs and gutters. This separated network would collect stormwater from this urban area and direct it to a detention basin at the end. This facility is necessary to storage stormwater for a short period of time so runoff peaks can be reduced to avoid collapsing the irrigation channel during severe rainfall events. Due to the fact that the base of the irrigation channel is much deeper than the base of the detention basin, a pumping station is required to empty it following each storm. Maximum pumping rate would be 650 l/s to accommodate the receiving irrigation channel capacity, as explained before. This rate has guided the design of the detention basin and the pumping station. The pipe system has been designed to cope with the 15 year return period storm + 10% increase to account for climate change. It is expected that pipe diameters can be reduced with the use of at source SuDS, but this has not been taken into account at this stage (outline/preliminary design).



3.3.2. Drainage infrastructures included in the scenario

The following infrastructures have been considered in this scenario:

- Conventional roof: This infrastructure is included to be compared with the green roof of Scenario 2. In total, an area of 2 880 m² is considered (10% of area of this plot), located in a plot that will be used for educational infrastructure (i.e. a school).
- Standard pavements: These infrastructures are included to be compared with the permeable pavements of Scenario 2. In total, an area of 20 260 m² of public parking lots is considered.
- Pipe network: Separated conventional network that collects stormwater from this urban area. Total length is about 1 230 m. This length only represents the part of the pipe that in the SuDS scenario is replaced by a vegetated swale.

- Detention basin: This detention basin is at the end of the drainage infrastructure and it has been designed to store the design storm (T=15 years and duration 2 hrs, accounting for climate change) with a maximum outflow of 650 l/s (maximum capacity of outflow channel). It is 2.5 m depth and it has a volume of 18 000 m³.

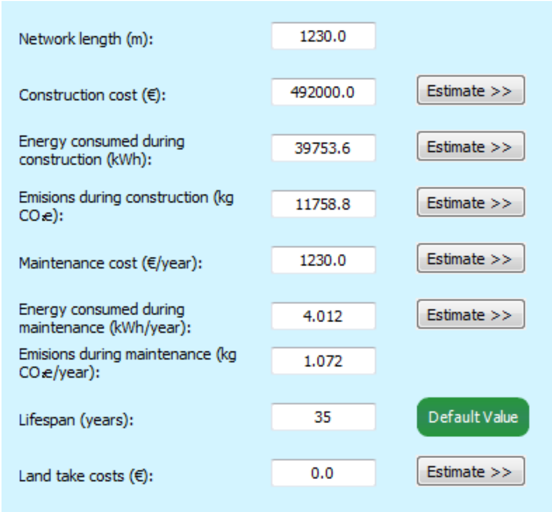
- Pumping station: It pumps water to the outflow drainage channel. Maximum pumping rate: 650 l/s. It has been introduced using the "Other drainage infrastructure" option.

- Gardens and parks: Used to introduce construction and maintenance costs of planned gardens and parks, in order to make a fair comparison with planned rain gardens and bioretention areas. Total area: 33 614 m².

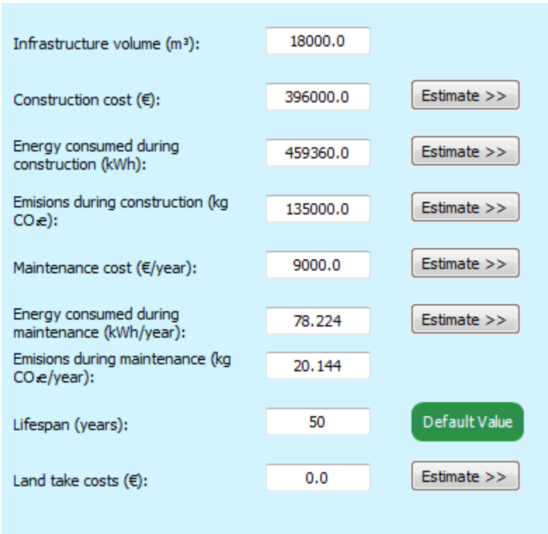
For the **conventional roof**, defaults values have been used. Summary of values included in the DST are presented in the following figure:

For the **standard pavement**, defaults values have been used. Summary of values included in the DST are presented in the following figure:

For the **pipe network**, a unitary cost of 400 €/m has been considered. In the rest of costs, energy consumptions and emissions, defaults values have been used. Summary of values included in the DST are presented in the following figure:



For the **detention basin**, defaults values have been used. Summary of values included in the DST are presented in the following figure:



For the **pumping station**, the other drainage infrastructure's tab has been used. Construction cost has been estimated from an existing project for the area, which estimated a cost of a pumping station for a maximum flow of 1.13 m^3/s to be 140 000 €. Bearing in mind that maximum flow to be pumped in this case (restricted by the irrigation channel capacity) is 650 l/s, the construction cost is estimated to be 100 000 €. A cost of 1 000 €/year has been estimated for maintenance. Values for energy consumption and CO_2 emissions has been calculated using default values of a 240 m^3 structural detention facility. Summary of values included in the DST are presented in the following figure:

Construction cost (€):	100000.0
Energy consumed during construction (kWh):	203829.6
Emisions during construction (kg CO_2e):	64564.8
Maintenance cost (€/year):	1000.0
Energy consumed during maintenance (kWh/year):	57.6
Emisions during maintenance (kg CO_2e/year):	14.4
Lifespan (years):	20
Land take costs (€):	0.0

Finally, for the **gardens and parks**, defaults values have been used for rain gardens, since they have a similar construction and maintenance. Summary of values included in the DST are presented in the following figure:

Infrastructure area (m²):	33614.0
Construction cost (€):	1680700.0
Energy consumed during construction (kWh):	3966115.86
Emisions during construction (kg CO_2e):	1209431.72
Maintenance cost (€/year):	84035.0
Energy consumed during maintenance (kWh/year):	3365.8458
Emisions during maintenance (kg CO_2e/year):	886.828
Lifespan (years):	30
Land take costs (€):	0.0

3.3.3. Water reuse

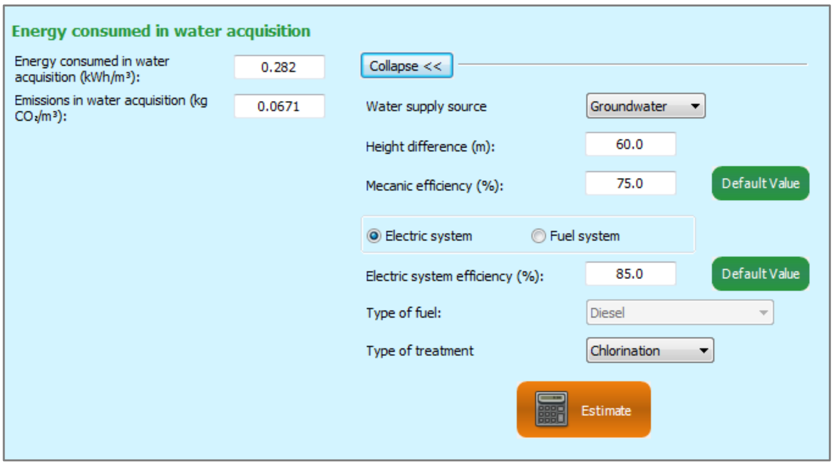
Values for water supply cost have been obtained from the municipality. Values depend on the consumption, as follows:

- Less than 10 m^3: Cost = 0.236 €/m^3.
- Between 10-15 m^3: Cost = 0.333 €/m^3.
- More than 15 m^3: Cost = 0.474 €/m^3.

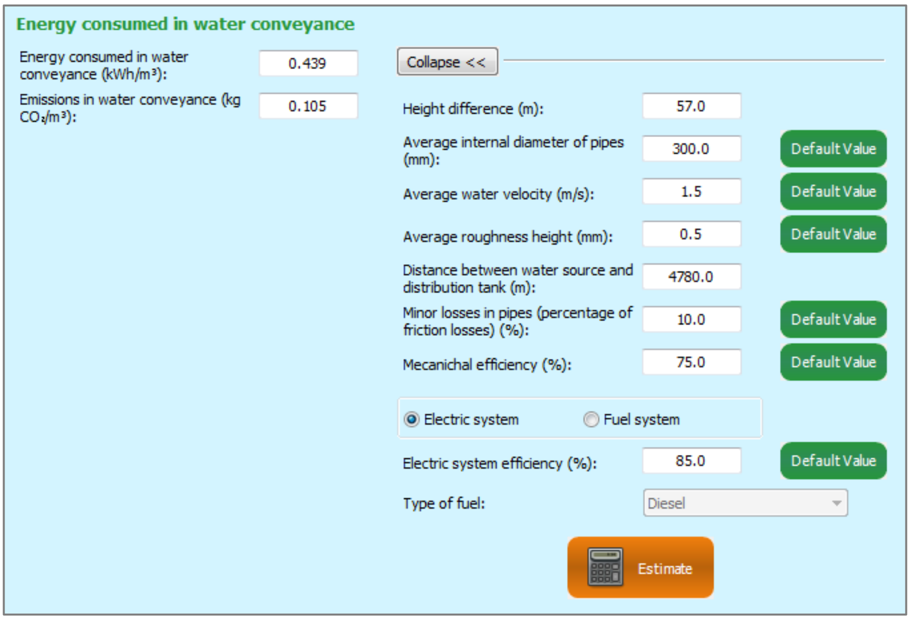
A value of 0.474 €/m^3 has been used for Pilot Case 2.

Water losses in network obtained from the municipality (difference between recorded extracted and supplied volumes), with a value of 37%.

Energy consumed in water acquisition estimated using DST tool, with data as follows (default values used for mechanic efficiency and electric system efficiency):



Energy consumed in water conveyance estimated using DST tool, with data as follows:



As it can be observed, default values have been used for average water velocity, minor losses in pipes and mechanical efficiency. For the average roughness height, a value within the bracket presented in table 2.9 of the guidelines for concrete pipes has been used (0.5 mm).

Being a gravity system, there is no energy consumption in water distribution.

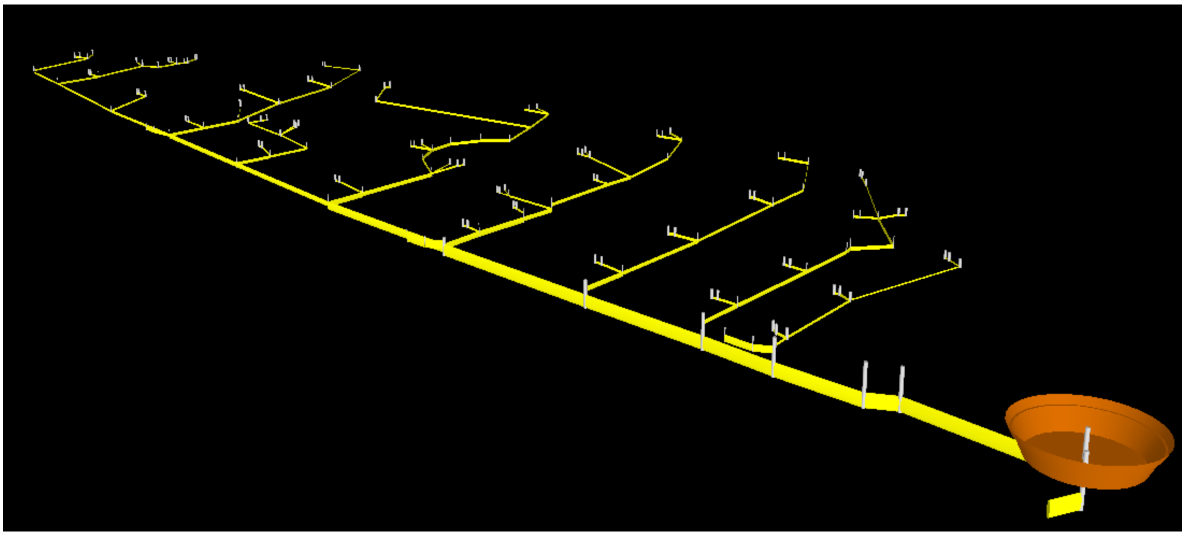
Water consumption for irrigation has not been calculated. As it is needed for comparison for Scenario 2, the volume of water consumed assumed in this Scenario is the volume that has been calculated that the "retention" permeable car parks can store for water reuse in the year 2013, which is 1 474 m^3. This volume has been corrected to represent the average year (432 mm), since the year 2013 was quite dry (238 mm). Therefore, this stored volume for the average year has been estimated proportionally, obtaining a value of 2 675 m^3.

Results are as follows:

Results for water supply	
Total cost (€/year):	1268
Total energy consumed (kWh/year):	3061.4
Total emissions (kg CO_2e/year):	730.74

3.3.4. Stormwater runoff

Proprietary software from XPSolutions, called MicroDrainage (v2014.1.1), has been used for the hydraulic model to analyse runoff. Modelling is undertaken with the Wallingford Procedure, simulating using time/area full hydrograph methodology including energy and momentum equations for dynamic analysis. More information can be obtained from their website (http://xpsolutions.com/Software/MICRO-DRAINAGE/). The 3D view of the simulated model can be observed in the following figure:

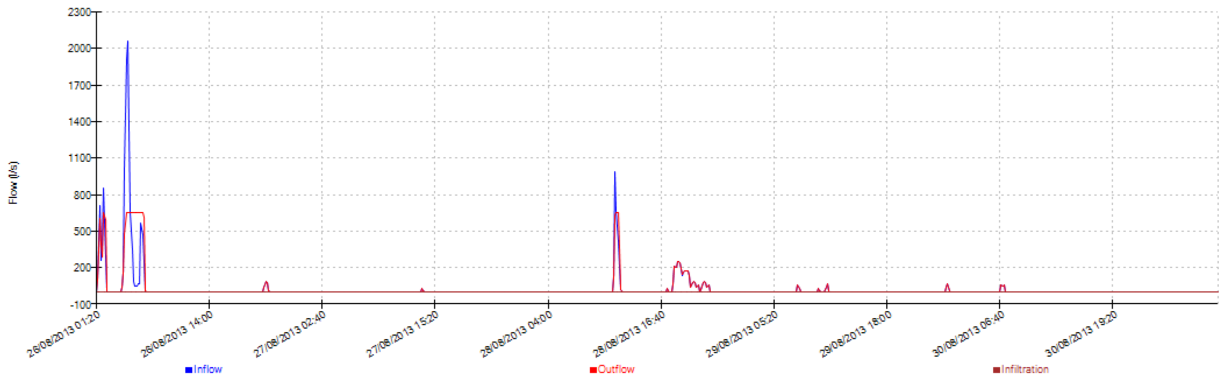


Rainfall data from year 2013 has been used for the volume calculations, and peak outflow estimated using “DesignT15+CC-2hr” design storm. The outflow discharged volume obtained in 2013 (54 041 m³) has been corrected to represent the average year (432 mm), since the year 2013 was quite dry (238 mm). Therefore, this discharged volume for the average year has been estimated proportionally, obtaining a value of 98 091 m³. In this case, there is not aquifer recharge in the drainage system.

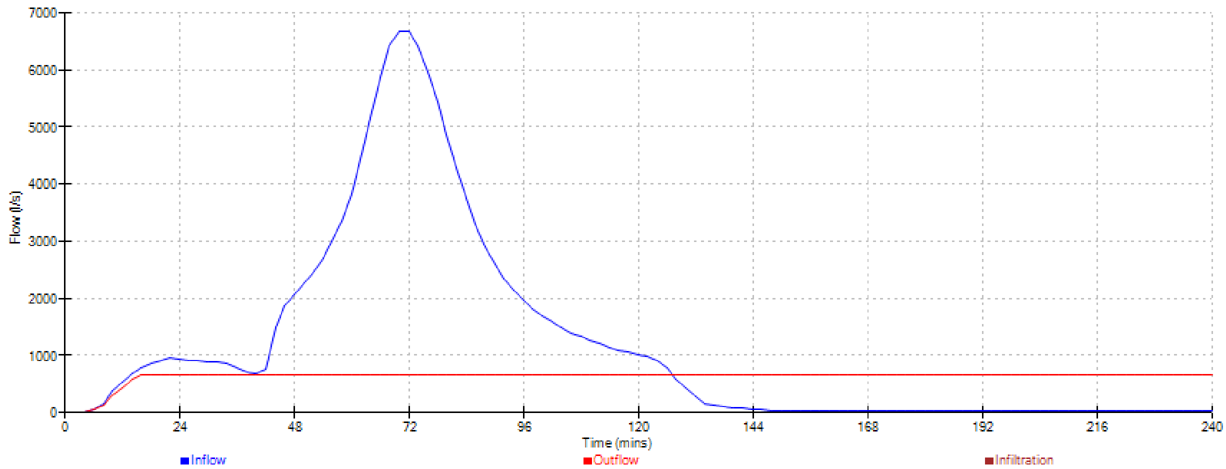
Results obtained are introduced in the DST as follows:

Runoff volume (m³/year):	98091
Aquifer recharge and evapotranspiration (m³/year):	0
Peak outflow rate for design storm (m³/s):	0.65

Graphs below show inflows and outflows in the detention basin for the most critical storm in 2013 (26th August 2013) and for the design storm.



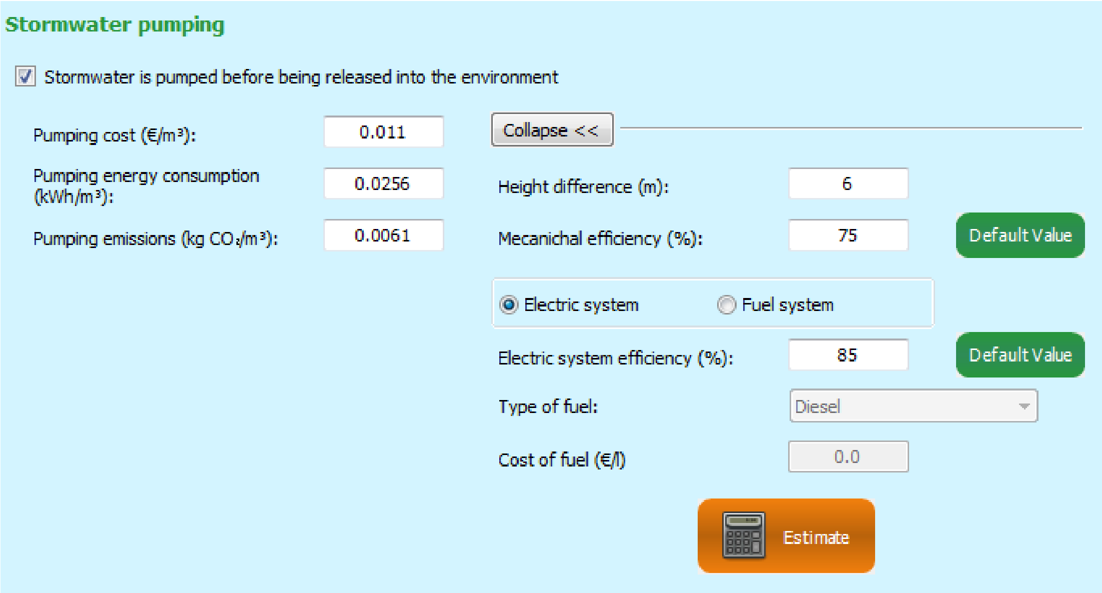
Inflow (blue) and outflow (red) for 26th August 2013 storm in Scenario 1: Conventional



Inflow (blue) and outflow (red) for DesignT15+CC-2hr storm in Scenario 1: Conventional

3.3.5. Conveyance and treatment

Stormwater is pumped before being released into the environment. Using the Estimate tool, we have obtained the following data:

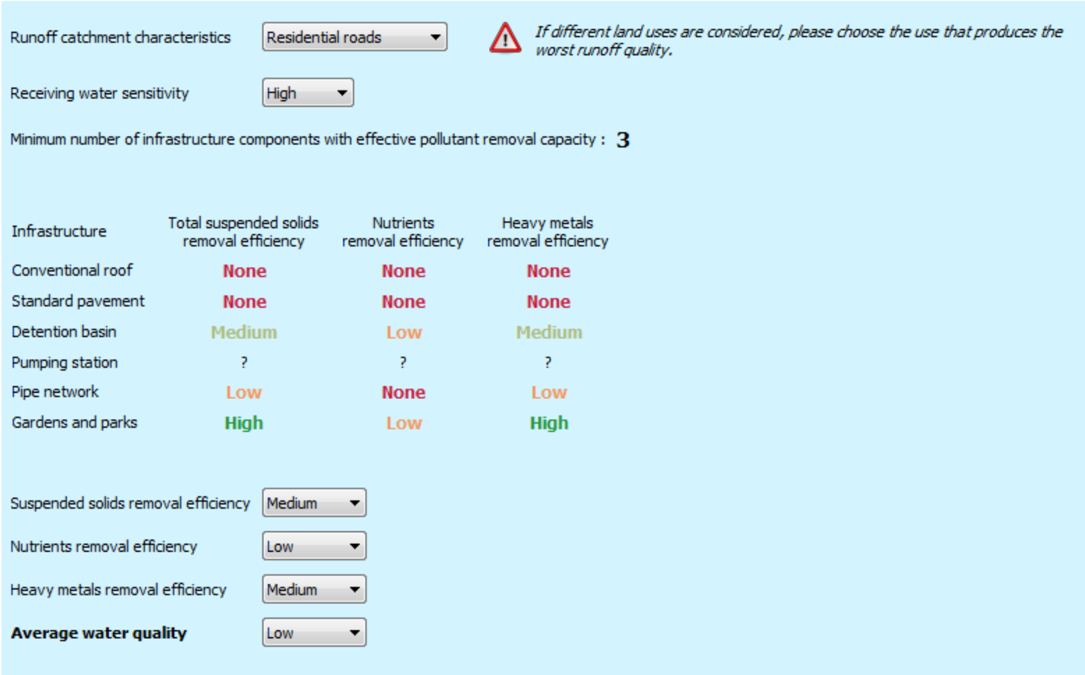


Assuming that stormwater is not further treated before being release into the environment, results are as follows:

Results for stormwater treatment and conveyance	
Volume of stormwater conveyed (m^3/year):	**98091**
Volume of stormwater treated (m^3/year):	**0**
Total cost (€/year):	**1079**
Total energy consumed (kWh/year):	**2511.1**
Total emissions (kg CO_2e/year):	**598.36**

3.3.6. Water quality

Level of treatment needed for residential roads and parking areas have been considered, being 3 in both cases. The detention basin is the infrastructure that has to be considered for providing water quality improvement. An average value of "Low" has been assigned, as receiving waters are considered highly sensible and only one level of treatment is in place. Results are as follows:



3.3.7. Flood protection

Not applicable.

An evaluation of flood protection is not going to be used as a criterion in the decision-making process for this Pilot Case 2, as in both cases is very similar.

3.3.8. Building insulation

Not applicable in Scenario 1.

3.3.9. Ecosystem services

Detention basins can potentially provide the following ecosystem services: aesthetics, amenity and habitat provision and enrich biodiversity. However, in this case it has been conceived as a deep, fenced basin, not suitable for recreation. Hence, global ecosystem services have been evaluated as low.

3.3.10. Summary

Results table:

Results	Financial cost	Energy consumption	Emissions
Construction of infrastructures	3.8545e+06 €	8.3599e+06 kWh	2.5839e+06 kg CO_2e
Maintenance of infrastructures	1.0553e+05 €/year	3521.8 kWh/year	926.61 kg CO_2e/year
Infrastructure landtake	0 €	-	-
Potable water consumed and saved	1268 €/year	3061.4 kWh/year	730.74 kg CO_2e/year
Stormwater conveyance and treatment	1079 €/year	2511.1 kWh/year	598.36 kg CO_2e/year
Flood protection	0 €/year	-	-
Building insulation	0 €/year	0 kWh/year	0 kg CO_2e/year
Carbon dioxide reduction	-	-	0 kg CO_2e/year
Other costs and benefits	0 €/year	0 kWh/year	0 kg CO_2e/year

Negative values indicate financial savings, energy savings and emissions avoided.

Other costs and benefits: Not considered

Energy consumed in the urban water cycle table:

Energy consumed in the urban water cycle	Energy conssumption (kWh/m³)	Emissions (kg CO_2e/m³)
Water supply acquisition	0.282	0.0671
Water supply conveyance	0.439	0.105
Water supply distribution	0	0
Stormwater conveyance	0.0256	0.0061
Stormwater treatment	0.5	0.119

3.4. Scenario 2: Development with SuDS

3.4.1. General description

The main objective of this solution is to preserve the original drainage patterns in quantity and quality. The proposed solution is a combination of:

- Green roofs: Their main purpose is building isolation and education. They are proposed to cover 20% of the one public parcel dedicated to educational infrastructure. Total area of green roof: 2 880 m².

- Rain gardens: Their main purpose is to reduce runoff volume, while lowering runoff peak and providing water treatment. They occupy 10% of allow density residential parcels and public built up areas (“equipamiento”). In total, 30 640 m².

- Permeable pavement in public parking lots: Being 100% constructed with permeable pavement, which main purpose is to reduce runoff volume, while lowering runoff peak and providing water treatment. Total permeable area: 20 260 m².

- Underground cisterns: 2 of the 6 large permeable parking lots will be constructed as rainwater harvesting infrastructure for the 90% of their surface area, whereas the remaining 10% will allow infiltration of local overflows. Total infrastructure volume will be 280 m³.

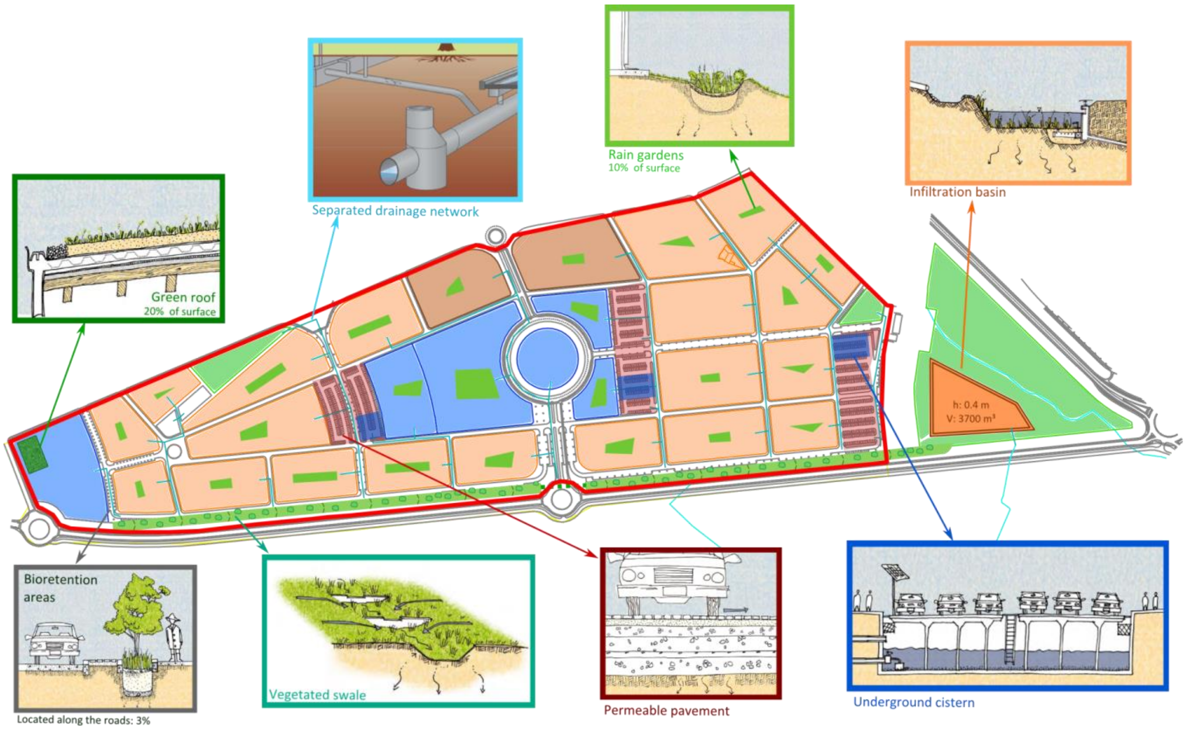
- Bioretention areas: Located along the roads, their main purpose is water treatment and they will occupy an area of 2 974 m² (3% of the road system total area).

- Separated drainage pipes: They collect stormwater from the urban area to the vegetated swale. They are not included in the DST since they are equivalent in both scenarios.

- Vegetated swale: It conveys water from the separate network to the downstream infiltration basin. Its area will be about 3 870 m².

- Infiltration basin: Large and shallow landscaped depression used to collect, hold and infiltrate stormwater runoff. It would be located in the lowest part of this urban area. During dry periods, this basin could have recreational uses. The depth planned for this basin is 0.4 m with a retention volume of 3 700 m².

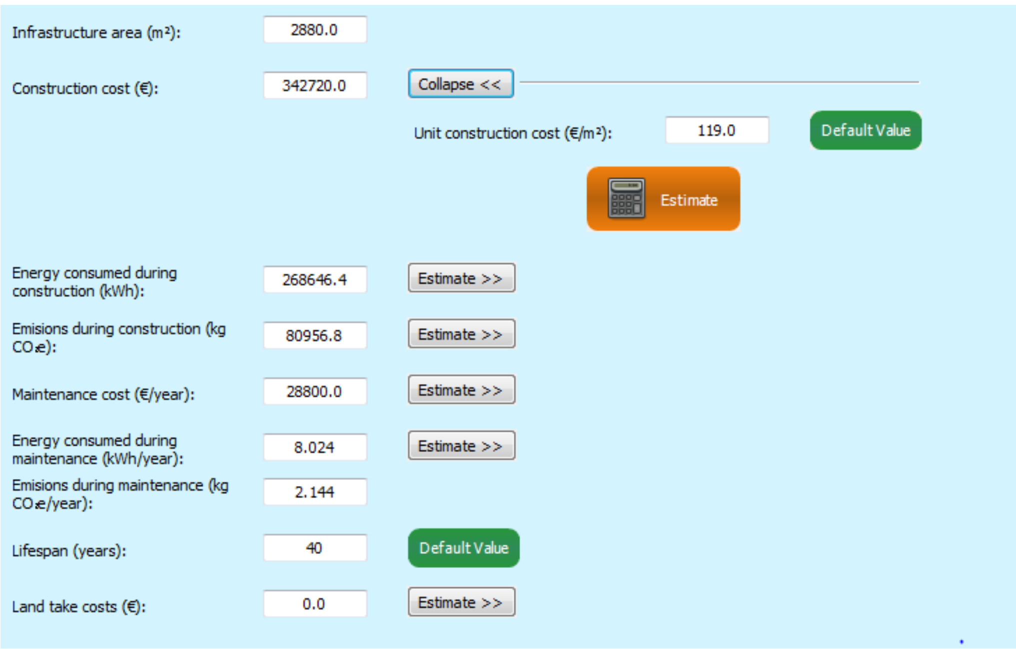
In this case, SuDS located at source will drastically reduce flows and runoff volume; hence a smaller and shallower detention facility will be needed at the end of the piped system. In addition, as they provide water treatment, runoff that reaches the end of pipe structure can be infiltrated, avoiding the need of a pumping station. For high intensity rainfall events, runoff will overflow by gravity to the irrigation channel, and the outlet structure will be designed so flows do not trespass its capacity (650 l/s maximum allowable discharge).



3.4.2. Drainage infrastructures included in the scenario

The infrastructures included in this scenario are listed in the previous section. Like in Scenario 1, maximum outflow would be 650 l/s to accommodate the receiving irrigation channel's capacity. This rate has guided the design of the final infiltration basin. The drainage system has been designed to cope with the 15 year return period storm + 10% increase to account for climate change.

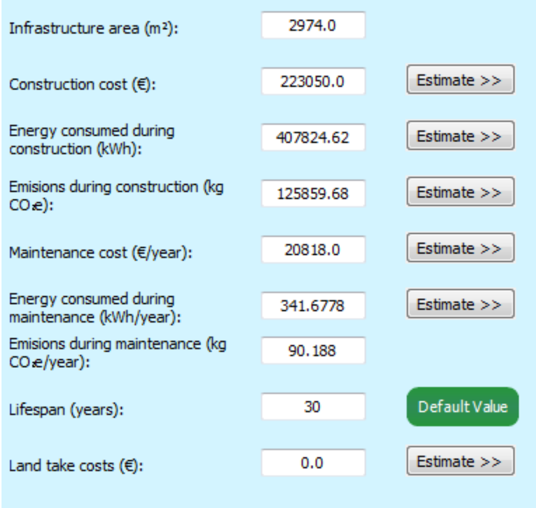
For the **green roof**, construction value has been estimated considering real construction costs for the one recently built in Benaguasil within the E[2]STORMED project. Defaults values have been used for the rest of the parameters. Summary of values included in the DST are presented in the following figure:



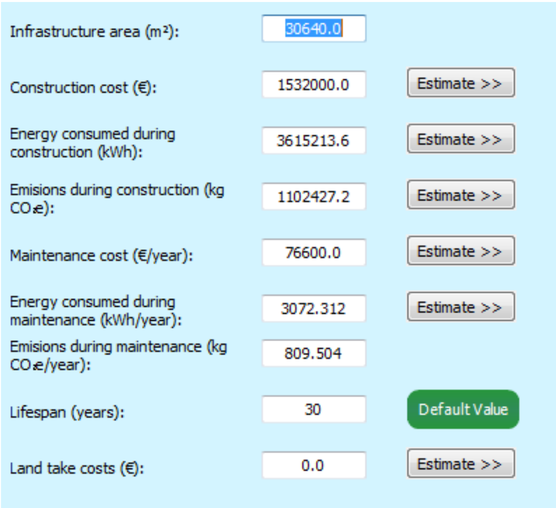
For the **permeable pavement**, defaults values have been used. Summary of values included in the DST are presented in the following figure:

For the **underground cistern**, defaults values have been used. Summary of values included in the DST are presented in the following figure:

For the **bioretention areas**, defaults values have been used. Summary of values included in the DST are presented in the following figure:



For the **rain gardens**, defaults values have been used. Summary of values included in the DST are presented in the following figure:



For the **vegetated swale**, defaults values have been used. Summary of values included in the DST are presented in the following figure:

Infrastructure area (m²):	3870.0	
Construction cost (€):	58050.0	Estimate >>
Energy consumed during construction (kWh):	165713.4	Estimate >>
Emisions during construction (kg COₑ):	51896.7	Estimate >>
Maintenance cost (€/year):	387.0	Estimate >>
Energy consumed during maintenance (kWh/year):	741.183	Estimate >>
Emisions during maintenance (kg COₑ/year):	195.288	
Lifespan (years):	30	Default Value
Land take costs (€):	0.0	Estimate >>

For the **infiltration basin**, defaults values have been used. Summary of values included in the DST are presented in the following figure:

Infrastructure volume (m³):	3691.0	
Construction cost (€):	239915.0	Estimate >>
Energy consumed during construction (kWh):	57801.06	Estimate >>
Emisions during construction (kg COₑ):	15686.75	Estimate >>
Maintenance cost (€/year):	18455.0	Estimate >>
Energy consumed during maintenance (kWh/year):	22.4189	Estimate >>
Emisions during maintenance (kg COₑ/year):	5.835	
Lifespan (years):	50	Default Value
Land take costs (€):	0.0	Estimate >>

3.4.3. Water reuse

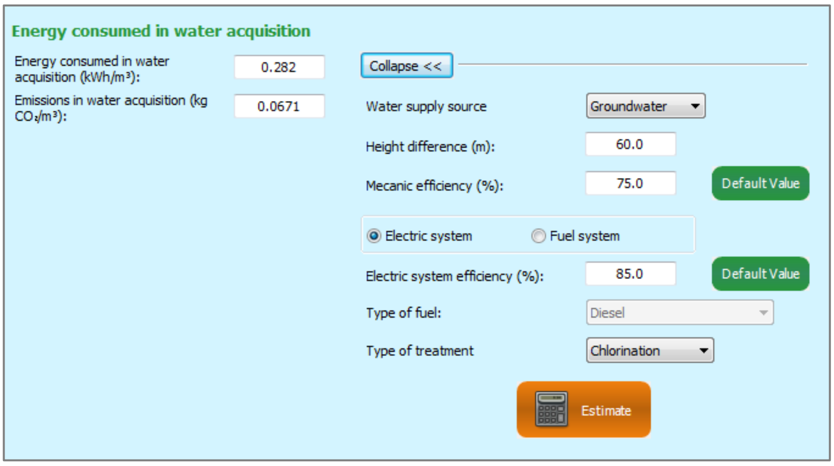
Values for water supply cost have been obtained from the municipality. Values depend on the consumption, as follows:

- Less than 10 m^3: Cost = 0.236 €/m^3.
- Between 10-15 m^3: Cost = 0.333 €/m^3.
- More than 15 m^3: Cost = 0.474 €/m^3.

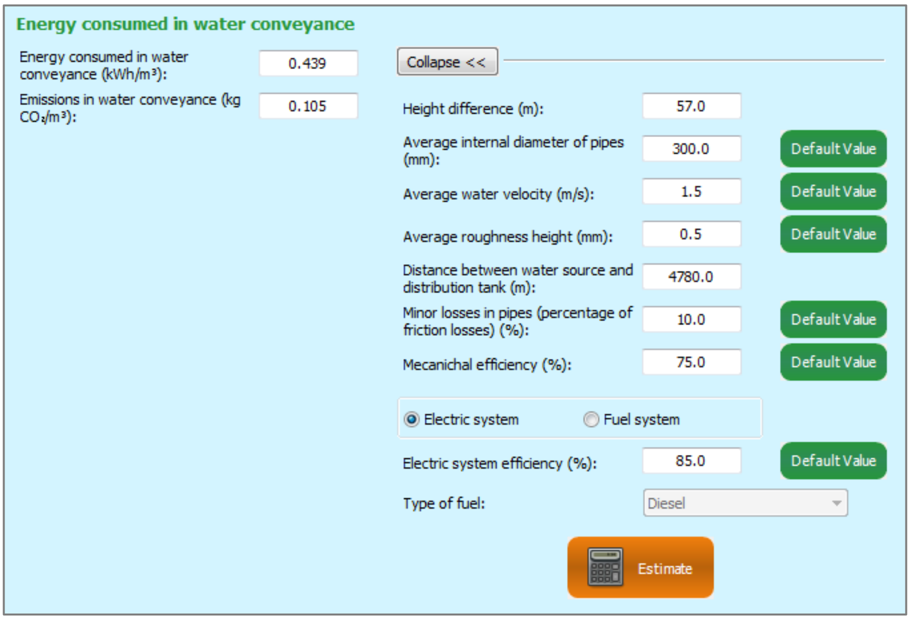
A value of 0.474 €/m^3 has been used for Pilot Case 2.

Water losses in network obtained from the municipality (difference between recorded extracted and supplied volumes), with a value of 37%.

Energy consumed in water acquisition estimated using DST tool, with data as follows (default values used for mechanic efficiency and electric system efficiency):



Energy consumed in water conveyance estimated using DST tool, with data as follows:



As it can be observed, default values have been used for average water velocity, minor losses in pipes and mechanical efficiency. For the average roughness height, a value within the bracket presented in table 2.9 of the guidelines for concrete pipes has been used (0.5 mm).

Being a gravity system, there is no energy consumption in water distribution.

Water consumption for irrigation has not been calculated. As it is needed for comparison for Scenario 1, the volume of water consumed assumed in this Scenario is the volume that has been calculated that the "retention" permeable car parks can store for water reuse in the year 2013, which is 1 474 m^3. This volume has been corrected to represent the average year (432 mm), since the year 2013 was quite dry (238 mm). Therefore, this stored volume for the average year has been estimated proportionally, obtaining a value of 2 675 m^3.

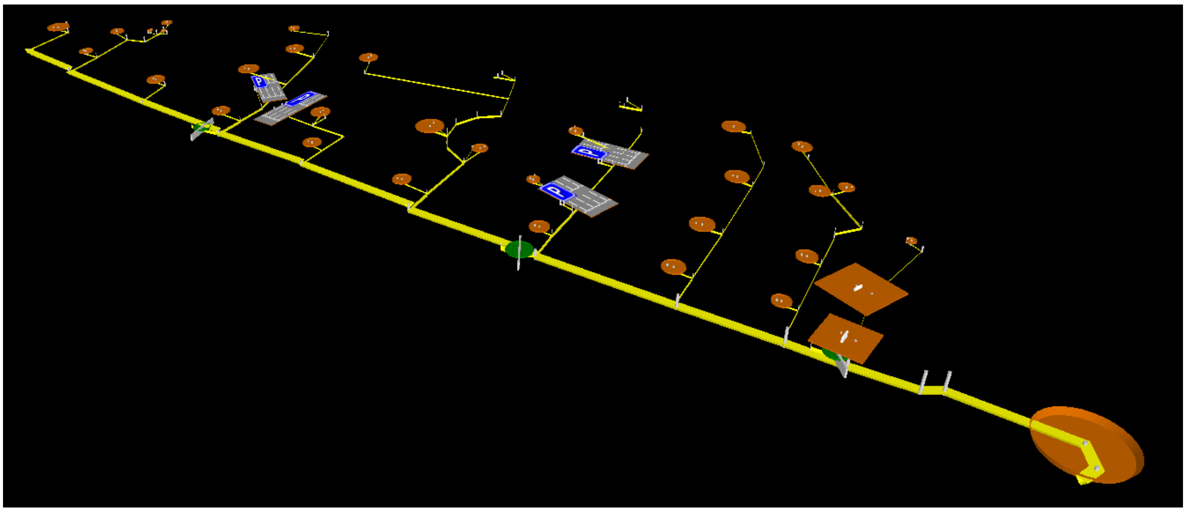
2 675 m^3 is also the volume of water included in the rainwater reuse tab, since in this scenario, this is the volume reused thanks to the underground cisterns.

Results are as follows:

Results for water supply	
Total cost (€/year):	1268
Total energy consumed (kWh/year):	3061.4
Total emissions (kg CO_2e/year):	730.74

3.4.4. Stormwater runoff

Proprietary software from XPSolutions, called MicroDrainage (v2014.1.1), has been used for the hydraulic model to analyse runoff. Modelling is undertaken with the Wallingford Procedure, simulating using time/area full hydrograph methodology including energy and momentum equations for dynamic analysis. More information can be obtained from their website (http://xpsolutions.com/Software/MICRO-DRAINAGE/). The 3D view of the simulated model can be observed in the following figure:

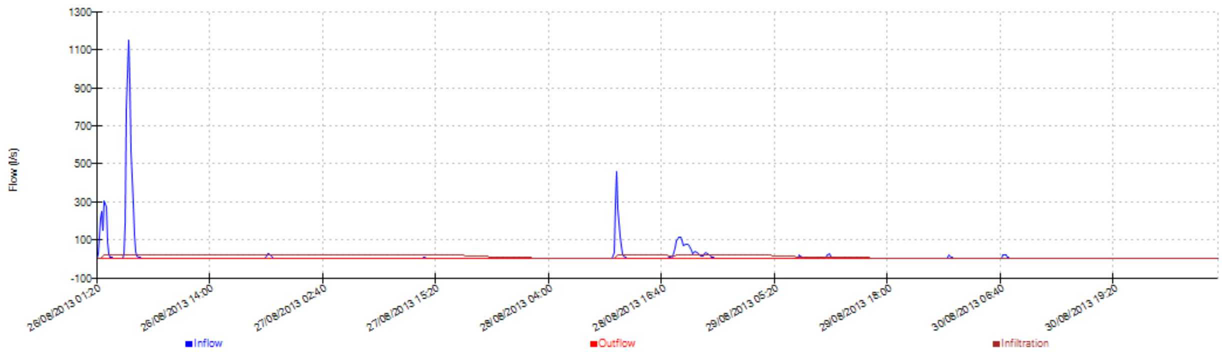


Rainfall data from year 2013 has been used for the volume calculations, and peak outflow estimated using "DesignT15+CC-2hr" design storm. The results of the simulation of the year 2013 show that there is not runoff discharged to the irrigation channel since all this water is infiltrated. The total infiltration volume during this year is equal to 56 910 m³, which is equivalent to 103 299 m³ in the average year.

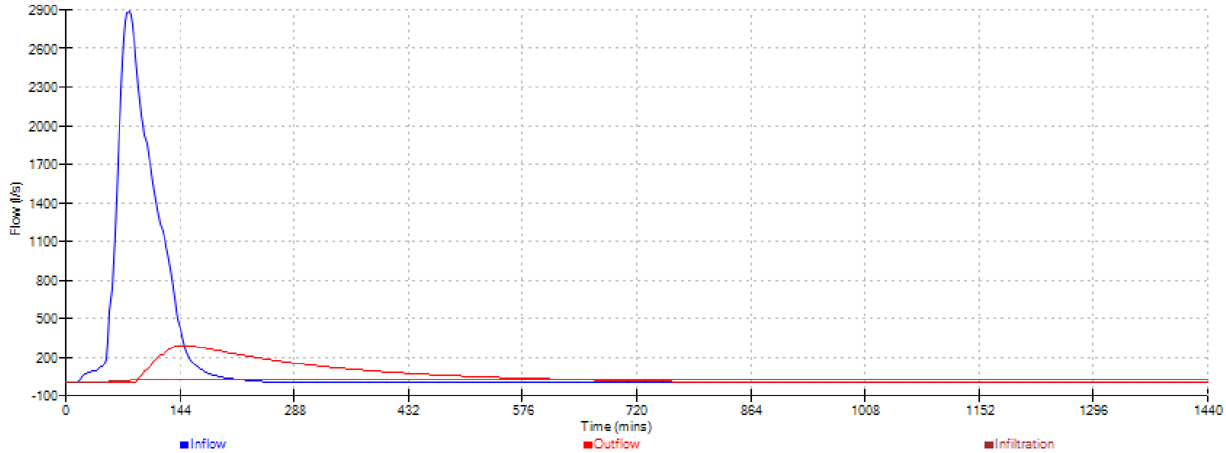
Results obtained are as follows:

Runoff volume (m³/year):	0	Estimate >>
Aquifer recharge and evapotranspiration (m³/year):	103299	
Peak outflow rate for design storm (m³/s):	0.297	*Complete if flow rate is a decision criterion.*

Graphs below show inflows and outflows in the downstream infiltration basin for the most critical storm in 2013 (26th August 2013) and for the design storm.



Inflow (blue), infiltration (brown) and overflow (red) for 26th August 2013 storm in Scenario 2: SuDS



Inflow (blue), infiltration (brown) and overflow (red) for DesignT15+CC-2hr storm in Scenario 2: SuDS

It would have been good to be able to estimate tools for comparison, but the problem is that the average yearly rainfall data is used (432), instead of the one for 2013 (235 mm), so values are not comparable.

3.4.5. Conveyance and treatment

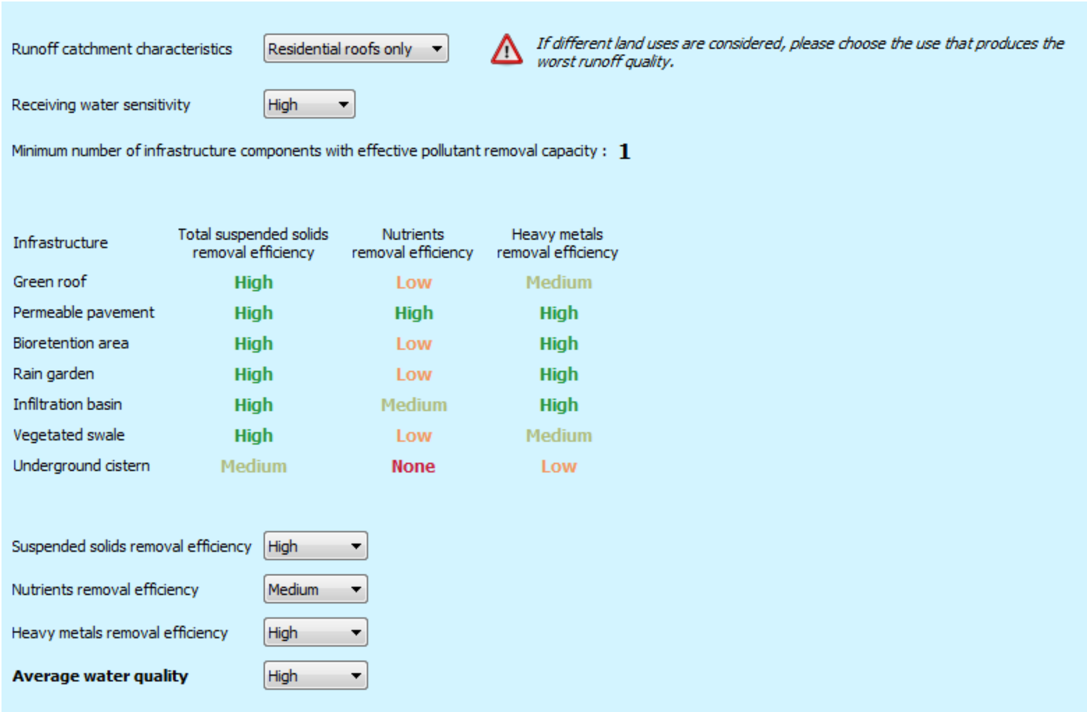
Stormwater is neither pumped nor does it receive further treatment before being released into the environment. Hence, results are as follows:

Results for stormwater treatment and conveyance	
Volume of stormwater conveyed (m³/year):	0
Volume of stormwater treated (m³/year):	0
Total cost (€/year):	0
Total energy consumed (kWh/year):	0
Total emissions (kg CO₂/year):	0

Estimate

3.4.6. Water quality

Level of treatment needed for residential roads and parking areas have been considered to be 3 in both cases, as receiving waters are considered highly sensible. Treatment levels are accomplished by using permeable pavement at car parks and bioretention areas along roads for the most contaminated runoff. These infrastructures can be considered to provide 2 levels of treatments by themselves, but in addition further treatment is accomplished along the swale. The third/fourth level or treatment is provided by the infiltration basin. For the no trafficked areas, two levels are considered sufficient. They are provided by the swale (and the rain gardens in some locations), together with the infiltration area. Hence, an average value of "High" has been assigned. Results are as follows:



Runoff catchment characteristics: Residential roofs only

If different land uses are considered, please choose the use that produces the worst runoff quality.

Receiving water sensitivity: High

Minimum number of infrastructure components with effective pollutant removal capacity : **1**

Infrastructure	Total suspended solids removal efficiency	Nutrients removal efficiency	Heavy metals removal efficiency
Green roof	High	Low	Medium
Permeable pavement	High	High	High
Bioretention area	High	Low	High
Rain garden	High	Low	High
Infiltration basin	High	Medium	High
Vegetated swale	High	Low	Medium
Underground cistern	Medium	None	Low

Suspended solids removal efficiency: High

Nutrients removal efficiency: Medium

Heavy metals removal efficiency: High

Average water quality: High

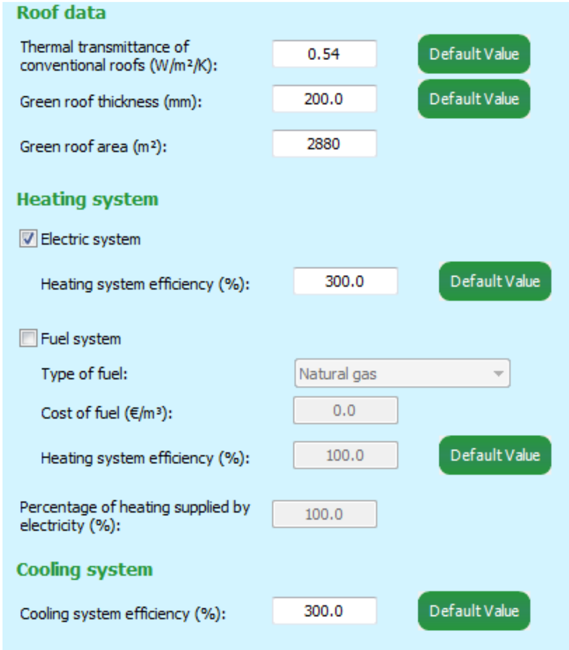
3.4.7. Flood protection

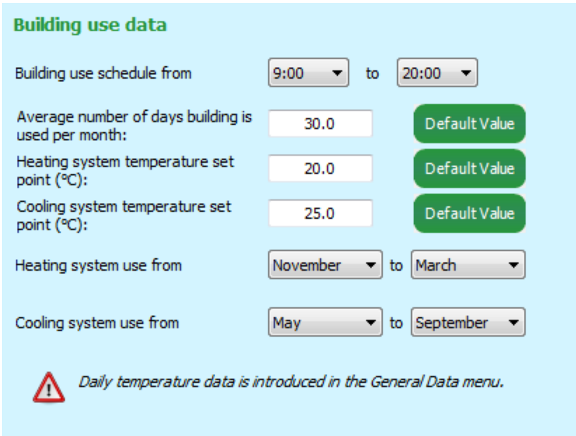
Not applicable.

An evaluation of flood protection is not going to be used as a criterion in the decision-making process for this Pilot Case 2, as in both cases is very similar.

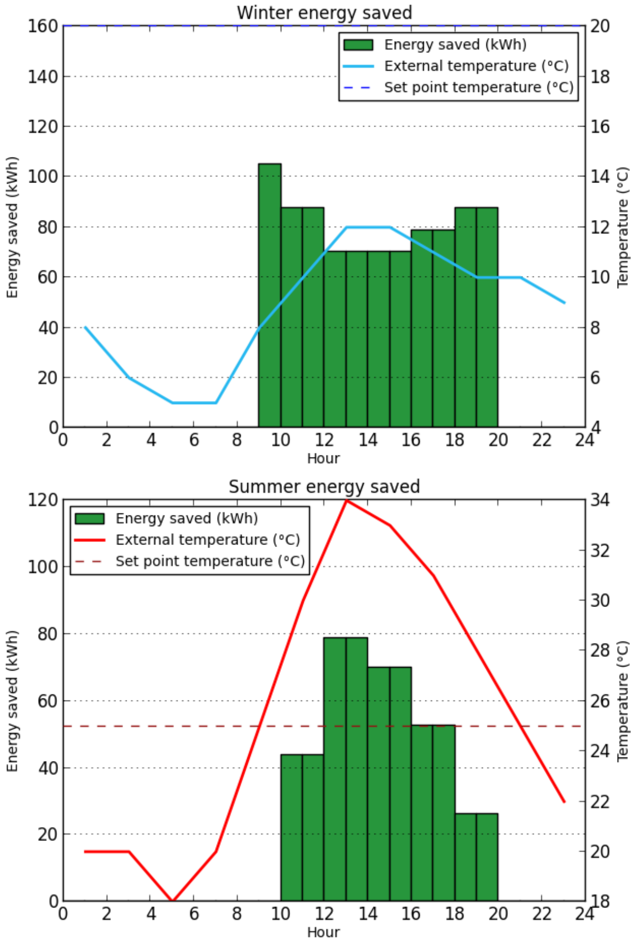
3.4.8. Building insulation

Building insulation is analysed to consider the energy savings produced by the green roof. Default values have been used for the performance of the heating and cooling systems. It has been considered that the building will be used from 9h to 20h. The heating system will be used from November to March and the cooling system from May to September. The data introduced is shown in the following figure:





The energetic profile obtained for the green roofs is:



Finally, the energy savings and benefits of this building insulation improvement are:

Building insulation benefits (€/year):	614.35
Energy consumption avoided (kWh/year):	1436.1
Emissions avoided (kg CO_2e/year):	341.79

3.4.9. Ecosystem services

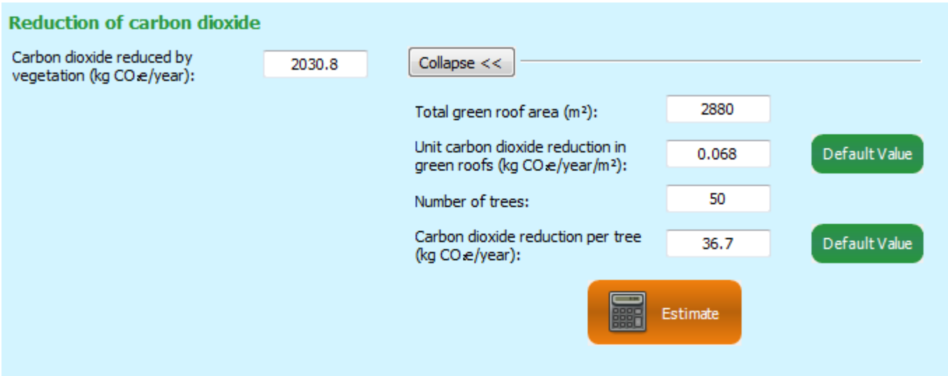
Many ecosystem services are provided by Scenario 2 infrastructure. Ecosystems services values for each one of them are:

- Green roof: high.
- Permeable pavement: medium.
- Bioretention area: high.
- Rain garden: high.
- Infiltration basin: low.

- Vegetated swale: high.
- Underground cistern: none.

As there will be one green roof and many bioretention areas and rain gardens distributed around the site, and the infiltration basin will be designed to provide additional ecosystem services not usually present (e.g. community education and engagement), global ecosystem services have been evaluated as high.

In addition, it is expected that the SuDS scenario will include 50 more trees in this urban area than the conventional scenario. The carbon dioxide reduction of this vegetation and the green roof has been included using the default vales:



3.4.10. Summary

Results table:

Results

	Financial cost	Energy consumption	Emissions
Construction of infrastructures	3.7233e+06 €	6.6206e+06 kWh	2.0431e+06 kg CO_2e
Maintenance of infrastructures	1.6574e+05 €/year	4230 kWh/year	1115.4 kg CO_2e/year
Infrastructure landtake	0 €	-	-
Potable water consumed and saved	0 €/year	0 kWh/year	0 kg CO_2e/year
Stormwater conveyance and treatment	0 €/year	0 kWh/year	0 kg CO_2e/year
Flood protection	0 €/year	-	-
Building insulation	-614.35 €/year	-1436.1 kWh/year	-341.79 kg CO_2e/year
Carbon dioxide reduction	-	-	-2030.8 kg CO_2e/year
Other costs and benefits	0 €/year	0 kWh/year	0 kg CO_2e/year

Negative values indicate financial savings, energy savings and emissions avoided.

Other costs and benefits: not considered

Energy consumed in the urban water cycle table:

Energy consumed in the urban water cycle

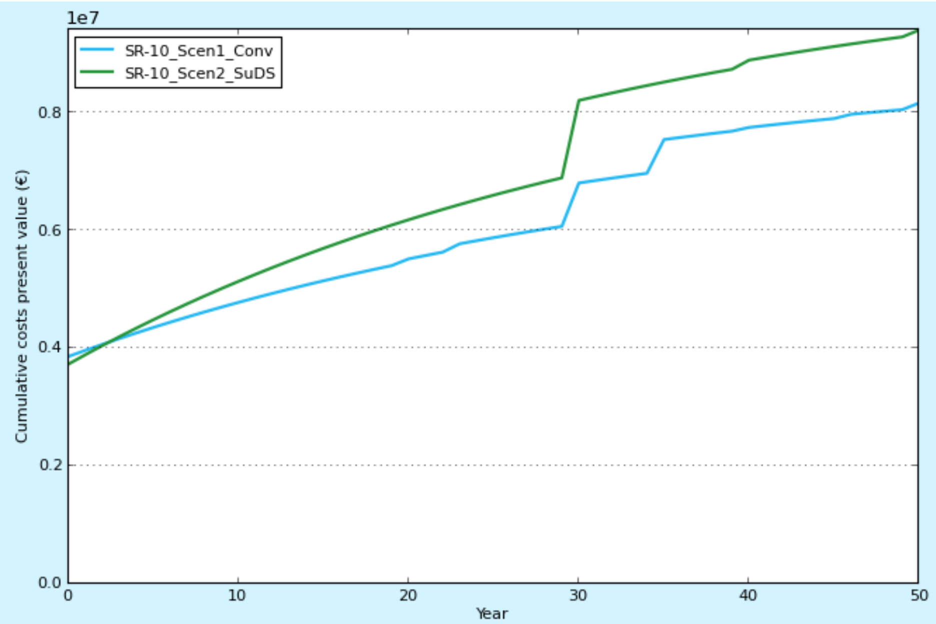
	Energy consumption (kWh/m³)	Emissions (kg CO_2e/m³)
Water supply acquisition	0.282	0.0671
Water supply conveyance	0.439	0.105
Water supply distribution	0	0
Stormwater conveyance	0	0
Stormwater treatment	0.5	0.119

3.5. Results

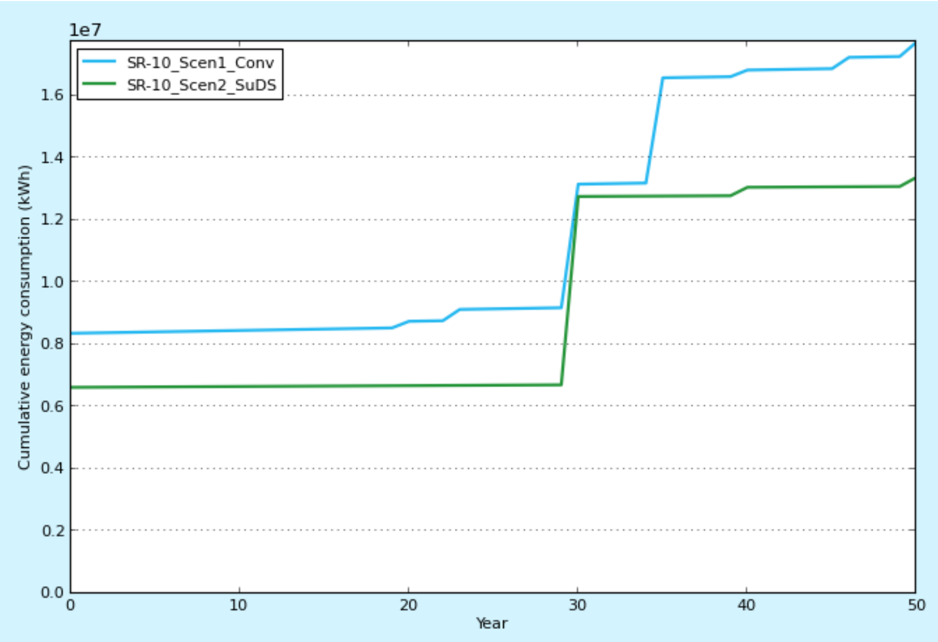
3.5.1. Time graphs

- Global time graphs obtained with the DST (graph and tables).

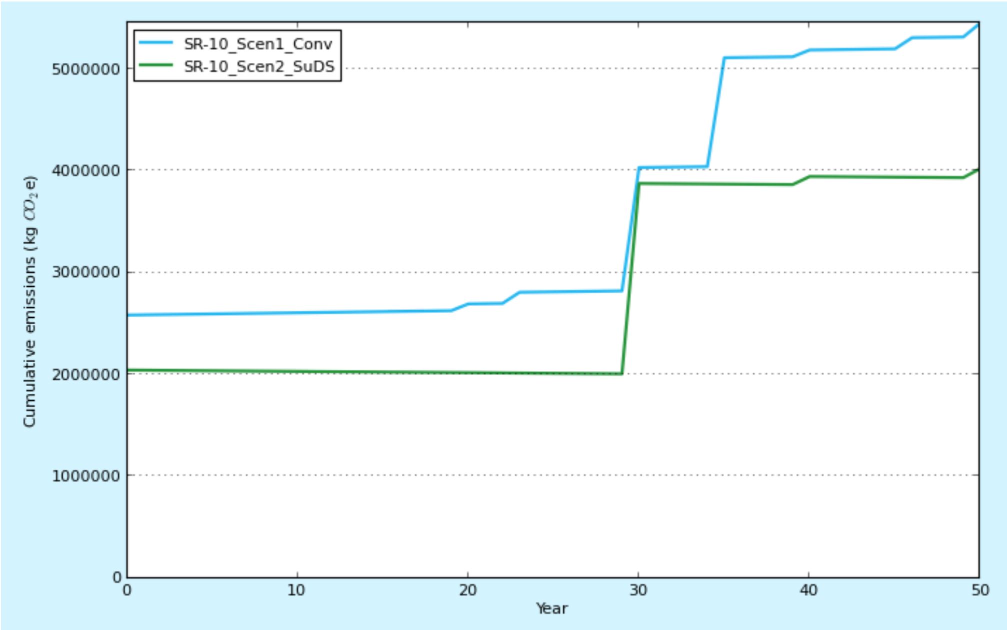
- Cost present value:



- Energy consumption:



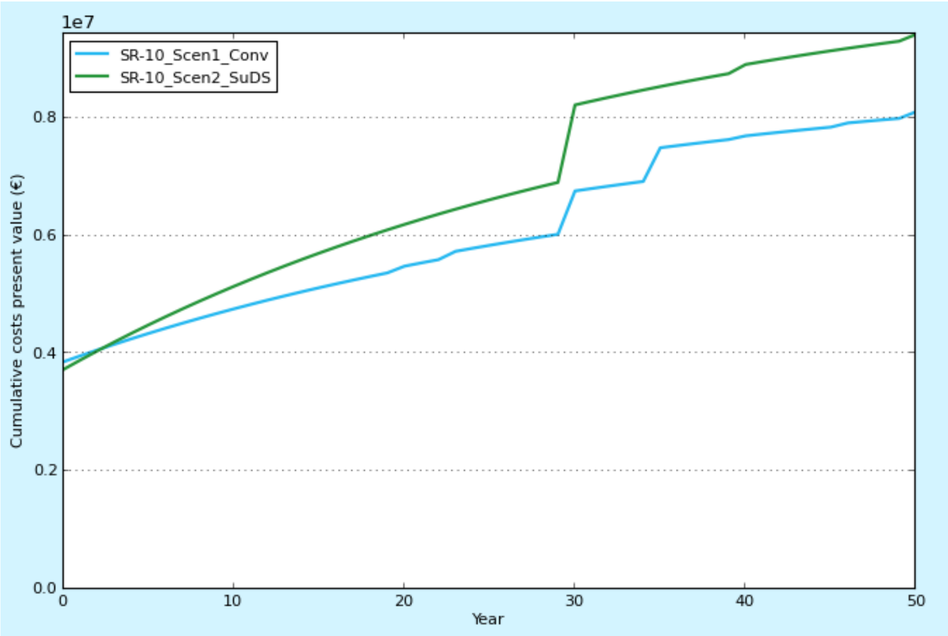
- CO_2 emissions:



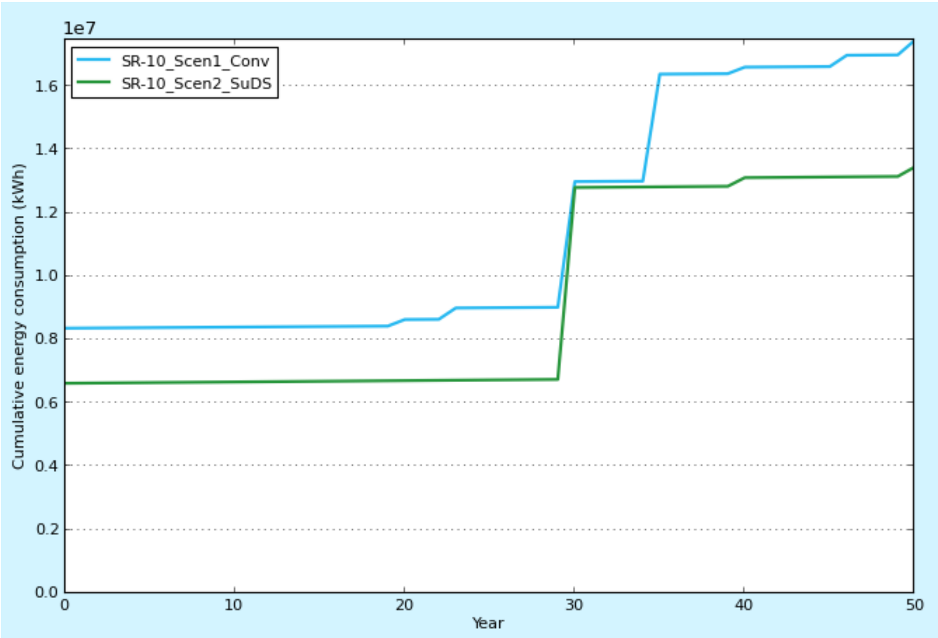
Year	Costs Present Value		Energy conssumption		CO2e Emissions	
	Scen1	Scen2	Scen1	Scen2	Scen1	Scen2
0	3854500	3723335	8359917	6620567	2583899	2043137
1	3959239	3883651	8369012	6623361	2586155	2041880
2	4060927	4039298	8378106	6626155	2588411	2040622
3	4159653	4190411	8387200	6628949	2590666	2039365
4	4255504	4337123	8396295	6631743	2592922	2038108
5	4348563	4479562	8405389	6634537	2595178	2036851
6	4438912	4617852	8414483	6637331	2597433	2035593
7	4526629	4752115	8423578	6640125	2599689	2034336
8	4611791	4882466	8432672	6642919	2601945	2033079
9	4694473	5009021	8441766	6645712	2604201	2031822
10	4774746	5131890	8450861	6648506	2606456	2030565
11	4852682	5251181	8459955	6651300	2608712	2029307
12	4928347	5366996	8469049	6654094	2610968	2028050
13	5001809	5479439	8478144	6656888	2613223	2026793
14	5073131	5588606	8487238	6659682	2615479	2025536
15	5142376	5694594	8496332	6662476	2617735	2024278
16	5209604	5797495	8505427	6665270	2619990	2023021
17	5274873	5897399	8514521	6668064	2622246	2021764
18	5338242	5994393	8523615	6670858	2624502	2020507
19	5399765	6088562	8532710	6673652	2626758	2019249
20	5514864	6179988	8745634	6676446	2693578	2017992
21	5572855	6268751	8754728	6679240	2695834	2016735
22	5629157	6354929	8763822	6682033	2698090	2015478
23	5771376	6438597	9127358	6684827	2807740	2014220
24	5824446	6519827	9136453	6687621	2809996	2012963
25	5875971	6598692	9145547	6690415	2812252	2011706
26	5925995	6675260	9154641	6693209	2814508	2010449
27	5974561	6749598	9163736	6696003	2816763	2009191
28	6021714	6821771	9172830	6698797	2819019	2007934
29	6067493	6891841	9181924	6701591	2821275	2006677
30	6804364	8207655	13157134	12760703	4032962	3876588
31	6847515	8273703	13166229	12763497	4035218	3875330
32	6889409	8337827	13175323	12766291	4037474	3874073
33	6930083	8400084	13184417	12769085	4039729	3872816
34	6969573	8460528	13193512	12771879	4041985	3871559
35	7542764	8519210	16578776	12774673	5111748	3870301
36	7579986	8576184	16587871	12777467	5114004	3869044
37	7616125	8631498	16596965	12780261	5116260	3867787
38	7651210	8685202	16606059	12783055	5118515	3866530
39	7685274	8737341	16615154	12785849	5120771	3865272
40	7749001	8893024	16828078	13057289	5187591	3944972
41	7781110	8942170	16837172	13060083	5189847	3943715
42	7812283	8989885	16846266	13062877	5192103	3942457
43	7842548	9036210	16855361	13065671	5194359	3941200
44	7871932	9081185	16864455	13068465	5196614	3939943
45	7900460	9124851	16873549	13071259	5198870	3938686
46	7972521	9167245	17237085	13074053	5308521	3937429
47	7999411	9208404	17246180	13076847	5310777	3936171
48	8025518	9248364	17255274	13079640	5313032	3934914
49	8050865	9287160	17264368	13082434	5315288	3933657
50	8165804	9405101	17732823	13380831	5452544	4023412

- Time graphs obtained with only construction and maintenance.

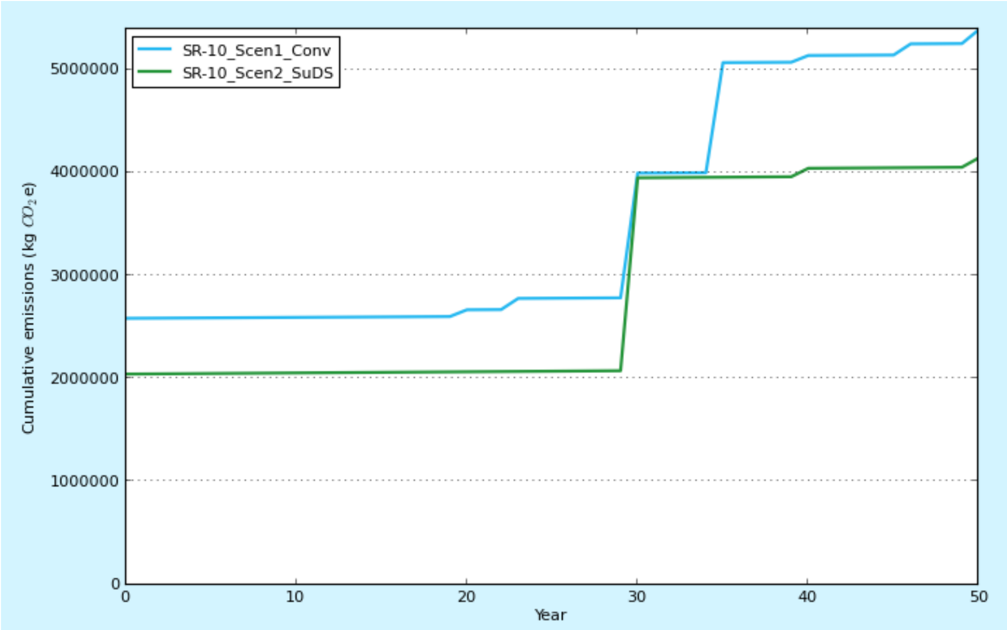
- Cost present value:



- Energy consumption:



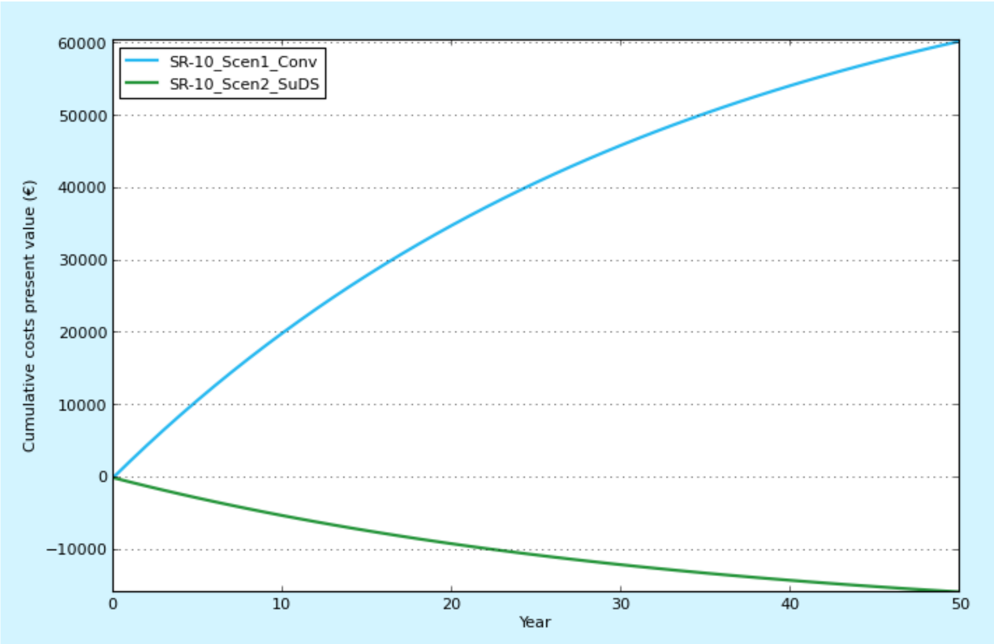
- CO_2 emissions:



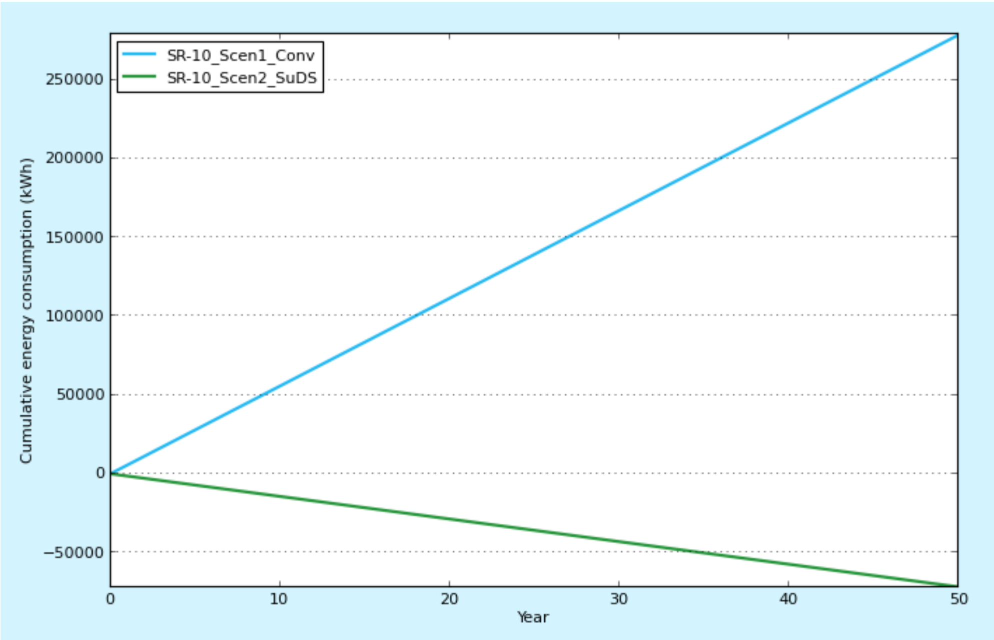
Year	Costs Present Value		Energy conssumption		CO2e Emissions	
	Scen1	Scen2	Scen1	Scen2	Scen1	Scen2
0	3854500	3723335	8359917	6620567	2583899	2043137
1	3956960	3884248	8363439	6624797	2584826	2044252
2	4056436	4040473	8366961	6629027	2585752	2045368
3	4153015	4192149	8370483	6633257	2586679	2046483
4	4246780	4339407	8374005	6637487	2587606	2047598
5	4337815	4482376	8377527	6641717	2588532	2048714
6	4426198	4621180	8381048	6645947	2589459	2049829
7	4512007	4755942	8384570	6650177	2590385	2050944
8	4595316	4886779	8388092	6654407	2591312	2052060
9	4676199	5013805	8391614	6658637	2592239	2053175
10	4754726	5137131	8395136	6662867	2593165	2054290
11	4830966	5256865	8398657	6667097	2594092	2055406
12	4904986	5373112	8402179	6671327	2595018	2056521
13	4976849	5485972	8405701	6675557	2595945	2057636
14	5046620	5595546	8409223	6679787	2596872	2058752
15	5114358	5701928	8412745	6684017	2597798	2059867
16	5180123	5805212	8416266	6688248	2598725	2060983
17	5243973	5905487	8419788	6692478	2599652	2062098
18	5305963	6002842	8423310	6696708	2600578	2063213
19	5366148	6097361	8426832	6700938	2601505	2064329
20	5479947	6189128	8634183	6705168	2666996	2065444
21	5536677	6278221	8637705	6709398	2667923	2066559
22	5591754	6364720	8641227	6713628	2668849	2067675
23	5732784	6448699	8999190	6717858	2777171	2068790
24	5784699	6530232	9002712	6722088	2778098	2069905
25	5835103	6609390	9006234	6726318	2779024	2071021
26	5884039	6686243	9009756	6730548	2779951	2072136
27	5931549	6760857	9013278	6734778	2780878	2073251
28	5977675	6833298	9016799	6739008	2781804	2074367
29	6022458	6903629	9020321	6743238	2782731	2075482
30	6758363	8219696	12989959	12803786	3993089	3947765
31	6800575	8285990	12993481	12808016	3994016	3948881
32	6841558	8350353	12997002	12812246	3994942	3949996
33	6881347	8412842	13000524	12816476	3995869	3951111
34	6919977	8473510	13004046	12820706	3996796	3952227
35	7492334	8532411	16383738	12824936	5065230	3953342
36	7528747	8589597	16387260	12829166	5066156	3954457
37	7564099	8645117	16390782	12833397	5067083	3955573
38	7598422	8699020	16394304	12837627	5068010	3956688
39	7631744	8751353	16397826	12841857	5068936	3957803
40	7694752	8907225	16605177	13114733	5134428	4039876
41	7726162	8956554	16608699	13118963	5135354	4040991
42	7756657	9004446	16612221	13123193	5136281	4042106
43	7786264	9050943	16615742	13127423	5137207	4043222
44	7815008	9096086	16619264	13131653	5138134	4044337
45	7842916	9139914	16622786	13135883	5139061	4045452
46	7914374	9182465	16980749	13140113	5247382	4046568
47	7940679	9223778	16984271	13144343	5248309	4047683
48	7966218	9263886	16987793	13148573	5249236	4048798
49	7991014	9302827	16991315	13152803	5250162	4049914
50	8105417	9420908	17454197	13452636	5386089	4142041

- Time graphs obtained without construction and maintenance.

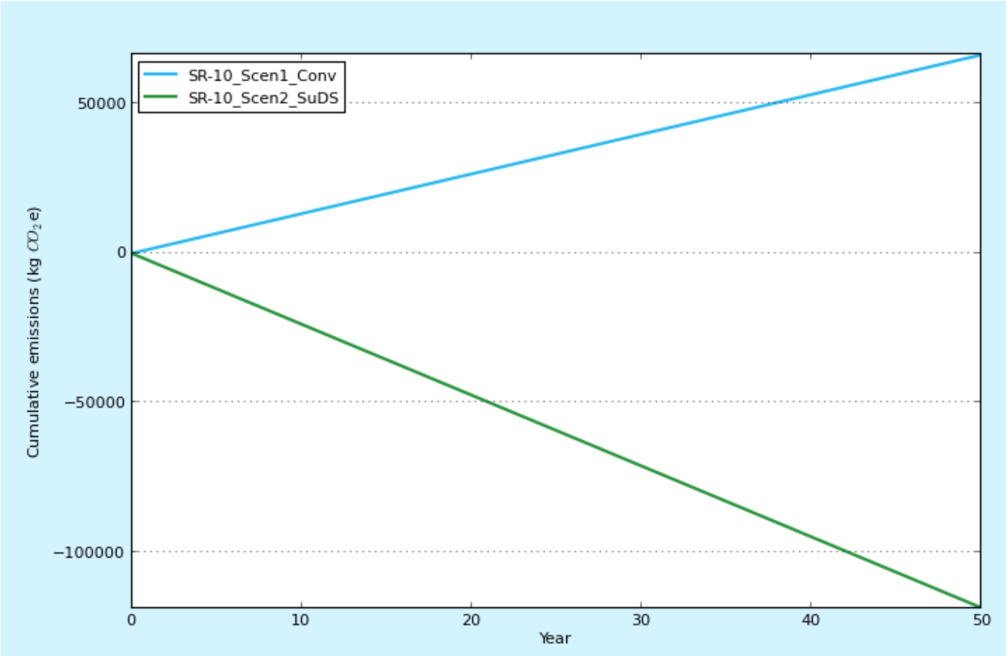
- Cost present value:



- Energy consumption:



- CO_2 emissions:



Year	Costs Present Value		Energy conssumption		CO2e Emissions	
	Scen1	Scen2	Scen1	Scen2	Scen1	Scen2
0	0	0	0	0	0	0
1	2279	-596	5573	-1436	1329	-2373
2	4491	-1176	11145	-2872	2658	-4745
3	6639	-1738	16718	-4308	3987	-7118
4	8724	-2284	22290	-5744	5316	-9490
5	10748	-2814	27863	-7181	6645	-11863
6	12714	-3328	33435	-8617	7975	-14236
7	14622	-3828	39008	-10053	9304	-16608
8	16475	-4313	44580	-11489	10633	-18981
9	18274	-4783	50153	-12925	11962	-21353
10	20020	-5241	55725	-14361	13291	-23726
11	21715	-5684	61298	-15797	14620	-26098
12	23362	-6115	66870	-17233	15949	-28471
13	24960	-6534	72443	-18669	17278	-30844
14	26511	-6940	78015	-20105	18607	-33216
15	28018	-7334	83588	-21542	19936	-35589
16	29480	-7717	89160	-22978	21266	-37961
17	30900	-8089	94733	-24414	22595	-40334
18	32279	-8449	100305	-25850	23924	-42707
19	33617	-8800	105878	-27286	25253	-45079
20	34917	-9140	111450	-28722	26582	-47452
21	36178	-9470	117023	-30158	27911	-49824
22	37403	-9791	122595	-31594	29240	-52197
23	38592	-10102	128168	-33030	30569	-54570
24	39747	-10404	133740	-34466	31898	-56942
25	40868	-10698	139313	-35903	33227	-59315
26	41956	-10983	144885	-37339	34557	-61687
27	43013	-11259	150458	-38775	35886	-64060
28	44038	-11528	156031	-40211	37215	-66433
29	45034	-11788	161603	-41647	38544	-68805
30	46001	-12042	167176	-43083	39873	-71178
31	46940	-12287	172748	-44519	41202	-73550
32	47851	-12526	178321	-45955	42531	-75923
33	48736	-12757	183893	-47391	43860	-78295
34	49595	-12982	189466	-48827	45189	-80668
35	50429	-13201	195038	-50264	46518	-83041
36	51239	-13413	200611	-51700	47847	-85413
37	52025	-13618	206183	-53136	49177	-87786
38	52789	-13818	211756	-54572	50506	-90158
39	53530	-14012	217328	-56008	51835	-92531
40	54249	-14201	222901	-57444	53164	-94904
41	54948	-14383	228473	-58880	54493	-97276
42	55626	-14561	234046	-60316	55822	-99649
43	56284	-14733	239618	-61752	57151	-102021
44	56924	-14901	245191	-63188	58480	-104394
45	57544	-15063	250763	-64625	59809	-106767
46	58147	-15221	256336	-66061	61138	-109139
47	58732	-15374	261908	-67497	62468	-111512
48	59300	-15523	267481	-68933	63797	-113884
49	59851	-15667	273053	-70369	65126	-116257
50	60386	-15807	278626	-71805	66455	-118630

- Explanation and justification of results.

As shown in the previous graphs and tables, the second option has lower energy consumptions and emissions in all the period of analysis. In contrast, it has higher costs in most of the period due to the higher maintenance costs. In general, the most important costs are produced in construction and maintenance, so the estimation of these costs should be made in detail for further analysis.

3.5.2. Decision criteria

In the decision making process, the following important issues need to be considered:

- Construction and maintenance cost of drainage infrastructures.
- Volume of stormwater reused.
- CO_2 emissions in the urban water management cycle.
- Runoff: water quality.
- Aquifers recharge.
- Landscaping integration of infrastructures and educational opportunities.

Decision criteria have been chosen in accordance to the above, in a way that comparison of how different options achieve them can be made, and including what the costs are. They have been preliminary chosen by technicians carrying out the application of the DST, and later on, reviewed and modified considering the opinion of decision makers and technical staff within the municipality. In addition, the criteria selected and their weights have been discussed in the meetings with the RWGEE.

Being a new development, costs are not as important as in the retrofitting action, since a new urbanization is being built. In contrast, outflow water quality is really significant, since outflow runoff is directly discharged into the drainage channel connected with the Turia River. Hence, selected decision criteria are as follows:

- Net cost of stormwater management (total present value of stormwater management cost obtained adding costs of infrastructures construction and maintenance and runoff treatment and conveyance minus benefits produced by water reuse and building insulation): Weight 10%. Financial criteria.
- Net energy consumed by stormwater management (total stormwater management energy consumed obtained adding energy consumed by infrastructures' construction and maintenance and runoff treatment and conveyance minus energy saved by water reuse and building insulation): Weight 25%. Energy criteria.
- Net emissions of stormwater management (total stormwater management CO_2 emissions obtained adding emissions of infrastructures construction and maintenance and runoff

treatment and conveyance minus emissions saved by water reuse and building insulation): Weight 5%. Energy and environmental criteria.

- Global outflow water quality (Protection of receiving water bodies): Weight 35%. Environmental and water quality criteria.
- Volume of water reused (optimization of drinking water use): Weight 10%. Other quantitative criteria.
- Aquifer recharge: Weight 5%. Other quantitative criteria.
- Landscaping integration of infrastructures and educational opportunities: Weight 10%. Additional qualitative decision criterion (ecosystem services). Very low for Scenario 1 and Very high for Scenario 2.

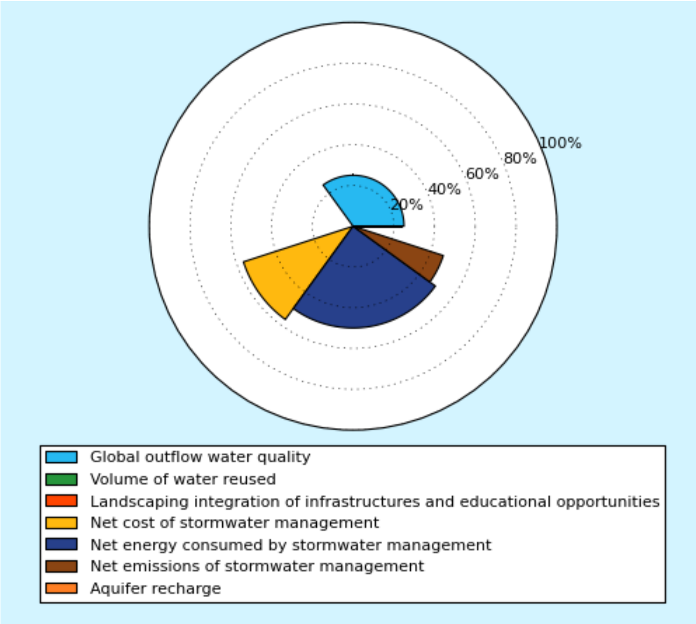
Minimum and maximum values considered in each criterion are:

- Net cost of stormwater management. Worst: 18 800 000 € (just above the double of max of both scenarios); Best: 0 €.
- Net energy consumed by stormwater management. Worst: 35 400 000 kWh (double of max of both scenarios); Best: 0 kWh.
- Emissions of stormwater management. Worst: 10 900 000 $kgCO_2e$ (double of max of both scenarios); Best: 0 $kgCO_2e$.
- Volume of water reused. Worst: 0 m^3; Best: 2 675 m^3 (volume reused in Scenario 2).
- Aquifer recharge. Worst: 0 m^3/year; Best 10 330 m^3/year (runoff generated in that area for the average year).

3.5.3. Multi-criteria analysis results

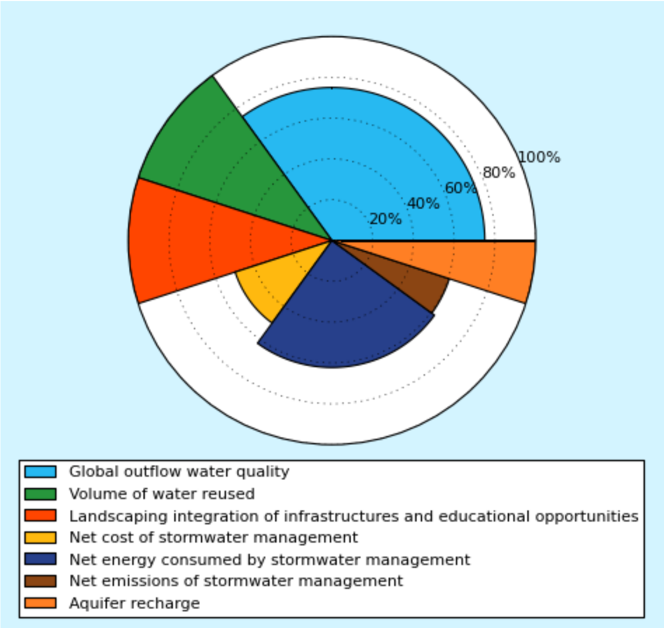
- Circular results per scenario (graphs and table).

- Scenario 1_Conventional:



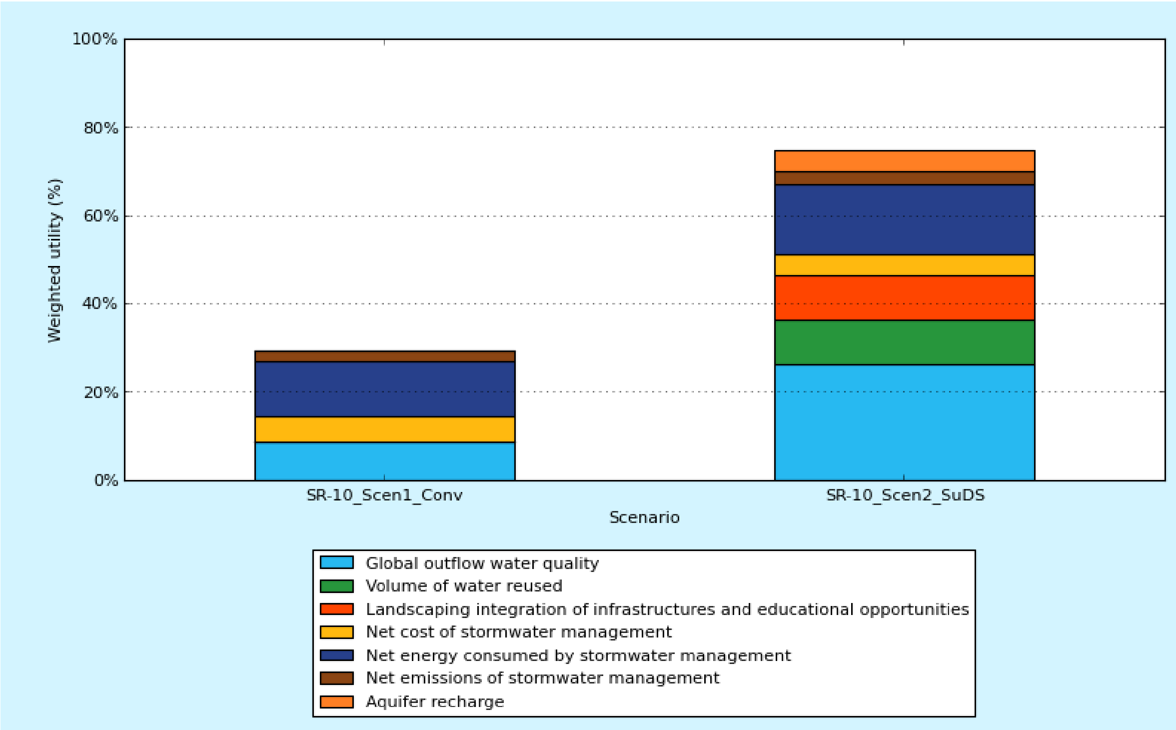
Criterion	Weight (%)	Utility (%)
Global outflow water quality	35	25.00
Volume of water reused	10	0.00
Landscaping integration of infrastructures and educational opportunities	10	0.00
Net cost of stormwater management	10	56.56
Net energy consumed by stormwater management	25	49.91
Net emissions of stormwater management	5	46.54
Aquifer recharge	5	0.00

- Scenario 2_SuDS:



Criterion	Weight (%)	Utility (%)
Global outflow water quality	35	75.00
Volume of water reused	10	100.00
Landscaping integration of infrastructures and educational opportunities	10	100.00
Net cost of stormwater management	10	49.97
Net energy consumed by stormwater management	25	62.20
Net emissions of stormwater management	5	60.55
Aquifer recharge	5	100.00

- Global results (graph and table).



Criterion	Weighted utility (%)	
	Scen1	Scen2
Global outflow water quality	8.75	26.25
Volume of water reused	0.00	10.00
Landscaping integration of infrastructures and educational opportunities	0.00	10.00
Net cost of stormwater management	5.66	5.00
Net energy consumed by stormwater management	12.48	15.55
Net emissions of stormwater management	2.33	3.03
Aquifer recharge	0.00	5.00
Total	**29.21**	**74.83**

- Explanation and justification of results.

Relative results of the utility are highly dependent on best and worse values chosen in each criterion. For this reason, when worse value was not clear, a value double of the worse value of the two scenarios has been chosen.

In any case, independently of the worst and best values chosen, the second scenario's utility is higher than the utility of the first scenario, since it scores better in all the criteria, but in the costs criteria, in which the utility of scenario 1 is slightly higher due to maintenance costs.

3.6. CONCLUSIONS

In this case, two scenarios have been compared for the drainage system of a new developed area in Benaguasil (part of SR-10 development) following two different approaches: Conventional and SuDS. These two scenarios have been designed to limit the outflow discharge into an irrigation channel which maximum capacity is estimated in 650 l/s. Scenario 1 (conventional) includes a detention basin at the end of a separated drainage network while Scenario 2 includes different retentions at source (permeable pavements, bioretention areas, rain gardens, a green roof), a vegetated swale that directs runoff to the end point, where an infiltration basin has been located.

The conclusions obtained with the multi-criteria analysis show that the second option (SuDS) should be selected since it has betters scores in most of the criteria selected for the comparison. This result highlights that using SuDS in new developments will produce for a better and more energy-efficient stormwater management. The SuDS solution produces the following benefits:

- Lower energy consumptions in stormwater management, especially in the construction, maintenance and water treatment.
- Lower CO_2e emissions and CO_2 reduction by vegetation included in these infrastructures.
- Better water quality of the outflow discharged into the Turia River.
- Better integration of stormwater infrastructures in the urban landscape. Combining stormwater management with educational and recreational uses maximizes the benefits of drainage infrastructures.
- Higher aquifer recharge.

These first results show that the construction cost of both scenarios would be very similar and the maintenance cost would be slightly higher for the SuDS option. For this reason, the only criterion in which the Scenario 1 has better utility value is the financial one. These costs have been estimated using the default values provided by the DST, so in a more detailed analysis, it would be necessary to compute these costs with local data due to its importance for the stormwater costs results. In fact, in the Benaguasil case study, it has been observed that SuDS costs can be overestimated with the DST default values.

In addition, green roofs might look expensive (compared to other SuDS options, easier to fit in new development areas) if comparison is only based on stormwater management, but their use can be recommended when educational aspects, building insulation, urban comfort and other ecosystem services are important.

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