Application of the E²STORMED Decision Support Tool in Pisa

E²STORMED PROJECT
Improvement of energy efficiency in the water cycle by the use of innovative storm water management in smart Mediterranean cities
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L'Europe en Méditerranée
Europe in the Mediterranean

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

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Date: May 2015

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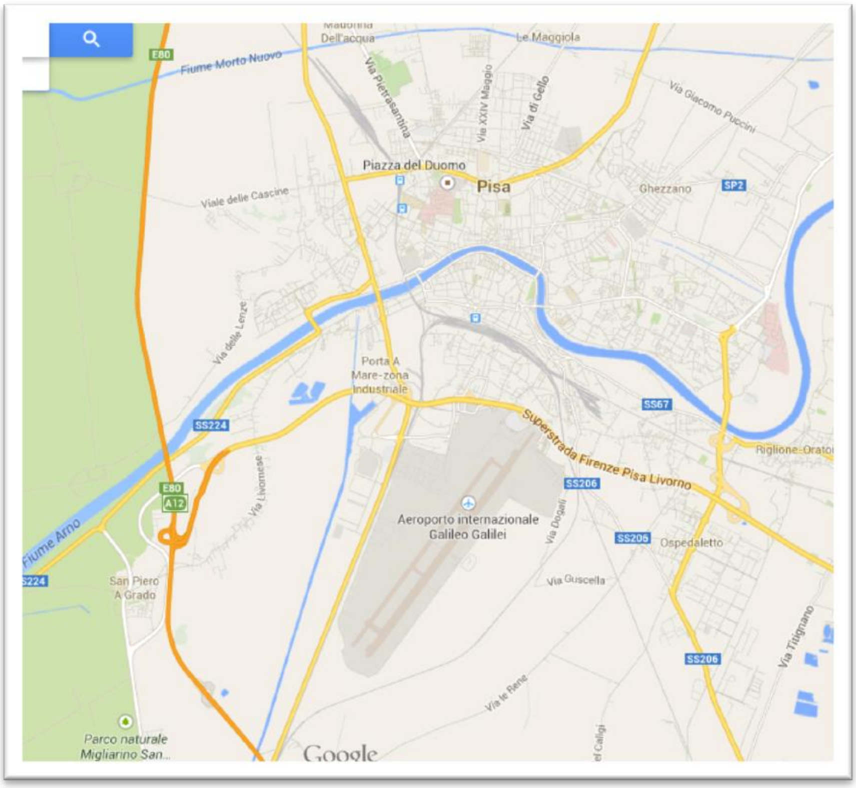
1. PILOT CITY DESCRIPTION

General description

Pisa is located in Tuscany, Central Italy. The city sits on the right bank of the mouth of the River Arno (on the Tyrrhenian Sea). The municipal territorial area is 185,18 km^2, the city counts over 90000 inhabitants, with a population density of 498,16 hab/km². Starting from 1981 Pisa has a steady loss of population with a negative annual growth rate of – 0.4%. Pisa is a university town with a significant variation during the summer time when student and other no resident people, like off-site workers, come back home. On the other hand during the summer time people coming from the neighboring municipalities make the population grow, increasing the pressure due to tourism flows.



Climate

Pisa features a Mediterranean climate, with wet autumns and dry summers. On average the hottest month is July, with a mean temperature of about 29°C (84°F), while January is the coolest month with an average temperature of about 11°C (52°F). Average yearly rainfall is 854 mm.

Water resources

Water management system

River Basin Authority, Department of the Soil Protection (Tuscany Region), Province and Prefecture are responsible for storm water planning while storm water management and maintenance is entrusted to a committee that handles emergencies through a steering group made up of different actors and authorities having jurisdiction in the matter.

Water related issues and challenges

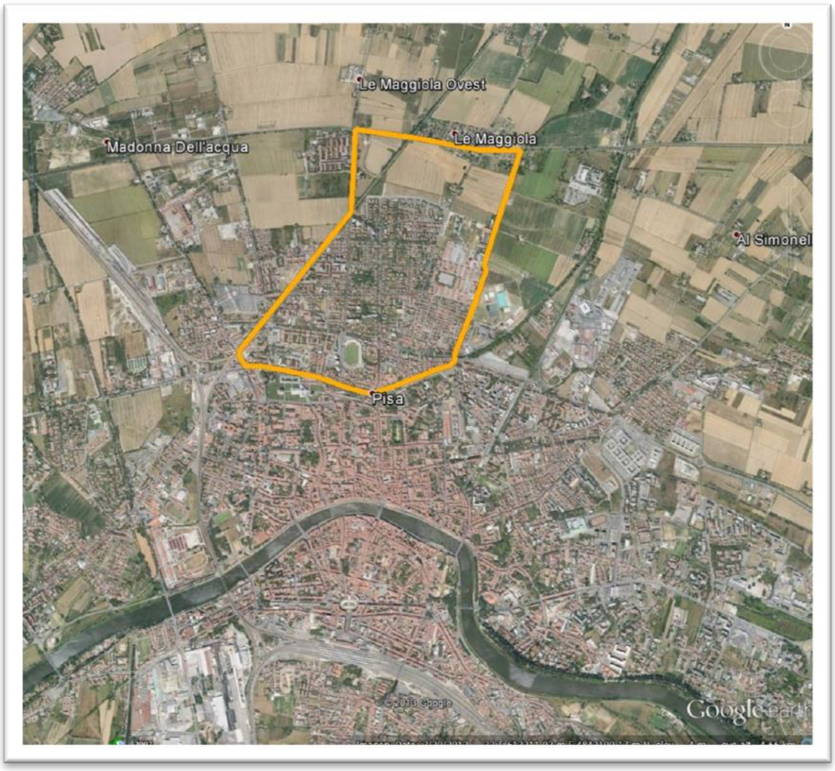
- Inability to implement wastewater treatment plants
- Non-sustainability of new growth forecasts
- High losses in the distribution network
- Polluted water resources
- Low cost recovery for water supply services
- Storm water management.

2. Pilot case 1: Developed area

2.1. General description

Area: 1 988 834 m^2

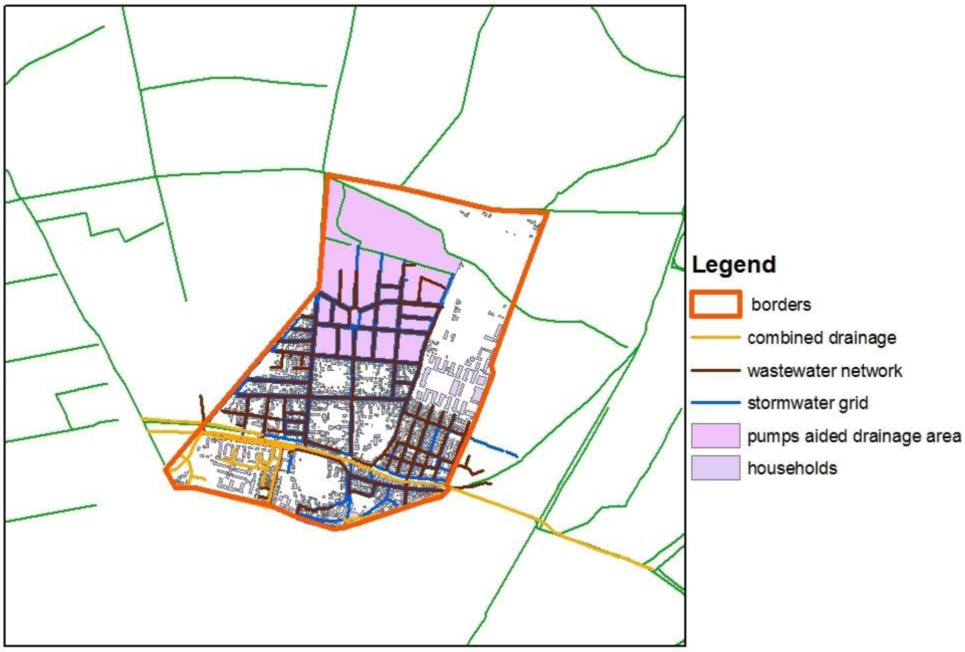
Land use: residential, agricultural

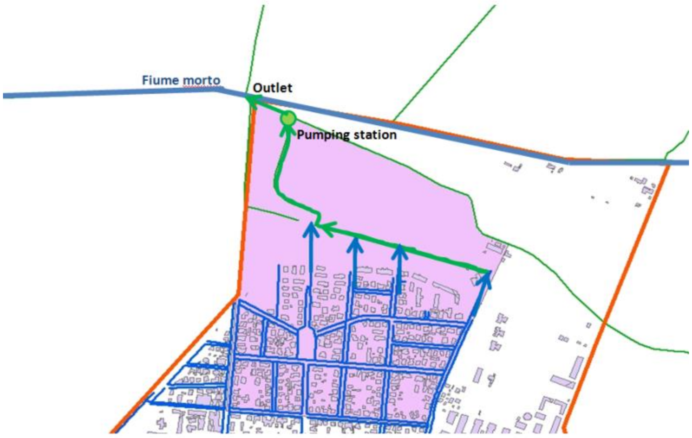


The selected area is part of Fiume Morto drainage system. The area is mainly served by a separate wastewater grid connected to a wastewater treatment facility (San Jacopo 40.000 PE) and partly by a combined network.

The main criticalities are related to the management of the exceptional events of the Arno River (Tr=200 years). Apart from that the area suffers of minor grid inadequacy to flash storm.

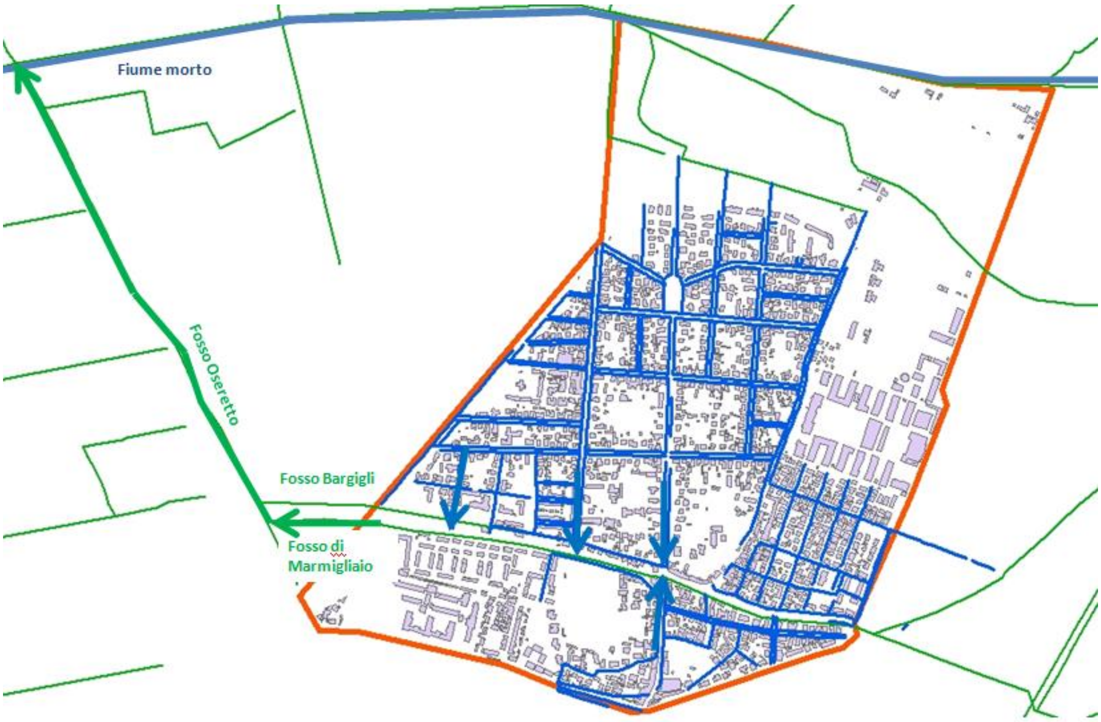
The drainage in the area can be divided in two sub basins. One (pink area) is served by a pumping station that rises water to Fiume Morto.





The pumping station is equipped with two pumps (with a design discharge of 500 l/sec each, whereof only one is working due the lack of an adequate connection to the electric grid) and is design for a return period of 30 years.

The remaining area is served by a drainage network that conveys the stormwater along a main underground water carrier (east to west direction) called Fosso Marmigliaio and a secondary one called fosso Bargigli (that flows parallel). These are connected to Fiume Morto through Fosso Oseretto (natural flow).



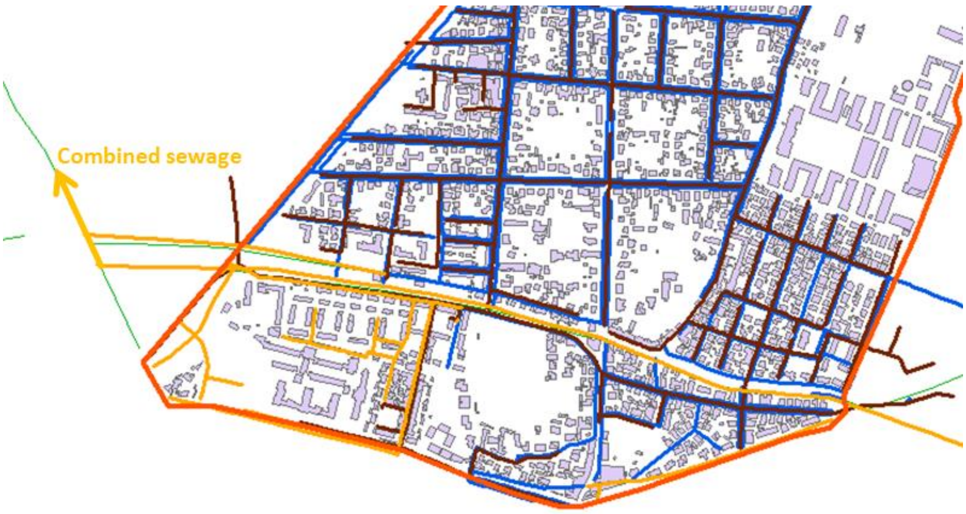
This area suffers of frequent overflows during severe storms (e.g. recent flood events of 11 nov. 2012 and 11 march 2013). This is due the inability of Fosso Marmigliaio and Fosso Bargigli to drain all the rainfall: these canals represent the real "bottle neck" of the entire area. Some interventions have already been adopted to avoid these criticalities, operating emergency pumping during high rainfall events (operations managed by civil protection) to bypass the Fosso Marmigliaio.

Some additional interventions have been planned by the Pisa Municipality and the Land Reclamation Consortium ("Consorzio 4 Basso Valdarno", ex "Consorzio di bonifica Ufficio dei Fiumi e Fossi Pisa"). These interventions have been here introduced in the Scenario 2 (see section 2.4.1) whereas they are not present in Scenario 1.

Waste water is collected towards a main pipe that is collocated along Fosso Marmigliaio and then flows to San Jacopo WWTP (potentially 461,710 cubic meters/year).

Only few household in the southern part are connected to a combined sewage system that is linked to Fosso Mamigliaio and Fosso Bargigli (and from there to Fosso Oseretto ending to Fiume Morto). Fosso Mamigliaio and Fosso Bargigli are now just pipes under the street or parking places (the hydrography was heavily modified there in the last 50 years), while Fiume Morto is an open channel.

An important issue is related to the presence of a shallow water table: by an hydrological point of view, the area maintains characteristics similar to a marsh. As such, to maintain the area free from groundwater and excess surface runoff, the whole Pisa area is divided in a number of land reclamation basins and pumps are needed operating 365 day/year. Many households use submergible pumps to prevent water inflow in underground constructions and this raises further problems in stormwater management. Consequently, a large amount of energy is needed for maintaining such a system.



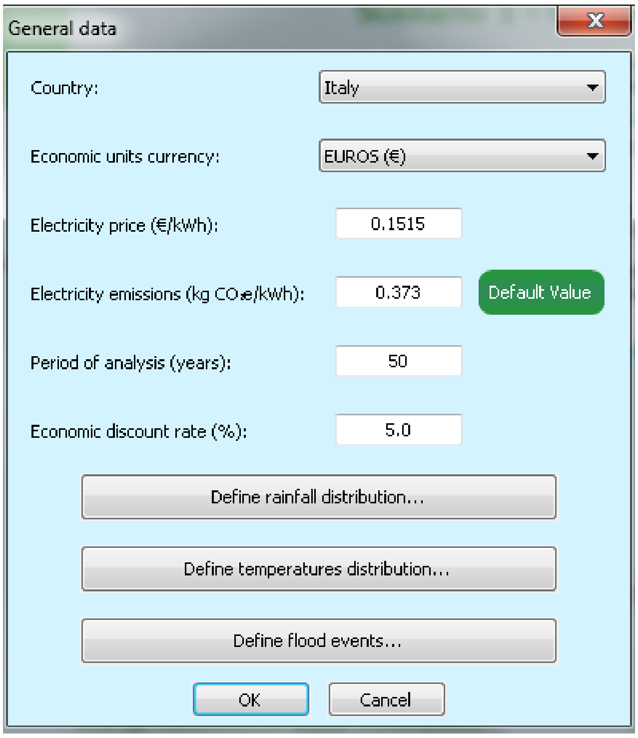
Stormwater management has definitely to be improved in order to assure the safety of the area during extreme events.

In evaluating conventional against sustainable drainage scenarios, same performance strategy is followed considering flood protection benefits. Therefore, flood protection benefits are not included in the analysis since they are assumed to be the same in both scenarios.

Expected energy benefits with Sustainable Drainage Systems (SuDS) option are related to runoff volumes reduction. It will then result in the reduction of pumping needs and hence less energy consumption.

2.2. GENERAL MODEL DATA

General model data are presented in the picture below.



Following are the data included in the General Data menu with the source.

Electricity price (€/kWh): 0.1515 (Source: Acque spa)

Electricity emissions (kg CO_2/kWh): 0.373 (Source: Istituto Superiore per la Protezione e la Ricerca Ambientale, http://www.sinanet.isprambiente.it/it/sia-ispra/serie-storiche emissioni/fattori-di-emissione-per-la-produzione-ed-il-consumo-di-energia-elettrica-in-italia/view)

Period of analysis (years): 50

Economic discount rate (%): 5 (source: “Guida per la certificazione da parte dei Nuclei regionali di valutazione e verifica degli investimenti pubblici”, Conferenza dei Presidenti delle Regioni e delle Province autonome)

Rainfall distribution (Source: Centro Funzionale Regionale, Regione Toscana):

January Average rainfall (mm)	62
Feb Average rainfall (mm)	52
Mar Average rainfall (mm)	47.3
Apr Average rainfall (mm)	73.7
Maj Average rainfall (mm)	65.8
Jun Average rainfall (mm)	44
Jul Average rainfall (mm)	19.9
Aug Average rainfall (mm)	43.4
Sept Average rainfall (mm)	88.9
Oct Average rainfall (mm)	125.3
Nov Average rainfall (mm)	137.5
Dec Average rainfall (mm)	93.5

Flood events (flood event return period): 15

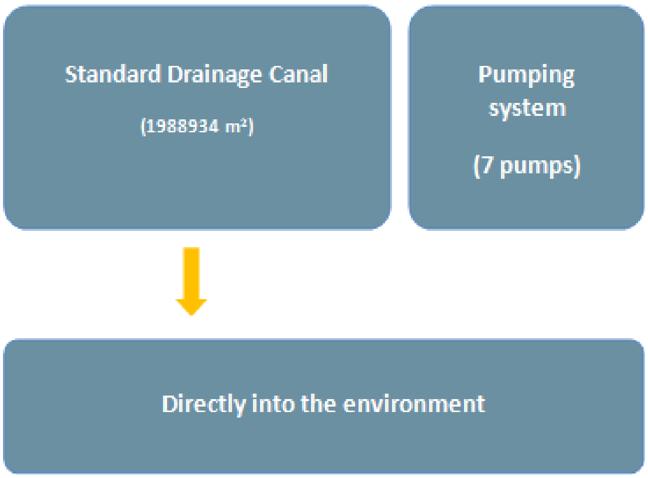
- The only comparable data is the Electricity emissions one. Our value (0.373 kg $C0_2$/kWh) is lower than the default one 0.406 kg $C0_2$/kWh.

2.3. Scenario 1: Conventional development

2.3.1. General description

The conventional intervention includes the realization of two main canals that are connected with the stormwater grid and bring the runoff toward the Northern part of the area (that is served by the pumping station) avoiding overloading of Fosso Marmigliaio. The realization of the two new canals must be combined with a proper resizing of the pumping station. For this purpose 7 pumps* were defined. The design of such drainage infrastructure mainly follows the criteria of assuring the safety of the area during extreme events by quickly removing runoff volumes. Following are the data included in the Water Supply menu (with sources and notes).

The following sketch shows the model used for the conventional scenario.



2.3.2. Drainage infrastructures included in the scenario

- In the Conventional Scenario only standard drainage canals with 7 pumping stations have been considered:

- An open channel (2000 meters, 3 meters wide at the bottom and 9 meters at the surface) **
- A pipeline (1200 meters)**
- A pumping station equipped with 7 pumps (692 kW, overall)*

*A number of 5 pumps (overall peak flow rate: 7 m^3/s, about 481 KW) are considered adequate in the SuDS development (as required by the Land Reclamation Consortium “Consorzio 4 Basso Valdarno”, ex “Consorzio di bonifica Ufficio dei Fiumi e Fossi Pisa”, see section 2.4, this report). Based on the different values of runoff produced in the two scenarios, a number of 7 pumps was estimated for the conventional scenario through a linear relationship.

** (Source: Chart IDR.04, IDR.05, Sistemazione idraulica Pisa Nord Opere a servizio dell'abitato di Porta a Lucca, Comune di Pisa & Consorzio di bonifica Ufficio dei Fiumi e Fossi Pisa)

The "pumping station", raising water from the canal, was created as independent infrastructure in order to properly account for Energy and Emissions associated to the pumps' construction and set in place. The drainage surface of such infrastructure is anyway considered as null.

- **Summary of values included in the DST.**

Type of data			Assigned value	Availability check	Source (PERSON)	Source of data	Note
Water supply cost							
	Water cost (€/m³)		1.74		Pisa Municipality experts	Acque spa (http://www.acque.net/tariffe-fornitura)	Excluding the fixed rates per annum and assuming that households are the 60%, industrial 10% and services 20%. Household tariff is 1,41 €/m3 (between 0-80 m3/year) + € 2,82/m3 (between 81-200 m3/year); Industry tariff is € 2,43/m3 (between 0- 180 m3/year); Services tariff (non domestic users) is € 2,43/m3 (between 0 - 180 m3/year)
Energy consumed in water acquisition							
	Energy consumed in water acquisition (kWh/m³):						
	Emissions in water acquisition (kg CO_2/m³):						
		Water supply source:	groundwater				
		Height difference (m):	150		Pisa Municipality experts		The acquifer is between 100 and 200 meters deep
		Mechanic efficiency (%):	75	Missing data		DEFAULT Value is used	
		Electric system efficiency (%):	85	Missing data		DEFAULT Value is used	
		Type of treatment:	chlorination				
Energy consumed in water conveyance							
	Energy consumed in water conveyance (kWh/m3):						
	Emissions in water conveyance (kg CO2/m3):						
		Height difference (m):	7		Pisa Municipality experts		Estimated
		Average internal diameter of pipes (mm):	250	Missing data		DEFAULT Value is used	
		Average water velocity (m/s):	1.5	Missing data		DEFAULT Value is used	
		Average roughness height (mm):	0.007	Missing data		DEFAULT Value is used	
		Distance between water source and distribution tank (m):	3500		Pisa Municipality experts		Computed as the average between San Biagio wells distance to its tank (0 meters) and Filettole wells to Orzignano tank (7000 meters)
		Minor losses in pipes (percentage of friction losses) (%):	10	Missing data		DEFAULT Value is used	
		Mecanichal efficiency (%):	75	Missing data		DEFAULT Value is used	
		Electric system efficiency (%):	85	Missing data		DEFAULT Value is used	
Energy consumed in water distribution							
	Energy consumed in water distribution (kWh/m3):						
	Emissions in water distribution (kg CO2/m3):						
		Height difference (m):	33		Pisa Municipality experts		Calculated as the average between San Biagio deposit-utilities height difference (3 meters) and Orzignano tank-utilities height difference (63 meters)
		Average internal diameter of pipes (mm):	150	Missing data		DEFAULT Value is used	
		Average water velocity (m/s):	1.5	Missing data		DEFAULT Value is used	
		Average roughness height (mm):	0.007	Missing data		DEFAULT Value is used	
		Distance between distribution tank and water supply point (m):	5000		Pisa Municipality experts		Calculated as the average between tank Orzignano distance to the utilities (6000 meters) and San Biagio distance to the utilities (4000 meters)
		House water pressure (kPa):	300	Missing data		DEFAULT Value is used	
		Minor losses in pipes (percentage of friction losses) (%):	15	Missing data		DEFAULT Value is used	
		Mecanichal efficiency (%):	75	Missing data		DEFAULT Value is used	
		Electric system efficiency (%):	100	Missing data		DEFAULT Value is used	
Water supply network							
	Water losses in the network (%):		30		Pisa Municipality experts	Acque spa	

In the Conventional scenario, the volume of water consumed for irrigation or cleaning of drainage infrastructures should be null. Anyway, in order to properly compare conventional and sustainable scenarios (the latter having rainwater harvesting systems) we estimated non-potable water demand (i.e. toilet flush) for the pilot area and considered reasonable to take it into account in the simulations by including such volumes in the total volume of water consumed for irrigation or cleaning of drainage infrastructures. We estimated the volume of water consumed for toilet flushes in the area as 1500 m³/month (18000 m³/year), by assuming 1000 users per day and 10 liters per toilet flush.

- **Process followed to estimate construction and maintenance costs**

Construction costs:

Standard Drainage Canal: 545940 € for excavation (18000 m^2 * 30,33 euro/m^2, source: adapted from "Piano particolareggiato per ampliamento della zona produttiva di Ospedaletto"- Consorzio area produttiva intercomunale Pisa-Cascina);

Pumps: 396000 € (this cost has been estimated assuming the unit cost for a pump in the SuDS case study, which is 56000 € each); Land take costs = 9 m * 2000 m * 0.127 €/m^2 (fallow land take cost in Pisa Province; Agenzia delle Entrate, 2013) = 2286 €.

Maintenance costs:

Standard Drainage Canal: 1800 €/year (= 18000 m^2 * 0,1 €/m^2, default maintenance value for vegetated swale from DST)

Pumps: 28800 €/year (this cost has been estimated assuming the unit indicative value for a pump provided by staff of Reclaimed Land Consortium)

- **Process followed to estimate energy consumed and emissions during construction and maintenance.**

We assume default values as it wasn't possible to get specific values. In detail we assumed vegetated swale default values for standard drainage canal energy consumed and emissions during construction.

Standard canal:

770760 KWh for energy consumed during construction (18000 m^2 * 42.82 KWh/m^2)

241380 kgCO_2 for emissions during construction (18000 m^2 * 13.41 kgCO_2/m^2);

3359 KWh/year for energy consumed during maintenance;

885 kgCO_2/year for emissions during maintenance;

Pumps:

For pumps we collected technical information and Life-cycle assessment (LCA) analyses about pumping systems (i.e. Xylem Water Solutions AB). We assumed the following values:

Pump energy consumption during the production phase: 128 [KWh/KW]

Pump emissions during the production phase: 23300 [kg CO_2 equiv./kW]

86140 KWh for energy consumed during construction (128 KWh/KW *692 KW)

15680108 kgCO_2 for emissions during construction (23300 kg CO_2 equiv./kW * 692 KW);

2.3.3. Stormwater runoff

- **Description of the hydraulic model used to analyze runoff.**

We didn't use any hydraulic model to analyze runoff, we just used the DST estimation panel.

Total drainage area: 1988934 m^2
The contributing area is drained by the Standard drainage canal
An area weighted runoff coefficient was calculated considering impervious and vegetated areas:
((roofs, standard streets, sidewalks, parks and standard drainage canal surface)*0.93 + (urban and agricultural vegetated areas)*0.13)/total area=
(((695469+18000)*0.93) + ((475465+800000)*0.13))/1988934 = 0.42

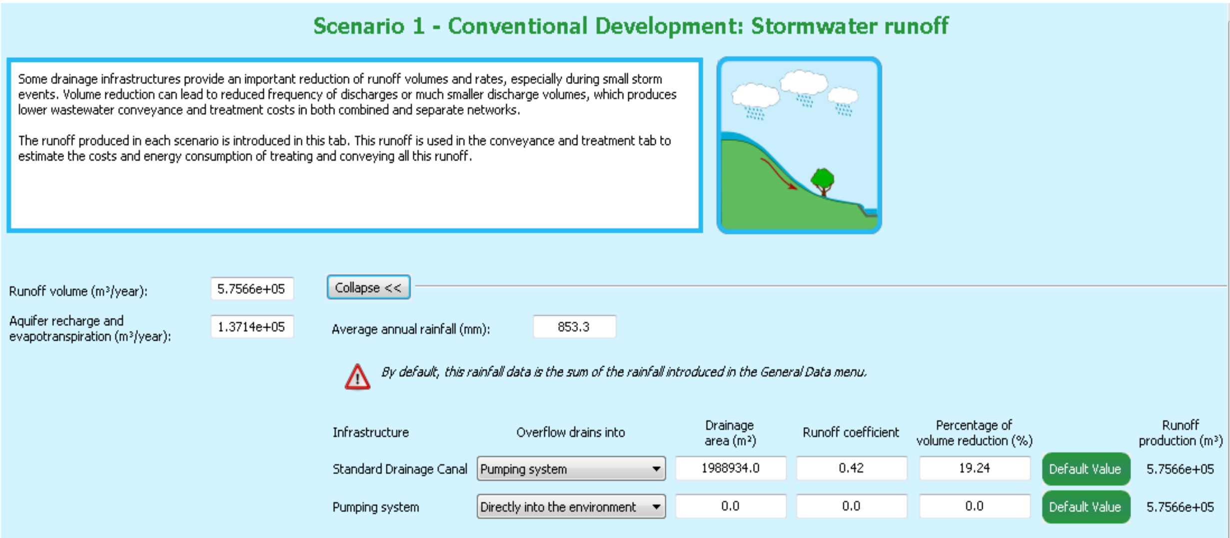
Percentage of volume reduction was also computed as area weighted value:

((roofs, standard streets, sidewalks, parks and standard drainage canal surface)*0% + (urban and agricultural vegetated areas)*30%)/total area=
(((695469+18000)*0%) + ((475465+800000)*30%))/1988934 = 19.24%
Runoff coefficients for impervious and vegetated areas were taken from "Acque Meteoriche di dilavamento", Paolo Montin, Dario Flaccovio Editore, 2012. (see annex 1)

- **Comparison between hydraulic model results and runoff results obtained with the estimation panel.**

Not applicable

- **Global results obtained in this tab.**



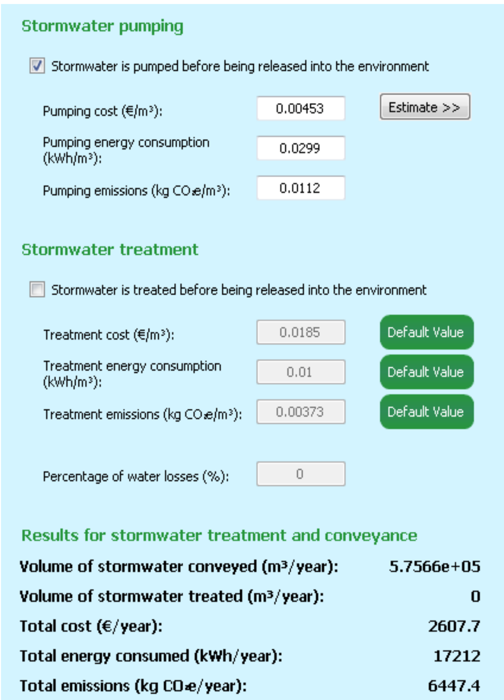
It's worth to be noticed that, in the assumed drainage model, the pumping station has no its own contributing area. The pumping station is the point where all the water drained by the Standard Drainage Canal are conveyed. Conveyance and treatment

Following are the data included in the ***Conveyance and treatment*** menu (with sources and notes).

Type of data	Assigned value	Availability check	Source (PERSON)	Source of data	Note
Stormwater pumping					
Stormwater is pumped before being released into the environment					
Pumping cost (€/m3):	0.003		SSSA	Source: Consorzio di Bonifica - Ufficio dei Fiumi e Fossi (Pisa)	
Height difference (m):	6.4		Pisa Municipality experts		
Mecanichal efficiency (%):	75	Missing data		DEFAULT Value is used	
Electric system efficiency (%):	85	Missing data		DEFAULT Value is used	
Pumping energy consumption (kWh/m3):	0.012		SSSA	Source: Consorzio di Bonifica - Ufficio dei Fiumi e Fossi (Pisa)	
Pumping emissions (kg C02/m3):	0.004		Pisa Municipality experts		Pumping energy consumption (kWh/m3) * per Electricity emissions (kg C02/kWh)
Stormwater treatment					
Stormwater is treated before being released into the environment?	no				
Treatment cost (€/m3):	0				
Treatment energy consumption (kWh/m3):	0				
Treatment emissions (kg CO2/m3):	0				
Percentage of water losses (%):	0				
Flood protection benefits (€/year):	0		Pisa Municipality experts		On the basis of the damage repayments to private citizens authorized by the civil protection office
Case without these drainage infrastructures					
Number of households flooded					
Average damage per household (€)					
Case with these drainage infrastructures					
Number of households flooded					
Average damage per household (€)					

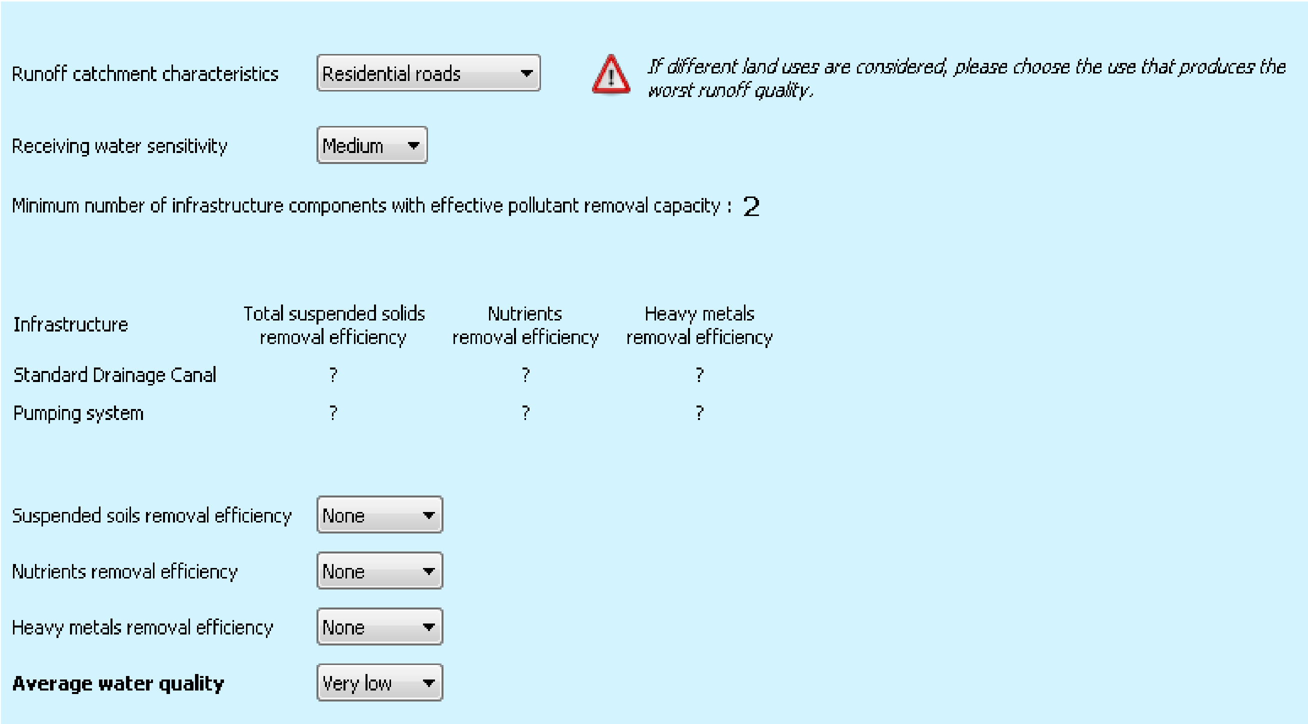
Treatment values have not been implemented as stormwater is not treated.

- **Global results obtained in this tab**



2.3.4. Water quality

A qualitative value of outflow water quality has been estimated as follows:



2.3.5. Flood protection

Same performance strategy is followed to compare the two scenarios. Therefore, flood protection benefits do not need to be included in the analysis since they are assumed to be the same in both scenarios.

2.3.6. Building insulation

This section has not been considered in the analysis.

2.3.7. Summary

- Please, go to section 2.4 for summary tables.

The main issue in performing the analysis is the scarcity of reliable data concerning construction and maintenance costs of drainage infrastructures for the pilot area (we sometimes had to assume default values).

A sensitivity analysis tool would then be needed.

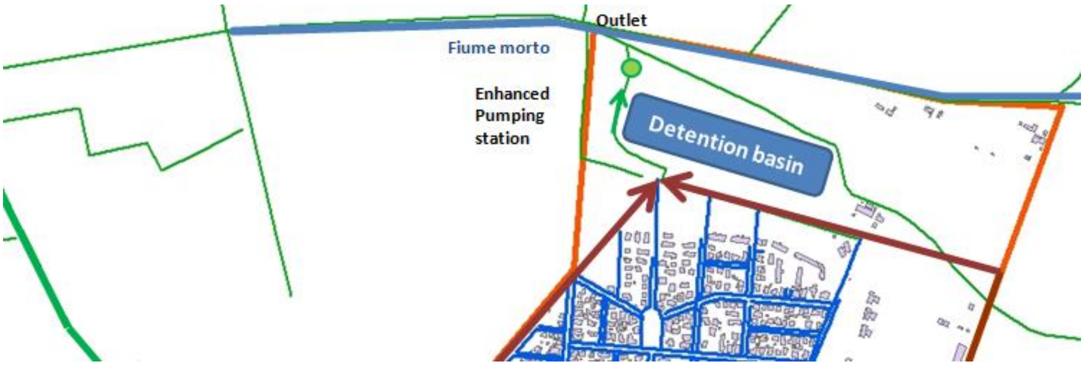
2.4. Scenario 2: Development with SuDS

2.4.1. General description

- ***General description of proposed solution.***

A proposal of intervention with SuDS drainage structure has already been discussed by Pisa Municipality and it considers the realization of a detention basin to provide flood protection to the Pilot area. Such proposal also considers the realization of a standard drainage canal, similar to the previous one. In the SuDS scenario, we hypothesize to replace the standard drainage canal with a vegetated swale. A number of 5 pumps is foreseen in this development.

- ***Map of these solutions.***



- ***General criteria that have guided the design of drainage infrastructures.***

The general criteria followed in the design was to assure the safety of the area during extreme events.

2.4.2. Drainage infrastructures included in the scenario

- ***Description of included infrastructures.***

In this Scenario the following infrastructure have been set in place:

<u>*Vegetated swale*</u> (1800*9 = 16200 m^2)

<u>*Grass lined Detention basin*</u> (128000 m^2) (Source: Chart IDR.04, Sistemazione idraulica Pisa Nord Opere a servizio dell'abitato di Porta a Lucca, Comune di Pisa & Consorzio di bonifica Ufficio dei Fiumi e Fossi Pisa). A volume of 25600 m^3 was set.

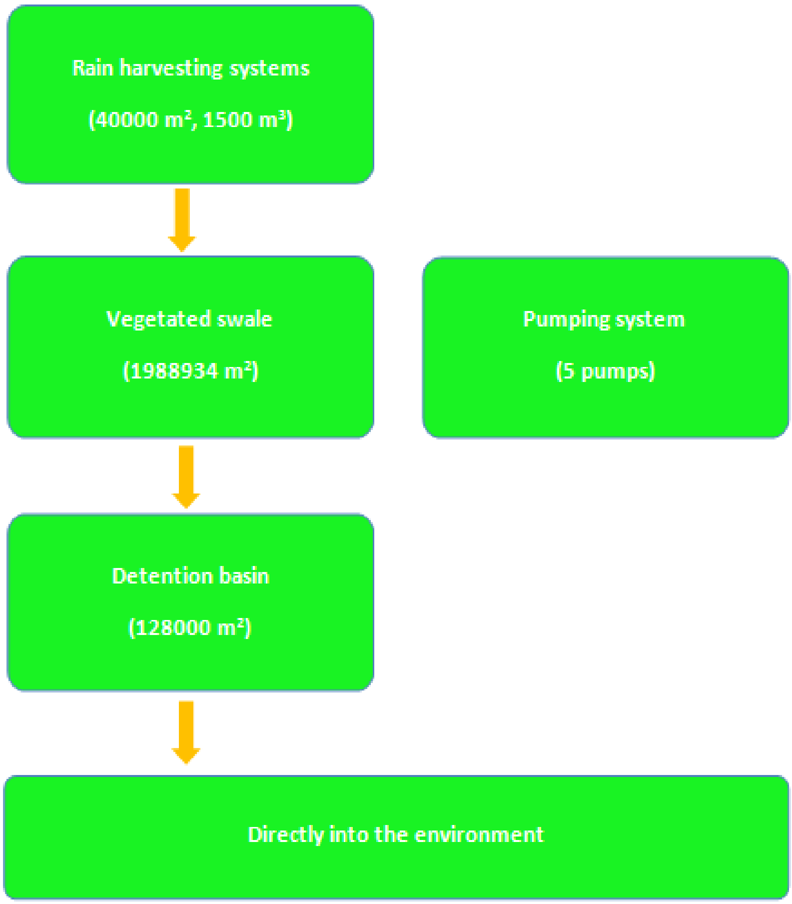
<u>*Pumping station*</u> equipped with 5 pumps*;

<u>*Rain harvesting systems*</u> in the form of a simple water reuse deposit (40000 m^2, 1500 m^3).

*A number of 5 pumps (overall peak flow rate: 7 m^3/s, about 481 KW) are required by the Land Reclamation Consortium "Consorzio 4 Basso Valdarno", ex "Consorzio di bonifica Ufficio dei Fiumi e Fossi Pisa"

The "pumping station", raising water from the canal, was created as independent infrastructure in order to properly account for Energy and Emissions associated to the pumps' construction and set in place. The drainage surface of such infrastructure is anyway considered as null.

Following is a sketch of the proposed SuDS solution.



- ***Summary of values included in the DST.***

Type of data	Assigned value	Availability check	Source (PERSON)	Source of data	Note
Water supply cost					
Water cost (€/m^3)	1.74		Pisa Municipality experts	Acque spa (http://www.acque.net/tariffe-fornitura)	Excluding the fixed rates per annum and assuming that households are the 60%, industrial 10% and services 20%. Household tariff is 1,41 €/m3 (between 0-80 m3/year) + € 2,82/m3 (between 81-200 m3/year); Industry tariff is € 2,43/m3 (between 0- 180 m3/year); Services tariff (non domestic users) is € 2,43/m3 (between 0 - 180 m3/year)
Energy consumed in water acquisition					
Energy consumed in water acquisition (kWh/m^3):					
Emissions in water acquisition (kg CO_2/m^3):					
Water supply source:	groundwater				
Height difference (m):	150		Pisa Municipality experts		The acquifer is between 100 and 200 meters deep
Mechanic efficiency (%):	75	Missing data		DEFAULT Value is used	
Electric system efficiency (%):	85	Missing data		DEFAULT Value is used	
Type of treatment:	chlorination				
Energy consumed in water conveyance					
Energy consumed in water conveyance (kWh/m3):					
Emissions in water conveyance (kg CO2/m3):					
Height difference (m):	7		Pisa Municipality experts		Estimated
Average internal diameter of pipes (mm):	250	Missing data		DEFAULT Value is used	
Average water velocity (m/s):	1.5	Missing data		DEFAULT Value is used	
Average roughness height (mm):	0.007	Missing data		DEFAULT Value is used	
Distance between water source and distribution tank (m):	3500		Pisa Municipality experts		Computed as the average between San Biagio wells distance to its tank (0 meters) and Filettole wells to Orzignano tank (7000 meters)
Minor losses in pipes (percentage of friction losses) (%):	10	Missing data		DEFAULT Value is used	
Mecanichal efficiency (%):	75	Missing data		DEFAULT Value is used	
Electric system efficiency (%):	85	Missing data		DEFAULT Value is used	
Energy consumed in water distribution					
Energy consumed in water distribution (kWh/m3):					
Emissions in water distribution (kg CO2/m3):					
Height difference (m):	33		Pisa Municipality experts		Calculated as the average between San Biagio deposit-utilities height difference (3 meters) and Orzignano tank-utilities height difference (63 meters)
Average internal diameter of pipes (mm):	150	Missing data		DEFAULT Value is used	
Average water velocity (m/s):	1.5	Missing data		DEFAULT Value is used	
Average roughness height (mm):	0.007	Missing data		DEFAULT Value is used	
Distance between distribution tank and water supply point (m):	5000		Pisa Municipality experts		Calculated as the average between tank Orzignano distance to the utilities (6000 meters) and San Biagio distance to the utilities (4000 meters)
House water pressure (kPa):	300	Missing data		DEFAULT Value is used	
Minor losses in pipes (percentage of friction losses) (%):	15	Missing data		DEFAULT Value is used	
Mecanichal efficiency (%):	75	Missing data		DEFAULT Value is used	
Electric system efficiency (%):	100	Missing data		DEFAULT Value is used	
Water supply network					
Water losses in the network (%):	30		Pisa Municipality experts	Acque spa	

Type of data	Assigned value	Source	Note
Irrigation or cleaning of drainage infrastructures			
Volume of water consumed (m^3/year):	18000	SSSA	Estimated
Rainwater reuse by harvesting systems			
Storage capacity (m^3):	1500		
Drainage area (m^2):	40000		
Runoff coefficient:	0.93		
Filter efficiency (%):	90		
October Water demand (m^3)	1500		non-potable uses (i.e. flushes)
November Water demand (m^3)	1500		non-potable uses (i.e. flushes)
December Water demand (m^3)	1500		non-potable uses (i.e. flushes)
JanuaryWater demand (m^3)	1500		non-potable uses (i.e. flushes)
February Water demand (m^3)	1500		non-potable uses (i.e. flushes)
March Water demand (m^3)	1500		non-potable uses (i.e. flushes)
April Water demand (m^3)	1500		non-potable uses (i.e. flushes)
May Water demand (m^3)	1500		non-potable uses (i.e. flushes)
June Water demand (m^3)	1500		non-potable uses (i.e. flushes)
July Water demand (m^3)	1500		non-potable uses (i.e. flushes)
August Water demand (m^3)	1500		non-potable uses (i.e. flushes)
September Water demand (m^3)	1500		non-potable uses (i.e. flushes)

- ***Process followed to estimate construction and maintenance costs.***

Construction costs:

Vegetated swale:

16.57 euro/m^2 construction costs, assuming an average depth of 1.6 meters and including 0.39 euro/m^2 (costs of sowing)

total costs = (16.57)*9*1800 = 268434 €

Grass lined detention basin: 25600 m^3 (assuming an average depth of 0.2 meters)

3.41 euro/m^3 (costs of ground digging)

7.41 euro/m^3 (costs of backfilling the excavated material)

Source: "Piano particolareggiato per ampliamento della zona produttiva di Ospedaletto"- Consorzio area produttiva intercomunale Pisa-Cascina

In order to favor the maintenance of a grass layer by reducing evapotranspiration, and generally obtain aesthetic/environmental benefits, 200 tall trees (300 €/tree) can be planted on the area devoted to the grass lined detention basin.

The total construction cost would then be:

25600 * (10.82) + 60000 = 336992 €

276992+ 60000 = 336992 €

5 Pumps: 275000.0 € (this cost has been estimated assuming the unit cost of 56000 € each);

Rain harvesting systems: 1500*250 €/m^3 (default construction value from DST) = 375000 €

Maintenance costs:

Vegetated swale: 1800*9*0,1 €/m^2 (default maintenance value for vegetated swale from DST) = 1620 €/year

Grass lined detention basin: 25600 m^3*0,11 €/m^3 (by assuming a maintenance of 10% of the infrastructure volume once every 10 years) = 2816 €/year

Pumps: 20000 €/year (5 water pumps maintenance - indicative value provided by staff of Reclaimed Land Consortium)

Rain harvesting systems unit maintenance cost: 5 €/year/m^3 (= 375000/(2*30*1500, by assuming a maintenance of 50% of the infrastructure cost once every 30 years).

Yearly maintenance cost = 7500 €/year

- **Process followed to estimate energy consumed and emissions during construction and maintenance.**

We assume default values as it wasn't possible to get specific values. In detail we assumed vegetated swale default values for standard drainage canal energy consumed and emissions during construction.

Pumps:

For pumps we collected technical information and Life-cycle assessment (LCA) analyses about pumping systems (i.e. Xylem Water Solutions AB). We assumed the following values:

Pump energy consumption during the production phase: 128 [KWh/KW]

Pump emissions during the production phase: 23300 [kg CO2 equiv./kW]

61528 KWh for energy consumed during construction (128 KWh/KW *692 KW)

11200077 kgCO_2 for emissions during construction (23300 kg CO2 equiv./kW * 692 KW);

2.4.3. Water reuse

Rainwater reuse by harvesting systems

Volume of water reused (m³/year): 1.8e+04

Collapse <<

Storage capacity (m³): 1500.0

Drainage area (m²): 40000.0

Runoff coefficient: 0.93 Default Value

Filter efficiency (%): 90.0 Default Value

Month	Inflow volume (m³)	Water demand (m³)	Initial water volume (m³)	Final water volume (m³)	Water reused (m³)
October	4195	1500.0	0	1500	1500
November	4604	1500.0	1500	1500	1500
December	3130	1500.0	1500	1500	1500
January	2076	1500.0	1500	1500	1500
February	1741	1500.0	1500	1500	1500
March	1584	1500.0	1500	1500	1500
April	2467	1500.0	1500	1500	1500
May	2203	1500.0	1500	1500	1500
June	1473	1500.0	1500	1473	1500
July	666.3	1500.0	1473	639.4	1500
August	1453	1500.0	639.4	592.4	1500
September	2976	1500.0	592.4	1500	1500

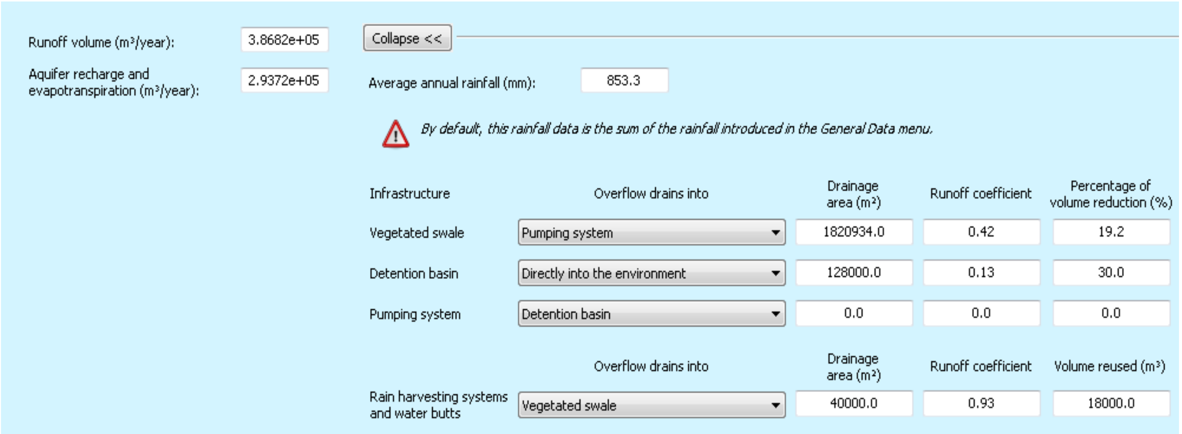
Rainwater reuse by harvesting systems was estimated on the basis of inflow water from rainfall and water demand volumes. The water demand was assimilated to the volume of water consumed for toilet flushes in the area by commercial/working sector. This volume was accounted to be an average of 1500 m^3/month (18000 m^3/year) by assuming 1000 users per day, flushing 5 times per day and considering 10 liters of water per toilet flush.

2.4.4. Stormwater runoff

- **Description of the hydraulic model used to analyze runoff.**

We didn’t use any hydraulic model to analyze runoff, we just used the DST estimation panel.

- **Global results obtained in this tab.**



Total surface of the Pilot area: 1988934 m^2

Grass lined Detention basin

Drainage area: 128000 m^2

Runoff coefficient: 0.13 (see annex 1, we assume that Detention basin is empty)

Percentage of volume reduction: 30 % (Source: DST Guidelines)

Rain harvesting systems:

Total drainage area: 40000 m^2

Vegetated swale

Total drainage area: 1988934 m^2

Drainage area: 1988934-128000-40000 = 1820934 m^2

An area weighted runoff coefficient was calculated considering impervious and vegetated areas:

((roofs, standard streets, sidewalks,parks)*0.93 + (urban and agricultural vegetated areas + vegetated swale)*0.13)/total area=

((655469*0.93) + ((347465+800000+18000)*0.13))/1820934 = 0.42

Percentage of volume reduction was also computed as area weighted value:

((roofs, standard streets, sidewalks,parks and standard drainage canal surface)*0% + (urban and agricultural vegetated areas)*30%)/total area=
(((695469)*0%) + ((347465+18000+800000)*30%))/1820934 = 19.24%

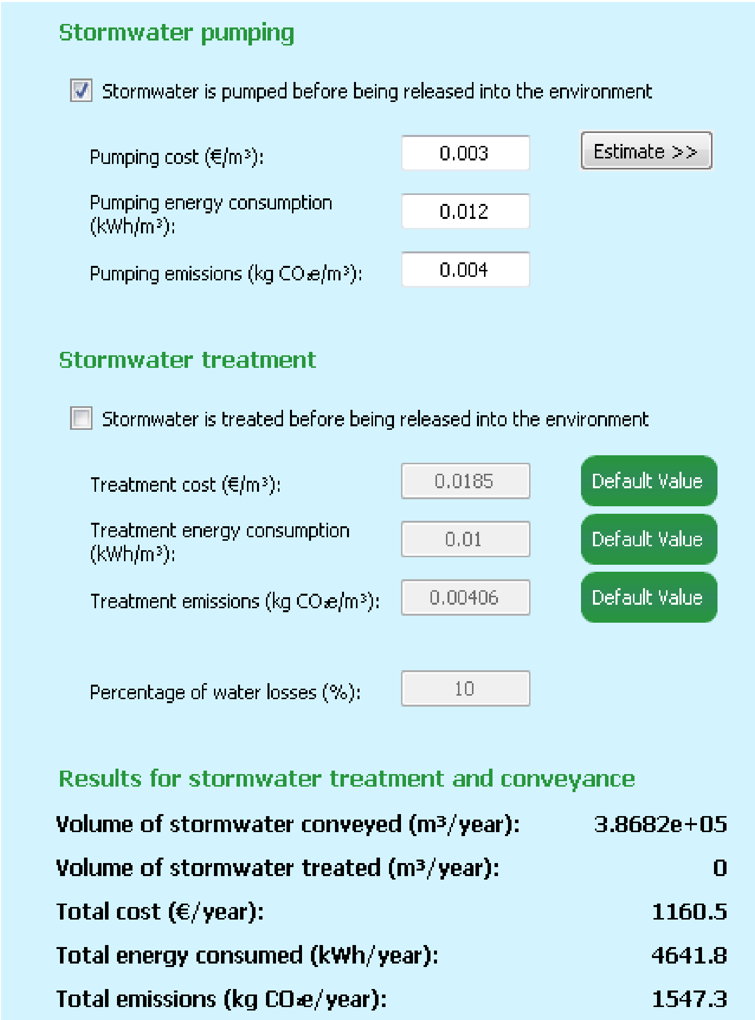
Runoff coefficients for impervious and vegetated areas were taken from "Acque Meteoriche di dilavamento", Paolo Montin, Dario Flaccovio Editore, 2012. (see annex 1)

2.4.5. Conveyance and treatment

- **Description of data included in this tab.**

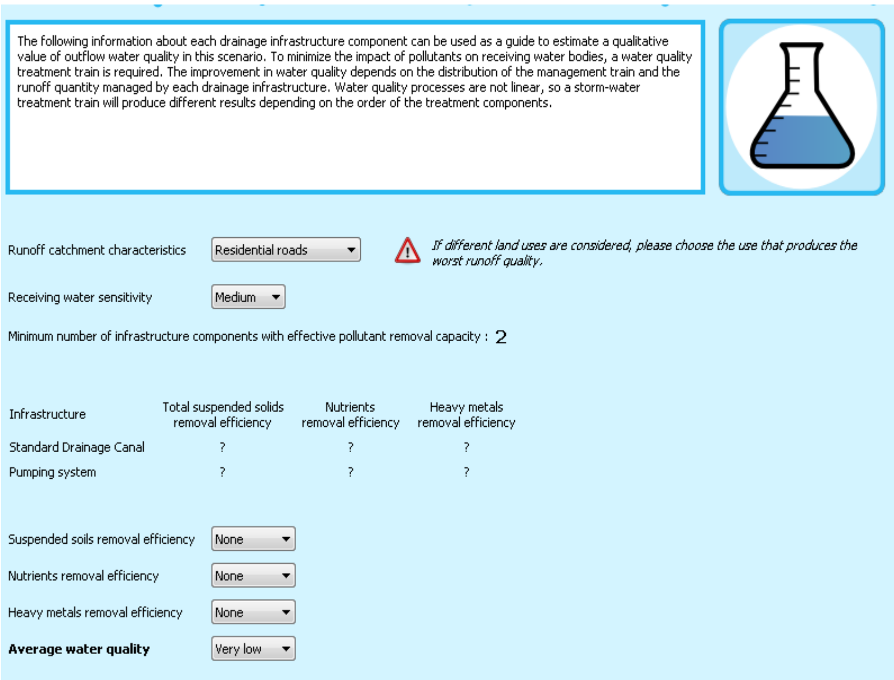
Same data used for the conventional scenario.

- **Global results obtained in this tab**



2.4.6. Water quality

A qualitative value of outflow water quality has been estimated as follows:



2.4.7. Flood protection

Same performance strategy is followed to compare the two scenarios. Therefore, flood protection benefits do not need to be included in the analysis since they are assumed to be the same in both scenarios.

2.4.8. Summary tables

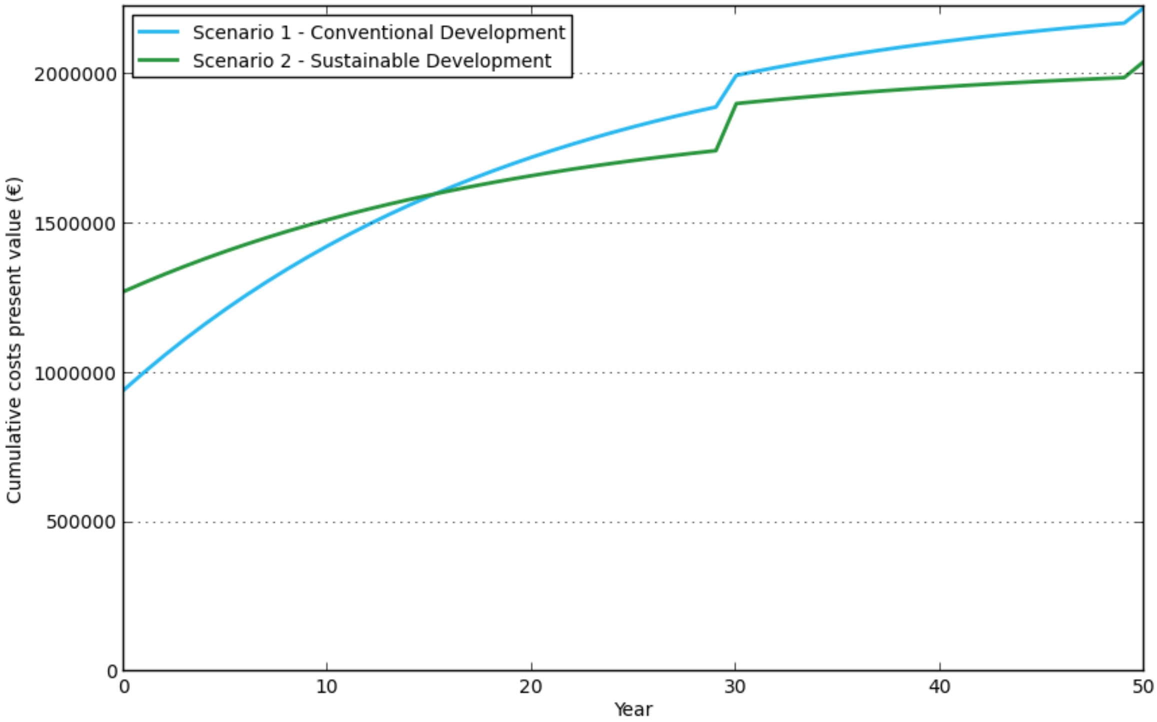
Following are the tables both for the Conventional and the SuDS Scenario.

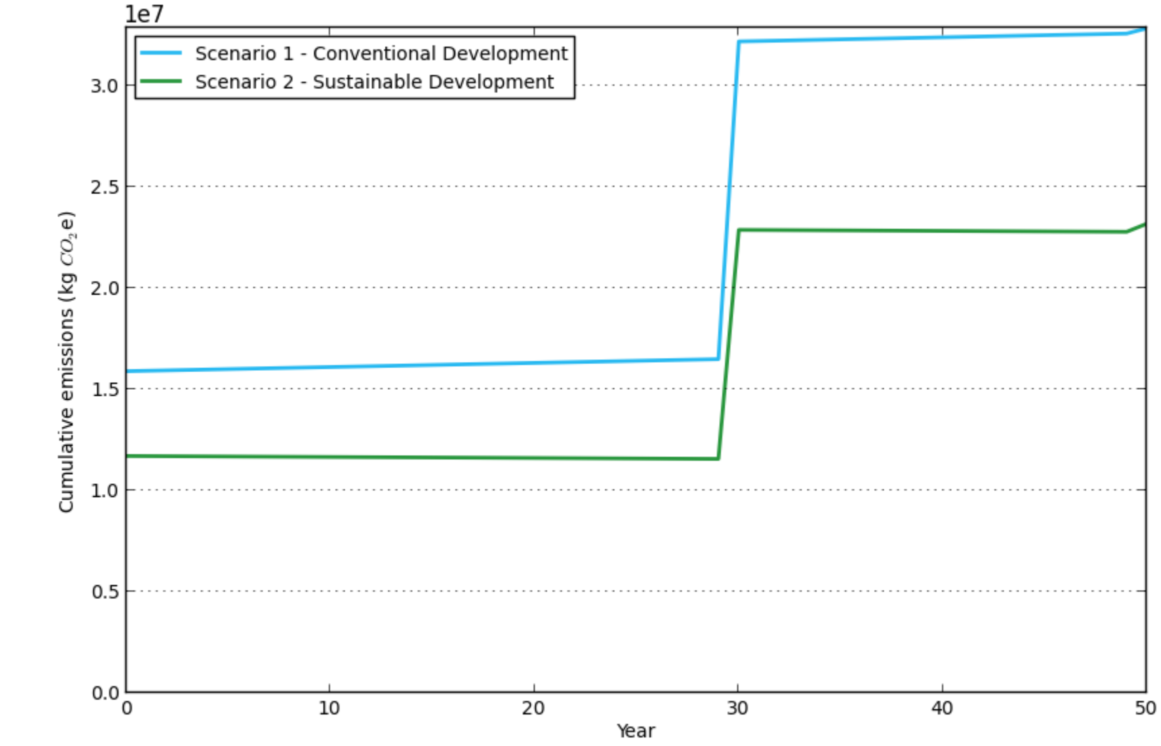
Scenario		Financial cost	Energy consumption	Emissions
Scenario 1	Construction of infrastructures	9.4194e+05 €	8.569e+05 kWh	1.5921e+07 kg CO_2e
	Maintenance of infrastructures	30600 €/year	3359 kWh/year	885 kg CO_2e/year
	Infrastructure landtake	2286 €	-	-
	Potable water consumed and saved	31320 €/year	35229 kWh/year	13143 kg CO_2e/year
	Stormwater conveyance and treatment	2607.7 €/year	17212 kWh/year	6447.4 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
Scenario 2	Construction of infrastructures	1.2554e+06 €	1.7767e+06 kWh	1.173e+07 kg CO_2e
	Maintenance of infrastructures	31936 €/year	3141.8 kWh/year	826.88 kg CO_2e/year
	Infrastructure landtake	18313 €	-	-
	Potable water consumed and saved	0 €/year	0 kWh/year	0 kg CO_2e/year
	Stormwater conveyance and treatment	1160.5 €/year	4641.8 kWh/year	1547.3 kg CO_2e/year
	Flood protection	0 €/year	-	-
	Building insulation	0 €/year	0 kWh/year	0 kg CO_2e/year
	Carbon dioxide reduction	-	-	-7340 kg CO_2e/year
	Other costs and benefits	0 €/year	0 kWh/year	0 kg CO_2e/year

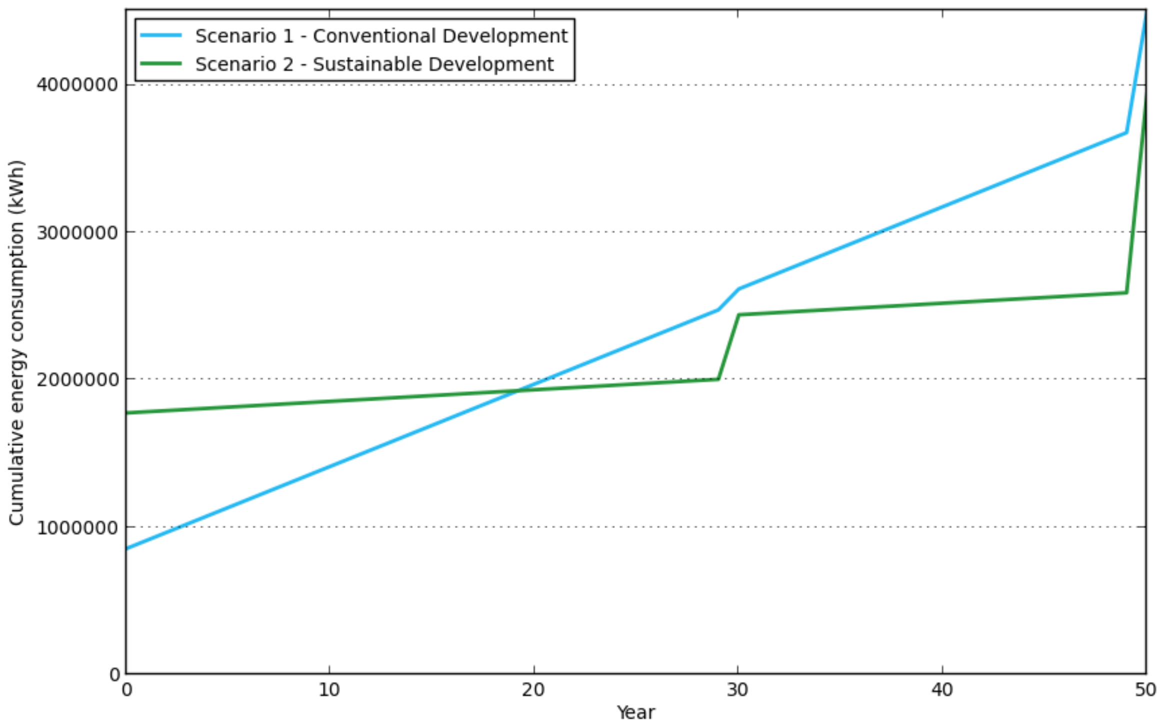
2.5. RESULTS

2.5.1. Time graphs

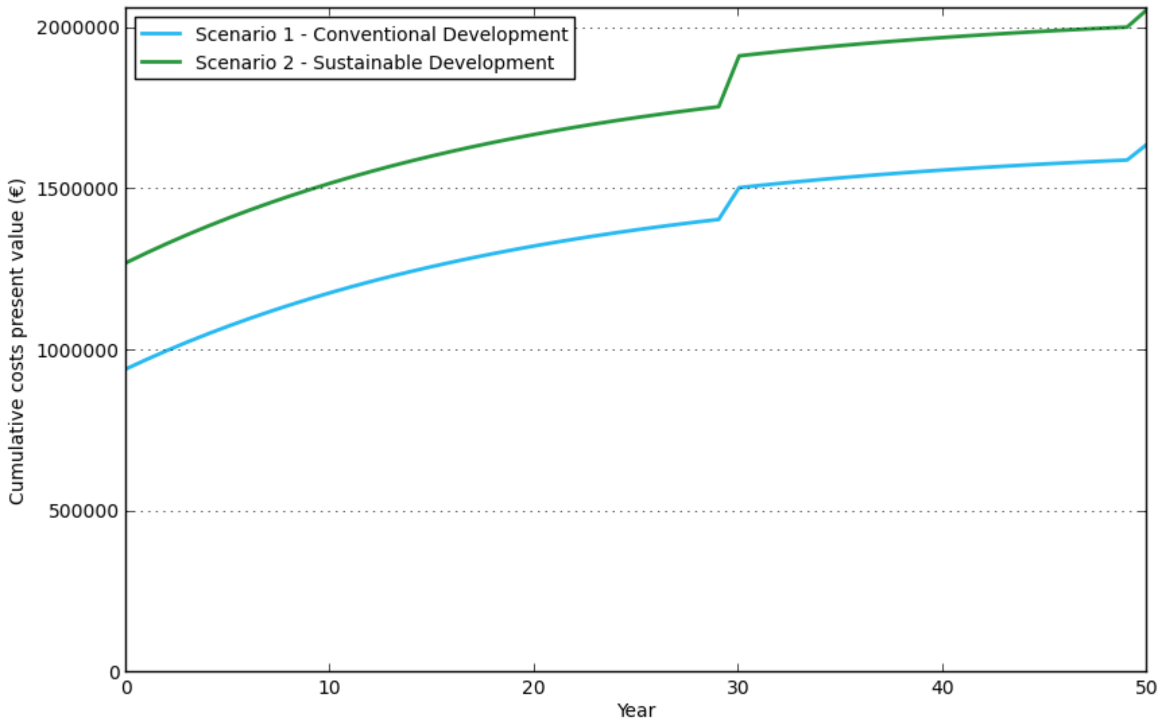
- **Global time graphs obtained with the DST.**

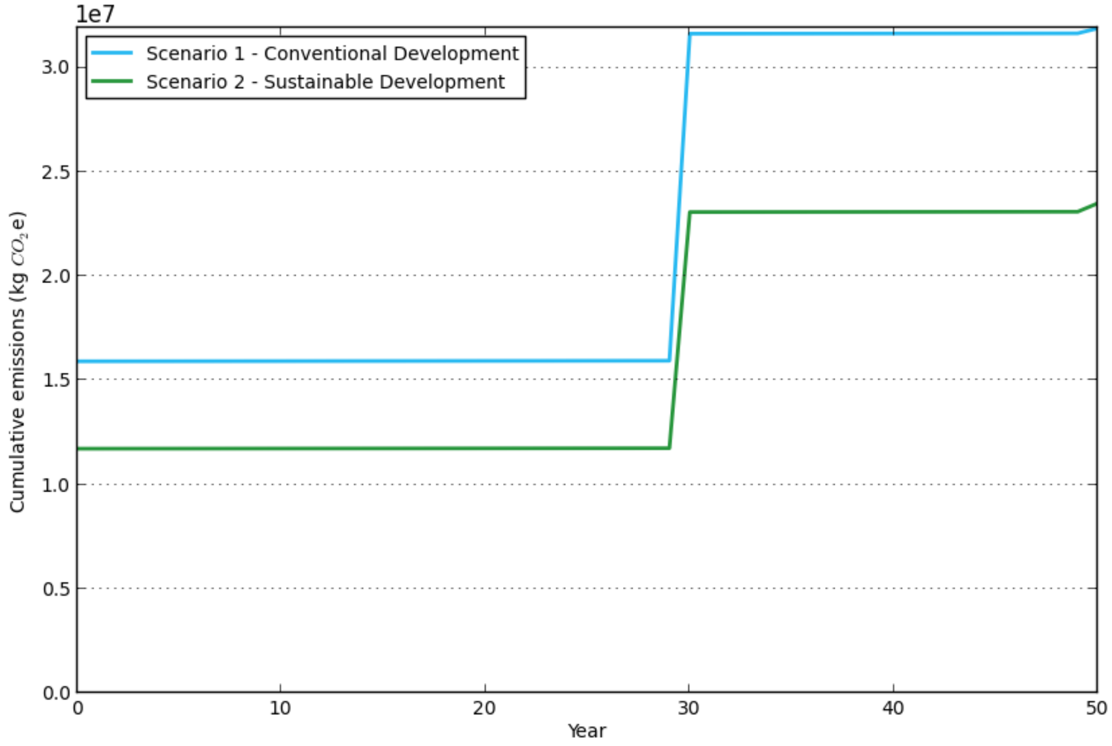


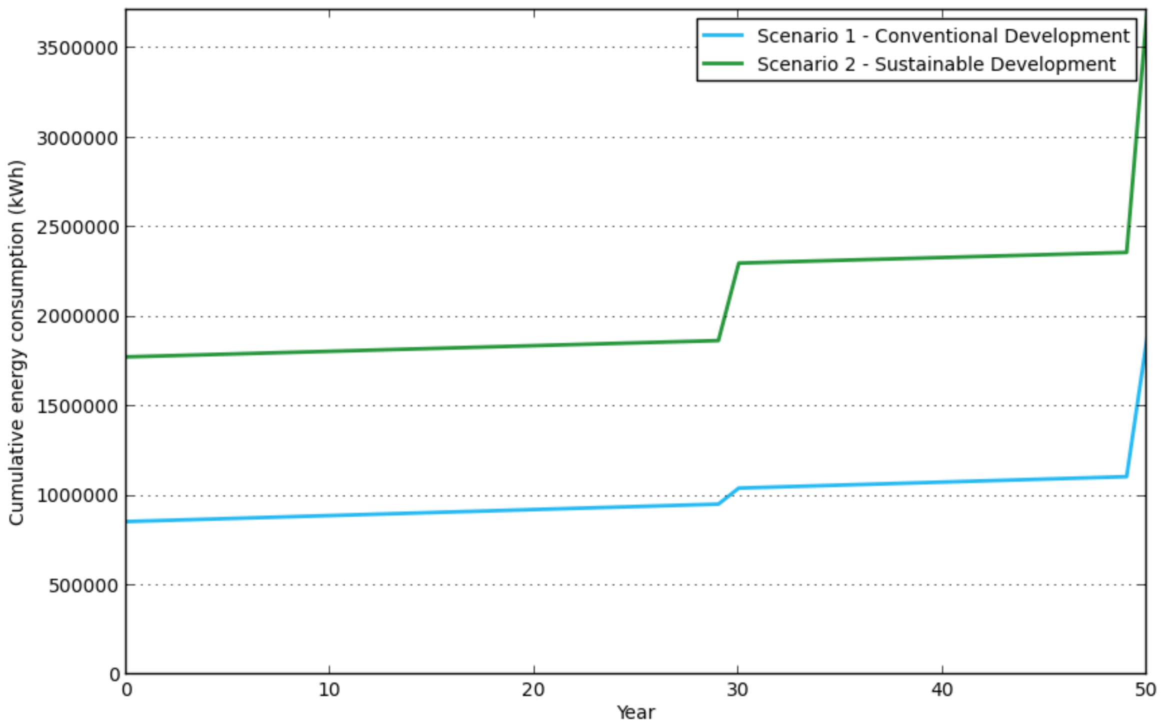

1e7
Scenario 1 - Conventional Development
Scenario 2 - Sustainable Development
Cumulative emissions (kg CO_2 e)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
10
20
30
40
50
Year


Scenario 1 - Conventional Development
Scenario 2 - Sustainable Development
Cumulative energy consumption (kWh)
0
1000000
2000000
3000000
4000000
0
10
20
30
40
50
Year

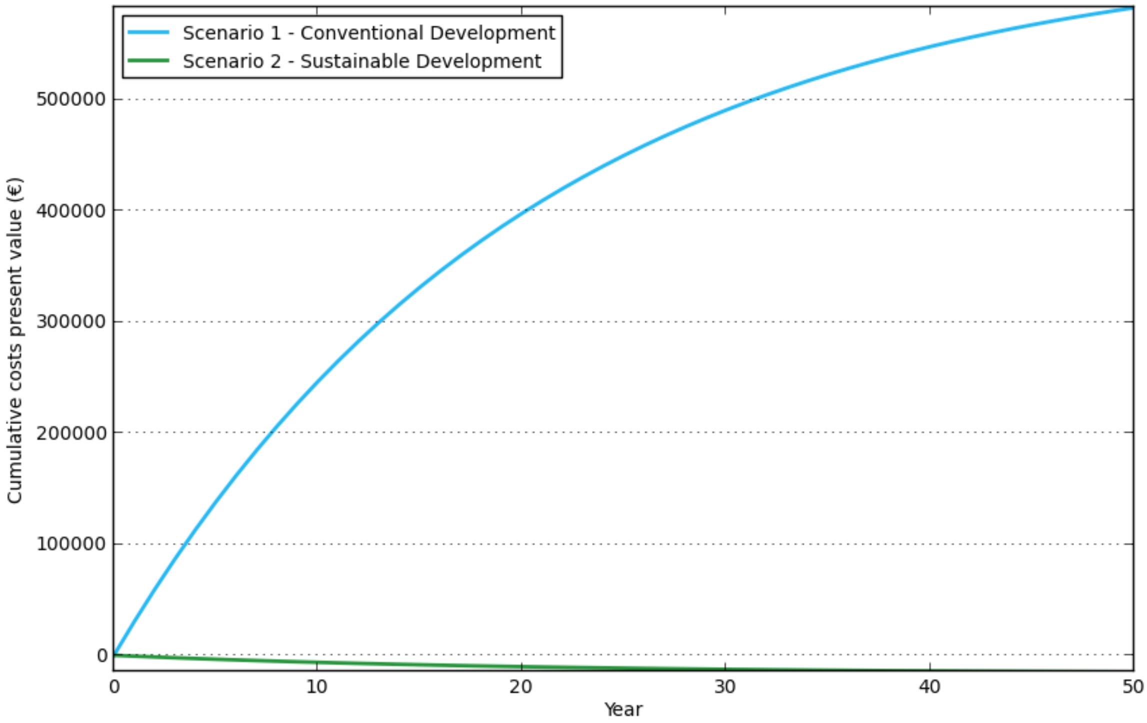
- **Time graphs obtained with only construction and maintenance.**

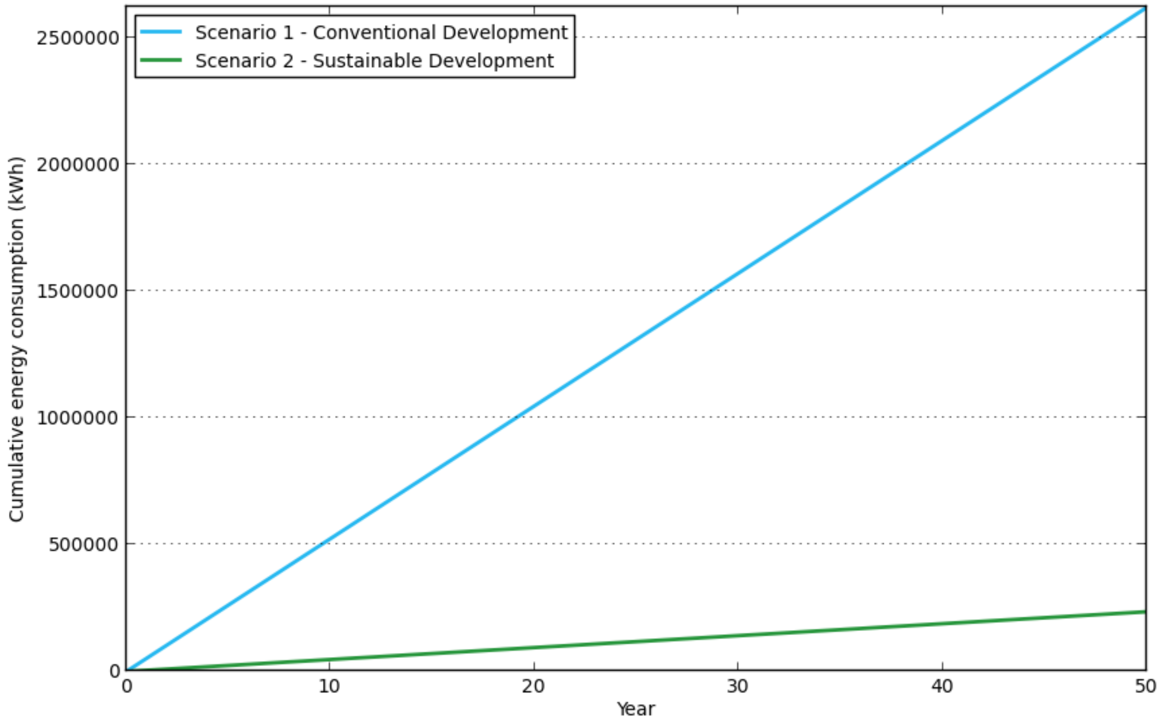


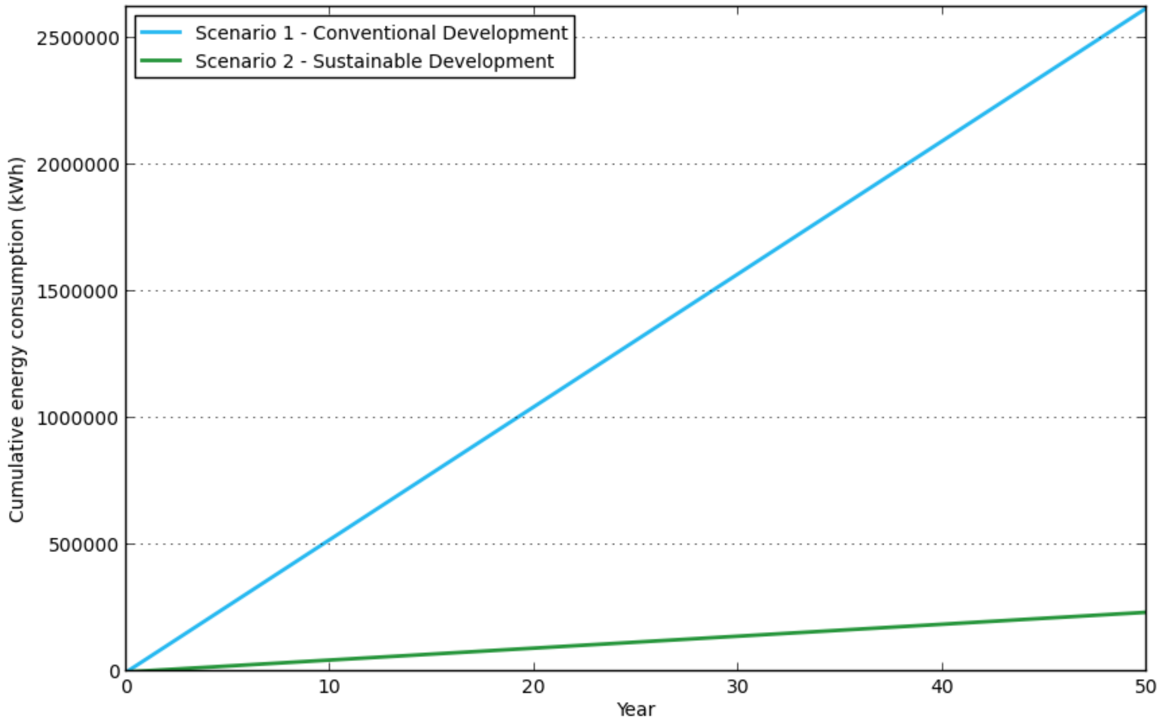

1e7
Scenario 1 - Conventional Development
Scenario 2 - Sustainable Development
Cumulative emissions (kg CO_2e)
Year


Scenario 1 - Conventional Development
Scenario 2 - Sustainable Development
Cumulative energy consumption (kWh)
Year

- **Time graphs obtained without construction and maintenance.**




Scenario 1 - Conventional Development
Scenario 2 - Sustainable Development
Cumulative energy consumption (kWh)
Year
0
500000
1000000
1500000
2000000
2500000
0
10
20
30
40
50


Scenario 1 - Conventional Development
Scenario 2 - Sustainable Development
Cumulative energy consumption (kWh)
Year
0
500000
1000000
1500000
2000000
2500000
0
10
20
30
40
50

- **Explanation and justification of results.**

Critical issue in the comparison between the two scenarios is the determination of accurate values for construction and maintenance of the infrastructures. In the selected scenario, the costs of construction and maintenance for the detention basin and rain harvesting system greatly overwhelm energy savings attained by raising a lower volume of drained water. Anyway, the global cost time graph shows that already after about 15 years the sustainable scenario costs equal the conventional scenario ones, due to water reuse savings.

2.5.2. Decision criteria

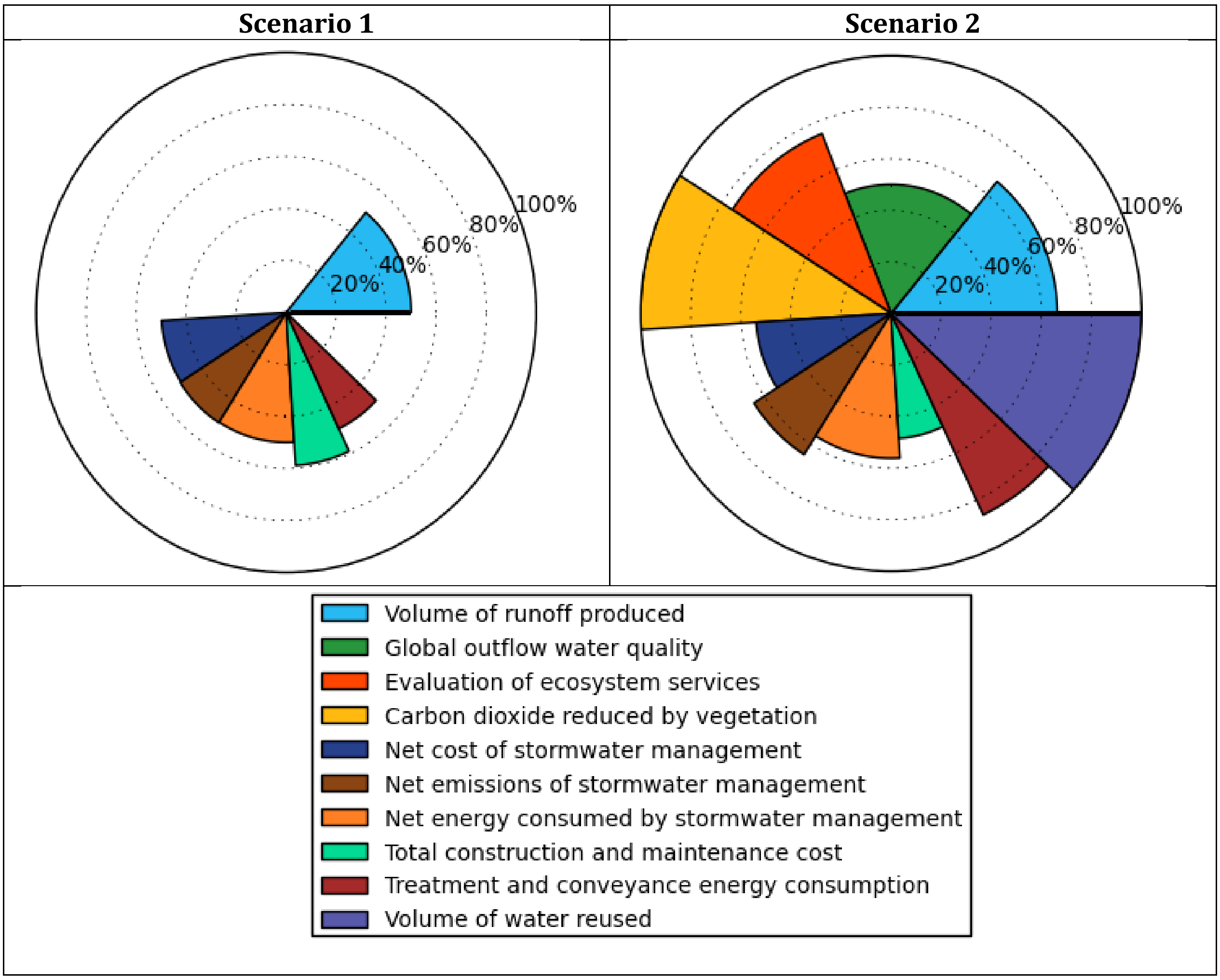
- **Decision criteria chosen.**

The selected criteria are shown in the following table along with respective weights assigned. Stakeholders and managers took part in the decision process (See the "IV Regional Working Group on Energy Efficiency minutes" in attachment for details).

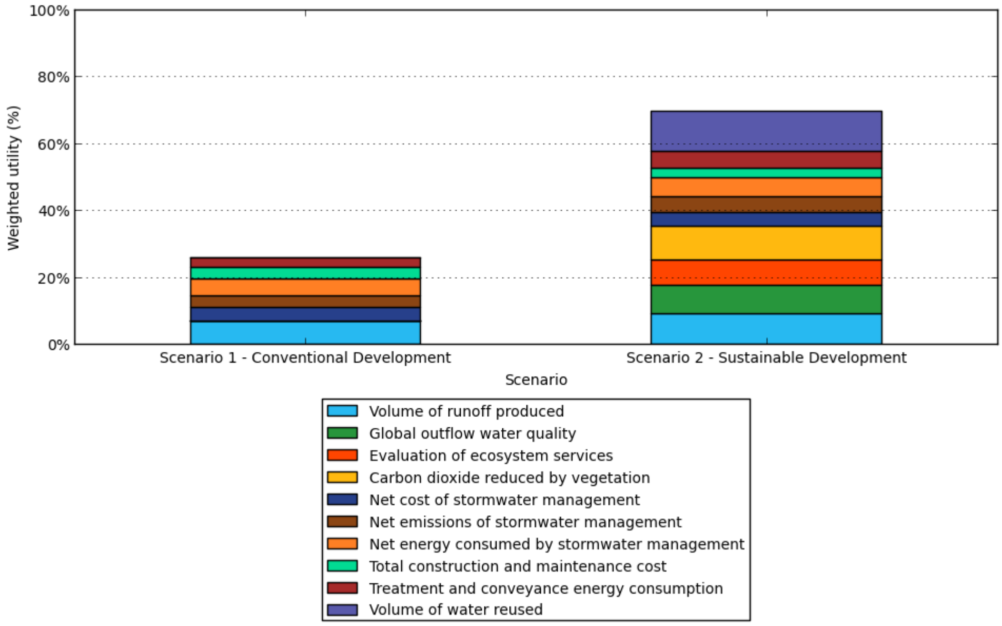
Selected decision criteria	Weight assigned by stakeholders																			Average weight (%)
Carbon dioxide reduced by vegetation	0	0	10	15	0	7.5	8	15	40	15	10	5	15	20	5	0	0	8	10	**10**
Evaluation of ecosystem services	20	25	10	25	0	5	4	5	10	15	10	5	15	0	20	0	0	7	10	**10**
Global outflow water quality	10	10	15	10	70	15	5	10	5	20	10	30	15	20	20	20	10	15	15	**17**
Net cost of stormwater management	0	0	10	0	0	10	15	5	20	0	0	5	15	0	5	20	30	8	5	**8**
Net emissions of stormwater management	0	0	10	0	0	5	8	10	5	0	10	5	15	20	10	30	0	7	10	**7**
Net energy consumed by stormwater management	5	0	15	15	0	20	15	10	5	0	10	2.5	10	0	10	30	20	15	10	**10**
Total construction and maintenance cost	5	5	20	0	5	5	10	5	5	20	0	2.5	0	0	5	0	0	10	10	**6**
Treatment and conveyance energy consumption	10	10	0	25	5	10	15	10	6	0	0	5	0	0	5	0	0	8	0	**6**
Volume of runoff produced	40	40	5	0	0	15	15	20	2	0	25	30	5	20	10	0	30	7	10	**14**
Volume of water reused	10	10	5	10	20	7.5	5	10	2	30	25	10	10	20	10	0	10	15	20	**12**

2.5.3. Multi-criteria analysis results

- Circular results per scenario (graphs and table).



- Global results (graph and table).



2.6. CONCLUSIONS

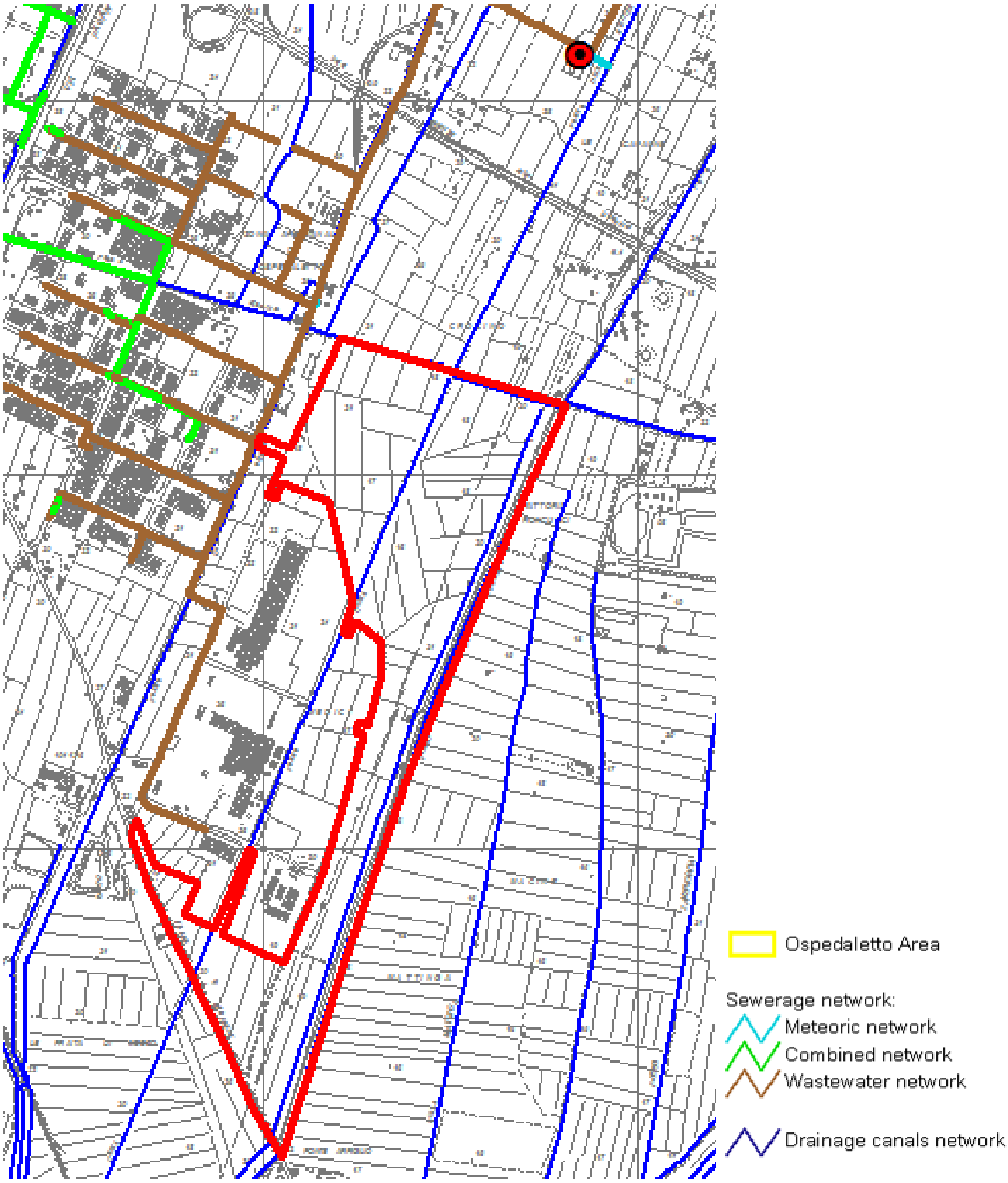
Being the area densely populated and already developed, a retrofitting solution is needed. In that framework, and given the low cost of pumps, SuDS are economically not convenient. An important issue is also related to the presence of a shallow water table which make SuDS not the best sustainable drainage solution. Moreover, a critical issue is the determination of accurate values for construction and maintenance of the infrastructures. In the selected scenario, the costs of construction and maintenance for the detention basin, greatly overwhelm energy savings attained by raising a lower volume of drained water. Hence, reliable data are needed in order to apply the DST and properly compare the two scenarios.

3. PILOT CASE 2: NEW DEVELOPMENT AREA

3.1. GENERAL DESCRIPTION

Area: 651 185 m^2

- **Location map of this area.**



- **Main characteristics**

Selected area, within Ospedaletto, is at present a rural one – with farming still going on in some cases.

Ospedaletto area belongs to the basin of Fossa Chiara, which is partly natural drainage and partly mechanical drainage. The drainage channels of high water flow naturally (by gravity) to the Fossa Chiara, those of shallow water flow into the Fossa Chiara by Arnaccio dewatering pump. Then the Fossa Chiara flows into the Canale dei Navicelli which flows into the Canale Scolmatore of Arno River which reaches the Thyrrenian Sea.

- **Main problems/issues to be solved.**
- Ospedaletto is a natural depressed area, its elevation is below the sea level
- The sections of the channels and the lights of the bridges are not sufficient during sever storm
- The channels are subject to silting
- Flood levels in drainage channels cause sewers overflow and backwater phenomena
- Sewage discharges directly into stream
- There are losses in wastewater network system due to the average life of pipes

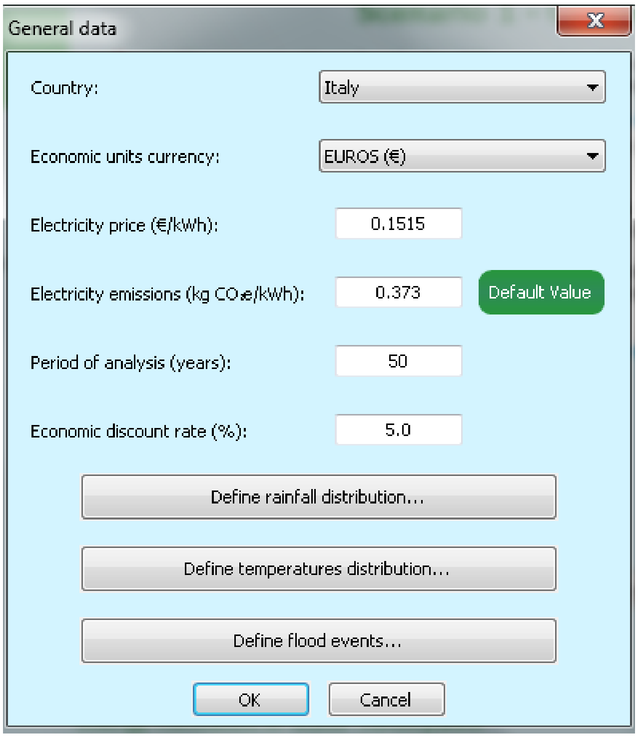
In evaluating conventional against sustainable drainage scenarios, same performance strategy is followed considering flood protection benefits. Therefore, flood protection benefits are not included in the analysis since they are assumed to be the same in both scenarios.

- **Expected energy benefits with SuDS option.**

  As for the previous area, expected energy benefits are related to reduction of stormwater pumping.

3.2. General model data

General model data are presented in the picture below.



Following are the data included in the General Data menu with the source.

Electricity price (€/kWh): 0.1515 (Source: Acque spa)

Electricity emissions (kg $C0_2$/kWh): 0.373 (Source: Istituto Superiore per la Protezione e la Ricerca Ambientale, http://www.sinanet.isprambiente.it/it/sia-ispra/serie-storiche emissioni/fattori-di-emissione-per-la-produzione-ed-il-consumo-di-energia-elettrica-in-italia/view)

Period of analysis (years): 50

Economic discount rate (%): 5 (source: "Guida per la certificazione da parte dei Nuclei regionali di valutazione e verifica degli investimenti pubblici", Conferenza dei Presidenti delle Regioni e delle Province autonome)

Rainfall distribution (Source: Centro Funzionale Regionale, Regione Toscana):

January Average rainfall (mm)	62
Feb Average rainfall (mm)	52
Mar Average rainfall (mm)	47.3
Apr Average rainfall (mm)	73.7
Maj Average rainfall (mm)	65.8
Jun Average rainfall (mm)	44
Jul Average rainfall (mm)	19.9
Aug Average rainfall (mm)	43.4
Sept Average rainfall (mm)	88.9
Oct Average rainfall (mm)	125.3
Nov Average rainfall (mm)	137.5
Dec Average rainfall (mm)	93.5

Flood events (flood event return period): 15

- The only comparable data is the Electricity emissions one. Our value (0.373 kg $C0_2$/kWh) is lower than the default one 0.406 kg $C0_2$/kWh.

3.3. Scenario 1: Conventional development

3.3.1. General description

- **General description of proposed solution.**

Within this scenario conventional structures have been selected, their aim, being mostly impervious structures, is to get rid of stormwater as fast as possible – no considerations were made on runoff reduction or potential energy or CO_2 emissions savings.

- **General criteria that have guided the design of drainage infrastructures.**

General criteria is related to the need to relief the area from intense rainfall events (water bombs) causing flash floods.

3.3.2. Drainage infrastructures included in the scenario

- **Summary of values included in the DST**

Type of data	Assigned value	Availability check	Source (PERSON)	Source of data	Note
Water supply cost					
Water cost (€/m^3)	2.21		Pisa Municipality experts	Acque spa (http://www.acque.net/tariffe-fornitura)	Excluding the fixed rates per annum and assuming that households are 30%, the industrial 50% and services 20%.Household tariff is 1,41 €/m3 (between 0-80 m3/year) + € 2,82/m3 (between 81-200 m3/year). Industry tariff is € 2,43/m3 (between 0- 180 m3/year). Services tariff (non domestic users) is € 2,43/m3 (between 0 - 180 m3/year).
Energy consumed in water acquisition					
Energy consumed in water acquisition (kWh/m^3):					
Emissions in water acquisition (kg CO_2/m^3):					
Water supply source:	groundwater				
Height difference (m):	150		Pisa Municipality experts		The acquifer is between 100 and 200 meters deep
Mechanic efficiency (%):	75	Missing data		DEFAULT Value is used	
Electric system efficiency (%):	85	Missing data		DEFAULT Value is used	
Type of treatment:	chlorination				
Energy consumed in water conveyance					
Energy consumed in water conveyance (kWh/m3):					
Emissions in water conveyance (kg CO2/m3):					
Height difference (m):	7		Pisa Municipality experts		Estimated
Average internal diameter of pipes (mm):	250	Missing data		DEFAULT Value is used	
Average water velocity (m/s):	1.5	Missing data		DEFAULT Value is used	
Average roughness height (mm):	0.007	Missing data		DEFAULT Value is used	
Distance between water source and distribution tank (m):	3500		Pisa Municipality experts		Computed as the average between San Biagio wells distance to its tank (0 meters) and Filettole wells to Orzignano tank (7000 meters)
Minor losses in pipes (percentage of friction losses) (%):	10	Missing data		DEFAULT Value is used	
Mecanichal efficiency (%):	75	Missing data		DEFAULT Value is used	
Electric system efficiency (%):	85	Missing data		DEFAULT Value is used	
Energy consumed in water distribution					
Energy consumed in water distribution (kWh/m3):					
Emissions in water distribution (kg CO2/m3):					
Height difference (m):	33		Pisa Municipality experts		Calculated as the average between San Biagio deposit-utilities height difference (3 meters) and Orzignano tank-utilities height difference (63 meters)
Average internal diameter of pipes (mm):	150	Missing data		DEFAULT Value is used	
Average water velocity (m/s):	1.5	Missing data		DEFAULT Value is used	
Average roughness height (mm):	0.007	Missing data		DEFAULT Value is used	
Distance between distribution tank and water supply point (m):	6000		Pisa Municipality experts		Calculated as the average between tank Orzignano distance to the utilities (9500 meters) and San Biagio distance to the utilities (2500 meters).
House water pressure (kPa):	300	Missing data		DEFAULT Value is used	
Minor losses in pipes (percentage of friction losses) (%):	15	Missing data		DEFAULT Value is used	
Mecanichal efficiency (%):	75	Missing data		DEFAULT Value is used	
Electric system efficiency (%):	100	Missing data		DEFAULT Value is used	
Water supply network					
Water losses in the network (%):	30		Pisa Municipality experts	Acque spa	

In the Conventional scenario, the volume of water consumed for irrigation or cleaning of drainage infrastructures should be null. Anyway, in order to properly compare conventional and sustainable scenarios (the latter having rainwater harvesting systems) we considered reasonable to estimate non-potable water demand (i.e. toilet flushes) for the pilot area and to take it into account as coming from the water supply network in the simulations. The water demand was assimilated to the volume of water consumed for toilet flushes in the area by commercial/working sector. This volume was accounted to be an average of 1500 m^3/month (18000 m^3/year) by assuming 1000 users per day, flushing 5 times per day and considering 10 liters of water per toilet flush.The total yearly Water demand was then estimated as 18687 m^3/year on the basis of demand for non-potable uses, urban green surfaces and evapotranspiration (after Hargreaves).

- **Description of included infrastructures**.

In this scenario we included infrastructures which are planned in the "Piano particolareggiato per ampliamento della zona produttiva di Ospedaletto"- Consorzio area produttiva intercomunale Pisa-Cascina, respecting the areas, but implementing barely impervious ones. They are:

Standard street (Infrastructure area 52977 m^2);

Standard sidewalk (Infrastructure area 9613 m^2);

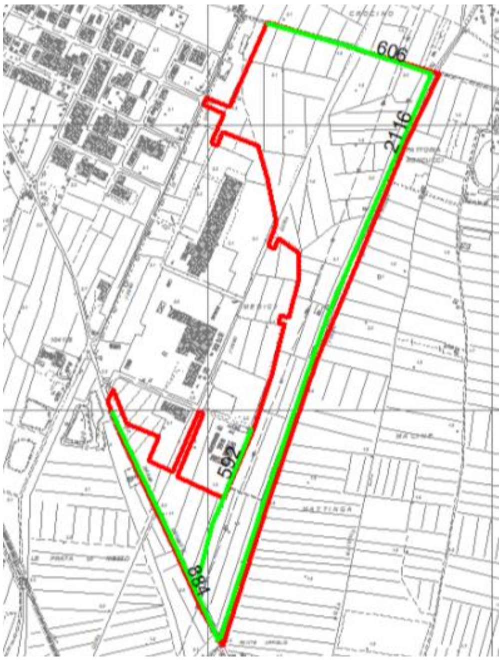
Standard park (Infrastructure area 21584 m^2);

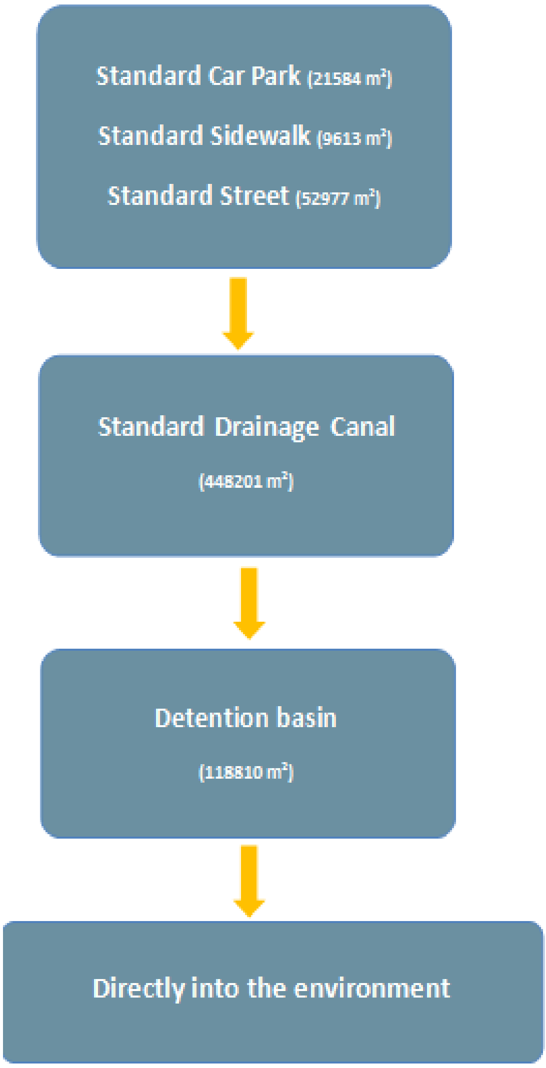
Standard drainage canal (Infrastructure area 25918 m^2):

Nugolaio di Ceria Acque Basse (1766 m * 9.7 m) and Scolo di Via Maggiore (8788 m * 5.2 m)

Detention basin (118810 m^2 and 122277 m^3) ;

Design sketches and maps.





- **Process followed to estimate construction and maintenance costs**.

We estimated construction and maintenance costs from the "Piano particolareggiato per ampliamento della zona produttiva di Ospedaletto"- Consorzio area produttiva intercomunale Pisa-Cascina, where useful data were available.

Construction costs:

<u>Standard street</u> unit construction cost (€/m^2): 78 €/m^2 (source: "Piano particolareggiato per ampliamento della zona produttiva di Ospedaletto", Consorzio area produttiva intercomunale Pisa-Cascina);

<u>Standard sidewalk</u> unit construction cost (€/m^2): 35 (source: "Piano particolareggiato per ampliamento della zona produttiva di Ospedaletto" - Consorzio area produttiva intercomunale Pisa-Cascina);

<u>Standard park</u> unit construction cost (€/m^2): 78 (source: "Piano particolareggiato per ampliamento della zona produttiva di Ospedaletto" - Consorzio area produttiva intercomunale Pisa-Cascina);

Detention basin (122277 m^3, 118810 m^2): 3.41 €/m^3 (costs of ground digging) + 7.41 €/m^3 (costs of backfilling the excavated material) = 10.82 €/m^3 (source: "Piano particolareggiato per ampliamento della zona produttiva di Ospedaletto" - Consorzio area produttiva intercomunale Pisa-Cascina);

Total cost = 122277 m^3 *10.82 €/m^3 = 1323037 €

Standard Drainage Canal unit construction cost: 16,18 €/m^2 (source: "Piano particolareggiato per ampliamento della zona produttiva di Ospedaletto" - Consorzio area produttiva intercomunale Pisa-Cascina);

Total cost = 25918 m^2 * 16,18 €/m^2 = 419353 €

Maintenance costs:

Standard Drainage Canal: 2591 €/year (= 25918 m^2 * 0,1 €/m^2, default maintenance value for vegetated swale from DST)

Detention basin unit maintenance cost: 0.11 €/m^3/year (= 10.82/10/10 by assuming a maintenance of 10% of the infrastructure volume once every 10 years. Source: "Piano particolareggiato per ampliamento della zona produttiva di Ospedaletto" - Consorzio area produttiva intercomunale Pisa-Cascina);

As regards unit maintenance costs for standard sidewalks, streets and parks, we couldn't find any maintenance plan therefore we computed them as the 50% of the total infrastructure cost (from the "Piano particolareggiato per ampliamento della zona produttiva di Ospedaletto"- Consorzio area produttiva intercomunale Pisa-Cascina) over 30 year.

Standard sidewalk unit maintenance cost: 0.6 (€/year/m^2)

Standard street unit maintenance cost: 1.3 (€/year/m^2)

Standard park unit maintenance cost: 1.3 (€/year/m^2)

- **Process followed to estimate energy consumed and emissions during construction and maintenance.**

As regards Unit energy consumed during construction, Unit emissions during construction, Unit maintenance cost, Unit energy consumed during maintenance and Unit emissions during maintenance, default values from software were assumed since specific value were not available.

As regards standard drainage canal no default value was available, therefore default values provided by the DST for vegetated swale were assumed

3.3.3. Stormwater runoff

- **Description of the hydraulic model used to analyze runoff.**

We didn't use any hydraulic model to analyze runoff, we just used the DST estimation panel.

Calculation for estimating runoff generation

3576 m^2 urban green

651185 m^2 Total pilot area surface

12696 m^2 vegetated areas

406011 m^2 pervious surfaces

52977 m^2 new development streets

21584 m^2 new development sidewalk

9613 m^2 new development parks

118810 m^2 Detention basin drainage area

25918 m^2 Standard drainage canal

Computation of Runoff coefficient Volume reduction for the Drainage area of the Standard Canal:

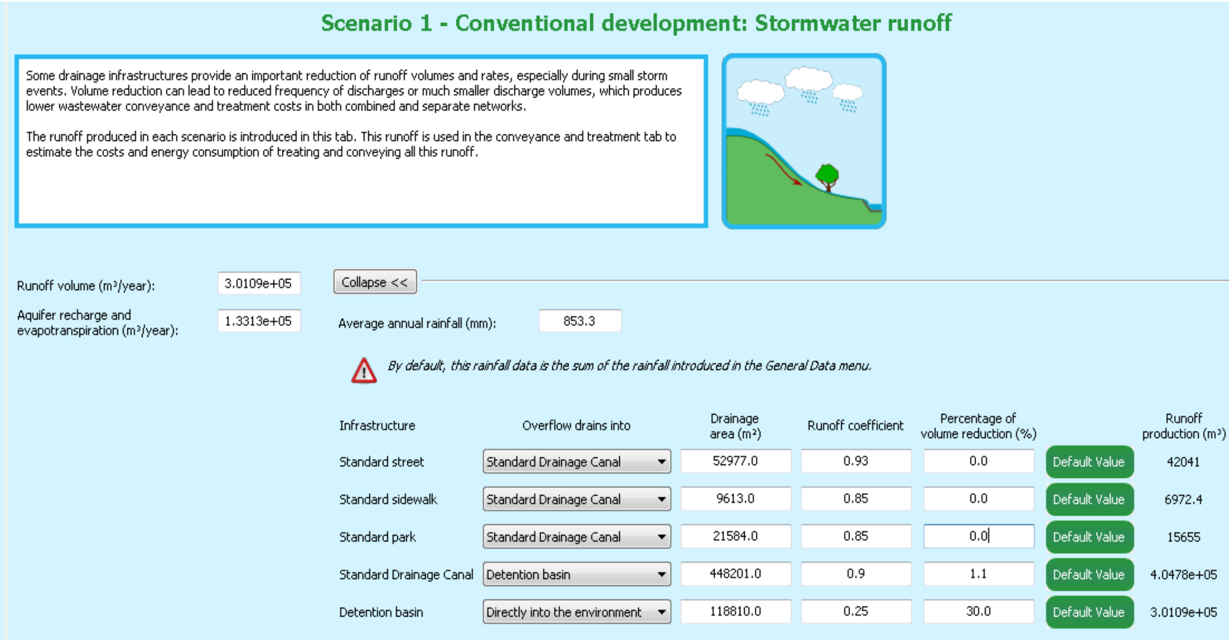
Drainage area of the Standard Canal: Total area – pavements – detention basin = 651185-(52977+9613+21584)-118810 = 448201 m^2

Impervious surfaces were assigned a runoff coefficient of 0.93 and green areas 0.13.

Average Weighted Runoff coefficient =((406011+25918)*0.93 + ((3575+12696)*0.13))/448201 = 0.9

Average Weighted Volume reduction (%) = ((406011+25918)*0 + ((3575+12696)*30))/448201 = 1.1

- **Global results obtained in this tab**



3.3.4. Conveyance and treatment

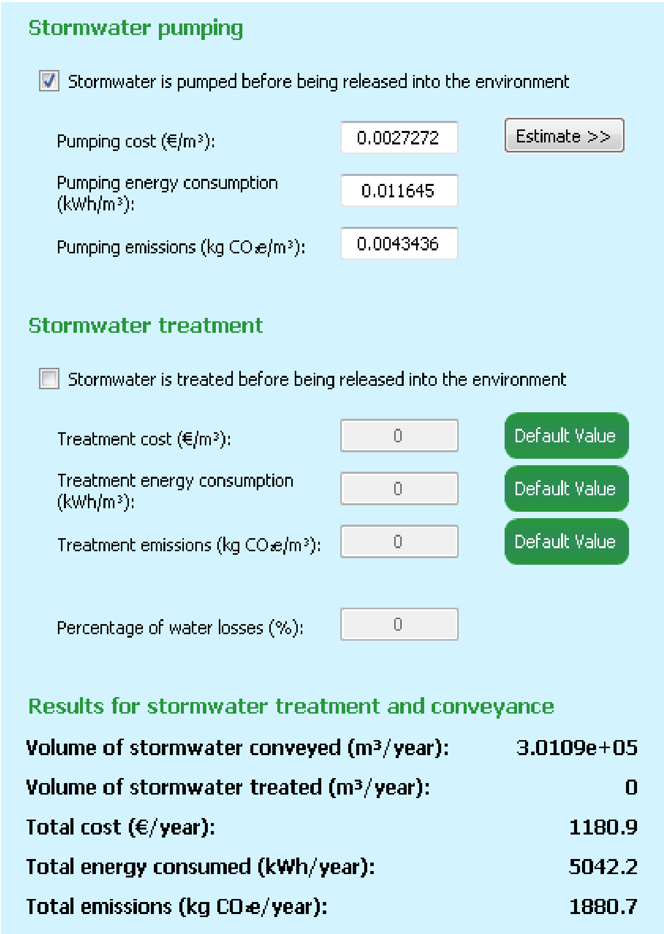
- **Description of data included in this tab.**

Following are the data included in the ***Conveyance and treatment*** menu (with sources and notes).

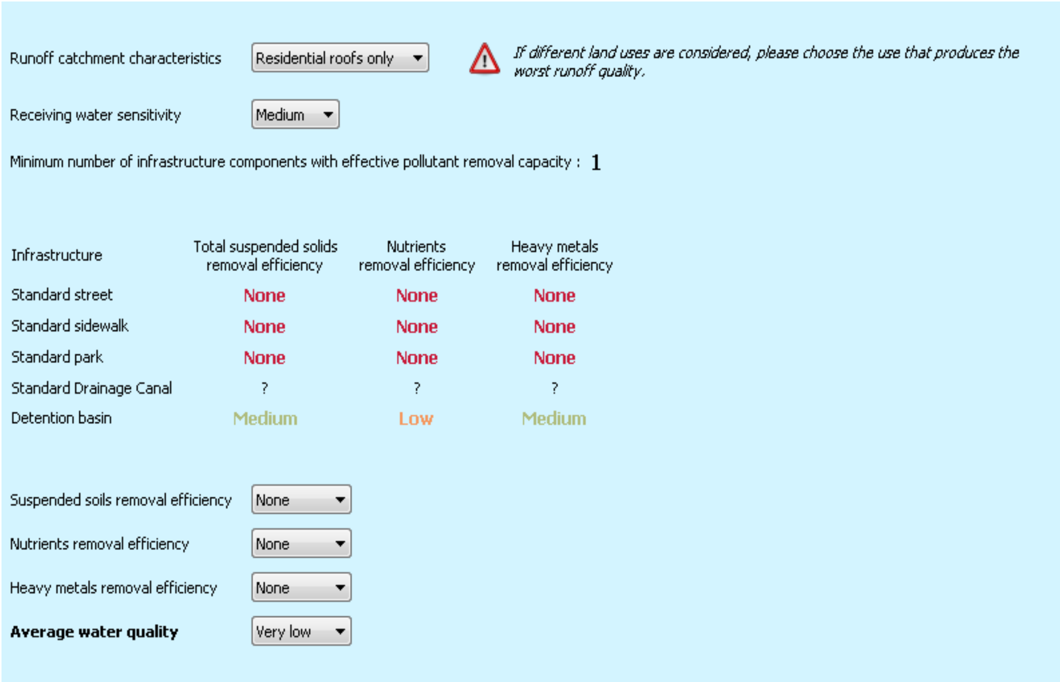
Type of data	Assigned value	Availability check	Source (PERSON)	Source of data	Note
Stormwater pumping					
Stormwater is pumped before being released into the environment					
Pumping cost (€/m3):	0.003		SSSA	Source: Consorzio di Bonifica - Ufficio dei Fiumi e Fossi (Pisa)	
Height difference (m):	2		Pisa Municipality experts		
Mecanichal efficiency (%):	75	Missing data		DEFAULT Value is used	
Electric system efficiency (%):	85	Missing data		DEFAULT Value is used	
Pumping energy consumption (kWh/m3):	0.012		SSSA	Source: Consorzio di Bonifica - Ufficio dei Fiumi e Fossi (Pisa)	
Pumping emissions (kg C02/m3):	0.004		Pisa Municipality experts		Pumping energy consumption (kWh/m3) * per Electricity emissions (kg C02/kWh)
Stormwater treatment					
Stormwater is treated before being released into the environment?	no				
Treatment cost (€/m3):	0				
Treatment energy consumption (kWh/m3):	0				
Treatment emissions (kg CO2/m3):	0				
Percentage of water losses (%):	0				
Flood protection benefits (€/year):	0		Pisa Municipality experts		On the basis of the damage repayments to private citizens authorized by the civil protection office
Case without these drainage infrastructures					
Number of households flooded					
Average damage per household (€)					
Case with these drainage infrastructures					
Number of households flooded					
Average damage per household (€)					

Treatment values have not been implemented as stormwater is not treated.

- **Global results obtained in this tab**



3.3.5. Water quality



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: Medium

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

Infrastructure	Total suspended solids removal efficiency	Nutrients removal efficiency	Heavy metals removal efficiency
Standard street	None	None	None
Standard sidewalk	None	None	None
Standard park	None	None	None
Standard Drainage Canal	?	?	?
Detention basin	Medium	Low	Medium

Suspended soils removal efficiency: None

Nutrients removal efficiency: None

Heavy metals removal efficiency: None

Average water quality: Very low

3.3.6. Flood protection

Same performance strategy is followed to compare the two scenarios. Therefore, flood protection benefits do not need to be included in the analysis since they are assumed to be the same in both scenarios..

3.3.7. Building insulation

This section has not been considered for the analysis

3.3.8. Summary

Summary tables are shown in the section 3.4.8.

3.4. Scenario 2: Development with SuDS

3.4.1. General description

- **General description of proposed solution.**

Within this scenario sustainable structures have been selected, their aim, being mostly pervious structures, is to enhance infiltration as much as possible – in order to reduce runoff production and energy consumption and emissions production. **General criteria that have guided the design of drainage infrastructures.**

General criteria is related to the need to relief the area from intense rainfall events (water bombs) causing flash floods, while at the same time decreasing energy consumption costs.

3.4.2. Drainage infrastructures included in the scenario

- **Description of included infrastructures**.

We included in the scenario the same surfaces as in the conventional scenario design, but selecting for them corresponding SuDS infrastructures (pervious pavement):

<u>Pervious street</u> (Infrastructure area 52977 m^2);

<u>Pervious sidewalk</u> (Infrastructure area 9613 m^2);

<u>Pervious grass lined park</u> (Infrastructure area 21584 m^2);

Reference: M. Volterrani, N. Grossi, S. Magni, and S. Miele 2001. Turf parking lots: performance of different growing media and cool season turfgrass misture. International Turfgrass Society Research Journal Volume 9.

<u>Filter strip</u> along via di Titignano (2116 m *6 m) = 12696 m^2

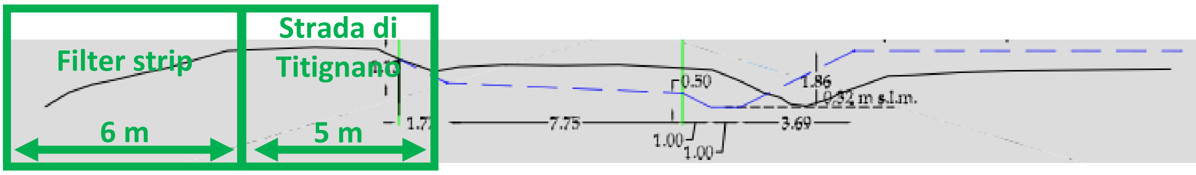
<u>Grass lined Detention basin</u> (118810 m^2);

<u>Vegetated swale</u> (25918.0 m^2);

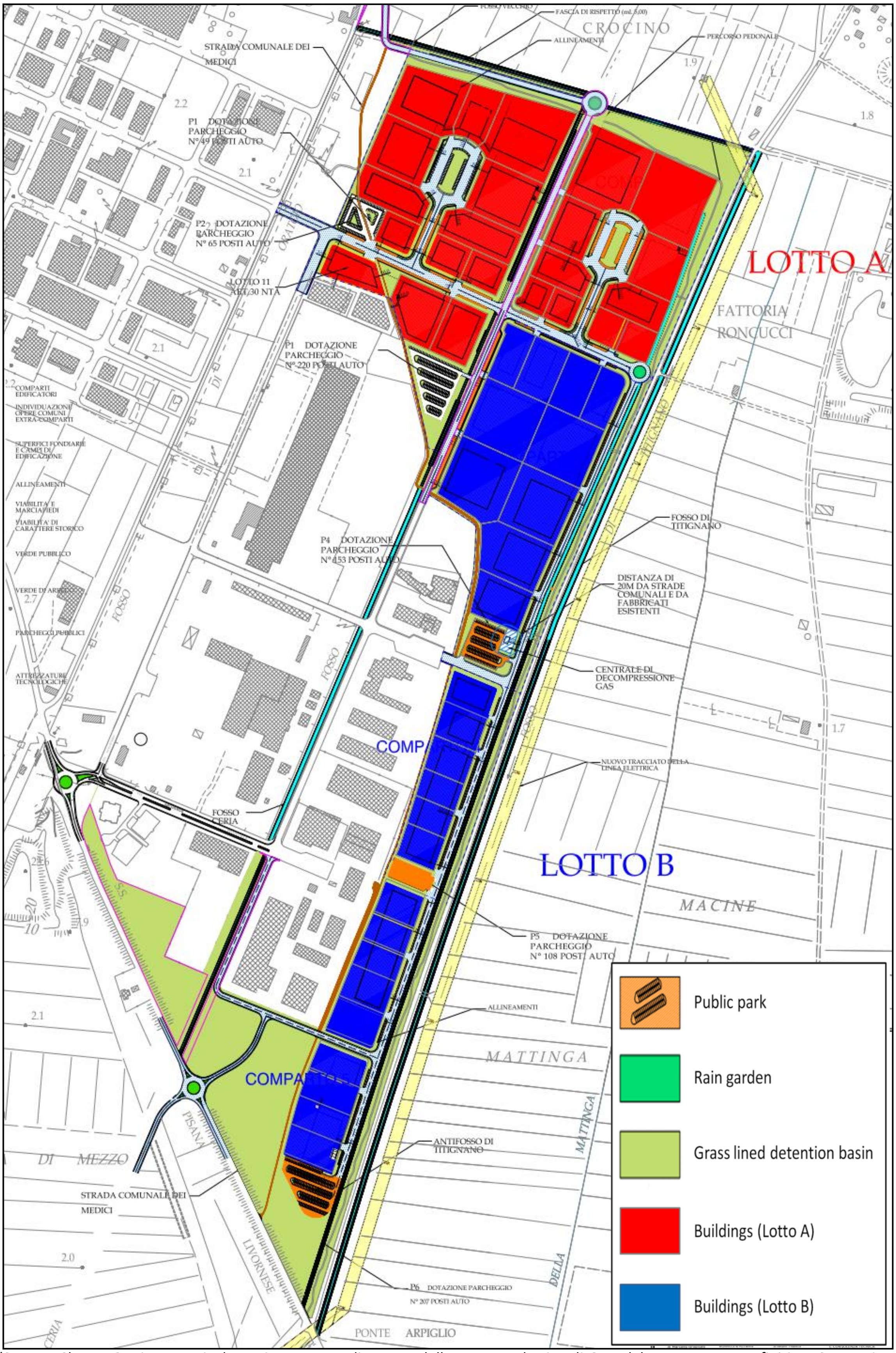
<u>Rain gardens</u> (3576 m^2);

<u>Rain harvesting systems</u> in the form of a simple water reuse deposit (40000 m^2, 1500 m^3).

- **Design sketches and maps.**

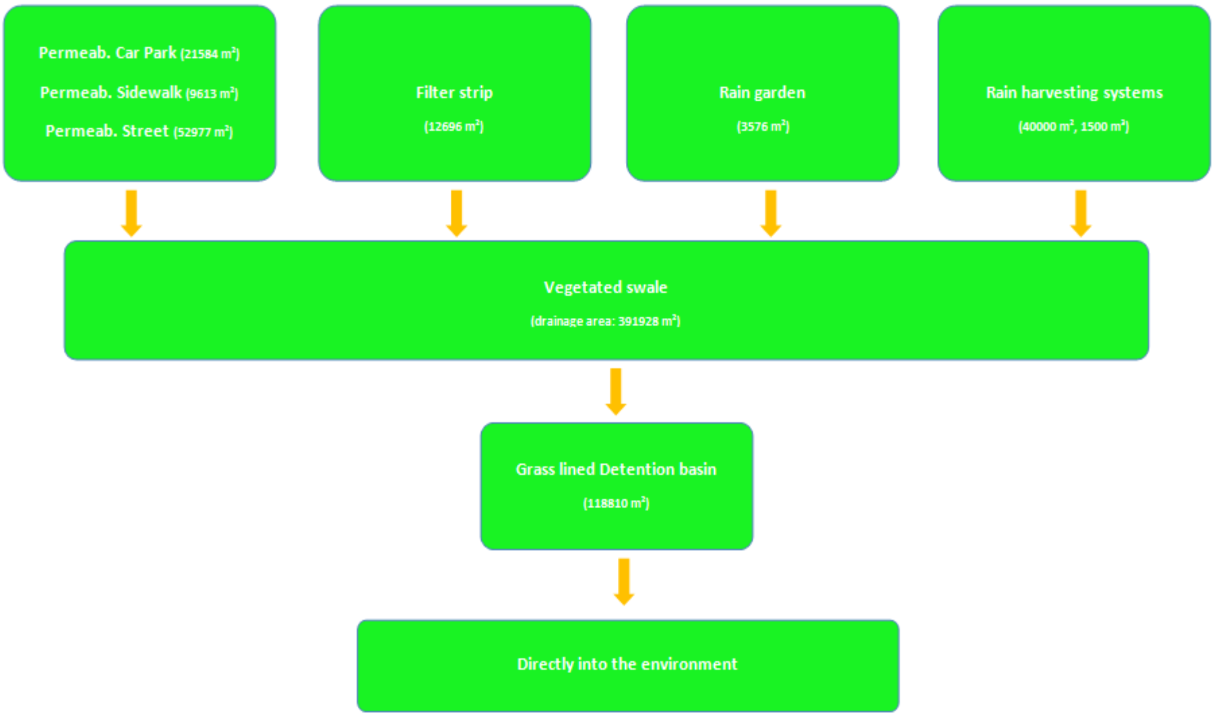


(Source: Chart 3.2, Piano particolareggiato per ampliamento della zona produttiva di Ospedaletto Progetto Definitivo, Consorzio area produttiva Intercomunale Pisa-Cascina)



(Source: Chart 1.3, Piano particolareggiato per ampliamento della zona produttiva di Ospedaletto Progetto Definitivo, Consorzio area produttiva Intercomunale Pisa-Cascina)

The following sketch shows the infrastructures included in the scenario and their drainage surfaces



Summary of values included in the DST.

Type of data	Assigned value	Availability check	Source (PERSON)	Source of data	Note
Water supply cost					
Water cost (€/m^3)	2.21		Pisa Municipality experts	Acque spa (http://www.acque.net/tariffe-fornitura)	Excluding the fixed rates per annum and assuming that households are 30%, the industrial 50% and services 20%.Household tariff is 1,41 €/m3 (between 0-80 m3/year) + € 2,82/m3 (between 81-200 m3/year). Industry tariff is € 2,43/m3 (between 0- 180 m3/year). Services tariff (non domestic users) is € 2,43/m3 (between 0 - 180 m3/year).
Energy consumed in water acquisition					
Energy consumed in water acquisition (kWh/m^3):					
Emissions in water acquisition (kg CO_2/m^3):					
Water supply source:	groundwater				
Height difference (m):	150		Pisa Municipality experts		The acquifer is between 100 and 200 meters deep
Mechanic efficiency (%):	75	Missing data		DEFAULT Value is used	
Electric system efficiency (%):	85	Missing data		DEFAULT Value is used	
Type of treatment:	chlorination				
Energy consumed in water conveyance					
Energy consumed in water conveyance (kWh/m3):					
Emissions in water conveyance (kg CO2/m3):					
Height difference (m):	7		Pisa Municipality experts		Estimated
Average internal diameter of pipes (mm):	250	Missing data		DEFAULT Value is used	
Average water velocity (m/s):	1.5	Missing data		DEFAULT Value is used	
Average roughness height (mm):	0.007	Missing data		DEFAULT Value is used	
Distance between water source and distribution tank (m):	3500		Pisa Municipality experts		Computed as the average between San Biagio wells distance to its tank (0 meters) and Filettole wells to Orzignano tank (7000 meters)
Minor losses in pipes (percentage of friction losses) (%):	10	Missing data		DEFAULT Value is used	
Mecanichal efficiency (%):	75	Missing data		DEFAULT Value is used	
Electric system efficiency (%):	85	Missing data		DEFAULT Value is used	
Energy consumed in water distribution					
Energy consumed in water distribution (kWh/m3):					
Emissions in water distribution (kg CO2/m3):					
Height difference (m):	33		Pisa Municipality experts		Calculated as the average between San Biagio deposit-utilities height difference (3 meters) and Orzignano tank-utilities height difference (63 meters)
Average internal diameter of pipes (mm):	150	Missing data		DEFAULT Value is used	
Average water velocity (m/s):	1.5	Missing data		DEFAULT Value is used	
Average roughness height (mm):	0.007	Missing data		DEFAULT Value is used	
Distance between distribution tank and water supply point (m):	6000		Pisa Municipality experts		Calculated as the average between tank Orzignano distance to the utilities (9500 meters) and San Biagio distance to the utilities (2500 meters).
House water pressure (kPa):	300	Missing data		DEFAULT Value is used	
Minor losses in pipes (percentage of friction losses) (%):	15	Missing data		DEFAULT Value is used	
Mecanichal efficiency (%):	75	Missing data		DEFAULT Value is used	
Electric system efficiency (%):	100	Missing data		DEFAULT Value is used	
Water supply network					
Water losses in the network (%):	30		Pisa Municipality experts	Acque spa	

Water demand was estimated on the basis of urban green surfaces to be irrigated and Evapotranspiration (after Hargreaves). The demand for non-potable uses (i.e. flushes) was also estimated.

Water demand was estimated on the basis of rain gardens to be irrigated and Evapotranspiration (after Hargreaves). The demand for non-potable uses (i.e. flushes) was also estimated (1500 m^3/month and 18000 m^3/year). In the following table assigned monthly total values of water demand are shown.

Type of data	Assigned value	Source	Note
Irrigation or cleaning of drainage infrastructures			
Volume of water consumed (m^3/year):	18687	SSSA	Estimated
Rainwater reuse by harvesting systems			
Storage capacity (m^3):	1500		
Drainage area (m^2):	40000		
Runoff coefficient:	0.93		
Filter efficiency (%):	90		
October Water demand (m^3)	1500		non-potable uses (i.e. flushes)
November Water demand (m^3)	1500		non-potable uses (i.e. flushes)
December Water demand (m^3)	1500		non-potable uses (i.e. flushes)
JanuaryWater demand (m^3)	1500		non-potable uses (i.e. flushes)
February Water demand (m^3)	1500		non-potable uses (i.e. flushes)
March Water demand (m^3)	1500		non-potable uses (i.e. flushes)
April Water demand (m^3)	1500		non-potable uses (i.e. flushes)
May Water demand (m^3)	1506		non-potable uses (i.e. flushes) and rain gardens irrigation
June Water demand (m^3)	1678		non-potable uses (i.e. flushes) and rain gardens irrigation
July Water demand (m^3)	1821		non-potable uses (i.e. flushes) and rain gardens irrigation
August Water demand (m^3)	1681		non-potable uses (i.e. flushes) and rain gardens irrigation
September Water demand (m^3)	1500		non-potable uses (i.e. flushes)

- **Process followed to estimate construction and maintenance costs.**

Costs were estimated from the “Progetto di riqualificazione ambientale area Artigianale Industriale di Ospedaletto a Pisa (APEA)”, Comune di Pisa, and from the “Piano particolareggiato per ampliamento della zona produttiva di Ospedaletto Progetto Definitivo, Consorzio area produttiva Intercomunale Pisa-Cascina”. In some cases default values from DST were used.

Construction costs:

Vegetated swale:

(16.18 + 0.39) €/m^2 * 25918.0 m^2 = 429461 €

Grass lined Detention basin:

costs of ground digging and backfilling the excavated material + costs of lawn grass sowing and topdressing

(7.41 + 3.41) €/m^3 * 122277 m^3 + 0.39 €/m^2 * 118810 m^2 = 1369373 €

Pervious street 72.155 €/m^2 (source: APEA project);

Pervious park 37.68 €/m^2 (Detailed construction budgets from various neighboring municipalities were collected and the average value was assumed);

Pervious sidewalk 60.165 €/m^2 (source: APEA project);

Filter strip: 2.8 €/m^2 (Source: Piano particolareggiato per ampliamento della zona produttiva di Ospedaletto Progetto Definitivo, Consorzio area produttiva Intercomunale Pisa-Cascina);

Rain gardens: 19.4 €/m^2 (Source: estimation based on nearby municipality's works on green spaces)

Rain harvesting systems: 1500*250 €/m^3 (default construction value from DST) = 375000 €

Maintenance costs:

As regards unit maintenance costs, we couldn't find any maintenance plan for permeable sidewalks, street and car parks. Therefore we computed the first two as the 50% of the total infrastructure cost (from the "Piano particolareggiato per ampliamento della zona produttiva di Ospedaletto"- Consorzio area produttiva intercomunale Pisa-Cascina) over 30 year. We assumed no maintenance is needed for permeable grass lined car parks.

Permeable Sidewalk unit maintenance cost: 1 (€/year/m^2)

Permeable Street unit maintenance cost: 1.2 (€/year/m^2)

Permeable Car Park unit maintenance cost: 0 (€/year/m^2)

Yearly maintenance cost = 7500 €/year

Vegetated swale unit maintenance cost: 0.32 €/m^3/year (= 0.08 + (10.11*0.2/10) + 0.39/10 by assuming a yearly cut of the grass, a 20-cm reshape and sowing every 10 years. Source: "Piano particolareggiato per ampliamento della zona produttiva di Ospedaletto" - Consorzio area produttiva intercomunale Pisa-Cascina);

Grass lined Detention basin unit maintenance cost: 0.11 €/m^3/year (= 10.82/10/10 by assuming a maintenance of 10% of the infrastructure volume once every 10 years. Source: "Piano particolareggiato per ampliamento della zona produttiva di Ospedaletto" - Consorzio area produttiva intercomunale Pisa-Cascina);

Rain gardens: 0.32 €/year/m^2 computed as the 50% of the total cost over 30 year;

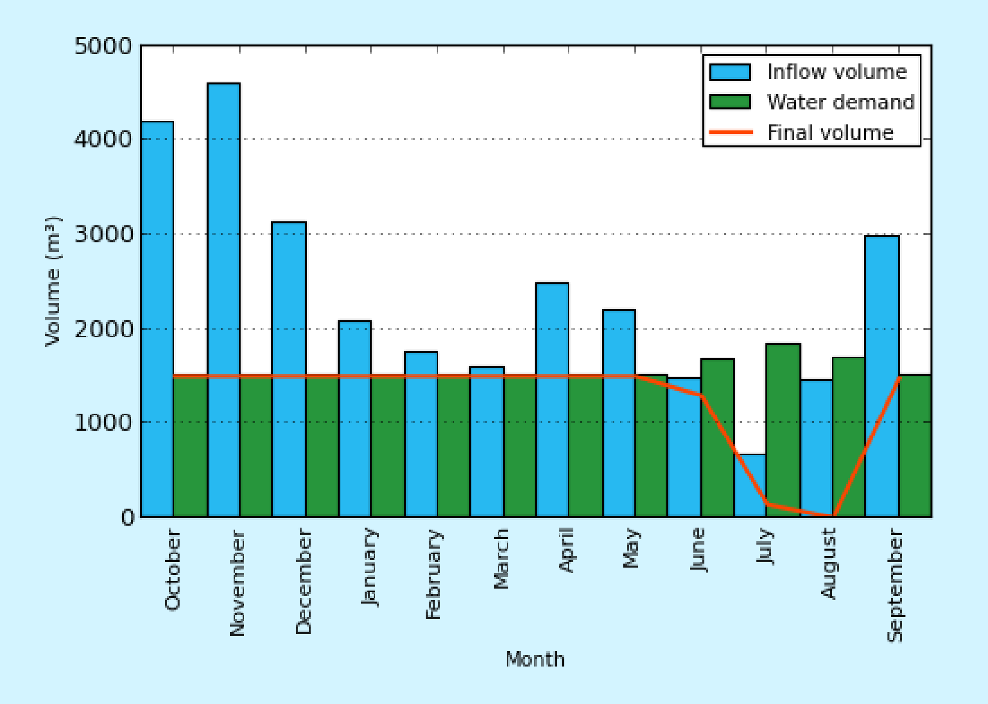
Rain harvesting systems unit maintenance cost: 5 €/year/m^3 (= 375000/(2*30*1500, by assuming a maintenance of 50% of the infrastructure cost once every 30 years).

- **Process followed to estimate energy consumed and emissions during construction and maintenance.**

As regards Unit energy consumed during construction, Unit emissions during construction, Unit maintenance cost, Unit energy consumed during maintenance and Unit emissions during maintenance, default values from software were assumed since specific value were not available.

3.4.3. Water reuse

Rainwater reuse by harvesting systems was estimated on the basis of inflow water from rainfall and water demand volumes. The water demand was computed as the sum of water consumed for toilet flushes and water consumed for rain garden irrigation. The volume of water consumed for toilet flushes in the area was quoted as 1500 m^3/month (18000 m^3/year) by assuming 1000 users per day and 10 liters per toilet flush.



3.4.4. Stormwater runoff

- **Description of the hydraulic model used to analyze runoff.**

We didn't use any hydraulic model to analyze runoff, we just used the DST estimation panel.

Calculation for estimating runoff generation

651185 m^2 Total pilot area surface

12696 m^2 filter strip

366011 m^2 pervious surfaces (roofs excluding surfaces drained by rain harvesting systems)

52977 m^2 new development streets

21584 m^2 new development sidewalk

9613 m^2 new development parks

118810 m^2 Grass lined detention basin drainage area

3576 m^2 Rain gardens

25918 m^2 vegetated swale = (1766*9.7)+(1690*5.2)

40000 m^2 surfaces drained by rain harvesting systems

Computation of Runoff coefficient Volume reduction for the Drainage area of the vegetated swale:

Drainage area of the vegetated swale: 391928 m^2

Impervious surfaces were assigned a runoff coefficient of 0.93 and green areas 0.13.

Average Weighted Runoff coefficient =

((391928-(1766*9.7)-(1690*5.2))*0.93+((1766*9.7)+(1690*5.2))*0.13)/391928 = 0.88

Average Weighted Volume reduction (%) =

((391928-(1766*9.7)-(1690*5.2))*0+((1766*9.7)+(1690*5.2))*30)/391928 = 1.98

- **Global results obtained in this tab.**

Runoff volume (m³/year): 2.2388e+05

Aquifer recharge and evapotranspiration (m³/year): 1.1977e+05

Average annual rainfall (mm): 853.3

By default, this rainfall data is the sum of the rainfall introduced in the General Data menu.

Infrastructure	Overflow drains into	Drainage area (m²)	Runoff coefficient	Percentage of volume reduction (%)		Runoff production (m³)
Permeable street	Vegetated swale	52977.0	0.3	80.0	Default Value	2712.3
Permeable sidewalk	Vegetated swale	9613.0	0.3	80.0	Default Value	492.17
Permeable park	Vegetated swale	21584.0	0.3	80.0	Default Value	1105.1
Vegetated swale	Grass lined Detention basin	391929	0.88	1.98	Default Value	3.0665e+05
Grass lined Detention basin	Directly into the environment	118810.0	0.13	30.0	Default Value	2.2388e+05
Filter strip	Vegetated swale	12696.0	0.1	0.0	Default Value	1083.3
Rain garden	Vegetated swale	3576.0	0.13	99.0	Default Value	3.9668

	Overflow drains into	Drainage area (m²)	Runoff coefficient	Volume reused (m³)	Runoff production (m³)
Rain harvesting systems and water butts	Vegetated swale	40000.0	0.93	18600.0	13143

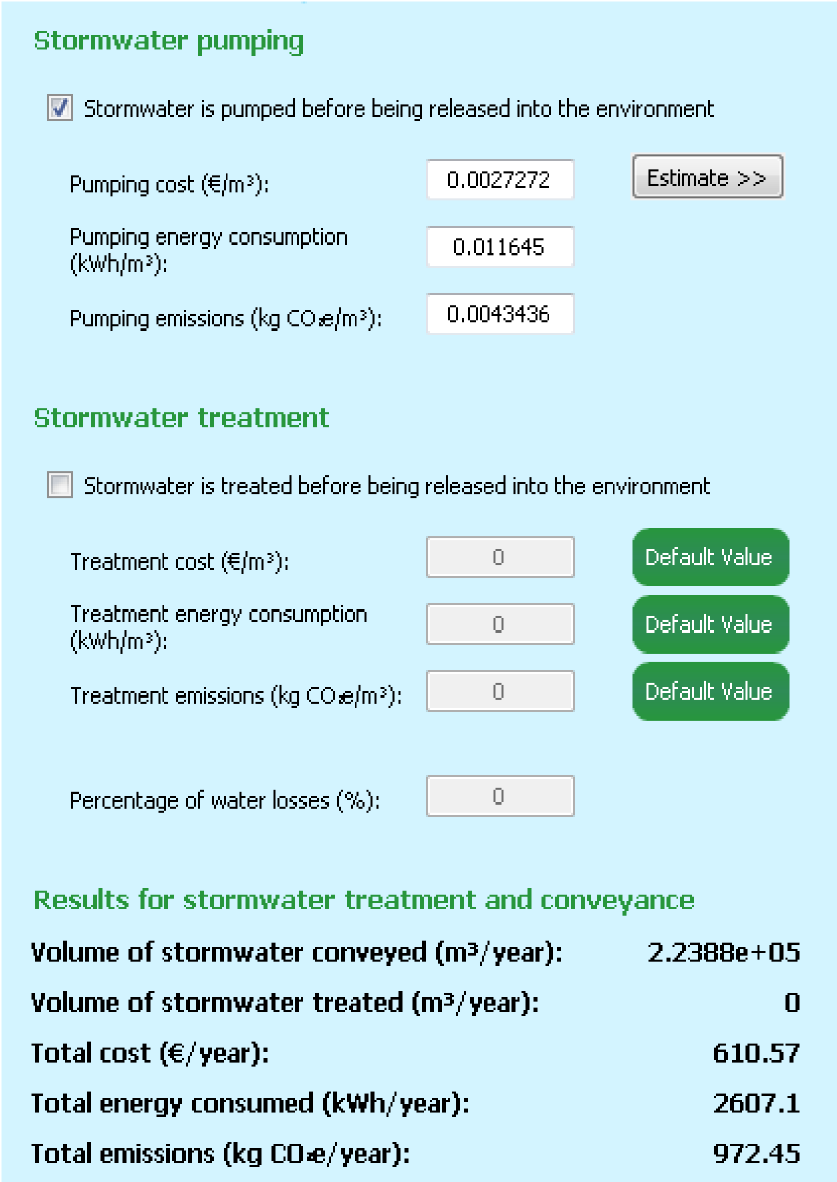
The runoff volume reduction produced by rain harvesting systems and water butts should be the reused volume computed in the Water supply tab.

3.4.5. Conveyance and treatment

- **Description of data included in this tab.**

  Data used here are same as in 3.3.4

- **Global results obtained in this tab**



3.4.6. Water quality

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: Medium

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

Infrastructure	Total suspended solids removal efficiency	Nutrients removal efficiency	Heavy metals removal efficiency
Permeable street	High	High	High
Permeable sidewalk	High	High	High
Permeable park	High	High	High
Vegetated swale	High	Low	Medium
Grass lined Detention basin	Medium	Low	Medium
Filter strip	Medium	Low	Medium
Rain harvesting system	High	Low	Medium
Rain garden	High	Low	High

Suspended soils removal efficiency: High

Nutrients removal efficiency: Medium

Heavy metals removal efficiency: Medium

Average water quality: Medium

3.4.7. Flood protection

Same performance strategy is followed to compare the two scenarios. Therefore, flood protection benefits do not need to be included in the analysis since they are assumed to be the same in both scenarios..

3.4.8. Summary tables

Scenario 1

	Financial cost	Energy consumption	Emissions
Construction of infrastructures	7.8948e+06 €	1.8092e+07 kWh	5.6509e+06 kg CO_2e
Maintenance of infrastructures	1.1874e+05 €/year	8306 kWh/year	2209.5 kg CO_2e/year
Infrastructure landtake	29071 €	-	-
Potable water consumed and saved	41298 €/year	37588 kWh/year	14029 kg CO_2e/year
Stormwater conveyance and treatment	1180.9 €/year	5042.2 kWh/year	1880.7 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

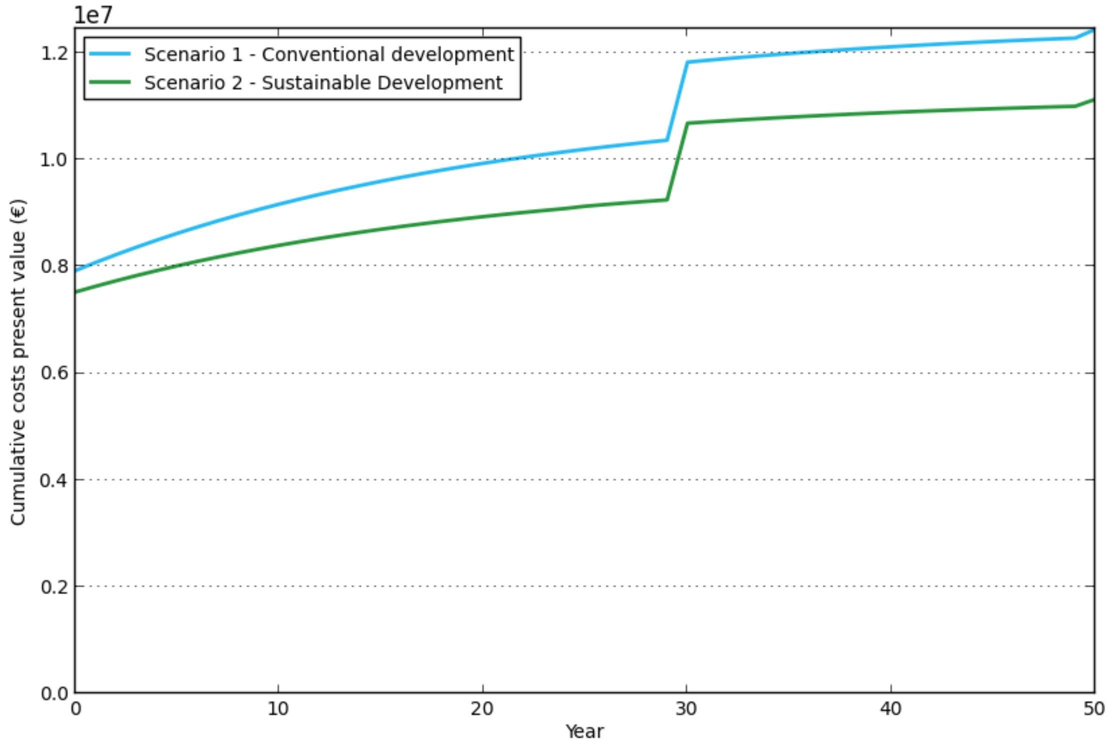
Scenario 2

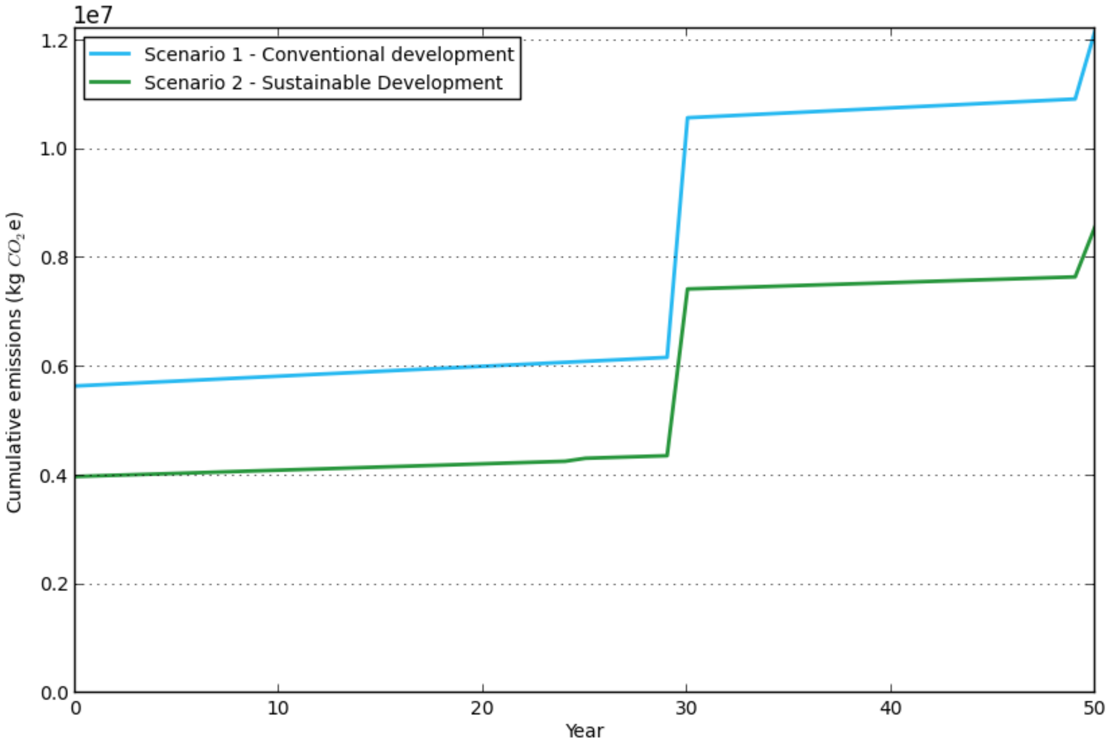
	Financial cost	Energy consumption	Emissions
Construction of infrastructures	7.493e+06 €	1.2838e+07 kWh	3.9867e+06 kg CO_2e
Maintenance of infrastructures	1.0424e+05 €/year	30236 kWh/year	7756.8 kg CO_2e/year
Infrastructure landtake	30683 €	-	-
Potable water consumed and saved	8356 €/year	7967.1 kWh/year	2971.3 kg CO_2e/year
Stormwater conveyance and treatment	610.57 €/year	2607.1 kWh/year	972.45 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

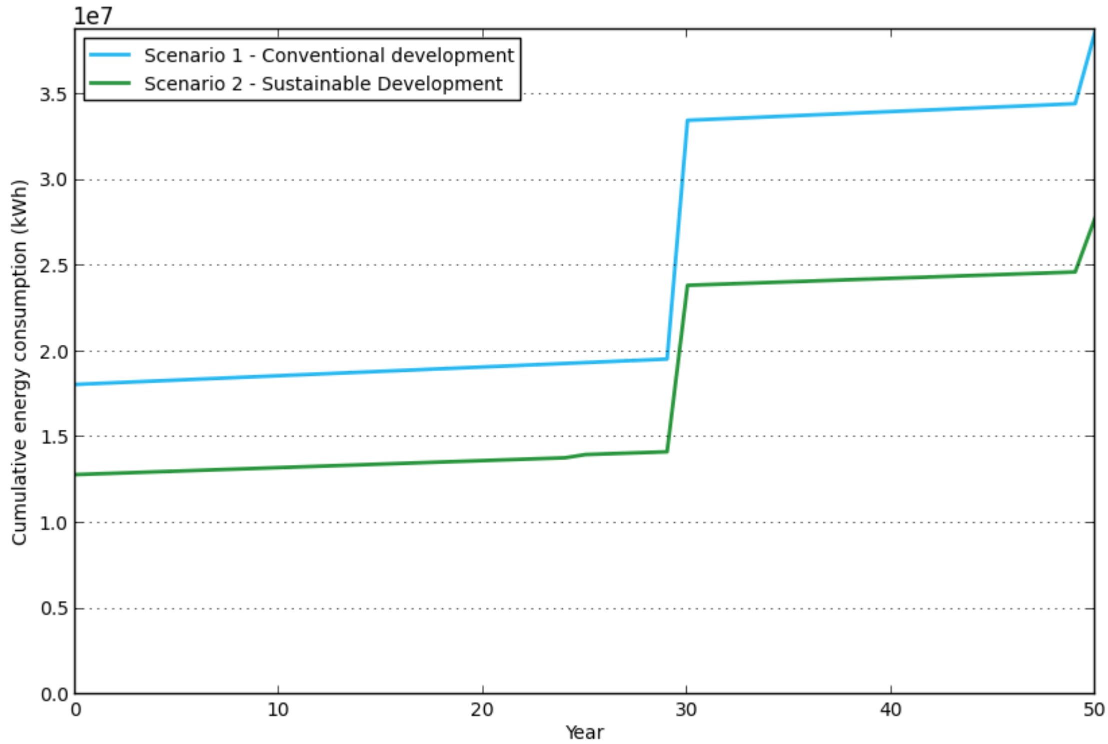
3.5. RESULTS

3.5.1. Time graphs

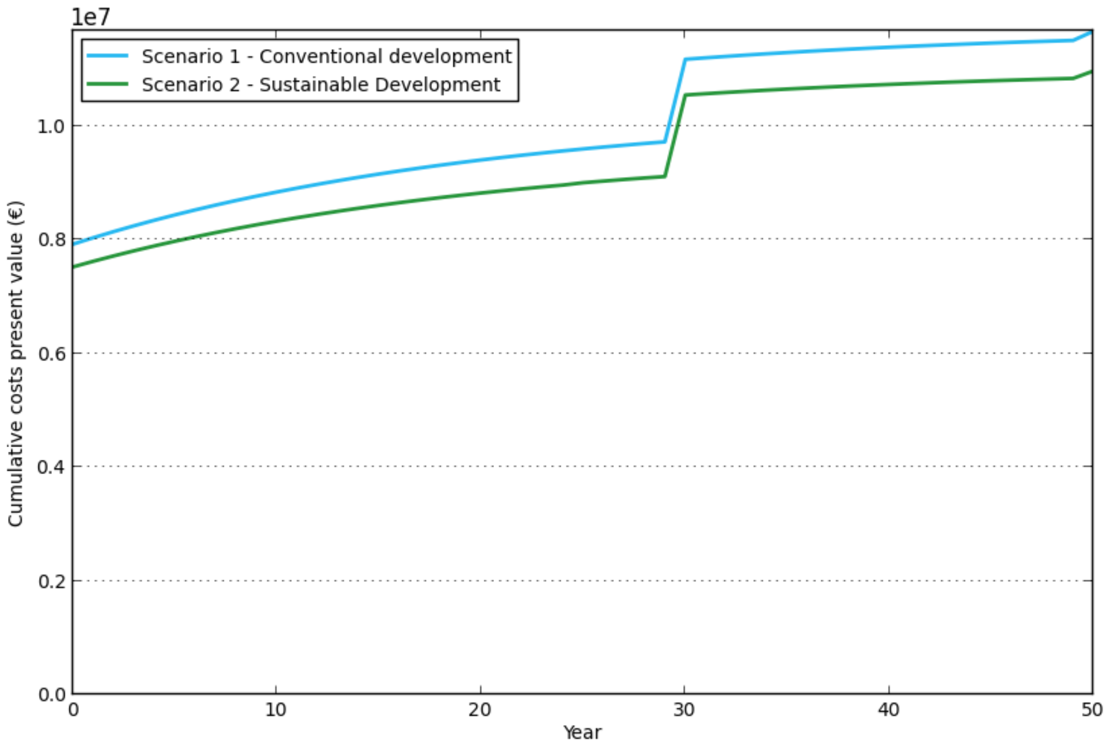
- **Global time graphs obtained with the DST (graph and tables).**

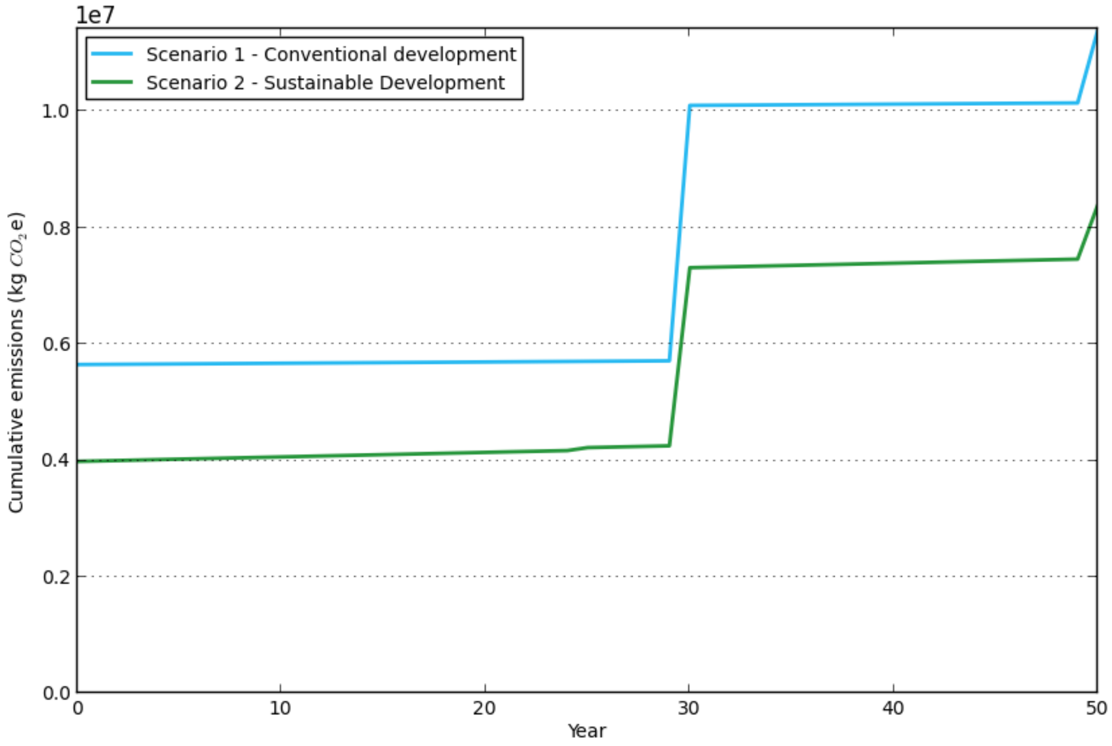


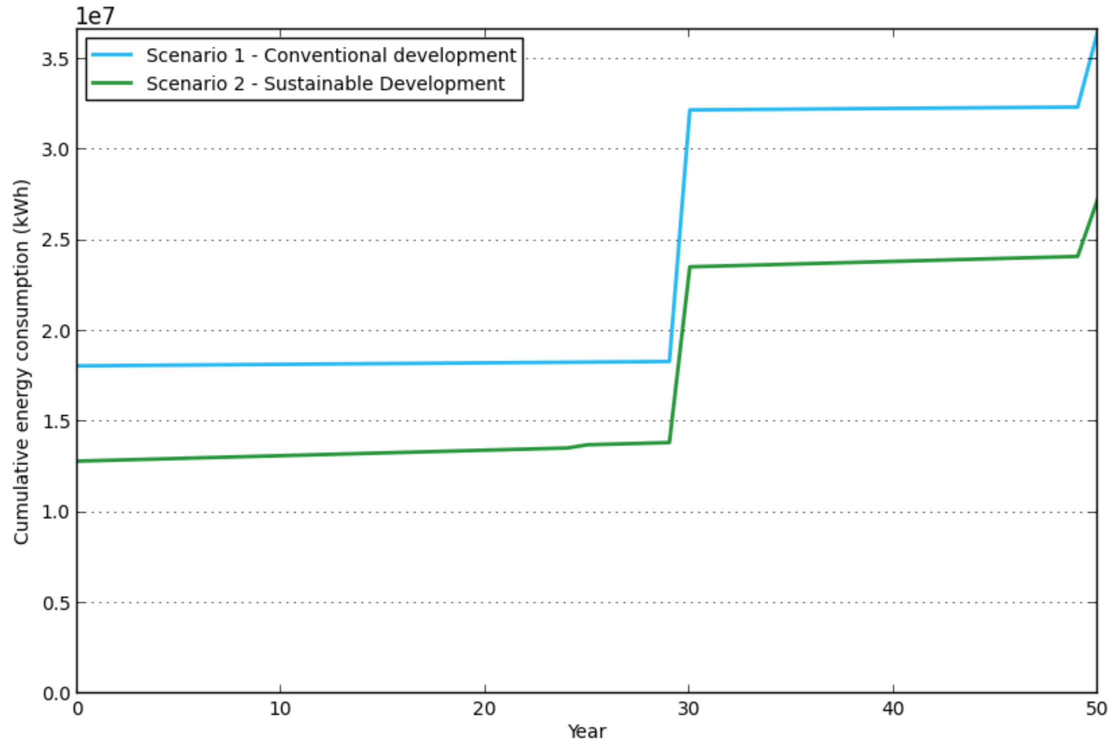

1e7
Scenario 1 - Conventional development
Scenario 2 - Sustainable Development
Cumulative emissions (kg CO_2 e)
Year
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
10
20
30
40
50


1e7
Scenario 1 - Conventional development
Scenario 2 - Sustainable Development
Cumulative energy consumption (kWh)
Year
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
0
10
20
30
40
50

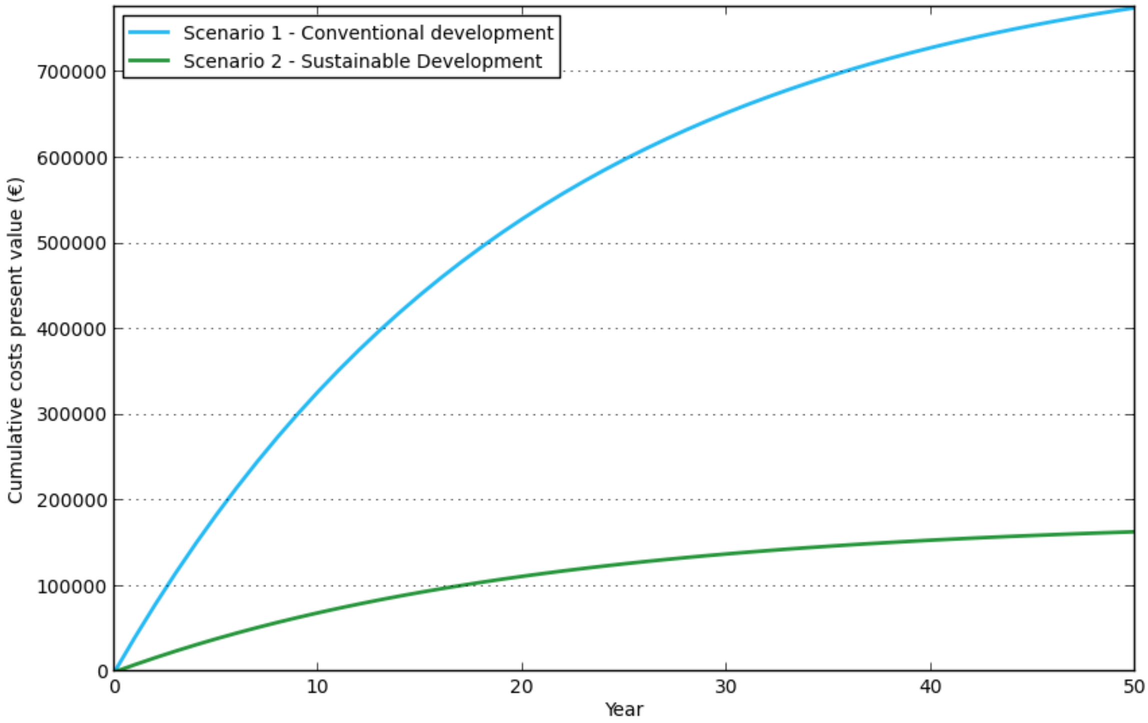
- **Time graphs obtained with only construction and maintenance.**

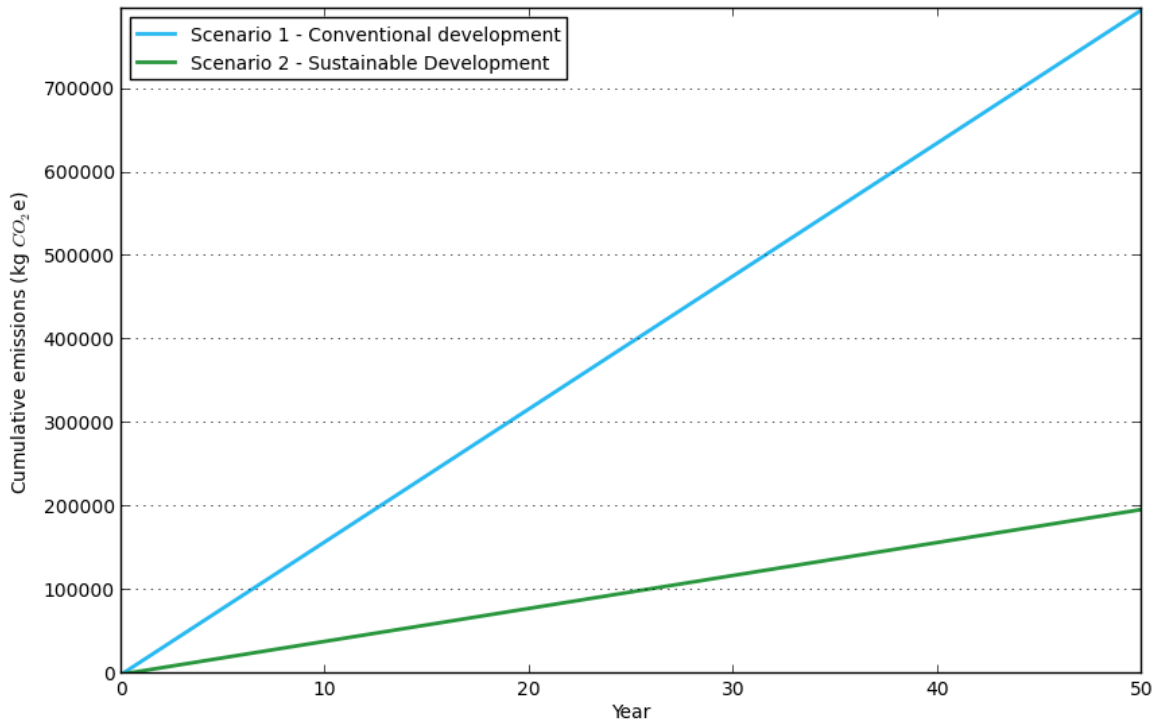


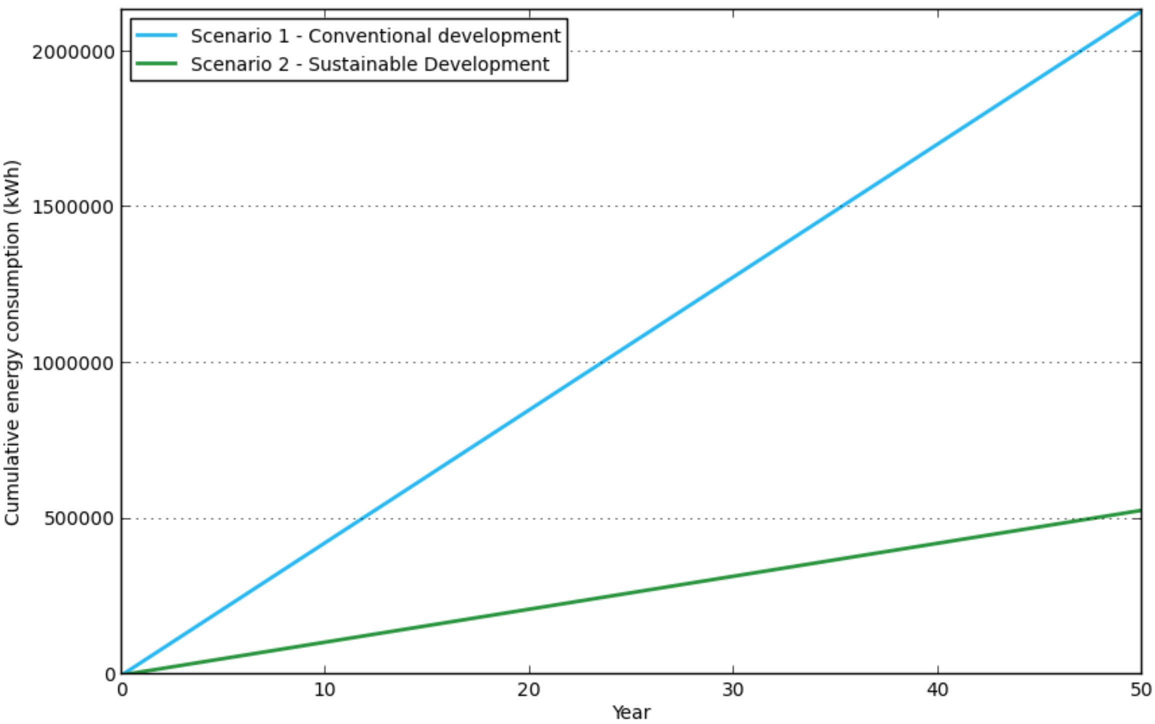

1e7
Scenario 1 - Conventional development
Scenario 2 - Sustainable Development
Cumulative emissions (kg CO_2e)
Year
0.0
0.2
0.4
0.6
0.8
1.0
0
10
20
30
40
50


1e7
Scenario 1 - Conventional development
Scenario 2 - Sustainable Development
Cumulative energy consumption (kWh)
Year
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
0
10
20
30
40
50

- **Time graphs obtained without construction and maintenance.**




Scenario 1 - Conventional development
Scenario 2 - Sustainable Development
Cumulative emissions (kg CO_2 e)
700000
600000
500000
400000
300000
200000
100000
0
0
10
20
30
40
50
Year


Scenario 1 - Conventional development
Scenario 2 - Sustainable Development
Cumulative energy consumption (kWh)
2000000
1500000
1000000
500000
0
0
10
20
30
40
50
Year

- **Explanation and justification of results.**

Design of stormwater management is effectively achieved by planning SuDS infrastructures in the new development area. Still questions arise about the need of having reliable data about construction and maintenance costs.

3.5.2. Decision criteria

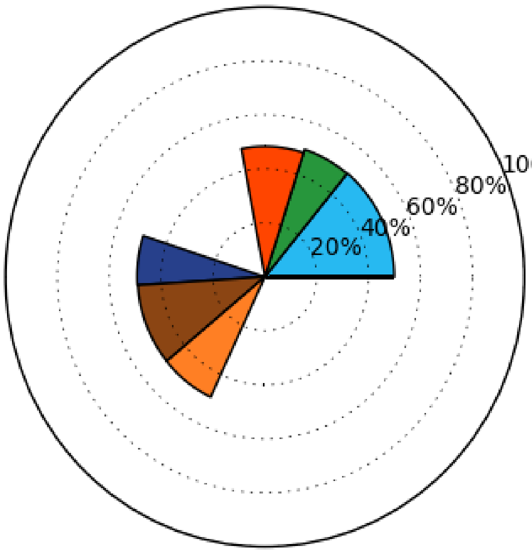
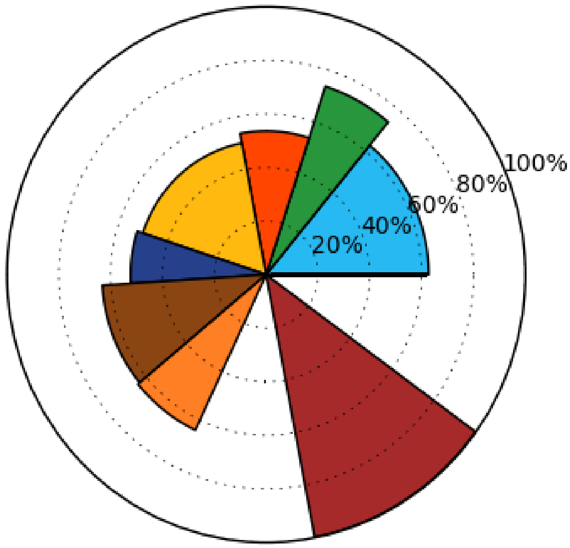
Decision criteria chosen.

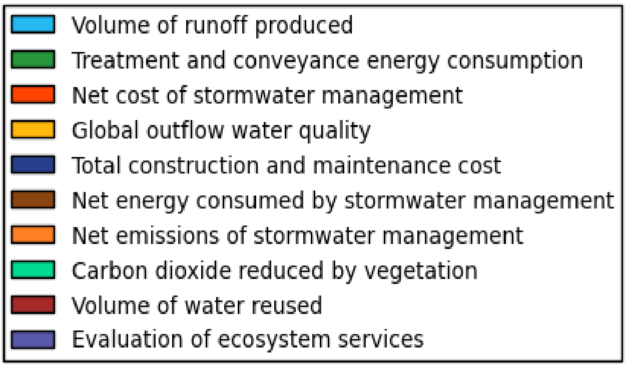
The selected criteria are shown in the following table along with respective weights assigned. Stakeholders and managers took part in the decision process (See the “IV Regional Working Group on Energy Efficiency minutes” in attachment for details).

Selected decision criteria	Weight assigned by stakeholders																			Average weight (%)
Carbon dioxide reduced by vegetation	0	0	10	15	0	7.5	8	15	40	15	10	5	15	20	5	0	0	8	10	**10**
Evaluation of ecosystem services	20	25	10	25	0	5	4	5	10	15	10	5	15	0	20	0	0	7	10	**10**
Global outflow water quality	10	10	15	10	70	15	5	10	5	20	10	30	15	20	20	20	10	15	15	**17**
Net cost of stormwater management	0	0	10	0	0	10	15	5	20	0	0	5	15	0	5	20	30	8	5	**8**
Net emissions of stormwater management	0	0	10	0	0	5	8	10	5	0	10	5	15	20	10	30	0	7	10	**7**
Net energy consumed by stormwater management	5	0	15	15	0	20	15	10	5	0	10	2.5	10	0	10	30	20	15	10	**10**
Total construction and maintenance cost	5	5	20	0	5	5	10	5	5	20	0	2.5	0	0	5	0	0	10	10	**6**
Treatment and conveyance energy consumption	10	10	0	25	5	10	15	10	6	0	0	5	0	0	5	0	0	8	0	**6**
Volume of runoff produced	40	40	5	0	0	15	15	20	2	0	25	30	5	20	10	0	30	7	10	**14**
Volume of water reused	10	10	5	10	20	7.5	5	10	2	30	25	10	10	20	10	0	10	15	20	**12**

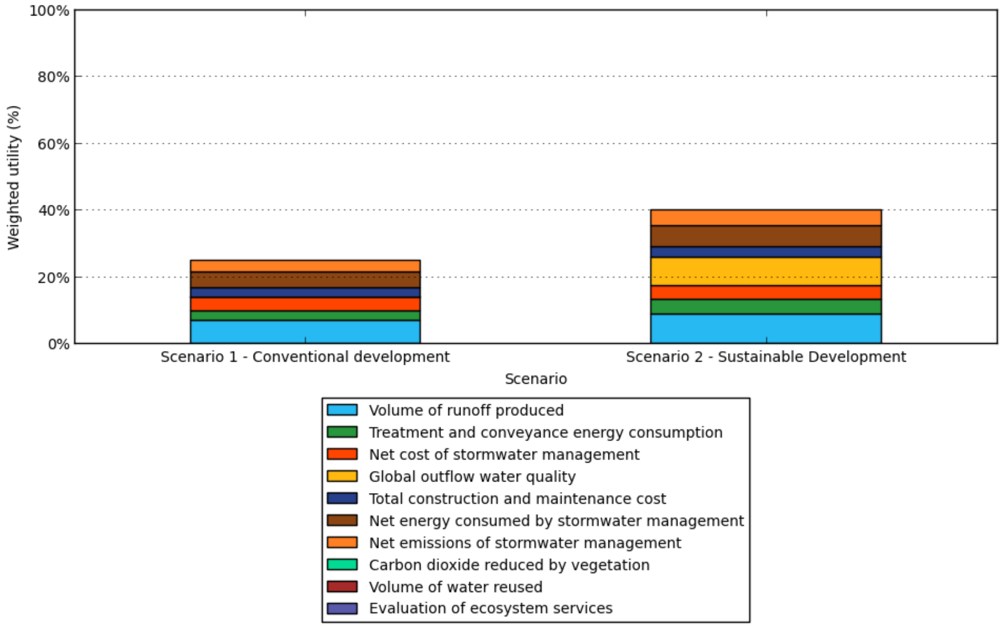
3.5.3. Multi-criteria analysis results

- **Circular results per scenario (graphs and table).**

Scenario 1	Scenario 2
	



- **Global results (graph and table).**



- **Explanation and justification of results.**

As it can be observed from the graph, the score is higher in the scenario 2 than in the scenario 1 and from the multi-criteria analysis point of view scenario 2 would be recommended. In particular, for the "global outflow water quality" criteria the scenario 2 is definitely better than the scenario 1; the same could be said concerning the "treatment and conveyance energy consumption", the "volume of runoff produced", the "net energy consumed by stormwater management" and the "net emissions of stormwater management.

3.6. Conclusions

SuDS solution, by reducing runoff volumes may play a major role in protecting new urbanization areas from flood risks, while having reasonable costs and contributing in energy saving for stormwater management. However, in the simulations performed appeared that retrofitting highly urbanized areas located within land reclamation works might not be the appropriate solution because of lack of adequate spaces and of a shallow water table. On the other hand, the case of new development, SuDS may constitute a viable solution in order to reduce stormwater runoff, reducing good quality water and energy consumption and increasing the aesthetic values of the urbanized areas.

ANNEX 1. COMPLEMENTARY DOCUMENTS

Selected runoff coefficients:

The runoff coefficients were selected on the basis of the values provided by Paolo Montin, “Acque meteoriche di dilavamento”.

Tipologia superficie	φ
Verde su suolo profondo, prati, orti, superfici agricole	0,10-0,15
Terreno incolto, sterrato non compattato	0,20-0,30
Superfici in ghiaia sciolta – parcheggi drenanti	0,30-0,50
Pavimentazioni in macadam	0,35-0,50
Superfici sterrate compatte	0,50-0,60
Coperture tetti	0,85-1,00
Pavimentazioni in asfalto o cls	0,85-1,00

In particular, the runoff coefficient values were derived by computing the average of maximum and minimum range values. In the case of filter strip, parks/sidewals and pervious pavements the minimum value of the range was retained in order to take into account the vegetation density, vegetation presence and drainage characteristics, respectively. Following are the runoff coefficients used in the DST application:

Roofs: 0.93

Impervious streets: 0.93

Vegetated surfaces (urban irrigated areas, detention basin and vegetated swales): 0.13

Excavated and uncoltivated soil: 0.25

Filter strip: 0.1

Standard parks and sidewalks: 0.85

Pervious pavements (street, parks and sidewalks): 0.3

Vegetated swale: 0.13

IV Regional Working Group on Energy Efficiency Report:

The IV Regional Working Group on Energy Efficiency was organized by the Municipality of Pisa on January the 29th, it took place at the Scuola Superiore Sant'Anna and it was open to a wide public as a workshop.

During the meeting, the uses and potentialities of SuDS were introduced by experts and the work done in the framework of the E^2STORMED project in Pisa was presented. In detail the application of the decision support tool (DST) to the pilot areas in Pisa was described and different drainage scenarios were compared.

A set of qualitative and quantitative decision criteria to be used in a multi-criteria analysis were proposed to the stakeholders; in order to establish a shared decision criteria weight assessment a questionnaire was delivered to stakeholders (attachment 1) and we got 21 compiled questionnaires back. Two questionnaires were removed since the sum of the weights of criteria was bigger than 100.

In the following table results are shown and in the last column the average criteria weight (%) is presented.

Selected decision criteria	Weight assigned by stakeholders																			Average weight (%)
Carbon dioxide reduced by vegetation	0	0	10	15	0	7.5	8	15	40	15	10	5	15	20	5	0	0	8	10	**10**
Evaluation of ecosystem services	20	25	10	25	0	5	4	5	10	15	10	5	15	0	20	0	0	7	10	**10**
Global outflow water quality	10	10	15	10	70	15	5	10	5	20	10	30	15	20	20	20	10	15	15	**17**
Net cost of stormwater management	0	0	10	0	0	10	15	5	20	0	0	5	15	0	5	20	30	8	5	**8**
Net emissions of stormwater management	0	0	10	0	0	5	8	10	5	0	10	5	15	20	10	30	0	7	10	**7**
Net energy consumed by stormwater management	5	0	15	15	0	20	15	10	5	0	10	2.5	10	0	10	30	20	15	10	**10**
Total construction and maintenance cost	5	5	20	0	5	5	10	5	5	20	0	2.5	0	0	5	0	0	10	10	**6**
Treatment and conveyance energy consumption	10	10	0	25	5	10	15	10	6	0	0	5	0	0	5	0	0	8	0	**6**
Volume of runoff produced	40	40	5	0	0	15	15	20	2	0	25	30	5	20	10	0	30	7	10	**14**
Volume of water reused	10	10	5	10	20	7.5	5	10	2	30	25	10	10	20	10	0	10	15	20	**12**

Table 1 – Results of the delivered questionnaire

E²STORMED PROJECT

Improvement of energy efficiency in the water cycle by the use of innovative storm water management in smart Mediterranean cities

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