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Feasibility study on "tailormade" SWMED solutions for the project target areas in Ragusa

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1. Analysis and selection of the target areas

1.1 Summary

This document aims to present the feasibility study developed by SVIMED, partner of the project SWMED - Sustainable Domestic Water Use in Mediterranean Region, in order to support the integration of ad-hoc sustainable strategies into the Mediterranean local/regional policies.

During the elaboration of this survey, many aspects have been taken in account, by a deep research and analysis phase that allowed to identify the water supply and wastewater management system, treatment and waste water disposal (sewer network, wastewater treatment system, drains) and evaluating the cases of some sub-urban sprawl zones or planned into the building code: some of these areas are actually not yet equipped of water supply networks and/or drainage systems.
The information about water supply networks and drainage systems characteristics and also of Ragusa's wastewater treatment systems, were gained by Waste Water Network Actuation Plan (PARF) and by recent studies conduct in this area by Ragusa Municipality and related partners.
In order to collect all the information necessary for the development of a well-done feasibility study, several meetings have been arranged with Ragusa Municipality's technicians (Integrate Water Service Sector 6 – Environment, Energy, Civil Protection and Green areas and with Territorial Planning and Use Sector) to collect documents about water and wastewater plants, urban aspects of the agglomerations not served by water and drainage systems and so on.
Many information are missed by the competent authorities too, so some interviews have been developed directly with citizens of the target areas for allowing the approximation of some data (e.g. yearly consumption of water, wastewater treatment or number of house seasonally occupied).
The overview of water resources and waste water disposal system in Ragusa, urban systems and economic and social activities developed in the target areas of Ragusa, was useful for identified the three case studies and their peculiar properties:

- ✓ Urban Residential area: Building Cooperatives Soraya and Doriana
- ✓ Rural Agglomeration: Borgo San Giacomo
- ✓ Coastal Agglomerations with a high season inhabitants fluctuation: Villaggio Cerasella, Marina di Ragusa's recent settlement beside the Provincial Street 25.

The last part of the document aims to illustrate the possible scenarios applicable to the three cases studies and the results of the related feasibility evaluation.

1.2 Criteria of Selection of the target area

The territory of Ragusa has a territorial surface of 442 Km^2 and a resident population of 73.333 inhabitants (official data – ISTAT 2010).
Drinking water resources actually available and used by Ragusa's municipality is constituted entirely by subterranean water (wells and springs) except for Borgo San Giacomo, supplied by Santa Rosalia's dam, Irminio's river.

The volumes inserted in the system, for the drinking water supply of Ragusa, amount at 15,453 Mlnm^3/year, how we can observe in the tables 1 and 2, where for each well is indicated the location, the users base and further technical information (diameter, depth and volumes):

Denominazione	Ubicazione	Bacino di utenza	Portata media	Volume utilizzato	Profondità	Diamentro	In esercizio
Pozzo Macello	C.da Conservatore	Ragusa - Centro Urbano	15	473.040	300	200	SI
Pozzo "I"	C.da Lusia	Ragusa - Centro Urbano	55	1.734.480	65	300	SI
Pozzo "I1"	C.da Lusia	Ragusa - Centro Urbano	27	851.472	120	300	SI
Pozzo "I2"	C.da Lusia	Ragusa - Centro Urbano	40	1.261.440	120	300	SI
Pozzo "H"	C.da Lusia	Ragusa - Centro Urbano	20	630.720	120	300	SI
Pozzo "G"	C.da Lusia	Ragusa - Centro Urbano	10	315.360	78	300	SI
Pozzo "F"	C.da Arancelli	Ragusa - Centro Urbano	50	1.576.800	138	n.d.	SI
Pozzo "A1"	C.da Arancelli	Ragusa - Centro Urbano	45	1.419.120	86	300	SI
Pozzo A	C.da Arancelli	Ragusa - Centro Urbano	30	946.080	85	300	SI
Pozzo B	C.da Ciaramita	Ragusa - Centro Urbano	40	1.261.440	138	300	SI
Pozzo B1	C.da Ciaramita	Ragusa - Centro Urbano	40	1.261.440	150	300	SI
Pozzo E	C.da Ciaramita	Ragusa - Centro Urbano	38	1.198.368	140	300	SI
Pozzo S. Leonardo	Centro Urbano	Ragusa - Centro Urbano	5	0	20	n.d.	NO
Pozzo S. Leonardo	Centro Urbano	Ragusa - Centro Urbano	9	0	108	250	Da attivare

Denominazione	Ubicazione	Bacino di utenza	Portata media	Volume annuo utilizzato	Quota Prelievo	In esercizio
Sorgente San Leonardo	Centro Urbano	Ragusa - Centro Urbano	15	473.040	365	SI
Sorgente Cilone	n.d.	Ragusa - Centro Urbano	6	189.216	570	SI
Sorgente Fontana Grande	C.da Fontana Grande	Ragusa - Centro Urbano	8	252.288	535	SI
Cava Misericordia Sorgente Oro	C.da Misericordia	Ragusa - Centro Urbano	10	315.360	545	SI
Sorgente Misericordia 2	C.da Misericordia	Ragusa - Centro Urbano	20	630.720	540	SI
Sorgente Cava Volpe	C.da Cava Volpe	Ragusa - Centro Urbano	6	189.216	600	SI
Sorgente Corchigliato	C.da Corchigliato	Ragusa - Centro Urbano	15	473.040	100	SI

Tab.1 - 2 – Wells and Springs that fuel Ragusa's aqueduct

Red lines indicate wells and springs polluted and at this moment not used for the allocation, generating in some cases water emergency in Ragusa. Green line indicates urgent drilling works planned for answering to the actual emergency in Ragusa, in an adjacent area to the abandoned well San Leonardo, no more considered in a good quality.

From the collected data results a yearly volume of water supplied to the system for a drinking water use of 15,453 Mlnm^3.

Comparing the volumes insert on the system and the volumes invoiced (4,65 Mlnm^3/year) we obtain a percentage of leaks of 70% that become 55% if we consider the volumes allocated but not invoiced (as municipal school, public green areas and sports facilities).

Considering a resident population in Ragusa city of 69333 inhabitants, we obtain:

- A daily water supply of 610 l/inhab (considering volumes insert in the system);
- A daily effective consumption of 270 l/inhab (considering 55% of loss);
- A daily consumption of 184 l/inhab (considering volumes invoiced).

Ragusa's urban centre is served by two wastewater treatment system (both making biological treatment, activated sludge with separated stabilization) located in C.da Lusia where are collected also the wastewater of Ragusa's industrial area.

Wastewater volumes yearly treated by C.da Lusia WWTP amount at 5,3×106 m^3 for a plant planned for treating 6,4×106 m^3.

The wastewater is collected to the WWTP "Lusia" by two conduits: one resultant by the industrial area and "Ragusa alta", and one by "Ragusa bassa" and Ragusa ibla.

Taking in account the information collected and the state of art of the Ragusa Area, we identified the three case studies with the aim to characterize different situations, the urban case, the rural/mountain village and the costal agglomeration. These three cases represent situation that we can find at regional at national level with similar problems, as tackling the isolation and water supply related problems; facing the problem of illegal settlements that have been build during the last 50 years without planning any water facilities and the problem of seasonal areas with related needs for supplying adequate services for a population that in particular during summer period increase exponentially in number.

1.3 Description of the sites

1.3.1 Urban Residential area

Ragusa's water allocation system is composed by a principal water supply network, that sources by 9 reservoirs with a total capacity of 8.650 cubic meters, thus, a secondary network connects it to the private users.
Final users need a private reservoir for collecting water, distributed by competent authority by means of a turnover system during the day.
Grey and black water are addressed to the same network to be discharged into the wastewater treatment plant of C.da Lusia, while stormwater is collected in a separate public network.
In the existing buildings, usually, each apartment has equipped with a water volumetric counter: the water is collected in a common reservoir (and a first volumetric counter has done) and thus, thanks to the water-meter in each apartment, it's possible to measure the single consumption.
The new urban settlements, as that one included into the Economic and Popular Buildings Plans (PEEP), adopt the same system for water allocation and water supply (black, grey and white), but furthermore, in these cases, each buildings' unit has a reservoir for collecting drinking water.

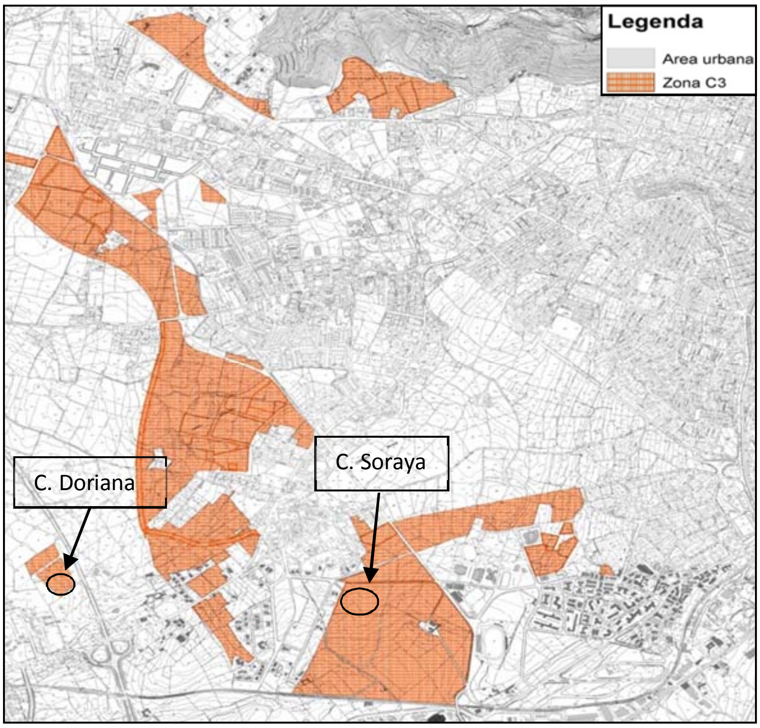


Fig. 2 – Identification of Economic and Popular Buildings Plans (PEEP)

Moreover, technical execution norms establish that each single building must be equipped with alternative energy sources in a percentage of 30% relating to building needs: solar panels useful for heating and/or producing warm water and photovoltaic panels for supplying electricity, or adoption of techniques and strategies for energy saving until the 30% for the normal consumption. In addition, common illumination system should be powered through photovoltaic panels.
These are some of the rules that have to be followed by the cooperatives that are committed (at public and private level) to draft and build the new expansion zones inside and outside Ragusa City. In Ragusa we count more than 100 cooperatives and two of these collaborate with Svimed for collecting necessary data for the case study: Cooperatives Soraya and Doriana, that are associated to Legacoop Ragusa.

Building Cooperative Soraya

Soraya's cooperative is part of the building programme approved with the decree of 17/02/05 of Regional Public Works Department and is located in C.da Selvaggio (Ragusa).
The surface allocated by Cooperative Soraya is about 7000 m^2 where are planned to realize 20 lodgings grouped in 10 small double family houses of 70 m^2 each, two floors and a garage.
Only for the buildings with low ground is provided a green area with variable surface from 300 to 600 m^2.

Fig. 3 – General Lot Plan

Drinking water is provided through the municipal network and the water store reservoir is placed under the garage.
Grey and black water are addressed to the municipal network and then to the wastewater treatment plant of C.da Lusia .
A system for rainwater recovery and reuse is not taken in account in these projects, thus, rainwater is addressed to the municipal white water network.

Building Cooperative Doriana

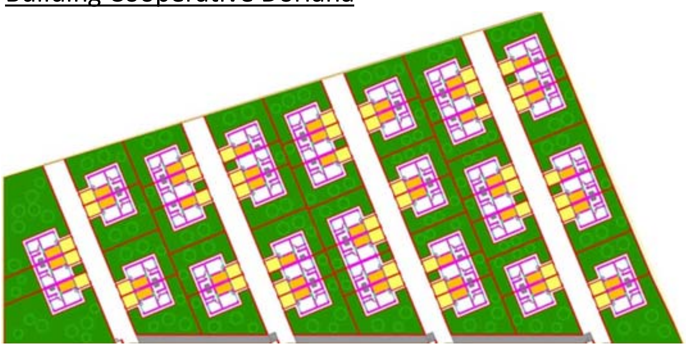


Fig 4 – General Lot Plan

Building cooperative Doriana is part of the building programme approved with the decree of 28/10/04 of Regional Public Works Department and is located in C.da Cisternazzi (Ragusa).
The surface occupied by Cooperative Doriana is about 18000 m^2: the project plans the realisation of 18 buildings composed by two or three duplex apartments, making a total of 48 double family small houses of 95 m^2

with two floors and a garage of 18 m^2. Green area can have a variable surface from 45 to 500 m^2. Here too, grey and black water is addressed to the municipal network and then to the wastewater treatment of C.da Lusia plant.

1.3.2 Rural Agglomeration Borgo San Giacomo

Borgo San Giacomo is part of the mountain urban system located at 500 m over sea level in the north of municipal territory, it's 18 km far from Ragusa's urban centre and counts about 500 inhabitants.

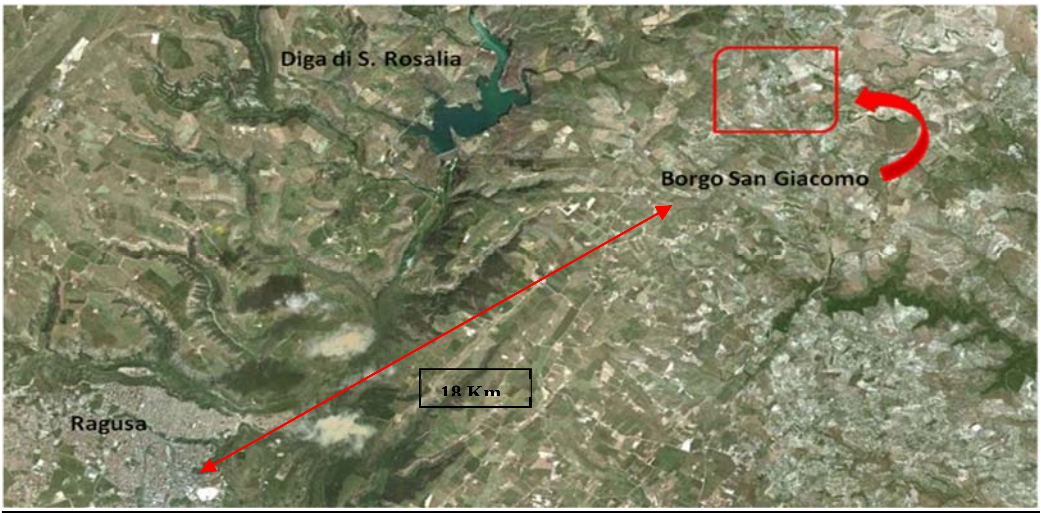


Fig. 5 – Rural agglomeration Borgo San Giacomo

San Giacomo is a settlement essentially connected to traditional agricultural activities, in a peculiar context where operate numerous farming enterprises.
The original centre goes back to the end of 1800 and the majority of the housing units are rural buildings, while the new buildings are single buildings.
To collect all the information about the buildings, we carried out an analysis dividing urban estate units (U.I.U.) took a census of land register relating to the housing compartments and floors number.
The analysis results are:
17% of urban estate units has maximum 3,5 compartments;
53% has from 4 to 6 compartments;
30% has more than 6 compartments.
Furthermore there are many buildings allocated to storage use (31) and several farming fabricates.
Concerning the division of the urban estate units, 67% result composed of a single floor, while 33% composed of two floors.

<u>Water consumption and waste water disposal</u>

Water allocation of Borgo San Giacomo takes advantage of an aqueduct realised by the "Ente Sviluppo Agricolo", who manages the drinking water (by the dam of S. Rosalia) and the aqueduct for irrigation use.

Household water consumption is about 100 l/inhabxday (value resulted by a calculation on the basis of collected data by interviews to people leaving in Borgo San Giacomo – no official data available on the issue)

Borgo S.Giacomo hasn't drainage system and many ex potable-water's tanks, after the connection with the aqueduct, have been used for wastewater storage.

Wastewater disposal takes place two or three times per year through tankers of 15000 l: people non-residents will ask for private enterprises, while for the residents, the municipality has provided a facilitated service based on incomes:

Income from €	Income up to €	First transfer cost €	Other transfer cost €
	6.000,00	----------	----------
6.001,00	15.000,00	16,00	7,00
15.001,00	25.000,00	30,00	15,00
25.001,00	40.000,00	40,00	20,00
40.001,00	Over	60,00	30,00
Rate for productive activities		60,00	30,00

Tab. 3 – Waste Water disposal costs

Cost per household is difficult to estimate because is related to the dimension of the tank, to the frequency of emptying and to the income of the household. Considering a production of 100l/p.e. of wastewater per day and a household of 4 persons, the annual production is 150 m3/year. Considering a 10 m3 capacity of the truck, it means 15 transfer per year; assuming for a rough estimate an average cost of 25 € per transfer, it means 375 €/year per household.

<u>Prevision of Ragusa's Drainage system Actuation Plan</u>

Concerning Borgo San Giacomo the existing strategy for improving wastewater municipal system has planned to build a drainage system network exploiting the natural gravity of the town and following the main roads existing from North-West to South-East of the area.

The plan envisages that the drainage system will address wastewater to the constructed wetlands (about 4.000 m^2) located out of urban centre and close to the provincial road to Giarratana.

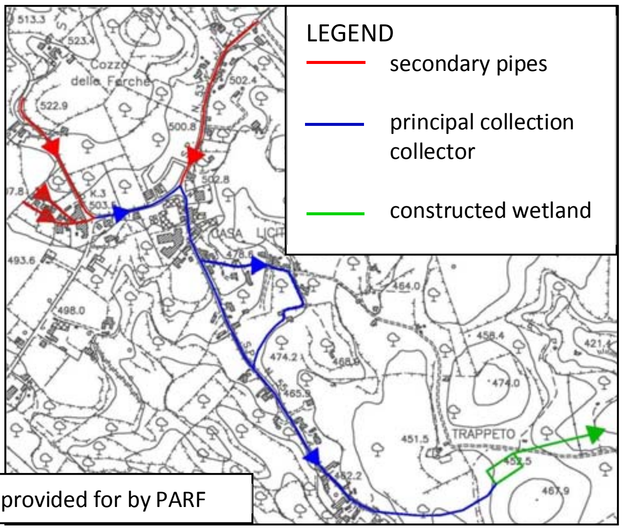


Fig. 6 – Drainage system allocation provided for by PARF

1.3.3 Coastal Agglomerations

Urban coastal system, interested by a high seasonal fluctuation of people, accommodates mainly a lot of vacationers coming from urban centres, but also from the rest of Italy.

Marina di Ragusa is the summer town of Ragusa city where more than 50% of the people from Ragusa will spend the summer period. This area is served by a drinking water network linked to 3 reservoirs with a total capacity of 900 m^3, which distributes about 0.93 $Mlnm^3$ of water between September and June (almost 9 months) and 0.75 $Mlnm^3$ of water between June and September (less than 3 months) creating problem of scarcity during the top of the summer period – middle of august. Wastewater drainage system served 95% of people living in Marina di Ragusa by means of a treatment plant planned for 25000 inhabitant equivalent. A separate network has been created for collecting white water. Wastewater, after treatment, is discharged on the sea at 1800 m from the water's edge. At the moment, the treatment plant is assuring, also during the summer period, the respect of the quality of water as required by the national law D.Lgs. 152/06.

Recent development of settlements, in a large part squatting, graves negatively in the global territorial system management for their sprawl diffusion and expansion (unfortunately sometimes also when these settlement are approved by competent authority, nobody takes in account all the water and waste facilities necessary for their normal development).

The aim of this study is point the attention on one of these settlements that can be representative for the other ones inside and outside the department of Ragusa. Mainly these settlements have been built to the close to Marina di Ragusa and or Ragusa, on the main road to Ragusa, Provincial Street 25.

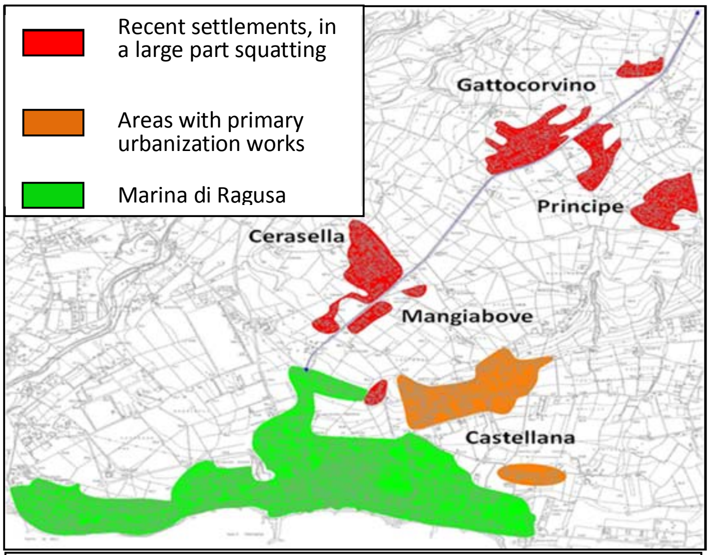


Fig. 7 – Coastal Agglomerations

They are seasonal settlements, most of them are constituted from single family small houses with one or two floors.

These areas have the problem to not be connected with the water supply network and waste water system and, thus, if not well managed and controlled they can determine potential pollution of aquifers from which competent authorities picks up the water used for Marina di Ragusa drinking water consumption.

<u>Villaggio Cerasella</u>

Villaggio Cerasella represents one of the numerous settlements of recent realization, illegally born in 80's at the side of Provincial Street 25, without any water management and drainage system.

Residents are about 60, while during vacation period reach the 800 units. On average the number of inhabitants for each family is 4 persons.

Fig. 8 – Villaggio Cerasella's map

How the most of Marina di Ragusa illegal buildings, Villaggio Cerasella is composed by single family small houses with one or two floors and garage.

Through the land register inquiry, competent authority declared that: 8% has 3,5 compartments, 59% has from 4 to 6 compartments and 33% has more than 6 compartments; furthermore the 11% results not built, 25% presents buildings with 3 levels while 64% is characterized by buildings at 2 levels.

Water consumption and waste water disposal

C.da Cerasella inhabitants provided autonomously drinking water through tankers' service to 15000 l, on average 4 times a year, and in particular 3 times in the period of July – August and one time in the rest of year .

Considering 205 houses, water consumption for each house, in the period July – August, is about 750 l/day, for a total of 153.750 l/day for the village.

Considering 4 inhabitants for each family, water consumption average for each inhabitant is 190 l/day.

Some practices for the rainwater reuse for irrigation purpose, have been developed by inhabitants, but it's not diffused in the entire village.

Villaggio Cerasella hasn't drainage system, wastewater management takes place through Imhoff tanks, which normally are emptied two times per year, through private enterprises for the non residents, while for the resident, through a cheaper municipal service.

Water and drainage intervention prevision

Municipality identified possible interventions for tackling the problems of Marina di Ragusa and related settlements, for supplying to these areas adequate quantity of drinking water: they planned to realize an aqueduct among Ragusa and Marina di Ragusa exploiting the different level, thus the gravity.

This aqueduct should be connected, as well as municipal water source already used, to the dam of S. Rosalia.

Comune di Ragusa signed an agreement with ESA, Ragusa's Province and Municipalities of Modica and Scicli for managing the dam's water of S. Rosalia's, for providing, each year, 500.000 m^3 of water for a maximum flow rate not exceeding 100 l/s, to satisfy the summery potable water request of the coastal zone. Furthermore, Ragusa's municipality submitted a project, already financed, for connecting Marina di Ragusa, to S. Rosalia's dam (about 0,5Mlnm2/year of water).

This project plans the realization of a treatment plant for drinking water located in C.da Camemi, with a maximum flow rate of 50 l/s, for supplying drinking water to the villages besides the Provincial Street 25.

Concerning wastewater management, the competent department of Ragusa Municipality planned to realize a drainage system: a collector 4200 m long located in Provincial Street 25 confluents in the wastewater treatment plant of Marina di Ragusa.

2. Draft feasibility evaluations

Analyzing the data collected during the survey on the three case studies, it's clear that these isolated areas face many infrastructural problems related to water and drainage system. This situation has to be read in a global context where the territory is afflicted by a significant water loss (about 60%) and that citizens are not often conscious about water wastefulness linked to their behaviors.
In all the areas should be planned the promotion of the water saving kits, as water diffusers, dual flush button and also system of rainwater harvesting to encourage the water reuse. Furthermore water supply system should be enhanced by a grey and black water separation system in order to pipe grey water into a treatment plant and black water pipe to the existing municipal water wastewater plant of C.da Lusia.
Taking in account the 3 cases study, the following solution can be proposed:

- concerning Urban Residential areas, the recommended solutions are to be addressed to the grey water separation system for improving the reuse at domestic level;
- having to do with the Rural Agglomerations the main problem to tackle is related to the absence of a drainage system that should be solved building a constructed wetland plant in order to improve the adoption of more sustainable solutions and reuse of water, also in agriculture, the main activity around the village;
- the Coastal Agglomerations have to face the problem due to the absence of connection with the main facilities of the close city, thus, a large water saving campaign is proposed for supporting the adoption of sustainable solutions for domestic water reuse, as water saving kits, separation of grey and black water and storage of rainwater.

Furthermore the remarkable inhabitants' fluctuation in the summery time implies the necessity to adequate the water related facilities in order to maintain efficient the system during the entire year, preventing during summer period a water resources surplus in residential zone and a deficit in the coastal zone.
An adequate system of water recovery and reuse could help competent authorities and citizens to tackle the problem of wastefulness of drinking water, saving a quantity of water enough for avoiding the periodical deficit, for example in august.

Here below a brief list of the possible tools suitable for the Ragusa territory and related cases studies, with some essential explanation and clarifications in order to understand better the selection of the various tools in the proposed alternatives.

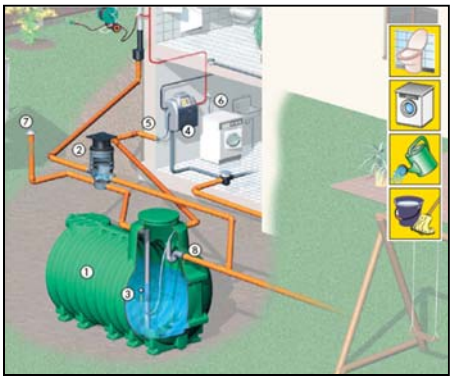
Water Saving devices
A wide range of fittings and equipment able to reduce water consumption is available on the market. Most effective products are taps aerators and low flow shower-heads. Among the different tap types are lever taps, taps with timers with electronic shutoff, etc. There are also devices which can be adapted for different tap systems like reduced flow, and Tap aerator. Many models of new taps have these devices already incorporated. In addition, these devices are almost always compatible with each other. You can find mixer taps that have a built-in aerator.

	Savings for supply point
Flow restrictors	30-40%
Tap aerator	30-70%
Water pressure limiter	10-40%
Water saving showers	50%
Mixer taps	30-40%
Automatic taps	30-40%
Electronic taps	40-50%
Thermostatic taps	50%

The flush toilet can be adapted in order to use significantly less water than a full-flush toilet. Low-flush toilets use a special design of the cistern and the siphon in order to allow the removal of faeces and excreta with less water. Most often, they also include a dual flush system, with one flush being designed for urine only, using even less water than the other designed for faeces. Today, there exist many suppliers of different models of low-flush toilets all over the world.

Rainwater Harvesting (Urban) and (Rural) realized in a rooftop is the most common technique of rainwater harvesting (RWH) for domestic consumption. It can be done easily, doesn't cost much and is applicable at small-scale with a minimum of specific expertise or knowledge; or in more sophisticated systems at large-scale (e.g. a whole housing area). Rainwater is collected on the roof and transported with gutters to a storage reservoir, where it is either used for groundwater recharge or provides water at the point of consumption. Rainwater harvesting can supplement water sources when they become scarce or are of low quality like brackish groundwater or polluted surface water in the rainy season. However, rainwater quality may be affected by air pollution, animal or bird droppings, insects, dirt and organic matter. Therefore regular maintenance (cleaning, repairs, etc.) as well as a filtration treatment before water consumption are very important.
The main components of a system for rainwater harvesting are:
• The collecting surface: only connect suitable roof surfaces if the system does not include a treatment. Take into consideration possible erosion of hazardous matter from the roof. With an appropriate treatment water from pavements can also be used.
• Gutters and downspouts (gullies and rainwater drains)
• Filter – mechanical or natural (as raingarden)
• Tank below ground
• A distribution system for reuse in irrigation or for WC flush

The treatment could be a simple mechanical filter; there are several models on the market, generally they are very simple and permit a basic filtration, due to the presence of mesh grid and/or exploiting forced hydraulic patterns to separate the coarse solids from the water. Generally the models on the market can cover roof surface until 3-400 m^2.



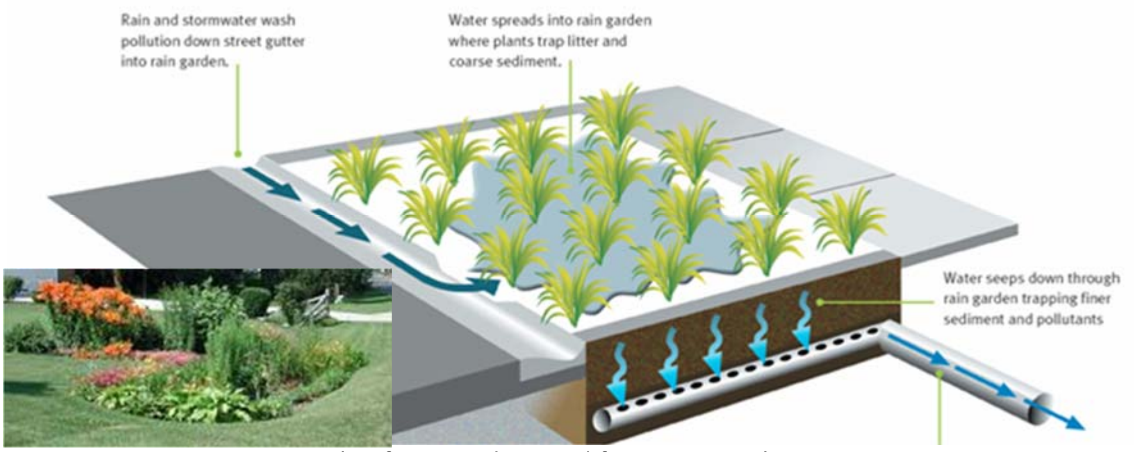
1)tank
2)stormwater mechanical filter
3) suction pipe with floating filter
4) control panel and external pump for reuse
5) dual network for WC
6) emergency connection to potable network in case of empty tank
7) emergency overflow with check valve connected to stormwater network
8) ventilation pipe (optional)

Example of rainwater harvesting at household level with mechanical filter.

If there is available space, the surface of the roof is higher and a higher purification capacity is required, natural treatment systems permit to achieve better results.

Vegetated natural filters (rain gardens) are intended to be landscaped areas that treat stormwater runoff. Homeowners or custodians can treat these gardens, giving them significant attention, or they can blend them into the landscape and make them look "natural." Whatever the context, a rain garden should look like part of the landscape: plants—particularly shrubs and trees—surrounded by mulch. However, the true nature of a rain garden is to treat stormwater. Water is directed into them by pipes, swales, or curb openings. The garden is a depression or bowl that temporarily holds and treats water.
The treated stormwater can be collected by a drainage system for the reuse or infiltrated for groundwater recharge.

- Help alleviate problems associated with flooding and drainage.
- Enhance the beauty of individual yards and communities.
- Provide habitat and food for wildlife including birds and butterflies.
- Allow reuse of treated stormwater



Example of raingarden used for rainwater harvesting

Grey water reuse

Any water that has been used in the household, excluding faecal water from toilets (black water), is called greywater. Shower, sink, laundry, and dishwashing effluents represent up to 70 % -80% of residential and touristic wastewater and as it is relatively clean, it is easier to treat. As drinking water is constantly used, domestic greywater is available in a constant quality and quantity. This is an important advantage for the reuse of greywater for toilet flushing, indoor and outdoor irrigation of plants and cleaning purposes. Major benefits of greywater reuse are the reduction of need for fresh water supply and sewage treatment. Especially in areas with low precipitation rates and water supply deficiencies, reuse for landscaping also has a benefit in reducing demands on high quality water supply.

Grey water are collected by a separate sewer, pre-treated by simple static degreaser, piped into a treatment system to reach the reuse limits and then stocked in a reservoir from which come out depurated water that can be inserted again into house pipes. Constructed wetland and compact precast plant (most of them based on SBR technology, but in some case also simplified MBR (membrane bio reactor) and MBBR (mobile bed biological reactor) are the most diffused as treatment tools.

Constructed Wetland

Constructed Wetland are nowadays one of the most worldwide diffused technology for the wastewater treatment; their functioning principles are based on the biological, physical and chemical processes that occur in natural wetland, even if the CWs (especially subsurface types) are engineered systems studied and monitored since the end of '70.

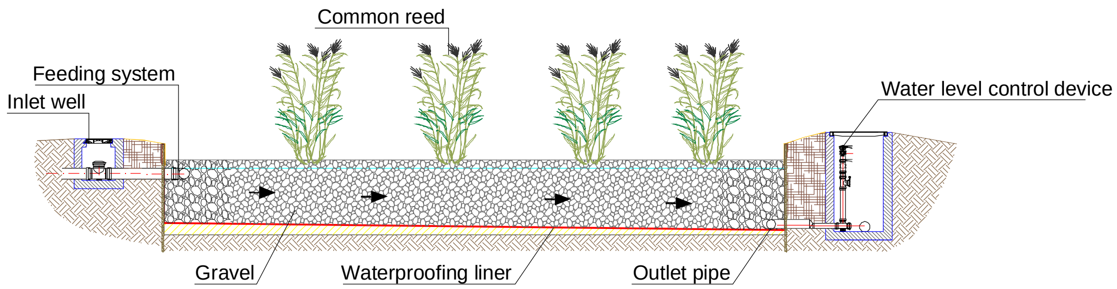
The most diffused are the submerged filters (horizontal and vertical flow type) where the wastewater is filtered by a medium (composed by gravel and/or sand) planted with aquatic macrophyte plants (generally Phragmites Australis or Typha latifolia); these systems require less area than free water systems (more similar to natural wetland) and permit both secondary and tertiary treatment of wastewater (e.g. greywater or blackwater). Because the water is not exposed during the treatment process, the risk associated with human exposure to pathogenic organism is minimized. Generally they require a primary treatment for coarse solids (a manual or automatic grid) and suspended solids removal (a septic tank or imhoff tank). The water is treated by a combination of biological and physical processes. The effluent of a well-functioning constructed wetland can be used for irrigation and aquaculture (in these cases a combination of horizontal flow and vertical flow could be suggested for blackwater and mixed water, considering the low capacity of ammonia reduction of HF) or safely been discharged to receiving water bodies.

If the design requires expert knowledge, the implementation is very easy because it requires only a basic knowledge of simple hydraulic and civil works (earthmoving, waterproofing, hydraulic connection, small concrete structures); for the littler plants sometimes it is possible also the self-construction. Moreover CWs are relatively inexpensive to build where land is affordable and can be maintained by the local community as no high-tech spare parts, electrical energy or chemicals are required.

Horizontal Flow Constructed Wetland

HF constructed wetlands consist of waterproofed beds planted with hydrofite vegetation tipical of swamps and marshes (generally common reed - Phragmites Australis - is the most used, but to improve aesthetic amenity we could use together also other ornamental essence as Iris pseudacorus) and filled with gravel. The wastewater is fed by a simple inlet device and flows slowly in and around the root and the rhizomes of the plant and through the porous medium under the surface of the bed in a more or less horizontal path until it reaches the outlet zone. The filling material (coarse gravel, fine gravel and coarse sand) has to offer an appropriate hydraulic conductivity but also a large surface for the biofilm growing. Because the water is not exposed during the treatment process, the risk associated with human exposure to pathogenic organism is minimized. Properly designed HF beds do not provide suitable habitat for mosquitoes or other vector organism and permit public access in wetland area.

HF beds are typically comprised of inlet feeding system, a synthetic liner, filter media, emergent vegetation, berms, and outlet piping with water level control.



HF wetland schematic longitudinal section

Advantages/Benefits
- High treatment efficiency;
- Excellent environmental integration;
- Low investment cost and low maintenance requirements;
- No Energy consumption;
- The final effluent can be reused;
- High tolerance to seasonal and daily variation of fluxes and dry periods.

Disadvantages/Limitations
- Land requirement;
- High evapotranspiration at high temperatures
- Constrains on geometry (rectangular, ratio between Lenght and Width)

Operation and maintenance
- Management of primary sludge (periodic emptying of primary treatment)
- Annual mowing of emerging macrophytes.

The performance of HF systems are influenced by the wastewater temperature and the hydraulic retention time (HRT): HRT must be minimal 1 day for greywater (3 days for black water) to permit removal performances of organic matter over 60-70%. High temperatures positively influence the natural purification processes.

BOD_5	85-95%
Suspended Solids	70-95%
Total Nitrogen	55-75%
Ammoniacal Nitrogen	50-70%
Phosphorus	50-90%
Pathogen micro-organisms	97-99,999%

Typical removal of a well designed HF system

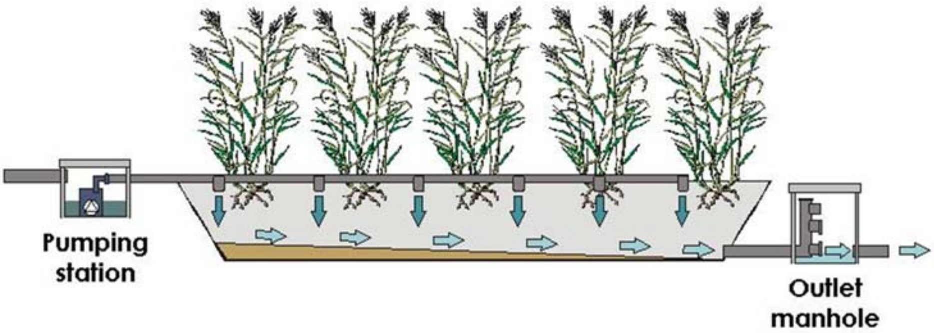
The horizontal flow system is well suitable to treat greywater that contain low content of ammonia and bacteria compared to mixed wastewater and a fast biodegradable organic content; usually 2-3 days of HRT are enough to ensure a safe reuse of greywater.

HF system fro greywater reuse in Preganziol (TV) for 240 a.e.

Vertical Flow Constructed Wetland

In the vertical flow systems (VF) the wastewater is applied through a distribution system on the whole surface area and passes the filter in a more or less vertical path. The pre-treated wastewater is dosed on the bed in large batches (intermittent feeding), thus flooding the surface. During the time between the feedings the pores within the filter media can fill up with air which is trapped by the next dose of liquid. Thus oxygen requiring nitrifying bacteria are favored and full nitrification can be achieved, but only a small part of the formed nitrate is denitrified under aerobic conditions. The treated water is collected in a bottom drainage system to be discharged.
The loading of Vfs normally happens intermittently by pumps, or by gravity using special self-priming siphon devices if there is enough difference of level between the primary treatment and the wetland basin.

This kind of CW is particularly efficient in nitrification, carbon and suspended solids removal. Due to its prevalently aerobic conditions denitrification is poor.



Advantages/Benefits
- High treatment efficiency;
- Excellent environmental integration;
- Low investment cost and low maintenance requirements;
- Low Energy consumption;
- The final effluent can be reused
- High tolerance to seasonal and daily variation of fluxes and dry periods.

Disadvantages/Limitations
- Land requirement (generally a little bit less than HF);
- Constrains on geometry (to permit uniform distribution on the surface)

Operation and maintenance
- Management of primary sludge
- Annual mowing of emerging macrophytes;
- Periodic inspection of the feeding system (usually centrifugal submerged pumps).

The performance of VF systems are influenced by the Hydraulic Loading Rate (m^3/m^2 per day) and the Organic Loading Rate (grCOD/m^2 per day). The typical removal efficiency are listed below:

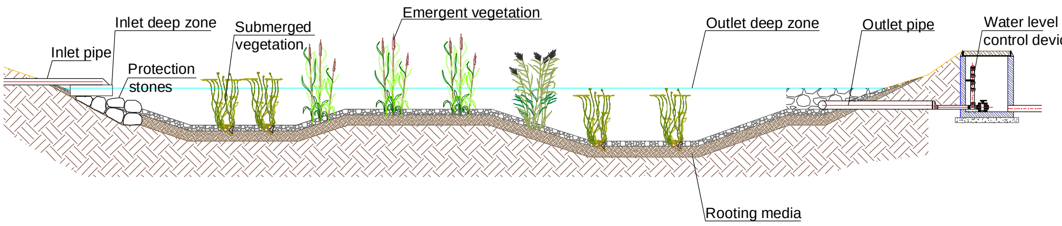
BOD_5	85-95%
Suspended Solids	80-95%
Total Nitrogen	55-75%
Ammoniacal Nitrogen	80-90%
Phosphorus	50-90%
Pathogen micro-organisms	2-3 log

Free Water System (FWS)
Generally surface flow wetlands are densely vegetated basins that contains open water, floating vegetation and emergent plants. They need of soil or another suitable medium to support the

emergent vegetation. When the FW systems are applied for the control of diffusion pollution, they don't need of waterproofing with plastic liner, due to the low risk of groundwater contamination.
The main components of a FW wetland are:

- An inlet distribution system, followed by an inlet deep zone to allow the removal of heavier sediments;
- Shallow marsh areas with varying depths (0,4 - 0,6 m) with wetlands vegetation;
- An outlet deep zone to clarify the final effluent;
- An outlet device to control the water level.

The most common application of these systems is the tertiary treatment due to their power of denitrification and pathogens removal (due to the high exposure of the wastewater to the UV component of the sunlight). FW systems are also largely used to control diffuse pollutions: these systems are one of better choice for the treatment of agricultural, urban and industrial stormwater, because of their ability to deal with intermittent flows and low concentrations



Advantages/Benefits
• Environmental restoration;
• Provides aesthetic amenity and increases biodiversity;
• Buffer effect when used as tertiary treatment;
• No energy consumption.

Disadvantages/Limitations
• High land requirements.
• Risk of mosquitoes diffusion.
• High evapotranspiration rates
• not indicated for secondary treatment (large area and bad odor diffusion)

Operation and maintenance
• Examine the functioning of the system;
• Annually mow emergent vegetations.

SBR:
A technological and compact sewage treatment systems that permit to clean the sewage water permitting to discharge the outflow in a water body or to reuse the treated water.
In the Sequencing Batch Reactors (SBR) the process is the same of classic activated sludge plants: oxygen is bubbled through the waste water to reduce pollutants by oxidation processes.
While there are several configurations of SBRs the basic process is similar. The installation consists of at least two identically equipped tanks with a common inlet, which can be switched between

them, or of an equalization tank followed by one SBR tank. The functioning is based on a "batch mode", permitting to release the various stages of the treatment process (loading, oxidation, sedimentation, discharge) in a single tank (whereas in a Activated sludge plant, sedimentation and aeration are carried on in different tanks). These sequential phases are controlled by a automatic control panel; the conditions of mixing and equalization are normally better than a classic activated sludge plant and also the management is a little bit more simple; for this reason this particular process is well indicated for small and medium agglomerates and generally where a fluctuation of the inlet hydraulic and organic loads are expected. However the system requires skilled labor for its management and maintenance.
Simplified compact SBR systems are also commercialized for the greywater treatment and reuse.

Advantages/Benefits
• High treatment efficiency;
• low space required;
• affordable investment cost
• The final effluent can be reused with an additional disinfection unit
• High tolerance to seasonal and daily variation of fluxes and dry periods.

Disadvantages/Limitations
• high energy consumption;
• high surplus sludge production
• skilled labor maintenance requie
• higher maintenance cost compared to natural and other low-tech treatment

Operation and maintenance
• Management of surplus sludge
• weekly analytical control of sludge and wastewater characteristics
• Periodic inspection and maintenance of E&M equipment

Tool	Applicability in the region	Diffusion in the region	Remarks/ comments
CASE 1 URBAN RESIDENTIAL AREA – Buildings Cooperatives			
Water saving devices	++	++	
CW for greywater	+	-	
SBR for greywater	+	-	
Rainwater harvesting - filter	++	++	
Rainwater harvesting - raingarden	+	-	
CASE 2 RURAL AGGLOMERATIONS – Borgo San Giacomo			
Water saving devices	++	-	
SBR	++	-	
CW for wastewater	++	+	
Treated wastewater reuse in agriculture	+	-	
CASE 3 COASTAL AGGLOMERATIONS – Villaggio Cerasella			
Water saving devices	++	-	

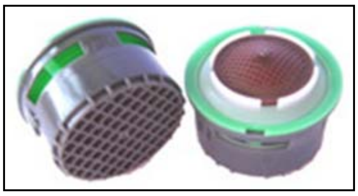
Centralized approach (connection to sewer of Marina di Ragusa)	++	++	
Constructed Wetland	++	-	

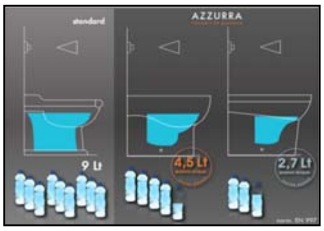
++ applicable without constraints / very diffused
+ applicable with constraints / used in some cases
- not applicable / not used

3. Elaboration of alternative options

Urban Residential area

1. Water Saving devices to reduce water consumption at home: as above explained tools for regulating the water flow, shower diffusers, WC "Water Saving" that drains with 3 l instead of 9 l like the traditional WC and low flush toilet.





In some case, a low cost intervention, compared to the substitution of the WC cassette, could be considered: the introduction of 1 or 2-litre toilet tank bag in the flushing will ensure the use of a lower volume of water with each flush. These too can be considered as soft measures, which however require the effective engagement of the eventual user to ensure that they are effectively installed in the flushings.

The cost of the application of these facilities can vary depending the type of product and the supplier.

Measure Type	**Device**	**Estimated cost per household (Euro)**
Water Flow Restrictor	Efficient Shower Head	4.02
	Aerator Type 1	5.25
	Aerator Type 2	1.74
WC Volume Displacement	Toilet Tank Bag	0.78
WC Volume Displacement	New cassette with double flush	45,00

Some of these facilities are already present in the household in the last year and it is very difficult to estimate where a substitution or an improvement of the water devices is needed.

2. Greywater reuse for WC/irrigation

In this case we compared cost of CW and SBR for greywater reuse. Normally Constructed wetland are more affordable when the plant is carried on by the owners, because the maintenance operation are easier and without need of skilled labour. The only disadvantage of CWs is the higher area required for the treatment; instead SBR could be installed underground or in some case also inside the buildings, but it requires more attention in operational and maintenance phase that has to be conducted by skilled labour.

In these two cases it seems easy to find adequate external surfaces for CW installation, therefore a natural treatment is more convenient and efficient; in the multi-criteria analysis we'll consider a constructed wetland horizontal flow type (the most simple type of CWs, very suitable for greywater considering that they contain a limited quantity of ammonia and therefore the treatment doesn't require an high oxygen content).

In the comparison we have considered the same level of efficiency for CWs and SBR and a centralized approach for both. It could be possible also to provide small SBRs at household level reducing the pipeline length: there are some companies that sell them in Italy, as i.e. Hansgrohe Aquacycle, but the costs are higher.

The cost of Constructed Wetland are calculated using parametric costs deduced by the official cost list issued by Region Sicily and by quotation of local companies for the materials not included. Maintenance costs are very low and limited to the yearly emptying of the degreaser and to the cut of plants.

The cost of SBR is at the same time calculated using the unitary prices deduced by the official cost list issued by Region Sicily for civil and electrical works and by quotation of specialized companies for a precast SBR system. The operational and maintenance costs are related essentially to energy consumption for aeration and pumping and to the periodic visits conducted by skilled workers (generally the company that furnish the SBR offers also this maintenance service); the sludge instead can be discharge in the black water sewer line. We assumed in the rough estimation a cost of 0,8 €/m^3 treated, but it could be vary significantly depending the extraordinary maintenance costs and the conditions of the company that carry on the maintenance services.

SORAYA				
Greywater recovery with CW			**Greywater recovery with SBR**	
Number housing	20		20	
Daily Water consumption	184	l/inhab.	184	l/inhab.
Resident each housing (average)	3,5		3,5	
Greywater production	9	mc/g	9	mc/g
Constructed wetland HF	140	mq	N°1 SBR	unit
Installation investment cost including connections	32578	€	30778	€
Yearly maintenance cost	560	€/year	2632,672	€/ year
m3 cost of treated water (investment payback time 20 years 20 years)	0,74	€/mc	1,41	€/mc
Recovery quantity for WC	1278	mc/ year	1278	mc/ year
Water for irrigation and other uses	1684	mc/ year	1684	mc/ year

Doriana				
Greywater recovery with CW			**Greywater recovery with SBR**	
Number housing	48		48	
Daily Water consumption	184	l/inhab	184	l/inhab
Resident each housing (average)	3,5		3,5	
Greywater production	22	mc/g	22	mc/g
Constructed wetland HF	336	mq	N° 1 SBR	Unit
Installation investment cost including connections	66923	€	59323	€
Yearly maintenance cost	1344	€/ year	6318,41	€/ year
M3 cost of treated water (investment payback time 20 years 20 years)	0,66	€/mc	1,31	€/mc
Recovery quantity for WC	3066	mc/ year	3066	mc/ year
Water for irrigation and other uses	4042	mc/ year	4042	mc/ year

3. Roof rainwater harvesting and reuse for WC/irrigation

The reuse of wastewater presents an opportunity to save water and financial resources by reducing water consumption. Collected rainwater can be used for example to irrigate common green areas and at household level, setting up apposite pipes for treated water into the house. Furthermore collected rainwater can supplement other water sources under stress (quality and quantity related problem).

This area is far away urban centre and isn't subjected to particular pollution so for rainwater is sufficient a mechanical filter, cheaper than rain garden, if the rainwater recovery is considers at single or double houses level; anyway in the presence of open areas and in the case we decide to centralized rainwater recovery, we can consider also the use of natural filtration systems (such rain garden).

We can take a tank of 5 mc every 100 mq of roof. The cost of the filter and the tank is 2000-2500 €/family (SORAYA: 50.000 €; DORIANA: 100.000 €).

Cooperative's Soraya

In the following table a tentative hydraulic balance is showed, based on the average monthly rainfall of Ragusa furnished by Hydrographical Institute of Palermo and referred to the hydrological station of Ragusa (515 m a.s.l) during the period 1961 – 2001.

WC consumption is estimated considering a specific consumption of 50 l/person per day.

Greywater production is estimated considering 70% of the total as per literature indications for residential case (the total water consumption is assumed 184 l/day per person, i.e. without considering the saving of WSDs)
The recovery capacity of the roof is calculated simply multiplying the surface of the roof per the mm of rainfall per month and applying a reductive coefficient (0,85) that take in account water losses and efficiency of the filtration system in a conservative approach.

Month	Ragusa mm.	Roof recovery capacity (m3/month)	Greywater recovery capacity (m3/month)	Requirements WC (m3/ month)	Water requirements for irrigation (m3/ month)	Balance (m3/ month)	Cover requirements only greywater	Cover requirements only rainwater	Cover requirements grey+rainwater
January	96,29	164	270	105	0	282	258%	156%	413%
February	74,29	126	270	105	0	248	258%	120%	378%
March	54,48	93	270	105	0	230	258%	88%	346%
April	45,04	77	270	105	111,0	96	125%	35%	161%
May	21,5	37	270	105	222,0	-31	83%	11%	94%
June	9,26	16	270	105	444,0	-272	49%	3%	52%
July	9,65	16	270	105	444,0	-270	49%	3%	52%
August	20,76	35	270	105	333,0	-149	62%	8%	70%
September	41,64	71	270	105	111,0	119	125%	33%	158%
October	85,01	145	270	105	0	282	258%	138%	395%
November	72,98	124	270	105	0	265	258%	118%	376%
December	101,36	172	270	105	0	296	258%	164%	422%
Total	632,26	1075	3246	1260	1665		111%	37%	148%

The total of rainwater can cover WC requirements for 6-7 months, allowing the recovery of 800-900 m^3/year; while for the irrigation aren't sufficient considering scarce summer rain.

Furthermore greywater allows to recover all WC water (1260 m^3/year) and to make available for the irrigation 60% of the requirements during summer months, recovering further 1000 m^3.

Grey and rainwater allowing to recovering more water even if the difference compared to the Alternative 2 relating to the requirements is low (about 100-200 mc extra in a year), unless we don't realise huge and expensive storage tanks.

With the application of WSDs the total water consumption could be reduced by 70% and therefore a consumption of 130 l/day person is assumed (40 liter for WC, 90 liter for greywater). Therefore the quantity of treated water available for irrigation is slightly reduced.

Month	Ragusa mm.	Roof recovery capacity (m3/month)	Greywater recovery capacity (m3/month)	Requirements WC (m3/month)	Water requirements for irrigation (m3/month)	Balance (m3/month)	Cover requirements only greywater	Cover requirements only rainwater	Cover requirements grey+rainwater
January	96,29	164	189	84	0	221	225%	195%	420%
February	74,29	126	189	84	0	187	225%	150%	376%
March	54,48	93	189	84	0	170	225%	110%	336%
April	45,04	77	189	84	111,0	36	97%	39%	136%
May	21,5	37	189	84	222,0	-91	62%	12%	74%
June	9,26	16	189	84	444,0	-332	36%	3%	39%
July	9,65	16	189	84	444,0	-331	36%	3%	39%
August	20,76	35	189	84	333,0	-209	45%	8%	54%
September	41,64	71	189	84	111,0	59	97%	36%	133%
October	85,01	145	189	84	0	222	225%	172%	397%
November	72,98	124	189	84	0	204	225%	148%	373%
December	101,36	172	189	84	0	235	225%	205%	431%
Total	632,26	1075	2272	1008	1665	372	85%	40%	125%

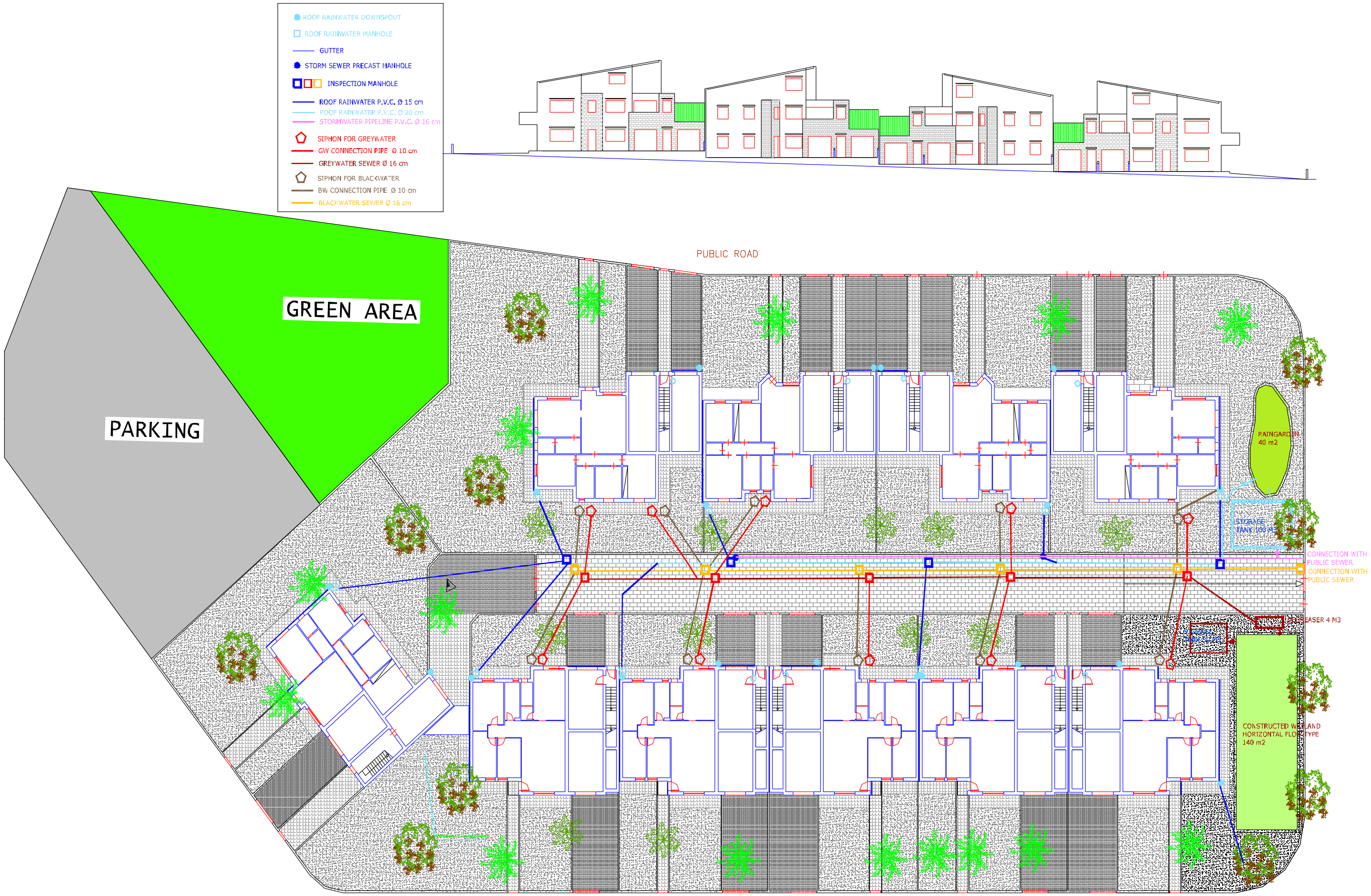
In the following annex two layout are showed, the first one before the segregation of greywater and rainwater, the second one with a proposal of greywater and rainwater harvesting and reuse, using constructed wetland and raingarden.

In the next tables instead the costs of each alternatives and the possible benefits are showed; with the application of the proposed measures a reduction until 90 l/p.e. is reachable (more than 50% of reduction of the potable water consumption); moreover the withdrawal of water (from the water network or from the underground resources) could be reduced of almost 1000 m^3/year (60% of reduction).

Cooperative Soraya	**ALT 0**	**ALT 1**	**ALT 2**	**ALT 3**
Water saving devices	NO	Yes	Yes	Yes
Greywater reuse for WC/irrigation	NO	NO	35.000	35.000
Roof rainwater harvesting and reuse for WC/irrigation	NO	50.000	NO	50.000

	ALT 0	**ALT 1**	**ALT 2**	**ALT 3**
Household Water consumption (assuming 30% for WSD)	185 l/p.e.	130 l/p.e.	90 l/p.e.	90 l/p.e.
Irrigation (potable or underground water)	1600 m^3/y	1480 m^3/y	770 m^3/y	650 m^3/y


ROOF RAINWATER DOWNSPOUT
ROOF RAINWATER MANHOLE
GUTTER
STORM SEWER PRECAST MANHOLE
INSPECTION MANHOLE
STORMWATER PIPELINE P.V.C. Ø 15 cm
STORMWATER PIPELINE P.V.C. Ø 25 cm
SIPHON FOR MIXED WASTEWATER
WW CONNECTION PIPE Ø 10 cm
SEWER Ø 25 cm
PUBLIC ROAD
GREEN AREA
PARKING
CONNECTION WITH PUBLIC SEWER
CONNECTION WITH PUBLIC SEWER


ROOF RAINWATER DOWNSPOUT
ROOF RAINWATER MANHOLE
GUTTER
STORM SEWER PRECAST MANHOLE
INSPECTION MANHOLE
ROOF RAINWATER P.V.C. Ø 15 cm
ROOF RAINWATER P.V.C. Ø 20 cm
STORMWATER PIPELINE P.V.C. Ø 16 cm
SIPHON FOR GREYWATER
GW CONNECTION PIPE Ø 10 cm
GREYWATER SEWER Ø 16 cm
SIPHON FOR BLACKWATER
BW CONNECTION PIPE Ø 10 cm
BLACKWATER SEWER Ø 16 cm
PUBLIC ROAD
GREEN AREA
PARKING
RAINGARDEN
40 m2
STORAGE
TANK 100 M3
CONNECTION WITH
PUBLIC SEWER
CONNECTION WITH
PUBLIC SEWER
DEGREASER 4 M3
CONSTRUCTED WETLAND
HORIZONTAL FLOW TYPE
140 m2

Cooperative's Doriana

For the Constructed Wetland localisation we can foresee centralised solutions or 2-3 installations decentralized and equipped by an independent irrigation tank; in this case we will have more cost for sewer, dual network, green area design and different property allocations. A solution is showed in the annex. However we can also choose a very decentralized system, foreseen an individual recovery and reuse system for each accommodation or group of accommodation; in this case sewer lines and dual network are minimum, but the total cost of the systems increases.
For rainwater instead it could be better to decentralize considering the high sewer cost for the bigger diameters and provide for each building a storage tank equipped with a simple mechanical filter.

In the following table a tentative hydraulic balance is showed, based on the average monthly rainfall of Ragusa furnished by Hydrographical Institute of Palermo and referred to the hydrological station of Ragusa (515 m a.s.l) during the period 1961 – 2001.

WC consumption is estimated considering a specific consumption of 50 l/person per day.

Greywater production is estimated considering 70% of the total as per literature indications for residential case (the total water consumption is assumed 184 l/day per person).

The recovery capacity of the roof is calculated simply multiplying the surface of the roof per the mm of rainfall per month and applying a reductive coefficient (0,85) that take in account water losses and efficiency of the filtration system in a conservative approach.

Month	Ragusa mm.	Roof recovery capacity (m^3/month)	Greywater recovery capacity (m^3/month)	Requirements WC (m^3/ month)	Water requirements for irrigation (m^3/ month)	Balance (m^3/ month)	Cover requirements only greywater	Cover requirements only rainwater	Cover requirements grey+rainwater
January	96,29	346	649	252	0	642	258%	137%	395%
February	74,29	267	649	252	0	571	258%	106%	363%
March	54,48	196	649	252	0	533	258%	78%	335%
April	45,04	162	649	252	323,3	161	113%	28%	141%
May	21,5	77	649	252	646,6	-196	72%	9%	81%
June	9,26	33	649	252	1293,1	-882	42%	2%	44%
July	9,65	35	649	252	1293,1	-879	42%	2%	44%
August	20,76	75	649	252	969,8	-534	53%	6%	59%
September	41,64	150	649	252	323,3	211	113%	26%	139%
October	85,01	305	649	252	0	644	258%	121%	379%
November	72,98	262	649	252	0	606	258%	104%	362%
December	101,36	364	649	252	0	672	258%	144%	402%
Total	632,26	2270	7790	3024	4849,2		99%	29%	128%

The total rainwater can covers WC requirements for 6-7 months, allowing the recovery of 2000-2100 m^3/year; while for the irrigation aren't sufficient considering scarce summer rain.
Furthermore greywater allows to recover all WC water (3000 m^3/year) and to make available for the irrigation 50% of the requirements during summer months, recovering further 2400 m^3.
Grey and rainwater allowing to recovering more water even if the difference compared to the Alternative 2 relating to the requirements is low (about 300-350 mc extra in a year), unless we don't realise huge and expensive collects.

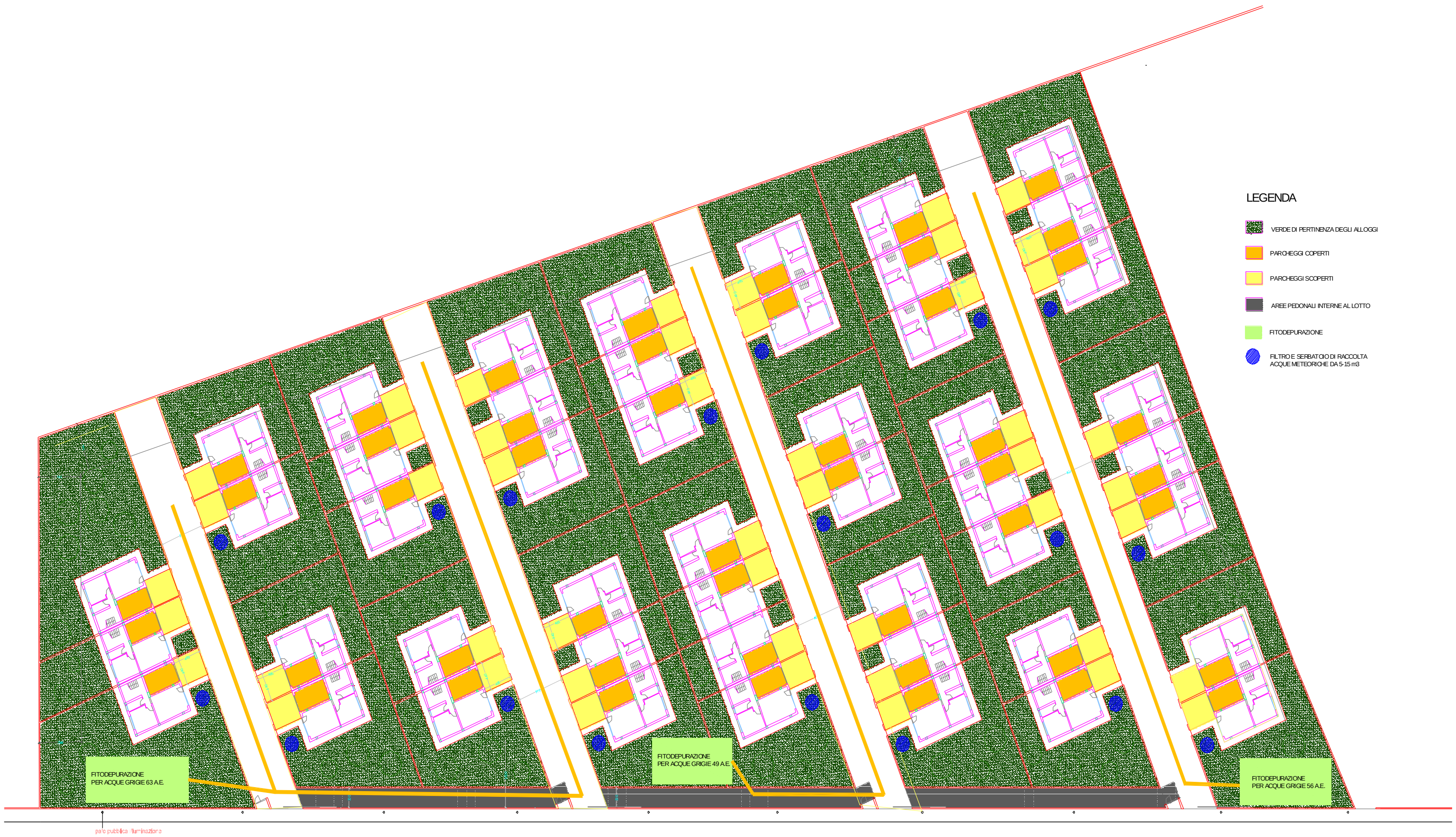
With the application of WSDs the total water consumption could be reduced by 70% and therefore a consumption of 130 l/day person is assumed (40 liter for WC, 90 liter for greywater). Therefore the quantity of treated water available for irrigation is slightly reduced.

Month	Ragusa mm.	Roof recovery capacity (m^3/ month)	Greywater recovery capacity (m^3/ month)	Requirem. WC (m^3/ month)	Water requirements for irrigation (m^3/ month)	Balance (m^3/ month)	Cover requirements only greywater	Cover requirements only rainwater	Cover requirements grey+rainwater
January	96,29	346	459	201,6	0	502	228%	171%	399%
February	74,29	267	459	201,6	0	430	228%	132%	360%
March	54,48	196	459	201,6	0	393	228%	97%	325%
April	45,04	162	459	201,6	323,3	21	87%	31%	118%
May	21,5	77	459	201,6	646,6	-336	54%	9%	63%
June	9,26	33	459	201,6	1293,1	-1022	31%	2%	33%
July	9,65	35	459	201,6	1293,1	-1019	31%	2%	33%
August	20,76	75	459	201,6	969,8	-674	39%	6%	46%
September	41,64	150	459	201,6	323,3	71	87%	28%	116%
October	85,01	305	459	201,6	0	503	228%	151%	379%
November	72,98	262	459	201,6	0	466	228%	130%	357%
December	101,36	364	459	201,6	0	532	228%	181%	408%
Total	632,26	2270	5504	2419,2	4849,2		76%	31%	107%

In the next tables the costs of each alternatives and the possible benefits are showed; as for the first case, with the application of the proposed measures a reduction until 90 l/p.e. is reachable (more than 50% of reduction of the potable water consumption); moreover the withdrawal of water (from the water network or from the underground resources) could be reduced of 2100 m^3/year (43% of reduction).

Cooperative Doriana	**ALT 0**	**ALT 1**	**ALT 2**	**ALT 3**
Water saving devices	NO	Yes	Yes	Yes
Greywater reuse for WC/irrigation	NO	NO	70.000	70.000
Roof rainwater harvesting and reuse for WC/irrigation	NO	100.000	NO	100.000

	ALT 0	**ALT 1**	**ALT 2**	**ALT 3**
Household Water consumption (assuming 30% for WSD)	185 l/p.e.	130 l/p.e.	90 l/p.e.	90l/p.e.
Irrigation consumption (from potable or underground water)	4850 m^3/y	4490 m^3/y	3110 m^3/y	2750 m^3/y


LEGENDA
VERDE DI PERTINENZA DEGLI ALLOGGI
PARCHEGGI COPERTI
PARCHEGGI SCOPERTI
AREE PEDONALI INTERNE AL LOTTO
FITODEPURAZIONE
FILTRO E SERBATOIO DI RACCOLTA ACQUE METEORICHE DA 5-15 m3
FITODEPURAZIONE PER ACQUE GRIGIE 63 A.E.
FITODEPURAZIONE PER ACQUE GRIGIE 49 A.E.
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Rural Agglomerations – Borgo San Giacomo

For this case study we didn't consider the sewer connection to Ragusa, because there are evident disadvantages:

- the investment cost is very high (6,3 €/m^3 in 20 years), due to the length of the connection (as clearly showed by the preliminary analysis in the table below)
- the level of consumption remains the same (100 l/inhab)
- we get lost 18250 m^3/year of water which can be reused or at least remain locally balancing the withdrawal.

Sewer connection to Ragusa (preliminary valuation)	
Connector realisation cost	2.160.000,00 € (18.000 ml X 120 €/m)
Yearly additional treatment cost in the Ragusa WWTP	0,3 €/m^3
after 20 years of centralization	2.269.500,00€

For facing the problem of wastewater management, normally collected by tanks that has empty two or three times per year, it's suitable the idea, already proposed at municipal level, to realize a decentralized treatment plant for the village of San Giacomo, and evaluating also the possibility to reuse the treated water for irrigation or just "scatter" on the field. The proposed system, approved in the PARF, was a constructed wetland. In the following scenarios we have considered a technological option too (SBR).

The realization of a treatment plant requires obviously also the implementation of an appropriate sewer network to connect all the households. This additional cost is common to all the alternatives, except the alternative Zero where no interventions is provided and the households continue to use and empty the storage tanks.

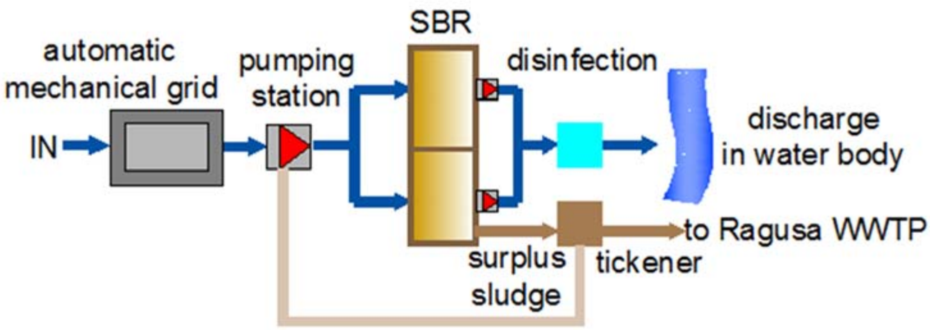
The sewer is by gravity, constituted by a main pipe of about 1200 m and secondary trunks for a total length of 1700 m. The total cost could be roughly estimated in 330.000 € excluding VAT and design services.

1. SBR

The first option is to provide an activated sludge process to treat the sewage of the village; considering the low number of person connected to the sewer, we propose a SBR system that could be more suitable in this case due to the higher fluctuation of the inlet characteristics in small agglomerates.

In the preliminary stage, the suitability of the receiving water body has to be examined more deeply from a hydrogeological point of view, being a poor area of surface water bodies; many of them are in fact natural watersheds that convey water only as a result of rainfall events during the summer. According to Italian law, the intervention ranks below 2000 inhabitants so the sewage can be submitted to an "appropriate treatment" not subjected to specific limits in reference to D.L. 152/06; in these cases the regions set the limits more or less restrictive depending on local criticality. From the point of view of the method of disposal, it will be assessed the optimal criterion on the basis of geological and hydrogeological information and on the basis of the groundwater vulnerability; if a significant water body (with no flow for more than 120 days per year) was not identified, can be evaluated the exploitation of the watersheds in the area, ensuring that there is no swamping and slump downstream.

In the developed hypothesis, both SBR system and constructed wetland, are considered capable of achieving high removals, in line with the limits imposed by Table 3 Part III Annex 5 D.Lgs. 152/06; at the advanced design stage, depending on the vulnerability of the areas of intervention, these aspects must be investigated with the local authorities.

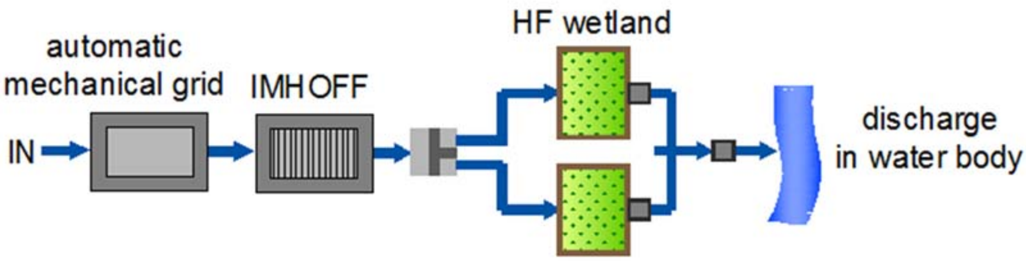


Borgo san giacomo	500 inhabitants	
Water consumption	100 l/inhab x day	
Wastewater production	18250 m^3/year	
SBR		
Automatic screw screen	€ 10.000,00	
Pumping station	€ 10.000,00	
SBR system including concrete tanks and civil engineering works, E&M equipments and accessorios	€ 140.000,00	
Landcsaping and ancillary works	€ 10.000,00	
Connection pipes	€ 10.000,00	
Total Cost (V.A.T. excluded)	€ 180.000,00	
Yearly maintenance cost	18250 €/year	
m3 cost of treated water (investment payback time 20 years)	1,66 €/m^3	
Cost per person every year	54,5 €/ year	

The cost of the treatment system is calculated using parametric costs deduced by the official price list issued by Region Sicily and by the quotation of local companies for the materials and the E&M equipment not included.

2. Constructed Wetland

As natural and low-tech alternative, we have considered to realize a CW system, horizontal flow type, reshaped compared with that provided by the PARF.

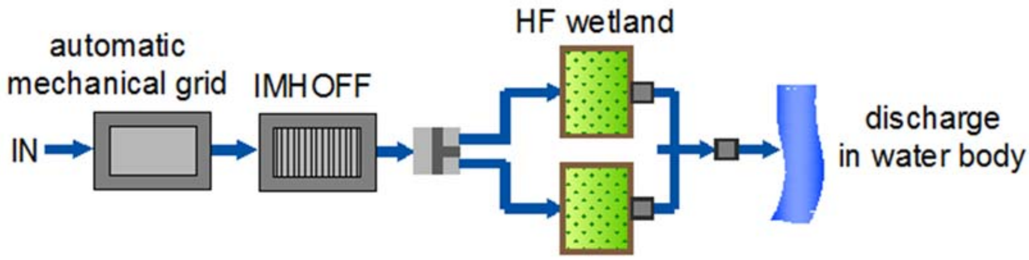


Borgo san giacomo	500	inhabitants
Water consumption	100	l/inhab x day
Wastewater production	18250	mc/year
CW		
Automatic screwscreen	€ 10.000,00	
Imhoff Tank	€ 24.000,00	
Horizontal Flow 1200 m^2	€ 90.000,00	
Connection pipes	€ 12.000,00	
Landscaping and ancillary work	€ 8.000,00	
Total Cost (V.A.T. excluded)	**€ 144.000,00**	
Yearly maintenance cost	7.000	€/year
m3 cost of treated water (investment payback time 20 years)	0,86	€/m^3
Cost per person every year	28,4	€/ year

3. Constructed Wetland and Water Saving devices

The presence of water saving devices guarantees at least 20% decrease of consumption and so also of the plant size, thus, consequently of investment costs.

The cost of Constructed Wetland are calculated using parametric costs deduced by the official price list issued by Region Sicily and by quotation of local companies for the materials not included. Maintenance costs are very low and limited to the yearly emptying of the Imhoff tank and to the cut of the aquatic plants and the grass in the treatment area. The cost don't include design and supervision technical services, neither the cost to buy the land (approximately 1700 m^2).



Borgo san giacomo	500	inhabitants
Water consumption	80	l/inhab x day
Wastewater production	14600	mc/year
CW		
Automatic screwscreen	€ 10.000,00	
Imhoff Tank	€ 22.000,00	
Horizontal Flow 1000 m2	€ 75.000,00	
Connection pipes	€ 12.000,00	
Landscaping and ancillary work	€ 8.000,00	
Total Cost (V.A.T. excluded)	**€ 127.000,00**	
Yearly maintenance cost	7000	€/year
m^3 cost of treated water (investment payback time 20 years)	1,02	€/m^3
Cost per person every year	26,7	€/ year

4. Reuse of treated wastewater for agriculture

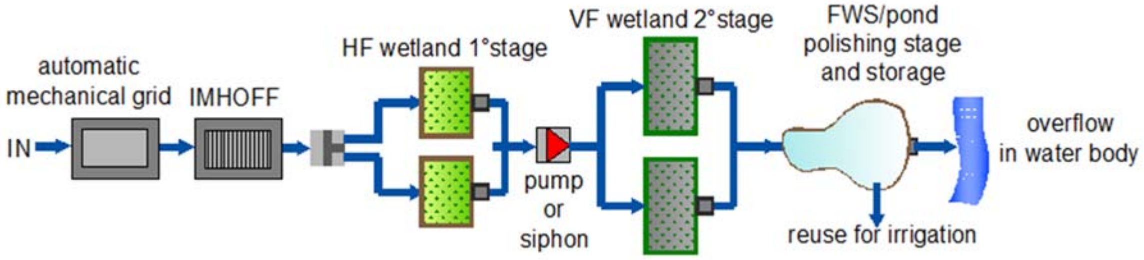
In this option we have considered the possibility of reuse the wastewater for irrigation, that in this case remains the recommended solution in the absence of water bodies to unload.

For the treatment of wastewater we can realize a constructed wetland hybrid system composed by a Horizontal Flow Constructed Wetland (HF) and a Vertical Flow Constructed Wetland (VF). The CW is sized to reach the limits for reuse in agriculture (DM185/03).

The expected outlet value are listed below:
BOD < 20 mg/l
SST < 20 mg/l
Escherichia Coli < 10^2 UFC/100 ml (a additional emergency disinfection could be suggested)
N-NH4 < 2 mg/l
Ntot < 35 mg/l (according the final destination for land irrigation)
Ptot < 10 mg/l (according the final destination for land irrigation)

The appliance of the DM185/03 to the reuse of small communities is not clear at all and it has noticeably slowed down the practice of reuse in Italy; even if the volume are not so high, the treated water could be sold to the farmer, recovering part of the investment and operational cost and decreasing the withdrawal from underground water. Unfortunately this solution could be not economically convenient considering that the cost of underground water is very low and the price of treated water is higher due principally to the stringent limits and the very expensive periodic monitoring required by the law. Another option is that the treated water could be available for public purposes (i.e. public garden irrigation); in this case the Province should fix the reuse norms, generally according to the limits of DM185/03.

The cost of Constructed Wetland are calculated using parametric costs deduced by the official price list issued by Region Sicily and by quotation of local companies for the materials not included. The cost don't include design and supervision technical services, neither the cost to buy the land (approximately 2500 m^2).



Borgo san giacomo	500	inhabitants
Water equipment	80	l/inhab
Wastewater production	14600	m^3/year
CW		
Automatic screwscreen	€ 10.000,00	
Imhoff Tank	€ 22.000,00	
Horizontal Flow 500 m^2	€ 37.500,00	
Vertical Flow 500 m^2	€ 42.500,00	
Free Water system/Pond as polishing stage and storage of about 500 m^3; total surface 500 m^2	€ 12.500,00	
E&M works	€ 6.000,00	
Connection pipes	€ 15.000,00	
Landscaping and ancillary work	€ 10.000,00	
Costo totale al netto Iva	**€ 155.500,00**	
Yearly maintenance cost	8000	€/year
m3 cost of treated water (investment payback time 20 years)	1,20	€/m^3
Cost per person every year	31,55	€/ year

5. Summary of the alternatives

In the next table the figure with the calculated costs for the various option is presented.

	ALT 0	ALT 1	ALT 2	ALT 3	ALT 4
Water saving devices **(WSD)**	NO	YES	NO	YES	YES
SBR	NO	YES	NO	NO	NO
Constructed Wetland for WW treatment **(CW)**	NO	NO	YES	YES	YES
Reuse of treated wastewater for agriculture **(CW+Reuse)**	NO	NO	NO	NO	YES
COSTS (€/m^3 on 20 years)	2,5	1,66	0,9	1	1,2
COSTS (€/person per year on 20 years)	227	54,5	28,4	26,7	31,5

To compare the 4 options with the zero alternative, we have to consider also additional cost related to technical services (12% of the investment costs), land acquisition (we consider an average value of 20 €/m^2) and sewer construction. The cost of alternative zero remains the highest.

ALTENATIVE 1		
Total plant cost (excluded VAT)	**€ 180.000,00**	
sewer realization	**€ 330.000,00**	
technical services	€ 61.200,00	
land cost	€ 6.000,00	
Total investment cost (excluded VAT)	**€ 577.200,00**	
Yearly maintenance cost	18250	€/year
m3 cost of treated water (investment payback time 20 years)	2,87	€/m^3
Cost per person every year	94,22	€/year

ALTENATIVE 2		
Total plant cost (excluded VAT)	**€ 144.000,00**	
sewer realization	€ 330.000,00	
technical services	€ 56.880,00	
land cost	€ 40.000,00	
Total investment cost (excluded VAT)	**€ 570.880,00**	
Yearly maintenance cost	7000	€/year
m3 cost of treated water (investment payback time 20 years)	2,16	€/m^3
Cost per person every year	71,088	€/year

ALTENATIVE 3

Total plant cost (excluded VAT)	**€ 127.000,00**	
sewer realization	€ 330.000,00	
technical services	€ 54.840,00	
land cost	€ 34.000,00	
Total investment cost (excluded VAT)	**€ 545.840,00**	
Yearly maintenance cost	7000	€/year
m3 cost of treated water (investment payback time 20 years)	2,61	€/m^3
Cost per person every year	68,584	€/year

ALTENATIVE 4

Total plant cost (excluded VAT)	**€ 155.500,00**	
sewer realization	**€ 330.000,00**	
technical services	€ 58.260,00	
land cost	€ 54.000,00	
Total investment cost (excluded VAT)	**€ 597.760,00**	
Yearly maintenance cost	8000	€/year
m3 cost of treated water (investment payback time 20 years)	2,88	€/m^3
Cost per person every year	75,776	€/year

Coastal Agglomerations – Villaggio Cerasella

Villaggio Cerasella and the near settlements are mainly occupied during spring and summer, while during the winter the inhabitants are much less. These settlements are without a sewer network that permit to drain the wastewater in the villages and to collect them to a treatment plant. The disposal of wastewater occurs, as for San Giacomo village, in the best of cases, emptying periodically private storage tanks. Cerasella has about 60 residents, but the population increase to 800 residents during summer; also the other settlements have a similar behaviour reaching during the touristic season approximately 5000 p.e.; this data has to be confirmed by future deepen study in this area, for the purpose of this project we consider in detail only Cerasella and the possibility to extend the approach to the other settlements (Mangiabove, Castellana, Gatto Corvino, Principe and other minor settlements).

The realization of sewer collector and of a treatment plant requires obviously also the implementation of an appropriate sewer network to connect all the households. This additional cost is common to all the alternatives, except the alternative Zero where no interventions is provided and the households continue to use and empty the storage tanks.

We don't have enough data to provide a preliminary design of the sewer network; anyway consider the extension of Cerasella, we could assume as rough estimation a cost similar to Borgo San Giacomo (350.000 € excluding VAT and design services), and a cost for all the agglomerations of about 1.500.000 €.

1. Sewer connection to Ragusa

Cerasella is the nearest one to the Ragusa sewer network and a connection to it requires a collector along the Provincial road about 1 Km long. The solution seems to be affordable from a economical point of view. An increasing of 500 p.e. in the total load shouldn't affect the efficiency of the municipal treatment plant, even if during summer this WWTP seems to be overloaded due to the high number of tourists.

The connection of the other settlements requires a prolongation of the main pipe of about 3.2 Km; probably in this case also an upgrading of the WWTP will be required.

Sewer: main pipeline cost	**220.000,00**	**€**
Existing WWTP upgrading	0,00	€
Additional treatment cost of WWTP	0,3	€/m^3
Sewer maintenance cost	0,2	€/m^3
Overall cost on 20 years	388.150,00	€
m^3 cost of treated water (investment payback time 20 years)	1,15	€/m^3
Cost per person every year	24,26	€/year
Total cost for all the coastal agglomerations (5000 P.e.)	**€ 924.000,00**	€/year

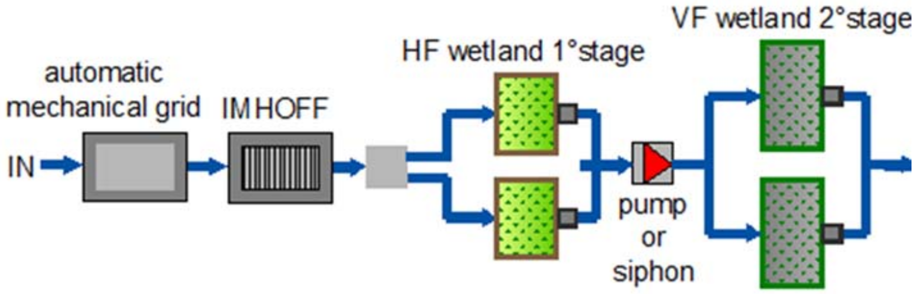
2. Constructed Wetland

In this second alternative, we consider to treat the wastewater of Cerasella locally, i.e. without the realization of the main pipe to the Ragusa network but only providing a sewer to connect the various buildings. The characteristic of the area is the absence of any water body, except local ditches for the runoff of the rain water. The final discharge of the treated water has therefore to be well evaluated on the basis of a hydrogeological survey, in order to individuate the best final disposal of the water (infiltration in the sub-superficial soil, vertical infiltration by drainage wells, or more simply a discharge in a rain ditch if this solution doesn't create wet zones downstream, etc.). The expected performance of the plant has to be better than in the case of river discharge, according to the Italian water law.
The choosen treatment is a constructed wetland; we have already evaluated in Case Study n°2 that a natural treatment is more feasible, if enough space is available, than a technology option (as SBR) for 500 p.e. moreover in this case we have 500 p.e. only during summer and natural treatments are more adaptable to strong seasonal variations of hydraulic and organic load typical of touristic areas.
The pro-capita consumption are higher than Borgo San Giacomo. The yearly wastewater production is calculated considering the presence of occasional residents for 90 days per year (mainly in the summer season); the average flow passes from 11 m^3/day during winter to a peak of 152 m^3/day during summer.
The local situation from the hydrogeological point of view will be studied more deeply in the following phases; the area is characterized by the total absence of receptor water bodies and therefore there is the necessity of discharges on the soil and / or in the superficial layers of the subsoil. As per San Giacomo, the capacity of the plants are below 2000 p.e. so according to Italian law they may be submitted to appropriate treatments not subjected to specific limits by the national legislation; in these cases the Regions have to set limits more or less restrictive depending on local criticality.
From the point of view of the method of disposal, will be assessed case by case the optimal criterion, depending on the geological and hydrogeological information and on the vulnerability of the groundwater; considering that these villages are characterized by a very small number of people during winter and a limited number also during the summer, viable solutions could be infiltration trenches in the soil or the exploitation of watersheds which dispose of rainwater, in the latter case by ensuring that there are no swamps and slumps downstream.
In the developed hypothesis, it shall be considered system capable of achieving high removals, in line with the max limits imposed by Table 3 Part III Annex 5 D.Lgs. 152/06; in a more advanced design stage, depending on the vulnerability of the areas of intervention, these aspects has to be investigated together with the local authorities.
To minimize the required space and enhance the overall efficiency of the system during the peak season, we have considered a multi-stage hybrid system that combines horizontal and vertical flow type. The CW is sized to reach the limits for final discharge in a water body, using the mathematic models recognized by scientific literature for process calculation of constructed wetland. The system can guarantee during peak season a good removal of organics, suspended solids and bacteria, with outlet value respectively below 40 mg/l for BOD, 30 mg/l for SST and 10^4 UFC/100 ml. The presence of the Vertical flow stage permits also a good removal ammonia, maintaining it under 15 mg/l. During winter, the wastewater production of 60 p.e. is enough to

maintain in good conditions the aquatic plant; probably the high evapotranspiration rate will limit strongly the effluent that in any case will present concentrations of pollutants near to zero, thanks to the high retention time.

The cost of Constructed Wetland are calculated using parametric costs deduced by the official price list issued by Region Sicily and by quotation of local companies for the materials not included. Maintenance costs are very low and limited to the yearly emptying of the Imhoff tank and to the cut of the aquatic plants and the grass in the treatment area. The cost don't include design and supervision technical services, neither the cost to buy the land (approximately 2500 m^2).

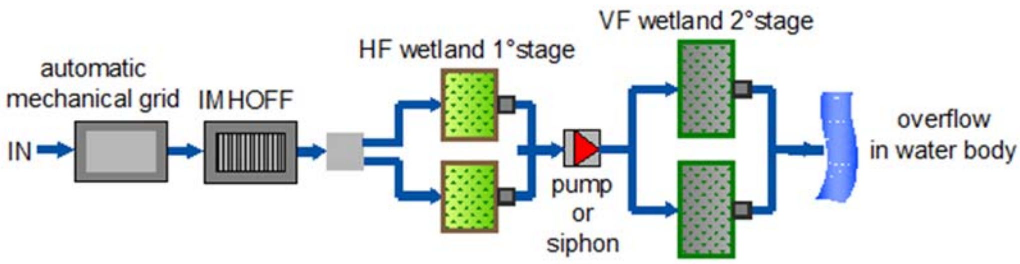
As a very rough estimation, we report in the last line of the following table the total cost for the realization of similar decentralized systems (probably 4/5 treatment plant depending by the designed network, the natural slopes and the available lands) for Cerasella and all the other agglomeration.



Cerasella		
Yearly residents	60	inhabitants
Seasonal occasional residents	800	inhabitants
Water equipment	190	l/ inhabitants
Wastewater production	16815	m^3/year
CW		
Automatic screw screen	€ 10.000,00	
Imhoff tank	€ 37.000,00	
Multistage wetland (Horizontal + vertical flow type) 1500 m^2	€ 112.500,00	
Connection pipes and E&M works	€ 25.000,00	
Landscaping and ancillary works	€ 10.000,00	
Total cost (V.A.T. excluded)	**€ 194.500,00**	
Yearly maintenance cost	5600	€/year
m3 cost of treated water (investment payback time 20 years)	1,01	€/m^3
Cost per person every year	19,16	€/year
Total cost for all the coastal agglomerations (5000 P.e.)	**€ 1.215.625,00**	€/year

3. Constructed Wetland and Water Saving devices

Considering that C.da Cerasella inhabitants provided autonomously to the water supply through tanker service and also to the final disposal of wastewater, the recourse to water saving device is strongly suggested and it could be the first step of a medium term planning for the design and realization of a sewer network and a treatment system. With these systems they can reduce the amount of water necessary of about 30%, reducing also the footprint of the natural treatment.
The cost of Constructed Wetland are calculated using parametric costs deduced by the official price list issued by Region Sicily and by quotation of local companies for the materials not included. Maintenance costs are very low and limited to the yearly emptying of the Imhoff tank and to the cut of the aquatic plants and the grass in the treatment area. The cost don't include design and supervision technical services, neither the cost to buy the land (approximately 2500 m^2).
As a very rough estimation, we report in the last line of the following table the total cost for the realization of similar decentralized systems (probably 4/5 treatment plant depending by the designed network, the natural slopes and the available lands) for Cerasella and all the other agglomeration.



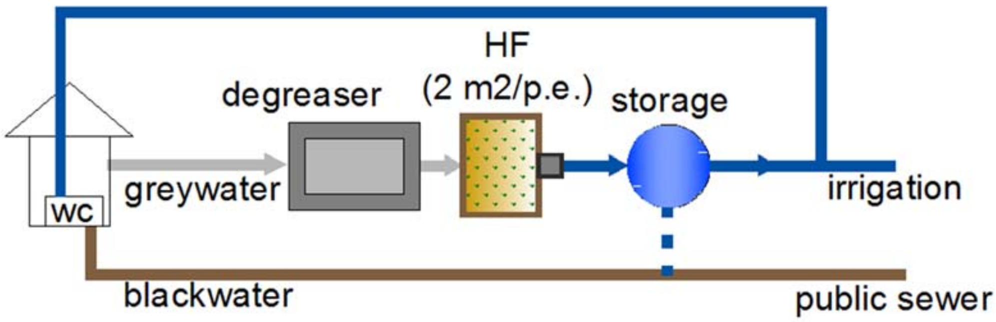
Cerasella		
residents	60	inhabitants
Summer residents	800	inhabitants
Water equipment (30% saving with WSD)	133	l/ inhabitants
Wastewater production	11770,5	m^3/year
CW		
Automatic screw screen	€ 10.000,00	
Imhoff tank	€ 30.400,00	
Multistage wetland (Horizontal + vertical flow type) 1350 m^2	€ 101.250,00	
Connection pipes	€ 10.000,00	
E&M works	€ 15.000,00	
Landscaping and ancillary works	€ 10.000,00	
Total cost (V.A.T. excluded)	**€ 176.650,00**	
Yearly maintenance cost	5440	€/year
m^3 cost of treated water (investment payback time 20 years)	1,35	€/m^3
Cost per person every year	17,84	€/year
Total cost for all the coastal agglomerations (5000 P.e.)	**€ 1.104.062,50**	€/year

4. Constructed Wetland, greywater reuse and Water Saving devices

Stronger reduction can be reached by more intensive intervention of water saving as greywater segregation, treatment and reuse or runhoff harvesting (as detailed in the case study n°1); it is noticeable that there are existing buildings and these interventions have to be evaluated case by case, depending of the grade of separation in the structure of greywater and rainwater.

We didn't consider this alternative in the MCA because it is difficult to estimate correctly the feasibility and the cost of these interventions for every household and how many household will decide to implement a greywater recovery system; furthermore the implementation of a water supply network and a sewer system will reduce the cost of the water per household.
But the economic convenience of greywater recovery, that in this case can have approximately a short payback time due to the high cost of supply and disposal of consumed water (probably about 5-7 years), depends strongly by the time of implementation of the sewer and water network. The greywater reuse for WCs could also reduce the volume that will be discharge in the sewer in the future (approximately of 40-50 l/person per day, about 30%; 100 liter per day or more if they reuse the greywater for irrigation) and consequently the dimensions of the treatment plant (if the greywater reuse is applied on 100% of buildings, approximately 300 m^2 less in case of a CW, that means about 25.000 € less in the investment costs).

A greywater treatment plant at household level (4 p.e.), composed by a degreaser, a little HF constructed wetland, a storage tank and a dual network for WC can cost approximately 5-6000 € and it permits to save 200 liter per day (and to make available other 200 liter per day for irrigation); it means that the household will save 200 liter per day to buy the water for potable uses and 400 liter per day to dispose it by trucks.



5. Summary of the alternatives

Cerasella	ALT 0	ALT 1	ALT 2	ALT 3
Water saving devices (**WSD)**	NO	NO	NO	YES
Sewer connection to Ragusa **(Sewer)**	NO	YES	NO	NO
Decentralized Constructed Wetland for CW treatment (**CW)**	NO	NO	YES	YES
COSTS (€/m^3 on 20 years)	3	1,15	1	1,35
COSTS (€/person per year on 20 years)	62,6	24,26	19	17,84

Coastal Agglomerations	ALT 0	ALT 1 Sewer	ALT 2 CW	ALT 3 CW+ WSD
Water saving devices	NO	NO	NO	YES
Sewer connection to Ragusa	NO	YES	NO	NO
Decentralized Constructed Wetland for CW treatment	NO	NO	YES	YES
COSTS (€/m^3 on 20 years)	3	1,18	1	1,35
COSTS (€/person per year on 20 years)	62,6	24,67	19	17,84

Note that the cost per person is reduced with alternative 2 and 3 comparing to the alternative of connection to the sewer and the alternative zero.

To compare the 3 options with the zero alternative, we have to consider also additional cost related to technical services (12% of the investment costs), land acquisition (we consider an average value of 20 €/m^2) and sewer construction.

Alternative zero remains the highest in term of cost per person. The other three alternatives are very similar in term of cost per m3 of treated water and cost per person; also the investment costs are similar, both if we consider all the villages, than in case of connection of only Cerasella village.

Alternative 1 - Cerasella		
Sewer: main pipeline cost	€ 220.000,00	
sewer realization	€ 350.000,00	
technical services	€ 68.400,00	
land cost	€ 0,00	
Total investment cost (excluding VAT)	**638.400,00**	**€**
Existing WWTP upgrading	0,00	€
Additional treatment cost of WWTP	0,3	€/m3
Sewer maintenance cost	0,2	€/m3
Overall cost on 20 years	764.370,00	€
m^3 cost of treated water (investment payback time 20 years)	3,03	€/m3
Cost per person every year	47,77	€/year
Total investment cost for all the agglomerates (excluded VAT)	**€ 3.274.880,00**	

ALTERNATIVE 2		
Cerasella		
Plant cost (excluded VAT)	**€ 194.500,00**	
sewer realization	€ 350.000,00	
technical services	€ 65.340,00	
land cost	€ 50.000,00	
Total investment cost (excluded VAT)	**€ 659.840,00**	
Yearly maintenance cost	5600	€/year
m^3 cost of treated water (investment payback time 20 years)	2,55	€/m3
Cost per person every year	48,24	€/year
Total investment cost for all the agglomerates (excluded VAT)	**€ 3.436.500,00**	

ALTERNATIVE 3		
Cerasella		
Plant cost (excluded VAT)	**€ 176.650,00**	
sewer realization	€ 350.000,00	
technical services	€ 63.198,00	
land cost	€ 40.000,00	
Total investment cost (excluded VAT)	**€ 629.848,00**	
Yearly maintenance cost	5440	€/year
m^3 cost of treated water (investment payback time 20 years)	3,49	€/m^3
Cost per person every year	46,17	€/year
Total investment cost for all the agglomerates (excluded VAT)	**€ 3.249.050,00**	

4. Definition of sustainability criteria for evaluation

URBAN RESIDENTIAL AREA

Health issues		weight (1-5)
Don't causes any risk of	additional mosquitoes (or other insects) growth	4
	illness	5
Reduced exposure to pathogens	of users	5
	of waste workers	4
	of resource recoverers /reusers	4
	of "downstream" population	5
Impact to environment / nature		
use of natural resources	Minimize water use	5
	Low land requirements	4
	Low energy requirements	4
	Uses mostly local Construction material	3
low emissions and impact to the environment	Surface water	5
	Ground water	5
	soil/ land	4
	Air	3
	Noise and vibration	5
	aesthetic	4
	odours	4
good possibilities for nutrients recovering resources	energy	1
	Organic matter	1
	Water	5
	Landscape integration	4
Technical issues		
allows simple construction		3
low level of technical skills required for construction		3
High level of efficiency (wastewater input/depurated/timing)		5
Purification capacity (wastewater depurated/soil used by the plant)		5
has high robustness and long lifetime/high durability		4
enables simple and low operational procedures		4
Low maintenance and low skills required		5
not reliant on a continuous supply of a resource (such as water or energy)		3
adaptable to unexpected future changes (adaptability)		2
Good quality of effluent (according to the receiving environment)		5
Amount and quality of generated sludge		3
reduction of the imbalance water at the basin level		3
Economical and financial issues		
Provides benefits to the local economy (business opportunities, local employment, etc.)		5
provides benefits or income generation from reuse		4
Social, cultural and gender		
Improves quality of life		2

requires low level of awareness and information to assure success of technology	4
requires low operation & maintenance and little involvement by the user/workers	2
high level of satisfaction of the local people regarding the implemented technology	3
requires low policy reforms at local, regional or national level.	4
educational impacts	5
Costs	
Investment cost (€)	4
Maintenance cost (€/year)	4

Weight definition: number from 1 to 5, 5 is the max score, 1 is the minimum score

RURAL AGGLOMERATIONS – Borgo San Giacomo

Health issues		weight (1-5)
Don't causes any risk of	additional mosquitoes (or other insects) growth	3
	illness	5
Reduced exposure to pathogens	of users	5
	of waste workers	4
	of resource recoverers /reusers	4
	of "downstream" population	5
Impact to environment / nature		
use of natural resources	Minimize water use	5
	Low land requirements	3
	Low energy requirements	4
	Uses mostly local Construction material	3
low emissions and impact to the environment	Surface water	5
	Ground water	5
	soil/ land	4
	Air	3
	Noise and vibration	3
	aesthetic	4
	odours	3
good possibilities for nutrients recovering resources	energy	1
	Organic matter	1
	Water	5
	Landscape integration	4
Technical issues		
allows simple construction		3
low level of technical skills required for construction		3
High level of efficiency (wastewater input/depurated/timing)		5
Purification capacity (wastewater depurated/soil used by the plant)		5
has high robustness and long lifetime/high durability		4
enables simple and low operational procedures		4
Low maintenance and low skills required		5
not reliant on a continuous supply of a resource (such as water or energy)		3
adaptable to unexpected future changes (adaptability)		2

Good quality of effluent (according to the receiving environment)	5
Amount and quality of generated sludge	3
reduction of the imbalance water at the basin level	3
Economical and financial issues	
Provides benefits to the local economy (business opportunities, local employment, etc.)	5
provides benefits or income generation from reuse	4
Social, cultural and gender	
Improves quality of life	2
requires low level of awareness and information to assure success of technology	4
requires low operation & maintenance and little involvement by the users	2
high level of satisfaction of the local people regarding the implemented technology	3
requires low policy reforms at local, regional or national level	4
educational impacts	5
Costs	
Investment cost (€)	4
Maintenance cost (€/year)	4

COASTAL AGGLOMERATIONS – CERASELLA

Health issues		weight (1-5)
Don't causes any risk of	additional mosquitoes (or other insects) growth	4
	illness	5
Reduced exposure to pathogens	of users	5
	of waste workers	4
	of resource recoverers /reusers	4
	of "downstream" population	5
Impact to environment / nature		
use of natural resources	Minimize water use	5
	Low land requirements	3
	Low energy requirements	4
	Uses mostly local Construction material	3
low emissions and impact to the environment	Surface water	5
	Ground water	5
	soil/ land	4
	Air	3
	Noise and vibration	4
	aesthetic	4
	odours	4
good possibilities for nutrients recovering resources	energy	1
	Organic matter	1
	Water	5
	Landscape integration	4
Technical issues		
allows simple construction		3
low level of technical skills required for construction		3

High level of efficiency (wastewater input/depurated/timing)	5
Purification capacity (wastewater depurated/soil used by the plant)	5
has high robustness and long lifetime/high durability	4
enables simple and low operational procedures	4
Low maintenance and low skills required	5
not reliant on a continuous supply of a resource (such as water or energy)	3
adaptable to unexpected future changes (adaptability)	2
Good quality of effluent (according to the receiving environment)	5
Amount and quality of generated sludge	3
reduction of the imbalance water at the basin level	3
Economical and financial issues	
Provides benefits to the local economy (business opportunities, local employment, etc.)	5
provides benefits or income generation from reuse	4
Social, cultural and gender	
Improves quality of life	2
requires low level of awareness and information to assure success of technology	4
requires low operation & maintenance and little involvement by the users	2
high level of satisfaction of the local people regarding the implemented technology	3
requires low policy reforms at local, regional or national level	4
educational impacts	5
Costs	
Investment cost (€)	4
Maintenance cost (€/year)	4

COASTAL AGGLOMERATIONS

The "weights" will be multiplied for the specific indicator "measures" in order to obtain a final value that will contribute to the calculation of an aggregated and normalised index for each macro-indicator.

5. Evaluation of the proposed scenarios based on a multi-criteria analysis

The kind of procedure to be applied is essentially the same used for a cost-benefit analysis and an environmental risks assessment (like in a EIA), considering not only the direct effects but also the most important indirect effects; the effects/impacts can be both material or immaterial, and so some of them can be measured while some others will need to be quantified by indicators. At the end of every evaluation of possible alternatives, simple and objective indicators should be the results of the multi-criteria analyses, so to provide the stakeholders with proper and "easy to understand" instruments for choosing the most appropriate alternative considering all the environmental, economical and social contexts for every case.

The economic evaluations will have to include the O&M costs for all the lifespan of the realizations and some recommendations in each feasibility study about the locally available fund raising options could be highly welcome from the stakeholders and considered as a very important contribution for the future application in real scale of the proposed solutions.

SORAYA - DORIANA

Health issues		alternative 0	alternative 1	Alternative 2	Alternative 3
Causes any risk of	additional mosquitoes (or other insects) growth	3	3	4	4
	illness	5	5	5	5
Reduced exposure to pathogens	of users	5	5	4	4
	of waste workers	2	5	4	4
	of resource recoverers /reusers	1	4	5	5
	of "downstream" population	2	3	4	4
Impact to environment / nature					
use of natural resources	Low land requirements	1	4	4	5
	Low energy requirements	3	3	4	4
	Uses mostly local Construction material	1	5	5	5
	Low water amounts required for construction	3	3	3	3
low emissions and impact to the environment	Surface water	1	5	5	5
	Ground water	2	5	5	5
	soil/ land	3	3	3	3
	Air	3	3	3	3
	Noise and vibration	3	3	3	3
	aesthetic	1	3	5	5
	odours	1	5	4	4
good possibilities for nutrients recovering resources	energy	1	4	4	4
	Organic matter	2	3	4	4
	Water	1	4	5	5
	Landscape integration	1	3	5	5
Technical issues					
allows simple construction		1	5	4	4
low level of technical skills required for construction		1	5	4	4

High level of efficiency (wastewater input/depurated/timing)	1	5	4	4
Purification capacity (wastewater depurated/soil used by the plant)	2	3	4	4
has high robustness and long lifetime/high durability	4	5	5	5
enables simple and low operational procedures	2	5	4	4
Low maintenance and low skills required	2	5	4	4
not reliant on a continuous supply of a resource (such as water or energy)	1	5	4	4
adaptable to unexpected future changes (adaptability)	2	3	4	4
Good quality of effluent (according to the receiving environment)	5	5	5	5
Amount and quality of generated sludge	1	3	4	4
reduction of the imbalance water at the basin level	1	4	4	5
Economical and financial issues				
Provides benefits to the local economy (business opportunities, local employment, etc.)	1	3	4	4
provides benefits or income generation from reuse	1	4	4	5
Social, cultural and gender				
Improves quality of life	3	3	3	3
requires low level of awareness and information to assure success of technology	3	5	5	5
requires low operation & maintenance and little involvement by the users	3	3	3	3
high level of satisfaction of the local people regarding the implemented technology	2	3	3	3
requires low policy reforms at local, regional or national level.	3	5	5	5
Educational impacts	2	4	5	5
Costs				
Investment cost (€)	0	150.000	105.000	220.000
Maintenance cost (€/year)	-	2000	1000	3000.00

BORGO SAN GIACOMO

Health issues		alternative 0	alternative 1	Alternative 2	Alternative 3	Alternative 4
Causes any risk of	additional mosquitoes (or other insects) growth	3	3	4	4	4
	illness	3	3	4	4	4

Reduced exposure to pathogens	of users	2	3	4	4	4
	of waste workers	2	3	4	4	4
	of resource recoverers /reusers	1	5	5	5	5
	of “downstream” population	2	3	4	4	4
Impact to environment / nature						
use of natural resources	Low land requirements	3	5	5	5	5
	Low energy requirements	3	3	4	4	4
	Uses mostly local Construction material	3	5	5	5	5
	Low water amounts required for construction	3	3	3	3	3
low emissions and impact to the environment	Surface water	2	3	4	4	4
	Ground water	1	3	4	4	4
	soil/ land	1	3	4	4	4
	Air	3	3	3	3	3
	Noise and vibration	3	3	3	3	3
	aesthetic	3	3	5	5	5
	odours	2	3	4	4	4
good possibilities for nutrients recovering resources	energy	3	4	4	4	4
	Organic matter	3	3	4	4	5
	Water	1	4	4	4	5
	Landscape integration	3	3	4	4	4
Technical issues						
allows simple construction		3	3	4	4	4
low level of technical skills required for construction		3	3	4	4	4
High level of efficiency (wastewater input/depurated/timing)		1	3	5	5	5
Purification capacity (wastewater depurated/soil used by the plant)		1	3	5	5	5
has high robustness and long lifetime/high durability		3	3	3	3	3
enables simple and low operational procedures		3	4	4	4	4
Low maintenance and low skills required		3	3	4	4	4

not reliant on a continuous supply of a resource (such as water or energy)	5	5	4	4	4
adaptable to unexpected future changes (adaptability)	1	3	4	4	4
Good quality of effluent (according to the receiving environment)	1	3	5	5	5
Amount and quality of generated sludge	2	3	4	4	4
reduction of the imbalance water at the basin level	1	4	5	5	5
Economical and financial issues					
Provides benefits to the local economy (business opportunities, local employment, etc.)	2	3	4	4	4
provides benefits or income generation from reuse	1	4	5	5	5
Social, cultural and gender					
Improves quality of life	3	3	3	3	4
requires low level of awareness and information to assure success of technology	3	4	4	4	4
requires low operation & maintenance and little involvement by the users	3	3	3	3	3
high level of satisfaction of the local people regarding the implemented technology	2	3	3	3	4
requires low policy reforms at local, regional or national level.	5	5	5	5	2
Educational impacts	2	4	4	4	5
Costs					
Investment cost (€)	0	577000	571000	546000	598000
Maintenance cost (€/year)	0	18000	7000	7000	8000

COASTAL AGGLOMERATIONS

Health issues		alternative 0	alternative 1	Alternative 2	Alternative 3
Causes any risk of	additional mosquitoes (or other insects) growth	3	3	4	4
	illness	3	3	4	4
Reduced exposure to pathogens	of users	2	3	4	4
	of waste workers	2	3	4	4
	of resource recoverers /reusers	1	4	5	5
	of “downstream” population	2	4	5	5
Impact to environment / nature					

use of natural resources	Low land requirements	1	3	3	5
	Low energy requirements	3	3	4	4
	Uses mostly local Construction material	3	3	4	4
	Low water amounts required for construction	3	3	3	3
low emissions and impact to the environment	Surface water	3	3	3	3
	Ground water	1	3	4	4
	soil/ land	1	3	4	4
	Air	3	3	3	3
	Noise and vibration	3	3	3	3
	aesthetic	3	3	4	4
	odours	2	3	4	4
good possibilities for nutrients recovering resources	energy	1	2	4	4
	Organic matter	3	3	4	4
	Water	1	1	5	5
	Landscape integration	3	3	5	5
Technical issues					
allows simple construction		3	4	4	4
low level of technical skills required for construction		3	4	4	4
High level of efficiency (wastewater input/depurated/timing)		1	2	4	4
Purification capacity (wastewater depurated/soil used by the plant)		1	2	4	4
has high robustness and long lifetime/high durability		3	2	4	4
enables simple and low operational procedures		3	2	4	4
Low maintenance and low skills required		3	2	4	4
not reliant on a continuous supply of a resource (such as water or energy)		3	2	4	4
adaptable to unexpected future changes (adaptability)		2	4	4	4
Good quality of effluent (according to the receiving environment)		1	4	4	4
Amount and quality of generated sludge		1	1	4	4
reduction of the imbalance water at the basin level		3	3	4	4

Economical and financial issues				
Provides benefits to the local economy (business opportunities, local employment, etc.)	1	1	4	4
provides benefits or income generation from reuse	3	3	4	4
Social, cultural and gender				
Improves quality of life	3	3	3	3
requires low level of awareness and information to assure success of technology	2	2	4	4
requires low operation & maintenance and little involvement by the users	3	3	3	3
high level of satisfaction of the local people regarding the implemented technology	3	3	4	4
requires low policy reforms at local, regional or national level.	3	5	4	4
Educational impacts	2	4	4	5
Costs				
Investment cost (€)	0	638.000	660.000	630.000
Maintenance cost (€/year)	0	6300	5600	5500

Alternative 0 = no intervention
++ or 5 the criterion is very fulfilled by this alternative
+ or 4 the criterion is fulfilled by this alternative
0 or 3 the criterion is neutral to this alternative
- or 2 the criterion does not fulfilled well by this alternative
-- or 1 the criterion does not at all fulfilled by this alternative

(the + and – can be substituted by numbers in the range 1-5 as specified above)

6. Conclusions

In the following section we report the results of the multi-criteria analysis, based on the scores and weights previously assigned for each case study, accompanied by some technical comments.

6.1 Definition of the optimal "tailormade" alternative

Legenda

5	the criterion is very fulfilled by this alternative
4	the criterion is fulfilled by this alternative
3	the criterion is neutral to this alternative
2	the criterion does not fulfilled well by this alternative
1	the criterion does not at all fulfilled by this alternative

1. DORIANA-SORAYA

		ALT 0	ALT 1	ALT 2	ALT 3
Health issues		3,1	4,2	4,3	4,3
Impact to environment / nature		1,8	3,8	4,2	4,3
Technical issues		2,1	4,5	4,2	4,3
Economical and financial issues		1,0	3,4	4,0	4,4
Social, cultural and gender		2,6	4,1	4,3	4,3
Investment cost (€)		0,0	150000,0	105000,0	220000,0
Maintenance cost (€/year)		0,0	2000,0	1000,0	3000,0
	WEIGHT	ALT 0	ALT 1	ALT 2	ALT 3
Investment cost (€)	4	3,0	3,5	4,0	3,0
Maintenance cost (€/year)	4	3,0	4,0	5,0	4,0
COST		3,0	3,750	4,5	3,5
TOTAL SUM		**13,5**	**23,74**	**25,5**	**25,1**

The best alternative is the Alternative 2, although it should be noted that the difference with the alternatives 1 and 3 is very limited. From the point of view of the health, technical, social and environmental impacts the three alternatives are essentially equivalent, but the alternative 2 presents the main advantage in economic terms. The alternative 2 is the best especially from the economic point of view in relation to the recoverable volumes. From one hand the Alternative 1 involved only the recovery of rainwater which alone could cover the needs of all the toilet for 6-7 months of the year but they are not sufficient for irrigation for the low summer rainfall; from the other hand the recovery of the grey water allows to fully cover the consumption of toilet and to make immediately available for irrigation about 50% of irrigation needs during the summer

months, without the need of large storage tanks that represent a significant item of cost. Furthermore the recovery of the greywater allows to greatly alleviate the hydraulic load conveyed into the sewer and to reduce the treatment cost.
Alternative 3 allows to fully cover the irrigation needs and to close the loop, but the additional cost are higher compared to the low increase in the recovered volumes, unless you make significant and costly build-up, which would be justifiable only in a context of real supply difficulties; therefore a different study of the green area design may be more sustainable, with the aim to reduce lawn surfaces in favor of less water demanding solutions.
The benefits of grey water recovery are more obvious, when there is available space, providing for natural technologies application such as constructed wetlands, which have lower costs of investment management and the lower management commitment required in the operational phase to end users.

2. BORGO SAN GIACOMO

		ALT 0	ALT 1	ALT 2	ALT 3	ALT 4
Health issues		2,2	3,3	4,2	4,2	4,2
Impact to environment / nature		2,3	3,5	4,1	4,1	4,2
Technical issues		2,2	3,3	4,3	4,3	4,3
Economical and financial issues		1,6	3,4	4,4	4,4	4,4
Social, cultural and gender		3,0	3,9	3,9	3,9	3,8
Investment cost (€)		0,0	577000,0	571000,0	546000,0	598000,0
Maintenance cost (€/year)		0,0	18000,0	7000,0	7000,0	8000,0
	WEIGHT	ALT 0	ALT 1	ALT 2	ALT 3	ALT 4
Investment cost (€)	4	3,0	3,0	3,5	4,0	3,0
Maintenance cost (€/year)	4	3,0	2,0	5,0	5,0	4,5
COST		3,0	2,5	4,3	4,5	3,8
TOTAL SUM		**14,2**	**19,8**	**25,1**	**25,3**	**24,6**

In this case study, the optimal solution is the Alternative 3, although with very minimal variance compared to the alternatives 2 and 4. Instead the alternative 0 is not acceptable because, even if it has no cost to the government, it has a very high disposal cost for users. So the most important result seems to prefer low-tech solutions for the treatment of municipal wastewater originated from small decentralized agglomerations, compared to more compact solutions but with an higher technological level (Alternative 1, SBR), which require a greater commitment management both from technical than economical point of view. Moreover, the use of natural technologies for agglomerates below 2000 inhabitants is also encouraged by the current water legislation (Legislative Decree no. 152/06 Part III) and it has widely correspondence in the concept of "appropriate treatment".

In the best alternative (No. 3) there is only the addition of water-saving devices; the promotion and the use of water saving devices at low cost, has always an effect on the sizing of the treatment system, so it should be encouraged.
It has to be studied more deeply the local situation from the hydrogeological point of view, characterized by the lack of significant receptor water bodies (having zero flow for periods of less than 120 days per year, according to national legislation). Anyway these interventions are requested below 2000 inhabitants so they may be submitted to "appropriate treatments" not subject to specific limits; in those cases the regions set limits more or less restrictive depending on local criticality.
Finally, as regards to the alternative No. 4 which also includes the re-use of wastewater, the plant designed for re-use, pursuant to Ministerial Decree 185/03, has a higher cost and complexity. The recovered costs per m^3 are not higher (approximately 20%), although they are probably intended to be higher in the case not all the volumes are recovered.
As already pointed out, there are several factors of uncertainty for this solution:

- The application of the DM 185/03 for reuse in the small clusters is not easy to apply because of the required monitoring frequency and of the high costs of testing, that can impact significantly on small plants; it's also not clear how the distribution of purified water, especially where this is not sold by the operator of the dual network but reused locally, as in the case of small potentialities where the produced daily water are certainly not enough to support a complex dual network; for this reason the practice of reuse in Italy is greatly slowed, especially for small and medium potentialities;
- The cost of groundwater remain very low, not only in the territory of Ragusa; for this reason the possibility to recover the higher costs of investment from a possible sale of treated water to farmers is limited.

As also evidenced by the DM 185/03 and Legislative Decree no. 152/06, the reuse of wastewater would be sustainable from many points of view, if applied in a systemic manner, allowing the reduction of water withdrawals aquifer and a more rational use of water resources and nutrients (already found in the wastewater and which therefore could reduce the consumption of fertilizers).

An alternative would be to allocate those waters for public use (i.e. public garden irrigation), in order to cover also an educational application of good management practices, beyond the purely economic considerations. However, this option would be explored with both the council assessing the real interest, both with local authorization with regard to the specific rules to be observed on the reuse and monitoring.

3. CERASELLA

	ALT 0	ALT 1	ALT 2	ALT 3
Health issues	2,2	3,3	4,3	4,3
Impact to environment / nature	2,2	2,8	3,8	4,0
Technical issues	2,2	2,6	4,0	4,0
Economical and financial issues	1,9	1,9	4,0	4,0
Social, cultural and gender	2,6	3,5	3,8	4,1
Investment cost (€)	0,0	638000,0	660000,0	630000,0
Maintenance cost (€/year)	0,0	6300,0	5600,0	5500,0

	WEIGHT	ALT 0	ALT 1	ALT 2	ALT 3
Investment cost (€)	4	3,0	5,0	4,0	5,0
Maintenance cost (€/year)	4	3,0	3,0	4,0	4,0
COST		3,0	4,0	4,0	4,5

TOTAL SUM		**14,0**	**18,1**	**23,9**	**24,9**

In this case study, the alternative 0 cannot be maintained because the law requires to equip each cluster of sewage collection and wastewater treatment. The alternative of collecting Cerasella Village to Marina di Ragusa WWTP (Alternative 1) seems to be less cost-effective than alternatives 2 and 3 that provides a decentralized WWTP, mainly because they are to be realized over 4 km of sewer along public roads. The catchment approach to the treatment plant could become more convenient from the economic point of view if all the other neighbouring towns are connected, but in this case should be required also an up-grading of centralized sewage treatment plant that already works at the limits of their potential during the summer.

It will be carefully evaluated from the point of view of local planning, if it is better to pursue a centralized approach, or if it is better to follow the opposite path, keeping the existing sewage treatment plant and trying to lighten the loads coming to it through the implementation of decentralized natural treatment systems, characterized by low cost of investment and management, and through the promotion of large-scale water-saving devices and practices to reduce the volume of water discharged into the sewer.

The last option has a positive effect even on the dimensioning of the decentralized constructed wetland. In this case, the optimal alternative is n ° 3, which couples the adoption of WSD to a natural purification system for Cerasella.

It will be studied in deep the local situation from the hydrogeological point of view, characterized by the total absence of receptors water bodies and therefore from the necessity of discharges on the soil and / or in the superficial layers of the subsoil. Such interventions are below 2000 inhabitants so they may be submitted to “appropriate treatments” not subject to specific limits by national legislation and where the Region Authority can set limits more or less restrictive depending on local criticality.