OSCAR Final Workshop
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A decision support tool for water and energy saving in the integrated water system

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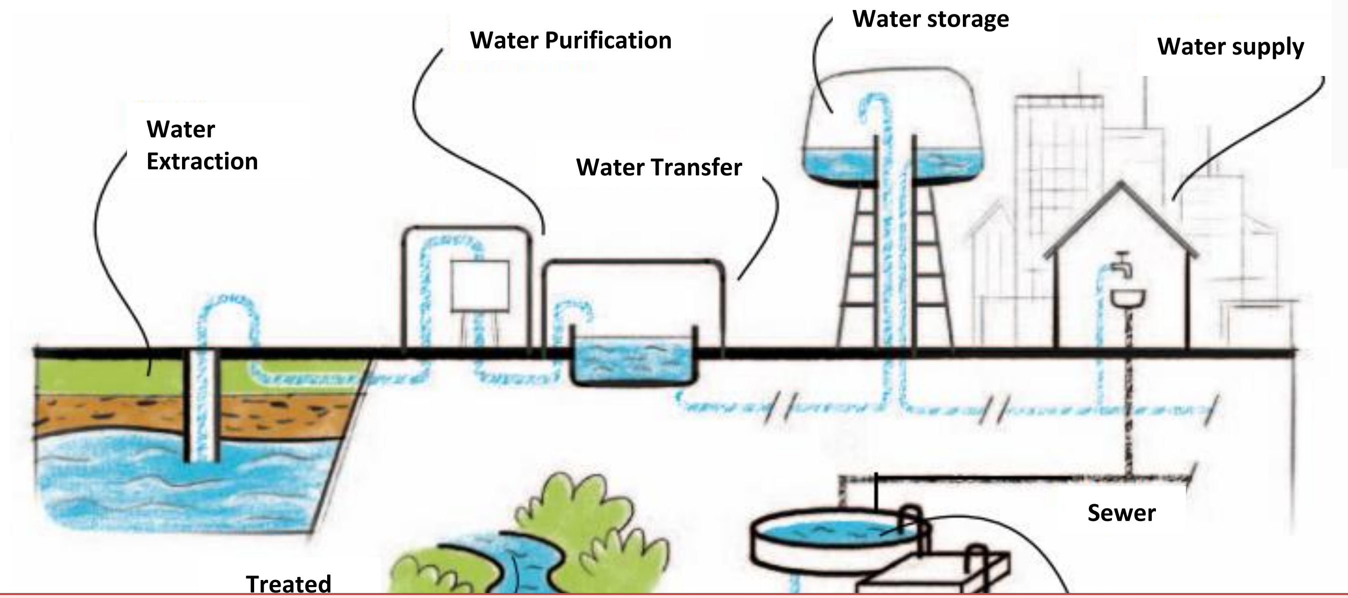
Introduction

- Delivering water and wastewater services is an energy-intensive effort
- Energy is needed in every phase of water use…

INTEGRATED WATER SYSTEM



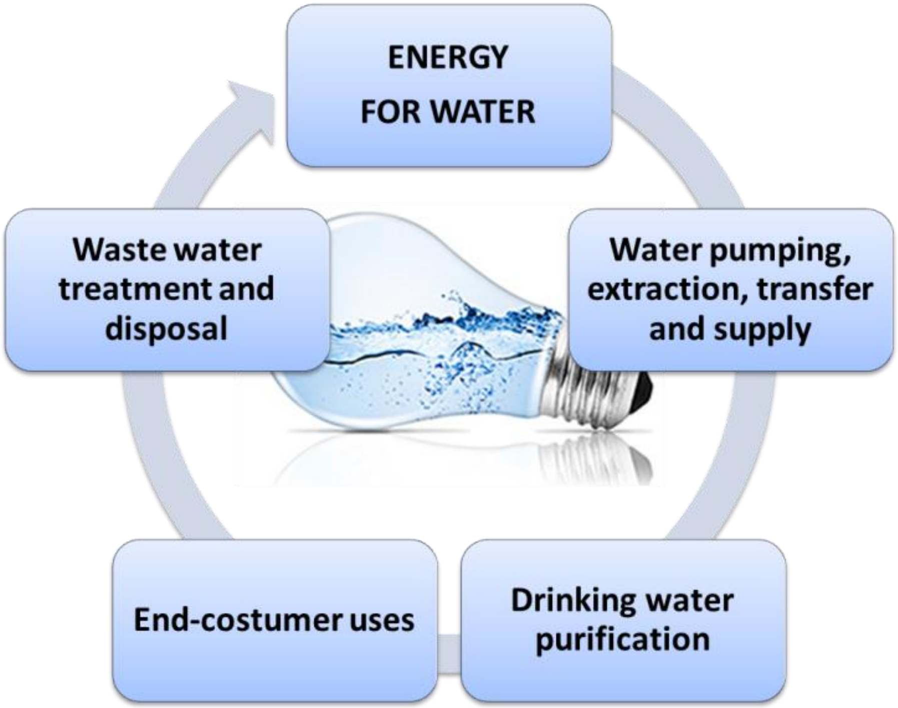
Energy cost is about the 40% of water utility operating costs and it is expected to increase due to population growth and tightening drinking water regulations.

WATER ENERGY NEXUS

- In the last decades a growing attention on energy saving associated with water resources usage has been recorded at both national and international level.

- To understand the energy transformation processes occurring in the integrated water system, the main concern is identifying energy impacts associated to each macro-area of water system and analysing the potential interactions between them

- Unfortunately, only overall energy consumptions are usually available at national level

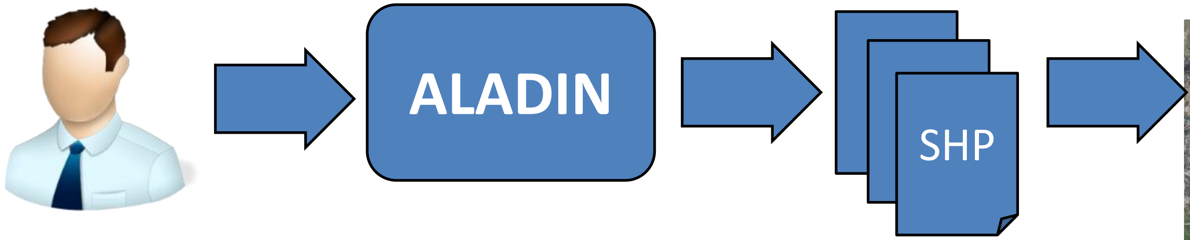


Objectives

A decision support tool able to:

- Improving the understanding of energy consumption in integrated water system
- Assessing the system water and energy balance and identifying efficient solutions
- Reducing water losses and energy consumptions

Aladin Decision Support System



ALADIN is able:

- To receive input data from different information sources (operator, monitoring network, databases,…)
- To evaluate the system water and energy balance and analyse the results in terms of performance indicators (PIs).

WATER LOSSES REDUCTION

ENERGY CONSUMPTION

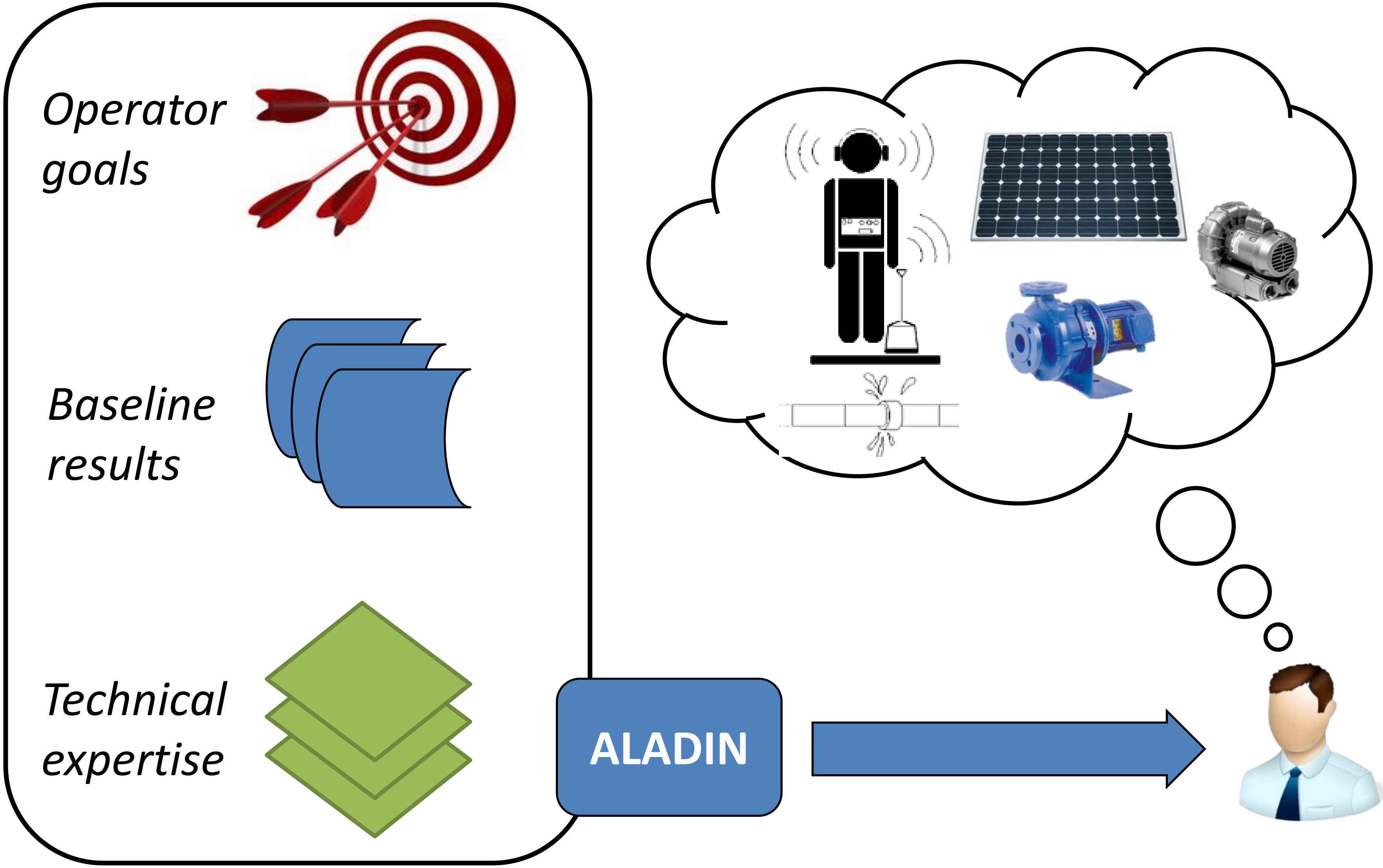
ENVIROMENTAL IMPACTS (GHG EMISSIONS)

FINANCIAL COSTS

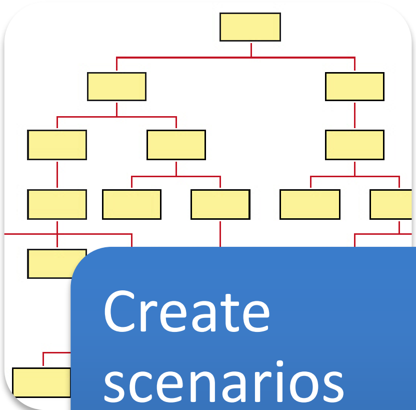
QUALITY OF SERVICE

OPERATIONAL ASPECTS

Aladin Decision Support System

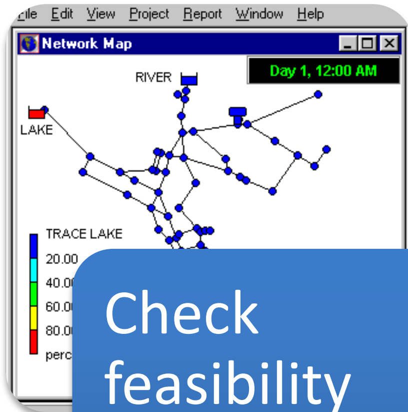


Aladin Decision Support System



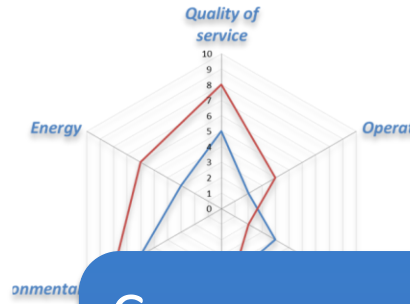
Create scenarios

- Wizards



Check feasibility

- Hydraulic models



Compare scenarios

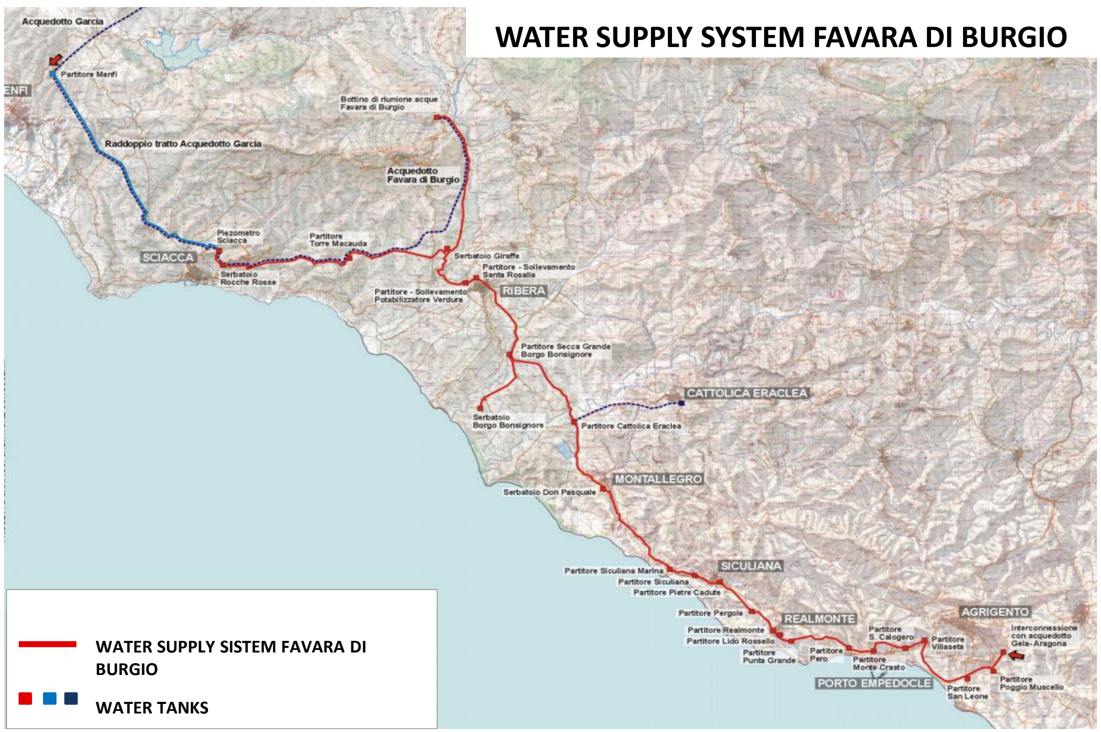
- Global performance scores

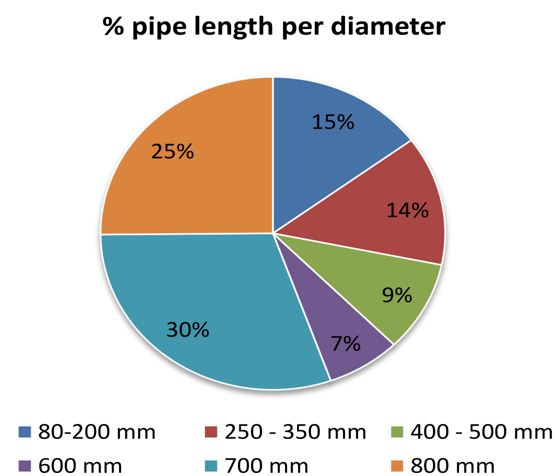
Beneficiary

- Water utility
- Professional
- Public administration

The case study

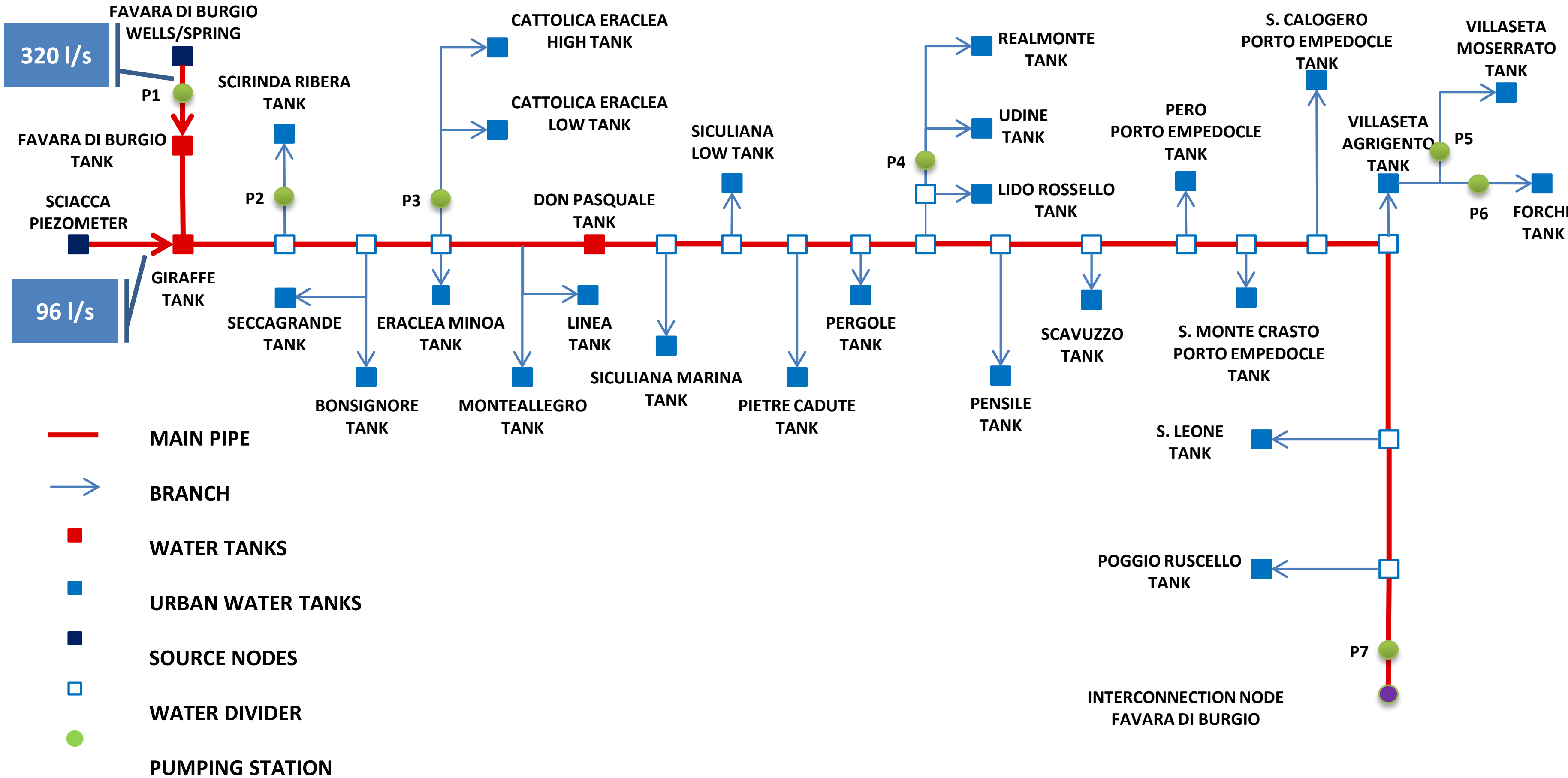
- It supplies around 170.000 inhabitants living in six different towns
- The system layout is long about 132 Km with pipes in steel, cast iron and HDPE and diameters ranging between 80 and 800 mm.
- About 100 km of the main pipes were reconstructed between 2002-2004.





The case study

7 pumping stations currently operate to supply 25 local tanks



PIs selected for the case study

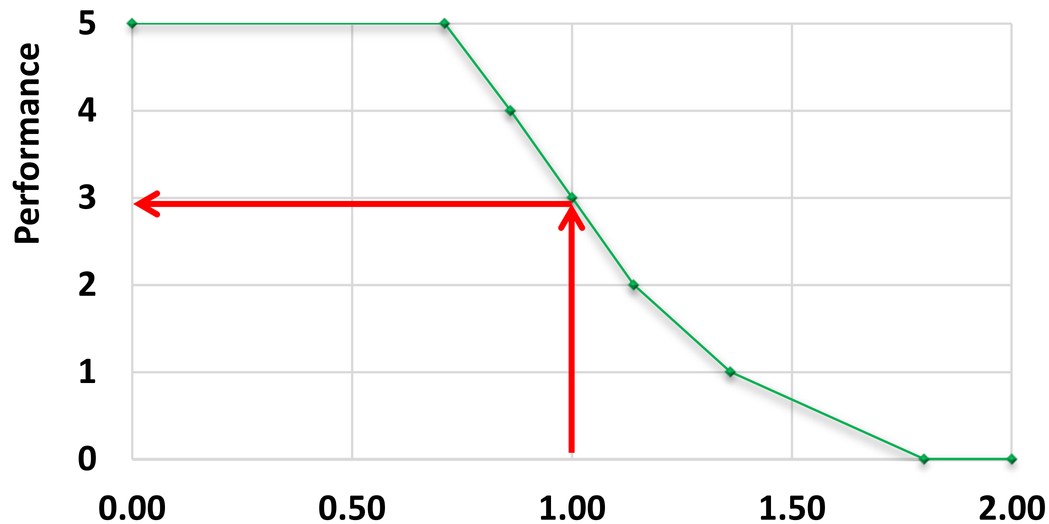
The system was closer analysed by means of some PIs representative of the system performance with regard to water leakages reduction (W1), energy consumption (E1-E2- E3), environmental impact (G1-G2) and financial cost (F1-F2-F3-F4-F5-F6-F7-F8)

Performance Indicator		Formulation	U.M.
W1	Non-revenue water ratio	NRW / Input system volume	%
E1	Energy consumption per cubic meter of inlet system volume	Global energy consumption / Input system volume x 100	kWh/mc/yr
E2	Pumping energy consumption per cubic meter of pumped volume	Pumping energy consumption / pumped volume	kWh/mc/yr
E3	Photovoltaic energy coverage ratio	PV energy production / Global energy consumption x 100	%
G1	Pumping stations GHG emissions	GHG emissions / pumped volume	tCO2eq/mc/yr
G2	Avoided GHG emissions from photovoltaic electricity	PV energy production x GHG conversion coefficient / PV nominal power	tCO2eq/kW/yr
F1	Electrical energy costs ratio	Energy cost / Global operational cost x 100	%
F2	Imported (raw and treated) water costs ratio	Imported water cost / Global operational cost x 100	%
F3	Leakages survey cost ratio	Leakages survey cost / Global operational cost x 100	%
F4	Investments for asset replacement and renovation ratio	Investments for asset replacement and renovation / Global investments x 100	%
F5	Investments for energy consuming devices replacement ratio	Investments for energy consuming devices replacement / Global investments x 100	%
F6	Investments for RES installation	Investments for RES installation / Nominal RES power	€/kW
F7	Average water charges for exported water per unit water volume	Average water charges for exported water / exported water volume	€/mc
F8	Economic performance of pumping system	Energy cost / pumped volume	€/mc

Performace analysis

PI value → Penalty Curve → PI performance

0	NO SERVICE
1	UNACCEPTABLE
2	POOR
3	SUFFICIENT
4	GOOD
5	OPTIMUM



PI: $wEn01_{adim}$

The penalty curves are built according to the judgment of experts and data collected by statistical analysis carried by government or research agencies.
For each PI it is established a threshold value below which Aladin detects a critical issue for the analyzed system

Water balance baseline

System name: *Aqueduct*						
Sector: *Water supply and distribution network*						
Category: *Water supply system*						
ID	Name	Description	Location	Input volume [m^3/yr]	Outlet volume [m^3/yr]	NRW [m^3/yr]
1	*Fava di Burgio*	*Water supply system*	37.554214, 14.293284	13.111.407,4	9.889.374,2	3.222.033,1

Add new

NRW volume is about the 25% of the input volume

The total cost of the water volumes drawn from resources is equal to € 1.716.993

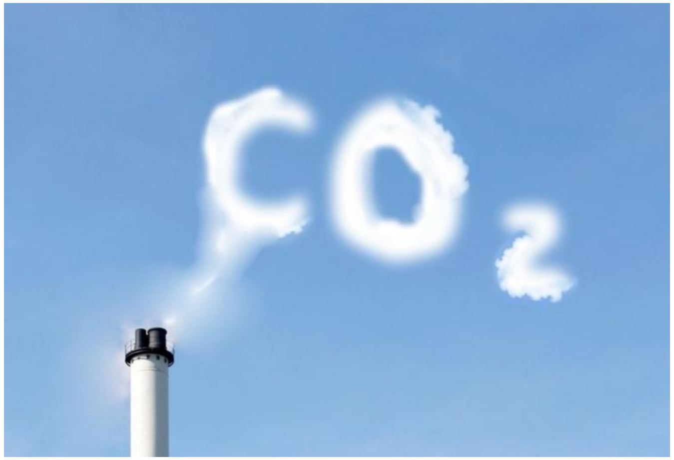
Energy balance baseline

System name: *Aqueduct*					
Sector: *Water supply and distribution network*					
Category: *Water supply system*					
Sub-category: *Favara di Burgio*					
ID entity	Q (l/s)	Pump head (m)	Pump power (kW)	Pumped water volume (m3/yr)	Energy consumption (kWh/yr)
P1	312.0	9.75	23.94	9839232.00	448225.51
P2	49.14	234.88	184.75	1549679.04	1618410.00
P3	15.36	143.41	10.43	484392.96	299154.00
P4	14.76	107.83	34.15	465471.36	209714.40
P5	22.71	78.30	26.88	716182.56	235468.80
P6	70.46	210.00	204.20	2222026.56	1788792.00
P7	68.75	3.45	51.17	2168100.00	91366.80

The actual energy consumption is about 4.691.132 kWh/yr,
The total energy cost is € 1.071.627 corresponding to 0,13 €/m^3 of water drawn by the sources.

GHG emission

To estimate the GHG emission linked to the actual energy consumption, the water sources (the environment) and the urban tanks (the users) were assumed as the system boundaries and the year was selected as time period of the analysis.



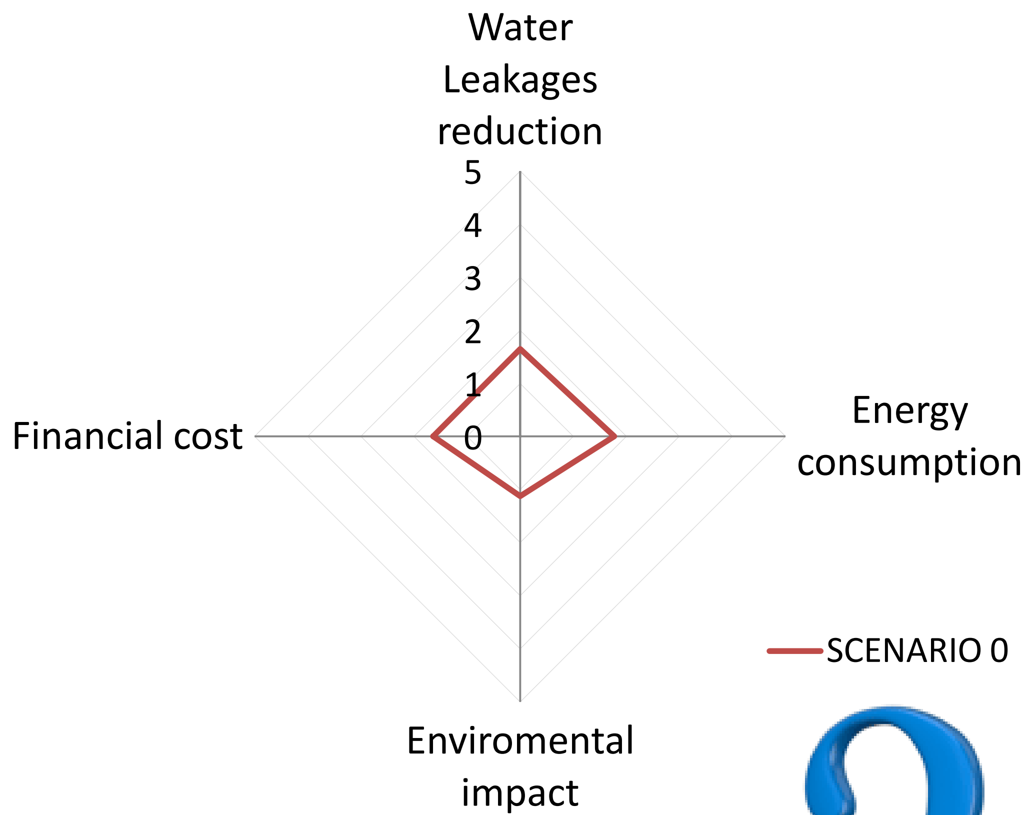
The national energy mix defined by the Italian Energy Authority (GSE) was used for estimating carbon emission due to energy transport and production.

According to the GSE, the Italian energetic mix has an average cost of 0.08 €/kWh and produces 0.49 kg_{CO2eq} per kWh
The actual production of GHG is equal to 2266 t_{CO2eq} per year.

Actual system global performance

The water and energy balance results highlight that the actual system is affected by:

- a high percentage of leakages
- a great amount of energy consumption for pumping water volumes which are not supplied to the final user (urban tanks)

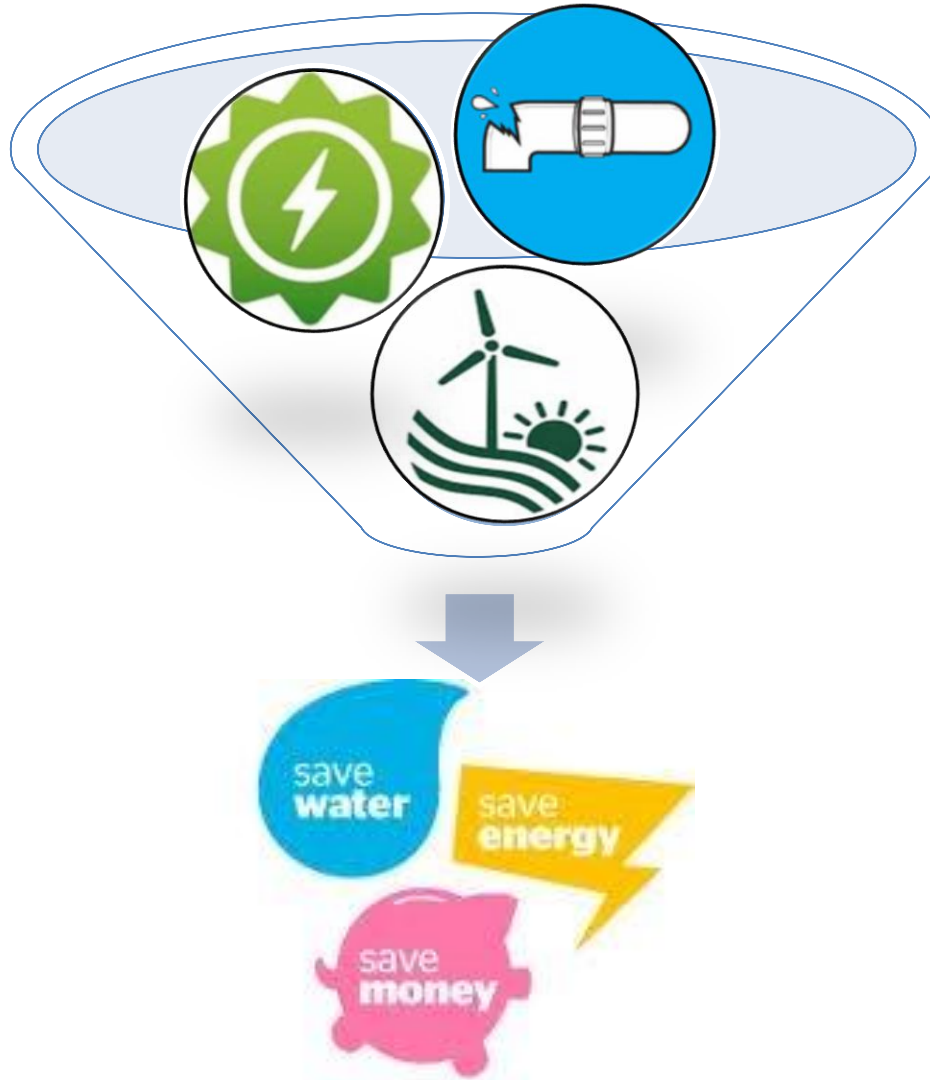


How you can improve system efficiency?

Mitigation measures proposed

Due to the existing interactions between water losses, energy consumptions and GHG emissions, the water resource management could be improved by means of several water and energy saving strategies, such as:

- active control of water losses
- adoption of energy efficient facilities
- use of renewable energy sources



Mitigation measures proposed

Employing measures aimed at leakage reduction

- **A**. To carry out a water leak detection and repair campaign on system branch only to reduce to 16% the actual water losses

Adopting more efficient pumps having η=0.75

- **B.** To replace all pumps
- **C.** To replace the more powerful pumps (P2 and P6)
- **D.** To replace the less powerful pumps(P1, P3, P4, P5 and P7)

Adopting more sustainable energy systems

- **E**. To install photovoltaic PV panels to cover the 40% of energy request by the less power pumping stations (P1, P3, P4, P5, P7)

Each mitigation measure could affect both
water and energy balance and water supply carbon footprint

Improving scenarios employed

- **Scenario 1** was only focused on water leakages reduction from 25% to 16 %
- **Scenarios 2** and **3** were aimed at the energetic improvement of the pumping systems by replacing pumps with more efficient ones
- **Scenarios 5, 6** and **7** combined together water losses reduction and pump replacement
- **Scenario 4** and **7** combined the replacement of the less power pumping systems together with the installation of photovoltaic panels to cover the 40% of pumps energy demand

Scenario	Improvement measures
0	-
1	A
2	B
3	C
4	D+E
5	A+B
6	A+C
7	A+D+E

- For all tested scenarios the water volume supplied at each one of the 25 urban tanks was the same of the actual scenario
- For each improving scenario, the hydraulic analysis was performed by means of EPANET model. The model has provided also the pumps energy consumption

Water and energy saving linked to Improving scenarios employed

- All proposed scenarios results in energy and economic saving
- The economic saving was obtained by comparing the sum of the annual capital and operational costs of the proposed scenario with the annual operational cost of the actual system
- Scenario 7 is characterized by the major water and energy saving and with a reduction of the total costs equal to -7.4% with respect to the actual scenario. **Therefore, the identified solution could be auto-financed by the water utility using the related operational cost economies.**

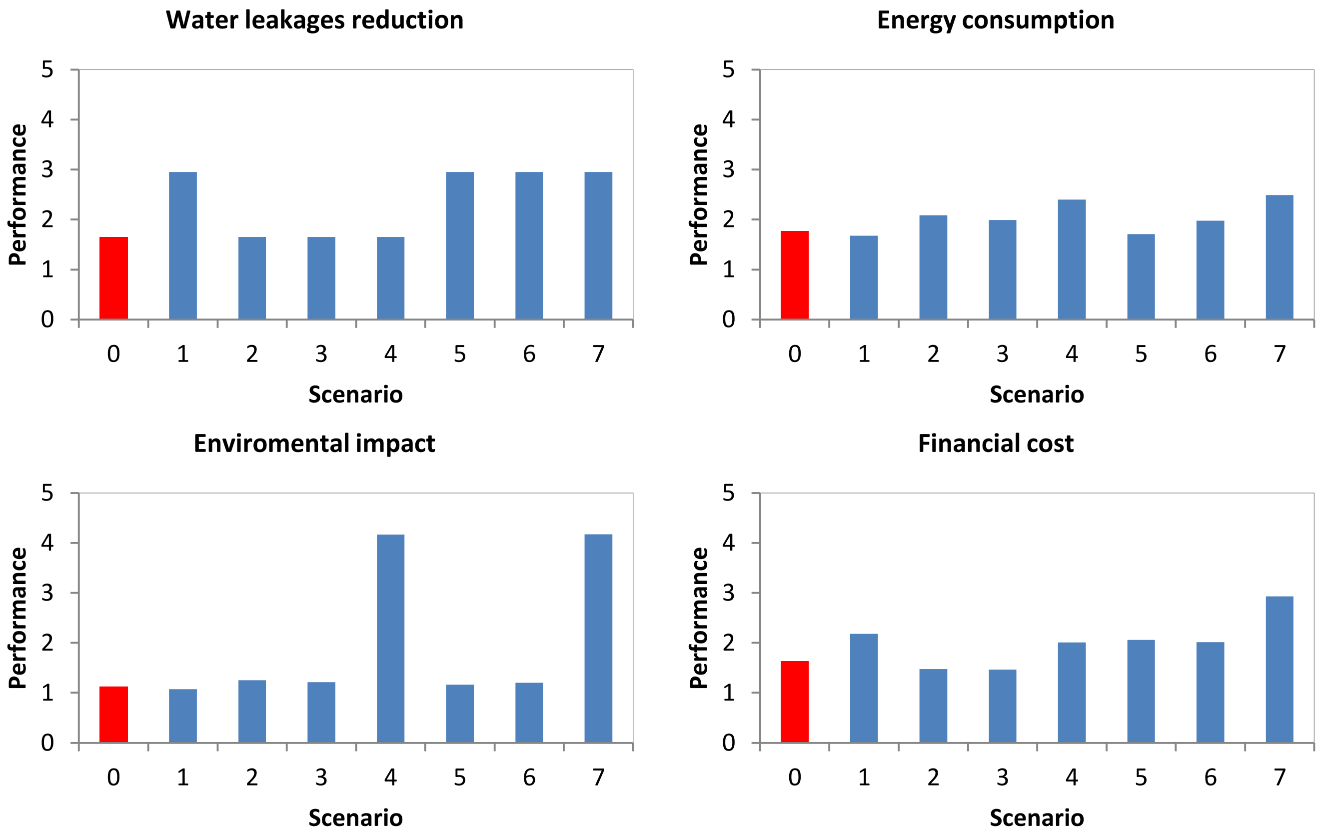
Scenario	Improvement measures	Input volume (m^3/yr)	NRW (%)	Energy consumption (kWh/yr)	PV energy yield (kWh/yr)	Energy saving (%)	Capital cost (€/yr)	Operational cost (€/year)	Economic saving (%)
0	-	13111407	25%	4691132	-	-	-	2983620	-
1	A	11800267	16%	4361502	-	-7.0%	39852	2771705	-5.8%
2	B	13111407	25%	4029096	-	-12.0%	68991	2855169	-2.0%
3	C	13111407	25%	4299384	-	-8.4%	51635	2894131	-1.3%
4	D+E	13111407	25%	4420844	405457	-13.1%	34157	2944659	-0.2%
5	A+B	11800267	16%	3811028	-	-17.5%	105109	659664	-7.3%
6	A+C	11800267	16%	3996998	-	-14.8%	88840	2688439	-6.9%
7	A+D+E	11800267	16%	3936997	430427	-24.5%	75078	2688439	-7.4%

PIs and related performance values

PI		TESTED SCENARIO							
		0	1	2	3	4	5	6	7
W1	PI value	24.57	16.19	24.57	24.57	24.57	16.19	16.19	16.19
	Performance	1.65	2.95	1.65	1.65	1.65	2.95	2.95	2.95
E1	PI value	0.36	0.37	0.31	0.33	0.34	0.38	0.33	0.34
	Performance	1.88	1.75	2.32	2.19	2.01	1.61	2.19	2.07
E2	PI value	0.27	0.28	0.24	0.25	0.26	0.26	0.25	0.26
	Performance	3.41	3.25	3.84	3.71	3.54	3.54	3.67	3.56
E3	PI value	0.00	0.00	0.00	0.00	9.85	0.00	0.00	11.14
	Performance	0.00	0.00	0.00	0.00	1.77	0.00	0.00	1.97
G1	PI value	0.000130	0.000136	0.000114	0.000119	0.000075	0.000125	0.000121	0.000075
	Performance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G2	PI value	0.00	0.00	0.00	0.00	5.52	0.00	0.00	5.52
	Performance	0.00	0.00	0.00	0.00	5.00	0.00	0.00	5.00
F1	PI value	35.92	35.95	33.03	33.94	35.07	33.25	33.96	33.96
	Performance	4.27	4.27	4.46	4.40	4.33	4.45	4.40	4.40
F2	PI value	57.55	55.75	60.14	59.33	58.31	58.10	57.48	57.48
	Performance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F3	PI value	0.00	1.27	0.00	0.00	0.00	1.32	1.30	1.30
	Performance	0.00	3.00	0.00	0.00	0.00	3.10	3.05	3.05
F4	PI value	0.00	100.00	0.00	0.00	0.00	37.91	44.86	68.38
	Performance	2.00	1.00	2.00	2.00	2.00	1.00	1.00	1.00
F5	PI value	0.00	0.00	100.00	100.00	100.00	62.09	55.14	31.62
	Performance	2.00	2.00	1.00	1.00	1.00	1.00	1.00	2.56
F6	PI value	0	0	0	0	60000	0	0	60000
	Performance	0.00	0.00	0.00	0.00	2.80	0.00	0.00	3.00
F7	PI value	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
	Performance	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93
F8	PI value	0.06	0.06	0.05	0.06	0.06	0.05	0.06	0.06
	Performance	1.96	1.89	2.20	2.12	2.03	2.31	2.04	2.04
Performance: 0 = no service; 1 = unacceptable service; 2 = poor service ; 3 = acceptable service; 4 = good service; 5 optimum service									

Global system performance

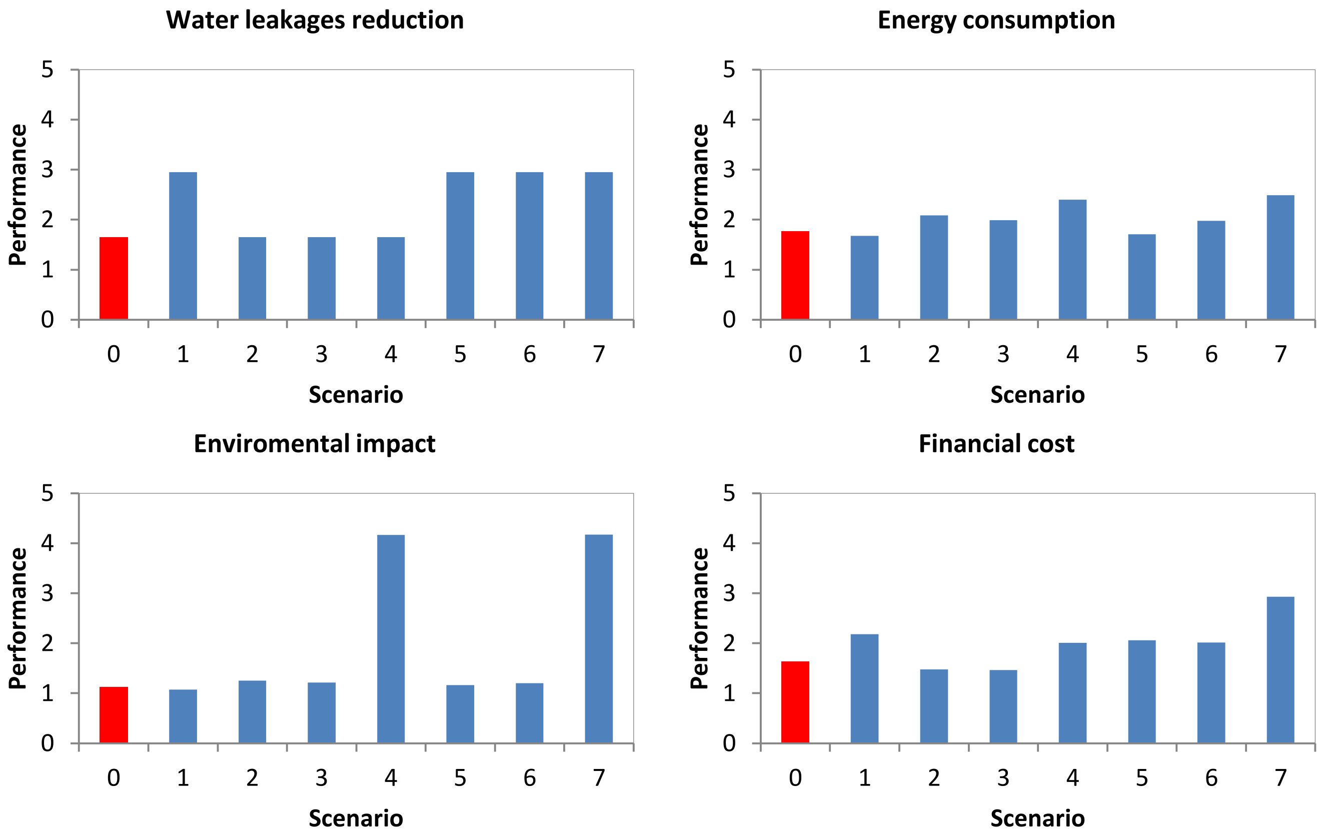
For each performance aspect, a global system performance was assessed as weighted average of the performance related to the PIs of a given group



The reduction of 10% of water losses applied in scenarios 1, 5, 6 and 7 corresponds to an increase in performance from unacceptable to acceptable service

Global system performance

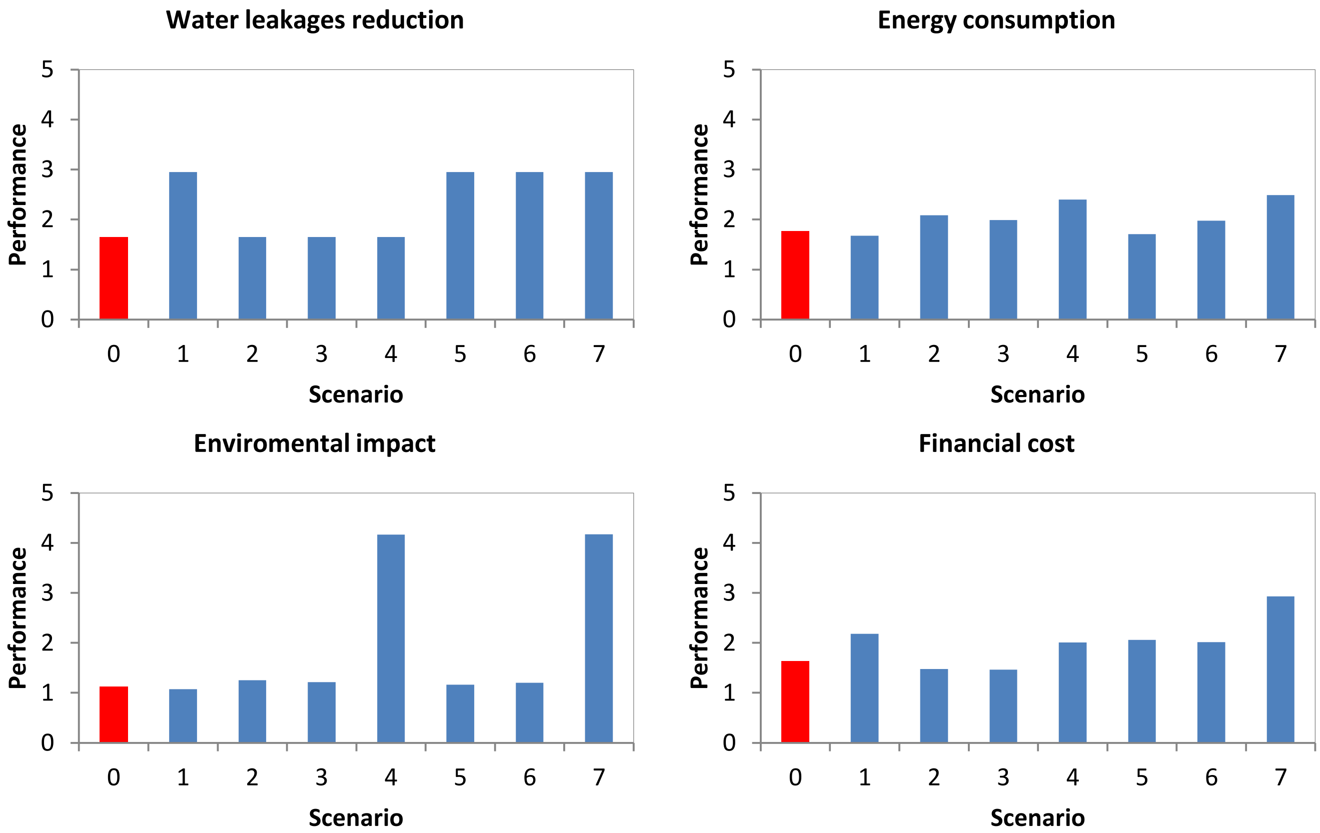
For each performance aspect, a global system performance was assessed as weighted average of the performance related to the PIs of a given group



With regard to energy consumptions all scenarios show a poor service (with performance < 3) due to the high water volumes pumped to supply urban tanks.

Global system performance

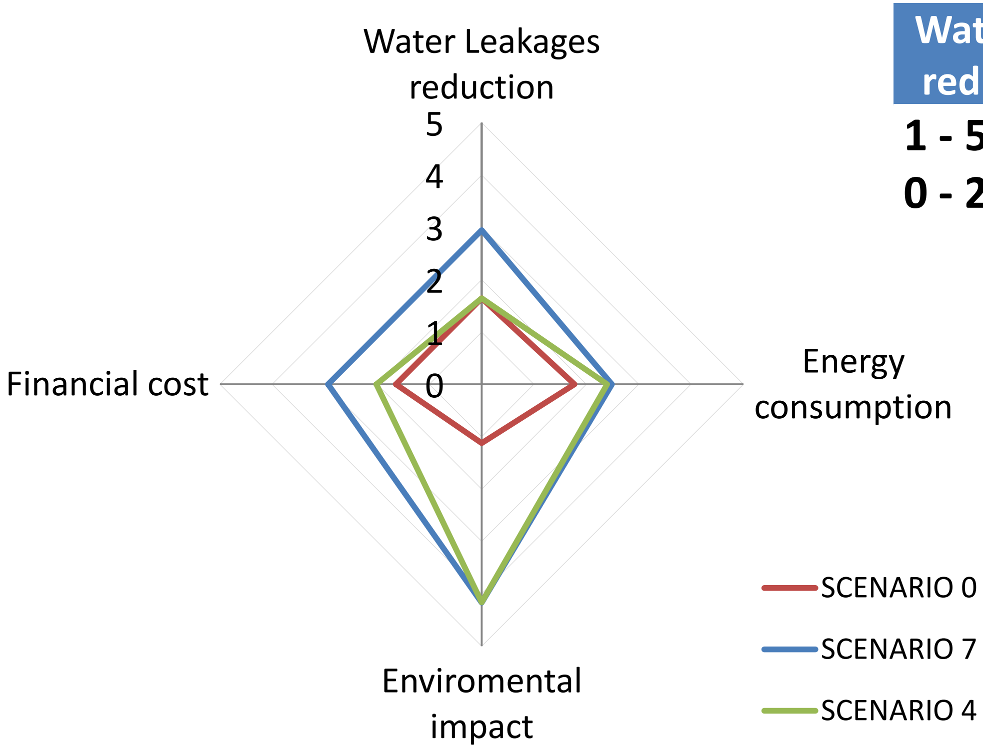
For each performance aspect, a global system performance was assessed as weighted average of the performance related to the PIs of a given group



Scenario 4 and 7 have a good environmental performance and the last one shows the best financial performance corresponding to an acceptable level of service

Scenario ranking

The global system performance were finally elaborated by means of a pairwise comparison procedure to obtain a scenario ranking for each investigated performance aspect



Water loss reduction	Energy consump.	Environm. impact	Financia l cost
1 - 5 - 6 - 7	7	7	7
0 - 2 - 3 - 4	4	4	1
	2	2	5
	3	3	6
	6	6	4
	0	5	0
	5	0	2
	1	1	3

The obtained rankings confirm the scenario 7 as recommendable in term of water leakages, energy consumption, environmental impact and financial cost reduction

Conclusions

- In the present study was presented a decision support tool, developed in the framework of the ALADIN project, aimed at increasing integrated water service efficiency both in terms of energy costs and of water leakages
- The reliability of the proposed tool was tested on the real water supply system which supply water to six different towns.
- The tool was useful to analyse the energy and water balance of the actual system and to suggest several feasible solutions to increase system efficiency in 4 performance aspects (leakages reduction, pump optimization, carbon footprint abatement, financial cost saving)
- The proposed actions were combined to build several operator-based improving scenarios which were analysed and compared with the actual scenario .
- The tool identified solutions that can be auto-financed by the water managers using the economies in the integrated water service

Project partners

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HYDRO ENGINEERING

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Thanks for your attention!

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