

SWIM and Horizon 2020 Support Mechanism

Working for a Sustainable Mediterranean, Caring for our Future

SWIM-H2020 SM EFS-LB-1

Measures to reduce unmet demand in the Nahr El-Kelb river basin: insight into the simulation process implemented

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Consultation Workshop with stakeholders to define policy targets and a PoM in the Nahr El-kelb

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Presentation Outline

- Basic definitions
- Process followed to design demand management options
- Demand management measures (concepts, definitions)
 - Urban sector
 - Agricultural sector
- Increase supply measures - NWRM
- Next steps

Basic Definitions

- **Demand management:** adoption of interventions and measures (technological, legislative, regulatory, financial, etc.) to achieve efficient water use by all sectors of the community (urban/ domestic, agricultural, industrial, tourism, etc.)

Demand reduction/ water saving measures:

Measures targeting to reduce demand and/or introduce water conservation

For example: reduce leakage, install water saving fixtures, increase irrigation conveyance and field application efficiency, create incentives, water tariffs, water markets, taxes, etc.

Increase supply measures:

Measures targeting to increase water supply

For example: greywater and wastewater reuse, water recycling, desalination, rainwater and stormwater harvesting, natural water retention measures.

**** Caution to potential environmental impacts**

Stepwise process

Step 1 – POLICY ASSESSMENT	Policy relevant assessment of the water balance and unmet demand (per sector) in the area of interests based on the results of detailed water balance models and calculations
Step 2 – IDENTIFY DM OPTIONS	Identification of potential demand management (including increase supply) measures for the most important sectors (e.g. urban and agricultural sector)
Step 3 – DISCUSS OPTIONS, SCREENING	First dialogue with the stakeholders: presentation of the measures, discussion on their efficiency and implementability, identification of limitation, agreement on a list of “ candidate measures ”
Step 4 - ASSESS COST- BENEFIT	Simulation of the performance “candidate measures” against a physical-based model to assess their cost-benefit
Step 4 – PRIORITIZE, SET TARGETS	Second dialogue with the stakeholders: presentation of the modeled/ simulation outcomes, agreement and prioritization of measures based on specified criteria (PoM), setting of targets

Which measures?

Sectors	Measures for water saving and/or increasing supply
Urban	<ol style="list-style-type: none">1. Low water using appliances (low flow taps and shower heads, dual toilet flushes, efficient washing machines, dishwashers, etc.)2. Domestic Greywater Reuse (GWR) (increase supply)3. Rainwater Harvesting (RWH) (increase supply)
Agriculture	<ol style="list-style-type: none">1. Replacement of open canals with closed pipes2. Change of irrigation methods<ul style="list-style-type: none">- Switch to drip irrigation from sprinklers and/or furrow irrigation systems
Cross-cutting	<ol style="list-style-type: none">1. Natural Water Retention Measures (NWRM)/ Detention ponds2. Wastewater treatment and reuse (within or across sectors)3. Increase dam capacity <p>* Economic Policy Instruments (EPIs), including water pricing reform (water metering is a pre-requisite)</p>

At what scales?

Scales	Measures for water saving and/or increasing supply
Micro	Low water using appliances (low flow taps and shower heads, etc.) Domestic Greywater Reuse (GWR) on-site Rainwater Harvesting (RWH) on-site
Meso	Replacement of open canals with closed pipes Switch to drip irrigation from sprinklers and/or furrow irrigation systems Natural Water Retention Measures (NWRM), e.g. retention ponds Rainwater Harvesting (RWH) and storage
Macro	Wastewater treatment and reuse (within or across sectors) Dams Economic Policy Instruments (EPIs), including water pricing reform Changing land use/ crops

Urban measures - Water saving fixtures & techniques

Tap flow restrictors



Aerators



Laminar flow showerheads



Showerhead flow regulators



Aerating showerheads



tank bank



toilet dam



Dual-flushing device



Passive infrared sensor



Waterless urinals



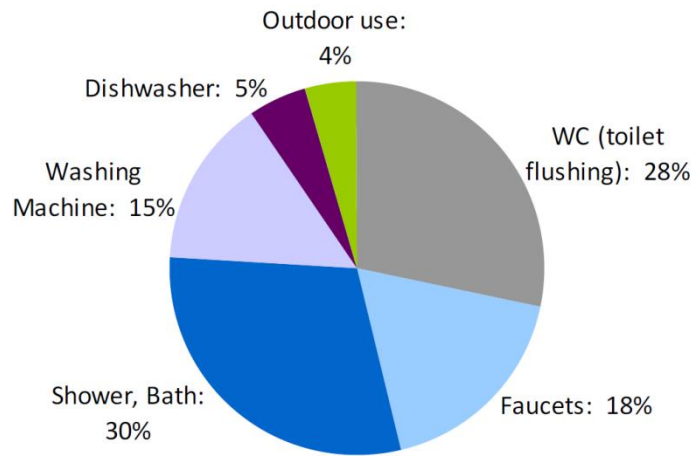
Hydraulic valve



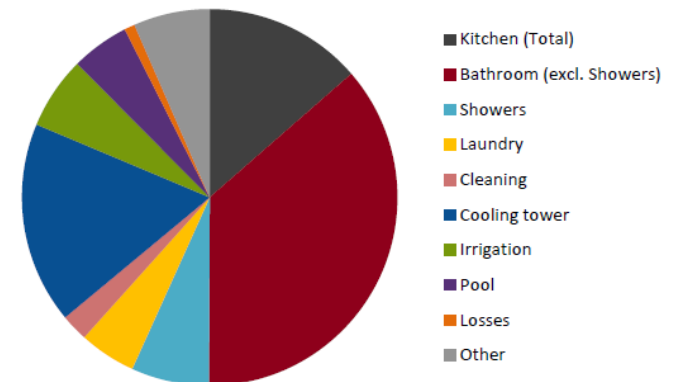
Urban measures – water saving fixtures

Water Using Product (WuP)	Consumption of “traditional” WuPs (lt/use)	Consumption of “efficient” WuPs (lt/use)	Water Saving Potential (%)
Low flush WC	6-12 lt/flush	3-4,5 lt/flush	30-50%
Showerhead	25 lt/min; 25.7-60 lt/shower	6-14 lt/min	50-70%
Faucet aerator	13.5 lt/min; 2.3-5.8 lt/use	2-5 lt/min	40-65%
Dishwasher, AAA class	21.3-47 lt/load	7-19 lt/load	40-60%
Washing Machines, AAA class	39-117 lt/load	40 lt/load	40%

Average water consumption share of different household micro-components



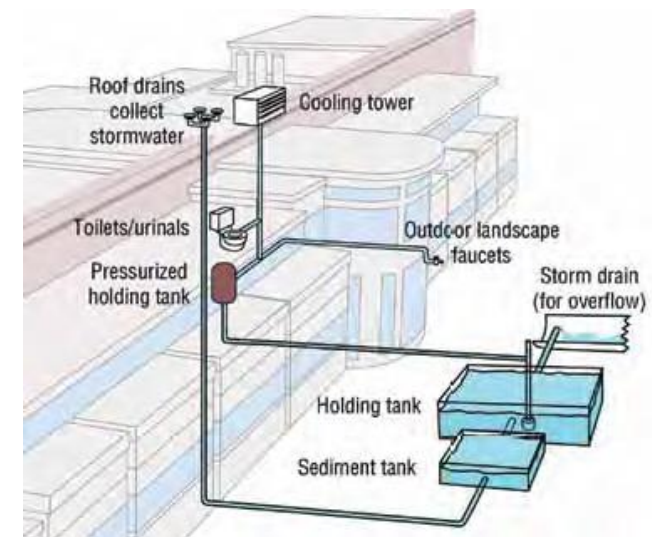
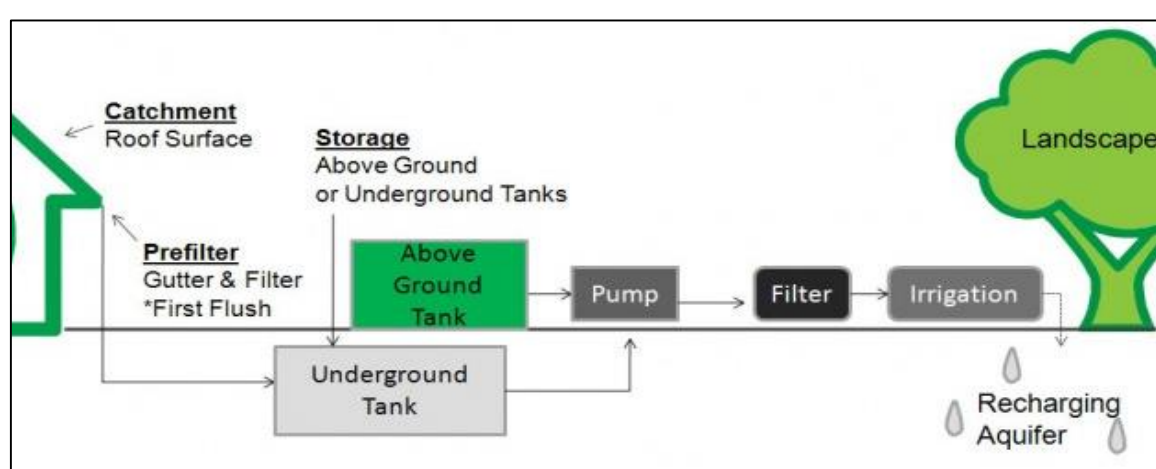
Average water consumption share in commercial buildings



Micro-components of water use

Urban measures – Domestic Rainwater Harvesting (RWH)

- Rainwater harvesting (RWH) is a **decentralized technique** of the collection and storage of rainwater for later use at or near the point where water is needed or used.
- Harvested rain water can be **utilized for several purposes**: washing, gardening, flushing and even drinking.
- Although rainwater is relatively clean and the quality is usually acceptable for many purposes, **filtration** and **disinfection** is usually appropriate
- A **RWH system**, which collects runoff from the roof, generally consists of a catchment area (generally the roof area), a filter, a storage tank, a supply network, pipes and an overflow unit (Environmental Agency 2008).



Urban measures – Domestic Rainwater Harvesting (RWH)

Benefits:

- Meet water demand when no other water sources are available
- Reduction of potable water consumption from the mains
- High collection and distribution efficiency
- Self sufficiency (less dependency on distant water courses).
- Reduction of flood risk (reduction of economic losses).
- Enhance rational utilization of water through decentralized systems
- Rain water can also be directed to recharge the aquifer thus increasing the ground water table

Cost effectiveness:

1 US gal=3.78 lt

- Great variation in capital costs because of options in terms of size, type of tank, and whether or not a pump is needed.
 - Range: from \$1.50 - \$3.00/gal of storage (for simple systems) to \$3.5 - \$8/gal for more sophisticated systems (EPA,2013)
 - The storage tank size is by far the largest factor of the total installation cost.
- Typical payback period is between 2 to 7 years
- The volume of water that is actually saved depends on the supply and demand for water.
- The amount of money saved depends on the price of water and the maintenance
- Approximately 0.62 gallons of water can be collected per square foot of collection surface per inch of rainfall (0.025 m³ per m²). In practice, however, assume an efficiency of 80%. (loses from first flush, evaporation from the roof surface, splash-out from the gutters)
- Annual production potential:
$$m^3 = \text{roof area (m}^2\text{)} \times \text{annual precipitation (in/yr)} \times (0.025 \times 0.8)$$

Urban measures – Domestic Greywater Reuse (GWR)

- GWR systems can vary significantly from simple, low-cost appliances that harvest greywater and convey it for direct use (e.g. in toilets and gardens), to composite systems integrating specialized treatment processes
- Cost and energy required can also vary, increasing mainly as more and better treatment is involved
- Water saving potential: variable, a reduction of 16-40% of potable water use is expected
- GWR systems are more suitable for new-built developments, as retrofitting existing systems can be more expensive

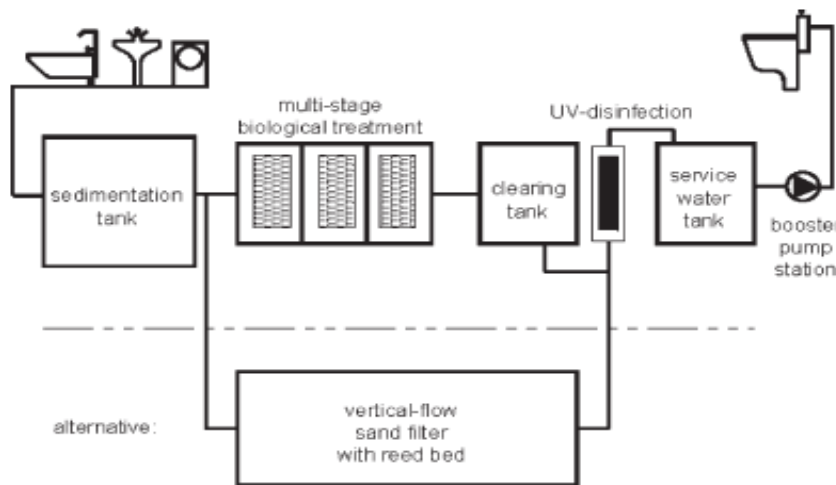


Figure 1 Recommended concept for greywater treatment

Requirements of a GWR for 280 users

Tank height	1.89 m
Required min. room height	2.39 m
System surface	about 15.0 m ²
Installation surface	max. 25.0 m ²
Suited for # of users	about 280
Recycling capacity	10,000 lt/day

Urban measures

Water Saving Measure		Performance (% water saving)	HH Micro-component targeted	HH Micro-component share (%)	Unit Cost €	AEC €	Expected water saving as % of total HH consumpt.
Tier #1	Dual Flush Toilet	40 %	WC	25 %	170 €	32 €	10 %
	Showerheads replacement	60 %	Bath + Shower	34 %	30 €	11 €	20.4 %
	Low flow taps (2 items)	50 %	Faucets	13 %	50 €	19 €	6.5 %
	Efficient Washing machine	40 %	Washing Machine	14 %	600 €	111 €	5.6 %
	Dishwasher	50 %	Dishwasher	8 %	700 €	130 €	4 %
			Outdoor use	6%			
Tier #1 TOTAL				100 %	1,550 €	303 €	46.5 %
Tier #2	Rainwater Harvesting ¹	40 % (incl. rainy months)	WC, washing machine, outdoors	29 %	2,500 €	356 €	11.6 %
	Greywater Reuse ²	22 %	WC, outdoors	21 % (15% WC + 6% outdoors)	3,500 €	498 €	4.6 %
Tier #2 TOTAL				44 %	6,000 €	854 €	16.2 %
GRAND TOTAL					7,550 €	1,158 €	62.7 %

$$AEC = \frac{r(1+r)^n}{(1+r)^n - 1} \times Inv + OMC$$

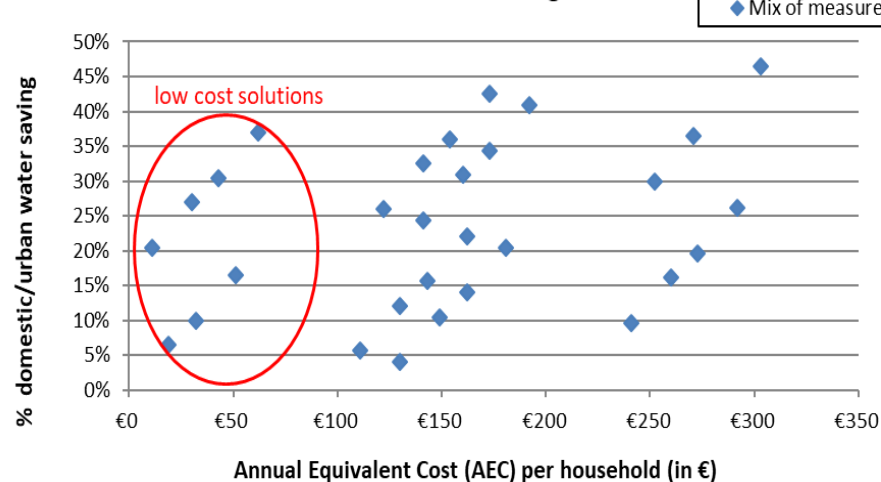
Urban measures' intervention curves – Tier 1

Results of the cost-effectiveness analysis of the urban water saving measures

Solution No. #	AEC per HH €	Water Saving % per HH	AEC per capita €	Water Saving % per capita	Total water saving * (mio m3) in the basin	Total AEC** (mio €) for the basin	€/m3 of water saved	Penetration (households adapting the measure)				
								Dual flush toilet	Shower-heads (1 item)	Low flow taps (2 items)	Efficient Washing Machine	Dish-washer
0 (BaU)	0 €	0.00%	0 €	0.00%	0	0	0					
1	11 €	20.40%	2.8 €	5.10%	3.07	0.52	0.17		✓			
2	19 €	6.50%	4.8 €	1.63%	0.98	0.89	0.91			✓		
3	30 €	26.90%	7.5 €	6.73%	4.04	1.41	0.35		✓	✓		
4	32 €	10.00%	8.0 €	2.50%	1.50	1.50	1.00	✓				
5	43 €	30.40%	10.8 €	7.60%	4.57	2.02	0.44	✓	✓			
6	51 €	16.50%	12.8 €	4.13%	2.48	2.40	0.97	✓		✓		
7	62 €	36.90%	15.5 €	9.23%	5.55	2.91	0.52	✓	✓	✓		
8	111 €	5.60%	27.8 €	1.40%	0.84	5.21	6.19				✓	
19	162 €	14.00%	40.5 €	3.50%	2.10	7.61	3.62	✓				✓
20	173 €	42.50%	43.3 €	10.63%	6.39	8.12	1.27	✓	✓	✓	✓	
21	173 €	34.40%	43.3 €	8.60%	5.17	8.12	1.57	✓	✓			✓
29	292 €	26.10%	73.0 €	6.53%	3.92	13.71	3.50	✓		✓	✓	✓
30	303 €	46.50%	75.8 €	11.63%	6.99	14.23	2.04	✓	✓	✓	✓	✓

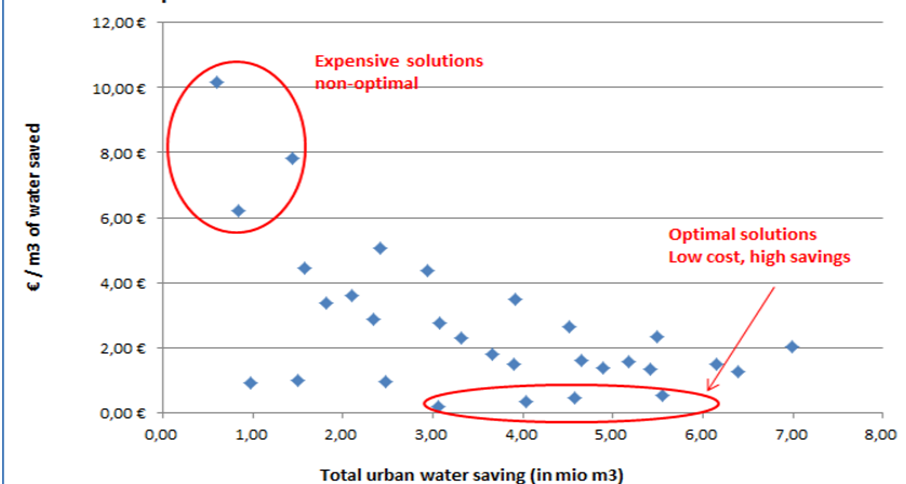
- Optimum solutions: 1,3,5,7,20. Easy and low cost to achieve conservation 20% (11 €/hh AEC)
- To achieve 37% the cost is still affordable (62 €/hh AEC)
- Above that level, the cost is increasing rapidly (introduction of relatively expensive measures as washing machines) and the equivalent unit cost exceeds 1€/m3 of water saved so the solutions cannot be considered as

Cost-effectiveness of the urban Tier-1 water saving measures



Urban cost-effectiveness curves:

unit cost in € per m3 of water saved with Tier-1 measures



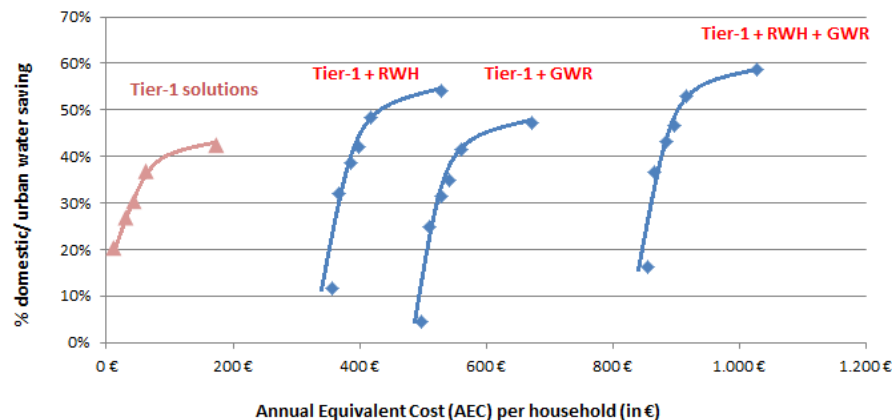
Urban measures' intervention curves – Tier 2

- GRW and RWH on top of the Tier-1 measures – INDEPENDANCY from mains
- Optimal solutions: No. 7r and 20r, since they deliver among the highest water savings (48.50% and 54.10%) with the lowest unit costs of AEC 2.69 and 3.06 €/m³ of water saved
- Additional good solutions: No. 7w, 20w, and 20m (max saving 58.7% per hh, with a unit cost of 5.47 €/m³ of water saved (or AEC 1,027€/hh).

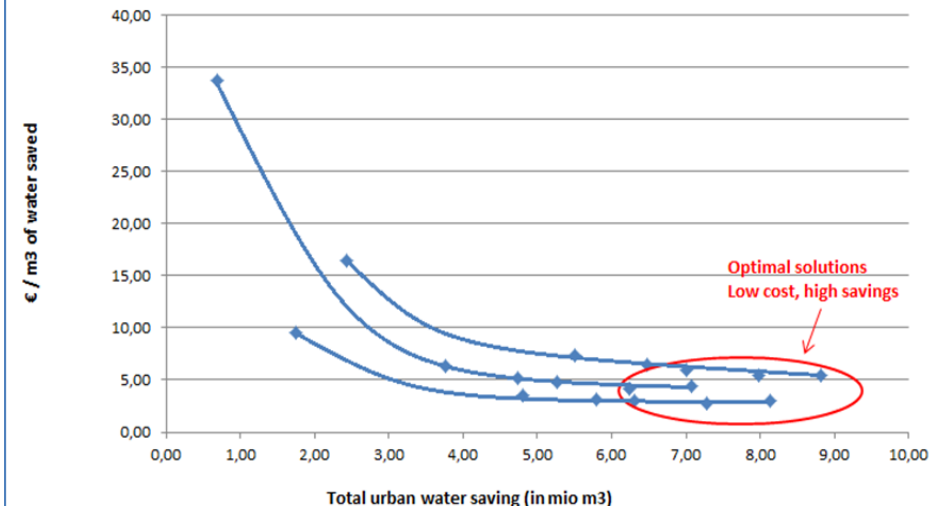
Results of the cost-effectiveness analysis of the urban increase supply measures

Solution No. #	AEC per HH €	Water Saving % per HH	AEC per capita €	Water Saving % per capita	Total water saving * (m ³ /m ³) in the basin	Total AEC** (m ³ /m ³) for the basin	€/m ³ of water saved	Penetration (households adapting the measure)						
								Dual flush toilet	Shower-heads (1 item)	Low flow taps (2 items)	Efficient Washing Machine	Dish-washer	Rainwater Harvesting	Greywater Reuse
1r	367 €	32.00%	91.8 €	8.00%	4.81	17.24	3.58		√				√	
1w	509 €	25.00%	127.3 €	6.25%	3.76	23.90	6.36	√						√
1m	865 €	36.60%	216.3 €	9.15%	5.50	40.62	7.38	√					√	√
5r	399 €	42.00%	99.8 €	10.50%	6.31	18.74	2.97	√	√				√	
5w	541 €	35.00%	135.3 €	8.75%	5.26	25.41	4.83	√	√					√
7r	418 €	48.50%	104.5 €	12.13%	7.29	19.63	2.69	√	√	√			√	
7w	560 €	41.50%	140.0 €	10.38%	6.24	26.30	4.22	√	√	√				√
7m	916 €	53.10%	229.0 €	13.28%	7.98	43.02	5.39	√	√	√			√	√
20r	529 €	54.10%	132.3 €	13.53%	8.13	24.84	3.06	√	√	√	√		√	
20w	671 €	47.10%	167.8 €	11.78%	7.08	31.51	4.45	√	√	√	√			√
20m	1,027 €	58.70%	256.8 €	14.68%	8.82	48.23	5.47	√	√	√	√		√	√
32	498 €	4.60%	124.5 €	1.15%	0.69	23.39	33.83							√
33	854 €	16.20%	213.5 €	4.05%	2.43	40.11	16.47						√	√

Cost-effectiveness of the urban mixed water saving (Tier 1) and water supply (Tier 2) measures



Urban cost-effectiveness curves: unit cost in € per m³ of water saved with Tier-2 measures



Urban measures: selected solutions for simulation

- Optimum Tier-1 solutions: 1, 3, 5, 7, 20
- Optimum Tier-2 solutions: 7r, 7w, 20r, 20w, 20m (on top of Tier-1)
- Applied in all 9 urban nodes: ~188,000 people ; 47,000 hh; water use rate 80 m³/yr/pp
- The measures have not been implemented in Beirut, since the target is to save water from the El-Kelb basin consumption so that more water could be available for Beirut

Urban measures: selected solutions for simulation

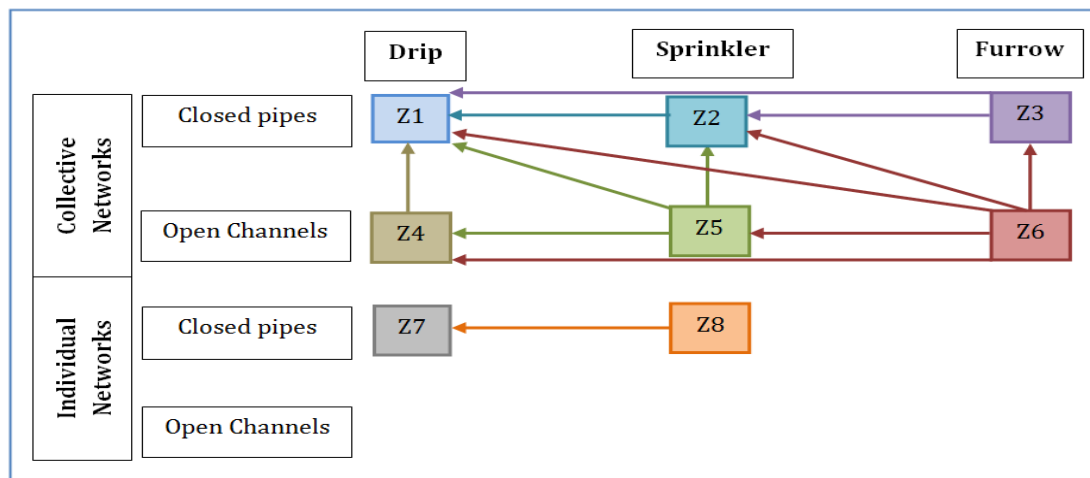
Solution No. #	Annual Equivalent Cost (AEC) per capita €	Water Saving per capita %	Penetration (households adapting the measure)				
			<i>Dual flush toilet</i>	<i>Showerheads (1 item)</i>	<i>Low flow taps (2 items)</i>	<i>Efficient Washing Machine</i>	<i>Dish-washer</i>
1	2.8 €	5.10%		√			
3	7.5 €	6.73%		√	√		
5	10.8 €	7.60%	√	√			
7	15.5 €	9.23%	√	√	√		
20	43.3 €	10.63%	√	√	√	√	

Solution No. #	Annual Equivalent Cost (AEC) per capita €	Water Saving per capita %	Penetration (households adapting the measure)						
			<i>Dual flush toilet</i>	<i>Showerheads (1 item)</i>	<i>Low flow taps (2 items)</i>	<i>Efficient Washing Machine</i>	<i>Dishwasher</i>	<i>Rainwater Harvesting</i>	<i>Greywater Reuse</i>
7r	104.5 €	12.13%	√	√	√			√	
7w	140.0 €	10.38%	√	√	√				√
20r	132.3 €	13.53%	√	√	√	√		√	
20w	167.8 €	11.78%	√	√	√	√			√
20m	256.8 €	14.68%	√	√	√	√		√	√

Agricultural measures – Increase irrigation efficiency

- Different options to improve conveyance efficiency and/or field application efficiency

Schematic representation of the optimization process



Aggregated values for irrigation efficiency (conveyance and field application)

Irrigation Method	Irrigation method's efficiency	Technology penetration (current)		Technology penetration (future)	
		Mountain	Coastal	Mountain	Coastal
Surface irrigation	60%	30%	40%	10% ↓	10% ↓
Sprinkler irrigation	75%	30%	40%	20% ↓	20% ↓
Drip irrigation	90%	40%	20%	70% ↑	70% ↑
Combined irrigation efficiency		76.5%	72%	84% (+7.5)	84% (+12%)

Irrigation Network	Network conveyance efficiency	Network type penetration (current)		Network type penetration (future)	
		Mountain	Coastal	Mountain	Coastal
Groundwater	75% (25% losses)	40%	60%	20% ↓	20% ↓
Open channels	65% (35% losses)	30%	30%	10% ↓	10% ↓
Closed pipes	90% (10% losses)	30%	10%	70% ↑	70% ↑
Combined network conveyance efficiency		76.5%	73.5%	84.5% (+8%)	84.5% (+11)

Agricultural measures – Precision Agriculture

■ Precision Agriculture (PA)

Soil moisture sensors, watering based on specific needs/ schedule

Costs associated with implementing Precision Agriculture (PA)

Cost items	Unit price (€)	Cost for 100 ha (€)	Cost per hectare (€/ha)
Yield monitor (1 item per 100 ha)	7,000	7,000	70
Soil moisture sensor (160 items per 100 ha)	35	5,600	56
Data logger (10 items per 100 ha)	200	2,000	20
Atmometer (10 items per 100 ha)	350	3,500	35
Sum of equipment cost		18,100	181
Drip irrigation modernization			650
Total cost for implementing PA			831
AEC (for a useful life n=5 years, and r=0.07)			202.67
Savings from reduced fertilisers' use (~30 kg N/ha)			-39
Savings from energy bills (reduced pumping)			-8
Net total cost for implementing PA (suggested for the Matlab model)			156 €/ha

■ Deficit Irrigation (DI): Application of water below the ET requirement

It is based on the concept that in areas where water is the most limiting factor, maximizing Crop Water Productivity (CWP) may be economically more profitable for the farmer than maximizing yields

$$\text{Market Value} = Y_a * \text{Area} * \text{Price}$$

Agricultural measures: selected solutions for simulation

- Converting from furrow or sprinkler to **drip irrigation**:
561 ha in mountain and 965 in coastal areas → **1,526 ha total**
- Converting from open channels to **closed pipes**:
748 ha in mountain and 1,158 in coastal areas → **1,906 ha total**

Cost items used in the simulation	Annual Equivalent Cost AEC per hectare (in €)	Total AEC (in €)
Converting to drip irrigation (useful life = 20 years)	347 €/ha	529,522 €
Implementing Precision Agriculture (PA) in existing drip irrigation systems (useful life = 5 years)	156 €/ha	
Converting from open channels to closed pipes (useful life = 50 years)	390 €/ha	743,340 €
Total Annual Equivalent Cost for the agricultural measures		1,272,862 €

Water Metering

You can't manage what you don't measure!!

- Average consumption volumes in absolute terms are ambiguous to report, since dependent on the number occupants (or employees) in each building, frequency of use & habits, existing leakage losses, etc.
- Metering of micro-components prior to decision-making is encouraged
- Meters and submeters can be integrated into a centralized building management system, making it easy to **track usage** and implement **water saving measures**
- They can also detect and **trigger alerts** for leaks or other operational anomalies



Increase supply – Natural Water Retention Measures (NWRM)

<http://nwrn.eu/>

Basins and ponds require a large accessible area that is relatively flat and with an appropriately sized drainage catchment. They can be installed in any type of area (urban, forest, agricultural...).

Account should be taken of natural features that could be used to form the basin and/or provide additional storage areas in order to minimise the need for artificial landscaping

Detention & Retention basins temporarily store runoff, then releasing it at a slower rate downstream, e.g. in to a receiving watercourse. The capacity to store runoff is dependent on the design of the basin, which can be sized to accommodate any size of rainfall event. Typical construction costs in range from \$20 to \$40 per m³ of storage.

Biophysical Impacts		Rating	Evidence
Slowing & Storing Runoff	Store Runoff	High	Volume of runoff storage: Total volume of the basin/volume available in the pond (total volume minus the volume of water already there before the rain event). No long term storage for the basins. For the pond, the potential storage is equal to the total volume of the pond. Peak flow reduction estimated to be between 15-30% for the Northumberland (Rural runoff attenuation in the Belford catchment, UK) project
	Slow Runoff	High	
	Store River Water	None	Storing of surface runoff only (system not connected to a river)
	Slow River Water	None	Storing of surface runoff only (system not connected to a river)



Increase supply measures' simulation (meso-scale)

- Detention/ retention ponds for the urban sector: not simulated due to water quality constraints (unsuitable for domestic water use except landscaping and land requirement/ acquisition constraints)
- Detention basins for the agricultural sector of 100-150 m³ capacity and 1km² drainage area and a total of around 20 ponds per sub-catchment/demand site: it is too small to be captured by the model (the combined total contribution is around less than 0.01% of most demands) unless you add 1,000 -10,000 ponds. Also a lot of assumptions to account for monthly runoff sources and inflow in sites where the topography is beneficial. Capital construction costs €30 per m³ of volume provided for storage, maintenance costs €3 per m² of basin, useful life 9w30 years, and thus the resulting AEC is €5.83/m³/year.

Increase supply measures' simulation (macro-scale)

- Bourj-Hamoud WWTP

Treated effluent suitable for agricultural purposes

WWTP capacity: expected to serve 2.2 million PE ; 200 lt per capita →

Estimated capacity ~0.5million m³/day

Linked to all urban demand nodes, to be operational in 2025

- Boqaata Dam

To be operational in 2025

Reservoir capacity 6 MCM