WA 5: Fostering the uptake of novel technologies in the water sector

LCA/LCC of MAR systems: case study in Sant Vicenc dels Horts

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   - Costs
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Introduction

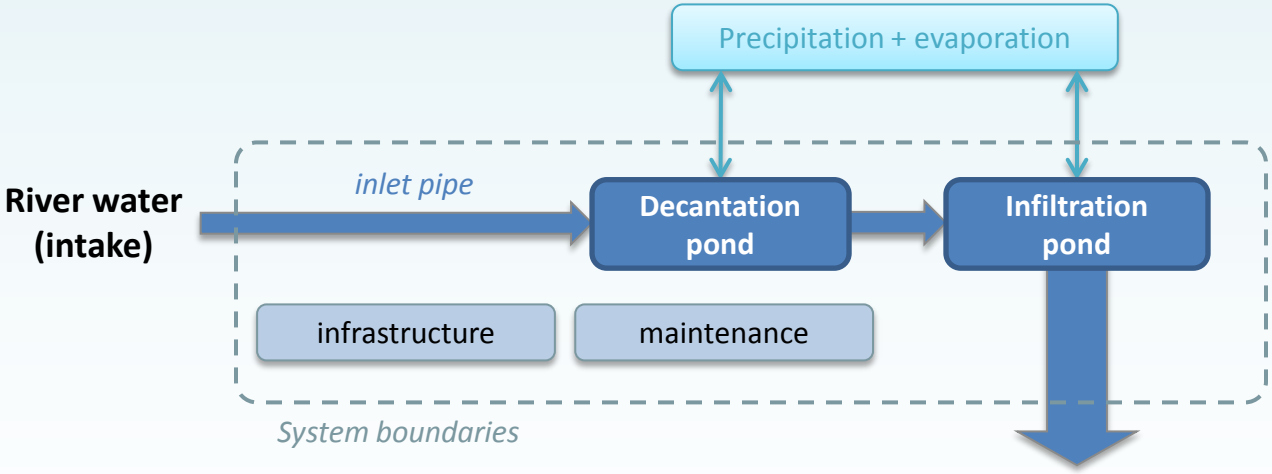
- **DEMEAU WA 5:** „foster market uptake of innovative technologies in the water sector“
  - Drivers?
  - Barriers?
  - Ask the stakeholders! → presentation and discussion to follow

- What is the **„unique selling point“** of the innovative technology?
  - Economic perspective
  - Environmental perspective

- Evaluation of technologies in their **life-cycle** :
  - Life Cycle Costing (LCC)
  - Life Cycle Assessment (LCA, ISO 14040/44)

Case study at SVH

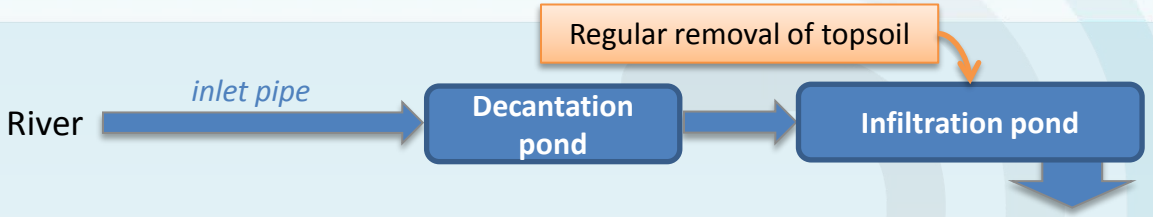
- Case study: MAR system in Sant Vicenc dels Horts
- Different scenarios are evaluated
- System analysis with LCA/LCC includes:
  - **Direct effects:** Groundwater recharge, elimination of trace organics and nutrients
  - **Indirect effects:** Energy, chemical demand, maintenance, and infrastructure



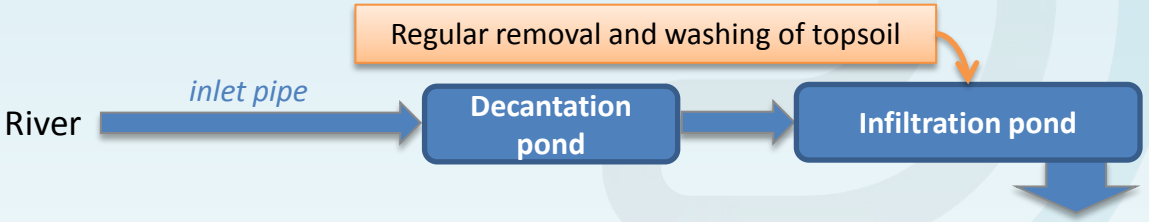
Sant Vicenc dels Horts

Scenarios for comparison

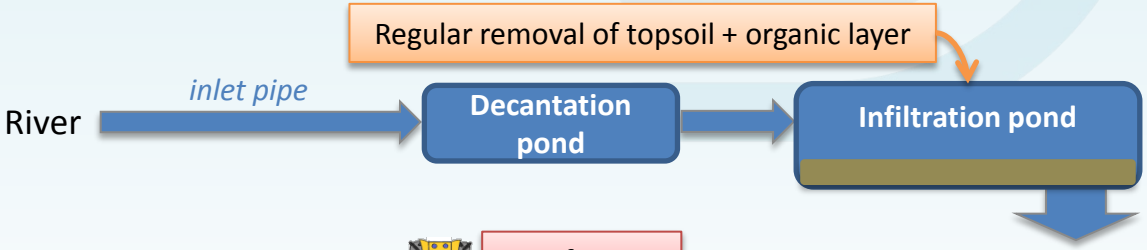
1.1 MAR („status quo“)



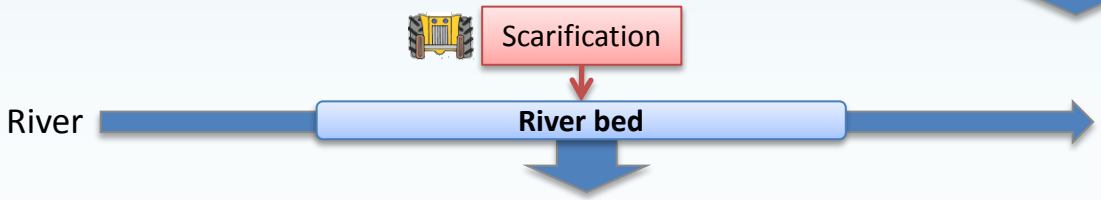
1.2 MAR with sand washing



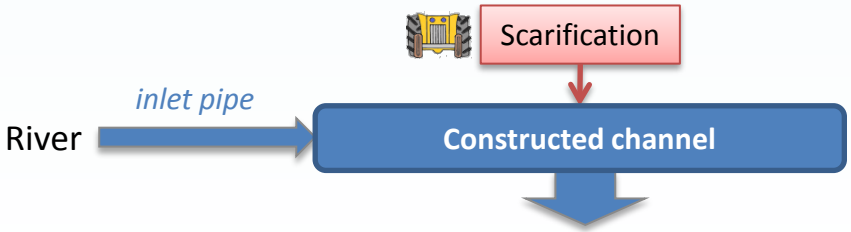
2. MAR with reactive layer



3. Scarification in river bed (traditional)



4. Scarification in constructed channel



Input data

collected by Marta Hernandez (CETaqua)		MAR	MAR + washing	MAR + layer	Scarification in river	Scarification in channel
Infiltration area	*m²*	5600	5600	5600	20000	23200
Operation time	*d*	250	250	250	300	300
Infiltration rate (min-max)	*m³/(m²*d)*	0.85 (0.5-1.2)	0.85 (0.5-1.2)	0.85 (0.5-1.2)	0.8 (0.1-1.0)	1.0 (0.25-1.5)
Maintenance		Topsoil (15cm) removal every 2nd year	Topsoil removal + sand washing	Topsoil removal + organic layer replacement (5a)	50d scarification machinery	150d scarification machinery
Personnel	*k€/a*	25	25	25	37	37
Machinery	*k€/a*	5	5 + 6.3	5	21	21
Instrumentation	*k€/a*	20	20	20	20	20
Analytics	*k€/a*	20	20	20	20	20
Infrastructure		Inlet pipe, ponds	Inlet pipe, ponds	Inlet pipes, ponds, organic layer		Inlet, channel
Ponds/pipes, layer	*k€*	5000	5000	5000 + 76	-	1300
Piezometres	*k€*	112	112	112	28	28
Expropriation	*€/m²*	1	1	1	-	-
Lifetime	*a*	18	18	18	-	3

Data to be confirmed

Input data (2)

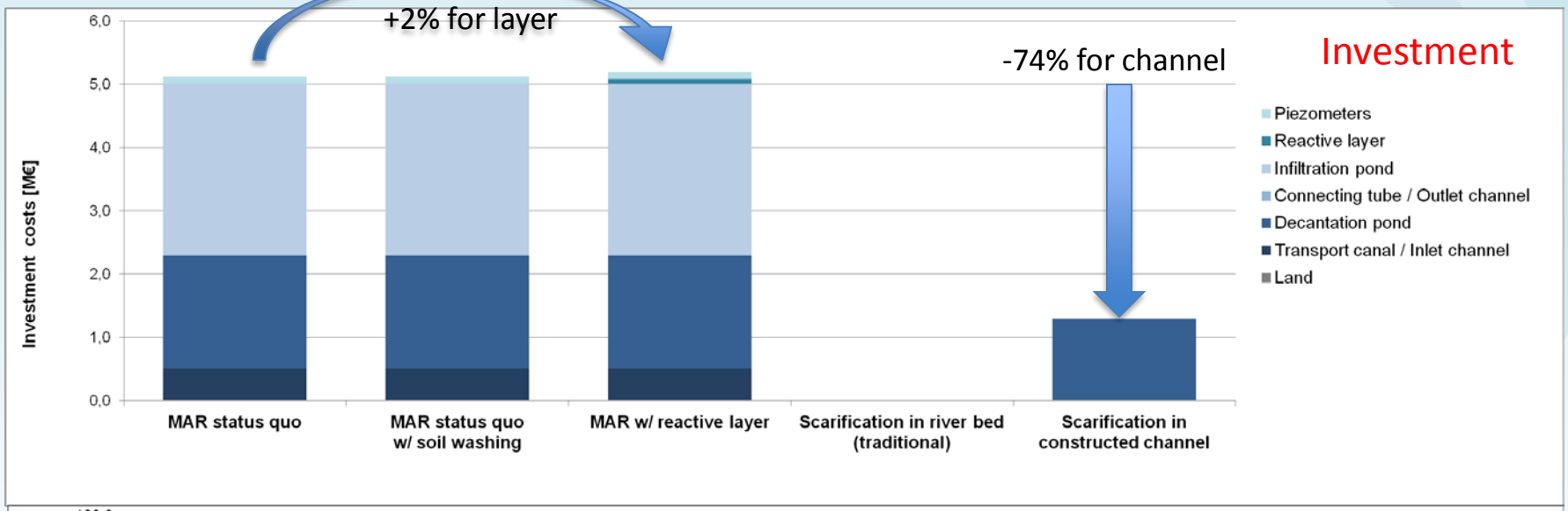
- Precipitation: 650 mm/a, evaporation: 1075 mm/a

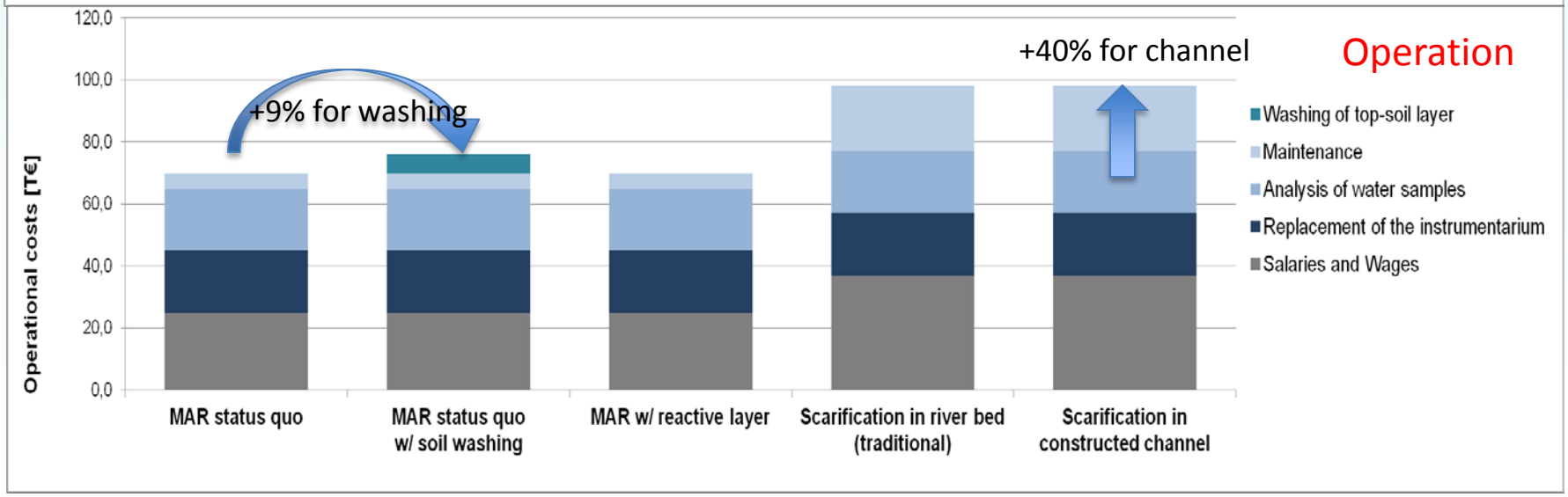
- Sand washing:
  - 8 kWh/m³ sand (data from Berlin)
  - total costs: 30€/m³ sand (estimate from literature)

- Organic layer:
  - Disposal in agriculture after 5a
  - 20 km transport by truck

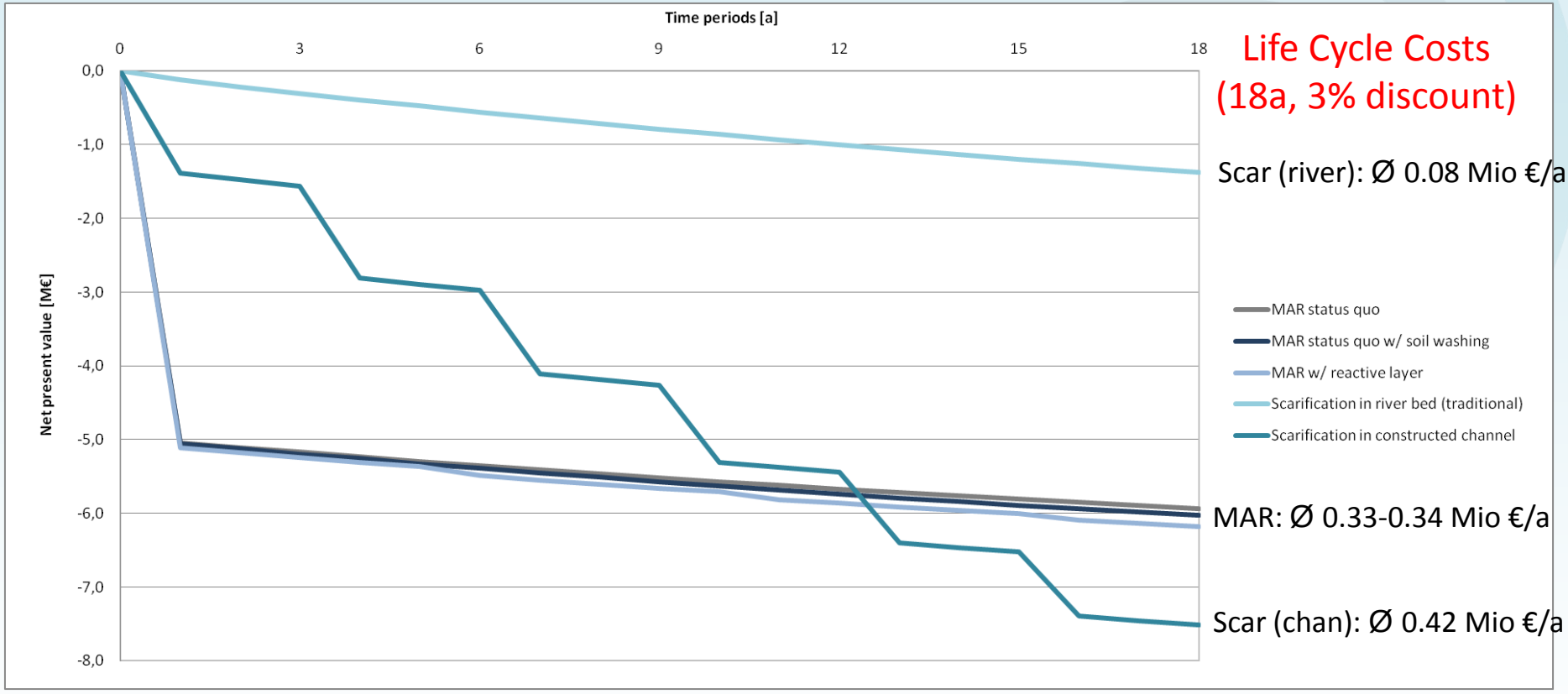
- Environmental footprint via LCA:
  - Infrastructure: concrete for pipes, excavation with hydraulic digger for ponds/channel
  - Maintenance: diesel fuel for skid-steer loader (topsoil removal) and scarification machine
  - Water quality data for river water and infiltrated water

OPEX and CAPEX





Total life cycle costs



Life Cycle Costs
(18a, 3% discount)

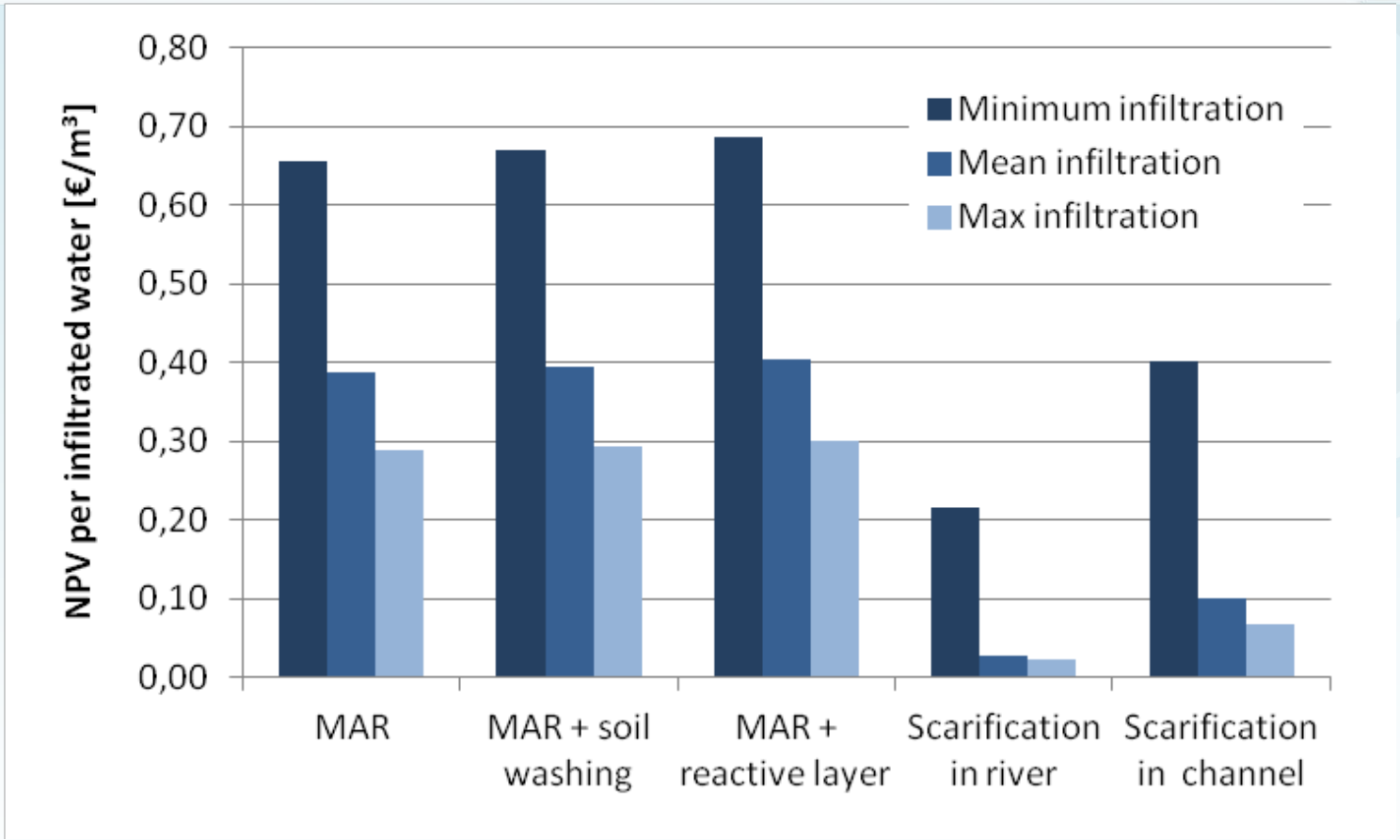
Scar (river): Ø 0.08 Mio €/a

MAR: Ø 0.33-0.34 Mio €/a

Scar (chan): Ø 0.42 Mio €/a

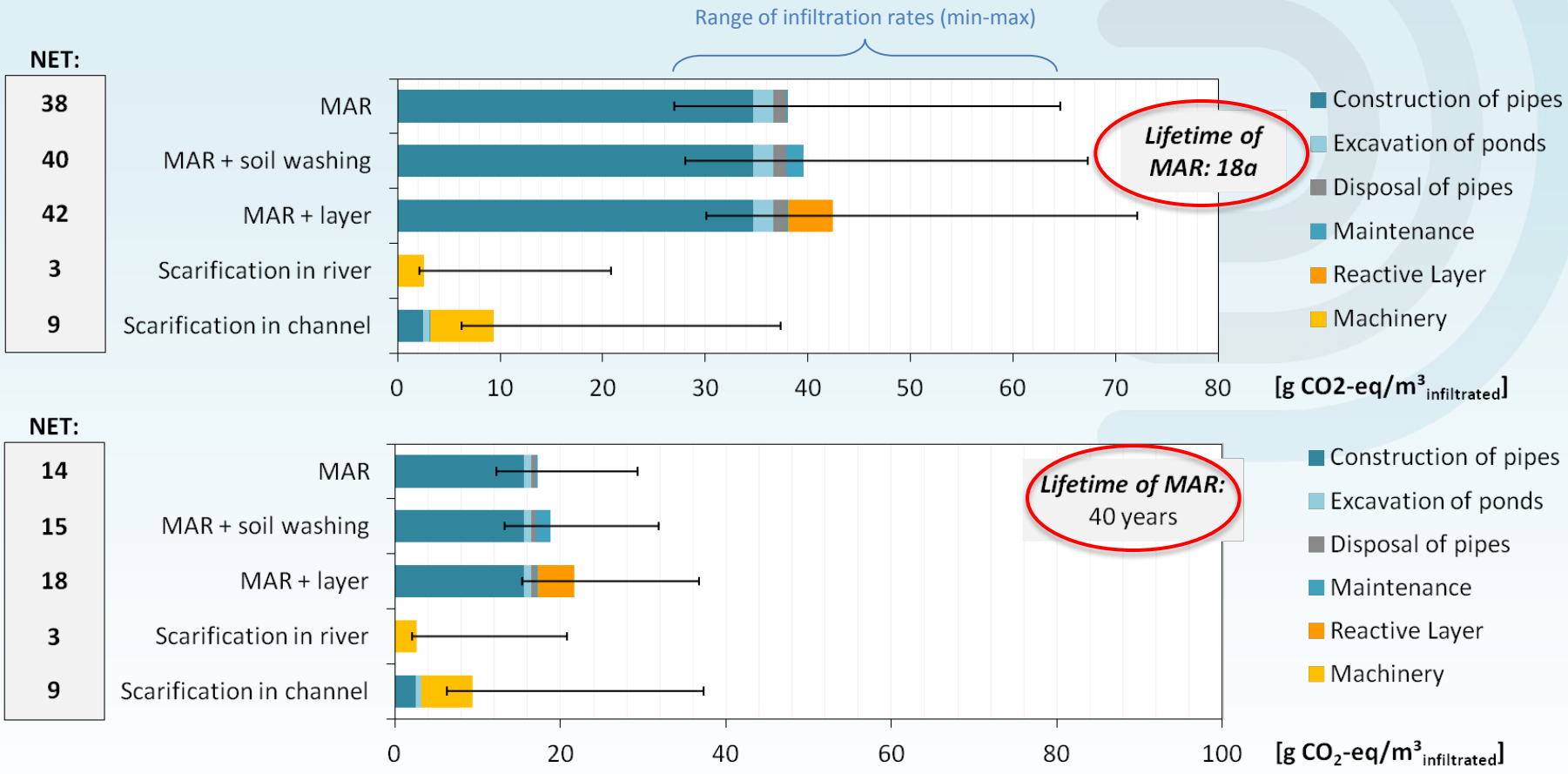
- Decisive parameter is expected lifetime of infrastructure:
  - MAR ponds and pipes: 18a → technical lifetime can be longer
  - Scarification channel: 3a → ?

Life Cycle Costs per m³



- Life cycle costs of MAR: 0.4 €/m³ infiltrated water (0.3-0.7 €/m³)
- Scarification in river: 0.03€/m³ (0.02-0.2)
- Scarification in channel: 0.1 €/m³ (0.07-0.4)

LCA: Carbon footprint per m³



- Carbon footprint of 3-42 g CO_2-eq/m³ infiltrated water
- Decisive parameter: technical lifetime of MAR infrastructure and channel

LCA: water quality

- Soil passage improves water quality: nitrogen, phosphorus, organic micropollutants, microbial parameters
- Data from soil columns
- Improved water quality will be evaluated with indicators for eutrophication and ecotoxicity → data pending

Parameter		Concentration in river	Elimination in MAR/riverbed infiltration	Elimination in MAR + layer	Evaluation in LCA
Trimethoprim	*ng/L*		99%	99%	✓
Bezafibrate	*ng/L*		48%	99%	✓
Metoprolol	*ng/L*		6%	99%	✓
Sulfamethoxazole	*ng/L*	54	0%	92%	✓
Iopromide	*ng/L*		58%	61%	✓
Diclofenac	*ng/L*		2%	27%	✓
Phenazone	*ng/L*		7%	12%	✓
Gemfibrozil	*ng/L*	60	7%	18%	
Carbamazepine	*ng/L*	25	0%	11%	✓
Primidone	*ng/L*		0%	12%	
1H- Benzotriazole	*ng/L*		16%	2%	✓
Nitrogen (anorg)	*mg/L*	6.9	50%	20%	✓
Total phosphorus	*mg/L*	0.185	62%	62%	✓
E. coli	*CFU/100mL*	10^{3}-$10^{4.5}$	1	1	
Enterococci	*CFU/100mL*	$10^{2.3}$-$10^{3.8}$	0	0	

Lab trials in soil column

Conclusions / Outlook

- Life-cycle costs (0.4 €/m³) and carbon footprint (40 g CO_2-eq/m³) of MAR are **dominated by infrastructure** → high influence of expected lifetime!

- Potential improvements for MAR system:
  - Organic layer (+ 4% in total costs, better removal of organic MPs)
  - Sand washing (+ 2% in total costs, long-term strategy)

- Alternative MAR technology (scarification in channel) with lower efforts in construction can **decrease costs per m³ and carbon footprint by 40-75%** (depending on realized infiltration rate)

- Unique selling point of MAR?
  - **Low-cost and low-energy technology**
  - Compare to alternative technologies for groundwater recharge (e.g. hybrid membranes) → next in DEMEAU!

DEMEAU WA 5:
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Thank you for your attention!

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SEVENTH FRAMEWORK PROGRAMME

Data for LCA

	abbr.	unit	INFLOW	SCENARIO 1.1: MAR status quo	SCENARIO 1.2: MAR status quo w/ soil washing	SCENARIO 2: MAR + reactive layer	SCENARIO 3: scarification in river bed (traditional)	SCENARIO 4: scarification in constructed channel	SCENARIO 5: REFERENCE TECHNOLOGY
Parameters									
Dimensions for Technology									
decantation pond	*A dec*	m²		4.000	4.000	4.000	-	-	-
infiltration pond / infiltration area	*A inf*	m²		5.600	5.600	5.600	20.000	23.200	-
depth of ponds / constructed channel	*d*	m		8	8	8	-	1	-
depth of reactive layer	*d RL*	m		-	-	0,6	-	-	-
days of operation		d/a		250	250	250	300	300	
expected lifetime of the system		a		18	18	18	40	3	
Infiltration rates									
MIN infiltration rate		m³/(m²*d)		0,5	0,5	0,5	0,1	0,25	-
MAX infiltration rate		m³/(m²*d)		1,2	1,2	1,2	1,0	1,5	-
MEAN infiltration rate (= hydraulic loading rate)		m³/(m²*d)		0,85	0,85	0,85	0,8	1,0	-
infiltrated volume per year (annual mean)		m³/a		1.190.000	1.190.000	1.190.000	4.800.000	6.960.000	
Water balance									
inflow volume	*Q in*	m³/a		1.194.080	1.194.080	1.194.080	4.808.500	6.969.860	
precipitation	*P*	mm		650	650	650	650	650	-
precipitation		m³/a		6.240	6.240	6.240	13.000	15.080	-
evaporation	*E*	mm		1.075	1.075	1.075	1.075	1.075	-
evaporation		m³/a		10.320	10.320	10.320	21.500	24.940	-
infiltrated volume (FU)	***Q out***	**m³/a**		**1.190.000**	**1.190.000**	**1.190.000**	**4.800.000**	**6.960.000**	

Construction and maintenance									
Construction of pipes									
length	*L*	m		2.005	2.005	2.005	-	concrete channel: 50 m	
diameter	*DN*	mm		1.000	1.000	1.000	-	concrete channel: 2 m	
depth under ground level	*d*	m		2,5	2,5	2,5	-	open (not buried)	
specific weight		kg/m		1.200	1.200	1.200	-	(depends on DN)	
total weight		t		2.406	2.406	2.406	-	#WERT!	
concrete (with density: 2380 kg/m³)		m³		951	951	951	-	(iterative calc.)	
reinfording steel (with 0.15 t/m³ concrete)		t		143	143	143	-	(iterative calc.)	
excavation of soil for pipes		m³		5.013	5.013	5.013	-	#WERT!	
Construction of ponds									
excavation of soil		m³		76.800	76.800	76.800	-	23.200	-
density of soil		kg/m³		1.600	1.600	1.600	-	1.600	-
concrete (for stabilisation of slopes)		m³		-	-	-	-	not expected	-
Maintenance									
Frequency of maintenance		times/yr		0,5	0,5	0,5	1 (stabilisation of river slope in the river bed)	2 (small reconstruction after a rainy episode)	
working days (8 h/d) per maintenance		days/time		2,0	2,0	2,0	1,0	1,0	
removal of top-soil layer		m		0,15	0,15	0,15	-	-	
amount of soil for washing on-site		m³/a		-	420	-	-	-	
electricity for washing		kWh/m³		-	8	-	-	-	
thickness of reactive layer		m		-	-	0,6	-	-	
frequency of removal of reactive layer		times/yr		-	-	0,2	-	-	
amount of reactive layer for further use		m³/a		-	-	672	-	-	

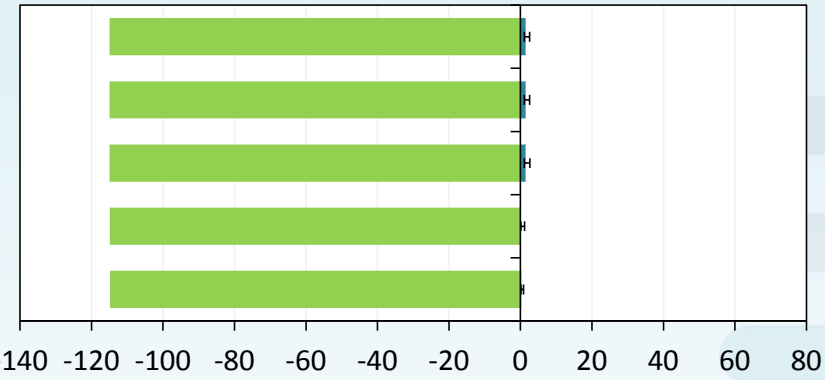
Data for LCC

Parameter	[units]	SCENARIO 1 Standard infiltration pond	SCENARIO 2 Infiltration pond + Reactive layer	SCENARIO 3 Scarification channel (to be constructed)
Decantation pond	m^2	4000	4000	Does not apply
Infiltration surface	m^2	5600	5600	23200
Effective days of operation	days	250	250	300
Maximum infitration rate	$m^3/m^2/d$	1,2	1,2	1,5
Minimum infitration rate	$m^3/m^2/d$	0,5	0,5	0,25
Mean infiltration rate	$m^3/m^2/d$	0,85	0,85	1
Infiltrated volume per year	m^3/a	1190000	1190000	6960000
Electricity for pumping	kWh/m^3	??	??	Does not apply
Expropiation / Comaandering rate	€/m^2	1,0	1,0	None: inside the public area of ACA
Execution of the facility	€	5000000	5000000	1300000
Expected life time of the system	years	18	18	3
Reactive layer material (60 cm)	€/m^2	Does not apply	4,5	Does not apply
Transportation of the reactive layer	€/m^3	Does not apply	4,0	Does not apply
Installation of the reactive layer	€/m^2	Does not apply	4,5	Does not apply
Cost of removal of the reactive layer	€/m^3	Does not apply	4,0	Does not apply
Frequency of organic layer reposition	years	Does not apply	5,0	Does not apply
Annual maintenance costs	€/year	5000	5000	21000
Replacement of the instrumentation	€/year	20000	20000	20000
Costs of analysis (Laboratory)	€/year	20000	20000	20000
Personnel costs for the operation (CUADLL)	€/year	25000	25000	37000
Number or piezometres in the observation network	units	16	16	4
Unitary cost of the piezometres	€/piezometre	7000	7000	7000
Life time of the piezometres	years	40	40	40

LCA: eutrophication

Freshwater Eutrophication Potential (P-Emissions)

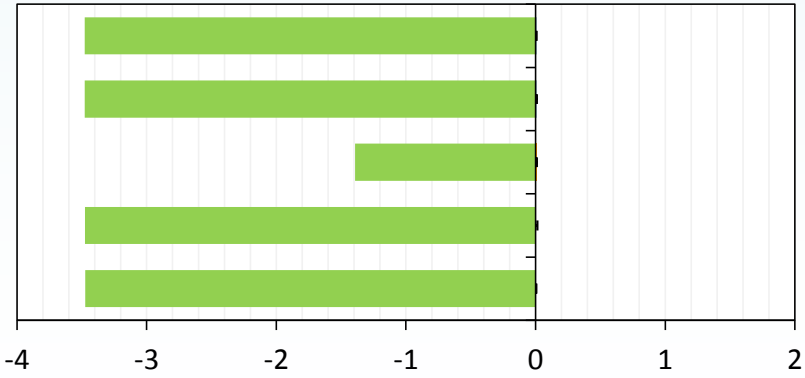
NET:	
-113	1.1 MAR status quo
-113	1.2 MAR status quo w/ soil washing
-113	2 MAR w/ reactive layer
-115	3 Scarification of river bed
-115	4 Scarification of constructed channel



- Construction of pipes
- Excavation of ponds
- Disposal of pipes
- Maintenance
- Reactive Layer
- Operation (Ploughing)
- INFILTRATION

Marine Eutrophication Potential (N-Emissions)

NET:	
-3,5	1.1 MAR status quo
-3,5	1.2 MAR status quo w/ soil washing
-1,4	2 MAR w/ reactive layer
-3,5	3 Scarification of river bed
-3,5	4 Scarification of constructed channel



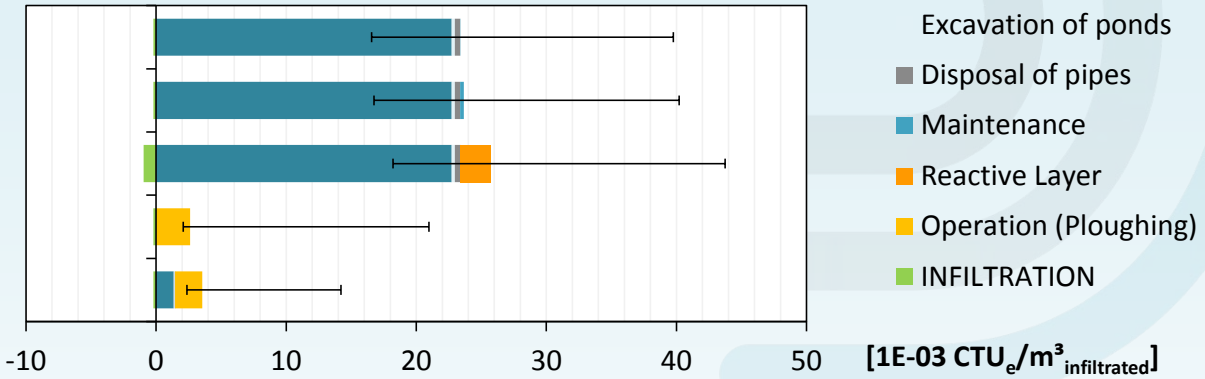
- Construction of pipes
- Excavation of ponds
- Disposal of pipes
- Maintenance
- Reactive Layer
- Operation (Ploughing)
- INFILTRATION

LCA: toxicity

Ecotoxicity Potential (USEtox)

NET:	
23,2	1.1 MAR status quo
23,5	1.2 MAR status quo w/ soil washing
24,8	2 MAR w/ reactive layer
2,4	3 Scarification of river bed
3,3	4 Scarification of constructed channel

*10^{-3}



Human Toxicity Potential (USEtox)

NET:	
6,6	1.1 MAR status quo
6,7	1.2 MAR status quo w/ soil washing
6,9	2 MAR w/ reactive layer
3,9	3 Scarification of river bed
3,5	4 Scarification of constructed channel

*10^{-9}