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Water as a new resource for bus operators

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Abstract

Water consumption for public transport is an uninvestigated issue, yet water is central in environmental policies as it is for energy and pollution. No standards, regular data or policies are available in this field and washing operations are managed at garages according to local practice, with very few cases of water post-treatment. This paper moves from here and presents a scenario assessment where three innovative technologies for saving water are applied at three washing plants, within the European Commission's LIFEH2OBUS project. The technologies are: water reclamation; water reclamation and harvesting; waxing without water. Simulations highlight an 84% reduction in average of water consumption after one year of implementation, i.e. 37 million fresh water saved, for a fleet of 680 buses. By reaching 50% of the European transit fleet in 5 years (342,143 buses), 18 billion liters/year can be saved, corresponding to -42% of the total water used by the transport sector, along with a 1,159 GWh reduction of energy consumption, and 504 ktCO$_2$eq greenhouse gas emissions less, equating to 151 million Euros saved. The research goal is to give rise to a new study field on water management in the transport sector and contribute to advance scientific knowledge further afield.

Keywords: Water; Bus; Washing; Sustainability; LIFEH2OBus.

Introduction

Sustainability is, one of the most powerful driver to innovate bus fleets in Europe. Pollute and consume less, reduce negative impacts, attract customers are all imperatives in these process-leading Research and Development (R&D) sectors to shape the so-called European "bus of the future", with the European Commission funding a series of successful research projects, since the beginning of the 2000s. Areas of innovation are many, and among these energy management (with a focus on electrification, cleaner engines and alternative fuels) has the lion's share (Musso and

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Corazza 2015, Bousse et al. 2018). In this, uncertainties in the energy supply (Johnstone and McLeish 2022), the increasingly stricter environmental regulations in Europe, the general consensus for green economy tools (Moretti et al. 2017) steer R&D in this process, with a major interest on the design of vehicles' components and parts (for example on-board auxiliaries' improved performance or batteries efficiency), especially to reduce emissions and energy consumptions.

Advantages and benefits are becoming more and more tangible, especially in terms of increased productivity and reliability, optimization of resources, costs reduction and environmentally-conscious performance and operations, with several studies evidencing that (Lopez et al. 2019, Campos et al. 2020, Meishner and Sauer 2020).

Thus, operators' willingness to innovate might be often driven by the need to save and meet more stringent environmental requirements; but, at the same time, when the higher costs of innovation are acknowledged, its attractiveness wears off or becomes unaffordable. This can be the case especially of small-size companies where the introduction of more technologies can be too expensive or difficult to accommodate at garages. This also means that different R&D avenues should be explored to provide transit managers with alternative ways to equally save and comply with the environmental regulations rather than "buy new".

Water management for washing buses is a typical case of underestimated area in this field. Unlike emissions reduction and exploitation of alternative fuels, water management and consumption seem to raise less concerns, not only among the transport operators but also the decision-makers and the researchers. The problem is so underrated that neither statistics, recommendations or guidelines, nor organized data at European Union - EU level are available about how much water is consumed by the public transport sector. To the Authors' best knowledge, the issues is also poorly described in literature on transportation, and in fact for the water management there are no contributions aside from grey literature, as further reported.

The research questions are, therefore, rather basic: "does water matter?" and, if yes, "how much?" in terms of savings? And eventually, in which way water can be saved? The EU recently-funded project LIFEH2OBUS - *Best practices for H2O management and savings for bus operators* tries to answer to all these questions by testing three different water-saving technologies, at three bus garages in Europe, and evaluating the achieved performance. The paper describes the process and results thus far achieved, with the goal to evidence that water can generate sound savings, thus paving the way for more case studies and advance scientific knowledge further afield.

1. Knowledge on water requirements for bus operations: where we are

To the Authors' best knowledge, water requirements for urban transit fleets are poorly described in literature on transportation and, as previously mentioned, very few contributions tackle water management in transportation studied. This is probably because, unlike emissions reduction and exploitation of alternative fuels, water management and consumption seem to raise less concerns, not only among the transport operators but also the decision-makers and the researchers in this field. Yet, environmental regulations at supranational level call for more stringent actions on water treatments and saving, and also for more awareness at national and local levels, thus stressing a discrepancy between policy development and current knowledge and practice.

1.1. A combined literature and regulations review

The above-mentioned discrepancy does not mean that water management and consumption are minor issues. Water scarcity is a global problem with worldwide-reported stress situations (Ungureanu et al. 2022). According to the European Environmental Agency - EEA, around 224 million people just in Europe are exposed to water stress (EEA 2021). The increasing water demand during the last 50 years went hand in hand with the decrease of the availability of renewable water, which is now – 24% per capita. Climatic changes are also behind that, as demonstrated by the recent repeated drought phenomena and, more in general, the detected net drop in precipitation in Europe (EEA 2018). More affected areas are in the Mediterranean, but northern regions (traditionally unaffected by the problem), namely in Germany and the United Kingdom, are starting to experience water scarcity, as well (EEA 2020). In terms of annual water use, the most demanding sector is the agricultural one (40%), followed by the energy production one (28%), with household requiring just the 12% (EEA 2018), which probably explains why transit operators seems to do little to economize in this field. However, if just few facts are considered, the role of water in transit management is not secondary.

The daily per capita water consumption, solely related to household activities, in Europe is 144 liters (EEA 2018), vs the around 360 litres daily amount needed by North-Americans (Safewater 2017). This is not far from the water needed to wash a bus, which requires around 300 litres of fresh water, 4 times per week (Arriva 2018). In other words, during a week a person needs around 1008 litres vs 1200 litres required by a bus to be cleaned. This corresponds to an annual water requirement per vehicle of around 62,400 litres. By upscaling this figure to the whole bus fleet registered in Europe, i.e. 684,285 vehicles (ACEA 2022), a total amount of around 43 million m^3 of fresh water are necessary just for washing operations. As an example, in 2009, the same amount was reserved to tackle water scarcity in the Indian city of Yavatmal, with a population of 122,000 inhabitants (Abraham 2009).

Although commercial literature on the different bus washing and wastewater systems abound on Internet, in scientific literature, water consumption is analyzed under the general problem of car washing operations (Zaneti et al. 2012, Monney et al. 2020, Kuan et al. 2022) and attention to the specific bus sector seems marginal, with the exception of few relevant case studies (Almeida et al. 2010, Coombes et al. 2010, Duran and Duran 2018). On the contrary, greater interest is on water treatment practice and technologies although not always strictly related to transit operations (Hatt et al. 2006, Ruffino, 2020, Ibrahim 2021), with a large focus on specific chemical features and processes (Breton et al. 2010, Tajuddin et al. 2020, Buitrago et al. 2020, Kashi et al. 2021).

The environmental (Rosa et al. 2011, Dadebo et al. 2022) and economic (Davis 2002, Hatch et al. 2013) implications of wastewater treatments are also stressed, but again with little or no interest for the transport sectors.

All of the above stress the need to build more specific knowledge on the potential of more sustainable practice for water management for bus operators and more evidence for that can be found in the current development of policies for more sustainable transport.

As an example, the recent European Green Deal (European Commission 2019) aims to achieve a 90% reduction in greenhouse gas emissions in the transportation sector by 2050. If the above mentioned higher costs of innovative vehicles are considered, to achieve this ambitious target, transit operators should contemplate other ways to mitigate pollution, including waste processing, utilities for facilities and water management. The former two are long documented in literature in a number of research fields (Demirbas 2011, Peri et al. 2019, Anser et al. 2020, Ramanditya et al 2021.), but again water management for transit seems to be neglected.

The United Nation - UN is aware of such underestimation and in the 2018 International Decade for Action, Water for Sustainable Development supports knowledge on water management. The interest for water is also stressed by the UN 6th Sustainable Development Goal, when tackling inefficiency in water use and wastewater-generated pollution.

Reduction of water consumption is specifically postulated by the European Parliament’s Water Directive (Regulation EU 2020/741), and its reuse is in line with the new EU Circular Economy Action Plan which specifically stresses the need to prevent water extraction and to reuse rainwater. Transit is a strategic sector in the water management also under the climate change point of view. Extreme hydrological events cause service disruption as evidenced by the 2021 Italian Ministry of Infrastructure’s report (MIMS 2022), stressing once again the need for a proper management of water to fight pollution and mitigate its toll on the urban communities. This approach is in line also with the EU Zero Pollution Action Plan which also aims to reduce the greenhouse gas emissions resulting from the energy spent to pump water or to purify it. Yet, when developing policies for green public procurement criteria for road transport (European Commission 2021), the EU misses to address this specific point focusing one more time on air and noise pollution reduction, as well as on other measures to mitigate energy consumption like the management of auxiliaries, fuels and tyres.

But for transit companies the goal of operating “green” necessarily includes a revision of current water management, especially for the wastewater process, and more research is urgent in this field. Some pioneering EC-funded projects (CANALS - *Changing Water Cultures*; SAID - *SmArt water management with Integrated Decision support systems*) focusing on water optimization albeit from different study fields (urban studies and public health) show the environmental benefits of appropriate usage of water, much more needed in a sector like transit where significant amounts of water are required to keep vehicles clean.

Last to consider, the 2020 pandemic events which also triggered a vast literature on spread and travel behaviors with cleanliness being a major factor in orienting travel choices (Abdullah et al. 2020, Benita 2021, Shortall et al. 2022). This was mostly analyzed in terms of the effects of on-board personal protection equipment and social distancing (Corazza et al. 2021a), with vehicle washing remaining neglected. Moreover, the need to increase the amount of fresh air intakes on-board might weaken last decade R&D’s efforts to manage energy for buses especially when designing “sealed” travel environment to minimize heat losses during stops (Corazza et al. 2021b), thus bringing back one more time the relevance of water to sanitize buses.

1.2. Water management at bus garages

Due to the lack of national or supranational regulations on “cleaning” standards for public transport vehicles, washing operations usually depend on the conditions agreed in the public tender documents between the transport operator and the local authority assigning the service. Thus, directions on washing rely just on consolidated garage maintenance operations, and less frequently at company level. This is also evidenced by the fact that water management is barely mentioned on the website of many transport companies or in their sustainability reports, where usually a general statement without facts or figures can be found.

Yet, car wash industry in Europe, e.g. in Austria, Germany and the Scandinavian countries is already regulated, with water recycling fully enforced (Belgium even started recycling water at wash stations ahead of the national regulation enforcing 70% of wastewater to be recycled, according to MacErlean, 2022). On the contrary, public transport operators implement any water saving solutions they consider more appropriate for each single garage, and according to local geographical and climate situations. Although it is not common for mid to large-sized fleets to be manually washed, often automated washing systems can be “water-inefficient” because designed when water saving was not a priority. Typical equipment can be composed by drive-through automated brush washers with water and detergents sprayed to clean the vehicle, or mobile brush washer driven around it; likewise, undercarriage cleanings is operated via low-or high-pressure water and soap sprays. Also wheels need to be regularly cleaned by additional jets located on the wash lane or by rotating brushes (Schiavone 1995). Interior cleaning requires much less water, being the on-board area most commonly vacuumed, with just floors mopped (which also requires efforts to drain off excessive water). Washing operations take place at the so-called “car wash depots”, similar to car wash lanes for cars but larger, with large quantities of water necessary, as further reported. Typically, the only treatment is just an oil separator, to separate oil and other substances like metal particles from wastewater. These substances are usually stored in sludge wells and their disposal is operated by specialized companies, which represents an additional cost for the transport operators, and in general contributes to raise complexity in the already uncertain waste disposal process and its management in cities (Singh 2019).

It is intuitive that these types of systems were initially designed without including specific wastewater treatment. Without that, wastewater directly discharged in the sewage is highly-pollutant and foul-smelling, and negatively impacts soils and aquatic lives, for example if salts are present as they increase alkalinity in the soils, highly detrimental for agricultural uses.

One more element to consider is the energy required in the process. If data coming from practice are considered, 64.2 kWh are needed to pump $1m^3$ water (Arriva 2019), thus around 2.77 TeraWh is the annual energy requirement to have the European bus fleet washed. In terms of CO_2eq emissions, for each cubic meter of water pumped, it could be calculated that 0.0277 tCO_2eq are consumed (EPA 2022). Thus, at European level, it is safe to assume that 1.2 Mt CO_2eq are emitted yearly by the bus sector just for washing operations.

Bus operations are “dictated” by budget, revenues and subsidizes, with staff representing the highest expenditure item; however, as previously mentioned, energy saving is also central when managing operations and water, according to the facts just reported, no longer can be considered a minor cost item, if only because in Europe, the cost of water escalated in the last decade and the price for sewerage and wastewater services followed this trend (OECD, 2013).

If bus operators want to meet the environmental requirements and, at the same time, save resources, switching from conventional washing systems to new technologies can be an opportunity and an alternative to the more demanding fleet renewal. State-of-the-art solutions are available (Table 1), although most of them have little implementation, and with the feasibility and benefits depending on several factors: for example, rainwater harvesting avoid depletion of mains supplies in case of shortages, but call, if possible, for rainy areas; water mineral composition varies by location, thus reverse osmosis can be more beneficial in those area where water is rich in salts. Moreover, as for any innovation, capital costs can be high, especially for small-to-medium companies. One more problem is that the garage managers might not be aware of or familiar with these technologies, due to the lack of best practice dissemination, or even reluctant to adopt that due to the difficulty in managing more technologies in a single depot.

Table 1. State-of-the art washing technologies.

Type	Process	Where
Partial and total water reclamation	Partial reclamation relies on recycled water for washing with fresh water just for final rinsing, thus reducing water requirement in average by 85%. Total reclamation may recycle up to 95% of water used, by processing water as in a closed loop	United Kingdom
Rainwater harvesting	Use of naturally soft rainwater to wash buses with 25% less chemicals if compared to the same process via naturally hard waters, thanks to more efficient spray nozzles reducing the amount of sprayed water	Croatia, Canada
Chemical and biological water reclamation	Recycling effluents and detergents so to reduce the amount of chemicals released in the wastewater, with clear savings in the amount of detergents needed for each washing operation	Denmark
Reverse Osmosis	During final rinsing, it eliminates mineral salts in water, thus avoiding streaking or spots on the vehicles	Portugal
Waxing	Developed from the Dutch company 010 Concepts and widely applied in the aviation sector, dry waxing instead of washing should keep exterior of buses clean like that of aircraft. No water needed	-

2. Exploring the water potential: methods and assessment

All of the above is sufficient to respond to the first research question: “yes, water does matter!” in bus operations if only for the fact that, for example, a major operator like Arriva, with a fleet of 18,000 buses in Europe, consumes in average 1,123 million litres of fresh water per year, enough to fill 450 Olympic pools. The LIFEH2OBUS project moves from here, with the goal to provide bus operators with tangible facts and figures on the benefits achievable from reusing wastewater after washing buses or even from not using it at all, and adopt waxing process like for aircraft.

To this end, a do-something scenario has been built, by simulating the introduction of three different technologies in three different garages in Europe and quantitatively assessing their saving potential under different evaluation categories: energy, operations, environment, thus to respond to the second research question, i.e. about the saving magnitude. In turn, the selection of three technologies is specifically aimed at providing responses to the second research question, i.e. how to save water from washing operations according to different alternatives, which are:

- wastewater treatment and recycling facility (*basic reclamation*)
- wastewater treatment and recycling facility combined with a rainwater harvesting system (*reclamation and harvesting*)
- waxing (*no water*)

all selected with the technical objective in mind, i.e. to reach the lowest percentage of consumed water possible, in a cost-effective way and give rise to a large-scale replication potential.

The basic reclamation technology is designed for a wastewater system including a separator and filtration process, consisting in a 5,500-litre sedimentation tank, a 1,000-litre oil separator with coalescent filter and a 5,500-litre post-sedimentation tank with water pump, which will allow for the removal of oils and suspended solid particles. The so-filtrated water enters the novel recirculation section, equipped with a sand filter, for an extra filtration and disinfection step, and is eventually stored in a 2,000-litre (cleaned) water tank, available for new washing operations (Figure 1).

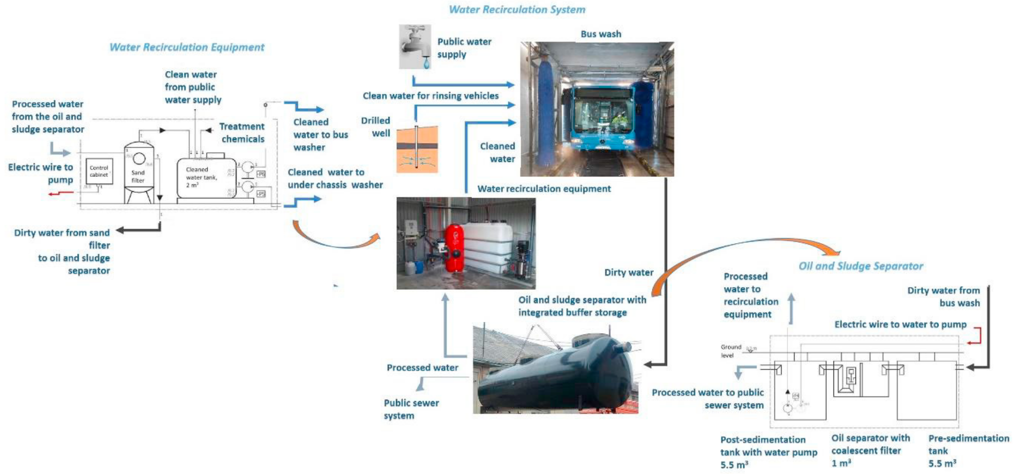

Fig. 1. The reclamation wastewater treatment facility layout

The basic reclamation technology can be associated with a rainwater harvesting system, by including a tank system to collect both rain and post-washing wastewater, which after the treatment, can "feed" the washing plant. The tank system includes, actually, more underground lamination and accumulation tanks or basins with variable capacity (usually from 200 to 40 m^3, although smaller 2m^3 tanks are used with buffer function), some of which are usually left empty, pending rainy months (Figure 2). The water process starts with the water collection via road gullies and pipes in the underground tanks; from there water is pumped to buffer tanks, having being previously treated, and made available for washing operations. The cleaning treatment is performed through sand filtration with a pre-programmed rinse cycle, ultraviolet process, and neutralisation to create a pH-neutral environment. The level of the water in the buffer tanks is continuously monitored via floats, to have the water from the underground tanks timely pumped. A Programmable Logic Controller (PLC) manages the whole process.

Waxing without water requires two staff units to polish a 12-m bus, for a treatment lasting 4 hours.

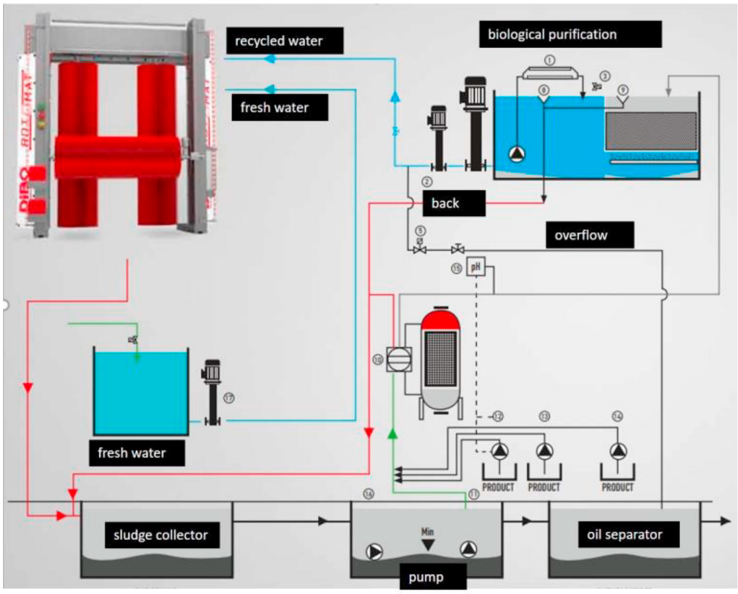

Fig. 2. The reclamation and harvesting wastewater treatment facility layout

2.1. Building the do-something scenario

It is intuitive that local climate conditions affect the possibility of harvesting rainwater, but reclamation is no less dependent especially in case of severe weather phenomena, especially drought. In the years to come, climate change-driven phenomena are expected to markedly increase in Europe, with extreme consequences like flooding or heat islands becoming regular seasonal events, and with some areas more exposed like east France, northern Italy, some regions in south-east Spain, the Balkans, and the Carpathians (EEA 2017). Thus, resorting to reclamation and harvesting for washing operations is not just a way to optimize water as a resource, but also a contribution to increase local resilience thanks to the possibility to reach, or get close to, water self-sufficiency at bus garages.

The acknowledgement of different weather situations was a leading criterion in the scenario building, which led to consider three different climate areas as representative of the general European weather conditions; more specifically, the areas were:

- Mediterranean, temperate with dry, hot summer
- Continental western Europe, temperate without dry season and warm summer
- Central Europe, temperate continental climate/humid continental climate without dry season and with warm summer

giving rise to the three scenarios reported in Table 2.

Table 2. The three test areas and scenarios features.

Fleet (units) and washing operations	Test areas		
	Mediterranean	Western Europe	Central Europe
Basic reclamation			105
Reclamation and harvesting	175	325	
Waxing	25	25	25

In each area, a specific bus garage has been identified as the actual test environment, more specifically in Italy (Mediterranean), the Netherlands (Western Europe) and Hungary (Central Europe); the three garages are located in areas facing several regional climate challenges, such as water shortages due to long periods of droughts and excess of water due to frequent downpours resulting in floods (which are not only due to climate change but also to patterns like population density, floodplain development and land use changes). The trial fleet, i.e. 680 buses managed by Arriva, corresponds to the actual fleets operating at each garage, according to the units reported in Table 2. For each test area the amount of vehicles have been selected according to availability and to avoid service disruption due to vehicles partaking in the project.

The do-something scenario was built according to different scales and time-spans, but without changing operational schedules (both for on-the-road regular service and maintenance at garage) which are, thus, assumed to be the same as the reference scenario; more specifically, as anticipated in section 1.1, reference and do-something washing operations are assumed to be 4 times a week, for each vehicle and with a water requirement of 300 litres per single operation.

Scenarios are built at test scale, at operator's scale (thus upscaling the test results for the 18,000 units of the Arriva fleet) and at continental level (by assuming that the three technologies can be applied to the European bus fleet, as further elaborated). Performance for the do something scenario are calculated by projecting the reference operational parameters for a 30-month scenario which corresponds to the amount of time needed for a given plant to have the reclamation and/or harvesting system designed, built and fully operational and enable a 12-month data collection to assess performance variations.

For what concerns costs, these have been calculated according to local situations and prices. The reclamation and harvesting equipment cost is estimated between 250,000 and 290,000 Euros, including the construction of tanks, reservoirs, cisterns, wells, pumps, oil separators, finishing filters, depurators, anti-flooding barriers, pipes and valves, electrical and control software units. The basic reclamation equipment is estimated around 110,000 Euros, with the higher cost items being the water re-rotation system (around 17,000 Euros) and the scissor bus lift (53,000 Euros). The design and site preparation costs (thus including hydraulics and groundworks) range between 50,000 and 70,000

Euros.

For no-water operations, one waxing process costs 250 Euros, and the scenario schedule is to have 10 operations per year, per vehicle, which for the 75 vehicles involved in the three garages accounts for a yearly expenditure of 187,000 Euros.

Lastly, it is estimated an average cost of around 10,000 Euros to train the maintenance staff to operate the new equipment.

3. Results: convenience and environmentally-friendliness

By simulating washing operations at the three test areas for the 30-month scenario and unvaried washing frequency, thanks to the implementation of the three technologies it is possible achieve an average water consumption reduction of 84%. Differences among the technologies are clear (Table 3), with waxing being the most water-saving solutions (-98%), reclamation and harvesting achieving a 92% reduction of fresh water intake and basic reclamation enabling just 60%.

Table 3. Water consumption (30-month do something scenario)

Type of technology	Scenario	Performance	Test areas		
			Mediterranean	Western Europe	Central Europe
Reclamation and harvesting	Reference	Garage fleet (unit)	200	350	
		Test fleet (unit)	175	325	
		Fresh water consumed per vehicle (l/unit/year)	62400	62400	
		Consumed fresh water by garage fleet (l/y)	12480000	21840000	
		Consumed fresh water by test fleet (l/y)	10920000	20280000	
	Do-something	Fresh water consumed per vehicle (l/unit/year)	4992	4992	
		Consumed fresh water by test fleet (l/y)	873600	1622400	
Basic reclamation	Reference	Garage fleet (unit)			130
		Test fleet (unit)			105
		Fresh water consumed per vehicle (l/unit/year)			62400
		Consumed fresh water by garage fleet (l/y)			8112000
		Consumed fresh water by test fleet (l/y)			6552000
	Do-something	Fresh water consumed per vehicle (l/unit/year)			24960
		Consumed fresh water by test fleet (l/y)			2620800
Waxing	Baseline	Test fleet (unit)	25		
		Consumed fresh water by test fleet (l/y)	156000		
	Do-something	Fresh water consumed per vehicle (l/unit/year)	1248		
		Consumed fresh water by test fleet (l/y)	31200		

In practical terms, this means that the weekly intake of fresh water passes from 1200 litres to 480 litres (basic reclamation), to 96 litres (reclamation and harvesting), to just 24 litres (when waxing), whereas the bulkiest part of the water is supplied by rainwater and/or treated wastewater. The combined effect of having in a single garage two technologies is described in Table 4, with a saving potential in the three test areas of more than 37 million fresh water.

Table 4. Combined effect of technologies on water saving (30-month do something scenario)

Type of technology	Scenario	Performance	Test areas		
			Mediterranean	Western Europe	Central Europe
Reclamation and harvesting	Reference	Consumed fresh water by garage fleet (l/y)	12480000	21840000	
	Do-something	Consumed fresh water by test fleet (l/y)	873600	1622400	
Basic reclamation	Reference	Consumed fresh water by garage fleet (l/y)			8112000
	Do-something	Consumed fresh water by test fleet (l/y)			2620800
Waxing	Do-something	Consumed fresh water by test fleet (l/y)	31200	31200	31200
		Total water consumed (l/y)	904800	1653600	2652000
		Total water consumption reduction (l/y)	-11575200	-20186400	-5460
		Total water consumption reduction (%)	93	92	67

Results thus far presented fully respond to the second research question in terms of resource-saving and the monetary translation is calculated according to assumptions coming from practice. Costs of water and energy clearly varies locally, but according to Arriva's analysis among its depots, water usage costs in average 0.13 Euro/m^3. For what concerns energy, considering the EU average energy price in the first semester of 2021 of 0.1283 Euro per kWh (Eurostat 2021), each cubic meter of water pumped to wash a bus costs 8.24 Euro, 64.2 kWh being needed to pump a m^3 of water. This means that the average cost of water for the full washing process is of 8.37 Euro/m^3. According to these assumptions, the -84 % water wasted in the three test areas correspond to more than 300,000 Euros saved and a reduction of tCO$_2$eq of more than 1000, calculated via the EPA (2021) model just for the 30-month scenario, as in Table 5.

Table 5. Monetary savings and pollution reduction (30-month do something scenario)

Performance	Test areas			
	Mediterranean	Western Europe	Central Europe	Total
Water consumption reduction (l/y)	-11575200	-20186400	-5460000	-37221600
Energy consumption reduction (kWh)	-743128	-1295967	-350532	-2389627
Pollution reduction - GHG (tCO$_2$eq)*	-321	-561	-152	-1034
Savings (Euro)	- 96884	-168960	-45700	-311545

*assumed rate: 0.0277 tCO$_2$-eq /m^3 (EPA 2022)

For what concerns the additional energy demand (including pumping) of the new treatment facilities this can be estimated in a rough forecast provided by the manufacturer of the new technology to be around 1.64 kWh.

Figures from Table 5 might seem small, but if projected at European level, their implications are clear even by considering a moderate upscaling scenario, as follows.

By applying the same maintenance standards to the European bus fleet (i.e. a washing frequency of 4 times a week), the total amount of around 43 million m^3 of fresh water needed to wash the 684,285 vehicles (ACEA 2022) corresponds to an energy consumption of 2.77 TeraWh per year and a pollution level of 1.2 MtCO$_2$eq of greenhouse gas emissions. By upscaling the saving potentials calculated for the three test areas (Tables 3-5) and assuming the possibility to reach 50% of the European bus transport sector in 5 years (a potential fleet composed of 342,143 buses), 18 billion liters/year can be saved, corresponding to -42% of the estimated 43 million m^3 of water used by transport sector. This also corresponds to a reduction of energy consumption as of 1,159 GWh and of 504 ktCO_2eq greenhouse gas emissions, for an overall cost reduction of 151 million Euros (which corresponds to an investment for the purchase of more than 230 state-of-the-art electric 12-m buses, according to a price tag of around 650,000 Euros each, or even the double amount in case of EURO-IV conventional models).

4. Water saving as a potential for the communities' development

If compared to an estimated budget of around 200,000 Euros as capital costs for a given transit company willing to adopt one or more of the technologies above described, the achievable monetary savings above reported can be a very convincing argument. But the impacts at community level can be even more rewarding and leading towards a new water culture for the transportation sectors. Moreover, for the first time placing emphasis on water may give rise for a new water culture in the transport sector.

4.1. Tangible benefits

The 37 million m^3 reduction in water consumption can certainly mitigate risks such as water over-abstraction or depletion, especially in those areas where drought or floods are stabilizing as seasonal phenomena. At the same time, the availability of continuous water supply thanks to harvesting or the need of an extremely reduced water demand as in the case of waxing, avoid public transport operators placing a burden on the supplies of the communities they serve when water is scarce.

Water reduction also implies less polluted water freely released in the sewage systems, once again mitigating risks such those of the soil pollution or contamination of ground waters, the amount of chemicals released in the wastewater being significantly reduced.

Introducing such an effective water management approach also means job opportunities. Staff can be reorganized at bus garages to manage the local water reclamation and/or harvesting facilities, which means creating new professional positions in transport companies. For example, at each test area the new staff requirements has been estimated to be around 1 Full Time Equivalent (FTE) in terms of employees, but the garages are relatively small-size (350 vehicles as maximum accomodated fleet) and it is intuitive that the larger the garage, the higher the FTE requirement will be.

In literature it has been long observed how cleanliness is a strong comfort factor to attract passengers to transit (Beirao and Cabral 2007, van Lierop and El-Geneidy 2016) and one of the lesson learnt from the recent pandemic is that passengers' perception of the service is a stronger factor than its actual efficiency when it comes to attract patronage. It is undisputable, then, that the possibility to provide passengers with regularly cleaned buses becomes pivotal in gaining again their favor, and the possibility to save water can certainly help, thanks to the possibility to increasing the washing frequency, especially when cleaning represents a not negligible expenditure item. Thus, the additional societal advantages are clear: the resulting more efficient management of the service due to improved cleanliness generates among the passengers the perception of improved quality, thus increasing the transit attractiveness.

4.2. A new water culture

As already stressed, mitigation of water consumption is pivotal in achieving higher sustainability levels in cities, as it implies optimization and reuse of resources, energy savings, limitation of pollution. At the same time, it has been observed in section 1, for the transport sectors and especially for transit managers, water consumption has never been properly addressed, in spite of its operational higher cost. This means that a new water culture is needed to give rise to more comprehensive environmental safeguard policies, including water as a resource. Semantically, in literature the word "clean" has been now associated with engines, fuels, vehicles, leaving aside the relevance of having "clean" waters when maintaining buses. Likewise, for saving, reduce fuels and energy, but not water, have become imperative in transit management.

The facts above reported and the LIFEH2OBus pioneering experience by quantifying for the first time the potential of saving water for bus operators in monetary terms, thanks to the scenarios built for the application of the three state-of-the art technologies, can pave the way for creating a sustainability-based reference for decision and policy makers, when assessing areas of improvements for local transit operations, typically when deciding whether or what renovate. In this case saving from more sustainable water management can be an assessment criterion when deciding whether to buy new vehicles or to invest in retrofitting by upgrading local washing technologies or both, but in any case deciding on an environmentally-consciousness basis. Given the moderate capital costs of the new washing technologies, this can be a solution for any low budget company wishing to meet more environmentally friendly standards.

The last point to consider is the possibility to create "bespoken" washing solution for each fleet and location. Transport operators, according to the presented findings, can select the most suitable technologies and opt for the best washing opportunities according to circumstances; for example, waxing can complement regular washing performed via reclamation and/or harvesting technologies or be used for vehicles used for specific services.

5. Concluding remarks

LIFEH2OBUS has just begun and the work ahead will be to develop specific cost-benefit analyses and life-cycle cost assessment for the three technologies to corroborate the presented scenario assessment. Along with that, one more study field is focusing on the possibility to have washing included among the dashboard functions of a predictive maintenance software already available to assess real-time emissions for buses (Corazza et al 2021), so to have operators washing buses when actually needed and not according to garage practice, thus saving even more water. The preliminary version of this dashboard function has been already tested and will be fully applied during the LIFEH2OBUS project.

The presented results evidence that for transit companies the goal of operating "green" necessarily includes a revision of current water management, especially for the wastewater process, and that research is urgent in this field. It is also expected that these results might contribute to future policies, with the specific goal to make of water management a major concern as currently applies to air quality or noise in the overall assessment of sustainable transport modes. The final ambition is to become a pioneering reference to create a framework to determine the right specifications for each fleet's water requirements within the European standardization programs, given the current lack of standards on this topic. For transit, this implies the creation of a new water culture, inspired by the circular economy concept, in line with the overarching "nexus approach" (Brouwer 2018), i.e. the synergetic management of energy, water and climate, and the do-something scenario do prove the centrality of water in mitigating transit negative impacts.

Eventually, it is to consider the potential of transferring the new technologies to other transport fields, and especially to logistics and paratransit and any other types of private companies. Such larger scale application can further demonstrate that an optimized water management could represent not only an important saving resource, but can increase resilience, and improve the quality of corporate social commitment.

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