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355

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Drivers of change in urban water and wastewater tariffs

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Abstract

Water and wastewater tariffs constitute a primary avenue for utilities to generate revenue towards covering the costs associated with water and wastewater service provisions. In the pursuit of achieving global access to safe and affordable water and sanitation, utilities and governments play an important role in regulating and setting combined tariffs, so that they are able to fund the necessary infrastructure while at the same time ensuring that tariffs do not impede on the ability of consumers to access these services. From a survey of 568 cities across 192 countries, this paper examines the main economic and financial drivers of change to regional urban water and wastewater tariffs from 2018 to 2019. Historically, the average global price for water and wastewater services increased from US$ 1.70/m^3 in 2011 to US$ 2.16/m^3 in 2019, equating to an annual rise in the mean global combined water tariff of ~3.4%. The analysis indicates that for the studied regions, the financial and economic costs associated with recurring droughts, old infrastructure, subsidy cuts, increasing energy costs and a shift to alternative water resources such as desalination all contribute to changes in tariffs. Further research on the social and political drivers of change in tariffs is needed, in order to provide a holistic understanding of the balance required to be struck between the objectives of affordability and cost-recovery for achieving global access to water and sanitation.

Key words: affordability, cost-recovery, Sustainable Development Goals, urban water management, water and wastewater tariffs, water pricing

HIGHLIGHTS

- The article surveys changes to urban water and wastewater tariffs in 568 cities across 192 countries between 2018 and 2019.
- Further historical data examined shows the average global price for water and wastewater services increased from US$ 1.70/m^3 in 2011 to US$ 2.16/m^3 in 2019.
- Whereas financial and economic drivers are the primary drivers examined for urban water and wastewater tariffs between 2018 and 2019, future research on the topic should integrate social and political factors in order to strike a balance between affordability and cost-recovery.

INTRODUCTION

The importance of water for human well-being and the environment is practically priceless. However, abstracting, treating and delivering drinking water to a growing urban population comes at a cost, regardless of whether one considers water a free good (Barlow & Clarke 2002; Savenije 2002) or an economic commodity (Segerfeldt 2005; McNeill 2009). Indeed, water and wastewater tariffs constitute a primary avenue for utilities to generate revenue towards covering the costs associated with water and

H_2Open Journal Vol 3 No 1
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wastewater service provision. Thus, in the pursuit of achieving global access to safe and affordable water and sanitation, utilities play an important role in regulating their combined water and wastewater tariffs incrementally in order to fund the necessary infrastructure, while at the same time having to ensure that tariffs do not impede the ability of consumers to pay (Savenije & van der Zaag 2002).

In 1999 and in 2007/2008, the Organisation for Economic Co-operation and Development (OECD) conducted surveys of residential water tariffs with a reference benchmark of 15 m^3 per household per month (OECD 2009). Zetland & Gasson (2012) analysed tariffs for 310 cities to examine the relationships between urban domestic water and wastewater tariffs and measures of sustainability, efficiency and equity in 2012. The World Bank also manages a database, the International Benchmarking Network (IB-Net) which has been growing since 1992 and currently (April 2019) contains 14,484 data points for urban water and wastewater tariffs. Moreover, Hoque & Wichelns (2013) studied water and wastewater tariffs for domestic and non-domestic sectors in 60 cities in a total of 43 developed and developing countries. The study disaggregated combined water and wastewater bills to gain insight into the proportions of fixed and variables costs that consumers pay. Finally, the International Water Association (IWA) also studied household water and wastewater bills in 39 countries and reported on water consumption, water abstraction and water delivery (IWA 2018).

This paper contributes to the aforementioned studies on water and wastewater tariffs by providing a state-of-the-art review and update of reported water and wastewater tariffs for 568 cities across 192 countries in 2019. Firstly, this paper reviews the most commonly found structures of water and wastewater tariffs and lays out the methodology applied. Subsequently, the investigation presents figures for combined water and wastewater tariffs at selected geographical scales and time intervals, before discussing the most influential economic and financial events that have contributed to driving changes in combined tariffs between 2018 and 2019 in selected countries. The scope of analysis is primarily concerned with the financial and economic impacts and drivers that influence the recorded changes in tariffs. Limited attention is paid to how political and social factors have impacted the changes presented in this paper, and these require further research in order to provide a holistic view of the balance that needs to be struck between the objectives of affordability and cost-recovery for achieving universal access to water and sanitation.

REVIEW OF WATER AND WASTEWATER TARIFF STRUCTURES

There is a notable difference between the water and wastewater structures within and between regions, the most prominent distinction being between metered and non-metered connections. Metered consumers pay according to the volume of water consumption, whereas non-metered consumers pay a fixed monthly charge. However, metered connections can also occur in several variations and the most common tariff structures and components are summarised in Table 1.

Dual tariffs: fixed and volumetric

Most water tariffs comprise a volumetric component and a basic service charge. This structure is based on an assumption that all connections impose a cost on the utility's operations. The fixed charge accounts for the infrastructure costs regardless of consumption making the utility less volatile. Volumetric charges give consumers flexibility in controlling the final bill as it is based on consumption. However, where the fixed component constitutes a majority of the combined tariff, consumers have limited control over the final bill which provides less incentive for the consumer to conserve water. Some utilities do not separate the fixed and variable charges but instead set a minimum charge that consumers must pay for a basic level of consumption.

H2Open Journal Vol 3 No 1
doi: 10.2166/h2oj.2020.031

Table 1 | Water and wastewater tariff components (adopted from Hoque & Wichelns 2013)

Tariff component	Description
Basic service charges	
Fixed charge	An annual or monthly fixed amount with no minimum consumption requirements. The charge typically depends on the size of the meter and covers infrastructure and account maintenance costs. Water and wastewater fixed charges can either be combined or separate.
Minimum charge	A fixed amount, typically monthly which allows for a free minimum water consumption quantity.
Volumetric water charge	
IBT	A charge per unit volume increasing stepwise according to the level of consumption.
DBT	A charge per unit volume decreasing stepwise according to the level of consumption.
Constant unit charges (CUCs)	A charge per unit volume, which remains the same for all levels of consumption.
Seasonal charge	A charge per unit volume, which changes according to the time of year accounting for peak (summer) and off-peak (winter) demands. Can be IBT, DBT or CUC.
Wastewater or sewerage charge	
Volumetric charge	The volumetric charge can be either IBT, DBT or CUC.
Flat	A fixed percentage of the water bill usually less than 100%. This could also be considered a volumetric charge but in the case of a flat rate, the per unit volume charge is not specified.
Additional components	
Conservation or pollution tax	A charge to account for shortage values of water or environmental externalities (i.e. wastewater discharge downstream effects). This is usually a fixed portion (%) of the total water bill.
Stormwater or property drainage charge	A monthly or annual fixed charge that varies according to property size, with the aim to account for the fact that rainwater falling on a paved surface ultimately discharges into public sewers, and increases the volume of wastewater treatment required.
Water resource development fee or capital contribution	Utilities may impose a temporary fixed charge on consumers to earn revenue for infrastructure development and expansion.

Increasing block-rate tariffs

One of the most globally adopted tariff structures, the increasing block-rate tariff (IBT) structure, sets the provision of a minimum amount of water required to fulfil basic water needs at an affordable price. Consumption of additional volumes of water is charged accordingly in increasing blocks. The IBT can cross-subsidise high- and low-income consumers to achieve conservation and revenue goals, but only succeed if the size of the blocks and volumetric rates are able to strike a balance between local and national priorities and water use patterns.

Three-part objectives of 'affordability', 'revenue generation' and 'conservation' can be achieved using an IBT structure: The first block rate should be subsidised, so that it is a social tariff that guarantees a basic volume of safe water at an affordable rate. How measures of 'affordable rates' and 'basic volumes' are determined vary. The UNDP defines affordability of water to constitute a water bill that does not account for over 3% of national average household income (Mack & Wrase 2017), whereas General Comment 15 on the Human Right to Water holds that affordability of water tariffs is a price level where it does not impede on the ability of consumers to access other universal human rights (e.g. access to education and healthcare) (de Albuquerque 2010; Hutton 2012). The second block rate needs to cover operational costs and subsidies provided to consumers in the first block. The volumetric rate in the third block should be sufficient to cover both operational, maintenance and investment costs.

H_2Open Journal Vol 3 No 1
doi: 10.2166/h2oj.2020.031

The most common argument against IBT is the disproportionate burden it imposes on households with a high number of members or where several households share a common connection (Whittington 1992). For the sake of convenience, this research assumes that each household has a separate meter and comprises four people. IBTs have the ability to subsidise poor consumers using small amounts of water but is not attractive if there is a large proportion of unconnected and informal settlements. Further challenges with IBT structures are the risk of leaving little desire for operators to expand services in poorer areas where consumption in the subsidies block rates fall under cost-recovery as efforts to increase the number of connections in areas with high-volume users is more profitable.

Single-part tariffs: linear charge

This simple form of volumetric tariffing appears efficient for utilities to calculate water bills easily and for consumers to understand their bill and control the final cost in relation to the level of consumption. The challenge to a flat volumetric charge is its lack of ability to promote water conservation compared to IBT. Nevertheless, the tariff structure has been shown to be more effective in generating revenue which in other instances may be lost upon non-payment.

Decreasing block rates

The decreasing block-rate tariff (DBT) structure is particularly appropriate in urban areas with abundant sources of raw water which allows the average cost of water to decline when water supply increases. The tariff structure, however, penalises consumers with low levels of water consumption and disincentivises water conservation. As would be expected, as marginal costs of providing water have increased, there is a tendency to not use this particular tariff. The 2009 OECD review revealed a continued decline in the use of DBTs in favour of two-part tariff structures consisting of a volumetric and a fixed charge.

MATERIALS AND METHODS

Data collection, caveats and assumptions

Historical data for domestic water and wastewater tariffs were obtained from the IB-NET database, internet searches, phone interviews, e-mails and social media. Tariffs were gathered in local currencies and converted into US$ using markets exchange rates for July 1st each year. The price of receiving 1 m^3 of drinking water or wastewater service was normalised by adding the volumetric component of a household of four consuming 15 m^3/month to fixed charge components and then dividing by 15 making it possible to compare water prices on a standard measure across the world, as tariff structures vary significantly between countries and regions.

Economic data (GDP per capita; mean household income) as well as statistics related to water consumption were derived from either national statistics offices or international statistics bureaus (International Monetary Fund, World Bank, World Health Organization, UNICEF). Analyses comparing combined water tariffs at the national and regional scales assume that the water tariffs in surveyed cities and countries can be aggregated accordingly and compared with each other as well as with national- and regional-scale statistics of human and economic well-being.

Furthermore, the benchmark level of 15 m^3 simplifies tariff schedules that have eight or more blocks, both in terms of price per cubic metre and threshold volume, into a single price per cubic metre. The data also assume a constant supply of water service delivery and therefore do not account

H$_2$Open Journal Vol 3 No 1
doi: 10.2166/h2oj.2020.031

for the cost of interruptions to services nor capture the costs associated with unmeasured households, self-supply and non-revenue water.

The 15 m^3 per month consumption benchmark for a household of four equates to ~125 litres per capita day (LCPD). This figure is perhaps more applicable to higher economically developed countries than to middle and lower economically developed countries due to significant differences in the number of people with reliable access to piped water supply services in these different areas. Indeed, what constitutes an adequate amount of water to meet human well-being varies. Whereas the WHO considers ~20 LCPD as the minimum standard for humanitarian water use (Howard & Bartram 2003), Chenoweth (2008) calculates that ~135 LCPD should constitute a minimum quantity needed in order to be consistent with socio-economic development. Nevertheless, this paper follows the benchmark level set by IB-NET for the sake of consistency but bears the caveats that this assumption poses in mind.

Furthermore, many wastewater companies, beyond handling municipal service provisions, also handle stormwater. Some systems clean the water before it leaves the areas, whereas others just export raw sewage. These mixed services put an added-layer to the complexity of establishing wastewater charges which are not presented in this research, as stormwater charges are included in the figures for wastewater.

RESULTS AND DISCUSSION

Changes in global and regional combined water and wastewater tariffs

Tracing changes to the mean combined water and wastewater tariff for selected countries (2011–2019) in Table 2 shows an increase in the global water and wastewater price per cubic metre of US$ 1.70/m^3 in 2011 across 106 countries (331 cities) to US$ 2.16/m^3 across 192 countries (568 cities) in 2019 (Table 2; Figure 1). At the regional scale, Western Europe and North America have historically had higher combined water bills than the global average, whereas the remaining regions fall below. Between 2015 and 2016, North American water and wastewater tariffs surpassed the Western European average, measured at a price of US$ 4.31/m^3 compared to US$ 4.04/m^3 for Western Europe in 2019.

Top and bottom 10 national and city-scale tariffs, 2019

The most expensive city for water and wastewater services in 2019 was Seattle (United States) charging US$ 9.73/m^3 followed by Essen in Germany and Portland, Oregon in the United States (Table 3, Column 1). After the failed attempt by water and wastewater utilities in Ireland and Northern Ireland to introduce tariffs for their services in 2016, these two regions did not charge its customers for water and wastewater services in 2019. Up until November 2018, water and wastewater charges had been free in Turkmenistan, but as part of ongoing reforms, tariffs were introduced in multiple sectors. Thus, after Belfast, Cork and Dublin, the city with the cheapest combined water and wastewater tariff in 2019 is Islamabad (Pakistan) charging US$ 0.01/m^3 followed by highly subsidised Havana (Cuba) and Lahore (Pakistan) each charging US$ 0.02/m^3 and US$ 0.03/m^3, respectively (Table 3, Column 2).

Aggregating city-level data to derive national average combined water and wastewater tariffs (Figure 2), the most expensive tariff in 2019 is found in the U.S. Virgin Islands, charging US$ 7.88/m^3 followed by Denmark and Iceland, charging US$ 7.17 and US$ 6.55/m^3, respectively. At the opposite end, Cuba charges US$ 0.02/m^3 followed by Bhutan (US$ 0.04/m^3), and Tajikistan and Pakistan both charging US$ 0.07/m^3 (Table 4, Column 2).

H2Open Journal Vol 3 No 1
doi: 10.2166/h2oj.2020.031

Table 2 | Combined water and wastewater tariffs 2011–2019 (US$/m^3) and regional study profiles

Region/year	Water and wastewater tariff (US$/m^3) 2011	2012	2013	2014	2015	2016	2017	2018	2019
North America	2.78	3.14	3.31	3.52	3.69	3.90	4.14	4.32	4.31
Latin America and the Caribbean	0.94	0.92	0.87	0.93	1.56	1.60	1.68	1.74	1.79
Western Europe	3.28	3.65	3.73	3.80	3.89	3.95	3.97	4.02	4.04
Eastern Europe and Central Asia	1.01	1.08	1.17	1.18	1.22	1.25	1.32	1.33	1.25
Asia Pacific	1.09	1.11	1.14	1.18	1.20	1.19	1.03	1.00	1.05
Southern Asia	0.11	0.12	0.13	0.13	0.13	0.13	0.37	0.37	0.37
Middle East and North Africa	0.91	0.91	0.89	0.91	0.90	0.89	0.89	0.89	0.94
Sub-Saharan Africa	0.62	0.67	0.67	0.74	0.85	0.95	0.96	1.11	1.07
Global	**1.70**	**1.84**	**1.87**	**1.91**	**1.98**	**2.03**	**2.11**	**2.07**	**2.16**
	Cities per region in annual survey								
North America	56	55	56	56	56	57	77	77	95
Latin America and the Caribbean	27	28	36	37	54	56	59	61	61
Western Europe	68	68	68	68	70	73	80	82	96
Eastern Europe and Central Asia	56	57	58	61	62	63	65	65	81
Asia Pacific	64	65	65	65	71	73	92	108	116
Southern Asia	22	22	22	23	23	24	34	37	37
Middle East and North Africa	19	19	20	20	22	25	26	32	31
Sub-Saharan Africa	19	19	22	25	33	36	33	50	51
Global	**331**	**333**	**347**	**355**	**391**	**407**	**466**	**512**	**568**
	Countries per region in annual survey								
North America	2	2	2	2	2	3	4	4	4
Latin America and the Caribbean	13	13	17	19	33	34	35	38	38
Western Europe	18	18	18	18	20	22	21	22	22
Eastern Europe and Central Asia	23	23	24	27	28	29	29	29	29
Asia Pacific	14	15	15	15	19	21	20	29	29
Southern Asia	5	5	5	5	5	5	6	7	7
Middle East and North Africa	13	13	14	14	15	17	17	18	17
Sub-Saharan Africa	18	18	21	23	30	31	28	45	46
Global	**106**	**107**	**116**	**123**	**152**	**162**	**160**	**192**	**192**

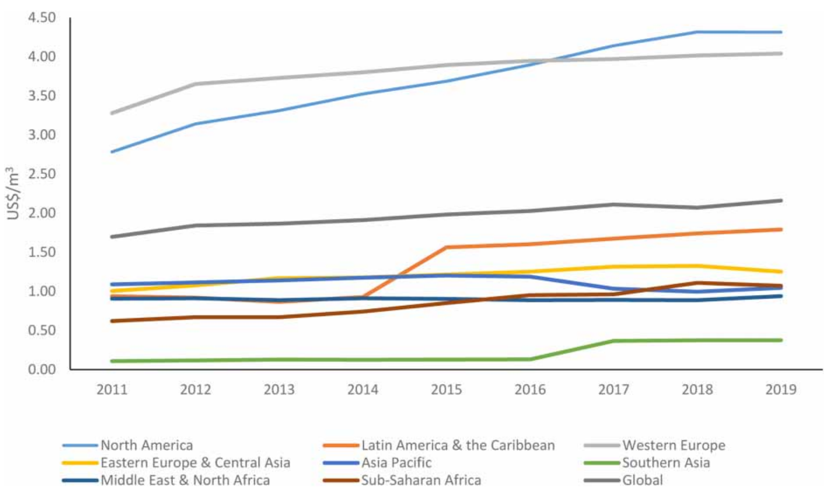

Figure 1 | Change in regional combined water and wastewater tariffs (2011–2019) (Data: IB-NET, interviews, social media and adaptation of Water Leaders Group draft white papers).

H$_2$Open Journal Vol 3 No 1
doi: 10.2166/h2oj.2020.031

Table 3 | Top 10 highest and lowest tariffs according to cities 2019

Top 10 cities with highest tariffs	Combined tariff (US$/m^3)	Bottom 10 cities with lowest tariffs	Combined tariff (US$/m^3)
1. Seattle (United States)	$9.73	1. Belfast (United Kingdom)	$0.00
2. Essen (Germany)	$9.04	2. Dublin (Ireland)	$0.00
3. Portland, OR (United States)	$8.80	3. Cork (Ireland)	$0.00
4. San Francisco (United States)	$8.37	4. Islamabad (Pakistan)	$0.01
5. Juneau (United States)	$8.20	5. Havana (Cuba)	$0.02
6. Aarhus (Denmark)	$8.12	6. Lahore (Pakistan)	$0.03
7. Honolulu (United States)	$7.93	7. Thiumphu City (Bhutan)	$0.04
8. St. Thomas (U.S. Virgin Islands)	$7.88	8. Chandigarh (India)	$0.05
9. Dortmund (Germany)	$7.83	9. Faridabad (India)	$0.06
10. Charleston, WV (United States)	$7.54	10. Rawalpindi (Pakistan)	$0.06

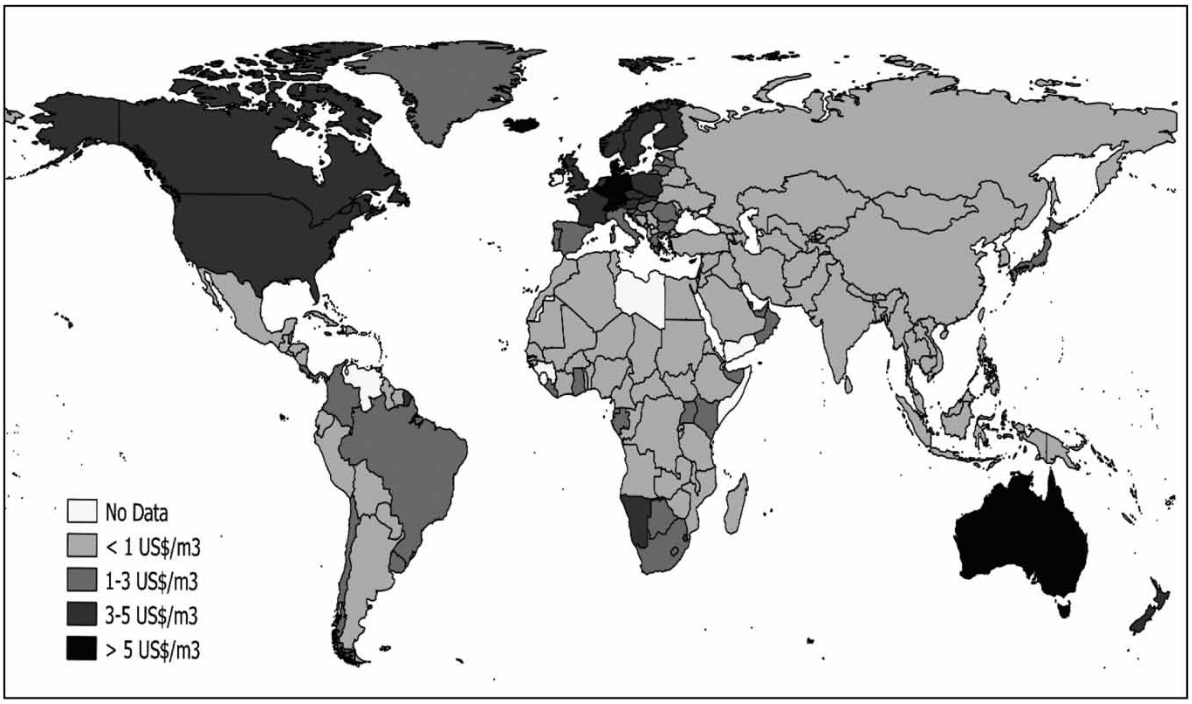

Figure 2 | Global combined water and wastewater tariffs (USD/m^3) across the world 2019.

Table 4 | Top 10 highest and lowest tariffs according to country 2019

Top 10 countries with highest combined average tariff	Combined tariff (US$/m^3)	No. of cities	Bottom 10 countries with the lowest combined average tariff	Combined tariff (US$/m^3)	No. of cities
1. U.S. Virgin Islands	7.88	1	Ireland	0.00	2
2. Denmark	7.17	2	Cuba	0.02	1
3. Iceland	6.55	1	Bhutan	0.04	1
4. Germany	6.29	15	Tajikistan	0.07	1
5. Bermuda (UK)	6.06	1	Pakistan	0.07	7
6. Curaçao	5.88	1	Brunei	0.08	1
7. Cayman Islands (UK)	5.86	2	Uzbekistan	0.08	1
8. Nauru	5.83	1	Kyrgyz Republic	0.11	1
9. Kiribati	5.72	1	Egypt	0.11	2
10. Switzerland	5.66	3	Honduras	0.11	1

H$_2$Open Journal Vol 3 No 1
doi: 10.2166/h2oj.2020.031

Regional tariff structures

The structure of water and wastewater tariffs across regions along the definitions laid out in Table 1 are shown globally in practice for the 2019 dataset in Figure 3. The most common type of tariff structure is the IBT with over 300 of the cities sampled charging customers this way. Customers pay according to the volume of water used within increasing blocks. It is the most common tariff type in Asia Pacific (107 cities), Latin America and the Caribbean (53 cities), North America (45 cities), South Asia (21 cities) and sub-Saharan Africa (41 cities). The second most widespread tariff structure practised is the linear structure, where customers are charged a flat fee per cubic metre consumed and metered, independent of the existence of blocks, which characterises IDB structures. A total of 203 cities sampled have this type of the tariff structure in place and is the most frequent structure sampled in Eastern Europe and Central Asia (73 cities) and Western Europe (50 cities). In the North American sample, 38 cities charge a linear tariff. The I-DBT structure is the least common type of tariff, only found in three cities – two in North America and one in sub-Saharan Africa, whereas 11 cities have fixed-only tariff structures and 14 have decreasing tariffs.

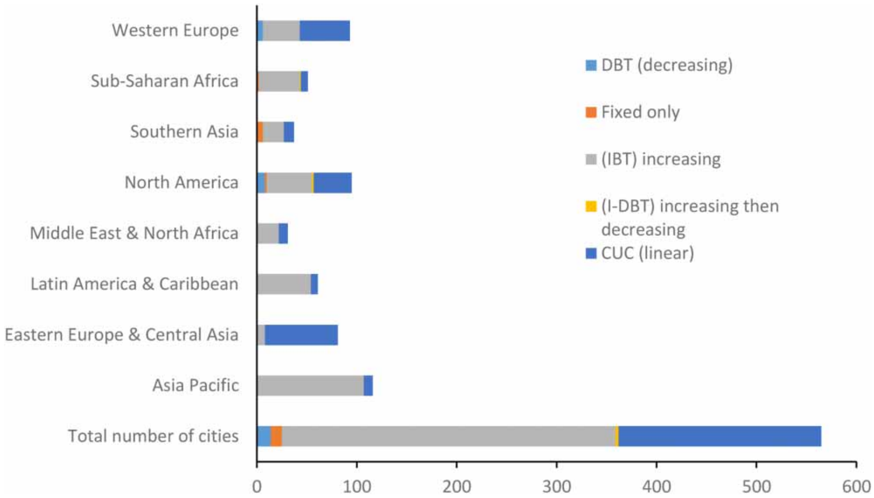

Figure 3 | Breakdown of tariff structures across different regions, 2018. Excludes cities in Ireland/N. Ireland.

Wastewater

The majority of cities (465) charge their customers separately for the wastewater they produce, whereas 98 cities make no distinction between water and wastewater bills often combining the cost of wastewater produced into the fixed charge component of the water bill (Table 5). Of the 465 cities that have separate wastewater tariffs, the most common type of wastewater found is a volumetric charge, tends to constitute the same type of volumetric charge type as that adopted for water tariffs. Fifty four cities operate solely with fixed wastewater charges, whereas 174 cities apply both volumetrics and fixed wastewater charges.

Drivers of changes in regional water and wastewater tariffs

Sub-Saharan Africa

The largest combined water and wastewater tariff increase in SSA between 2018 and 2019 was calculated at 77.1% in Kigali (Rwanda) where the country implemented its first tariff adjustment since 2015. The new tariff structure aims to reflect the growing cost of producing water and contribute to

H2Open Journal Vol 3 No 1
doi: 10.2166/h2oj.2020.031

Table 5 | Breakdown of wastewater billing structures

Sewage structure	Total number of cities	Asia Pacific	Eastern Europe and Central Asia	Latin America and Caribbean	Middle East and North Africa	North America	South Asia	Sub-Saharan Africa	Western Europe
Separate billing	465	102	80	39	21	90	21	24	88
Combined billing	98	14	1	21	10	5	16	27	4
n/a	5			1					4
Fixed only	54	23	1	8		8	6	3	5
Volumetric only	237	62	74	15	9	16	11	15	35
Volumetric and fixed	174	17	5	16	12	66	4	6	48

fund US$ 440 million investment into the country's water and wastewater infrastructure over the next three years (Nyiransabimana *et al.* 2019). The continent's second-highest tariff increase since 2018 at 19.0% was found in Lomé (Togo), where the West African country updated its tariff structure (Yomo *et al.* 2019) by adding a monthly fixed fee of US$ 1.25 for meter rental.

Mbabane (eSwatini) is also undertaking a three-year tariff adjustment plan resulting in a 13.6% increase in the combined water and wastewater bill since 2018. The city is the second most expensive city in SSA (US$ 4.79/m^3) after Praia (Cabo Verde) where combined tariffs were measured at US$ 5.13/m^3. SSA's cheapest city for water and wastewater is found in Addis Ababa (Ethiopia) with an average combined tariff of US$ 0.13/m^3.

In post-Mugabe Harare, Zimbabwe introduced its local currency (RTGS$) as the sole legal tender in June 2019 (Reniko & Kolawole 2019), which fell sharply against the dollar resulting in a 62.0% decrease in the country's combined tariffs, despite the actual local monetary value of the combined tariff increased. Prolonged droughts in Namibia caused NamWater in Windhoek to increase its combined water tariffs by 9.9% since 2018 (Neto & Camkin 2020). In Capetown (South Africa), the 2017/2018 drought had caused triple-digit increases in the city's tariffs as the City of Cape Town's Department for Water and Sanitation implemented strict 'Level 6' water restrictions in its attempt to reaching 'Day Zero' – the day that the city would run out of accessible drinking water (LaFrance 2018). However, heavy rainfall ended the city's drought challenges and reduced local restrictions to Level 1 which resulted in a 49.0% decrease in combined tariffs between 2018 and 2019. However, in other large South African cities such as Durban, Pretoria and Johannesburg, combined tariffs increased by 14.0, 10.0 and 9.9%, respectively.

Asia Pacific

In 2019, the regional average combined tariff in Asia Pacific was measured at US$ 1.06/m^3 with an average increase of 5% since 2018. Securing water supply in light of increasing climatic changes is the main driver behind the cost increases.

Across the Pacific Islands, residential tariffs have been affected by the pressures of climate change and population rise (Keen & Connel 2019). The regions' largest increase in combined water and wastewater tariffs were found in South Tarawa, Kiribati, where rates increased by 394.00% to US$ 5.72/m^3 as tariffs were restructured into an increasing block system as a requirement by a joint Asian Development Bank (ADB), World Bank and Green Climate Fund financed project. The steep increase has proven to make tariffs unaffordable as South Tarawa's Public Utilities Board has been able to only collect 50% of its revenue. This new tariff structure was implemented

H$_2$Open Journal Vol 3 No 1
doi: 10.2166/h2oj.2020.031

as an interim measure by the Government of Kiribati, while tariffs will be further reviewed in 2020. The aim is to ensure cost-recovery and the long-term sustainability of a planned seawater reverse osmosis desalination plant, which should be built by 2022. Future plans also include an upgrade and extension of South Tarawa's pipe network and the construction of a solar photovoltaic power plant for the desalination plant. On the island of Samoa, tariffs rose by 5.1% to cover the Samoa Water Authority's operating costs, whereas combined bills in Honiara, Solomon Islands rose by 5.0%. The country's water authority is expecting its costs to increase as it attempts to improve the reliability of supply and fund its share of improvements under a new donor-supported strategic plan for the next 30 years. Whereas the combined tariff in Yaren (Nauru) has remained unchanged from 2018, it remains the second most expensive tariff in the Asia Pacific region at US\$ 5.83/m^3.

The most expensive city in the region is Perth (Australia) with a combined tariff of US\$ 6.73/m^3 corresponding to an increase of 1.6% since 2018. The high reliance on desalination may further increase as the city faces cuts to its groundwater licences (Schmack *et al.* 2019). Elsewhere, despite having survived the Millennium droughts, cities in Australia continue to increase their combined water tariffs as a response to recurring droughts (Moglia *et al.* 2018). In Melbourne, water charges increased by 2.7% as demand for desalinated water from the Victoria desalination plant rose (Heihsel *et al.* 2019). Sydney is also bringing its desalination plant back into operation as it increased its water tariffs by 3.1%.

Tariffs in China have remained relatively unchanged since 2018 as the majority of the country's cities updated water and wastewater tariffs in 2015, 2016 and 2017 following the central government's targets set out in 2013 and 2015. The 2013 policy required that all cities set block water tariff systems by the end of 2015 (Ma *et al.* 2018). Only a few cities have not yet met this target, such as the city of Xining of the western Qinghai Province but are expected to implement this by the end of 2020. An additional policy issued in 2015 required a national increase in wastewater tariffs by the end of 2016, which has been met by all the cities. Although a block water tariff system has been implemented and an increase of combined tariffs has been seen in almost all the cities in China, the country's average tariff at US\$ 0.50/m^3 remains well-below the regional average.

Tariffs in Ulaanbaatar (Mongolia) rose for both water and wastewater at 15.7 and 23.4%, respectively, due to increasing electricity tariffs contributing to higher O/M costs (Dalai *et al.* 2019). However, Ulaanbaatar is also preparing for a new water supply and wastewater recycling project funded by the US Millennium Challenge Corporation. The cheapest city in the region is Bandar Seri Begawan (Brunei) at US\$ 0.08/m^3 with government-subsidised tariffs. The intention is for prepaid water meters to be introduced in 2020 in an attempt to control the country's high water usage. Tariffs elsewhere in Southeast Asia remain mostly unchanged since 2018, although in Manila (Philippines) Maynilad and Manila Water hiked tariffs by 7.6 and 1.7%, respectively, to account for inflation and foreign currency adjustments. Manila Water also has had to offer customers a bill rebate in June 2019 following a water shortage crisis earlier in the year (Horbulyk & Price 2019).

South Asia

The average combined water and wastewater tariff in South Asia was US\$ 0.37/m^3 in 2019 making it the lowest region surveyed in this paper. The region has gone from drought-like conditions to experiencing intense monsoons, yet the average combined water and wastewater tariff remains unchanged.

As Sri Lanka's national water board continues to struggle financially, Colombo's combined tariff rose by 11.1% since 2018. Across Indian cities, combined tariffs also increased by 4.98% in Pune, 4.87% in Nagpur and 2.31% in Bhubaneswar. Nagpur and the city's private water supply operators Vishvaraj and Veolia have a standing agreement to increase tariffs annually by ~5% (Deshkar 2019). Meanwhile, the most expensive combined water tariff in India is found in New Delhi, at US\$ 0.26/m^3 which remains unchanged since 2018. With the run-up to the Assembly election in

H_2Open Journal Vol 3 No 1
doi: 10.2166/h2oj.2020.031

2020, the Chief Minister of Delhi announced in August 2019, a one-time waiver of arrears in consumers' bills and a waiver on late-fee payments for consumers having metered connections. Poor wastewater infrastructure in particular hinders utilities in charging for wastewater fees in India. In April 2019, the National Green Tribunal (NGT) overturned a 2017 piece of legislation from the Ministry of Environment and Forestry and made sewage discharge standards more stringent. In August 2019, the NGT directed the Delhi Government to connect all areas of the city with sewage networks in order to address the problem of pollution discharged into the Yamuna River (Kumar *et al.* 2019). While the NGT order is yet to be enacted, utilities in India are under pressure to improve sewage treatment standards. The increasing role of the NGT in sewage treatment standards and downstream pollution monitoring is likely to expedite the expansion of wastewater networks and the collection of wastewater charges in other cities (Gitanjali 2019). Chennai has faced a severe shortage of drinking water since the beginning of summer 2019 resulting in steep rises in water tanker tariffs rather than municipal water tariffs (Upadhyay 2019). These water tanker tariffs are currently 10–20 times higher than the utility water tariff of US$ 0.12/m^3, unchanged from 2018.

Latin America and the Caribbean

The average combined water and wastewater tariff in 2019 in Latin America and the Caribbean was measured at US$ 1.79/m^3. Regional rate increases were primarily driven by capital investments in wastewater infrastructure, inflation and growing operational costs due to high electricity prices. The most expensive cities in the region are found in the Caribbean islands, with St. Thomas (U.S. Virgin Islands) charging a combined tariff of US$ 7.88/m^3 followed by West Bay (Cayman Islands, UK) at US$ 7.51/m^3 and Curaçao (Curaçao) at US$ 5.88/m^3 reflecting the high energy costs associated with the islands' reliance on seawater desalination (Brewster & Buros 1985; Fuldauer 2019). Whereas Havana (Cuba) has the lowest rates in the region at US$ 0.02/m^3 in part due to high subsidies in social tariff structures, the Council of Ministers plan to introduce progressive block tariffs in 2020 in an effort to encourage water conservation.

An additional driving force in the region behind the increase in water and wastewater tariffs is a growing effort to clean up natural water bodies. In Asuncion (Paraguay), wastewater rates rose by 124% since 2018 driving the overall increase of 50.2% in the combined bill. The infrastructure company Acciona has begun works on the city's Bella Vista wastewater plant to help the clean-up of the Bay of Asunción, and also plans to expand the area's sewer network and construct additional three wastewater treatment plants.

In Rio de Janeiro, Brazil, tariffs grew by 12.4% after a two-step rate increase was introduced in August and December 2018. The hike was approved by the regulatory agency Agenersa with the provision that the utility CEDAE must focus funding for the clean-up of Guanabara Bay and the Jacarepaguá Basin (Fernandez *et al.* 1994). Elsewhere in the country, Guanabara Bay has been subject to an ongoing clean-up project for the past 12 years, receiving global attention due to the failure of being adequately cleaned up before the 2016 Olympics (Fries *et al.* 2019). The new campaign that has been launched to clean the bay includes US$ 27.5 million government transfer, as part of a pledge made by the Rio de Janeiro State Government to spend US$ 2.5 million on monthly clean-up initiatives.

The water and wastewater tariffs in Medellín (Colombia) increased by 11.7 and 18.5%, respectively, in 2019, coinciding with the opening of the Aguas Claras wastewater treatment plant after a three-year delay. The US$ 500 million plant is part of efforts to clean the Medellín River and will serve more than 2 million inhabitants in Medellín and neighbouring Bello. Similarly, Cali (Colombia) raised combined tariffs by 10.9% as the city plans to invest US$ 9.6 million in water treatment plants to make water supply more resilient to recurring flood and drought events. In Mexico, the combined tariffs in several cities were impacted by the 100% increase in electricity rates charged by the Federal

H_2Open Journal Vol 3 No 1
doi: 10.2166/h2oj.2020.031

Electricity Commission. This hike contributed to the 11.1% rate increase in Chihuahua, a 6.1% increase in Ciudad Juárez and a 10.9% increase in Guadalajara.

Western Europe

The combined water and wastewater bill in Western Europe increased by an average of 0.59%, with an average price of US\$ 4.04/m³ in 2019. The drivers of regional tariff increases relate primarily to cost-recovery and much-needed infrastructure improvements (Houlihan 1994). Essen (Germany) was the most expensive city for water tariffs in Western Europe in 2019 with a combined water and sewerage charge of US\$ 9.04/m³. At the other end of the scale, Ireland and Northern Ireland do not charge residents directly for water and wastewater services. Following widespread protests at the attempted introduction of universal water tariffs in 2014, Irish Water has renewed its plans to impose tariffs on high consumers from 2021 onwards.

The highest increase in 2019 took place in Naples (Italy) as combined water and sewerage bills grew by 13.8%, bringing the cost to US\$ 1.81/m³. The increase was driven by a hike in wastewater tariffs of 41.4% after the local utility ABC Napoli took over management of the wastewater system from the municipality of Naples marking the first change in wastewater tariffs since 2015. Elsewhere in Italy, the utility regulator Autorità di Regolazione per Energia Reti e Ambiente imposed new requirements for utilities to separate tariffs between resident and non-resident consumers. The regulator also introduced per capita block tariffs with a subsidised bottom block of at least 30 m^3 per capita. The intention behind the new tariff scheme was to produce a fairer pricing system and encourage water conservation, as the tariff blocks depend on the number of residents in a household. The result has been a decrease of 2.5 and 9.9% in combined rates in 2019 for Venice and Milan, respectively.

Elsewhere, utilities are focussing on recalibrating tariffs to reflect the actual split in costs between water and wastewater. In Copenhagen (Denmark), the utility Hofor reduced water bills by 6.3%, while increasing wastewater charges by 5.6%. A more dramatic shift took place in St. Peter Port (United Kingdom) as Guernsey Water rebalanced their rates, with average wastewater charges increasing by 169% and average water tariffs decreasing by 49.3%.

Eyath, the water utility in Thessaloniki (Greece), took a different approach as it restructured its tariff system in 2018, resulting in a 5.7% decrease in the average water and wastewater bills in 2019. The new tariff policy is meant to more actively encourage water conservation as rates for the lowest blocks were reduced, while higher blocks became more expensive (van den Berge *et al.* 2019).

In Gothenburg, Sweden, a 7.1% increase in combined tariffs occurred in 2019 after it was discovered that the 22.0% reduction in water tariffs seen in 2017 had occurred due to a US\$ 6.4 million budgeting error which risks imposing further tariff increases in the future to make up for the losses. Meanwhile, residents of Oslo (Norway) can also expect water and wastewater costs to increase over the next decade. Average combined fees increased by 9.5% in 2019, and municipal budgets reveal the trend will continue as rates are set to increase by a total of 44.0% over the next four years. The rate increases are driven by growing debt pressures as the city starts work to ensure a supplementary water source, as well as replacing water and sewerage pipes. In London, United Kingdom, combined tariffs increased by 4.5% after the planned 6.4% increase was reduced in the form of a customer rebate due to excessive leakages. Rate hikes, however, are set to continue due to increased spending on the US\$ 6.2 billion Thames Tideway Tunnel Project (Loftus & March 2017). In other Western European countries that are known for having strong regulatory systems and apply social tariffs such as France, Spain and Belgium, combined tariffs increased relatively little by 0.24, 0.5 and 1.79%, respectively, whereas Portugal experienced a greater 4.28% increase.

H$_2$Open Journal Vol 3 No 1
doi: 10.2166/h2oj.2020.031

Middle East and North Africa

The average combined water and wastewater tariff in the Middle East and North Africa was measured at US$ 0.94/m^3 in 2019. The largest increase occurred in Manama (Bahrain) where combined rates for expats increased by 58.1% in 2019, following on from a 93.8% increase in 2018 and an 81.8% increase in 2017. Rates for Bahraini citizens meanwhile remained unchanged. This most recent rate hike marks the final year of a four-year plan to increase electricity and water tariffs following the oil price crash in 2014 (Emara *et al.* 2019).

In Egypt, utilities have continued with rolling tariff hikes as combined rates for Alexandria and Cairo increased by 13.6% in 2019. These increases follow on from similar increases since 2016 when the country secured a three-year US$ 12 billion International Monetary Fund loan. The increased tariffs are intended to direct the public towards sustainable water usage and to fund infrastructure development for the production, desalination and reuse of water (Lasheen 2019).

Rates in Jerusalem and Tel Aviv (Israel) rose by 8.0%, and by 7.0% in Haifa. Israel's tariff increases reflect the costs associated with an increasing reliance on desalination facilities as the country plans to increase its capacities to treat an additional 70 million m^3 as a consequence of a five-year drought.

In Tunis, Tunisia, the National Office for Sanitation increased combined water and wastewater tariffs by 3.2% after securing a US$ 173 million joint loan by the African Development Bank and the European Bank for Reconstruction and Development. Funds have been allocated to finance the construction of 24 wastewater treatment plants, 30 pumping stations and 862 km of additional sewerage pipeline to reach an additional 200,000 people.

Eastern Europe and Central Asia

The average combined tariff in Eastern Europe and Central Asia was measured at US$ 1.25/m^3 in 2019. Whereas 11 cities experienced double-digit increases in their average combined tariffs, three cities experienced similarly large decreases.

In Turkey, combined rates reveal a split in many of the cities surveyed, with the country's three largest cities, Istanbul, Ankara and Izmir, experiencing large decreases in combined rates, whereas Adana and Konya have had significant increases in their tariffs. In Istanbul, a combination of the first recession to hit the country in the last decade and the re-opening of the cities' mayoral elections led to both parties reducing tariffs as part of their election promises (Erkman *et al.* 2019). The originally seated party (AK Party) promised a decrease of 46.0% in water tariffs, while their main opposition (CHP), who narrowly won the original 2019 mayoral election, proposed to reduce rates by 40.0%. The municipal administration reduced tariffs by 32.0% in May 2019, before CHP won the re-run of the election in June by a much larger margin. In Ankara, the reduction in tariffs also coincided with local elections, but the Ankara Metropolitan Municipality Council holds that the main driving before behind the 30.3% decrease in the city's combined rates is due to the completion of the 9 km-long section of the Gerede Water Transmission Tunnel that has been operational since March. Rates in Izmir decreased by 4.4% since 2018, but residents will have experienced an actual decrease in their monthly bills that was greater, as tariffs were lowered further in August 2018. This additional reduction was driven by IZSU, the local utility, working on water-saving initiatives such as pipe replacements in their network to reduce non-revenue water and reducing the price of the first block of water to encourage water conservation. Combined water and wastewater tariff increases in Adana and Konya faced much controversy as the public demanded these municipalities reduce rates alongside other large cities in Turkey. However, these demands were not met as combined rates rose by 10.0% in Konya, and by 21.4% in Adana to generate funding for the large-scale Catalan Dam project.

H$_2$Open Journal Vol 3 No 1
doi: 10.2166/h2oj.2020.031

In Russia, an increase in VAT rates to both water and wastewater from 18.0 to 20.0% is the primary driver behind the country's rising combined tariffs (Moiseev *et al.* 2019). In Vladivostok, wastewater rates rose by 10.9% since 2018 whereas in Voronezh, plans to merge wastewater infrastructure to form a single network across the central river have caused the combined tariff to increase by 7.2% to cover additional construction costs.

In Sofia (Bulgaria), an increase to the combined tariff comes as Maya Manolova has campaigned for water and wastewater sectors, including regulation of investments, the introduction of social tariffs, licensing for operators and leakage reductions by upgrading infrastructure.

In Ukraine, rising operational costs increased both water and wastewater tariffs by 29.1% in Kiev, 26.9% in Odessa and 20.9% in Kharkiv. These rate hikes are influenced by a higher national minimum wage, surges in electricity costs and higher component and treatment reagent costs for treating drinking water. Similarly, such factors contributed to rate increases in the Ukrainian cities of Sebastopol and Lviv, where combined bills rose by 14.3 and 4.1%, respectively.

New regulations for utilities in Kazakhstan have also come into force in order to limit monopolies and unjustly high tariffs (van Dijk 2019). In keeping with the regulation of electricity and gas utilities, combined water and wastewater tariffs were reduced by 6.6% in Almaty and 9.6% in Nur-Sultan (formerly Astana). In Lithuania, a revision of pricing methodology and a more efficient operation from the utility Vilniaus Vandenys in Vilnius has also allowed for the lowering of combined tariffs for the second year in a row, with combined monthly billing reduced by 14.7% in 2019 and 17.0% in 2018.

North America

The combined water and wastewater bill in North America was estimated at US$ 4.31/m^3 in 2019. Seattle, Washington is the most expensive city in North America, with a combined cost of US$ 9.73/m^3 followed by Portland, Oregon where the combined rate is US$ 8.80/m^3.

Regional drivers of tariff increases in North America relate primarily to the continued need to repair, replace and maintain ageing water and sewer infrastructure (Qureshi & Shah 2014). In California, the greatest hikes took place in San Francisco and Los Angeles where rates rose by 8.4 and 7.9%, respectively. Rates in San Francisco grew after the San Francisco Public Utilities Commission (SFPUC) approved four years of rate increases in April 2018, aimed at generating funds for the SFPUC's improvement and upgrade of water and wastewater infrastructure.

Another common driver for combined tariff increases across many regions of North America – particularly in drought-stricken states such as Texas and California – is the need to improve water conservation (Gaur *et al.* 2016). Efforts to encourage conservation across the USA in recent years have had a meaningful impact on reducing national water usage levels (Aubuchon & Morley 2013). Whereas tariff structures designed to encourage conservation have played a great role, the decline of water use can also be attributed to the phenomenon of 'passive conservation' where the adoption of more water-efficient household appliances has reduced water usage without significant behavioural shifts (Price *et al.* 2014). The downside of reduced consumption for utilities is the downward pressure it places on its revenues, which has pushed more utilities to implement new rate structures and higher fixed fees to offset their reduced income. Following the 2014 droughts in San Jose, the city's residents have consistently met local government water conservation targets (Jedd 2019). However, these efforts have negatively affected the utility's finances, as 40.0% of its revenue is generated from volumetric charges. In response, California's Public Utilities Commission approved annual rate increases, causing dissatisfaction amongst obedient customers. This shift has resulted in combined rates increasing by 2.6% in 2019, following 4.8 and 14.9% increases in 2018 and 2017, respectively.

In Washington, DC, the 2009 DC Water Clean Rivers Impervious Areas Charge (CRIAC) which aims to fund the construction of tunnels to prevent sewer overflows after heavy rainfall, continues to raise combined tariffs, with an increase of 8.4% in 2019. The CRIAC was originally based on

H$_2$Open Journal Vol 3 No 1
doi: 10.2166/h2oj.2020.031

the impervious surface area, which sparked complaints by customers that the charge inequitably affects houses with large patios, driveways and roofs. In response, DC Water proposed to shift the CRIAC from a fixed to a volumetric charge based on a household's water and sewerage usage (Groves & Wolfe 2019). As a result, large buildings with more residents, but less impervious area, may see an increase in future charges as they have higher volumetric sewer output. DC Water plans to introduce this change in stages, with an 18.0% shift in 2020, a 28.0% shift in 2021 and a 37.0% shift in 2022.

The region's largest increase in combined tariff occurred in Hartford, Connecticut where bills increased by 18.2% to US\$ 5.72/m^3 in 2019, driven primarily by a 27.6% hike in wastewater rates to raise funds for capital infrastructure improvement projects. In Pittsburgh, Pennsylvania, the Pennsylvania Public Utilities Commission, which now oversees rate-setting for the Pittsburgh Water and Sewer Authority, had originally approved combined rate increases of 10.0% in 2019 and 11.0% in 2020. However, the Commission amended these figures and approved a rate increase of 13.8% in 2019.

Meanwhile, residents of Salt Lake City, Utah experienced a combined bill increase by 8.9% in 2019, in a first of a series of planned successive increases through to 2024, as the city's Department of Public Utilities aims to upgrade its infrastructure, including a US\$ 528 million wastewater treatment plant. Similar infrastructure-driven increases in rates were also implemented in Baltimore (Maryland), Cleveland (Ohio) and Portland (Oregon), where combined rates increased by 8.9, 6.8 and 7.1% respectively. In Texas, combined rates in El Paso increased for the fourth consecutive year by 5.4% in 2019, whereas rates in San Antonio rose by 4.4%. In 2018, the San Antonio City council approved a two-year rate increase which is driven by ambitions of the San Antonio Water System to buy water from the privately financed Vista Ridge pipeline project, due to be completed in 2020 (Hudock 2019). In Denver, Colorado, the third year of the US\$ 1.3 billion five-year capital improvement plan has caused an increase in combined rates of 4.1% since 2018, after having previously experienced an increase of 8.2% in 2018 and 10.5% in 2017.

In Ottawa, Canada, combined tariffs increased by 1.7% as the city has changed its tariff structure from a linear volumetric charge, to an increasing four-block tariff in an attempt to encourage water conservation. The city has also introduced fixed fees for water and wastewater in order to provide a stable stream of funding. Meanwhile, combined tariffs in Vancouver increased by 8.5% to US\$ 2.40/m^3 as the city aims to generate revenue to replace outdated infrastructure.

CONCLUSION

This paper presented changes to global water and wastewater tariffs and provided an examination related primarily to the major economic and financial drivers of change in combined water and wastewater tariffs in different regions between 2018 and 2019 based on a survey of 568 cities across 192 countries. Historically, the average global price for water and wastewater services has increased from US\$ 1.70/m^3 in 2011 to US\$ 2.16/m^3 in 2019 which equates to an average annual rise in the global combined tariff of ~3.4%.

In 2019, the region with the highest average combined water and wastewater tariff was North America (US\$ 4.31/m^3) followed by Western Europe (US\$ 4.04/m^3), Latin America and the Caribbean (US\$ 1.79/m^3), Eastern Europe and Central Asia (US\$ 1.25/m^3), sub-Saharan Africa (US\$ 1.07/m^3) and Asia Pacific (US\$ 1.05/m^3). At a price of less than one dollar per cubic metre was the Middle East and North Africa (US\$ 0.94/m^3) and South Asia (US\$ 0.37/m^3). Examining the drivers of change to urban water and wastewater tariffs across these regions between 2018 and 2019, the investigation indicated that prolonged droughts; subsidy cuts and reforms; ageing water and wastewater infrastructure that needs upgrading thereby passing the cost along to the customer; increasing energy costs and a shift to alternative water resources such as desalination, are all major

H_2Open Journal Vol 3 No 1
doi: 10.2166/h2oj.2020.031

financial and economic contributors to changes in combined water and wastewater tariffs. Other factors, while not the focus of discussion in this article but equally as important in impacting changes in combined tariffs relate to political and social factors such as local costs of water extraction, purification and distribution as well as varying perceptions of the status and role that water has in society.

Indeed, revenues generated from water and wastewater tariffs are vital for continued water and wastewater treatment and service delivery. However, their ability to reflect levels of full operating and maintenance cost-recovery remains in many instances inadequate. Policies that fail to keep the price of water at the full cost of service, risk increasing unsustainable water consumption practices, causing stress on supplies; dependence on outside sources of financing; service interruptions due to underfunding of operating and capital costs and inequality due to limits on services to informal settlements. Indeed, when water managers and utilities have constrained budgets and resources, they face the choice of what areas to serve. Particularly in less economically developed countries, the most common decision by water managers is to favour the powerful and rich over the poorest segments of the population, unless strong solidarity tariffs and pro-poor schemes are in place.

The suggestion that increased tariffs will provide better service provision and fulfil the Sustainable Development Goals (SDGs) by 2030 remains speculative and far from guarantees this. What is necessary to consider are the types of tariffs that reforms present and implement. Tariff reforms have to ensure both affordability and equity and facilitate governments, utilities and consumers to uphold and respect the rights and obligations associated with the existence of a human right to water and sanitation.

One practical recommendation is to shift the emphasis of water tariff reforms onto social tariffing. In instances where failure to keep up with payment of water and wastewater bills result in water services being cut off, social tariff structures that emphasise affordability might be much more cost-effective than the practice of pursuing debt-collection which is both time-consuming and costly. Philadelphia Water in Philadelphia, Pennsylvania (USA) was the first utility in the USA to successfully implement social water tariffs. In July 2017, the utility instituted an unprecedented plan to charge lower rates for households with incomes at or below 150% of the federal poverty line (~US$ 3,075/month for a family of four). Eligible households (approximately 60,000 out of 400,000 households in Philadelphia were eligible) could pay a fixed monthly fee for water, wastewater and stormwater charges which reduces the monthly bill to as low as $12 a month, compared to an average household bill of over $70. Indeed, future research needs to further evaluate and assess the status of affordability at national scales and examine the links between current water and wastewater tariffs and indicators for measuring progress towards the SDGs, in order to put into perspective the notion that whereas increased combined tariffs might generate higher rates of revenue geared towards cost-recovery, this cannot be done without factoring in the need for socially conscious tariffs.

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CONFLICTS OF INTEREST

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H$_2$Open Journal Vol 3 No 1
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All relevant data are included in the paper or its Supplementary Information.

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