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Socially fair domestic water pricing: who is going to pay for the non-revenue water?

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ABSTRACT

To plan and develop a socially fair water pricing policy is a difficult task to do since many factors need to be taken into consideration. Usually, a significant part of a water tariff structure is the fixed charge that should be associated to the opportunity cost the consumers have to pay. In many cases though, it is set just to balance the water utility's revenues and expenses. This weird billing practice results in the underestimation of the Non-Revenue Water (NRW) and in the minimization of water use efficiency. The application of the IWA Standard International Water Balance 2nd modification and its element, the Minimum Charge Difference (MCD) can reveal how big this "underestimation" is. MCD represents the water volume that although not consumed, generates revenues to the water utility. Another element towards a socially fair pricing policy is the allocation of the NRW-related cost. In every water network, two main water users are identified: the actual water consumers and the network itself due to the real water losses occurring. The paper presents a novel methodology to estimate the MCD and a new approach regarding a socially fair allocation of the NRW-related cost.

Keywords: Fixed charge; Non-revenue water; Water balance; Full water cost; Minimum charge difference; Water pricing

1. Introduction

As water is a vital good for life and well-being, it is important to safeguard it in every way. Although the demand for drinking water is a small part of the total water demand (as agriculture is the main water user) it is the most significant one since it involves humans' everyday life. It is common knowledge that water distribution networks have two kinds of consumers: the water users (regular customer as households; industries etc.) and the water network itself since significant water volumes are being constantly lost due to pipes' leaks and breaks. One third of the total water globally abstracted from its resources aimed to be used for drinking, is being lost along the "supply chain" due to leaks and breaks and at the same time 16 billion m^3 reach the customers' taps each year but are not being invoiced due to theft, poor metering, or corruption [1]. The so-called Non-Revenue Water (NRW—water not

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providing revenues to the water utility including real/physical losses and apparent/commercial ones) is estimated to be 50–60% of the water entering the network (System Input Volume-SIV) in low-income countries according the same study [1]. If NRW could be reduced in acceptable levels (5–10% of the SIV), the water needs of an additional 21–27% of the total world population would have been satisfied. The impacts of NRW do not refer only to water as a natural resource but they expand including the environmental impacts derived from the excessive use of energy and the energy losses due to leakage and also the economic impacts water utilities are facing. Although the NRW problem is well-known, some water utility managers do nothing to confront it even if these utilities are operating in areas suffering from water scarcity. This was actually the question that motivated the authors when they applied the well-acknowledged methodology (IWA Water Balance (WB)) to assess the performance of urban water distribution networks across the EU Mediterranean basin. Having studied these networks thoroughly, they realized that although the water systems were experiencing high NRW values (exceeding even 50% of the SIV in certain cases) there were no NRW reduction measures applied. This finding triggered the research towards the actual reasons for this irrational way of managing the networks, since it was not logical the water utility to lose revenues and valuable water resources. The present paper reveals that the actual reason for not applying NRW reduction measures when NRW levels are high usually is the predominant billing practice including the fixed charge included in the water bills.

The tool used to reveal this "malpractice" is the application of the IWA Standard International WB 2nd modification and its element, the minimum charge difference (MCD) revealing how big this "underestimation" is. MCD represents the water volume that although not consumed, generates revenues to the water utility. The MCD is used to balance a part of revenues lost due to water losses occurring in the water network. The paper presents a methodology to estimate this MCD component of the WB by identifying first the types of costs that should represent the opportunity cost the consumers should pay through the fixed charge. Eight cases are presented from the EU Mediterranean basin showing that although water utilities experience severe water losses in their networks do nothing to reduce them. The real cause of this negligence is that they actually recover a significant part of their water losses related lost revenues through the fixed charge included in their water tariffs.

Additionally the authors present a new methodology to allocate the responsibility regarding who has to pay for the NRW-related cost of each use as expressed in the WB in a socially fair way. The SIV is initially divided to different uses (WB components) and the responsibility of who pays for the cost of each use is allocated between these two major "users": the water utility customers and the network. The results of cases from Mediterranean countries are also provided.

2. Water distribution networks performance evaluation

2.1. Literature review

The WB and Performance Indicators (PIs) form a well acknowledged methodology used by many water utilities, practitioners and researchers worldwide, to assess and evaluate the performance level of water distribution systems (WDSs). The Standard International WB was firstly introduced by Lambert et al. [2], while the manual of PIs was initially published in 2000 and enriched in 2006 [3]. There are too many cases studied so far. It is generally noted that although NRW values are usually quite high in WDSs there is a lack of motivation to reduce them [4]. Gonzalez-Gomez et al. [4] indicate as possible reasons for this irrational behavior the lack of incentives for management units, corruption phenomena due to private interests, the poorly informed citizens and the lack of political will. Ismail and Puad [5] claim that to manage the NRW it is essential to understand the reasons and the factors causing it. They presented a study in a WDS in Selangor where a water losses reduction program was applied. It is also well noted that leakage in water systems causes loss of water (as a natural resource), potentially water quality problems and energy losses [6]. This study estimates energy losses in leaky pipes using EPANET to simulate the water losses' energy costs. It also shows the interconnection of total demand, the location of leaks and the topological complexity. Hydraulic simulation models are used to determine the nodal pipe leakage [7]. Many techniques and methodologies have been developed to reduce water losses [8]. A detailed strategy and its development was presented by Farley & Liemberger [8] while Puust et al. [9] stated that there is still room for real-time models enabling fusion of leakage detection, assessment and control methods.

2.2. The WB: a well-acknowledged tool for the WDSs' assessment

The WB methodology determines the NRW not bringing revenues to the water utility, consisting of: (a) the apparent losses (i.e. water theft, meters and metering errors and in-house leakages not metered); (b) the real losses (i.e. water losses due to breaks, leaks and tank overflows); and (c) the water volume consumed but not billed by the water utility due to various reasons [2]. Thus, figuring the WB is used to help water utilities managers estimate the level of the water losses in their networks and thus design strategies to reduce them focusing on their actual causes. WDSs usually suffer from high NRW values not being addressed. Especially in Southern Europe (and the Mediterranean), almost all local water utilities have adopted inclining block water rates (as the water use increases moving from one block to the next one, the unit price of water increases too) where a so-called "fixed charge" has been added, having nothing to do with the water consumption actually measured by the customer's water meter. This fixed charge is expressed either as minimum consumption (in m^3) or as minimum money charge (in €). So, if there is no actual water use, the customer has to pay a minimum amount of money (directly or through the minimum water use threshold set). Usually the water utility claims that this fixed charge is actually the "opportunity or access cost" the customer has to pay to have adequate quantity of good quality water in his tap whenever he wishes to. This is a logical argument. But in practice it seems that the water utility does not apply thorough, solid and appropriate economic analysis to reliably estimate the actual level of the opportunity cost in each case. On the contrary, it just tries to reach to a balanced budget merging the gap between costs and revenues related to water being abstracted, consumed and sold. As, this is usually how the fixed charge level is being estimated, it is not at all a socially fair pricing policy as the utility forces its customers to pay a part of the revenues lost due to its own incompetence. The influence of such billing practices is an issue presented in the literature in many countries [10]. A study in France [11] showed that the average fixed charge is more than one half of the average capital expenditures, showing that water utilities try to balance their expenses by applying high levels of fixed charge. The short-run results are underpricing of the water (as unit price) while the long-run results could include environmental damages and economic misleading messages to the consumers regarding the water's actual value [11].

Although the IWA Standard International WB is a volumetric tool, the need to use it as an economic one too became apparent during its implementation in several cases around the world. McKenzie et al. [12] presented its 1st modification, adding the water volume that although consumed is not being paid for (Table 1), a common issue met in Africa. The use of the WB in the Mediterranean area reinforced its 1st modification and drove to its 2nd one [13] (Table 1), that introduced the MCD as part of the revenue losses a water utility recovers through the fixed charge. The MCD is estimated depending on the expression of the fixed charge (minimum water volume or minimum money charge).

3. Water billing practices

3.1. The water bill

Water pricing policies differ a lot not only among different countries but also within the same country among the water utilities. Most of the times water use is being metered and there are many water pricing structures, such as inclining block rates, declining block rates, uniform rates and seasonal-peak rates. When the water use is not being metered, the customers are being charged a flat rate equalized for each customer or taking into consideration its individual characteristics [14]. Tariffs' structures in most European countries include a fixed charge whose value varies a lot (e.g. 35.5–65.6 €/year) when the water use is being metered (Table 2) [15]. Water unit price varies a lot, from 0.19 €/m^3 (in Slovenia) to 4.52 €/m^3 (in Scotland for 100 m^3 water consumption) (Table 2).

Water bills in Greece consist of: the actual water cost depending on the water consumption metered and the water price level; the fixed charge (as minimum water use or minimum money charge); a special fee charge (60–80% of the net water use cost) related to the waste water collection/treatment/disposal cost; connection fees; other charges such as water meter maintenance costs, etc.; and value added tax (VAT) [16]. A study including 84 water utilities revealed the paradox of high variations of the mean payable amount among different water utilities without any specific excuse [16]. The study showed that the mean payable amount is comparable in regions facing water scarcity conditions (where the WB is deficient) with the other regions of the country. In general the study showed that there is not a common pricing policy applied by the water utilities in Greece [16]. The fixed charge applied by the water utilities in Greece varies a lot too (Fig. 1). From the 84 water bills studied, the authors selected 33 water utilities serving cities with population higher than 15,000 people. The results showed that the fixed charge per month ranges from 1.17 to 18.00 € (Fig. 1) [16]. The results verify the authors' argument that the fixed charge impose serves only as a means to balance the expenses with the revenues and not as the real opportunity/access cost the consumer should pay. It is obvious that the water billing practice is far from being a uniform one.

Table 1
The Standard International WB and its two modifications

<table>
<tr><th colspan="5">IWA Standard International WB [2]</th><th>First modification [12]</th><th>Second modification [13]</th></tr>
<tr><td rowspan="7">System Input Volume</td><td rowspan="4">Authorized Use</td><td rowspan="2">Billed Authorized Use</td><td>Billed Metered Use</td><td rowspan="2">Revenue Water</td><td>Water billed and paid for (Free Basic)</td><td>Revenue Water</td></tr>
<tr><td>Billed Unmetered Use</td><td>Water billed but NOT PAID for (apparent NRW)</td><td>Water billed but NOT PAID for (apparent NRW)</td></tr>
<tr><td rowspan="2">Unbilled Authorized Use</td><td>Unbilled Metered Use</td><td rowspan="5">Non Revenue Water (NRW)</td><td rowspan="5">Water not being sold (Non-Revenue Water/real NRW)</td><td rowspan="4">Accounted for Non-Revenue Water</td></tr>
<tr><td>Unbilled Unmetered Use</td></tr>
<tr><td rowspan="3">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorized Use</td></tr>
<tr><td>Customer Meter Errors and Data Handling Errors</td></tr>
<tr><td colspan="2">Real Losses</td><td>Water generating revenues although not consumed (Minimum Charge Difference)</td></tr>
</table>

Table 2
Water tariff structures and average rates in European countries [15]

Country	Tariff structure	Average rates (€/m^3)		Time period
England & Wales	Fixed + charge based on rateable value of the house (if unmetered) + volumetric	Metered: 35.5 €/year + 132.6 cents/m^3	Unmetered: Fixed: 69.6 €/year + 75.7 cents/€ (house value)	2011–12
Scotland	Fixed (based on tax bracket)	Metered: for 100 m^3 = 1.51–4.52 €/m^3	Unmetered: 121.44–364.32 GBP/year	
Netherlands	Fixed + volumetric	1.43 €/m^3		2010
France	Fixed + volumetric	1.55 €/m^3		2009
Germany	Fixed + volumetric	65.6 €/year + 1.65 €/m^3		
Slovenia	Fixed + volumetric (sometimes solely volumetric)	0.19–1.48 €/m^3		
Croatia	Fixed + (sometimes) volumetric			
Serbia	Volumetric			
Spain	Fixed + volumetric (sometimes block rates)	Spain: 0.85 €/m^3; Catalonia: 1.14 €/m^3; Barcelona (province): 1.181 €/m^3		

3.2. *The socially fair dimension of the fixed charge*

As already mentioned water bills apart from the cost related to the actual water consumption, include also several other charges depending on the local utility individual policy. In a socially fair water pricing policy, the fixed charge should only represent the opportunity/access cost, as both the water utility and the infrastructure it daily manages simply exist to supply its customers with adequate quantity of good quality water. The fixed costs are distinguished in two groups. The first one includes costs not related to the water volume the customer consumes (i.e. water meters' and service pipes' maintenance cost, water connection fee, firefighting, public use costs etc.). These costs actually form the opportunity cost the consumer has to pay since they are related to its service, safety and satisfaction level. The second group of costs includes costs (proportionally) related to the water

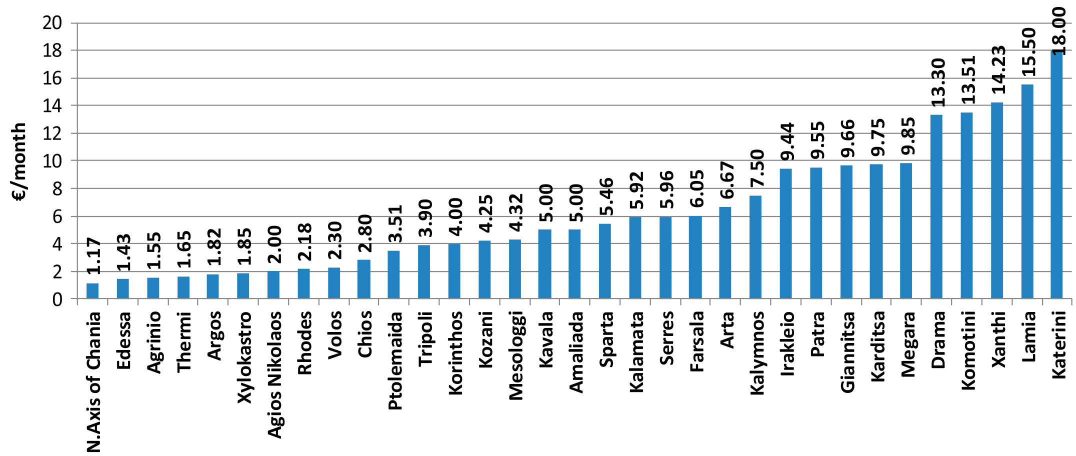

Fig. 1. The fixed charge in 33 water utilities in Greece (€/month) (Data based on [16]).

volume each customer consumes, such as water mains' (and not service pipes) repair costs, pipes and tanks washing costs, etc. All these costs should be appropriately incorporated in the unit selling price of the water use (of the first block in cases of inclining block rates applied) as they relate to the "water network percentage of use" index. Thus the fixed charge should represent only the opportunity cost the consumers must pay to have water of good quality and adequate quantity and pressure at their taps.

3.3. MCD level estimation methodology

To estimate the MCD two different methodologies are followed depending on how the fixed charge is charged to the consumers: minimum consumption (in m^3) or minimum money charge (in €). In all cases, it is accepted that the consumers should pay for the opportunity cost.

3.3.1. Calculating the MCD when the fixed charge is expressed in minimum money charge

When the fixed charge is expressed in € (included in the water bill), the MCD expresses the equivalent water volume (in m^3), that if sold (on net water price, excluding the fixed cost) would have resulted in the same revenues (in €), minus the actual fixed cost (opportunity cost). So, given a specific time period (T) of analysis, the Total Revenues (R) (in €) related to the water being sold (and related water services) within this time period (T) of analysis, are the sum of the revenues (R_{fc}) related to the fixed cost and those (R_{wuc}) related to the water being sold:

$$R = R_{fc} + R_{wuc} \tag{1}$$

The former (R_{fc}) can be expressed as the sum of the costs (R_{dc}) related to the water consumption and those (R_{ndc}) not related to that. R_{ndc} actually represents the opportunity cost the consumers have to pay:

$$R_{fc} = R_{dc} + R_{ndc} \tag{2}$$

The total water volume Q_{wst} (in m^3) entering the system (System Input Volume—SIV) is the sum of the water volume sold (Q_{ws}) and the water volume (Q_{wns}) not sold for various reasons (e.g. leaks, breaks, water theft, zero charge etc.):

$$Q_{wst} = Q_{ws} + Q_{wns} \Leftrightarrow Q_{ws} = Q_{wst} - Q_{wns} \tag{3}$$

The water volume sold (Q_{ws}) is the sum of the water volume (Q_{wsp}) generating revenues to the utility, and the water volume (Q_{wsnp}) that although being sold does not generate revenues:

$$Q_{ws} = Q_{wsp} + Q_{wsnp} \tag{4}$$

Although the mean unit rate (A) of revenues (in €/m^3) is:

$$A = \frac{R}{Q_{wsp}} \tag{5}$$

The mean apparent/actual unit charge of water use A_{wuc} (in €/m^3) is smaller:

$$A_{wuc} = \frac{R_{wuc}}{Q_{wsp}} \tag{6}$$

If R_{ndc} expresses (in €) the actual fixed cost of the water services (opportunity cost), then the MCD (in m^3) is:

$$MCD = \frac{R_{fc} - R_{ndc}}{\frac{R_{wuc}}{Q_{wsp}}} \tag{7}$$

3.3.2. Calculating the MCD when the fixed charge is expressed in minimum water use

When the Fixed Charge is expressed in m^3, then to calculate the MCD (in m^3) is quite straight forward. The MCD represents the water volume that although included in the water bills as water consumption, is not actually being used. It is evident that from this volume, someone must exclude the water volume that if sold under the mean apparent/actual unit charge of water use A_{wuc} (€/m^3) it would generate revenues equal to the actual Fixed Cost (opportunity cost). Thus the MCD equals to:

$$MCD = Q_{tot}^{bill} - Q_{tot}^{used} - Q_{opportunity\ cost} \tag{8}$$

where Q_{tot}^{billed} is the total billed water use (m^3); Q_{tot}^{used} is the total the water volume used; $Q_{opportunity\ cost}$ is the water use (m^3) representing the opportunity cost the consumer has to pay. The latter must be calculated based on the actual costs the water utility pays and are not related to the actual water use (m^3):

$$Q_{opportunity\ cost} = \frac{R_{ndc}}{A_{wuc}} \tag{9}$$

4. Socially fair water cost recovery allocation

Socially fair water pricing should not only include a fair estimation of the opportunity cost the consumers should pay but also allocate the full water services cost to the users. This is actually what the Water Framework Directive 2000/60/EC requires from all Member States: to apply strategies to reduce the NRW levels and recover the full cost of the water services provided. As the full water cost consists of the direct, the environmental and the natural resource costs it is almost certain that water prices will have to rise to recover a big part of the increased (full) water cost. However it is crucial to see what will happen in cases where NRW levels are high (up to 50% or more of the SIV). The water utilities' practice is to charge all the NRW related cost to the consumers although they are not fully responsible for it. For example if a WDS experiences a NRW level of 50% of the SIV, the water utility will charge twice the price of water to recover the cost of the NRW. A socially fair cost allocation of the water uses among the users should take place.

A WDS have two major water users: the consumers of all kinds (households; industries; etc.) and the water network itself since big water volumes are being lost in it through leaks and breaks. The water volume entering the network (Q_{SIV}) can thus be divided in two consumptions: (a) the one consumed by the consumers (Q_{CUST}); and (b) the one consumed by the network (Q_{DN}):

$$Q_{CUST} = a \times Q_{SIV} \tag{10}$$

$$Q_{DN} = (1 - a) \times Q_{SIV} \tag{11}$$

Based on the WB, the System Input Volume (Q_{SIV}) consists of:

$$Q_{SIV} = Q_{RW} + Q_{NRW} = Q_{RW} + Q_{UNB} + Q_{AL} + Q_{RL} \tag{12}$$

$$Q_{AL} = Q_{WTH} + Q_{MER} + Q_{RER} \tag{13}$$

$$Q_{RL} = Q_{CARL-EARL} + Q_{EARL-UARL} + Q_{UARL-UARLopt} + Q_{UARLopt} \tag{14}$$

where Q_{RW} is the revenue water; Q_{NRW} is the Non-Revenue Water; Q_{UNB} is the unbilled authorized consumption; Q_{AL} are the apparent losses; Q_{RL} are the real losses; Q_{WTH} is the unauthorized consumption; Q_{MER} are the meter errors; Q_{RER} are the reading errors; $Q_{CARL-EARL}$ is the difference between the Current Real Losses (CARL) and the Economic Real Losses (EARL); $Q_{EARL-UARL}$ is the difference between the EARL and the Unavoidable Real Losses (UARL); and $Q_{UARL-UARLopt}$ is the difference between the UARL and their optimum level (UARLopt). The latter represents the case where the unavoidable real losses are the minimum ones since the distribution network is well-maintained and operates at the lowest possible pressure (Fig. 2). UARL and UARLopt levels can be calculated from an empirical equation presented by Lambert et al. [2].

Thus, when designing a socially fair allocation of the costs related to the water volumes consumed in the water distribution network, the consumer has to pay for:

(1) The actual water volume he consumes which is the Revenue Water (Q_{RW});
(2) The unbilled consumption (Q_{UNB}) which is authorized including washing the mains and the tanks, firefighting, public buildings' consumption etc. All these consumptions aim at the consumers' quality of life improvement and provide services to him;
(3) The water volume not recorded because of the meters errors ($Q_{ME}R$) since this volume is actually consumed by the users (including leakage within his property);
(4) The optimum level of the Unavoidable Real Losses ($Q_{UARLopt}$) as the opportunity cost. The role of the water distribution network is to serve the users with water at their taps;
(5) A part of the difference between the Unavoidable Real Losses and the Economic ones ($Q_{EARL-UARL}$), proportionate to the part of the water volume entering the network that the customer consumes. The water volume $Q_{EARL-UARL}$ can be recovered using technical solutions but it is not economically effective since the recovery cost is higher that the revenues from selling the water. The level of this water volume depends on the cost of the techniques used and especially from the water price. Thus, the cost of this water volume should be shared proportionally among all consumers.

On the other hand, the water distribution network (the water utility) has to pay for:

(1) The water volume corresponding to the metering errors (Q_{RER}) since it is the utility's responsibility to record and transfer correctly the water meter recordings;
(2) The water volume consumed illegally (Q_{WTH}) e.g. water theft, illegal connections etc. as it is the utility's responsibility to perform audits and impose measures to avoid unauthorized uses;
(3) The difference between the Current level of Real Losses and the Economic ones ($Q_{CARL-EARL}$) as a kind of penalty because of the bad infrastructure and the fact that the utility does not implement any water losses reduction measures;
(4) All the difference between the Unavoidable level of Real losses and their optimum ones $Q_{UARL-UARLopt}$. The water utility must improve the performance level of its distribution network and take all the necessary measures (active leakage control; pressure management; speed and quality of repairs) to achieve the optimum level of unavoidable real losses;
(5) The attributable part to the utility (the part it uses being $(1 - a)$) of the difference between the unavoidable real losses and the economic ones ($Q_{EARL-UARL}$).

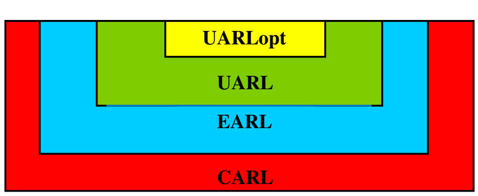

Fig. 2. The CARL, EARL, UARL and UARLopt levels.

If the Revenue water is 60% of the SIV and the water consumption is shared according to Table 3, then the allocation of the water consumption related costs between the consumers and the distribution network can be quantified (Table 3). The level of the optimum unavoidable real losses is considered to be 8% of the SIV.

The coefficient a can be calculated using the Eqs. (15) and (16) and it is found to be 87.37% for this specific case:

$$Q_{CUST} = a \times Q_{SIV} = (0.83 + 0.05 \times a) \times Q_{SIV} \tag{15}$$

$$Q_{DN} = (1 - a) \times Q_{SIV} = (0.17 - 0.05 \times a) \times Q_{SIV} \tag{16}$$

The results show that although the consumers are billed for the 60% of the SIV as this is their actual consumption, the water cost that must be recovered through their water bills is 87.37% (Q_{CUST}). This can be achieved through the respective variation of the weighted average unit price of water use. This practice is more socially fair from the one applied today, as the water utilities try to recover 100% of the full water cost, billing only 60% of the water volume entering the network. The practice used has to do with charging the weighted average unit price of water use increased by 14.46% (=100/87.37). The specific water cost allocation is more fair for the water utility too, since it recovers part of the NRW-related cost It must be stressed that this allocation refers to the average recovery/charge variables.

Table 3
Responsibility allocation of water cost recovery

Water quantities per use in the distribution network				Customer $Q_{CUST} = a \times Q_{SIV}$	Water utility $Q_{DN} = (1-a) \times Q_{SIV}$
Q_{SIV} (100%)	Q_{RW} (60%)	Q_{RW} (60%)	Q_{RW} (60%)	100% × (60%)	–
	Q_{NRW} (40%)	Q_{UNB} (5%)	Q_{UNB} (5%)	100% × (5%)	–
		Q_{AL} (15%)	Q_{WTH} (2%)	–	100% × (2%)
			Q_{MER} (10%)	100% × (10%)	–
			Q_{RER} (3%)	–	100% × (3%)
		Q_{RL} (20%)	$Q_{CARL-EARL}$ (5%)	–	100% × (5%)
			$Q_{EARL-UARL}$ (5%)	a% × (5%)	$(1-a)$% × (5%)
			$Q_{UARL-UARLopt}$ (2%)	–	100% × (2%)
			$Q_{UARLopt}$ (8%)	100% × (8%)	–
				$Q_{CUST} = (0.83 + 0.05 \times a) \times Q_{SIV}$	$Q_{DN} = (0.17 - 0.05 \times a) \times Q_{SIV}$

5. The cases studied—Results and discussion

To validate the argument that the fixed charge plays a very important role in the faulty estimation of the NRW in urban water supply networks, eight Mediterranean case study networks are examined. Three of them refer to Greek cities (i.e. Larisa, Kos, Kozani), one is Nicosia the capital of Cyprus, three refer to French cities (i.e. Baho, Argeles-sur-Mer, Thuir), and one refers to the Spanish city Castellbisbal (Table 4) [10,17]. The local water utilities use the fixed charge in the water bills in all cases (in two of them as minimum water use and in the remaining six as minimum money charge ranging from 34.14 to 79.45 €/year). For all the eight cases the 2nd modified WB was estimated using data provided by the water utilities [10,17]. As it is a common fact that the water utilities do not record all the necessary data, tips and tricks are used to make the necessary assumptions and reach to safe/reliable estimations [18,19]. The results obtained from the WB analysis of all eight cases include the WB components estimation in m^3/year (System Input Volume-SIV; Revenue Water-RW; Real Losses-RL; Apparent Losses-AL; NRW) (Table 5). WB analysis results clearly show that NRW

Table 4
The cases' basic characteristics [10]

Pilot case	Population served	Connections number	Pipes length (km)	Mean pressure (atm)	Fixed charge	Reference time
Baho (FR)	7,041	1,300	16.73	2.96	44.00 €/year	2010
Argeles-sur-mer (FR)	10,082/ winter; 100,000/ summer	6,581	135.77	2.96	71.34 €/year	2010
Thuir (FR)	7,519	3,257	66.70	3.0	79.45 €/year	2010
Castellbisbal (ES)	12,223	3,531	143.00	5.5	50.40 €/year	2010
Nicosia (CY)	223,640	65,094	1,330.00	3.5	34.14 €/year	2010
Larissa (EL)	192,000	~14,000	628.00	3.6	20 m^3/ 2 months	2006
Kozani (EL)	35,942	9,150	129.58	3.0–5.0	51.00 €/year	2010
Kos (EL)	18,000/winter; 40,000/summer	~5,000	122.00	3.0	8 m^3/ 2 months	2007

Table 5
The WB components [17]

Pilot case	SIV (m^3/year)	Revenue water (m^3/year)	Water billed but not paid for (m^3/year)	Apparent losses (m^3/year)	Real losses (m^3/year)	NRW (m^3/year)	MCD (m^3/year)	Accounted for NRW (m^3/year)	NRW (%SIV)
Castellbisbal	2,445,454	2,189,070	5,266	39,127	202,209	251,118	662,503	−411,385	10.27
Argeles	2,123,191	1,695,092	0	94,754	316,016	428,099	317,463	110,636	20.16
Nicosia	20,707,340	14,384,426	8,500	517,954	5,788,215	6,314,414	3,331,144	2,983,270	30.49
Larissa	17,770,139	11,687,062	0	1,066,208	4,245,809	6,083,077	1,820,537	4,262,540	34.23
Kos	3,100,180	1,942,506	0	186,011	905,618	1,157,675	159,624	998,050	37.34
Baho	220,159	107,424	0	7,573	103,300	112,735	61,649	51,086	51.21
Thuir	1,006,355	438,588	35,107	11,300	518,705	532,660	85,245	447,415	52.93
Kozani	5,688,642	2,212,474	156,827	293,816	2,944,752	3,319,341	2,311,834	1,007,507	58.35

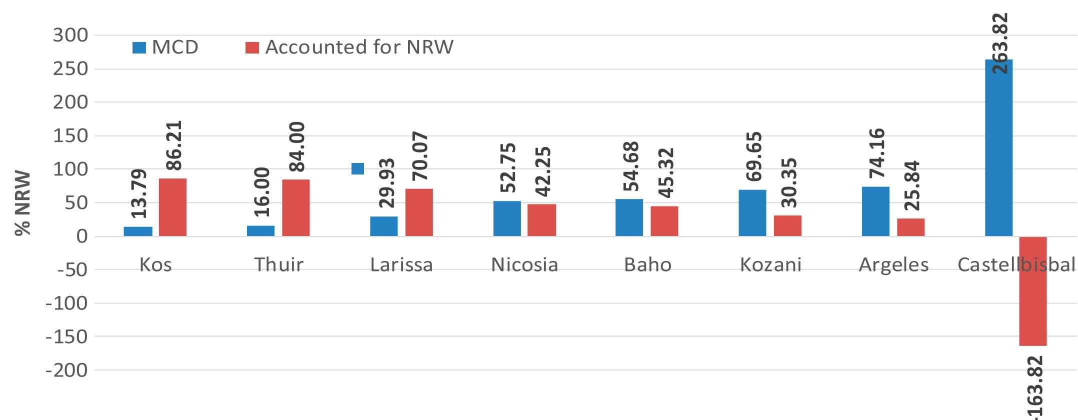

Fig. 3. MCD and accounted-for-NRW levels for the eight cases as % of NRW.

values are quite high in all cases. Kozani experiences the highest NRW values (58.35%) of SIV, followed by Thuir (52.93%) and Baho (51.21%) while Castellbisbal experiences the lowest NRW values (10.27%) followed by Argeles-sur-mer (20.16%) (Table 5).

The estimation of the 2nd modified WB highlighted a new element: the Accounted-for-NRW. This is the actual NRW value water utility managers perceive for their systems. The Accounted-for-NRW is MCD reduced by the NRW value. This is the actual reason water operators do nothing to reduce the NRW level in their networks. It must be noted that the initial calculations considered the whole fixed charge as MCD and not only its water consumption dependent part. The results for all four cases revealed that the MCD is a big part of the NRW resulting in lower accounted-for-NRW values (Fig. 3). The highest MCD values (%NRW) appear in Castellbisbal (263.82%) followed by Argeles-sur-mer (74.16%) while the lowest ones are met in Kos (13.79%) and Thuir (16%) (Fig. 3). It is worth-noting that in Castellbisbal case the MCD is 2.6 times the NRW meaning that the water utility recovers more than the whole NRW-related lost revenues through the fixed charge.

The final outcome is that water utility managers underestimate the actual NRW levels since they recover part of the NRW. This can be seen in the eight cases studied (Fig. 4). While the NRW level in Kozani is 58.35% of the SIV the water utility considers it to be only 17.7% of the SIV underestimating it by 70%! The underestimation of NRW ranges from 13.79% (Kos) to 263.8% (Castellbisbal) showing the significance of the MCD when estimating the WB (Fig. 4). It is evident that when the fixed charge is expressed in minimum money charge, the NRW faulty perception gets even bigger. The results revealed beyond any doubt why water utilities (like Kozani case) do not apply any NRW reduction policy!

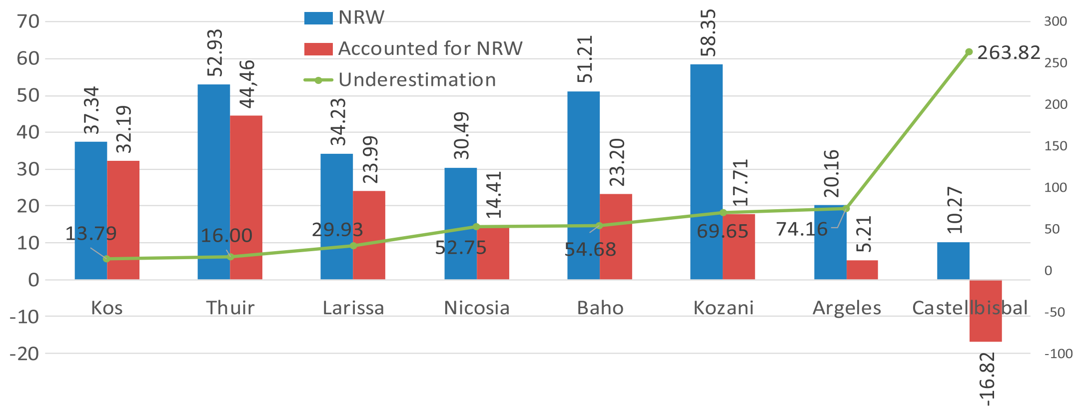

Fig. 4. NRW, accounted-for-NRW and underestimation of NRW levels for the eight cases as % of SIV.

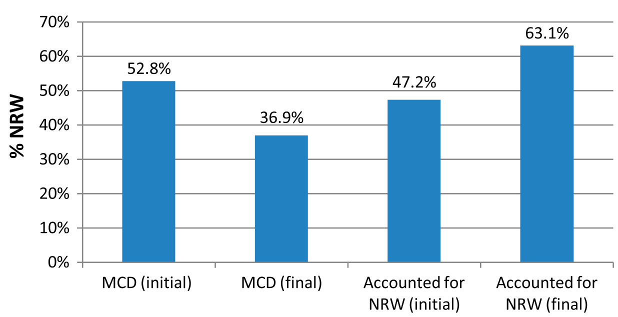

Fig. 5. Accounted-for-NRW values initially and finally estimated for Nicosia.

In all eight cases, the MCD estimation reflects all the fixed charge existing in the water bills. There is no discrimination between the costs depending on the water consumption from those that do not, due to the unavailability of respective data from the water utilities. On the contrary, the estimation of the MCD element in Nicosia case takes into consideration only the costs depending on water consumption and not the whole fixed charge. While the whole fixed charge is estimated to correspond to 3,331,144 m^3 (30% of the total), the actual MCD is 2,331,801 m^3 (70% of the total) for 2010 (Fig. 5). Thus, the Accounted-for-NRW value is increased only by 30%.

6. Conclusions

NRW has both environmental (water resources exploitation, energy consumption, carbon footprint) and economic (revenues losses) impacts and it is worth noting that water operators do nothing to confront it although they are aware of its existence. An analysis of the fixed charge as a part of the water bill justifies this weird behavior as a significant part of the water losses related revenues are recovered through the fixed charge. The fixed charge included in the water bills should be used to guarantee that water utilities will recover the revenues related to the opportunity cost the consumers have to pay for the opportunity of having good quality water at adequate quantity and pressure at their taps. A common practice followed by the mayors (most of the times) is to try to persuade the citizens that the water price charged is low, while the fixed charge is used as a means to fully balance the utilities' expenses. The major part of these expenses are due to operational practices followed the day-to-day operation of the networks. However this practice is not socially fair. To verify the role of the fixed charge the present paper presents a novel, detailed methodology to calculate the MCD element presented in the 2nd modification of the IWA WB. The 2nd modification of the WB is a useful tool used to estimate not only the NRW components but also the MCD and the Accounted for NRW values. This approach provides to the water operators the actual value of the NRW and all the necessary information they need in order to take the right decisions. To verify the argument that although NRW values are high but most of it is recovered through the fixed charge, eight cases from four countries (Greece, Cyprus, France and Spain) are analyzed. The underestimation of the actual NRW value due to the fixed charge ranges from 13.8 to 263.8%!

The paper's novelty has also to do with the presentation of an innovative methodology allocating the responsibility of "who has to pay" for each kind of water use described at the WB in a socially fair way. The responsibility is allocated between the consumers and the water utility operating the network. A socially fair allocation (according to the specific example used) requires that consumers should pay for the 87.4% of the SIV when their actual water use is 60%. This means that the water price will be decreased by 12.6% since according to the predominant practice the utility charges the consumers for the whole 100% of the SIV, instead of the 87.4%. The design of a socially fair tariff system includes a fixed charge equivalent to the opportunity cost and an adjusted water price including the water use allocated to the consumers. The final step is to develop a water tariff system based on the principle of social fairness.

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