Desalination and Water Treatment
www.deswater.com

doi: 10.5004/dwt.2017.21552

99 (2017) 72–82
December

Socially fair drinking water pricing considering the full water cost recovery principle and the non-revenue water related cost allocation to the end users

S. Tsitsifli[a,*], K. Gonelas[a], A. Papadopoulou[a], V. Kanakoudis[a], C. Kouziakis[b], S. Lappos[b]

[a]*Department of Civil Engineering, University of Thessaly, GR-38334 Volos, Greece, Tel./Fax: +30 24210 74156; email: tsitsifli@uth.gr (S. Tsitsifli)*
[b]*Municipal Water and Wastewater Utility of Kozani (DEYAK), GR-50100 Kozani, Greece*

Received 30 January 2017; Accepted 15 March 2017

ABSTRACT

Drinking water pricing policies differ a lot among different countries and among water utilities in the same country. The criteria to form a pricing policy are determined locally and sometimes are related to political decisions, especially in municipal water utilities. Drinking water pricing policies do not take into consideration environmental (e.g., river basin water balance) or economic issues (e.g., socially fair allocation of the water cost). However, the Water Framework Directive (WFD) 2000/60/EC clearly requires that all member states should develop and apply water pricing policies to recover the full water cost (FWC; including the direct cost, the environmental cost and the water resource cost). The paper applies a novel methodology to determine the socially fair water price based on the FWC recovery principle and taking into consideration non-revenue water, allocating its cost to the water users. The methodology is applied in Kozani (Greece) water distribution network.

Keywords: Water price; Full water cost; Water Framework Directive; Socially fair water pricing policy

1. Introduction

Efficient and sustainable water systems management toward worth living development contributes to social, economical and environmental balance, in a global level. With this respect, the Water Framework Directive (WFD) 2000/60/EC has established an institutional framework, providing guidance for common approach, objectives and shared principles regarding water resources and water supply management, in a European level. WFD requires all member state countries to develop and establish water pricing allowing full water cost (FWC) recovery, including direct cost (DC), environmental cost (EC) and resource cost (RC). As water pricing is a crucial issue for decision makers, water utilities and consumers, it is imperative that socially fair prices should be set, especially for drinking water. It is a fact that water pricing policies differ a lot not only among different countries but also within the same country among 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 [1]. Tariffs' structures in most European countries include a fixed charge whose value varies a lot. It is a fact that there is a significant water volume not generating revenues (non-revenue water – NRW) consisting of free provision of water from the water utility, commercial (apparent) and real losses. Usually water utilities transfer NRW cost to the customers adjusting the water price, which is not a socially fair policy. Until now there is no methodological framework to estimate a socially fair water price taking into consideration the FWC

* Corresponding author.

Presented at the conference on Efficient and Sustainable Water Systems Management toward Worth Living Development, 2nd EWaS 2016, Chania, Greece, June 1–4, 2016.

1944-3994/1944-3986

and the socially fair NRW cost allocation to the water users. The paper presents such a methodology allocating different water uses (consumers' water use, water theft, meter errors, real losses, etc.) to the two basic water users: the consumers and the water distribution network (WDN) and taking into consideration the FWC recovery principle. A new higher mean water price is estimated tending to fluctuate due to the water price elasticity of demand. Finally, the optimum mean water price is found by simulating its fluctuations.

This paper includes a review on drinking water costs and prices in countries around the word, following the presentation of the methodology developed by the authors to estimate the socially fair average water price in a water utility. The methodology is then tested in a Greek water utility.

2. Literature review: drinking water cost and pricing policies

2.1. The full water cost concept

The WFD 2000/60/EC obliged EU Member States to estimate the full cost of water services and the level of its recovery and set the objective of "good status" for European water bodies by 2015. The innovative feature of the WFD lies on the fact that it defines the river basin as the basic spatial and environmental framework for estimating EC and RC regarding the water sector. WFD is governed by the "principle of sustainability", the "polluter pays principle" and the "principle of proportionality". The FWC comprises of three components, the direct cost (DC), the EC and the RC. In urban water supply systems, the DC includes operating and maintenance costs of the water network, and the capital costs of water utilities. The organizational structure of the company, education and productivity of its staff and the infrastructure and operational level of the water system are considered as important factors in shaping DC. The specific costs included in DC are: (a) annual equivalent capital costs; (b) operating and maintenance costs and (c) administrative and other costs [2].

The EC reflects the environmental damage caused by the construction of the system infrastructure and increase of water use. This environmental damage is caused directly to the environment and indirectly to the users [3]. Environmental damage during human activities is caused when their results decrease the level of environmental quality [2]. Many EU states are far from achieving the objective of "good status" for water bodies and proposed solutions such as better coordination of Member States in fields like agriculture, energy generation, transport and production or use of chemicals [4]. It also became clear that the RC and EC are not included in many cases in the implementation of mitigation measures of the FWC recovery [5]. Crucial role in determining the size of the EC has the comparison of past environmental damage financial results, to extract some proportionality to be used as an assessment measure [6]. The focus on existing charges and payments [7] serves as an evaluation of the EC rate that has been recovered. There is a debate about whether the existing environmental charges are unreliable, while the values of environmental taxes vary widely across German states [8]. The assessment of the ECs may also take place by using a number of alternative methods, such as market price method, method of production function, etc.

RC is defined in areas affected by drought, as there are other water users suffering from lost earnings because water is abstracted beyond renewable reserves of water resources [9]. In many countries of Central and Northern Europe not facing water shortages, the above definition is not sufficient. Another interpretation states that the RC occurs when water is not consumed by its optimal use (in water scarcity), while there are alternative uses that can yield higher profits [7]. Then, RC is estimated as a result of economic misallocation of water use. In countries with water scarcity problems both definitions exist, and the overall RC includes both components [3].

In many cases, the EC and the RC have been incorporated by water utilities and are considered as DC. According to the WFD, these costs should be clarified and incorporated to EC and RC. The proper separation of FWC in its components will lead to the correct FWC and therefore to the proper full water pricing.

The estimation of the three FWC components is expected to increase the current cost of water but may also cause a reallocation of costs between the components. For example, costs considered today as DCs, such as energy costs, can ultimately be RCs due to groundwater over-pumping by farmers. Thus, this kind of cost should be paid by them. The water costs should be estimated on a monthly step as they depend on many different variables, such as seasonal water consumption, water abstraction sources (springs, boreholes), energy costs, etc. The WDN should be considered as a distinct water user and the costs due to poor WDN management should be estimated. Poor water pressure management and non-implementation of NRW reduction strategies reflect to high revenue loss and increased water price for the consumers. The estimation of economic annual real losses (EARL) which is the optimal economic level of leakage will act as a guide for implementing NRW reduction strategies which should reduce the FWC. In the long run the correct FWC estimation, the application of the "polluter pays principle", the implementation of NRW reduction measures and the application of the full water pricing will result into system's sustainable balance.

2.2. Drinking water pricing policies

In a European level, several member states have completed (fully or partially) the development of appropriate water pricing policies according to WFD 2000/60/EC toward the implementation of FWC recovery. More specifically, 25 out of the 27 except from Portugal and Greece have completed this obligation [10]. In Greece, the implementation of the WFD 2000/60/EC requirements is being monitored by following the implementation of 14 River Basin Management Plans (RBMPs), highlighting problems occurred and weaknesses identified. The Greek government launched in June 2016 the 14 RBMPs (1st revision) public consultation process, along with the draft Joint Ministerial Decision (JMD) regarding the "Adoption of general water pricing rules and services, methods and procedures for full water cost recovery in several water uses". This JMD is called to incorporate WFD 2000/60/EC requirements, covering all uses of water, including methodologies and tools for the estimation of FWC, including continuous monitoring and gradual improvement measures of public water services, along with guidelines for a socially fair water pricing policy.

Regarding, the level of EC and RC integration into pricing policies through economic instruments varies not only by Member State [11], but also by region or River Basin District [12]. The price of water and wastewater prices per household differs also between Member States (Fig. 1). In Switzerland, for example, is almost five times higher than in Bulgaria. One of the basic parameters is the differences in GDP between countries. The International Benchmarking Network for Water and Sanitation Utilities (IBNET) indicates the differences in water tariffs in a global level. The provision of comparative information and its use in benchmarking is an important management tool for managers and professionals in water and sanitation utilities [13].

Even in more developed countries, the price of water differs by region, partly because of structural differences and partly due to political and strategic differences. A comparative analysis of water tariffs based on a consumption of 15 m^3 per month (average tariffs per country weighted by population served) taking into consideration the GDP per capita (Gross Domestic Product, World Bank) of several countries also highlights the differences, in four regions globally (Fig. 1 and Table 1). The value per year per GDP is calculated by taking into consideration a monthly consumption of 15 m^3. It should be mentioned that the price of water in some countries is about a hundred times more expensive than others (i.e., South Korea comparing with Cape Verde).

The type of charging differs also in several countries. In Denmark, for instance, a number of water utilities have chosen to charge a fixed annual charge for water and/or wastewater and a price per cubic meter for water consumed, while others charge only for the water used [11]. Additionally, although water pricing structures in selected European countries (England and Wales, Scotland, Netherlands, France, Germany, Slovenia, Croatia, Serbia, Spain) are a combination of fixed and volumetric charge [12], in a number of OECD (Organisation for Economic Co-operation and Development) countries, the structure of prices for public water services are volumetric oriented rather than fixed charging [14]. In Greece, a fixed charge is also used additionally to a volumetric water pricing model. On the other hand, several countries such as Hungary, Poland and Czech Republic have already adopted water pricing policies only based on volumetric pricing with a trend in moving toward increasing block tariffs (Table 2).

A recent study [15] showed that there is no common pricing policy between the Greek water utilities. Each water utility charges different fees and tariffs to their water bills. The mean payable amount does not display great variation between low and high consumption while high consumption and water wasting are not discouraged [15].

Looking at the nexus between all specific parameters, reliable metering systems of water consumption are also a precondition for the application of efficient water pricing policies. Safeguarding both transparency and fairness of water pricing policies based on reliable water metering and improved cost-benefit assessments to ensure cost-recovery is one of the basic principles of the EC.

In conclusion, the development of "appropriate water tariffs" is influenced by a number of factors, such as local characteristics, different geological and climatic parameters and different institutional and regulatory framework [15]. With this respect, water utilities should adopt a more strategic approach that could be cost-effective and could be used to signal water scarcity and to create incentives for efficient domestic water use. The overall objective is to implement an appropriate water pricing policy in Greece, better designed tariff structures and targeted measures, to implement the EU guideline regarding FWC recovery.

3. Determining a socially fair drinking water pricing policy

3.1. The socially fair fixed charge

To determine a socially fair drinking water pricing policy, several principles must be met. In countries facing water

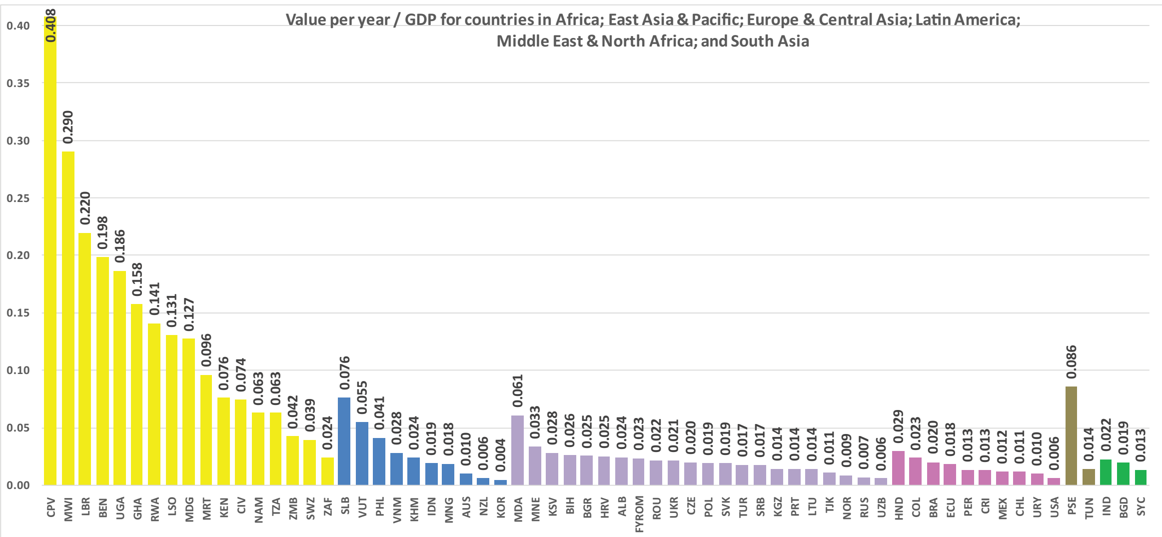

Fig. 1. Drinking water tariffs in relation to GDP for a 15 m^3 monthly water use for the year 2015 (average tariffs per country weighted by population served). (The colors refer to: Africa; East Asia and Pacific; Europe and Central Asia; Latin America; Middle East and North Africa; and South Asia. Country acronyms are given in Table 1.)

Table 1
Drinking water tariffs in relation to GDP for a 15 m³ monthly water use (year: 2015)

Region	Country	Acronym	Value (€)	Value per year (€)	GDP (€)	Value per year/GDP
Africa	Cape Verde	CPV	6.40	1,152.00	2,825.63	0.408
	Namibia	NAM	1.49	268.20	4,287.34	0.063
	Ghana	GHA	1.10	198.00	1,256.51	0.158
	South Africa	ZAF	0.69	124.20	5,250.94	0.024
	Benin	BEN	0.77	138.60	699.08	0.198
	Lesotho	LSO	0.71	127.80	978.81	0.131
	Uganda	UGA	0.67	120.60	647.01	0.186
	Mauritania	MRT	0.67	120.60	1,257.69	0.096
	Swaziland	SWZ	0.64	115.20	2,935.68	0.039
	Kenya	KEN	0.53	95.40	1,262.94	0.076
	Cote d'Ivoire	CIV	0.53	95.40	1,283.38	0.074
	Liberia	LBR	0.51	91.80	418.20	0.220
	Rwanda	RWA	0.50	90.00	639.72	0.141
	Malawi	MWI	0.55	99.00	341.24	0.290
	Tanzania	TZA	0.28	50.40	806.34	0.063
	Zambia	ZMB	0.28	50.40	1,197.04	0.042
	Madagascar	MDG	0.26	46.80	368.63	0.127
East Asia and Pacific	New Zealand	NZL	1.12	201.60	34,683.50	0.006
	Australia	AUS	2.76	496.80	51,657.41	0.010
	Vanuatu	VUT	0.78	140.40	2,573.48	0.055
	Solomon Islands	SLB	0.75	135.00	1,774.96	0.076
	Philippines	PHL	0.61	109.80	2,664.20	0.041
	South Korea	KOR	0.60	108.00	24,971.93	0.004
	Indonesia	IDN	0.32	57.60	3,069.93	0.019
	Mongolia	MNG	0.37	66.60	3,639.93	0.018
	Vietnam	VNM	0.30	54.00	1,936.67	0.028
	Cambodia	KHM	0.14	25.20	1,062.94	0.024
Europe and Central Asia	Norway	NOR	3.24	583.20	68,251.90	0.009
	Czech Republic	CZE	1.76	316.80	16,098.14	0.020
	Croatia	HRV	1.46	262.80	10,582.50	0.025
	Portugal	PRT	1.36	244.80	17,633.62	0.014
	Slovakia	SVK	1.53	275.40	14,758.74	0.019
	Montenegro	MNE	1.08	194.40	5,876.67	0.033
	Poland	POL	1.20	216.00	11,517.04	0.019
	Lithuania	LTU	0.99	178.20	12,977.93	0.014
	Romania	ROU	0.99	178.20	8,231.40	0.022
	Bulgaria	BGR	0.89	160.20	6,415.53	0.025
	Turkey	TUR	0.81	145.80	8,371.54	0.017
	Moldova	MDA	0.57	102.60	1,695.34	0.061
	Bosnia and Herzegovina	BIH	0.56	100.80	3,898.16	0.026
	Fyrom	FYROM	0.57	102.60	4,451.63	0.023
	Kosovo	KSV	0.51	91.80	3,267.24	0.028
	Albania	ALB	0.48	86.40	3,619.18	0.024
	Serbia	SRB	0.46	82.80	4,802.51	0.017
	Russia	RUS	0.31	55.80	8,341.17	0.007
	Ukraine	UKR	0.23	41.40	1,940.17	0.021
	Kyrgyz Republic	KGZ	0.08	14.40	1,012.05	0.014

(Continued)

Table 1 *(Continued)*

Region	Country	Acronym	Value (€)	Value per year (€)	GDP (€)	Value per year/GDP
	Uzbekistan	UZB	0.06	10.80	1,955.88	0.006
	Tajikistan	TJK	0.05	9.00	849.39	0.011
Latin America	United States	USA	1.66	298.80	51,478.30	0.006
	Chile	CHL	0.78	140.40	12,307.51	0.011
	Uruguay	URY	0.77	138.60	14,286.87	0.010
	Brazil	BRA	0.87	156.60	7,832.96	0.020
	Costa Rica	CRI	0.74	133.20	10,329.55	0.013
	Ecuador	ECU	0.57	102.60	5,692.28	0.018
	Colombia	COL	0.72	129.60	5,555.67	0.023
	Honduras	HND	0.38	68.40	2,319.90	0.029
	Mexico	MEX	0.53	95.40	8,260.85	0.012
	Peru	PER	0.40	72.00	5,529.04	0.013
Middle East and North Africa	West Bank and Gaza	PSE	1.25	225.00	2,629.89	0.086
	Tunisia	TUN	0.27	48.60	3,552.49	0.014
South Asia	Seychelles	SYC	1.02	183.60	14,197.08	0.013
	India	IND	0.18	32.40	1,466.18	0.022
	Bangladesh	BGD	0.12	21.60	1,111.57	0.019

Table 2
Type of water and wastewater charging in several countries

Country	Type of charging
Denmark	(a) Fixed annual charge for water and/or wastewater and a price per cubic meter for water consumed (b) Volumetric charge
England and Wales, Scotland, Netherlands, France, Germany, Slovenia, Croatia, Serbia, Spain, Greece, Bulgaria, Romania, Portugal, Italy, Norway, Belgium, Sweden, Austria, Cyprus, Switzerland	Combination of fixed and volumetric charge
Hungary, Poland and Czech Republic	Volumetric charge with a trend in moving toward increasing block tariffs

scarcity conditions, water pricing should follow an inclining block rates' policy to discourage excessive water consumption. Such water pricing policies include a fixed charge and inclining rates for water consumption blocks. The determination of the fixed charge is not an easy task. 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 [16]. The socially fair fixed charge should only include the fixed 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.). Fixed costs (proportionally) related to the water volume each customer consumes, such as water mains' (and not service pipes) repair costs, pipes and tanks washing costs, etc., 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 [16].

3.2. The socially fair water use allocation

Then, the FWC should be allocated to the water users, which in a WDN are the consumers (domestic, commercial, industrial, etc.) and the water utility as the water networks suffer from water losses (and NRW). The current water pricing policies charge the whole NRW cost to the consumers, which are not a socially fair practice, as the consumers are not responsible for all this cost. For example, if a water distribution system experiences a NRW level of 50% of the system input volume (SIV), the water utility will charge twice the price of water to recover the cost of the NRW. Thus, to estimate the socially fair water price, the NRW cost should be allocated among water users. Kanakoudis and Tsitsifli [16] developed such a methodology, allocating the water volumes included in the water balance to the user who is responsible for them (Table 3). Thus, the consumer has to pay for the actual water he consumes, that is revenue water (Q_{RW}); he has to pay for the unbilled consumption (Q_{UNB}) including washing the mains and the tanks, firefighting, public buildings' consumption, etc., as all these

Table 3
Responsibility allocation of water cost recovery [16]

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}	Q_{RW}	Q_{RW}	Q_{RW}	√	–
	Q_{NRW}	Q_{UNB}	Q_{UNB}	√	–
		Q_{AL}	Q_{WTH}	–	√
			Q_{MER}	√	–
			Q_{RER}	–	√
		Q_{RL}	$Q_{CARL\text{-}EARL}$	–	√
			$Q_{EARL\text{-}UARL}$	√a%	√(1 – a)%
			$Q_{UARL\text{-}UARLopt}$	–	√
			$Q_{UARLopt}$	√	–

consumptions aim at the consumers' quality of life improvement and provide services to him; water meter errors (Q_{MER}) as this water volume is actually consumed (also including in house leakage); the optimum level of the unavoidable real losses ($Q_{UARLopt}$) as they represent the opportunity cost. The role of the WDN is to serve the users with water at their taps. The consumer has to also pay for a part of the difference between the unavoidable real losses and the economic ones ($Q_{EARL\text{-}UARL}$), proportionate to the part of the water volume entering the network that the customer consumes. The water volume between the unavoidable and the economic real losses ($Q_{EARL\text{-}UARL}$) can be recovered using technical solutions but it is not economically effective since the recovery cost is higher than 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 [16]. The consumers consume a% of the water entering the system (SIV).

The water utility (as the WDN is one of the water users) has to pay for (Table 3) the water volume lost due to recording errors (Q_{RER}) since it is the utility's responsibility to record and transfer correctly the water meter recordings; the water volume consumed illegally (Q_{WTH}), for example, water theft, illegal connections, etc., as it is the utility's responsibility to perform audits and impose measures to avoid unauthorized uses; the difference between the current level of real losses and the economic ones ($Q_{CARL\text{-}EARL}$) as a kind of penalty because of the bad infrastructure and the fact that the utility does not implement any water losses reduction measures; all the difference between the unavoidable level of real losses and their optimum ones $Q_{UARL\text{-}UARLopt}$, as 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; and finally 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 ($Q_{EARL\text{-}UARL}$) [16].

3.3. *Estimating the socially fair water price*

A five-step methodology has been developed by the authors to estimate the socially fair water price for drinking water [17]:

- Estimate the FWC and its three components.
- Estimate the unit water cost (UWC or WP_0) based on the FWC recovery (Eq. (1)):

$$\mathrm{UWC} = \mathrm{WP}_0 = \frac{\mathrm{FWC}}{\mathrm{SIV}} \tag{1}$$

where UWC and WP_0 both represent the unit water cost; FWC is the full water cost (€) and SIV is the system input volume, that is the water volume entering the network (m^3).
- The unit water cost estimated using Eq. (1) is the average unit water cost if the whole SIV was sold to the consumers. As only a part of the SIV is sold to the consumers (and this is the revenue water [RW]), then a new unit water cost must be calculated. The new unit water cost (WP_A) is estimated by charging the whole cost to the consumers based on their consumption. If RW is b% of the SIV, then the unit water cost the consumers will pay is as follows:

$$\mathrm{WP}_A = \frac{\mathrm{FWC}}{\mathrm{SIV}}\frac{1}{b} = \mathrm{WP}_0\frac{1}{b} \tag{2}$$

- Estimate and allocate the responsibility among the water users based on the methodology described in section 3.2 [16]. Based on this methodology, it is socially fair that the consumers will pay a% of the SIV (as estimated in Table 3).
- Estimate the socially fair average water price, WP_1 (Eq. (3)):

$$\mathrm{WP}_1 = \frac{a}{b}\mathrm{WP}_0 \tag{3}$$

4. Estimating the socially fair water price in Kozani, Greece

4.1. *Kozani case study – current pricing policy*

Kozani is the capital city of the Kozani Regional Unit in North-Western Greece (region of Western Macedonia) with a population of approximately 71,000 people (according to the 2011 census). Kozani drinking water supply network consists of the water recourses, water pumping and transfer units, the water transfer mains and the distribution network. The municipal water utility responsible for drinking water and sewerage is DEYAK. The company's services include the operation, maintenance, construction and administration of water and sewerage network of the Municipality of Kozani. In 1995, the planning, construction, maintenance, administration and operation services related to the remote heating system were added to the day-to-day responsibilities of DEYAK [18]. Kozani WDN is supplied from "Ermakia" natural resources (since 1992) and two groups of boreholes in Vathylakkos. There are five tanks used to collect and distribute the water into the city and the districts of Kozani. DEYAK customers are being served through 28,281 water meters and 9,150 service connections [18]. The WDN of Kozani town has a total length of 129,584.4 m consisting of PVC, asbestos cement and HDPE pipelines. Water supply needs for the city were 5,535,078 m^3 in 2009; 5,688,642 m^3 in 2010 and 5,844,632 m^3 in 2011, presenting a small increase from year to year.

The case study selected to estimate the socially fair water price is the entire WDN of the city of Kozani (47,000 people) without the municipal districts. The billing period is 4 months, while a fixed charge of 17€/4 months is included in the inclining block tariffs water bill (Table 4). The fixed charge is being charged regardless the consumption. DEYAK faces high NRW values. The actual DEYAKs water pricing tariffs are separated by type of consumption (residential, commercial and public sector) and by certain social criteria in residential tariff, that is, social tariff for families with more than three children, patients suffering from kidney diseases, etc. DEYAK total revenues are composed of: the value of water volume consumed, the fixed charge of 17€/4 months (billing period), the water meter maintenance fee of 2.06€/4 months, the special fee which is equal to 80% of the water value and the sewerage charge which is equal to 85% of the water value. The public sector bills do not include the special fee and the sewerage charge (Table 4). Table 4 presents the current structure of the DEYAKs water pricing policy. It must be noted that all calculations refer only to the net revenues excluding value added tax (VAT).

The analysis of the current pricing policy (base year 2014) resulted in the following outcomes: (a) domestic consumption is 88.31% of the total consumption, while domestic water meters represent 96.5% of the total water meters and the revenues derived from the domestic consumption represent 87.88% of the total revenues (Fig. 2); (b) 10.83% of the total domestic water meters do not register any consumption and (c) the value of water represents only 22.99% of the total domestic revenues derived from the pricing policy (Fig. 3) while 34.85% of the total domestic revenues derive from the fixed charge; 18.39% from the special charge; 19.54% from the sewerage charge and 4.22% from the water meter connection charge (Fig. 3). Other water bill categories represent small parts of the water consumption and the water revenues. Commercial water consumption represents 4.92% of the total, public water consumption represents 3.73% of the total and 2.94% of the total water is consumed by families with four and more children (Fig. 2). Water revenues coming from commercial water consumption represent 5.95% of the total water revenues and 3.82% of the total water revenues come from the public consumers (Fig. 2). Multi-child families contribute with 2.29% to the total water revenues. The social domestic category contributes very little as it only consumes 0.11% of the total water consumption (Fig. 2).

4.2. Estimating the full water cost for Kozani water distribution network

For the FWC estimation, the total urban water supply system was deconstructed into seven sub-systems: water abstraction, supply, raw water treatment, storage, distribution, sewage water treatment and administration. The actual DC was estimated for each of its 14 (11 operation and

Table 4
Drinking water pricing policy for Kozani city (2014)

Residential		Multi-child families		Social tariff		Commercial tariff		Public sector tariff	
Scale (m^3)	Value (€)	Scale (m^3)	Value (€)	Scale (m^3)	Value (€)	Scale (m^3)	Value (€)	Scale (m^3)	Value (€)
0–20	0.38	0–60	0.38	0–20	0.19	0–80	0.60	0–80	1.68
21–40	0.46	61–100	0.60	21–40	0.23	81–500	0.99	81–160	1.90
41–60	0.60	101–160	1.25	41–60	0.60	>500	1.11	>160	2.12
61–80	0.76	>160	3.05	61–80	0.76				
81–100	1.01			81–100	1.01				
101–120	1.25			101–120	1.25				
121–160	1.53			121–160	1.53				
>160	3.05			>160	3.05				

Fixed charge: 17.00€/4 months
Water meter maintenance charge: 2.06€/4 months
Special fee: 80% of the water value
Sewerage charge: 85% of the water value
VAT: 13% of the water value
VAT: 23% of the fixed charge, the water meter maintenance charge, the sewerage charge and the special fee

Public sector tariff: Not subject to the special and the sewerage fee

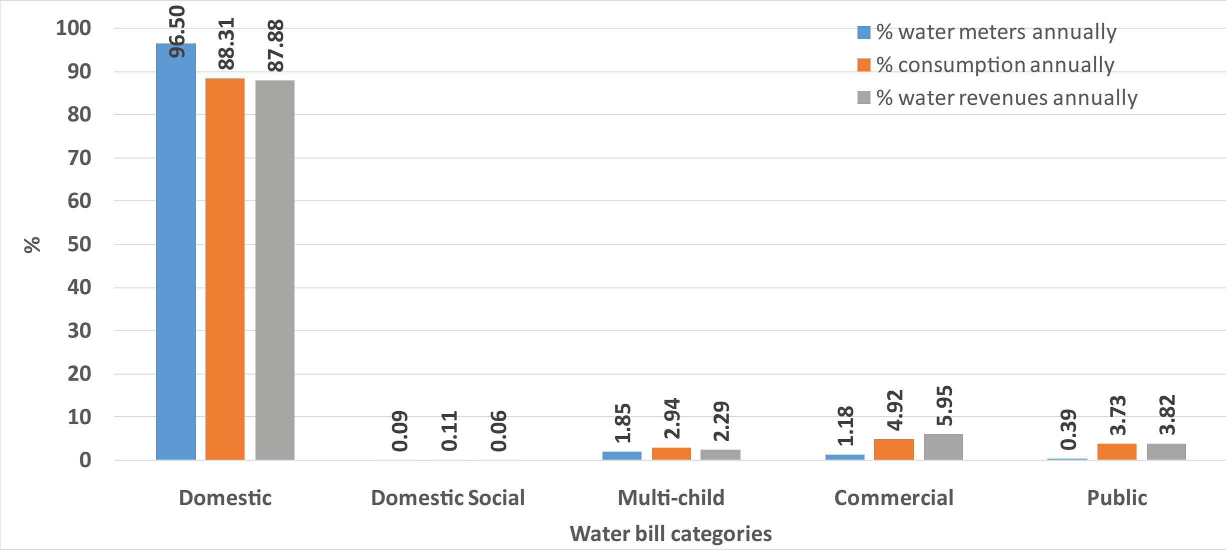

Fig. 2. Water meters, consumption and water revenues (%) for each consumption type (Kozani WDN) for 2014.

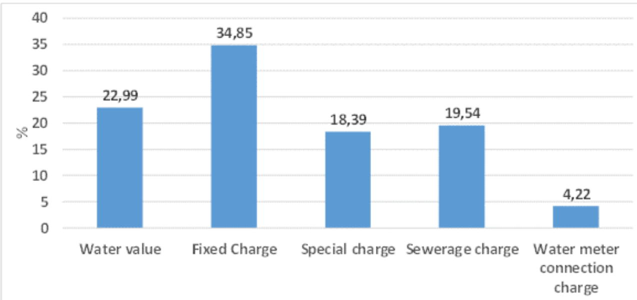

Fig. 3. Water value, fixed charge, special charge, sewerage charge and water meter connection charge values as percentage of the total domestic revenues (for Kozani town, 2014).

maintenance costs and 3 capital charges) potential parts. Each sub-system of the urban water supply system may involve any or all three FWC components. So, hidden EC and RC appeared as DC parts. For example, the wastewater treatment plant costs are not DC but EC. Trying to estimate the RC for Kozani water utility, the replacement of water abstraction points are taken into consideration. Water was initially abstracted from Ermakia springs, giving seasonal water by gravity and from wells in "Sarigkiol" area. Since 2008 new wells were drilled in "Vathylakkos" area with an increased water cost. The "Sarigkiol" area aquifer is about 10 years at least deficient of 10×10^6 m^3 due to the activity of Greek Public Power Corporation lignite mines. The problem exists as the lignite layers deposits are at greater depth than the aquifers and therefore the groundwater is first abstracted and then dropped into a small river. The groundwater layers are ruined because of the mines' extent which covers 80% of the area of the aquifer. Because of the lignite abstraction, the water utility abstracting water from the "Sarigkiol" aquifer had to plan alternative solutions and find new water resources. This resulted in increased abstraction and supply cost of abstracted water volume from "Vathylakkos" boreholes, which consist of new infrastructure's cost and the residual value of obsolete infrastructure in aquifer "Sarigkiol" which will not be depreciated. The value of the increased cost of these two urban water supply sub-systems to 1,734,711€ and represents the RC (Table 5). More specifically, the amount of 624,717.87€ is the increased depreciation cost of the new equipment due to the water abstractions in the new wells drilled in "Vathylakkos" area. The amount of 1,109,993.24€ is the higher energy cost needed for water pumping (a) because of the lower level of the new aquifer and (b) because the ground level is also lower than the wells positions in "Sarigkiol" area. EC includes the operating costs of the sewerage and wastewater treatment plant, estimated to be 3,920,819€ (Table 5), while the DC is estimated to be 4,333,134€ (Table 5). The EC and the DC are estimated based on the utility's annual balance sheet.

4.3. Estimating the socially fair water price for Kozani

The second step of the proposed methodology is to estimate the average unit water cost. Before estimating the following steps of the methodology, the IWA Standard International Water Balance is estimated for the WDN of Kozani city, for 2014 (Table 6).

As the SIV (water volume entering the network) for 2014 is 5,668,529 m^3, the unit water cost is estimated as:

$$\text{UWC} = \text{WP}_0 = \frac{\text{FWC}}{\text{SIV}} = 1.762\ €/\text{m}^3 \tag{4}$$

Given that b% is the RW as percentage of SIV, the new unit water cost (WPA) by charging the whole cost to the consumers based on their consumption is as follows:

$$\text{WP}_A = \frac{\text{FWC}}{\text{SIV}}\frac{1}{b} = 4.389\ €/\text{m}^3 \tag{5}$$

The responsibility allocation and the estimation of the consumers' percentage of responsibility are done for Kozani

Table 5
The three FWC components of the seven water supply sub-systems

Water supply sub-systems	Costs (€)			
	DC	RC	EC	Total
Abstraction	533,813.64	624,717.87	0.00	1,158,531.51
Supply	834,301.22	1,109,993.24	0.00	1,944,294.46
Storage	105,754.94	0.00	0.00	105,754.94
Raw water treatment	2,223.39	0.00	0.00	2,223.39
Distribution	2,082,841.77	0.00	0.00	2,082,841.77
Sewage water treatment	0.00	0.00	3,920,819.45	3,920,819.45
Administration	774,199.24	0.00	0.00	774,199.24
Total	4,333,134.20	1,734,711.11	3,920,819.45	9,988,664.76

Table 6
The IWA International Standard Water Balance for Kozani city (2014)

<table>
<tr><td rowspan="7">System input volume
5,668,529</td><td rowspan="4">Authorized water use
2,389,371</td><td rowspan="2">Billed authorized water use
2,276,000</td><td>Billed metered water use
2,276,000</td><td rowspan="2">Revenue water
2,276,000</td></tr>
<tr><td>Billed unmetered water use
0</td></tr>
<tr><td rowspan="2">Unbilled authorized water use
113,371</td><td>Unbilled metered water use
0</td><td rowspan="5">Non-revenue water (NRW)
3,392,529</td></tr>
<tr><td>Unbilled unmetered water use
113,371</td></tr>
<tr><td rowspan="3">Water losses
3,279,158</td><td rowspan="2">Apparent losses
284,285</td><td>Unauthorized water use
56,685</td></tr>
<tr><td>Meter and metering errors
227,600</td></tr>
<tr><td colspan="2">Real losses
2,994,873</td></tr>
</table>

WDN (Table 7) based on the International Water Balance presented in Table 6. The value of a is estimated to be 59.22%. This means that consumers should pay only for 59.22% of the water volume entering the system (SIV) and not for all of it. Thus, the socially fair average water price is:

$$\mathrm{WP}_1 = \frac{a}{b}\mathrm{WP}_0 = 2.60\ €/\mathrm{m}^3 \tag{6}$$

Consequently, the new price should be 47% higher than the initial one (WP_0). The current net average price is 1.983€/m^3. The current net average price excluding the revenues derived from the fixed charge of the water meters registering zero consumption, gets to 1.90€/m^3.

However, this is not the final water price. Kanakoudis and Gonelas [19] proposed a methodology to estimate the balanced average water price, based on the water price elasticity of demand. This methodology determines the balance point between urban water uses, after the water price increase resulting from its FWC. The system's balance is disturbed because of the water price increase which will be followed by the FWC increase. Water system's demand will decrease causing lower water abstraction (and finally lower FWC) due to the elasticity of billed consumption. FWC decrease causes water price reduction and consumption increase due to the price elasticity of water demand. These repeated fluctuations have converging extremes which result in a zero step variation [19]. Thus, by simulating the application of the new water price (2.60€/m^3) to the consumers they are expected to increase their water consumption, increasing at the same time the SIV and the FWC and thus a new higher water price will be estimated. The application of a higher water price will result in reduced water consumption and so on (Fig. 4). The system balances at a new average water price of about 2.36€/m^3. However, these loops did not take into consideration any possible measures the water utility will take to reduce NRW and water losses, affecting both water price and consumption level.

5. Conclusions

It is well known that there are major differences among pricing policies in different countries but also among different water utilities in the same country. Different billing policies are also identified. As WFD requires the Member States to develop and apply appropriate pricing policies to recover the FWC, water utilities should estimate the FWC and recover it by appropriate water pricing policies. Several issues arise from this obligation. First, there are big water volumes lost in WDNs carrying a significant cost. Who has to

Table 7
Responsibility allocation of water cost recovery for Kozani WDN

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} (40.15%)	Q_{RW} (40.15%)	Q_{RW} (40.15)%	40.15%	–
	Q_{NRW} (59.85%)	Q_{UNB} (2%)	Q_{UNB} (2%)	2.00%	–
		Q_{AL} (5.02%)	Q_{WTH} (1.00%)	–	1.00%
			Q_{MER} (4.02%)	4.02%	–
			Q_{RER} (–)	–	
		Q_{RL} (52.83%)	$Q_{CARL-EARL}$ (27.30%)	–	27.30%
			$Q_{EARL-UARL}$ (15.47%)	15.47% × a%	15.47% × (1 – a)%
			$Q_{UARL-UARLopt}$ (6.17%)	–	6.17%
			$Q_{UARLopt}$ (3.89%)	3.89%	–
				50.06% + 15.47% × a%	34.47% + 15.47% × (1 – a)%

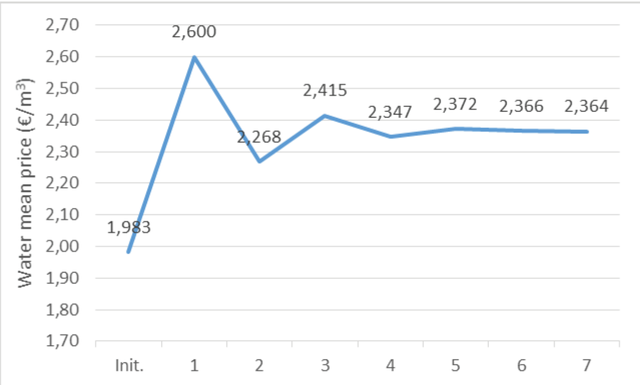

Fig. 4. Water price fluctuation.

pay for this? Second, water prices are expected to increase when the FWC will be recovered. Thus, water utilities should apply socially fair water pricing policies, as this is the only way to convince water users to pay for water services. The paper presents a novel methodological framework developing a socially fair pricing policy. This methodology is based on the FWC recovery principle and the allocation of NRW cost to the WDN's users (water consumers and the water utility). The methodology finally provides an average water price in €/m³. This methodology is applied in the WDN of Kozani city in Greece to validate it. The final average water price is derived after simulating the water price fluctuations due to the water price elasticity of demand. While the current average price is 1.983€/m³, the new average water price is 2.36€/m³. The authors have also proposed a methodology to estimate the socially fair fixed charge. Thus, the next step is to estimate the socially fair fixed charge to be applied in the pricing policy. All other charges will be eliminated. The final pricing policy will be an inclining block tariff policy with a standard fixed charge. The authors propose that the pricing policy should be updated every 3 years.

References

[1] E. Roth, Water Pricing in the WU – A Review, EEB 2001/002, 2001.

[2] WFD-CIS, Economics & the Environment – The Implementation Challenge of the Water Framework Directive (Water Framework Directive – Common Implementation Strategy), Guidance Document No. 1, European Communities, 2003, 270 p.

[3] V. Kanakoudis, K. Gonelas, Developing a methodology towards full water cost recovery in urban water pipe networks, based on the "user pays" principle, Procedia Eng., 70 (2014) 907–916.

[4] S. Richter, J. Völker, D. Borchardt, The Water Framework Directive as an approach for Integrated Water Resources Management: results from the experiences in Germany on implementation, and future perspectives, Environ. Earth Sci., 69 (2013) 719–728.

[5] J.A. Gómez-limón, J. Martin-Ortega, The economic analysis in the implementation of the Water-Framework Directive in Spain, Int. J. River Basin Manage., 11 (2013) 301–310.

[6] V. Kanakoudis, S. Tsitsifli, Water Volume vs. Revenues Oriented Water Balance Calculation for Urban Water Networks: The "Minimum Charge Difference" Component Makes a Difference! International Conference on "Water Loss 2010", IWA, Sao Paolo, Brazil, 2010.

[7] CIS-WG2 B, Drafting Group Eco 2, "Assessment of Environmental and Resource Costs in the WFD", 2004.

[8] B. Görlach, E. Interwies, Economic Valuation of Environmental and Resource Costs: The Case of Germany, International Conference on "Ecologic – Institute for International & European Environmental Policy", Berlin, Germany, 2005.

[9] Wateco, European Water Association Yearbook, Hennef, 2002.

[10] V. Kanakoudis, S. Tsitsifli, River basin management plans developed in Greece based on the WFD 2000/60/EC guidelines, Desal. Wat. Treat., 56 (2015) 1231–1239.

[11] Water in Figures, Benchmarking 2014 – Process Benchmarking and Statistics, Danish Water and Waste Water Association (DANVA), 2014.

[12] Assessment of Cost Recovery Through Water Pricing, Technical Report No. 16, European Environment Agency, 2013.

[13] Performance Benchmarking in Water and Sewerage Utilities, 2017. International Benchmarking Network for Water and Sanitation Utilities Database (IBNET). Available at: http://www.ib-net.org/ [Accessed January 2017].

[14] Pricing Water Resources and Water and Sanitation Services, Organization for Economic Co-Operation & Development, 2010.

[15] V. Kanakoudis, A. Papadopoulou, S. Tsitsifli, Domestic water pricing in Greece: mean net consumption cost versus mean payable amount, Fresenius Environ. Bull., 23 (2014) 2742–2749.

[16] V. Kanakoudis, S. Tsitsifli, Socially fair domestic water pricing: who is going to pay for the non-revenue water? Desal. Wat. Treat., 7 (2015) 11599–11609.

[17] V. Kanakoudis, S. Tsitsifli, K. Gonelas, A. Papadopoulou, C. Kouziakis, S. Lappos, Determining a socially fair drinking water pricing policy: the case of Kozani, Greece, Procedia Eng., 162 (2016) 486–493.
[18] V. Kanakoudis, S. Tsitsifli, C. Kouziakis, S. Lappos, Defining the level of the non-revenue water in the city of Kozani, Greece: is it a typical case? Desal. Wat. Treat., 54 (2015) 2170–2180.
[19] V. Kanakoudis, K. Gonelas, The optimal balance point between NRW reduction measures, full water costing and water pricing in water distribution systems. Alternative scenarios forecasting Kozani's optimal balance point, Procedia Eng., 119 (2015) 1278–1287.