DELIVERABLE 6.4

Novel Pricing Policies

PROJECT NUMBER: 619186
START DATE OF PROJECT: 01/03/2014
DURATION: 42 months

DAIAD is a research project funded by European Commission's 7th Framework Programme.

Dissemination Level	Public
Due Date of Deliverable	Month 42, 31/08/2017
Actual Submission Date	31/08/2017
Work Package	WP6, Water Demand Management
Task	Task 6.3 Pricing elasticity and novel policies
Type	Report
Approval Status	Submitted for approval
Version	1.0
Number of Pages	38
Filename	D6.4_Novel_pricing_policies.pdf

History

version	date	reason	revised by
0.1	19/07/2017	Initial Version	Christian Sartorius
0.2	03/08/2017	Multiple revisions	Christian Sartorius, Spiros Athanasiou, Ignacio Casals del Busto, Aaron Burton Anja Peters
0.3	04/08/2017	Minor revisions	Christian Sartorius
1.0	30/08/2017	Final version	Christian Sartorius

Author list

organization	name	contact information
ISI	Christian Sartorius	christian.sartorius@isi.fraunhofer.de
ISI	Anja Peters	anja.peters@isi.fraunhofer.de
AMAEM	Ignacio Casals Del Busto	ignacio.casals@aguasdealicante.es
Waterwise	Aaron Burton	aaron.burton@waterwise.org.uk
ATHENA RC	Spiros Athanasiou	spathan@imis.athena-innovation.gr

Abbreviations and Acronyms

AMAEM	Aguas Municipalizadas de Alicante E.M. (Water utility of Alicante)
VAT	Value-added tax

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1. Introduction

It is the vision of DAIAD to promote sustainable water consumption in two different ways. On the one hand, water consumers are enabled by DAIAD@home and DAIAD@know to self-monitor their water consumption through low-cost sensing technologies and, e.g., by comparing this information with consumption figures of reference groups, turn it into actionable knowledge and, eventually, into lower water use. This approach relies on the endogenous motivation of all water users and has been tested in the Trials (in WP7) and assessed in Deliverable 7.3. On the other hand, the water consumption data collected from different users and processed by DAIAD@utility can be combined with data concerning water supply and other relevant issues to enable the water utility to *react* on certain challenges, for instance an immanent water shortage (which is not uncommon in the city of Alicante during summertime).

In order to enable DAIAD@utility to support decision making in a water utility in such a way, it has to be able to explain the water consumption of the supplied people (e.g., the inhabitants of a city like Alicante) based on certain characteristics of those people and their environment. In a second step, DAIAD@utility enables predictions as to how the water consumption of those people may change in the future as a function of those characteristics. Eventually, in a third step, DAIAD@utility allows the water utility to compare alternative predictions and analyze how it can influence the conditions in such a way that the alternative preferred by the utility is also chosen by its clients. While the identification of the factors influencing water consumption (Step 1) and the prediction of water consumption (Step 2) are outlined in the Deliverables 6.2 and 6.3, this deliverable (D 6.4) covers with the third step – how different pricing policies and related measures can be used by the utility to influence the water quantities used by its customers.

In this context, it is important to recognize that, in order to be sustainable, an alternative pricing policy has to meet the following conditions. Depending on the respective circumstances, it may not be possible to reconcile all conditions to a maximum extent; in this case, a compromise has to be found.

- the pricing policy has to be **economically efficient**, i.e., in order to avoid disincentives, every user has to pay just enough to cover the cost of supplying the quantity of water used;
- it has to be **ecologically effective**, i.e., it should provide incentives not to use more water than is provided by, and can be abstracted without harming, the natural environment; and
- it must be **socially acceptable**, i.e., it should provide access to a basic volume of clean and healthy water at a price, which is affordable to everybody;
- It must be **transparent** to the water user with respect to the price and easy to handle and administer by the water supplier.

In order to identify pricing policies, which enable a utility to sustainably adjust the water volume consumed in its supply area to the conditions prevailing in just this area, we will proceed in the following steps. In Section 2, we will present alternative price schemes applied by water utilities in different parts of the world. In Section 3, it will be discussed whether, to which extent and why different elements of pricing schemes are sustainable in economic, ecological and social terms. In order to assess the actual pricing policy in Alicante, we will figure out in Section 4, which pricing elements are actually applied, what their operating conditions are and how they contribute to the sustainability of the entire scheme. Eventually (in Section 5), we will identify the remaining deficits of the pricing scheme applied in Alicante and discuss how these deficits can be eliminated by adjustments of the existing pricing scheme – by mere adaptations of the existing elements or inclusion or deletion of entire elements.

2. Alternative pricing schemes

The complexity of the pricing schemes applied by water suppliers to residential water users varies strongly and ranges from very simple tariffs to quite complicated ones. The simplest tariffs comprise either a fixed or a volumetric component, while a combination of both is most common. We begin with the discussion of those two components before addressing tariffs that are more complicated.

2.1. Single-component tariffs

2.1.1. Fixed price

Fixed price tariffs charge water users a price, which is *independent* of the quantity of water used by the respective user. It is a very simple approach insofar as there is *no need to measure* the used water volume and, in order to do so, install and maintain a respective metering system. A fixed-price water tariff builds on the assumptions that access to water is a *basic and equal right* and the quantity of water available is sufficient to serve all existing demands. The United Kingdom is a prominent example of a country, where it was common until quite recently, that water supply was not metered and a fixed price was charged (Dresner/Ekins 2006). The lack of the technical or administrative prerequisites can be a reason for applying the fixed-price approach predominantly in less developed countries (Whittington 2003).

Charging a fixed price, however, does not necessarily mean that the *same* price is charged to every user. To be exact, it was and is mostly not the individual users, but households, which serve as base for water pricing, and not all households pay necessarily the same price. In England and Wales, for instance, the owners or tenants of larger properties were assumed to use more water and be able to afford to pay a higher price. Therefore, the fixed price depends on the ratable value of their property. In Scotland, by contrast, the fixed price is based on the level of income and the related tax brackets (EEA 2013).

This argument leads to an issue we will have to discuss repeatedly in the course of this section. What is the base for applying a tariff, a household or a single individual? From the administrative point of view, it is much simpler to figure out, whether or not a house or an apartment is inhabited and water is used by all its inhabitants than to specify the exact number of people living in this house. Not only does this number change in the course of time, which would require continuous monitoring; if payments are based on the number of individuals, water users are even given the incentive to cheat and report lower than actual figures. This renders it much more difficult to refer the (not only fixed) pricing to individuals instead of households. On the other hand, as the quantity of consumed water strongly depends on the number of household members, it might be a matter of fairness that a large family pays more than a single person living under comparable circumstances.

2.1.2. Volumetric price

Fixed prices do not provide an incentive to save water or limit the volume of water used. As long as the number of users is small and water supply is plenty, this may not be a problem. In densely populated countries with limited water supply, however, it is. In this case, the wastage of water by one person goes at the expense of the other water users since it gives rise to physical water shortages or, if the supply capacity is adapted, higher (fixed) prices for all. Additionally, the over-exploitation of the natural water sources may cause far-reaching ecological problems, which again limit the room for maneuver of all actors in society, now and in the future.

In order to avoid such a wastage of resources and its negative consequences for the economy and the environment and charge more *fair* prices for the supply of water, volumetric prices were introduced by utilities in many countries. More recently and with the same intention, the European Commission required the EU member states and their water utilities in the Water Framework Directive to charge a price, which reflects the *real cost of water supply*. A first important step towards compliance with this request is the introduction of volumetric prices. Unlike in wastewater management, however, pure volumetric prices (with no fixed component) are more uncommon in water supply. Still, Poland, Hungary, Slovakia, Serbia and parts of Slovenia are among the countries, where water is priced exclusively on a volumetric base (OECD 2010, EEA 2013).

Both fixed-price and purely volumetric water tariffs, have the main advantage of being very transparent with regard to the price the water user can expect to pay. Additionally, volume-based water pricing avoids the wastage of water effectively, while it does not ensure the perfect allocation of water under all circumstances (as will be discussed in more detail in Section 3.1). In order to avoid this shortcoming, fixed and volumetric price components are combined to form more complex water tariffs.

2.2. Combined water tariffs

Combined water tariffs charge the water users a fixed price plus one or more volumetric components. Tariffs with one volumetric component charging each cubic meter of water uniformly are called single-block tariffs. Multi-block tariffs, by contrast, charge water use up to a certain volume (i.e., in the first block) at one price (per cubic meter) and volumes exceeding this first or any subsequent block at a higher price per cubic meter. This stepwise increase of the water price per volume is known as increasing block price and is preferred over a continuously increasing volumetric price because of the transparency of this price scheme to the water users.

2.2.1. Single-block tariff

Single-block tariffs are most common in countries not strongly challenged by water scarcity. In Europe, the list comprises mainly northern and central to western countries including Denmark, Finland, Sweden, Germany, France, Netherlands, Switzerland and Austria (see Table 1). Like for the fixed-price tariff, the base for charging the fixed component is mostly the meter size or, in Anglo-Saxon countries, the property value.

Table 1: Household tariff structure for drinking water supply in OECD countries in 2008

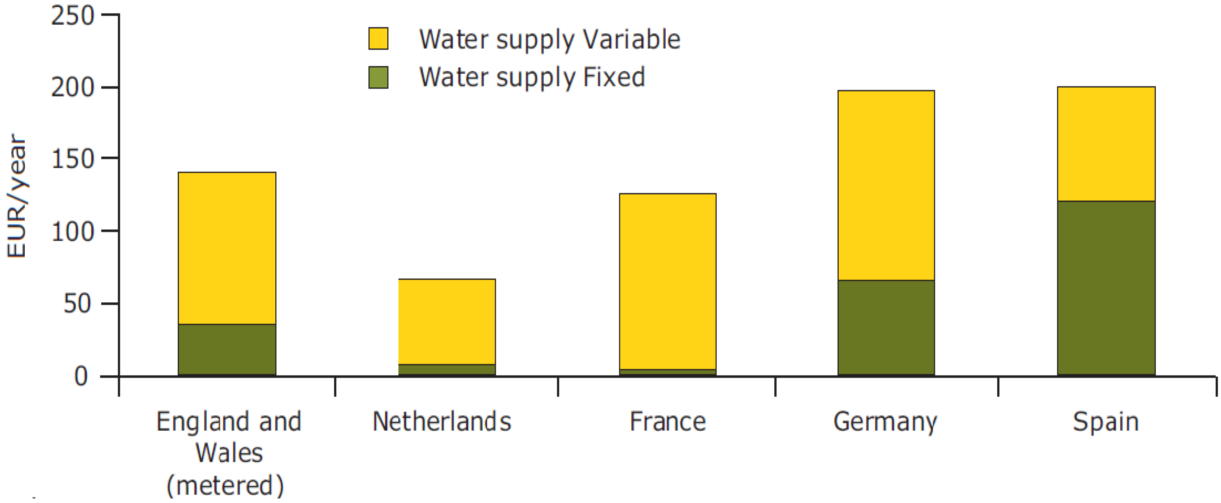
	Connection fees	Flat fee	Types of tariff structures[1] Constant volumetric			Increasing block tariffs			Fixed element base
			B1	B2	B3	C1	C2	C3	
Australia	..			x			x		..
Austria	..			o					..
Belgium									
Flanders	..						x		..
Brussels	Yes						x		..
Wallonia	Yes						x		..
Canada	Yes	x	x	x	x	x	x	x	Mainly property value
Czech Republic	Yes[2]	x	o						Pipe/meter size, user group
Denmark	Yes		x	x					Area (urban/rural)
Finland	Yes			x					Meter size
France	Yes			x					..
Germany[3]	..			x					Meter size
Greece	..			o			o		..
Hungary	Yes		o						..
Italy	Yes						x		..
Japan	..						o		..
Korea	Yes						x		Meter size
Luxembourg	..			o					..
Mexico	..						o	o	..
Netherlands	Yes			o					..
New Zealand	..			o					..
Norway[4]	Yes			o					..
Poland	..		o						..
Portugal	Yes						x		..
Slovak Republic	..		o						..
Spain	Yes						x	x	Meter size
Sweden	Yes	x	x	x	x				Meter size
Switzerland	Yes			x					..
Turkey	..		o			o			..
United Kingdom	..								..
N. Ireland	Yes	x							Property value
England and Wales		o		o					..
Scotland	..	x							Property value
United States	..		o	o		o	o		..

Notes: x = OECD 2007-08 Survey; o = GWI survey

1. Tariff types: B1 Constant volumetric with no fixed charge
   B2 Constant volumetric with fixed charge
   B3 Constant volumetric with minimum + fixed charge
   C1 Increasing block tariffs with no fixed charge
   C2 Increasing block tariffs with fixed charge
   C3 Increasing block tariffs with minimum + fixed charge
2. GWI 2008 database
3. Federal Association of German Gas and Water Industries (BGW) data
4. Kostra database

Source: OECD 2010

As can be learned from Figure 1, the proportions of the fixed and variable components of the water price differ strongly between countries. While the fixed component accounts for 10% of the total water price or even less in the Netherlands and France, its share is 60% in Spain (EEA 2013). Also remarkable are the differences in the total price of water supply, which are caused in part by the regionally specific conditions under which water is extracted, conditioned and distributed and the resulting costs. The other more relevant factor contributing to the water price is the cost share actually recovered by the water price, which can differ greatly from country to country. We will return to this point in Section 3.1.



Source: EEA (2013), adapted

Figure 1: Annual average water tariffs per household in surveyed EU member states

2.2.2. Multi-block tariffs

By definition, an increasing block price tariff includes at least two price blocks where the second block is characterized by a higher price and the lack of a volumetric limit at the upper end. Most commonly, block tariffs contain three to four blocks, while two or up to five blocks are not unusual. The application of increasing-block tariffs is motivated by the intention of the water supplier to avoid water shortages by applying higher prices in the upper block(s) and, at the same time, grant all water users inexpensive access to a basic volume of water by the application of the low-price block(s). Accordingly, multi-block tariffs are typically found in countries or regions with a higher evapo-transpiration-over-transpiration ratio (Gaudin 2006). The Mediterranean countries and the (south of the) USA are examples listed in Table 1.

Remarkably, most increasing-block prices are combined with a fixed-price component, although the latter runs counter to the intention of granting inexpensive access to a basic volume of water by means of the first block.

2.2.3. Seasonal or peak tariff

In some temporarily water-scarce countries the increasing-block tariff is further differentiated by applying an additional price increase at least to the larger-volume block(s). This seasonal or peak rate is intended to provide an additional, temporary incentive to save water especially in those seasons, when water is expected to be in short supply. It can be applied on a regular basis, in a period of the year known in advance to be problematic, or situation-dependent, when one or more scarcity indicators exceed certain predetermined levels. In Cape Town, South Africa, for instance, a long-lasting drought has forced the water supplier to introduce a double-progressive tariff with six volumetric blocks and four levels of water scarcity, which depend on the actual water level in the dam serving as water reservoir for the city. The lower the water level and the remaining usable water volume, the higher the scarcity level. And the higher the scarcity level, the progressively more expensive the water. As the progression proceeds along the volumetric blocks and the scarcity levels, the tariff is called 'double-progressive' (see Table 2; Gendries 2017). In addition to the price increases, increasing scarcity levels induce additional restrictions to water uses such as the watering of gardens or washing of cars. The actual scarcity level is communicated to the water users by means of a "Dashbord" shown on the website of the water supplier of Cape Town (2017).

Table 2: Double progressive water tariff in Cape Town (South Africa), 2016/2017, incl. VAT

Water tariff (Domestic full) Steps	Level 1 Normal tariff	Level 2 Level 2 restrictions	Level 3 Level 3 restrictions	Level 4 Level 4 restrictions
Step 1 (0 to 6 m^3)	0.00	0.00	0.00	4.56
Step 2 (>6 to 10.5 m^3)	14.89	15.68	16.54	17.75
Step 3 (>10.5 to 20 m^3)	17.41	20.02	23.54	25.97
Step 4 (>20 to 35 m^3)	25.80	32.65	40.96	43.69
Step 5 (>35 to 50 m^3)	31.86	48.93	66.41	113.99
Step 6 (>50 m^3)	42.03	93.39	200.16	302.24

Note: Water volumes are per month; 1 Rand = 0.073 € (6 March 2017)
Sources: Gendries (2017) and Cape Town (2017)

According to Calatrava et al. (2016), a more moderate and simple form of a double-progressive tariff has been introduced in Madrid: distinguishing only three blocks on the one hand and summer and the rest of the year on the other hand.

2.2.4. Social discounts

The sizes of price blocks refer usually to the metered unit, typically a household. Since the volume of water used in a household crucially depends on the number of people living in this household, it is evident that the larger the number of household members is, the more expensive will be the highest relevant price block and, thus, the average price. From a social perspective, this is counterintuitive, as larger families should not pay a higher average price than smaller families or even adults without children. Calatrava et al. (2016) provide examples for two approaches avoiding this shortcoming (see Figure 2). In one case, the sizes of the blocks are maintained, but the prices per cubic meter in each of the blocks is reduced. In the other case, the prices are kept constant, but the sizes of the blocks are increased. Depending on the progression of the prices along the blocks and the way the block sizes increase, the effect of both approaches can be quite similar in principle (i.e., lowering the average price for large families). The perception of both approaches might nevertheless be different, because in the former case, the focus lies on the larger block size, while the lower price is emphasized in the latter case. This might have implications for the quantity of water used in each of the cases.

Barcelona

Block	Euros/m^3
0 – 6 m^3	0.6188
7 – 9 m^3	1.2376
10 – 15 m^3	1.8564
16 – 18 m^3	2.4752
> 18 m^3	3.0940

Eligible households: families with 4 or more members

Discount → Blocks will be extended as follows:

- First block: 2 m^3/month per additional person.
- Second block: 3 m^3/month per additional person
- Third block: 5 m^3/month per additional person.
- Forth block: 6 m^3/month per additional person

Granada

Block	Euros/m^3
0 – 2 m^3	0.4053
3 – 10 m^3	0.6763
11 – 18 m^3	1.3996
> 18 m^3	1.9171

Eligible households: families with 3 or more children.

Discount: 50% in the variable charge corresponding to 10 m^3/month (two first blocks)

Source: Calatrava et al. (2016)

Figure 2: Family size adjustments in the residential water supply tariffs of two Spanish cities

2.3. Additional elements of water tariffs

While the preceding part of this section described tariff elements that can be implemented and adjusted by the water supplier itself, other elements cannot, or only influence it indirectly.

2.3.1. Levies and taxes

One category of such external price elements are levies and taxes. They are usually imposed by the central or regional government, while the water tariff is designed by the local water supplier. Like the value-added tax (VAT), taxes often represent a certain proportion of the value of the sold good – in this case, water. Accordingly, they change proportional to the net price of water and, therefore, may affect the overall demand for water, but not so much the differential effects of a sophisticated price scheme.

Some levies also depend on certain circumstances (e.g., environmental effects) accompanying the recovery or distribution of water. In this case, the relation between the water price and the levy may not be fixed and, if neglected, could possibly distort the intended effect of the original price scheme.

2.3.2. Wastewater charge

The wastewater charge is a type of levy. It is relevant for the effect of water tariffs insofar as both are usually calculated on a common base: the volume of water used in a household. As such, it is determined volumetrically, but unlike water supply, the wastewater charge usually includes no multiple blocks and only a smaller fixed element, if any. As a consequence, it renders water services as a whole more expensive.

3. Objectives attainable through tariff design

In the course of the discussion of various water supply tariffs in the preceding section it turned out that a variety of objectives exists, which are attained by the different tariff elements and combinations thereof to a larger or lesser extent. The ideal water supply tariff should be:

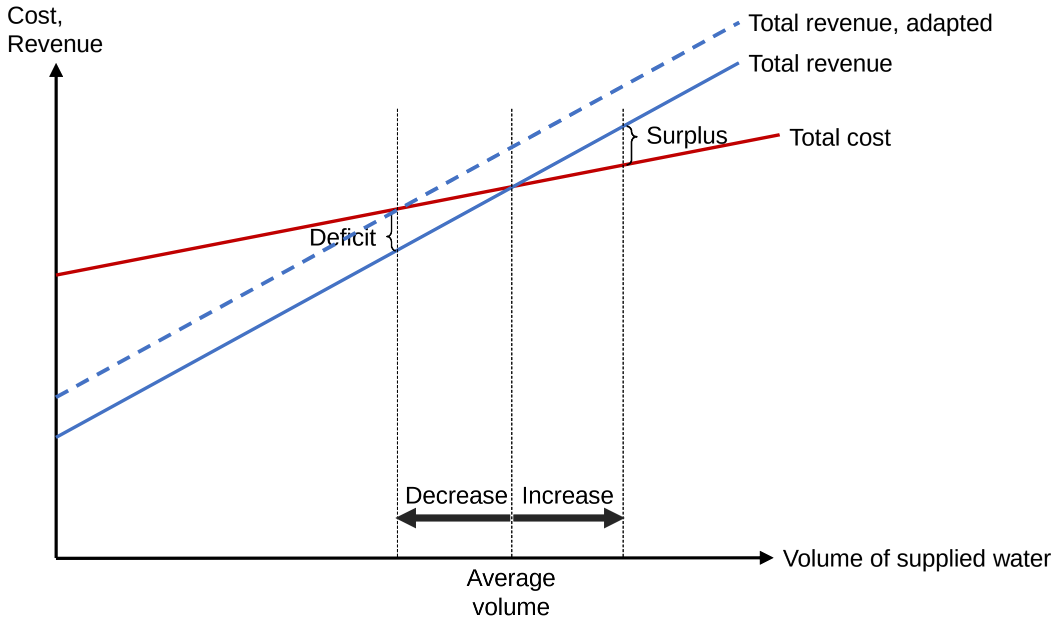
- Economically efficient, i.e. it should ensure that every water user pays exactly for the water supply service she or he receives;
- Socially acceptable implying that all, including the poorest, water users should be able to afford a basic, minimum water volume;
- Ecologically sustainable ensuring that total water consumption is in accordance with long-term natural supply; and
- Transparent to the water user with respect to the price and easy to handle and administer by the water supplier.

In the following, we will analyze how a water tariff would have to look like in order to account for each of these objectives.

3.1. Economic efficient tariffs

A water supply tariff is economically efficient, if the price imposed to the water user for utilizing the service reflects to a large extent the cost of this service. The logic behind this requirement is that the revenues based on the tariff should contribute to full cost coverage in the case of a public water supplier, or cost coverage plus a certain margin in the case of a private water supplier. In this context, the equivalence of revenue and cost (plus margin) should be given not only for the actual set of users and under the prevailing circumstances, but for a varying number and types of customers and circumstances changing within the lifetime of the infrastructure. An example may illustrate what this means. In Germany, the typical water supply tariff is composed of a fixed charge contributing to about one third of the total price paid by an average household. The remaining two thirds were contributed by a (single block) volumetric price. The cost structure is exactly the opposite: (more than) two thirds of the cost are fixed, while (less than) one third is volume-dependent. As long as the water demand remains constant or increases, the ratio between revenues and costs remains unchanged, or the former even exceed the latter. Both effects are unproblematic for the water supplier and, as the tariff is not changed, for their customers. After the reunification in 1990, water users in the eastern part of Germany had to pay cost-covering prices for the first time. Consequently, their average water consumption decreased by 34% between 1991 and 2005 (DeStatis 1992, 2006). At the same time, the revenues of the water suppliers decreased by 23%, while the cost decreased by only 10%. Additionally, the restructuring of the former socialist economy in Eastern Germany caused unemployment and, as a consequence, migration into more wealthy parts of the country. Together with the decreased per capita water demand, this lead to a decrease in total water consumption by 60% in cities like Magdeburg

(Kempmann 2008). Accordingly, the tariff had to be adapted and water became more expensive (see Figure 3).

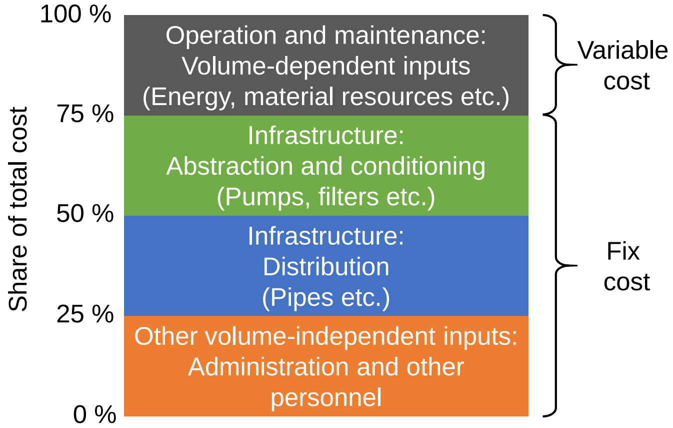


Source: Own compilation

Figure 3: Inefficient water tariff with need for adaptation after a decrease (or increase) of supplied water volume

3.1.1. Cost structure

In order to determine the economically efficient design of a water tariff, we have to learn first about the cost of the main constituents of water supply services and their dependence on the most important factors: the number of the supplied households and the supplied water volume. According to the Federal Statistical Agency (DeStatis 2010), the cost of water supply in Germany consists of roughly 25% variable cost, including the energy and materials required for the operation and maintenance of the water supply infrastructure. The remaining 75% is fix cost, which can be divided into the cost of the infrastructure (two thirds or 50%) and other fixed cost such as personnel and administration (one third or 25%). Eventually, the cost of infrastructure can be divided roughly half-and-half into the cost of water abstraction and conditioning and water distribution via the pipe network (both at 25%). The typical cost structure for German water suppliers is summarized in Figure 4. It should not differ largely from the cost structure of other water suppliers in other EU countries like Spain.

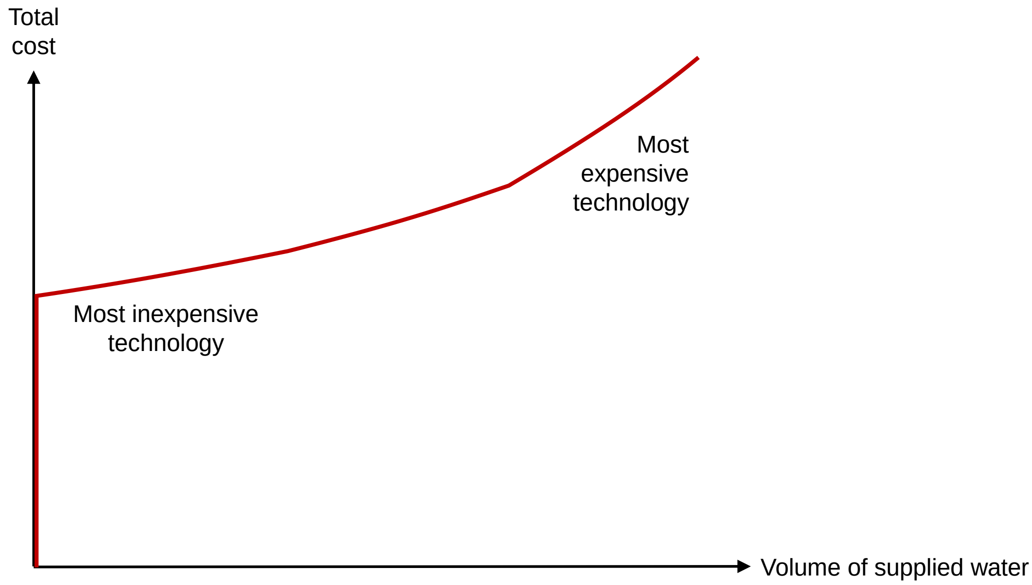


Source: DeStatis (2010) and own compilation

Figure 4: Fix and variable costs of water supply

3.1.2. Variable cost

If the quantity of supplied water is to be changed within the existing infrastructure, essentially only the variable cost is affected, since energy and material inputs have to be increased to pump and condition more water or decreased in the reverse case. If, additionally, a set of similar technologies is used for the provision and distribution of water, the cost of the input energy and materials may be somewhat higher below or above the point of highest efficiency of operation of the used machinery. It can nevertheless be assumed that the marginal cost of every incremental volume of supplied water is basically the same. The situation changes, if different water sources requiring technologies with different cost structures are used. The abstraction (i.e., pumping) cost of groundwater for instance, is higher than the abstraction cost of river or lake water, but the latter requires more processing effort (and cost) than the former to become drinking water. Which one of both is more costly in terms of specific variable (i.e., marginal) cost usually depends on the characteristics of the respective sources involved and the circumstances. In Spain, the use of surface water (i.e., rivers or lakes) as water source appears to be less costly than the use of groundwater (Garcia-Rubio et al. 2015). The water supplier will always choose the least costly source as long as it supplies sufficient quantities of water. If it does not, the second least costly source will be used and so on. The costliest water source in terms of specific variable cost is the desalination of seawater, which is not uncommon in the Mediterranean region, where groundwater can often not be used due to salt intrusion and the lack of precipitation, which causes low water levels in rivers and lakes at least in some periods of the year. The operation cost of desalination is at least twice as high as from the other sources. Consequently, it will be used only, if the other source(s) do not supply enough water (see Figure 5).



Note: The steeper the curve, the costlier the supplied water

Figure 5: Cost structure of water supply for a set of technologies with different (variable) cost

3.1.3. Fix cost

While fix cost cannot be changed in the short term, they are subject to change in the longer term. How long, depends on the lifetime of the respective assets. In the case of pipes and buildings, it can be 50 years or longer. In the case of pumps and other machinery, 20 to 30 years are adequate. Drive and control devices including computers are even more short-lived. As far as the personnel is concerned, it depends on the organization and property structure, whether and when employees could be decruited or recruited in order to respond to a decrease or increase of water sold. However, it is reasonable that the amount of work done by the employees depends only weakly on the quantity of water sold and does hardly justify such decruitment or recruitment. If the input of human resources were to be reduced, it would have to be compensated by other inputs, such as electronic data processing, including drive and control. We therefore assume that, for the period under consideration, the inputs subsumed under the label fix cost are indeed independent on the actual water volume supplied.

3.1.4. Adequate tariff structure

We learned in the beginning of Section 3.1 that, in order to be economically efficient, a water supply tariff has to reflect the cost structure of the water supply. In accordance with the cost characteristics of a typical water supplier, the fix price element has to constitute as much as three quarters of the water volume used by an average household. Only the remaining 25% is dependent on the used water volume. Whether the volumetric price is uniform or subject to block-wise changes, depends on whether the water supplier uses one single or several similar approaches in terms of cost for water abstraction and conditioning, or quite different approaches are combined. In the latter case, the sizes of the blocks (in cubic meters per household) should reflect their relative contribution to the average total water volume supplied and the price per cubic meter the cost per cubic meter of water supplied by this method (compare Figure 5).

As discussed above, the fact that the price structure should reflect the corresponding cost structure does not imply that the relationship between price and cost must be one-to-one. Several reasons for a possible divergence exist. For instance, it is possible that one part of the water supply infrastructure has been financed by transfers from the government. Also, perhaps the water users themselves have to contribute to the installation of the infrastructure before it is used. In this case, cost coverage is reached without price and cost being the same. Moreover, private water suppliers expect to gain a profit margin, which means that revenues have to be higher than costs.

3.2. Socially acceptable tariffs

Water is a basic part of human livelihood and accordingly, every person should have access to a basic amount of water regardless of her ability to pay. This is one of the arguments raised in favor of a price discount for at least a part of the water used in each household. Another argument concedes that the average water bill of households in the EU may be in the order of 1% of the average income, but emphasizes that there are many households with far below average incomes and/or above average water uses, which gives rise to much higher shares of the water bill with respect to the income. Large low-income families are instances of such uncomfortable conditions. In this context, the challenge for the designer of a socially acceptable tariff consists in providing a discount to the needy water users without giving up the principle of full cost coverage.

3.2.1. Low-price first block

In the context of increasing block tariffs, offering the first block at a very low price appears to be, at least at first sight, a quite common approach to a socially discounted water supply. The logic behind this approach is that the water required for the very basic needs (e.g., drinking, cooking, hygiene), is sometimes interpreted as the minimum quantity satisfying the basic human need for water, to which every person should have free access. This volume, which is essentially insensible to the price of water, should be available at low charge. In order to determine this volume, Martinez-Espineira and Nauges (2004) approached this issue econometrically using a Stone-Geary utility function, which distinguishes between a price-sensitive and a non-price-sensitive demand component and allows quantification of both. For the city of Seville in Spain, they found a price-insensitive quantity of 2.6 m^3 per person and month, which represents 40% of total consumption (6.35 m^3 per person and month). For Germany, Schleich (2010) calculated a similar price-insensitive volume of 3m^3 per person and month, which in this case represents 77% of average total consumption. Both studies form a basis too small to draw general conclusions, but they do give an idea of the size of this price-insensitive component.

In fact, it turns out that the volume of the low-price first block is often in the order of 3 to 6 cubic meters per *household* and month, which yields between 1 and 3 cubic meters per person and month for 2- to 3-persons households. However, it also turns out, that water utilities often combine low-price first blocks with a fix price component, which has to be paid regardless of the used volume of water. If we calculate the combined price of the fix price component and the cost and volume of the first block, we find that the resulting price per cubic meter is only slightly lower than the water price in the second block. Consequently, the low-cost first block appears to be better interpreted as a compensation for the fix cost than as a discount for the poorer water users. Additionally, it has to be recognized that all people are beneficiaries of the discount, regardless of whether they are rich or poor and how many people live in a household. The latter point matters in particular, because the low-cost first block is usually independent of the number of household members. While the low-price block may cover almost the entire water volume used in a single-person household, it is likely to cover only a fraction of the water used in a large-family household. They will therefore have to use the capacity of the subsequent, more expensive blocks, which is counter-intuitive from a social point of few. More generally, it may be questioned whether it is justified to suspend economic efficiency for a large part of the water supply of all water users in order to support just a part of them for social reasons.

3.2.2. Large-family discount

While the social acceptance of water tariffs always requires cross-subsidization of water supply to some extent, it should also be clear that this subsidization has to be well-focused on the needy people and altogether limited, in order to avoid a major disturbance of economic efficiency. One approach to narrow the focus is the large-family discount (see 2.2.4). More exactly, it grants families exceeding a certain number of children a rebate by reducing the water price directly or by increasing the price blocks, such that more use can be made of the lower-price blocks (Calatrava et al. 2016). This measure is indeed more focused and, thus, limits economic inefficiency. However, it may still be questioned, whether it focusses on the right group of water users, because the number of children (but not the family income) is usually the only criterion for the application of this discount. Accordingly, large higher-income families are among the beneficiaries, while single-person or small family households are excluded even if they are poor. Altogether, it could be argued that the large-family discount is not so much an attempt to adjust the balance of the payments between the rich and the poor according to their respective abilities to pay. Instead, it appears to be a mechanism for compensating the limitation of block price tariffs with respect to their neglect of the household size. Still, it is limited to families instead of large (multi-member) households in general, which may be justified by the fact that families are needier since children don't have their own income.

Altogether, large-family discounts appear to be a big advantage over low-price first blocks in terms of social justice. However, they could be improved further by extending the scheme to large households and including the number of household members in general and, eventually, by accounting for the household income. It is quite clear that this advantage would come at a significantly higher cost: the water utility would have to monitor and control the relevant figures (i.e., number of household members and the household income) continuously, because people move in or out or loose or gain their jobs at all times. In this context, it also needs to be considered that some customers could be tempted to take advantage of such a scheme by providing the utility with the wrong input figures (e.g., too low income or too large household size). From this perspective, the application of the large-family discount reduces the additional effort for the utility enormously, because the number of large families is relatively small and not all of them undertake the effort to apply for the discount, which is a precondition for its becoming effective. In Alicante, less than 1%

of all households applied for this discount since it was introduced in 2011 (see Section **Error! Reference source not found.**).

3.2.3. Discounted fix price

Another approach to introducing a socially motivated discount can possibly be adopted from the suppliers of residential electricity. They often offer two different tariffs, one with lower fix price, but higher price per kilowatt-hour for smaller (low use) households and another one with higher fix price and lower kilowatt-hour price for larger (high use) households. Usually the customers do not need to decide in advance which tariff they adopt; the utility will apply the more advantageous one *automatically* at the end of each billing period. The dependence of the resulting revenues on the consumed water volume is shown in the left-hand part of Figure 6. The kinked graph with the steeper part (with lower fix and higher variable price) to the left of the threshold volume and the flatter part to the right of it indicates that this tariff is equivalent to a decreasing block price. For those households using less than the threshold volume, this tariff is indeed less expensive than a tariff without the steep branch.

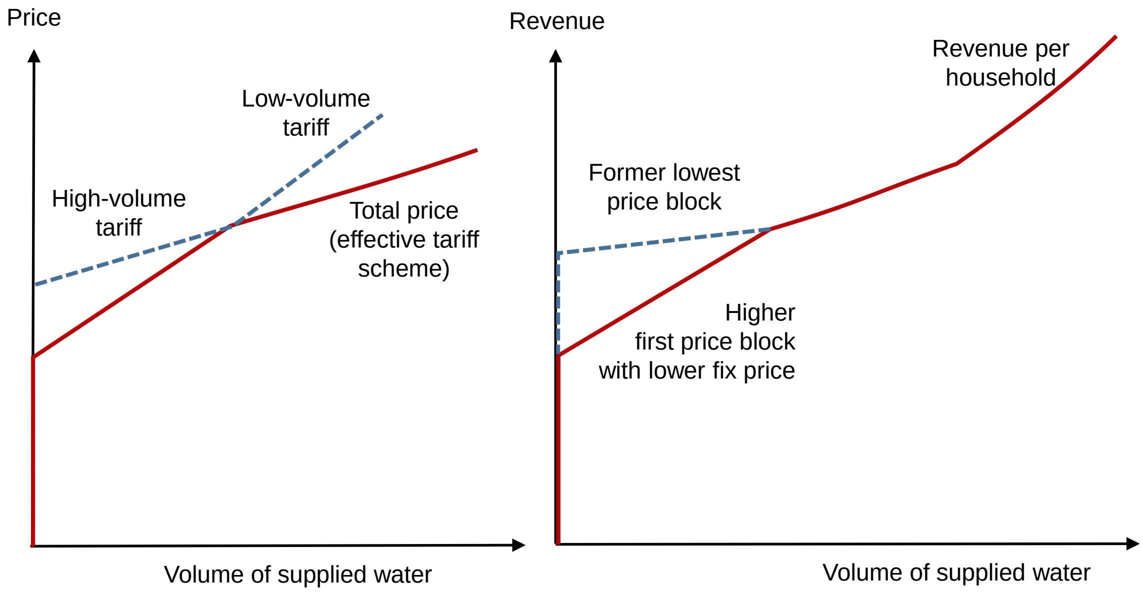


Figure 6: Increasing block tariff (left) and its integration into a multi-block tariff (right)

The integration of this discounted fix price into an economically efficient scheme with increasing price blocks (see Figure 5) leads to a lower fix price and a higher first price block in the beginning, followed by a less expensive, and then again more expensive price block(s) (see Figure 6, right).

With respect to the utility's revenues, the difference between the new mixed-block price scheme (red graph in Figure 6) and the former increasing block price scheme (dotted blue graph in Figure 6) is rather small as it comes to bear only with those customers who use less than the volume of the first block. This can only be households with a low number of members, which are also water-saving. Like in the previous examples, this tariff does not distinguish between rich and poor water users, but it can distinguish between (in person terms) smaller and larger households; and it does so without any additional administrative effort. No number of household members or income needs to be monitored. Accordingly, this type of tariff appears to be quite effective with respect to social justice and efficient with respect to the cost encountered for its implementation.

3.3. Ecologically sustainable tariffs

3.3.1. Inclusion of external cost

We have shown in Section 3.1 that economically efficient prices should reflect the cost and, thus, the effort it takes to supply the water service requested by the water users. The cost curve shown in Figure 5 is a supply curve representing the water supply sources sorted by increasing costs per cubic meter of water. Thereby, the curve can also serve as an indicator for the scarcity of water, since the higher the slope of the curve, the scarcer is the water. Consequently, economic efficiency should be able to indicate the ecological sustainability of a water tariff to some extent. However, the supply curve is only a short-term view on scarcity. It does not consider long-term (side) effects of the abstraction of water as, for instance, decreasing groundwater levels, or the intrusion of seawater into groundwater, which may make it necessary in the future to drill deeper wells, or build new wells because the existing wells are rendered useless. Such extra cost of the actual water use is not paid now, but in the future. An ecologically sustainable water price would have to include the cost of additional measures that avoid falling groundwater levels or seawater intrusion. It is beyond the scope of this report to quantify this cost, but it is evident that it would increase progressively, as the side effects are the stronger the more water is withdrawn from the sources. The same argument applies for water processing because it shows also side effects. For the supply side, we can therefore draw the conclusion that the ecologically sustainable cost and price curves show basically the same shape as the economically efficient curves, but with more strongly increasing slopes.

3.3.2. The role of price elasticity

Looking at the ecological sustainability of a tariff from the supply side shows that the neglect of external costs leads to too low prices and, consequently, too high demand. In order to decrease the water demand to ecologically sustainable levels, it appears useful to increase the price. In this context, it makes sense to account for price elasticity and increase only those components of the water price scheme that give rise to a decrease in the used water quantity. In Section 3.2.1, it was shown that slightly more than a half of a person's average water consumption is (completely) price-inelastic. This means that no additional price increase is able to decrease the used quantity of water further once this lower limit has been reached. Conversely, the price elasticity increases the more water is used. The reason behind this is that the various water uses of any person have different levels of urgency, and once the price increases, the least urgent uses are given up first. In some cases, like watering the garden or washing the car, these demand components are also those with the highest water volume. Accordingly, the demand perspective gives rise to the same conclusion as the supply perspective: in order to reduce the consumed water volume to an ecologically sustainable level, higher prices have to be assigned especially to the higher water consumption levels. This implies that it is useful especially for this purpose to implement increasing block prices and increase the price of especially the higher blocks above the levels implied by the cost perspective alone (see Figure 7).

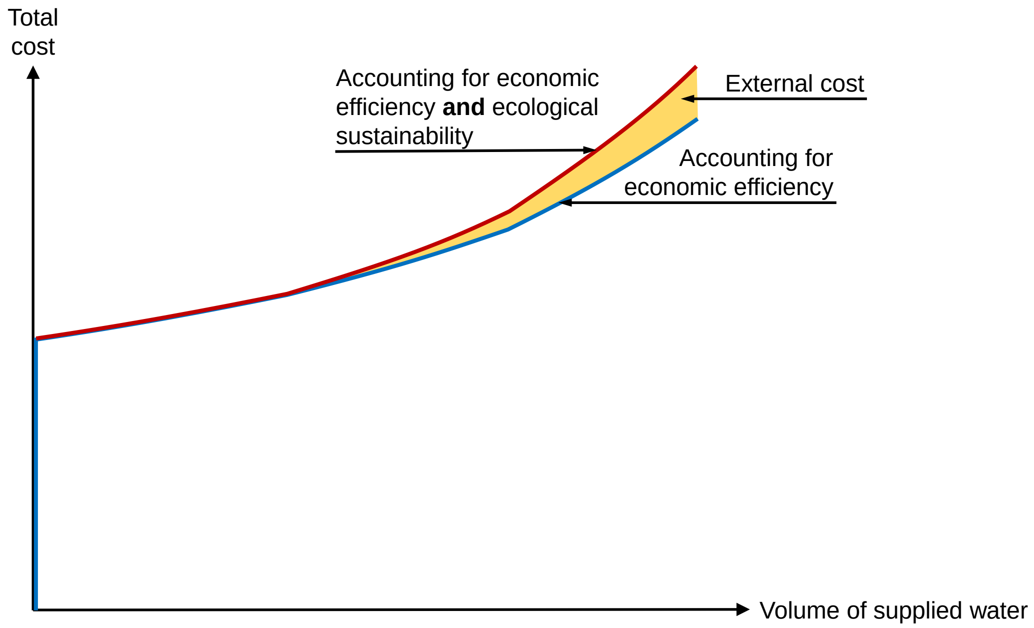


Figure 7: Adjustment of an increasing-block price tariff to include ecological sustainability

3.3.3. Short-term responses

From the ecological sustainability perspective, it is even more important than from the cost perspective that demand is adapted to supply changes (e.g., a draught-caused shortage) in short term, as overexploitation of a source can give rise to severe long-term effects. Technically or economically, periods of low or high water use can usually be balanced more easily. For this reason, seasonal or peak tariffs are especially relevant in this context (see 2.2.3). Seasonal tariffs are applied most easily, because they need no permanent communication between the water utility and its clients. The high-price tariff applies to a fixed period of the year, which shows statistically high temperatures, low precipitation, or other characteristics of a critical situation, but does not depend on specific circumstances. The advantage is that everybody knows in advance when the prices will be low or high and the prices are also predetermined. However, the response to a specific meteorological challenge is more indirect as critical periods may come to lie outside the predetermined season or the season may also cover uncritical periods. Accordingly, the water users may lose track of the reasons for the higher price, or even forget about the higher price altogether.

In this respect, peak tariffs are much more effective as they respond *directly* to a given challenge. Like in the example of Cape Town reported in Section 2.2.3, the water price directly responds to the actually prevailing drought conditions. These conditions are communicated to the water users via internet or messenger services and the like; so, every water user knows how much she will have to pay for the water she uses. This communication has the additional positive effect that the water user is *reminded* of the reason for the higher price and, if such a message is not sent too often, it focusses the water user's attention on the critical situation and the need to respond to it. This may raise an additional saving effect.

3.4. Conclusion: the 'ideal' tariff structure

It is hardly possible to specify one tariff structure jointly meeting the principles of economic efficiency, social acceptance or justice and ecological effectiveness, since the conditions specifying this tariff change too much between water utilities. However, a number of characteristics can be listed, which increase the likelihood that a tariff is in accordance with these principles.

- An **increasing-block tariff with a strong fix-price component** is the starting point, which ensures the ecologically sustainable use of the resource water and, in most cases, economic efficiency, i.e., the allocation of water to the most valued uses. The sizes (i.e., volumes) of the blocks and the respective prices should correspond to the cost of tapping the water sources used for water supply.
- The **prices for the higher-price blocks** should be **increased** additionally to account for the external cost of water abstraction and processing. Only if water is in plenty supply and easily accessible, a tariff with a strong fix-price and a single volumetric component (i.e., one block) may be preferable.
- In order to make water affordable for small households with low income, the high fix-price and first low-price components of the starting point can be replaced by a **lower fix price and a higher priced first block**. The size (volume) of the first block should be in the order of one person's average water consumption, the price (per cubic meter) higher than in the second block. The result would be a mixed-block tariff (decreasing in the beginning and increasing later on) or a decreasing block tariff (if the one block tariff is taken as starting point). Notice that a first (very) low-price block is hardly effective with respect to social justice and affordability if combined with a high fix price. If combined with a low fix price, it strongly impairs economic efficiency.
- Seasonal or peak prices are to be applied to the higher-price blocks in a progressive manner, that is, higher price increases in the highest-price blocks and lower increases in the intermediate price blocks (no increase in the first price block).
- Peak prices are more effective than seasonal prices in economic and ecological terms as they respond to changes in cost or environmental conditions more directly and effectively. Additionally, they can better focus the water user's attention to the challenge and the price increases; so, they give rise to more effective adaptation of the water use behavior.

4. Assessment of the water tariff of AMAEM

After a wide variety of water tariffs was described in Section 2 and assessed with respect to economic efficiency, social acceptability and ecological sustainability in Section 3, we will now evaluate the water tariff of the water utility of Alicante (Spain), AMAEM, with respect to these objectives. Subsequently, we will analyze how the prizing policy of AMAEM can be improved by the use of DAIAD.

4.1. The water tariff of AMAEM

The price scheme applied by the water supplier AMAEM in the city of Alicante is an increasing block price scheme consisting of one fix and four volumetric price blocks. The price of the fixed block depends on the size of the meter. For the majority of households, AMAEM uses the smallest meter (13 mm in diameter) as standard and charges its clients 8.01 EUR per month or 24.03 EUR per quarter for this meter (incl. the meter maintenance fee).[1] The variable price blocks are from 0 to 9, above 9 to 30, above 30 to 60 and above 60 cubic meters per quarter for the standard household. The price per cubic meter of water is especially low in the first and still rather low in the second block, while it increases strongly in the third and especially in the fourth block (see Table 3). With 35 cubic meters per quarter, the average household just reaches into the third block. So, there is economically a relatively strong incentive for a household to remain below average and within the first two blocks.

Table 3: Block sizes and prices in the standard water tariff

Block size (m^3/quarter)	Up to 9	Above 9 to 30	Above 30 to 60	Above 60
Price (EUR/m^3)	0.02	0.55	1.85	2.49

Source: AMAEM

In addition to the water supply price, all water users have to pay wastewater disposal and treatment fees for every cubic meter of water they consume. The wastewater tariff consists of two components. The first component (with the revenues in favor of the city of Alicante) with a structure very similar to the water supply price scheme, with the exception that the fix price is substantially lower and there are only three variable blocks with a much lower progression than in the water supply tariff. The second component (with the revenues in favor of the Valencian Community) has a fix and only one variable price block.

1 All price data are according to the actual (July 2017) tariff and valid since 2015.

Effective from 1 October 2010, AMAEM introduced a new discounted water tariff for larger families (with three or more children) having the same structure as the regular tariff with one exception: depending on the number of children, the size of the larger blocks was increased as shown in Table 4. Households wishing to benefit from this discount have to apply for it with AMAEM providing evidence for the children involved.

Table 4: Increases in block sizes (in m^3 per quarter) in the water tariffs with large-family discount

Tariff/no. of children	Block 1	Block 2	Block 3	Block 4
Regular/up to 2	0 to 9	>9 to 30	>30 to 60	>60
Large family/3	0 to 9	>9 to 35	>35 to 72	>72
Large family/4	0 to 9	>9 to 40	>40 to 84	>84
Large family/5	0 to 9	>9 to 45	>45 to 96	>96
Large family/6 and more	0 to 9	>9 to 50	>50 to 108	>108

Source: AMAEM

4.2. Assessment of the AMAEM water tariff

4.2.1. Assessment of economic efficiency

Assuming the average water consumption of a household to be 35 cubic meters per quarter (as yielded by the analysis conducted in Deliverable 6.2), the total price of water supply to the average household is 15.00 EUR per month or 1.29 EUR per cubic meter. This price agrees well with the figure of 1.22 EUR reported by Garcia-Rubio et al. (2015) for the province of Alicante. According to Garcia-Rubio et al. (2015), the latter price suffices to enable the water suppliers in the basin of the river Júcar (to which AMAEM belongs) to recover 86% of the cost of water supply. AMAEM itself asserts that it is able to recover 100% of the cost – in fact even 105%, if the 5% margin is included (AMAEM 2017a). In other regions of Spain, the rate of cost recovery ranges between 34% and 95%. Accordingly, the tariff applied by AMAEM appears to be fairly efficient with respect to total cost recovery. The remaining cost is covered by subsidies and other transfers from the government.

The fix, volume-independent part of the total water price is 0.69 EUR (per cubic meter) or 53%, which is lower than the actual share of fix cost from total cost (of about 75%) and slightly lower than the fix share (of 60%) of Spanish water suppliers reported by EEA (2013). However, it is higher than the fix share realized in most other countries (see Figure 1).

With respect to the various price blocks (see Table 3), it is evident that their sizes and prices do not reflect the cost structure of water supply. 35 to 50% of the water supplied by AMAEM is abstracted and processed by the company itself at a cost of roughly 0.25 EUR per cubic meter and comes from regional groundwater aquifers. The large remaining share of the supplied water is purchased from the Mancomunidad de Canales del Taibilla, which manages the water supply for the entire region (including the provinces of Murcia and Alicante). Its water sources are the nearby Taibilla River, the Tajo-Segura water transfer and, if the natural supply runs dry, the desalination of seawater. Although the cost of supplying water from each of those sources is quite different, AMAEM pays a (politically determined) uniform price of about 0.69 EUR per cubic meter, which was stable for many years in the past (AMAEM 2017b). Remarkably, the latter price is also independent of the season, although the higher share of desalinated water in the summer should render the corresponding water supply clearly more expensive. This is an evident example of cross-subsidization, however not on the part of AMAEM, but its supplier, the Mancomunidad de Canales del Taibilla.

With regard to these cost figures, only the price of the second block is in the right order of magnitude to cover roughly the cost of water supply. By contrast, the price in the first block is evidently too low to account for the cost of the supply of the corresponding water volume and the prices of the third and fourth block are too high. At the most, the supply of desalinized water could cause cost in that order (i.e., 1.80 to 2.50 EUR per cubic meter), but as we learned above, AMAEM is only paying a much lower (average) price for all the water bought from the Mancomunidad. Moreover, these high-price blocks apply to all water volumes used in households and exceeding 30 cubic meters per quarter, which is less than the average water use of 35 cubic meters. This leads us to the conjecture that the high-price blocks serve mainly the compensation of the loss of revenues caused by the first low-price block.

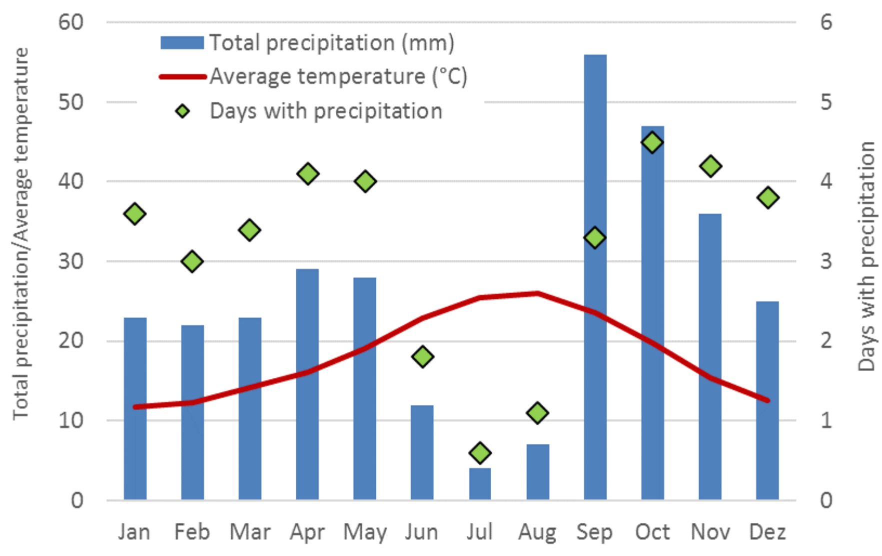
4.2.2. Assessment of social acceptability

Like the deficits of economic efficiency, the limited distributive effectiveness caused by the low-price first block has been discussed in Section 3.2.1 and needs no further elaboration here.

In contrast to the application of a first low-price block, the large-family discount offered by AMAEM is much more effective in terms of social justice as it supports exactly those households disadvantaged by the current regime, where the sizes of the price blocks apply to households instead of persons. Consequently, the low-price blocks likely apply to a substantial part of the water consumption of a one-person household, whereas they constitute only a minor share of the water consumption of a large multi-person household. The large-family rebate adjusts the size of the price blocks such that the block sizes per person decrease only slightly, if the household sizes exceed the number of four members. Only the first block is not adjusted, because its low price is evidently intended to compensate largely the fix price, which is also independent of the number of household members.

4.2.3. Assessment of ecological sustainability

We have discussed above, that the progression of the price blocks in the AMAEM tariff is stronger than justified by the mere cost of water supply (i.e., economic efficiency). One argument was the need to compensate the loss of revenue caused by the first low-price block. Another argument addresses the water scarcity prevailing in the region of Alicante. As shown in Section 4.3.1 of Deliverable 6.2, not only the annual rainfall is quite low (only 311 mm), but this precipitation concentrates significantly in spring and autumn. Accordingly, Alicante receives less than 8% of the annual rain during the summer, which leads to a significant reduction of the precipitation-dependent water sources by the end of the summer (see Figure 8).



Source: AEMET (2017)

Figure 8: Annual distribution of monthly temperature and precipitation in Alicante/Spain (average for the 1980 to 2010 period)

In this context, like in other Mediterranean regions, the high-price blocks are also intended to provide an incentive to save water (Gaudin 2006). With respect to the water-saving argument, however, the progression of the AMAEM tariff shows two types of deficits: static and dynamic. The static deficit refers to the argument that the price elasticity of water demand increases with the used water volume. This means that the responsivity to an increase in water price is the higher the more water is consumed. In order to promote the saving of water, the price should accordingly increase most strongly between the last price blocks. The largest price jump should therefore exist between the third and fourth price block. In the actual AMAEM tariff, by contrast, the increase between blocks 3 and 4 is smaller than the increase between blocks 2 and 3.[2]

Beyond the price relations between the different blocks, the dynamic deficit refers to the fact that these relations, as well as the block sizes in the AMAEM tariff remain unchanged and do not adjust to the changes in water scarcity occurring in the course of the years. This is where seasonal or peak tariffs (see Section 2.2.3) come to bear and, especially in the latter case, DAIAD could play a crucial role. In order to apply a seasonal tariff reasonably, the water utility should identify periods of the year typically characterized by higher or lower water availability. As shown in Figure 8, in Alicante, the months of June to August show a significantly lower precipitation than the rest of the year. Accordingly, higher prices of all or at least the higher-price blocks in the period from June to August than of the respective blocks in the rest of the year would likely promote the saving of water in those periods where water supply is scarce and costly[3] – on

[2] It should be noticed that in this context, the relevant price increases are relative increases. The price increase between blocks 3 and 4 is smaller than the increase between blocks 2 and 3 already in absolute terms and, therefore, even more in relative terms.
[3] Although AMAEM pays a uniform, source-independent price for its external water supply, this argument holds for the following reason. While the price did not change in the past, it is sensible to droughts like the actual one, where no water is supplied via the Tajo-Segura water transfer (Baja 2017). Moreover, if the lack of precipitation in the summer reduced the supply of AMAEM's

average, over the years. Still, there are years with more or less precipitation, with longer or shorter periods without precipitation, while the months of lowest precipitation can change substantially. This does not only lead to a divergence between the cost of water supply incurred by the utility and the received revenues – an issue easy to resolve by means of financial transfers (i.e., cross-subsidization), but more important is the setting of wrong incentives. Plenty of water supply in a high-price season, for instance, leads to an *unnecessary limitation* of water consumption. More crucially, the reverse case of low water supply in a low-price season may give rise to severe *over-exploitation* of the given water sources – with negative consequences for sustainable water supply in the future. It is possible to avoid these shortcomings by the application of a peak tariff, which renders the prices of single or several blocks dependent on the actual water scarcity. In the case of South-African Cape Town region, for instance, the water level in the dam serving as water reservoir for the city is used as an indicator for increasing or decreasing the water price levels (see Section 2.2.3). In Alicante, this could also be the water level a dam or in a river serving as water source.

In this context, the DAIAD system can serve as an instrument for the implementation of a peak tariff, as it can be used by the water utility to

- Communicate the need for to save water in the case of water scarcity;
- Provide intrinsic incentives to the water users for saving water; and
- Communicate price changes intended to serve as extrinsic incentives.

Other improvement potentials were discovered in particular in the contexts of cost-covering price blocks and socially desirable and economically efficient inexpensive access to a basic volume of water. As DAIAD does not play a role in approaching these potentials, they are not in the scope of the DAIAD project and will not be followed any further in this report.

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own water sources (which is actually not the case), they would have to purchase more water from the more expensive external source. In this case, the higher peak price(s) would enable them to balance the higher cost with higher revenues.

5. The use of DAIAD for implementing a peak tariff

In the previous section, we have argued that the actual water tariff of AMAEM exhibits certain limitations with respect to the incentives provided to its clients in the case of a water scarcity. In this section, we will show how DAIAD can serve as an instrument for avoiding this deficit and how it can be applied in conjunction with a new peak tariff structure. Before describing a possible implementation scenario, we will describe first, what the possible advantages of DAIAD with respect to the implementation of a peak water tariff are.

5.1. Advantages of DAIAD for peak tariff implementation

5.1.1. Feedback on price

Peak tariffs include price changes triggered by certain events such as the water level of a reservoir. In order to fulfill its function as a signal and incentive for water saving, it is essential that such price changes can be conveyed to, and perceived by, the water users. In the conventional context, water users learn about their actual water use and the respective price with a long time lag: the billing period, which is between three months (e.g., in Spain) and one year (e.g., in Germany). DAIAD@utility enables the utility to send the respective information and DAIAD@home enables its customer to receive this information with a very short time lag, which is only determined by how often the water users looks at her smart phone (and in the case of push notifications to mobile phones almost instantly). In other cases, such information has been broadcasted by radio, television or presented on the utility's website, which may be listened to, or visited less frequently. In this respect, DAIAD represents an additional and more direct means of communication of a forthcoming price change, as the respective message is pushed by the utility and received on the water user's mobile device in almost real-time.

5.1.2. Contextual feedback

In addition to, or beside the price change, the DAIAD system can also be used to communicate the *motivation* for the price change. Once the water users learn about the actual water scarcity as the reason for the price change and that reducing their water consumption can relieve the problematic situation, they are more likely to understand and accept the price increase as a necessary measure. Moreover, they may be willing to reduce their water consumption even beyond or beside the price increase, if this appears to be to the best of the community.

5.1.3. Feedback on volume

The latter effect, i.e., motivate people to contribute to the best of the community, can even be enhanced by explicitly appealing to water users to limit their water consumption under the given conditions in order to improve the state of the community, the environment or future generations. Like communicating the price change, DAIAD@home and DAIAD@utility can be used to raise a *campaign* asking the water users to help solve the actual water scarcity challenge. Additionally, DAIAD@home can be used to allude to certain attitudes of the water users, such as their competition (as an individual or a group) with other water users in trying to become the most advanced water saver.

In addition to DAIAD@home and DAIAD@utility, DAIAD@feel (i.e., the amphiro b1) can be used as a complementary tool for reducing the water consumption under a given water scarcity situation. DAIAD@feel tells water users in the first place how much water they use. Together with DAIAD@home, it helps them understand why it is generally preferable to reduce water consumption: because water is a scarce resource (even beyond the impending specific scarcity situation) and especially the use of *hot water* can affect the climate negatively.

5.1.4. Combined effects

In contrast to the price effects, which last as long as the price changes persist, many of the other effects depend on a certain state of attention or effort, which tends to *fade away* without renewed incentives (see next section). This *lack of continuity* appears to be a disadvantage whenever a long-lasting effect is to be achieved. However, as this effect relies on intrinsic motivation, it is quite strong and arises rapidly. Therefore, this mechanism exerts the strongest effect in the short term. In order to avoid rebound effects in the longer term, the incentive scheme has to be adjusted by using extrinsic motivators, such as money. Both types of incentives are neither substitutive nor additive, but they complement each other with respect of their total effect. Moreover, DAIAD can be used to provide feedback or information about used water volumes and prices in near real-time and thereby allow for the highest possible effectiveness of both mechanisms.

5.2. Quantitative effects on water consumption

As we discussed in Section 5.1, DAIAD is an instrument for the fast and effective communication of all (including specific) information that can serve as incentive for changing the water consumption of a large number of individuals. Supporting the communication of both intrinsic and extrinsic incentives, DAIAD is quite universal. In order to identify the most effective mode of its application, we also need to know the sizes of the effect that can possibly be achieved by means of the incentive mechanisms.

5.2.1. Effect of feedback about used water quantity

There is a variety of studies that aimed at inducing a reduction of water consumption by targeting an individual's perceptions, preferences, and abilities to induce eco-friendly behavior (Allen 1982; Poortinga et al. 2003; Steg 2008). In this context, interventions referring to a specific situation, state of knowledge, or feeling appear to yield higher savings than less specific interventions (Petkov et al. 2011). One way of providing such user-specific information is giving them immediate feedback about their actual consumption. McClelland & Cock (1980), for instance, used in-home displays to inform their respondents about the monetary cost of their current electricity use. Over a period of several months, the study's participants reduced their consumption by an average of 12 percent. In the context of water consumption, Willis et al. (2010) investigated the effects of a shower monitor, which displayed the actual water consumption and provided an acoustic alarm signal when a user-adjustable volume was exceeded. In this study, the authors report an average saving of 15%. In a more recent large field trial taking place in Switzerland, the display of the used amphiro devices showed real-time volume measurements for, and during, individual shower event. Based on feedback information from the display, hot water consumption per event declined by 22%. In other cases, where feedback was given more indirectly, the effect is smaller. In a pilot project conducted by IBM Research (Naphade et al. 2011) smart water meter data were collected and provided to the water users via an online portal. The savings effect yielded by this feedback mechanism was only 6.6%, which is explained by the fact that the water users receive this information timely independently of, and after, their water usage such that they can only react at the next event.

In certain contexts, providing this type of information could also lead to no reduction or even an increase in consumption, if the actual consumption and its respective cost turned out to be lower than expected (Brandon & Lewis 1999). This led to the conjecture and its confirmation by Schultz et al. (2007) that descriptive normative feedback (i.e., feedback on what other people typically do) leads to an increase or decrease in electricity usage depending on whether the observed user is a below or above-average consumer. In view of these effects of feedback on water consumption, it is possible to distinguish three levels of intervention power:

(1) Enable the water user to learn about real-time water consumption and how it can be influenced by changes in the user's behavior (e.g., turn off water during soaping);

(2) Allow the water user to set herself a target volume for each shower event (e.g., the average volume used by a reference group) and try not to exceed this volume; and

(3) Provide the water user with additional information serving as a norm, which is used to frame the water consumption context and force the user to use less water.

We have investigated the former two effects in more detail in the Trials performed in WP7 and obtained the following results (cf. D 7.3, Section 4.2):

- In the initial two-months period (in phase 2) of providing **diagnostic feedback** (on smart phone or PC, some time after the shower event), the average water consumption is reduced by **6%**;
- In the initial two-months period (in phase 2) of providing **real-time feedback** (via amphiro during the shower event), the average water consumption is reduced by **18%**;
- In the two-months period following phase 2 (where both types of feedback were given) the reduction of average water consumption is **reduced from 12% to 7%** (average of both treatments); so, roughly one half of the effect fades away within a two to three-months period;
- In the initial two-months period of providing **social comparison** (on smart phone or PC, some time after the shower event), the average water consumption is reduced by **13%**;
- In the initial two-months period of providing **both types of feedback and social comparison**, the average water consumption is reduced by **11%**, which indicates that the effects are not strictly additive.
- In the three-month period following the official end of the Trial, the average water consumption was reduced by **12%**, which we consider as the sustainable effect of the DAIAD system following its prolonged use.

These effects are roughly in line with the respective literature findings reported in the beginning of this section.

5.2.2. Effect of price changes

The effect of the water price on the consumed water volume is usually expressed as price elasticity, which is the percentage change of water demand for every one-percent change in price. As is discussed in detail in Deliverable 6.1, Section 2.2, water demand is known to be rather inelastic, meaning that a price increase by one percent leads to a decrease in demand by less than 1 percent. Therefore, the elasticity lies typically between 0 and -1, in most cases between -0.2 and -0.5. For the population of Alicante, we could calculate an average price elasticity of -0.37 (see D 6.2, Section 4.2.1). We also know from Deliverable 6.1 that, as a conclusion from a large number of studies, the short-run elasticity is lower than the long-run elasticity by about 0.3. The reason for this is that it may take the water user some time to realize some more complicated means for saving water. The implication of the larger long-term elasticity is that the price effect accrues more slowly and persists longer than the effects of intrinsic motivation.

Of particular importance with respect to a multi-block tariff such as the one existing in Alicante, is the fact that the price elasticity varies typically over the entire water volume consumed in a household. As is reported in Section 3.2.1, about one half of the average water volume consumed by one individual (which corresponds to the major part of the first block in an average-size household) is almost *completely inelastic* (elasticity = 0). By contrast, price elasticity in the largest block is much larger, as these volumes are used for less essential and more dispensable purposes such as the watering of gardens or the washing of cars. If the water volume used in a city was to be reduced, the higher price elasticity in the large-volume (and high-price) blocks would be an argument in favor of increasing the prices in these blocks more than in the lower-price blocks. Conversely, as is shown in Table 5, almost all water users use the full capacity of the first block and only a small share of them uses major shares of blocks 3 or 4. Accordingly, the larger price elasticity in block 4 is applied on the relatively small volume used from this block, and the low price elasticity in the first block is applied to a large volume. The combined effects have been calculated based on the average water use the 1000-smart-water-meters data set (see Deliverable 7.3, Section 3.3) and price elasticities assumed according to the arguments discussed above.

Table 5: Total volumes of water used in the blocks of the AMAEM tariff by the 680 households contained in the 1000-smart-water-meters data set in Alicante

	Volume per household (m^3/quarter)	Total volume used by all users (m^3/quarter)	Share (%)	Actual price (EUR/m^3)	Assumed price elasticity	Actual total revenue (EUR/quarter)
Block 1	0 – 9	5740	40.8	0.02	-0.1	115
Block 2	>9 – 30	7021	49.9	0.55	-0.3	3862
Block 3	>30 – 60	1104	7.8	1.85	-0.5	2042
Block 4	>60	218	1.6	2.49	-0.7	544
Total		*14083*	*100.0*			*6562*

As is shown in Table 5, More than 90% of the water are consumed in blocks 1 and 2 and less than 2% in block 4. As the water price in block 1 is especially low and the prices in blocks 3 and 4 rather high, it is little surprising that blocks 1 and 3 exchange their roles with respect to the most important contribution to the revenue yielded by AMAEM from selling their water. We will return to this effect and its meaning further below.

If a peak price tariff is to be developed, the question arises in which blocks the prices are to be increased, and by how much. In the actual AMAEM tariff, block 1 has the lowest price with the largest potential for increase. At the same time, the low price of block 1 is owing to (and to some extent protected by) equity reasons. By contrast, it is much easier to argue in favor of a price increase in block 4 as this concerns large-volume users and applications with high volumes and high responsiveness. Therefore, the number of concerned people and applications is rather low. Moreover, it has been argued in Section 3.3.2, that it would make sense especially for block 4 to increase its price above the levels implied by the cost perspective alone and, thus, further above the price of block 3. Concluding these arguments, a peak price schedule including a number of levels of increasing scarcity should respond to this increasing scarcity by increasing first the price in block 4, then in blocks 2, 3 and 4 and eventually in all four blocks.[4] The result of such a double-progressive price scheme is shown for exemplary price increases in Table 6. The price scheme is called *double-progressive* because prices increase progressively in each block *and* with respect to the increasing number of blocks involved. From level to level prices in the relevant blocks were increased by approximately 50%. Only the price in block 1 on level 3 was increased by a factor of 10, in order to yield a relevant consumption reduction at all.

*Table 6: Price and resulting volume changes for the water scarcity levels of a presumed peak price scheme in the AMAEM tariff**

	Water scarcity level 1			Water scarcity level 2			Water scarcity level 3		
	Prices (EUR/m^3)	Tot. volume (m^3/quart.)	Change (%)	Prices (EUR/m^3)	Tot. volume (m^3/quart.)	Change (%)	Prices (EUR/m^3)	Tot. volume (m^3/quart.)	Change (%)
Block 1	0.02	5740	0,0	0,02	5740	0,0	0,20	4553	-8,4
Block 2	0.55	7021	0,0	0,80	6270	-5,3	1,20	5548	-10,5
Block 3	1.85	1104	0,0	2,70	912	-1,4	4,00	748	-2,5
Block 4	4.00	156	-0,4	6,00	117	-0,7	9,00	88	-0,9
Total		*14021*	*-0,4*		*13040*	*-7,4*		*10938*	*-22,3*

Note: Prices, volumes and price elasticities for the initial (i.e., actual) situation are given in Table 5.

It has to be kept in mind that the price increases assumed in Table 6 are exemplary and intended to demonstrate how much water can be saved in principle. In fact, it would be the intention of the peak price scheme within a future AMAEM tariff to reduce the water supply just in those times when no water is

[4] Price increases in blocks 2 and 3 were introduced simultaneously in order not to end up with too many scarcity levels. They could also be conducted in separate steps (including one more level).

supplied by the Tajo-Segura water transfer and the extended (and very expensive) desalination of seawater has to fill this gap. This situation is characterized by extraordinary scarcity and requires a significant reaction in order not to over-exploit the remaining natural water sources. Moreover, this situation may indeed lead to an increase of the so far unchanged price for the external water supply, which also requires a price increase for the water supplied *by* AMAEM to remain cost-covering (Baja 2017).

In a case like this, it may be advisable to introduce a peak tariff with only one water scarcity level, which is directly connected with the fact that the water transfer is out of operation. This strict link between the cost-increasing event and the related price increase may also facilitate the price change from an administrative and political point of view, because the water price in Spain are strongly regulated and a price increase is difficult to manage in the short term since many institutions and stakeholders are involved in this process. Using the peak price scheme it is not necessary to make a distinct decision whenever a scarcity event occurs. Instead, a conditional decision can be made once and possibly beforehand and applied in short-term whenever the condition occurs.

In this context, two additional aspects also need to be considered. First, the price increases lead to a considerable increase in the *revenues* of the water supplier, which can be used to finance the supply of desalinated water without cross-subsidization. Compared with the revenues yielded in the actual situation (given in Table 5) revenues would increase by 1.2%, 26.5% and 73%, respectively, on application of the water scarcity levels 1, 2 or 3. The prices to be paid for water in block 4 on all water scarcity levels and in block 3 on water scarcity levels 2 and 3 (which are 2.70 EUR/m^3 or higher) also indicate that the respective revenues should be high enough to cover the cost of desalination.

Additionally, the increase of the water prices would not be the sole incentive for reduced water consumption in a DAIAD-based strategy. Although DAIAD can support the communication of price increases in the context of a peak price approach, it is even the primary approach of DAIAD to use the *intrinsic* motivation of water users to reduce their water consumption (as described in Section 5.1). As shown in Section 5.2.1, the reduction effect of these intrinsic approaches can be as high as 18%. Although this effect tends to decrease with time and cannot simply be added up with the effects of price increases, it is evident that there is a strong potential to achieve reduction rates well beyond -30% through the combination of intrinsic *and* price approaches. If there is no need for AMAEM to achieve such high reduction rates, the price scheme in Table 6 can be adjusted and the price increases between the levels decreased accordingly. How large the increases may be in the specific context of AMAEM and Alicante is difficult to say because we lack the necessary detailed cost and quantity figures and, much more importantly, we do not know how the intrinsic and extrinsic effects add up. In this context, it is the major advantage of the (double) progressive peak price approach that the water utility can employ subsequently increasing levels of intervention – based on extrinsic and intrinsic motivation – until the desired effect is reached. And as soon as the scarcity situation disappears again, the levels of intervention can also be reduced.

6. Conclusion

The assessment of the actual water supply tariff of AMAEM along the criteria of economic efficiency, social acceptability and ecological sustainability has shown a good performance in most respects. A certain deficit was identified with respect to the capability of the water tariff to respond to water shortages in the summer. Comparing all types of tariffs or tariff components applied elsewhere on earth, we found peak tariffs to be a very suitable approach to respond to this challenge. In addition, we found DAIAD to be a very effective instrument for applying peak tariffs. Since peak tariffs are characterized by price schemes that change water prices depending on certain conditions (e.g., water scarcity), they rely on receiving information about such critical situations and conveying this information and the corresponding incentives to the water users. Only if this communication works, the entire peak tariff can be expected to be effective. DAIAD is able to support this process in several respects.

- DAIAD@feel provides the water users with basic information concerning the water volume and heat energy they consume, which is a fundamental precondition for any water saving efforts. In this context, it is known that measuring a person's water consumption as such leads to a reduction of the consumed water volume;
- DAIAD@home provides the water users with additional information about their own and other users' current and historical water use, which can be used to set water saving targets leading to a reduced water consumption in the future;
- Both effects rely on the intrinsic motivation of the water users, which can be addressed by providing certain reference information (see above) or, additionally, by using DAIAD@home for framing the situation (e.g., water scarcity in the region) in a suitable way;
- DAIAD@utility can be used to transmit extrinsic incentives such as prices in near real-time and directly to the water user. This ensures that price signals translate into demand responses with highest effectiveness;
- Both intrinsic and extrinsic incentives do not simply add up with respect to their effects, but they replace one another to some extent, exhibiting complementary properties that are rather attractive in the given context. While the effectiveness of intrinsic motives increases quickly and fades away slowly thereafter, for instance, extrinsic incentives increase more slowly and remain effective longer.

It is evident, that with respect to the pricing policy of AMAEM and the implementation of the peak tariff in particular, the communication and data processing capacity of DAIAD is more important than the amphiro b1 device. However, the amphiro b1 device can serve as a "gadget" that brings water users in closer contact with the water supplier by prompting them to install the DAIAD application.

7. References

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