018530 - SWITCH

Sustainable Water Management in the City of the Future

Integrated Project
Global Change and Ecosystems

Deliverable 1.2.10: Reference and training manuals for all models
Model: City Water Economics & Application Cases

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PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Contents

Preface

This report concerns the documentation of the "City Water Economics" (CWE) model, developed by the National Technical University of Athens within the framework of Theme 1 of the SWITCH Integrated Project "Sustainable Water Management Improves Tomorrow's Cities' Health".

The main concepts behind City Water Economics pertain to the assessment of the implications of different forms of institutional organization and of alternative cost allocation schemes for urban water services. These are examined from the perspective of those dealing with water service provision at various levels (metropolitan area, metropolitan area subset, river basin) and from the social perspective, with emphasis placed on affordability and incentives offered by pricing schemes and cost allocation mechanisms. Such issues are relevant to both developing countries, where financial sustainability and affordability of urban water services are a major concern, but also to the EU, where the requirements of Art. 9 of the EC Water Framework Directive pose the need for a reform of water pricing to (a) guarantee adequate recovery of costs, (b) allocation of these on the basis of the "polluter-pays" principle, and (c) incentives towards efficient water usage. Policy relevant questions that can be addressed through CWE are summarized in Box 1.

Box 1: Policy questions relevant to City Water Economics

An Urban Water Management Plan has cost

- *How can it be financed?*
- *Are current financial resources adequate?*
- *Who pays and for what, esp. with regard to water services?*

What can be the consequences of alternative cost allocation schemes?

- *Can full cost recovery be attained? What can be the impact for low-income users?*
- *What subsidies will be necessary?*
- *What cross-subsidies will be necessary?*

Do current (or potential) water pricing schemes offer incentives for the implementation of water conservation solutions by the users?

The main functions that delineate the overall modelling approach concern:

- The conceptualization of the institutional framework for water service provision. This concerns all entities (water utilities, local authorities, etc.) that deal with water supply, wastewater collection and treatment and stormwater management, and the (financial) interrelations between them.
- The allocation of water service costs among the different water service providers and to different categories of end-users. The allocation is performed on the basis of the "user-pays" principle, and involves defining the share of infrastructure managed/used by each provider/user respectively.
- The analysis of alternative water pricing scenarios and mechanisms primarily aimed at the recovery of water service costs. Scenarios can be evaluated on the basis of different indicators, which assess the achievement of objectives for the set cost recovery scheme and its potential social implications and distributional effects.

City Water Economics has been developed as part of the CITY WATER suite of tools. CITY WATER is a knowledge and information sharing platform to support global and integrated urban planning. With its set of tools, CITY WATER is meant to help end-users understand the different components of the water system in their city, their inter-linkages and interrelations, and evaluate the future potential impacts of global trends and technical options towards impact mitigation and sustainability enhancement.

To that end, City Water Economics can be used in combination with: (a) the Combined Water Information System, enhancing its capability for data retrieval, manipulation and storage, scenario comparison and indicators' visualization, and (b) City Water Balance, to help users understand the cost recovery implications of future urban water management plans or interventions.

The document is structured in three Parts. **Part I** is the user manual of the software. It navigates through the different software functions, details input data, and presents results that can be obtained by the model. **Part II** constitutes the reference manual, presenting the main concepts, and documenting algorithms and equations used by the model. Finally, **Part III** provides information and results on the software application in three SWITCH demo cities, Birmingham, Alexandria and Accra. These application examples are intended to showcase the applicability of the model and its potential for supporting aspects of strategic planning towards the city of the future.

This document has been developed by the Environmental and Energy Management Research Unit of the School of Chemical Engineering of the National Technical University of Athens (NTUA). Case applications provided herein have been jointly developed with the following SWITCH partners: the University of Abertay (Accra application), the École Polytechnique Fédérale de Lausanne and the University of Birmingham (Longbridge, Birmingham) and CEDARE (Alexandria).

Part I: City Water Economics User Manual

1 Introduction

1.1 Scope

This Part of the City Water Economics documentation comprises the User Manual of the software. It mainly describes its functionalities, detailing also input data requirements, parameters and results that can be obtained through the model. As such, this Part covers primarily aspects that deal with the main concepts, the user interface and data requirements. It is structured in the following way:

- Section 2 provides a brief overview of the main concepts and functionalities;
- Section 3 describes the overall software navigation structure;
- Sections 4-6 detail the functionalities of the main model functions, including the configuration of a case, the definition of the infrastructure management framework and the analysis of different scenarios on cost recovery and tariff structures;
- The Annex details the structure of external input data requirements, which need to be prepared by the user and imported in City Water Economics.

The User Manual is complemented by Part II which is the Reference Manual of City Water Economics. Part II provides an in-depth description of the underlying concepts, algorithms and equations used for designing and evaluating different cost recovery schemes.

1.2 Installation and System Requirements

City Water Economics (CWE) is a Windows Application developed using the Visual Basic .NET programming language. The software requirements for CWE are:

- Operating Systems: Microsoft® Windows XP Service Pack 2 (32bit or 64bit) or Microsoft® Windows Vista (32bit or 64bit), or Microsoft Windows 7 with .NET framework installed;
- Microsoft® Excel™ 2007 (compatible with Microsoft Excel 97, 2000, 2003), in case that the external input data are provided in Excel format.

City Water Economics is installed by running the software setup program. The installation is simple, and the user just needs to go through the different installation steps by clicking "Next" at each screen. If required, different installation paths or use rights can be defined in the corresponding installation steps.

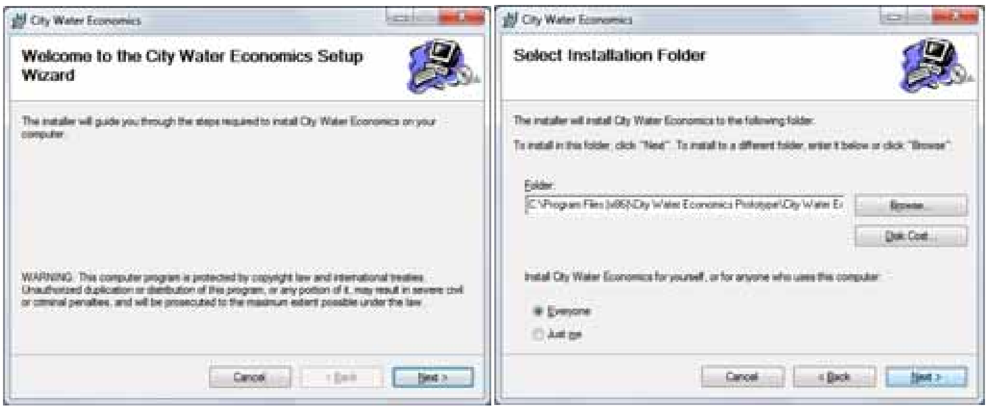


Figure 1: City Water Economics Installation – Part I
(Installation initiation and choice of installation path and use rights)

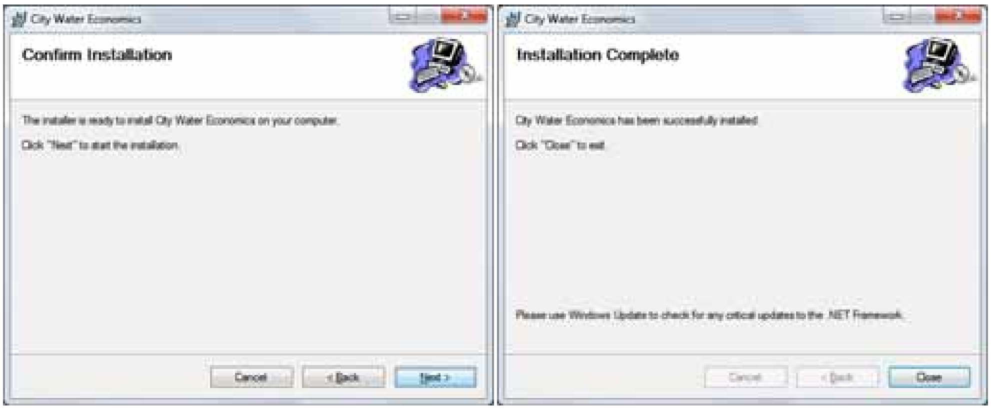


Figure 2: City Water Economics Installation – Part II (Installation confirmation and installation end)

2 Overview of the main model concepts and functionalities

City Water Economics is framed around the concepts of "Case" and "Scenario".

A **"Case"** comprises a conceptualization of the framework for water service provision in a given urban metropolitan area or a metropolitan area subset, as well as a scenario on alternative pricing schemes for different water services. A "Case" is built on baseline data, and can further include projections on water demand, supply, and future infrastructure investments, in order to analyze alternative schemes for the recovery of the corresponding financial costs. A **"Scenario"** builds on the data entered for a case, and involves the definition of parameters for allocating costs among water service providers, and for the design of cost recovery schemes. Scenarios can be evaluated through indicators and cross-compared to depict the most suitable alternatives according to chosen output indicators and evaluation criteria.

The steps encompassed in the CWE modelling approach are presented in Figure 3. These concern: (i) Case Configuration, (ii) Definition of the framework for water service provision, (iii) Cost allocation among water service providers, (iv) Definition of pricing schemes, and (v) Calculation of output indicators and sensitivity analysis.

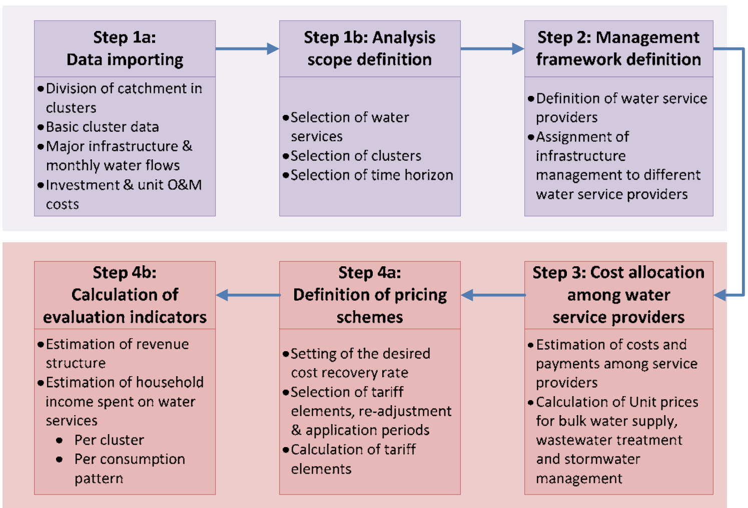


Figure 3: The CWE Case and Scenario analysis steps

The **configuration of a case** concerns the input of baseline data for a case to be developed and evaluated by the model. Relevant data and parameters concern (a) water flows and infrastructure elements for water supply, wastewater collection and treatment and stormwater management, over a specific timeframe (current or for a future plan), (b) water service areas, and (c) reference data on disposable income and consumption distribution among different population segments in the service areas. The **framework for water service provision** for the area of interest is mapped through the definition of all agents involved in the development, operation and maintenance of water supply, wastewater collection and treatment and stormwater systems, and their respective roles. This expands beyond the simple definition of utilities and authorities concerned with network management and rehabilitation, to also address more complex frameworks, involving agencies/management entities dealing with the management of storage reservoirs and conveyance networks upstream or downstream of the urban water system, and potential institutional reforms.

Defined scenarios concern the calculation and allocation of capital, operation and maintenance **costs among water service providers**. In this first step of scenario analysis, desired cost recovery objectives can be attained through the estimation of the corresponding bulk prices. These are based on the "user-pays" principle, i.e. the payment for water services received is equal to the cost that corresponds to these services. Bulk prices can also be user-assigned to address the case where these are the output of negotiations or government regulation. **Tariff schemes** for each urban water service can incorporate different elements, depending on overall goals and objectives. City Water Economics incorporates different, widely applicable, methods which can incorporate both fixed and variable charges. Rates are calculated by the model according to desired cost recovery objectives over specific timeframes and periods. Main **output indicators** for scenario evaluation concern: (a) the affordability of water charges, expressed as the annual expenditure and the corresponding share of disposable income spent on water services; (b) revenue patterns for water service providers, specifically analyzing the ratio of collected fees in relation to different cost elements; (c) the potential impact of the price elasticity of water demand to the range of objectives set; and (d) the rate of return and payback period for decentralized closed-loop systems (raintanks, SUDS, on-site wastewater treatment and reuse etc) and water saving appliances.

The following paragraphs describe in more detail the implementation of the above functionalities in City Water Economics.

3 Getting Started with City Water Economics

3.1 Application launch and start-up

City Water Economics can be launched using the shortcut that has been installed on the user's Desktop or the one of the Windows Start Menu.

With the launch of the software, the welcome screen of Figure 4 appears.

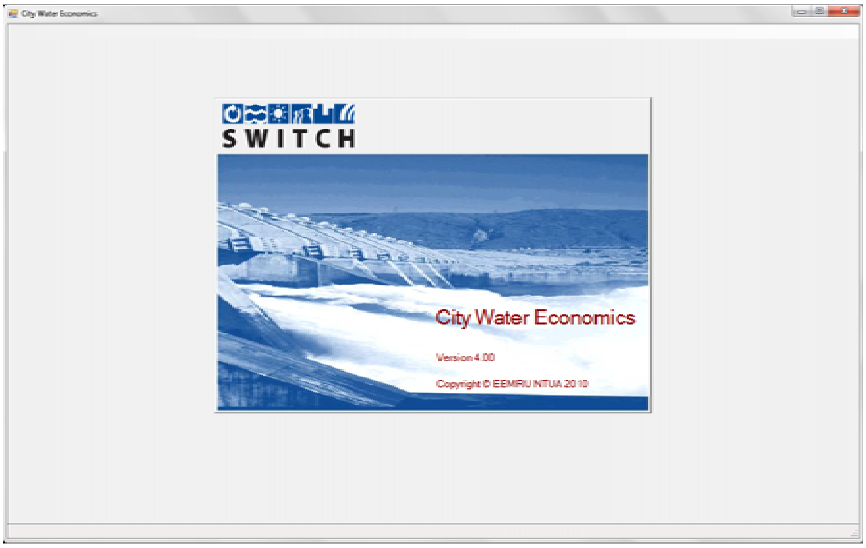


Figure 4: City Water Economics Start-Up Screen

To continue, the user must click on the welcome picture. Then, they are prompted to either "Create a New Case" or to select one of the cases recently developed and saved with City Water Economics. This can be performed by choosing the corresponding file from the list dialogue that appears (Figure 5).

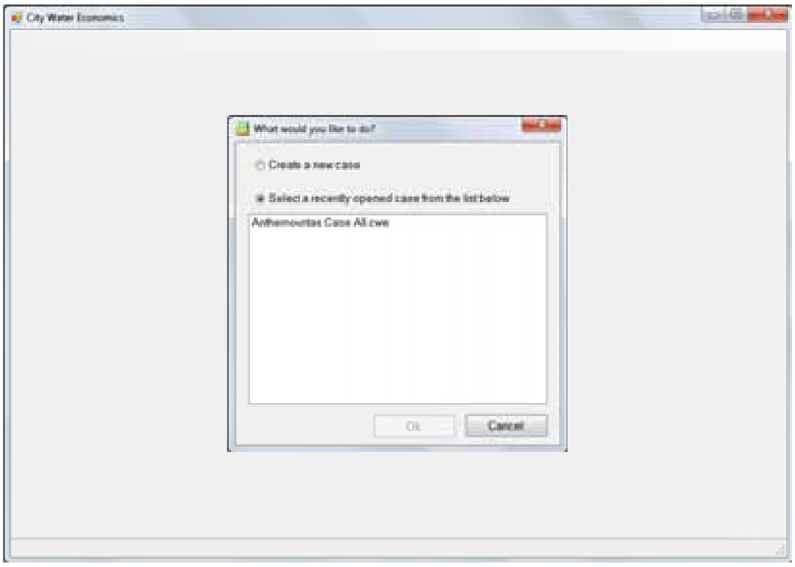


Figure 5: City Water Economics Start-Up Dialogue

Similar operations (Creation of a new case, opening of an existing one and case saving) are also available from the "File" menu, at the top left part of the main screen.

3.2 Overall software navigation structure

The main interface of City Water Economics is divided in two (2) main parts (Figure 6):

- The **left side** of the screen is used for navigating among the different screens and individual modules of the software. It is further subdivided in two sections:
  - The **top left part**, *"Case Data and Configuration"*, provides access to functionalities that concern the definition of the main parameters of the Case, the importing of external data, and the entering of additional information required to use City Water Economics.
  - The **bottom left part**, *"Scenario Configuration and Results"*, is used to define parameters for potential cost recovery schemes, and for visualizing results towards their evaluation.
- The **right side** of the screen changes, according to the selections of the left part. It is where the data are entered and results can be visualized.

An overview of the different functionalities included in City Water Economics is provided in Table 1.

Table 1: Description of Functionalities embedded in City Water Economics

Functionality Category / Name	Overview
Case Data and Configuration	
Case Configuration	Configuration of Case Parameters Importing of external data
Additional Cluster data	Definition of additional baseline cluster data, required to run City Water Economics. These pertain to three categories: Baseline Consumption Data, Baseline Pricing and Disposable income distribution data
Infrastructure Management Framework	Definition of the Water Service Provision Framework for the Case
Scenario Configuration and Results	
Allocation of costs among water service providers	Definition of parameters for financial cost estimation and their allocation among water service providers
Definition of tariff schemes	Definition and calculation of the components of tariff schemes for mains water supply, wastewater collection and treatment and stormwater management by individual water service providers
Main output indicators	Visualization of results for different evaluation indicators calculated by City Water Economics
Sensitivity analysis on elasticity	Assessment, through sensitivity analysis, of the impact of the price elasticity of water demand on main output indicators and design objectives of tariff schemes
Analysis of on-site management interventions	Evaluation of the impact of tariff schemes on the adoption of on-site urban water management interventions.

Furthermore, the "File" and "Help" menus at the top of the screen provide access to functionalities for creating new, opening existing and saving City Water Economics Case Files, and for accessing the user-support help file of the model.

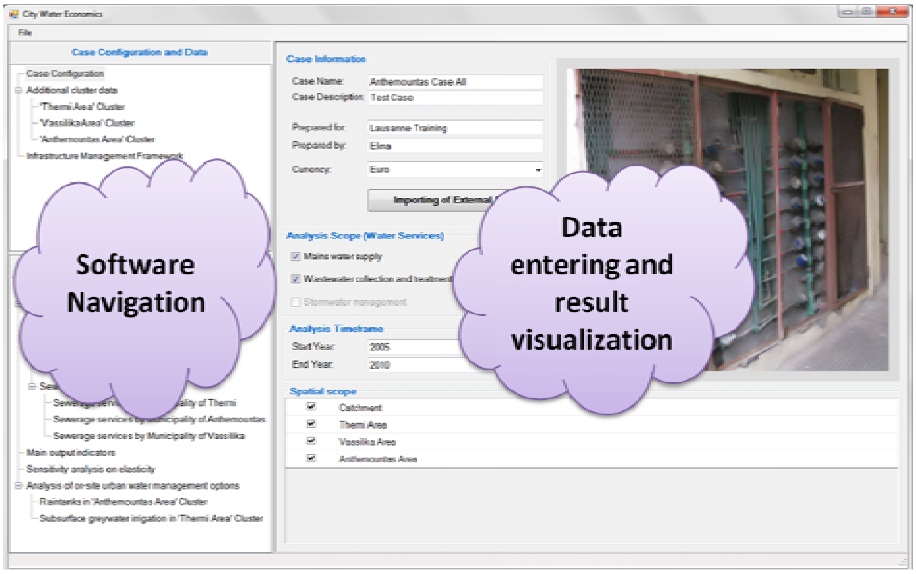


Figure 6: Structure of the main interface of City Water Economics

4 Creating and configuring a new case

The creation of a new case to be analysed with City Water Economics can be performed in two ways:

- Through the start-up screen, by selecting the "Create New Case" option;
- Through the "File" menu, by selecting "File>New Case".

The first step in developing a case concerns its configuration. This is performed by selecting the "Case Configuration" view from the top left part of the screen. The right part is then updated accordingly, displaying the configuration parameters of the Case, which can be modified.

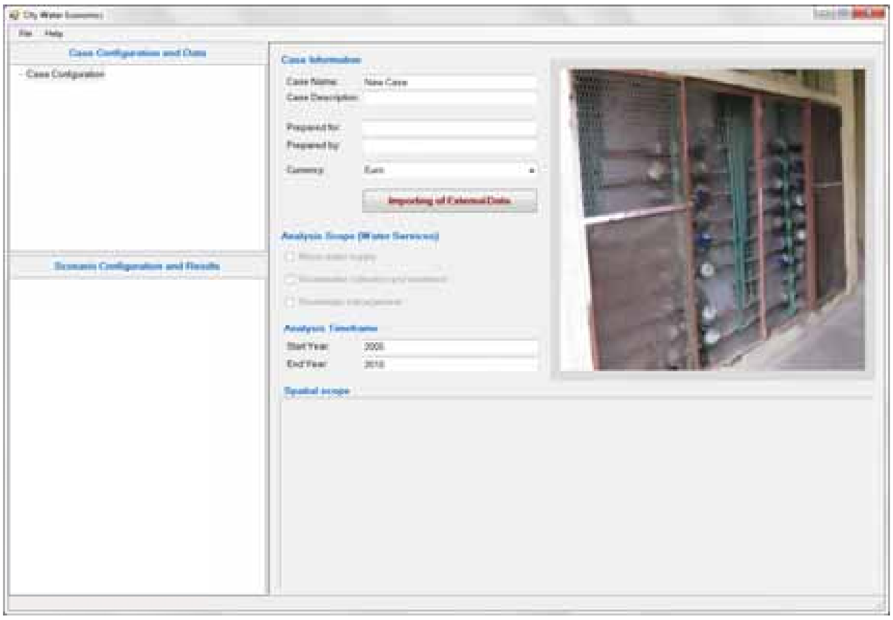


Figure 7: The Case Configuration Interface immediately after a new case has been created

The user first needs to define some basic information for the case, including a Name (required), a Description (optional), and the currency unit (required – Euro is selected as the default).

The most important and critical aspect of the configuration concerns the *"Importing of External Data"*, performed by hitting the corresponding button. The following restrictions and conditions apply:

- When data have **never** been imported for a case, the *"Importing of External Data"* button is marked in red. Only when data have been imported successfully do other software options and functionalities on the left part of the screen become available.
- Input data are also stored in the CWE Case Configuration file when this is saved. Potential data modifications in the input file are not taken into account, unless data are re-imported through the "Case configuration" interface".
- A new dataset can be imported at any time, but this would mean that several data and information would need to be re-entered through the various software screens. It is thus preferable to import the input data at the very beginning.

Overall, City Water Economics accepts three types of input files:

1. Excel files (Microsoft Office 2003 and above)
2. ASCII (txt) files
3. XML files that have been generated for the model through the Combined Water Information System (CWIS) platform.

External input data concern:

- The clusters of the area: Data requirements concern water demand, number of households and unit blocks (buildings), as well as the share of population connected to networks.
- Infrastructure used for water supply, wastewater collection and stormwater management. Data requirements include (a) infrastructure costs (investment, O&M), (b) interconnections between infrastructure elements and (c) the corresponding flows.
- On-site interventions, such as raintanks, on-site wastewater treatment units, etc. Data requirements concern reductions in individual water supply, wastewater outflows to the sewerage system and stormwater outflows.

A detailed description of input data and file structures is provided in the Annex.

When data have been successfully imported (Figure 8), the Configuration screen is updated according to the information included in the data file. Updates concern: (a) water services that can be analysed, depending on which categories of infrastructure and flow data have been entered; and (b) available clusters (geographical areas) that can be analysed. Furthermore, additional options for (i) entering Additional Cluster data and (ii) defining the Infrastructure Management Framework become available at the top-left part of the screen.

To complete the "Case Configuration" process, the user needs to also define the analysis scope, by selecting:

- The water services on which the case will focus. Available options depend on the data entered, and involve: (a) Mains water provision; (b) Wastewater collection and treatment; and (c) Stormwater management.
- The time frame for the analysis (Start and End Year), which should be a subset or the complete timeframe for which external data are provided.

- The spatial scope, which includes the clusters for which the analysis will be performed.

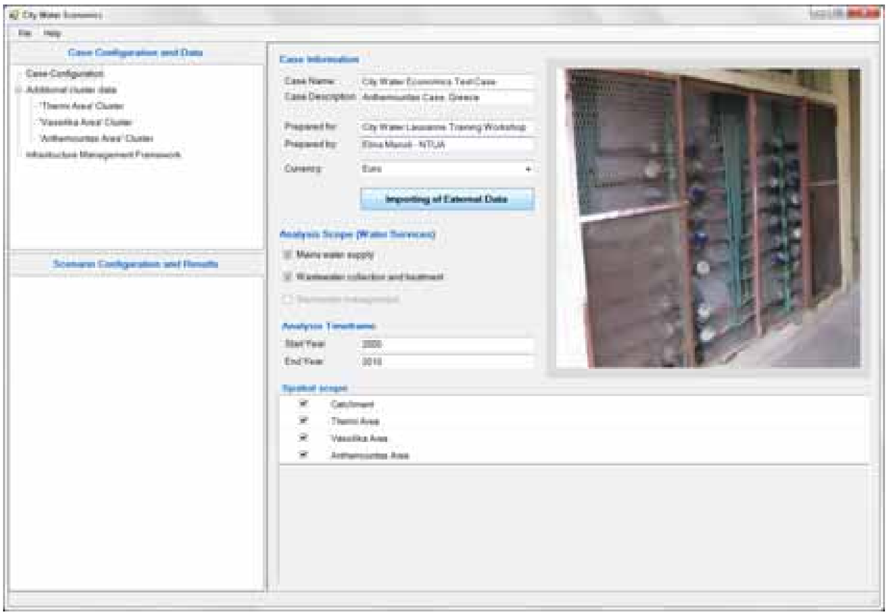


Figure 8: The Case Configuration Screen after data have been imported

After the initial configuration of the case, the user needs to undertake two further steps before proceeding to the development and evaluation of alternative cost recovery and pricing schemes. These concern (a) the entering of additional input data and (b) the definition of the infrastructure management framework and are explained in the next two paragraphs.

4.1 Entering additional cluster data

Additional cluster data concern:

- Baseline consumption data, which are used to define and validate demand distribution curves that are necessary for the analysis of certain pricing methods (Increasing Block and Decreasing Block Tariff schemes).
- Data on the existing tariff structures, required to perform comparisons among new schemes and the baseline system.
- Disposable income and relevant distribution data, required when performing an affordability analysis.

The above are entered for the individual clusters, as defined through the corresponding input file. The following paragraphs detail the corresponding information, indicating also required and optional parameters.

4.1.1 Baseline consumption data

Baseline consumption data refer to the total consumption at a given period and its distribution among metered connections. Information is used to derive the parameters corresponding to a dimensionless Weibull cumulative distribution, which indicates the share of the total consumption that corresponds to a specific share of connections. The Weibull parameters can be calculated either by City Water Economics, using a simplified regression method, or assigned by the user as a result of an independent regression exercise.

Data requirements concern:

- Consumption baseline data, which include the number of metered connections and the metered consumption for a base year or period;
- Parameters of the Weibull distribution, which is used to represent the statistical distribution of consumption and are derived by detailed consumption distribution data;
- Detailed consumption distribution data, which can be used by CWE to estimate the Weibull parameters that are required for subsequent estimations.

An example of the corresponding data is presented in Figure 9. In the example presented in the Figure, and for a given year, the number of metered household connections (5,470) and the corresponding total consumption (868,947 m^3) for 2004 have been obtained by the records of the local water utility. Furthermore, and as the water utility follows an Increasing Block Tariff system, there are records which indicate how many connections pertain to each of the existing IBT consumption blocks (e.g. in 2004, 3,600 connections consumed a volume between 0 and 150 m^3, whereas 1,582 connections consumed a volume between 150 and 300 m^3/yr, etc.).

In addition to water utility records, data sources can also include survey data, based on a representative share of connections, or proxy data from other areas, with similar water consumption patterns and socio-economic characteristics.

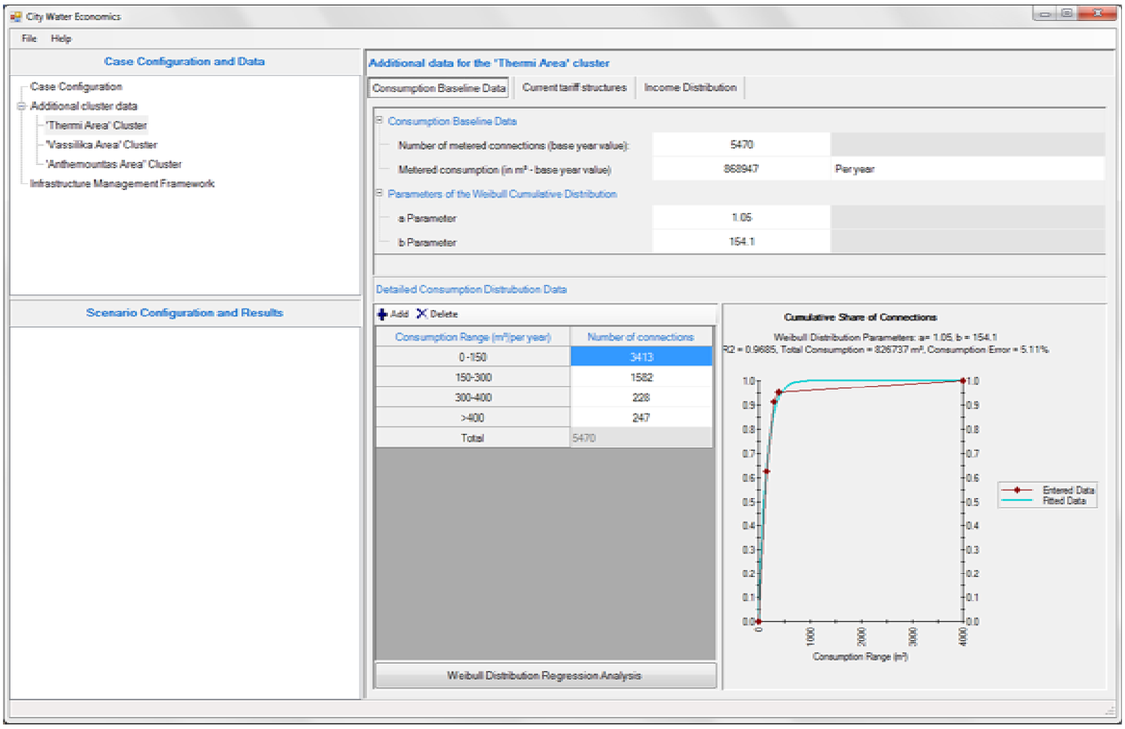


Figure 9: The Baseline Consumption Data Interface for a specific cluster area

To use the regression analysis embedded in CWE, the user needs to enter the corresponding information on the low right table of the screen. Subsequently, when hitting the *"Weibull Distribution Regression Analysis"* button, the Weibull parameters are calculated by the software and displayed as message. The message further displays the R2 coefficient of determination and the error of the fitting with regard to metered consumption. This information can help the user decide whether the derived Weibull distribution is a good representation of the baseline data. If the parameters are accepted by the user, the corresponding

chart is re-drawn, displaying both the entered data and the fitted curve. In addition, this action also updates the Weibull parameters displayed at the top part of the screen.

4.1.2 Current tariff structures

The *"Current tariff structures"* section of the *"Additional cluster data"* interface is used to describe the current pricing schemes for water services provided in each cluster. These concern:

- Mains water supply,
- Wastewater collection and treatment, and
- Stormwater management.

A screenshot example is presented in Figure 10.

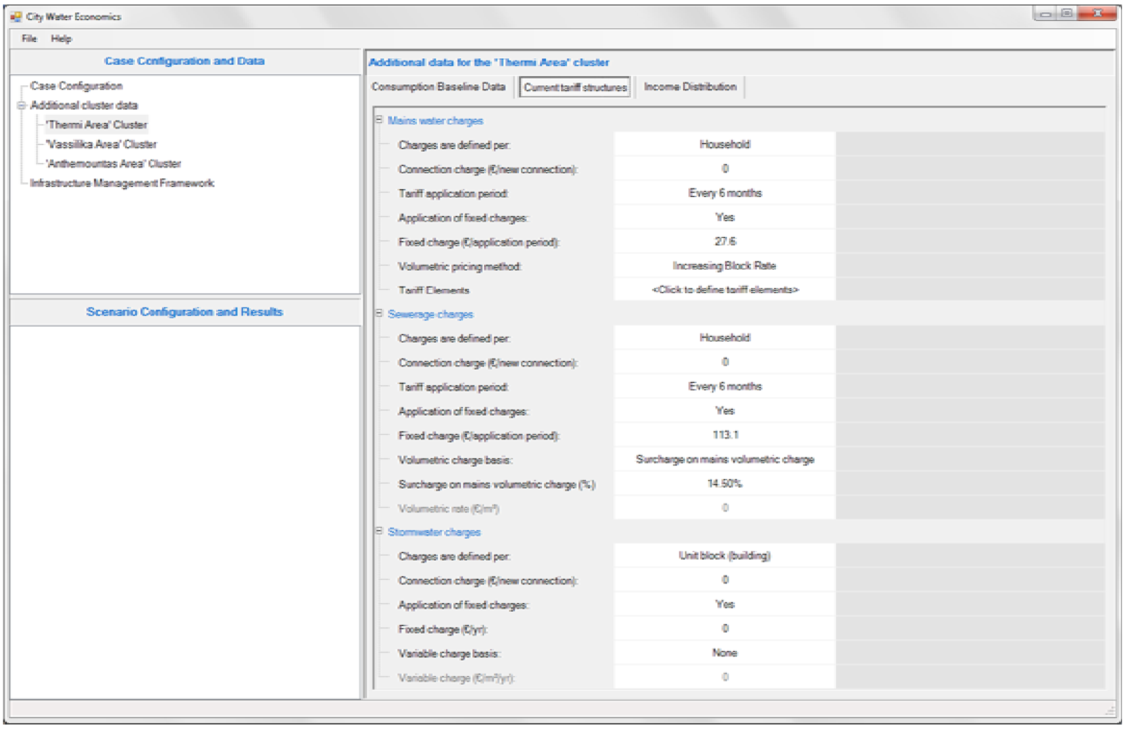


Figure 10: The "Current tariff structures" interface of the "Additional cluster data"

The elements used to define each current pricing scheme are further explained in Section 4 of the Reference Manual, as well as in Section 6.2 which deals with the design of tariff schemes. A brief description of these elements and the corresponding interface functionalities is provided in the Sections that follow.

4.1.2.1 Mains water pricing

The parameters used to describe the baseline tariff scheme for mains water provision comprise:

- The level at which charges are applied. Two options ("Household" or "Unit block (building") can be set through the list, depending on where water consumption is metered.
- The charge for new connections to the mains water supply system ("Connection charge").
- The billing period ("Tariff application period"). Available options are once per year, every 6, 4, 3 or two months and every month.

- Whether the current tariff includes a fixed charge; if the corresponding value is set to "Yes", the user is also required to enter the current amount for the fixed charge in the next row.
- The applied method for volumetric charges. Available options include:
  - "None", i.e. no volumetric charge;
  - "Uniform Volumetric rate", i.e. a fixed volumetric rate, independent of the amount of water used;
  - "Increasing Block Rate", i.e. volumetric rates that increase according to consumption; and
  - "Decreasing Block Rate", i.e. volumetric rates that decrease as consumption increases.

For the three last methods, the user needs to enter additional information, to describe the volumetric rate structure in the cluster area. This can be performed by clicking on the *"<Click to define tariff elements>"* button. In the screen that appears, the user is required to enter the applicable rates. An example, for an "Increasing Block Rate" structure is presented in Figure 11.

Depending on the chosen tariff application period, the user is required to define the volumetric rates applicable to each period, so as to signal any seasonal variation in applicable volumetric rates. In the case of increasing or decreasing block rates, additional consumption blocks can be inserted through the "Insert Block" button at the top of the screen; the user is then prompted to enter the corresponding water consumption bounds (lower and upper water consumption limits for the specific block). If the upper block limit is left blank, then it is considered the last one. In the case that an entered consumption range overlap existing ones, the existing ranges are adjusted accordingly.

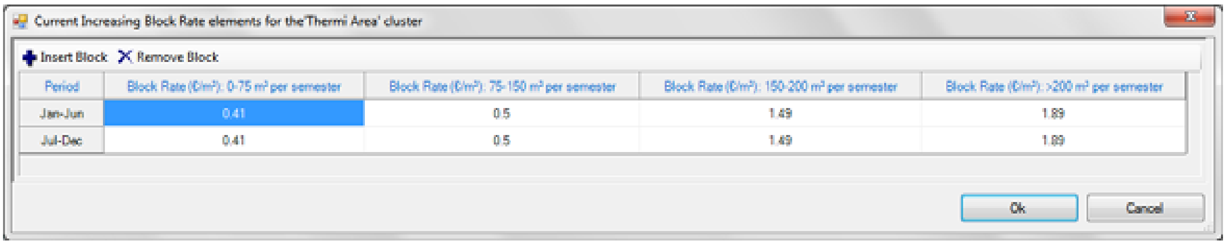


Figure 11: Definition of volumetric elements for current mains water pricing schemes

4.1.2.2 Wastewater collection and treatment

Parameters used to describe the baseline tariff scheme for wastewater collection and treatment include:

- The level at which charges are applied. Two options ("Household" or "Unit block (building") can be set through the corresponding list.
- The charge to be paid for new connections to the sewerage system ("Connection charge").
- The billing period ("Tariff application period"). Options available include per year, every 6, 4, 3 or two months and every month.
- Whether the current tariff includes a fixed charge; if the corresponding value is set to "Yes", the amount for the fixed charge should be entered in the next row.
- The basis for calculating volumetric charges. Three options are available: (a) none, which means that no volumetric charge is applied; (b) definition of charges based on a set percentage of the volumetric charge for mains water supply (surcharge on mains water volumetric charge); or (c) definition of charges based on an independent uniform volumetric rate, and a fixed percentage of mains water consumption. Depending on the chosen method, the user needs to also define the corresponding parameters in the next two rows.

4.1.2.3 Stormwater management

Baseline tariff schemes for stormwater management are described on the basis of the following parameters:

- The level at which charges are applied. Two options ("Household" or "Unit block (building") can be set through the corresponding list.
- The charge to be paid for new connections to the sewerage system ("Connection charge").
- Whether the current tariff includes a fixed charge; if the corresponding value is set to "Yes", the user is also required to enter the current amount for the fixed charge in the next row.
- The basis for calculating variable charges. Three options are available: (a) none (i.e. no variable charge); (b) definition based on the area of the property; (c) definition based on the impervious area of the property. Depending on the chosen method, the user should also specify the corresponding parameters in the next two rows.

4.1.3 Disposable income distribution data

The main data requirement of the "Income distribution data" is the average household disposable income within the cluster. The user has further the possibility to specify: (a) an average yearly income increase in %, and (b) the variation of the average disposable income among different customer classes (Figure 12). The latter information is required when performing a detailed affordability study of the examined schemes. In this case, it is necessary to calculate for different population segments the share of their income that is (or will be) allocated to cover water service charges.

In the above context, the income distribution data matrix allows to define all relevant parameters for each income class. These concern:

a. A description for the income group (e.g. middle class, upper-middle class, low, etc.)
b. The variation of disposable income for the specific group in relation to the average one;
c. The share of households of the area that pertain to the specific group;
d. The share of water consumption that corresponds to the specific group;
e. The variation of the property size of the average household that pertains to the specific group.

Data can be obtained through surveys or through statistical records (similar information is usually collected by National Statistical Services and local authorities). The following restrictions apply:

- To ensure that there is no discrepancy with regard to the average household disposable income information, the sum of products of income variation [(b)] and the share of households [(c)] across all income groups should be equal to 1.
- The sum of the share of households across income groups should be equal to 1.
- The sum of individual consumption shares across income groups should be equal to 1.

The relevant validation checks are presented at the bottom row of the Income Distribution Matrix.

An example of three income groups defined for a specific area in Greece is presented in Figure 12. Data are based on the 2002 Geographical Income Distribution Analysis, published by the Hellenic Ministry of Finance, and on-site surveys in the area concerned.

- The first income group concerns the lowest income class (39% of the average disposable income), which concerns 52% of households. The share of total consumption that corresponds to this group is 60% whereas the average property of their residence (owned or leased) is 80% of the average one.

- The second income group concerns the average income class (99% of the average disposable income), which concerns 28% of households. The share of total consumption that corresponds to this group is 20% whereas the average property of their residence (owned or leased) is equal to the average one.
- Finally, the third income group is classified as high income (250% of the average disposable income), and concerns 20% of households. The share of total consumption that corresponds to this group is similarly equal to 20% whereas the average property of their residence (owned or leased) is 150% the average one.

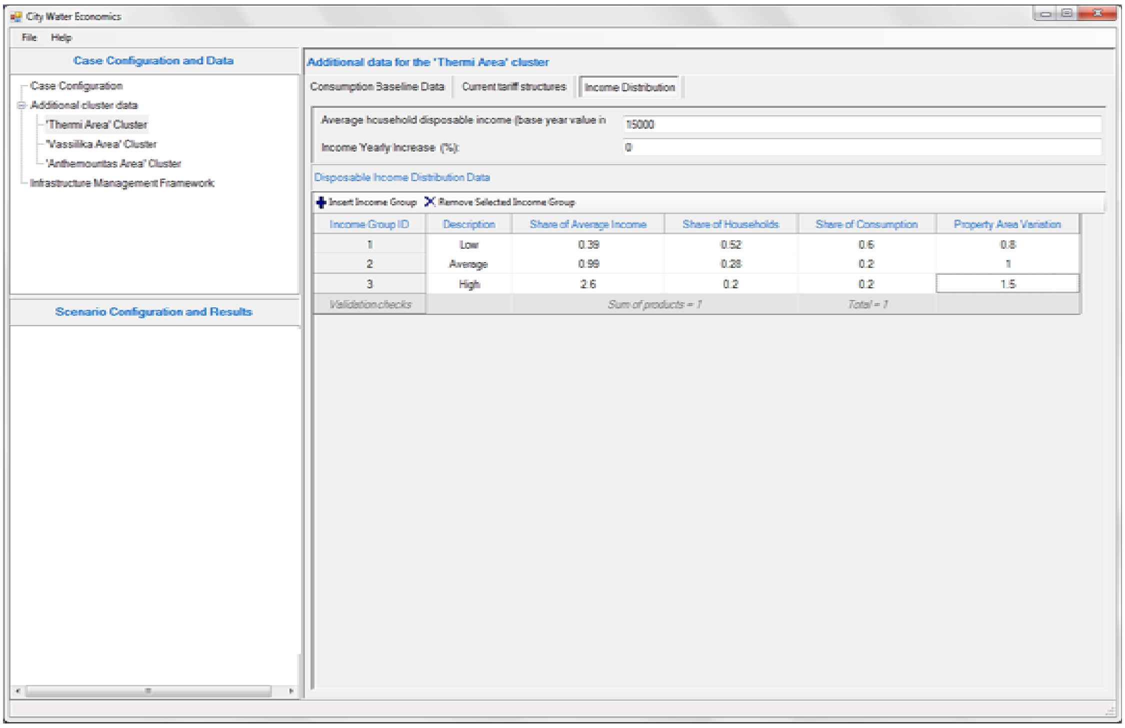


Figure 12: The "Income Distribution" Interface of City Water Economics

By default, and when no income groups have been entered by the user, a default income group is created, which represents an average group. Additional income classes can be created using the *"Insert income group"* button at the top of the Income Distribution Data matrix. An entry can be removed only after it has been selected, through the *"Remove Selected Income Group"* option.

To save entered information and proceed, the user must ensure that all entered information conform to the validation checks defined above.

5 Defining the institutional framework for water service provision

One of the most important steps in defining a case or scheme to be run and evaluated using City Water Economics is the definition of the framework for water service provision in the examined areas. This involves the following:

- Defining the water service providers in the area of interest. Following the definition of the EC Water Framework Directive, water services means all services which provide for households, public institutions or any economic activity: (a) abstraction, impoundment, storage, treatment and

distribution of surface water or groundwater, and (b) waste-water collection and treatment facilities which subsequently discharge into surface waters. Water service providers are those concerned with the management of the corresponding infrastructure. They can include state, regional or local authorities, water utilities, water transfer companies, etc. Their definition can be done through the *"Definition of water service providers"* list at the top part of the screen.

- Assigning the management of infrastructure elements to individual water service providers. Two main categories are included:
  - Catchment infrastructure, which involves all infrastructure elements that are either located outside the cluster areas, or supply more than one cluster area in the catchment. Examples can include dams and storage reservoirs, desalination units, large conveyance networks etc. Information on each element is entered separately through the table *"Management of catchment infrastructure"*, located in the centre of the screen.
  - Cluster infrastructure, which is managed by those water service providers that provide water services within the specific cluster area. This involves all assets (e.g. networks, reservoirs, pumping equipment etc.) that pertain to the specific cluster. The user does not need to specify the water service provider that assumes the management of each infrastructure element entered in the CWE data file; instead, they enter the corresponding information only for the specific cluster in the *"Management of cluster infrastructure"* table.

In order to proceed to the *"Scenario Configuration and Results"* section, the user needs to assign a water service provider for each catchment infrastructure element and cluster. Potential omissions (no assignments) will be coded in red, and may occur when: (a) an infrastructure element or cluster has been assigned to a water service provider and subsequently this water service provider is deleted from the "Providers" list at the top of the screen.

Figure 14 and Figure 15 provide an example of defining a management framework for water service provision in an area in Greece. Information entered in CWE follows the infrastructure management framework that is elaborated in Figure 13.

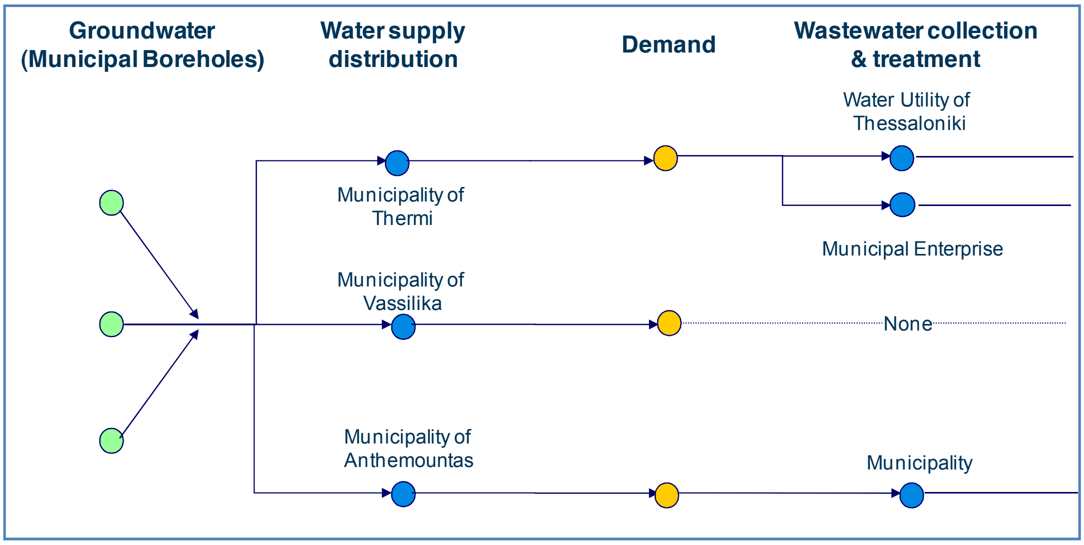


Figure 13: Example of a management framework for water service provision

In more detail:

- Concerning water supply, three water service providers are active in the areas of interest; these are the three municipalities, that each manages its local water supply sources (boreholes) and distribution networks. As presented in Figure 14, this framework requires assigning:
    - The individual boreholes to each municipality (see the “Management of catchment infrastructure” table), and
    - The management of each cluster area to the corresponding municipality (see the “Management of cluster infrastructure” table)
- On the wastewater side, wastewater treatment is undertaken by two providers: the water utility of a metropolitan area in the vicinity (EYATH S.A.) and one municipality. Sewerage networks remain under the management of the local municipalities. The corresponding assignments through CWE are presented in Figure 15.
    - The central WWTP is assigned to EYATH S.A. whereas the smaller, municipal WWTP is assigned to the local municipality (see the “Management of catchment infrastructure” table), and
    - Sewerage networks are assigned to the local municipal authorities (see the “Management of cluster infrastructure” table).

Similar operations are required for defining the framework for stormwater management services.

When all infrastructure elements have been assigned to specific water service providers, the “Scenario Configuration and Results” becomes populated with the relevant options, and the user can proceed to the allocation of costs among service providers, the definition of tariff schemes and their evaluation. These operations are described in the next chapter.

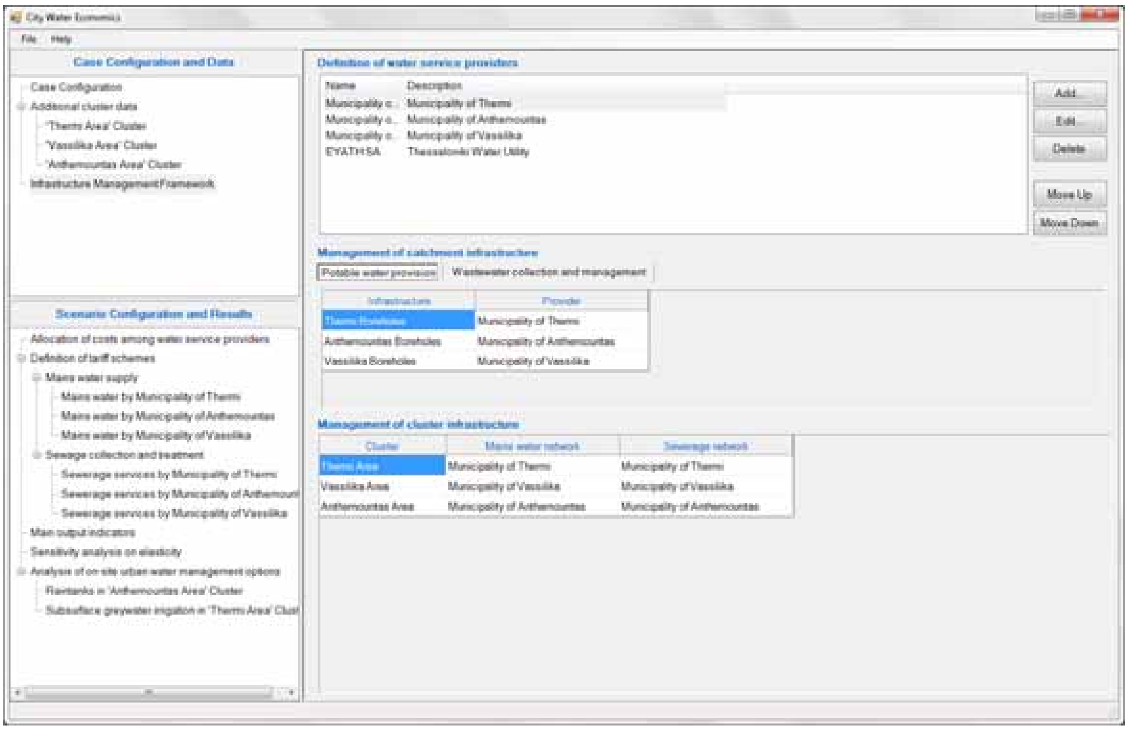


Figure 14: Infrastructure Management Framework – Definition of the framework for the provision of potable water supply

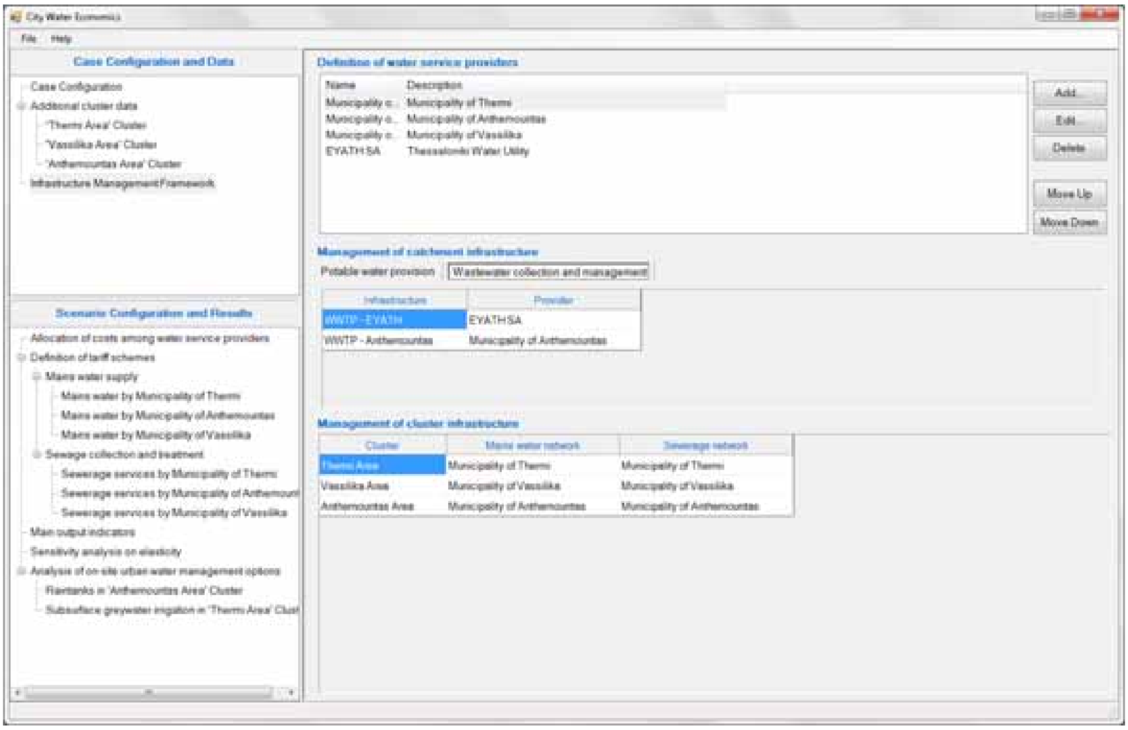


Figure 15: Infrastructure Management Framework – Definition of the framework for the provision of wastewater collection and treatment services

6 Analysis of scenarios

6.1 Allocation of costs among water service providers

The first step in the analysis of alternative scenarios concerns the "Allocation of costs among water service providers". This also includes the definition of mechanisms for the recovery of financial costs for water services they provide to each other, along the chain of water service provision. For example, in the above case, a payment should be made by the Municipality of Thermi to EYATH S.A. as the latter assumes the treatment of the wastewater that is collected in the municipality. The form of this payment, as well as the calculation of the individual price is determined in this stage of scenario analysis.

The first step for allocating costs among water service providers includes their computation, which involves the calculation of costs (Capital, Operation and Maintenance) for all infrastructure elements managed by each provider. For the estimation of capital costs, two options are available:

- Simple, linear depreciation, where the initial investment cost is distributed equally along the lifetime of the infrastructure element;
- Amortization of the investment cost along the lifetime of the infrastructure element, where the user also needs to enter the corresponding amortization rate.

Through the "Yearly Cost Increase" option, the user can further account for changes in costs (e.g. due to inflation, market price increases etc.), by specifying an annual increase rate.

Payments among water service providers can concern:

- Bulk water supply provision;
- Conveyance, treatment, and disposal of wastewaters;

- Conveyance, treatment and disposal of stormwater run-off.

Overall, payment calculations can be performed in two ways, by defining the “Bulk price estimation” option:

- The user can assign a default price or lump sum, which is horizontally applied to all similar water services (“Assign default lump sum/rate” option). This mechanism corresponds to a price or sum which is defined administratively, by the pertinent legislation.
- Individual prices can be calculated by CWE, on the basis of the yearly costs that correspond to each water service provider (“Calculate yearly rate” option). In the latter case, prices are calculated according to the “user-pays” principle, i.e. the payment for water services received is equal to the cost that corresponds to these services.

Results from this stage are presented per water service and water service provider through by selecting from the corresponding lists, and concern the cost components for each water service provider and service. They are displayed at the bottom part of the screen, and are available in graph and tabular form. Graphs can be customized, and both graphs and tables can be copied or exported for further processing using the toolbar at the bottom of the “*Result*” display section.

Figure 16 presents an example for the costs allocated to the Municipality of Thermi for wastewater collection and treatment. Capital and O&M costs correspond to sewerage network development, and operation and maintenance. Purchase costs correspond to payments made to EYATH S.A. which assumes wastewater treatment for the municipality. The individual rate, in €/m³ treated, is calculated by City Water Economics, and adjusted yearly for changes in costs and treated quantities, at a rate of 3%.

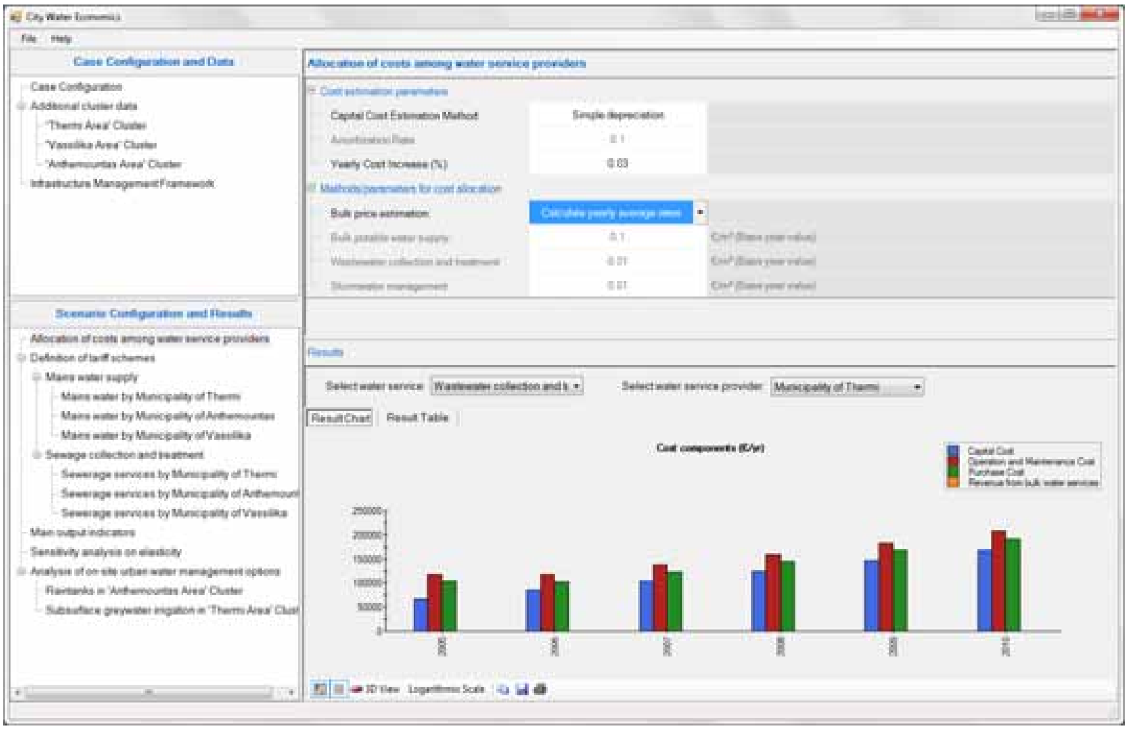


Figure 16: Options and results for the allocation of costs among water service providers

6.2 Definition of tariff schemes

A subsequent step in scenario definition concerns the design of tariff schemes for water services analysed in the context of the case. Tariff schemes are defined at the level of water service providers who assume the management of cluster infrastructure and are responsible for metering and invoicing. They are designed separately for each water service provided by the provider, considering that a key objective is related transparency (i.e. ensuring that recovered costs correspond only to the specific water service and that the assessment of tariff elements is transparent in relation to the specific cost components).

Thus, for the institutional and management framework described in Section 5, the following tariff schemes are designed (Figure 17):

- Mains water supply:
  - Tariff for mains water supply provided by the Municipality of Thermi;
  - Tariff for mains water supply provided by the Municipality of Vassilika;
  - Tariff for mains water supply provided by the Municipality of Anthemountas;
- Sewage collection and treatment:
  - Tariff for services provided by the Municipality of Thermi;
  - Tariff for services provided by the Municipality of Vassilika;
  - Tariff for services provided by the Municipality of Anthemountas.

As explained in Section 6.1, cost recovery schemes pertaining to wastewater treatment services provided by EYDAP S.A. concern payments made by the Municipality of Thermi and are thus calculated on the basis of parameters defined through the *"Allocation of costs among water service providers"* screen.

The following sections explain in more detail the parameters and estimates performed for each type of tariff scheme.

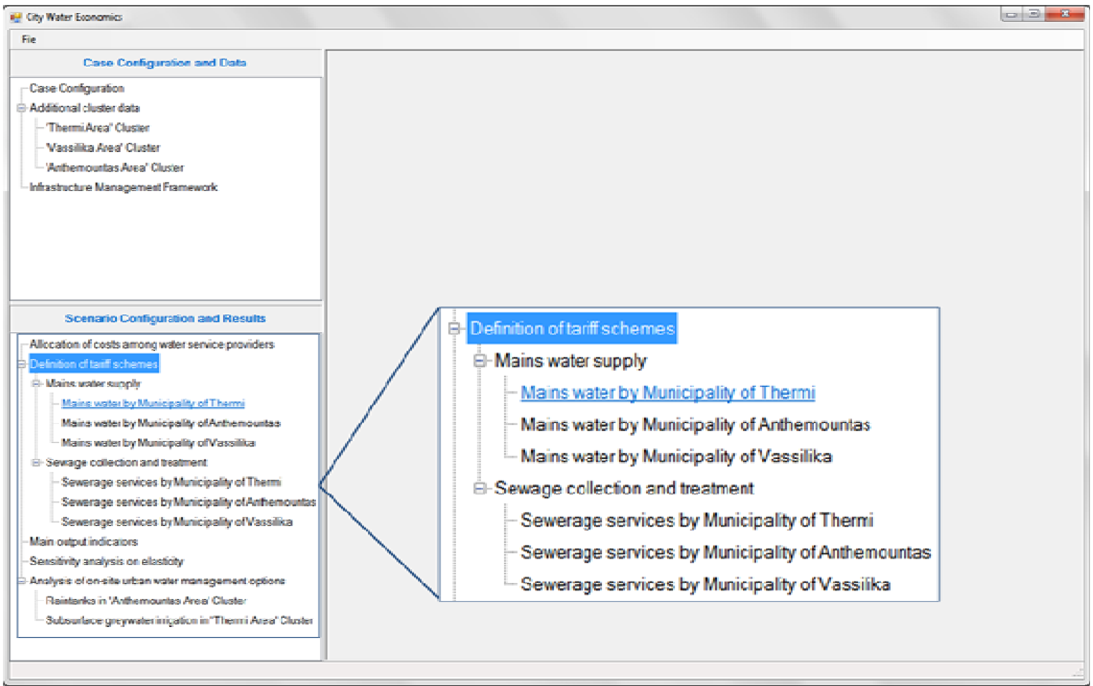


Figure 17: Design of tariff schemes options

6.2.1 Design of tariff schemes for mains water supply

The screen for tariff scheme design is divided in three main parts (Figure 18). The first, top part, displays what is currently being designed, and also to which clusters this is applicable, according to the information entered in the "Infrastructure Management Framework" section. The middle part is devoted to the definition of the tariff scheme parameters, whereas the bottom part ("Results") presents the main results, in graphical and tabular form.

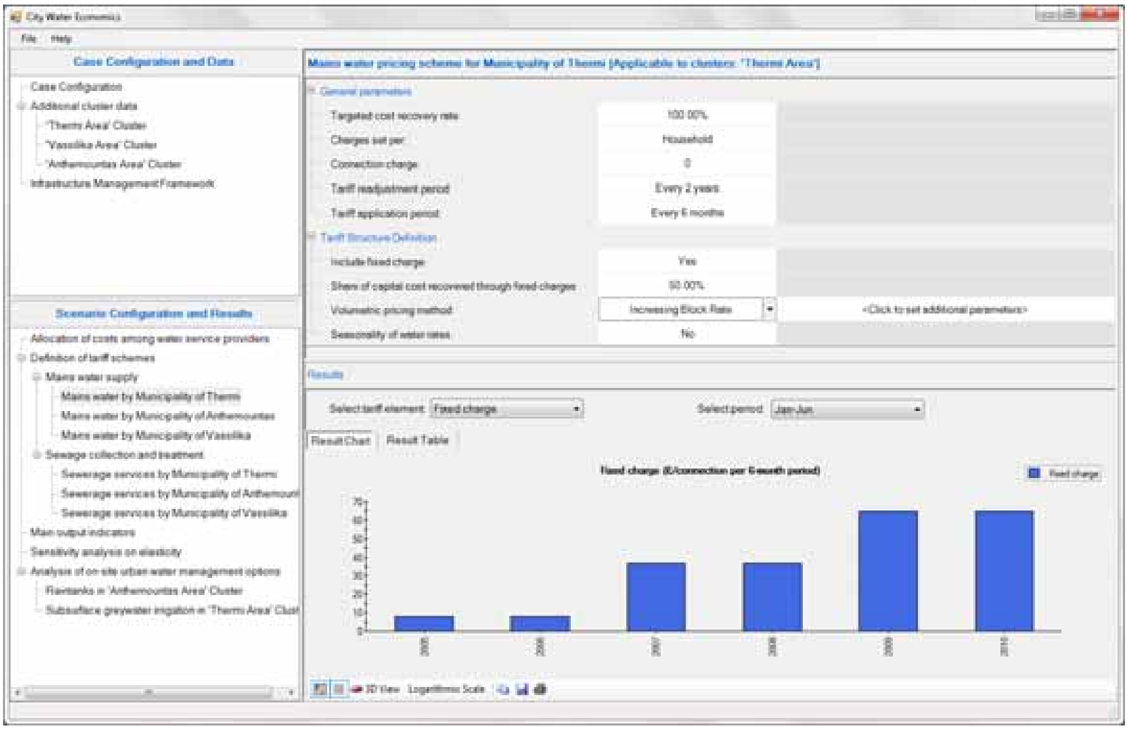


Figure 18: Design of tariff schemes for mains water supply

The tariff scheme design parameters are divided in two categories: (a) general parameters and (b) tariff structure definition.

General parameters concern the following:

- The desired cost recovery rate ("Target Cost Recovery Rate") in %. The rate can take values above 100% to signal cases where there is profit margin or need to raise additional capital for future investments. The rate of cost recovery is the main design criterion for the development of tariff schemes.
- The level at which water consumption is metered and invoicing is performed ("Charges set per:" option). This can either be at the level of households or unit blocks (buildings).
- The charge for new connections to the distribution network ("Connection charge" parameter). Although connection charges do not form an integral part of pricing schemes, they still may constitute important revenue for water utilities which needs to be considered in the overall estimation of individual charges.
- The "Tariff Readjustment Period", which can take values ranging from yearly up to 5 years. The tariff readjustment period signals the timeframe for the achievement of the cost recovery objective, and the timeframe at which charges will be readjusted, according to quantities sold and costs to be recovered. For example, a readjustment period of 3 years means that CWE will estimate those

charges and rates that can achieve the desired cost recovery rate for the entire 3-year period, considering the total 3-year cost and quantities delivered.

- The "Tariff Application Period" determines the timeframe for consumption metering and invoicing, which can be monthly, 2 months, 3 months, 4 months, 6 months or yearly.

Tariff structure parameters concern:

- Whether the tariff scheme includes fixed charges (i.e. an amount to be paid by each individual connection independently of water consumption). This is defined through the "Include fixed charges" option.
- The share of capital costs that is to be recovered through fixed charges, with values ranging from 0 to 100%. As detailed in the corresponding section of the Reference Manual, fixed charges are calculated by CWE to fully recover fixed maintenance costs plus a specific share of capital costs. The corresponding share is considered a design parameter as this affects the revenue stability for the water service provider.
- The volumetric pricing method, which includes the following options:
    a. None, meaning that no volumetric rates are applied;
    b. Uniform volumetric rate, meaning a rate that does not depend on the actual consumption;
    c. Increasing Block Rate, where rates increase according to the volume of water consumed;
    d. Decreasing Block Rate, where rates decrease according to water consumption.

  As explained below, additional data need to be entered, when methods (c) and (d) are chosen. This is performed through the button appearing next to "Click to set additional parameters", which becomes enabled when these last two options are selected.
- Whether rates will be seasonal or not, performed through the "Seasonality of water rates" option. When this is selected, the model calculate different rates for each application period, as defined through the "Tariff application period" option according to its share of consumption over the total yearly. This method can be useful when there is significant variation in seasonal water consumption (e.g. significantly higher consumption during the summer than in winter). In this case, it would be useful to set increased rates during the summer season, to account for potential scarcity costs, as well as additional infrastructure put in place only to meet the seasonal peak.

As mentioned above, the selection of Increasing or Decreasing Block Rates as the volumetric pricing method requires the definition of additional parameters. These concern the consumption blocks and the variation of the rates of each block with regard to the first one. An example of the input screen is presented in Figure 19.

In this example, the user defines the consumption blocks for each semester. The first block corresponds to consumption between 0-100 m^3/6-month period, the 2nd between 100 and 150 m^3/6-month period whereas the 3rd to consumption that exceeds 150 m^3/6-month period. Ranges can be added or deleted through the corresponding buttons at the top of the screen. For the 2nd and 3rd consumption block the user needs to further define the variation of the corresponding rates with regard to the 1st one, which is the actual output calculated by the model. In the example of Figure 19, the rate for the 2nd block is set at 120% of the second one (rate differential of 20%), whereas the rate for the 3rd block is set at 200% of the 1st one (rate differential of 100%).

Additional information provided to the user in this screen concerns the share of connections and the share of consumption that corresponds to each block. This information can be used to help the user in defining the corresponding consumption blocks. For example, if the share of connections pertaining to the 1st block

is above 80% it is evident that the pricing scheme does not take advantage of the incentive offered by the Increasing Block Rate structure, as most consumers will face the same volumetric rate. In this case it would be preferable to split the 1st block range in more, to ensure a more equal distribution of customers among the different blocks.

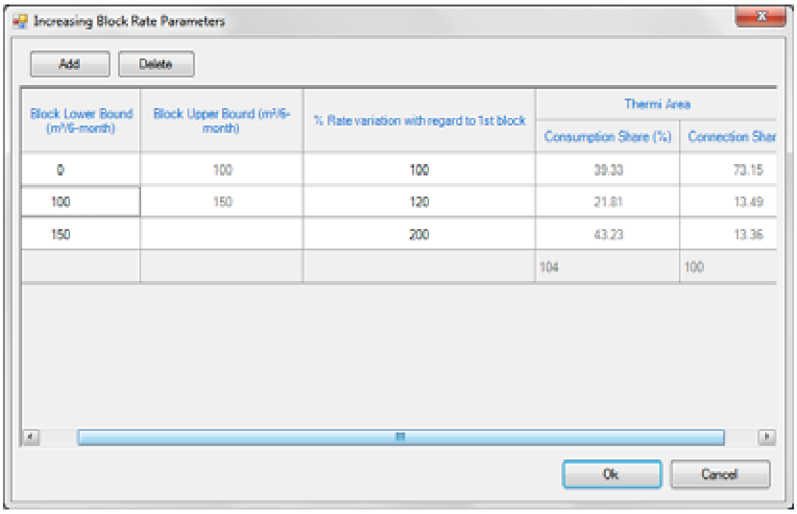


Figure 19: Definition of additional parameters for the "Increasing Block Rates" volumetric pricing method

The "Results" section displays the estimations of the tariff scheme elements. These concern the fixed charge and the volumetric rates for each tariff application period. Results can be accessed through the respective lists ("Select tariff element" and "Select Period").

Figure 20: Display of volumetric rates' results for mains water tariff schemes (top: graph, bottom: table)

6.2.2 Design of tariff schemes for wastewater collection and treatment

Similarly to tariff schemes for mains water supply, the screen for the design of tariff schemes for wastewater collection and treatment is divided in three main parts, for the display of what is currently being designed, the setting of the relevant design parameters and the visualisation of results (Figure 21).

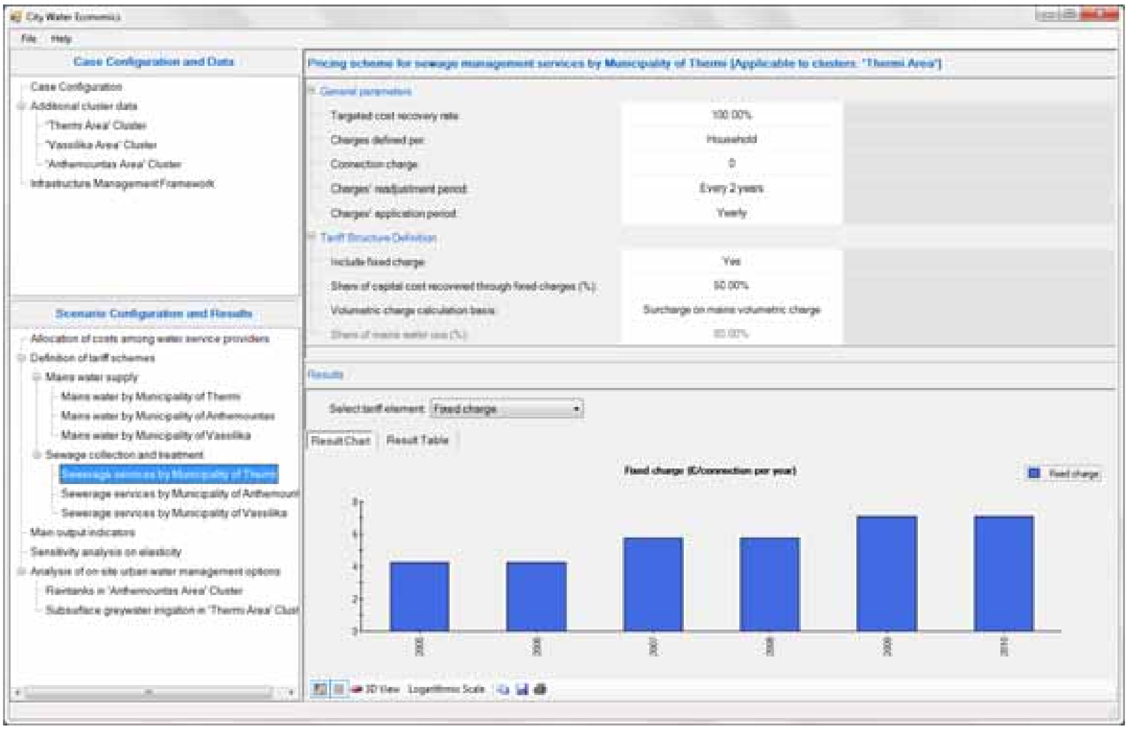


Figure 21: Design of tariff schemes for wastewater collection and treatment

The tariff scheme design parameters are divided in two categories: (a) general parameters and (b) tariff structure definition.

General parameters concern the following:

- The targeted cost recovery rate in %, which is the main design criterion for the tariff scheme;
- The level at which invoicing is performed ("Charges set per:" option). This can either be at the level of households or unit blocks (buildings). Although this will probably not differ from the corresponding parameter defined for mains water supply, the parameter is defined individually to account for cases where different service providers are involved in water supply and in sewerage, and where the case refers only to wastewater collection and treatment.
- The charge for new connections to the sewerage network ("Connection charge" parameter).
- The "Tariff Readjustment Period", which can take values ranging from yearly up to 5 years. The tariff readjustment period signals the timeframe for the achievement of the cost recovery objective, and the timeframe at which charges will be readjusted, according to wastewater production and costs to be recovered.
- The "Tariff Application Period", which determines the timeframe for invoicing, which can be monthly, 2 months, 3 months, 4 months, 6 months or yearly.

Tariff structure parameters concern:

- Whether the tariff scheme includes fixed charges (i.e. an amount to be paid by each individual connection independently of generated wastewater or water consumption). This is defined through the “Include fixed charges” option.
- The share of capital costs that is to be recovered through fixed charges, with values ranging from 0 to 100%. As detailed in the corresponding section of the Reference Manual, fixed charges are calculated by CWE to fully recover fixed maintenance costs plus a specific share of capital costs. The corresponding share is considered a design parameter as this affects the revenue stability for the water service provider.
- The basis for calculating volumetric charges, which includes the following options:
    a. None, meaning that no volumetric charges are applied;
    b. Surcharge on mains volumetric charge, which means that volumetric charges for sewerage services are estimated as a percentage of the volumetric charge for mains water supply. This option, when set, exploits the incentive offered by the pricing method chosen for mains water supply;
    c. Independent rate, based on share of mains water use, which means that a uniform rate is calculated based on a specific percentage of mains water usage. The parameter should correspond to the average return flow share per connection (i.e. the volume of water that returns as wastewater to the system). This parameter is defined through the “Share of mains water use” and can take values ranging between 1 and 100%.

The “Results” section displays the estimations of the tariff scheme elements. These concern the fixed charge and the volumetric charge basis. Similarly to the previous case, the results are displayed in graphical and tabular form (Figure 22).

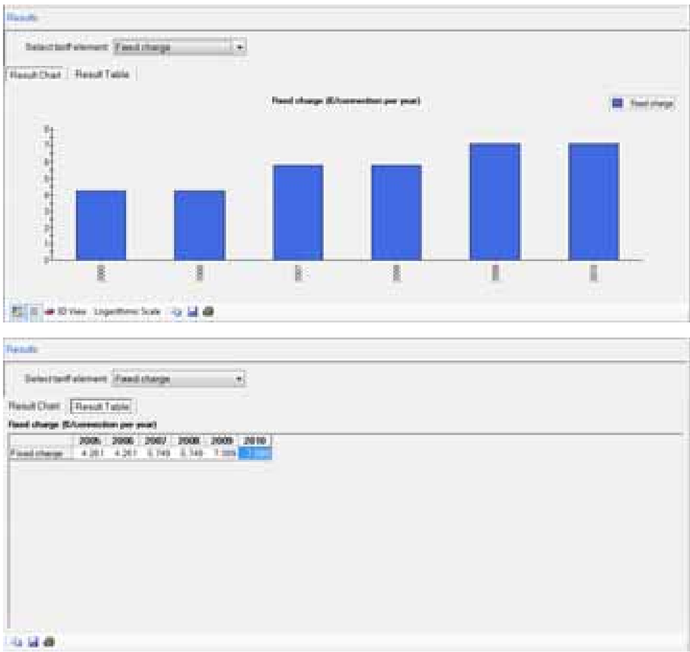


Figure 22: Display of fixed charge results for sewerage pricing schemes (top: graph, bottom: table)

6.2.3 Design of tariff schemes for stormwater management

The design of tariff schemes for stormwater management follows a similar logic (Figure 23).

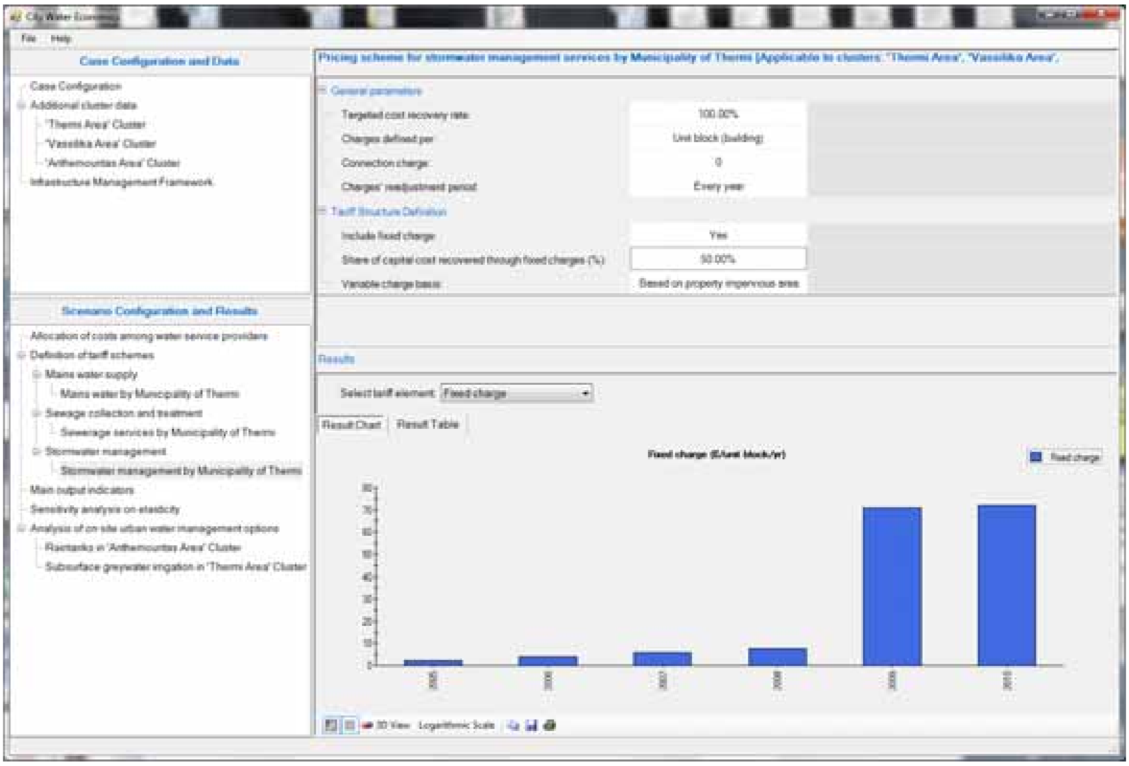


Figure 23: Design of tariff schemes for stormwater management

For stormwater management schemes, charges are calculated on a **yearly basis only**. General parameters for tariff design include:

- The targeted cost recovery rate in % (main design parameter);
- The level at which invoicing is performed ("Charges set per:" option). This can either be at the level of households or unit blocks (buildings).
- The charge for new connections to the drainage network ("Connection charge" parameter).
- The "Tariff Readjustment Period", which can take values ranging from yearly up to 5 years. The tariff readjustment period signals the timeframe for the achievement of the cost recovery objective, and the timeframe at which charges will be readjusted.

Tariff structure parameters concern:

- Whether the tariff scheme includes fixed charges. This is defined through the "Include fixed charges" option.
- The share of capital costs that is to be recovered through fixed charges, with values ranging from 0 to 100%. As detailed in the corresponding section of the Reference Manual, fixed charges are calculated by CWE to fully recover fixed maintenance costs plus a specific share of capital costs.

- The basis for calculating variable charges, i.e. charges which depend on the area of the property (household or unit block). The following options are available:
    a. None, meaning that no variable charges are applied;
    b. Charges based on the area of the property;
    c. Charges based on the impervious area of the property.

The "Results" section displays the estimations of the tariff scheme elements. These concern the fixed charge and the variable charge. Similarly to the previous cases, the results are displayed in graphical and tabular form (Figure 22).

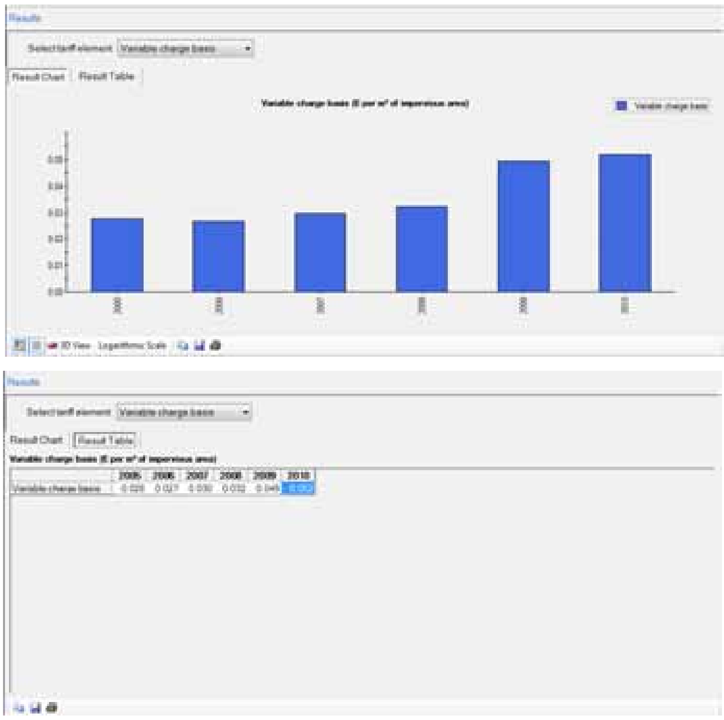


Figure 24: Display of variable charge results for stormwater schemes (top: graph, bottom: table)

6.3 Evaluation of schemes – Main output indicators

Following from the design of tariff schemes, CWE calculates indicators for their evaluation. These are generally grouped in two main categories:

- Indicators relating to the recovery of financial costs (financial sustainability indicators);
- Indicators relating to the affordability of water service charges.

Indicators are calculated **on an annual basis for each water service** and are outlined in Table 2.

Table 2: Main output indicators of CWE

Indicator category	Indicator description	Level of calculation	Usefulness
Financial Sustainability	Revenue structure	Water service provider	Shows the main sources of revenue for a water service provider. Can be useful in assessing revenue stability.
	Cost recovery	Water service provider	Annual variation can be useful when tariff schemes entail long re-adjustment periods (>2 years)
		Cluster	Shows whether there are cross-subsidies among different areas serviced by the same provider
Affordability	Annual household expenditure per income group	Cluster and overall	Shows how much a household spends on water service charges
	Share of disposable income spent for the water service for each income group	Cluster and overall	Shows the affordability of water service charges. Relevant thresholds range between 3 and 5%,

Figure 25 presents the interface for visualising and exporting the output indicators calculated by the model. Indicator values are displayed in a hierarchical way, according to their category, and can be accessed by selecting those relevant from the indicator tree.

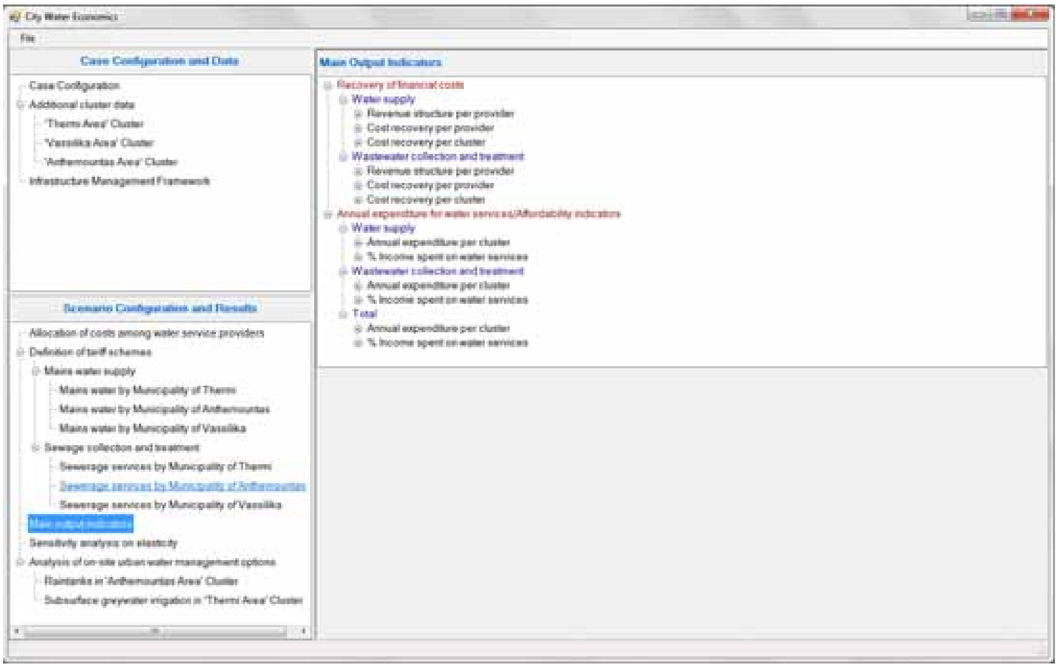


Figure 25: The output indicators' interface

Results are presented at the bottom right part of the screen, in graphical and tabular form. Graphs can be customized, exported and saved in jpeg format. Tabular results can also be copied and pasted in other programmes (e.g. MS Excel) if further processing or display customization are required.

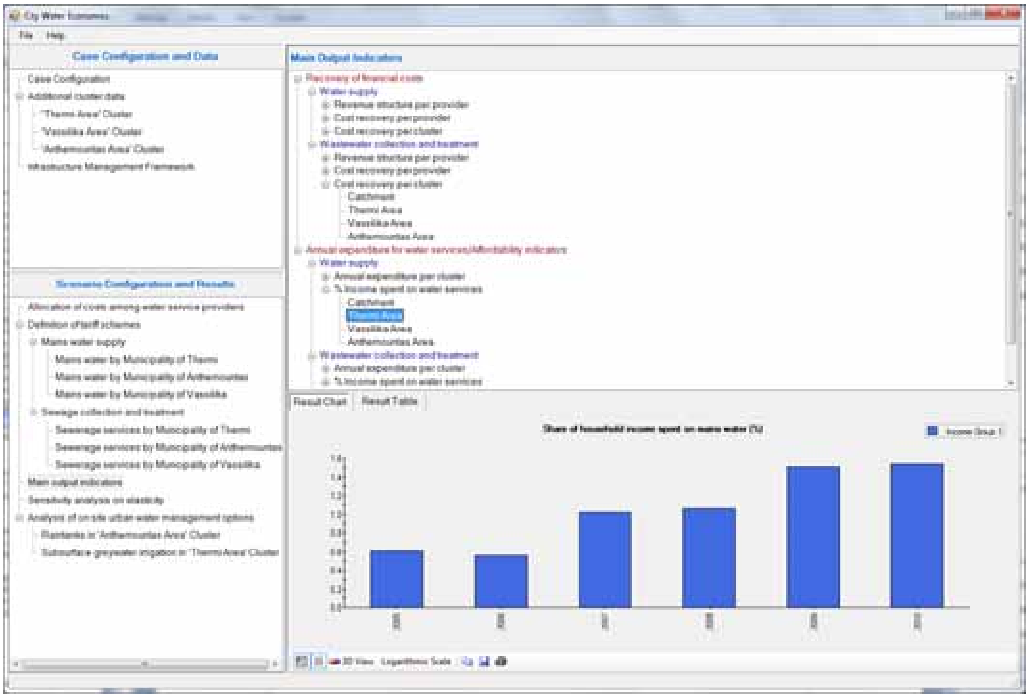


Figure 26: Output indicators display

6.4 Price Elasticity Analysis

In most cases, the attainment of improved cost recovery requires a significant increase of water rates. However, an increase of water rates can lead to lower-than-anticipated revenues, as consumers respond to the price increase by curtailing their water consumption. On the other hand, a decrease in consumption can also reduce water service costs related to quantities supplied (e.g. costs for treatment, pumping etc.).

In this context, City Water Economics embeds an elasticity analysis module, which can be used to perform sensitivity analysis to assess such impacts on main output indicators and tariff design objectives, for different values of demand elasticity. Two options are available:

a. Sensitivity analysis based on average price elasticity, which does not consider potential differentiation of rates for different levels of consumption;
b. Sensitivity analysis based on different price elasticities for different consumption ranges, to allow specifying highly elastic, rigid and inelastic consumption ranges.

The analysis can be performed only for a specific year of the examined timeframe (Figure 27). An option is also available for assessing the combined effect of water supply and sewerage volumetric charges. The choice of the method for the sensitivity analysis is performed from the top-right part of the input screen. Depending on the method, the following should be specified:

- The range of the average elasticity values (Method a);
- The range of elasticity values for each cluster area and consumption block (Method b).

When method b is chosen, elasticity ranges can be set for each cluster when it is selected through the corresponding list, and correspond to the baseline consumption ranges (i.e. the current conditions). As a

general rule, absolute elasticity values should be lower for the low consumption ranges, and increase as consumption increases, in order to correctly represent the demand curve.

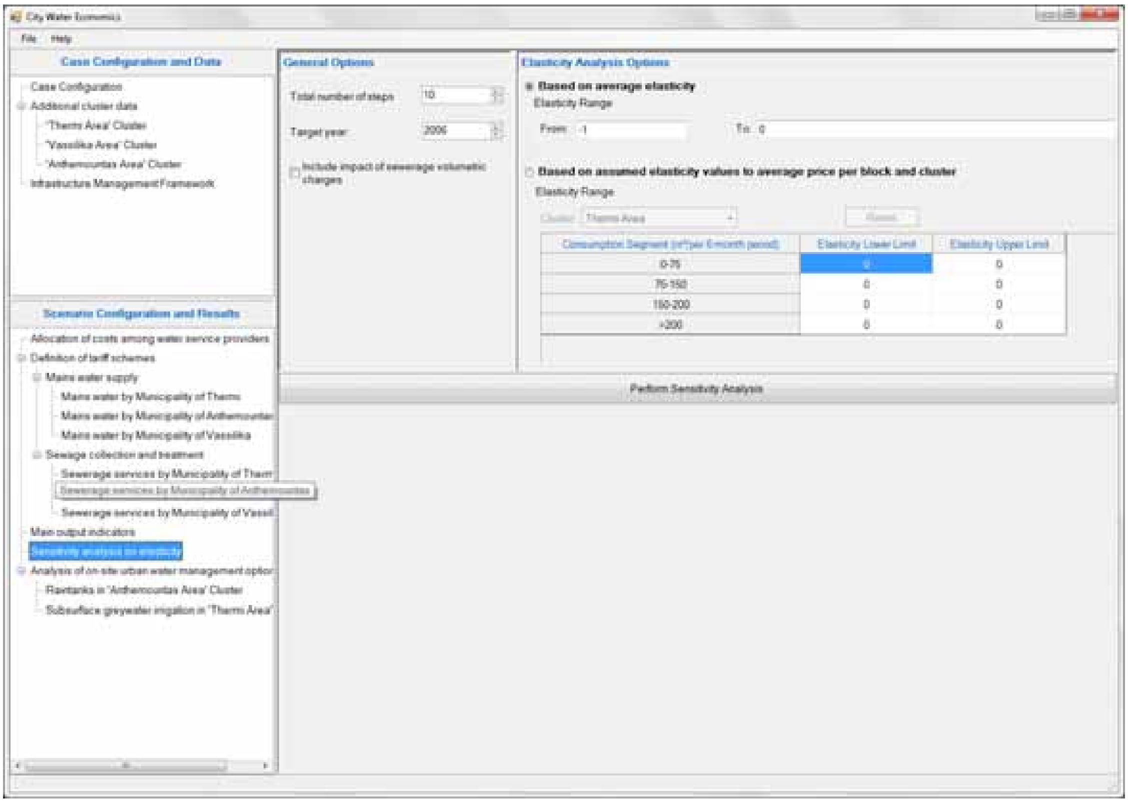


Figure 27: Sensitivity analysis on elasticity – Options and input parameters

The sensitivity analysis is performed by pressing the corresponding button ("Perform Sensitivity Analysis"), and results are displayed at the bottom right part of the screen. They include the following:

- Cluster-level results on:
  - Water supply and use, including sensitivity analyses for (i) water use, (ii) water supply cost per provider and cluster, (iii) revenues from water tariffs and (iv) cost recovery for water supply provision.
  - Sewage collection and treatment, including sensitivity analyses for (i) wastewater flows, (ii) sewage collection and treatment costs, (iii) revenues from sewerage charges and (iv) cost recovery for sewerage services.
- Provider-level results on:
  - The provision of water supply services, including sensitivity analyses for (i) total cost for water supply provision, (ii) total revenue from water supply charges, (iii) cost recovery rates;
  - The provision of wastewater collection and treatment services, including sensitivity analyses for: (i) total cost for wastewater collection and treatment, (ii) total revenue from wastewater charges and (iii) the corresponding cost recovery rates.

Figure 28 presents an example of results obtained on the sensitivity of cost recovery for water supply provision, assuming average price elasticities ranging from -1 to 0. The assessment shows that for two

water service providers, the cost recovery rates are not significantly affected, as water rates are not significantly increased. However, for the third water service provider (green line), the achieved cost recovery rate can vary between 120% (if the elasticity is -1) to less than 80% for inelastic demands. This result (which is rather unexpected) is interpreted by analysing the sensitivity analysis results on costs and revenues. As demand decreases, due to the increase of water rates, both revenues from volumetric charges and operational costs decrease. Nevertheless, the decrease in water supply costs is higher than the decrease of revenue, thus producing higher cost recovery rates for lower elasticity values.

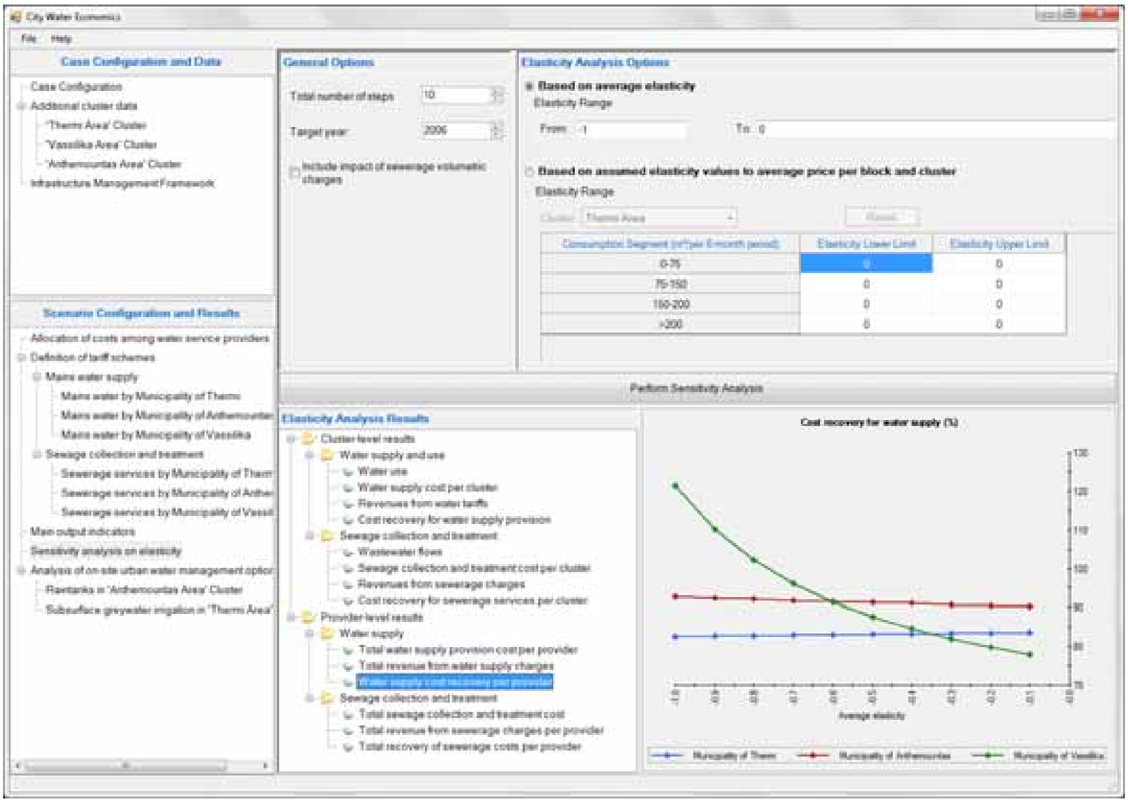


Figure 28: Example of sensitivity analysis results

6.5 Analysis of on-site urban water management options

The "Analysis of on-site urban water management options" is aimed at evaluating whether the scenario tariff scheme can render alternative water management options a financially attractive option for households.

The analysis is performed for each option included in the external input data file, and involves the calculation of financial savings from its implementation and the corresponding costs (investment and operation and maintenance). The analysis is performed: (a) for the entire lifetime of the option (Lifecycle analysis of savings and costs –Figure 29) and (b) for the studied period (Figure 30). Calculated indicators refer to an average household and are presented in Table 3. The assessment of savings (mains water use, wastewater and stormwater discharges) is based on the values entered in the input file. Economic indicators comprise costs and savings in expenditure for water services; they are estimated according to the discount rate, defined at the top part of the screen.

Table 3: Indicators for the analysis of on-site urban water management options

Indicator Category	Indicator	Description
Total savings per household	Reduction in mains water usage	The total reduction in the use of mains water as a result of the intervention, throughout its lifetime (m^3/household)
	Reduction in outflows to the sewerage network	The total reduction in the discharge to the sewerage network as a result of the intervention, throughout its lifetime (m^3/household)
	Reduction in outflows to stormwater network	The total reduction in the discharge to the stormwater network as a result of the intervention, throughout its lifetime (m^3/household)
Total savings in expenditure for water services	Savings from the mains water bill	Lifecycle savings from the expenditure for water supply services for an average household (Currency units/household)
	Savings from the wastewater bill	Lifecycle savings from the expenditure for sewerage services for an average household (Currency units/household)
	Savings from the stormwater bill	Lifecycle savings from the expenditure for drainage services for an average household (Currency units/household)
	Total savings	The total reduction in the expenditure for water services (Currency units/household)
Lifecycle Cost	Cost	The lifecycle cost associated with the intervention, including: (a) investment, (b) operation and maintenance costs in present value terms
Required subsidy or payback period	Total subsidy	The amount of subsidy required to make the option financially viable
	Subsidy as share of investment cost	The share of investment costs that need to be subsidized for the option to be financially viable
	Payback period	The option payback period (applicable only when the total reduction in the expenditure for water services is higher than lifecycle costs).

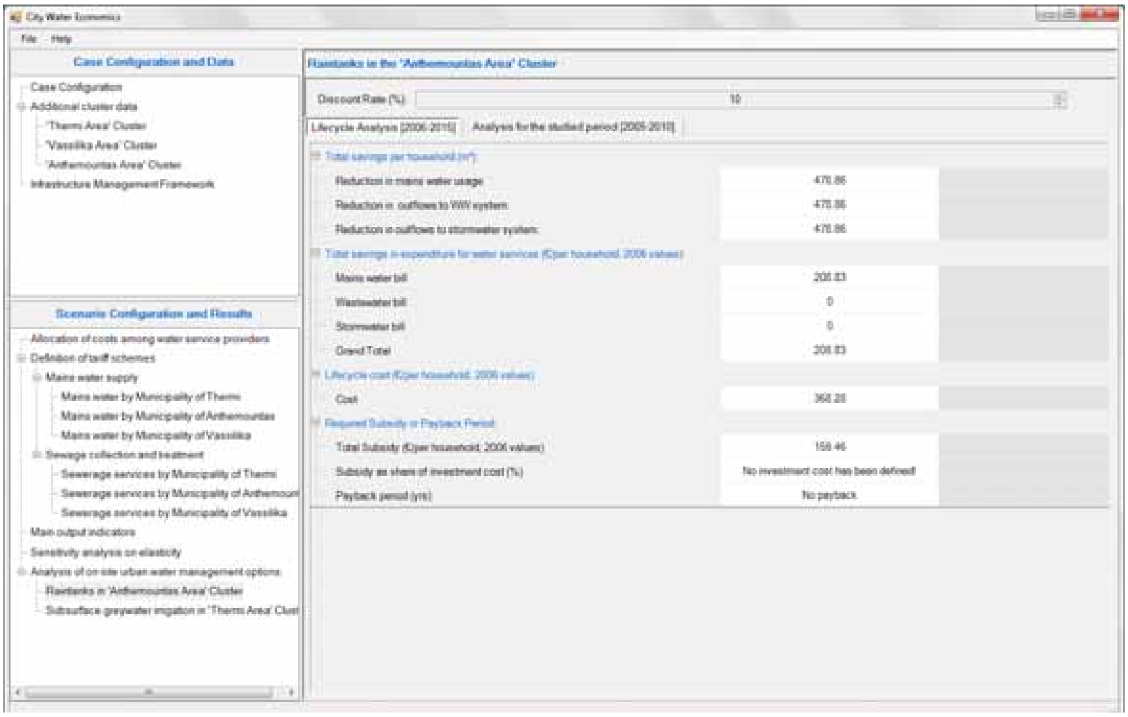


Figure 29: Lifecycle analysis of on-site urban water management options

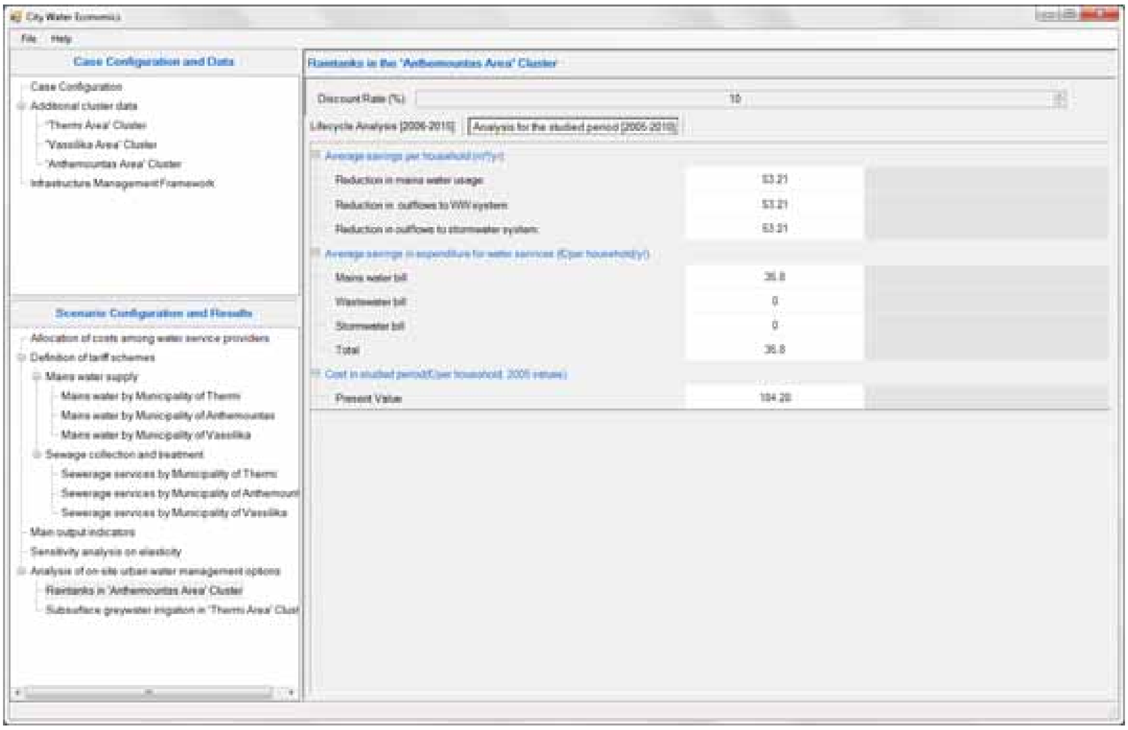


Figure 30: Analysis of water management options for the studied period

Annex I: City Water Economics Input data requirements and format

In its present form (Version 4.0) City Water Economics supports three different formats of input files:

- Excel files (version 2007 and below)
- Plain text files
- XML files generated by the City Water Information System. Results can also be exported in the CWIS format

Each input file provides data on ten (10) data lists presented in Section I.1.1. Each list contains a number of items and the attributes of each item are given in Sections I.1.2 to I.1.11.

Sections I.3 and I.4 present the structure of the input files in Excel or ASCII format.

I.1 Data description

I.1.1 Lists

There are a total of ten (10) lists required to run City Water Economics. These lists are shown in Table I-1.

Table I- 1: Input lists

Name	Description
Clusters	Data for clusters within the area examined
ClusterTS	Yearly time series data for the clusters
PotableWI	Data for each main infrastructure element for water supply provision in the examined area
WasteWI	Data for each main infrastructure element for wastewater collection and treatment in the examined area
StormWI	Data for each main infrastructure element for stormwater collection in the examined area
PotableFlows	Monthly time series data (flows) between the PotableWI elements
WasteFlows	Monthly time series data (flows) between the WasteWI elements
StormFlows	Monthly time series data (flows) between the StormWI elements
OnSiteInterventions	Data for each interventions implemented at the Unit Block Scale (e.g. water saving appliances to raintanks, on-site recycling and reuse, swales, raintanks, etc.)
OnSiteInterventionsTS	Monthly time series data for each On Site intervention, defined above

I.1.2 Clusters list

The Clusters list provides data for the clusters within the area examined. Each item in the list corresponds to a specific cluster and the attributes of each item are listed in Table I- 2.

Table I- 2: Attributes of items in Clusters list

Name	Description	Type
ID	A unique identifier for the cluster1	Integer
Name	The name of the cluster	String
Occupancy	Average Household Occupancy (in persons per household)	Double
AvgUnitBlockArea	Average area occupied by a unit block of the cluster (in m²)	Double

I.1.3 ClusterTS list

The ClusterTS list provides yearly time series describing the evolution of different parameters for the cluster. Each item corresponds to a specific cluster and year. The corresponding attributes of each item are listed in Table I- 3.

Table I- 3: Attributes of items in ClusterTS list

Name	Description	Type
Cluster	The identifier of the cluster (see Table I-2). Should be >=1.	Integer
Year	The year to which the attributes refer to	Integer
UnitBlocks	Total number of unit blocks in *Year* and for the *Cluster*	Double
Households	Total number of households in *Year* and for the *Cluster*	Double
CommercialEstablishments	Total number of commercial establishments in *Year* and for the *Cluster*	Double
IndustrialEstablishments	Total number of industrial establishments in *Year* and for the *Cluster*	Double
ShareOfUnitBlocksConToDistribNetwork	Share of Unit Blocks connected to the public water supply system in *Year* and for the *Cluster*	Double (values between 0 and 1)
ShareOfUnitBlocksConToSWNetwork	Share of Unit Blocks connected to the sewerage network in *Year* and for the *Cluster*	Double (values between 0 and 1)
ShareOfUnitBlocksConToStormNetwork	Share of Unit Blocks connected to the stormwater network in *Year* and for the *Cluster*	Double (values between 0 and 1)
ShareOfResidentialDemand	Share of residential demand over total water demand from the public water supply system in *Year* and for the *Cluster*	Double (values between 0 and 1)
ShareOfCommercialDemand	Share of commercial demand over total water demand from the public water supply system in *Year* and for the *Cluster*	Double (values between 0 and 1)

[1] Each cluster list should always contain an item with ID equal to 0. This represents the entire modeled area (catchment).

Name	Description	Type
ShareOfIndustrialDemand	Share of industrial demand over total water demand from the public water supply system in *Year* and for the *Cluster*	Double (values between 0 and 1)
ImperviousShareOfUnitBlockArea	Share of unit block area that is impervious (see also *AvgUnitBlockArea* attribute in Table I-2)	Double (values between 0 and 1)

I.1.4 PotableWI list

The PotableWI list provides data for all water infrastructure in the catchment that is used for water supply provision. Examples include:

- Drinking water treatment plants
- Boreholes
- Conveyance networks
- Distribution networks for a specific area,
- Pumps, network reservoirs, etc.

Each item corresponds to a specific infrastructure and the attributes of each item are listed in Table I- 4.

Table I- 4: Attributes of items in PotableWI list

Name	Description	Type
ID	A unique identifier of the infrastructure element.	Integer
Name	Description of the element	String
ConsYear	Operation start year	Integer
ConsCost	Investment cost in currency units	Double
FixedOMCost	Annual fixed costs (relating to the maintenance of the element) in currency units/year	Double
UnitOMCost	Unit Operation and Maintenance Cost in Currency Units/m³ of outflow	Double
Cluster	The cluster identifier where the element belongs to. A zero value corresponds to infrastructure supplying more than one clusters (e.g. drinking water treatment plants, conveyance networks etc).	Integer
Lifetime	The lifetime of the infrastructure element	Double
Type	The type of infrastructure. Values can be equal to 0, 1 or 2 • 0 stands for freshwater abstraction and treatment infrastructure • 1 stands for network elements (conveyance and distribution networks)	Integer

I.1.5 WasteWI list

The WasteWI list provides data for the waste water infrastructures within the area examined. Each item corresponds to a specific infrastructure item and the attributes of each item are listed in Table I- 5.

Table I- 5: Attributes of items in WasteWI list

Name	Description	Type
ID	A unique identifier of the infrastructure element.	Integer
Name	Description of the element	String
ConsYear	Operation start year	Integer
ConsCost	Investment cost in currency units	Double
FixedOMCost	Annual fixed costs (relating to the maintenance of the element) in currency units/year	Double
UnitOMCost	Unit Operation and Maintenance Cost in Currency Units/m³ of inflow	Double
Cluster	The cluster identifier where the element belongs to. A zero value corresponds to infrastructure servicing more than one clusters.	Integer
Lifetime	The lifetime of the infrastructure element	Double
Type	The type of infrastructure. Values can be equal to 0 and 1 • 0 stands for central wastewater treatment/storage infrastructure • 1 stands for sewerage network elements	Integer

I.1.6 StormWI list

The StormWI list provides data for the storm water infrastructures within the area examined. Each item corresponds to a specific infrastructure and the attributes of each item are listed in Table I- 6.

Table I- 6: Attributes of items in StormWI list

Name	Description	Type
ID	A unique identifier of the infrastructure element.	Integer
Name	Description of the element	String
ConsYear	Operation start year	Integer
ConsCost	Investment cost in currency units	Double
FixedOMCost	Annual fixed costs (relating to the maintenance of the element) in currency units/year	Double
UnitOMCost	Unit Operation and Maintenance Cost in Currency Units/m³ of inflow	Double
Cluster	The cluster identifier where the element belongs to. A zero value corresponds to infrastructure servicing more than one clusters.	Integer
Lifetime	The lifetime of the infrastructure element	Double
Type	The type of infrastructure. Accepted values are equal to 0 or 1: • 0: Stormwater storage/treatment infrastructure • 1: Stormwater network elements	Integer

I.1.7 PotableFlows list

The PotableFlows list provides monthly timeseries data. Each item describes flows **between** specific infrastructure elements, in a specific year and month. The attributes of each item are listed in Table I- 7.

Table I- 7: Attributes of items in the PotableFlows list

Name	Description	Type
FromWI	The Potable WS infrastructure element identifier from which the inflow is received	Integer
ToWI	The Potable WS infrastructure element identifier to which outflow is diverted	Integer
Year	Reference year	Integer
Month	Reference month	Integer
QFrom	Inflow from the Potable WS infrastructure element *FromWI* in *Month* and *Year*	Double
QTo	Outflow from the infrastructure element *ToWI* in *Month* and *Year*	Double

I.1.8 WasteFlows list

The WasteFlows list provides monthly timeseries data. Each item describes flows **between** specific infrastructure elements, in a specific year and month. The attributes of each item are listed in Table I- 8.

Table I- 8: Attributes of items in the WasteFlows list

Name	Description	Type
FromWI	The Wastewater CT infrastructure element identifier from which the inflow is received	Integer
ToWI	The Wastewater CT infrastructure element identifier to which outflow is diverted	Integer
Year	Reference year	Integer
Month	Reference month	Integer
QFrom	Inflow from the Wastewater CT infrastructure element *FromWI* in *Month* and *Year*	Double
QTo	Outflow from the Wastewater CT infrastructure element *ToWI* in *Month* and *Year*	Double

I.1.9 StormFlows list

The StormFlows list provides monthly timeseries data. Each item describes flows **between** specific infrastructure elements, in a specific year and month. The attributes of each item are listed in Table I- 9.

Table I- 9: Attributes of items in the StormFlows list

Name	Description	Type
FromWI	The infrastructure element identifier from which the inflow is received	Integer
ToWI	The infrastructure element identifier to which outflow is diverted	Integer
Year	Reference year	Integer
Month	Reference month	Integer
QFrom	Inflow from the infrastructure element *FromWI* in *Month* and *Year*	Double
QTo	Outflow from the infrastructure element *ToWI* in *Month* and *Year*	Double

I.1.10 OnSiteInterventions List

Each item of the list corresponds to interventions implemented at the Unit Block scale. Interventions can range from simple water saving measures (e.g. installation of efficient water appliances), to on-site recycling and reuse systems, swales, raintanks, etc.). The attributes of each item are listed in Table I- 10.

Table I- 10: Attributes of items in the OnSiteInterventions list

Name	Description	Type
ID	A unique identifier of the infrastructure element.	Integer
InterventionName	Description of the element	String
ClusterID	The cluster identifier where the element belongs to. A zero value corresponds to infrastructure servicing more than one clusters.	Integer
ImplementationYear	Operation start year	Double
InvestmentCost	Investment cost in currency units	Double
FixedOMCost	Annual fixed costs (relating to the maintenance of the element) in currency units/year	Double
UnitOMCost	Unit Operation and Maintenance Cost in Currency Units/m³ of inflow	Integer
Lifetime	The lifetime of the infrastructure element (years)	Double
ShareOfHouseholds	The share of Households to which the intervention is applied	Double (value between 0 and 1)
PercentAverageReductionInImperviousArea	The resulting reduction in the impervious area per household (>0 only for interventions that reduce surface run-off)	Double (value between 0 and 1)

I.1.11 OnSiteInterventionsTS List

The OnSiteInterventionsTS list provides monthly timeseries data for the list described in Section 2.10. Each item describes the resulting savings from the implementation of the intervention in a specific year and month. The attributes of each item are listed in Table I- 11.

Table I- 11: Attributes of items in the OnSiteInterventionsTS list

Name	Description	Type
ID	The unique identifier of the infrastructure element	Integer
Year	Reference year	Integer
Month	Reference month	Integer
MainsWaterSavings	The total reduction in mains water usage, as a result of the implementation of the on-site intervention in *Year* and *Month*	Double
WastewaterReduction	The resulting total reduction in outflows to the wastewater system, as a result of the implementation of the on-site intervention in *Year* and *Month*	Double
StormwaterReduction	The resulting total reduction in outflows to the stormwater system, as a result of the implementation of the on-site intervention in *Year* and *Month*	Double

I.2 Excel input file structure

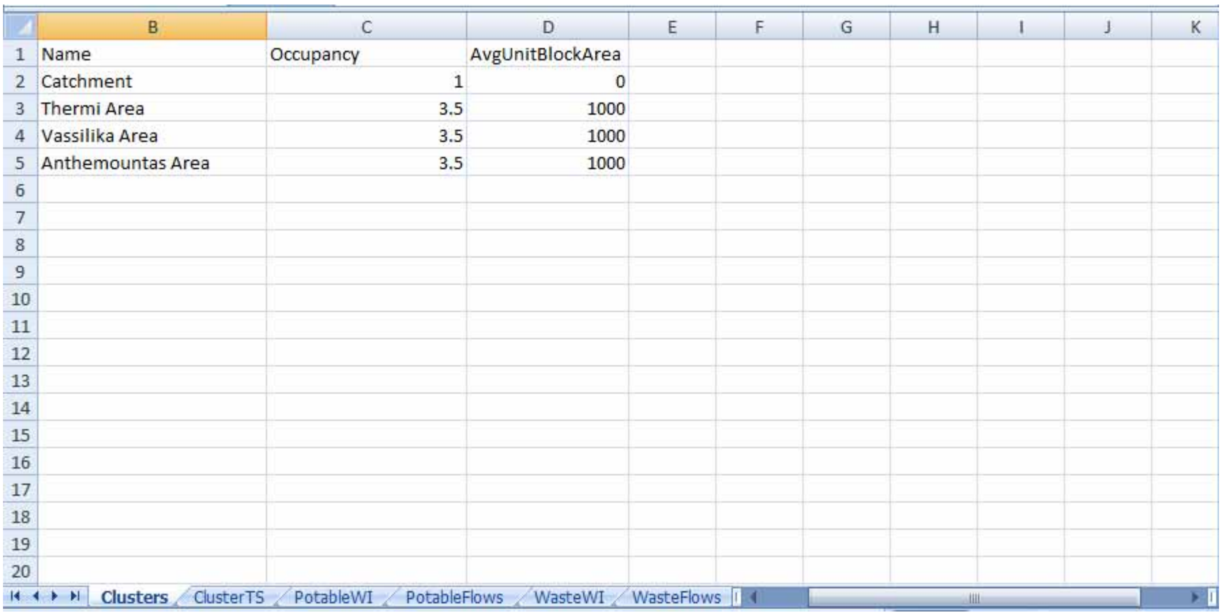
CWE accepts Excel input files, in version 2007 and below. The following rules define the format of a valid Excel input file.

- Each list is in a separate worksheet, named with name of the corresponding list.
- The first row of each worksheet contains the names of the attributes. Each attribute name is in a separate column, starting from column A.
- Each item is in a separate row in the corresponding worksheet, starting from row 2. The attribute values of each item are in the corresponding columns (as defined in the first row) of the item row.

Comments

- All lists (worksheets) and attributes names (first row in each worksheet) must be present even if the lists are empty.
- The names of the worksheets (lists) and attributes (column names) are case-insensitive.
- The order of the worksheets in the workbook and the attribute names in each worksheet is not important.
- Empty rows between items are not allowed.

The following is an example of a valid worksheet for the Clusters list.



	B	C	D
1	Name	Occupancy	AvgUnitBlockArea
2	Catchment	1	0
3	Thermi Area	3.5	1000
4	Vassilika Area	3.5	1000
5	Anthemountas Area	3.5	1000

I.3 Text input file structure

The following rules define the format of a valid text input file.

- Each list begins with a header containing two semicolon ";" separated values: The name of the corresponding list and the number of items in the list.
- Below the header is the list of the corresponding items.
- Each item spans an entire row containing the attribute values, semicolon ";" separated.

Comments

- All lists (headers) must be present even if the corresponding lists are empty.

- The names of the headers are case-insensitive.
- The order of the headers is not important.
- The order of the attribute values is important and must conform to the order given in Tables I-2–11.

```
Clusters; 2
0; Cathcment; 1; 0
1; Municipality of Thermi; 3.5; 1000
ClusterTS; 1
1; 2005; 8758.60888162028; 8758.60888162028; 0; 0; 1; 1; 1; 1; 0; 0; 1
PotableWI; 6
1; Water Transfer from Aliakmonas DWTP; 2010; 0; 0; 0.2; 0; 25; 0
2; Network Expansions-Improvements; 2001; 590999.013939839; 185675.704225124; 0.11; 1; 50; 1
3; Network Expansions-Improvements; 2002; 305371.11; 0; 0; 1; 50; 1
4; Network Expansions-Improvements; 2003; 246163.92; 0; 0; 1; 50; 1
5; Network Expansions-Improvements; 2004; 525217.16; 0; 0; 1; 50; 1
6; Own Boreholes; 1995; 0; 0; 0.3; 1; 50; 1
PotableFlows; 12
1; 2; 2005; 1; 500; 475
1; 2; 2005; 2; 500; 475
1; 2; 2005; 3; 500; 475
1; 2; 2005; 4; 500; 475
1; 2; 2005; 5; 500; 475
1; 2; 2005; 6; 500; 475
1; 2; 2005; 7; 500; 475
1; 2; 2005; 8; 500; 475
1; 2; 2005; 9; 500; 475
1; 2; 2005; 10; 500; 475
1; 2; 2005; 11; 500; 475
1; 2; 2005; 12; 500; 475
WasteWI; 0
WasteFlows; 0
StormWI; 0
StormFlows; 0
OnSiteInterventions;0
OnSiteInterventionsTS;0
```

Part II: City Water Economics Reference manual

1 Introduction

1.1 Scope

This Part of the City Water Economics documentation comprises the Reference Manual of the software. It is thus aimed at describing the main algorithms and calculations performed by the model, as well as the underlying concepts relating to cost recovery, pricing and tariff setting. The Reference Manual is complemented by Part I, the City Water Economics User Manual, which covers aspects that deal with the practical use of the software, the functionalities of its interface and data requirements.

The Reference Manual is structured in the following way: **Section 1.2** provides a brief overview of the City Water Economics functionalities and analysis steps. Section 2 describes the underlying concepts relevant to the model. It is aimed at introducing potential software users to aspects relating to cost recovery, water service financing and application of economic instruments. **Sections 3-7** describe the background concepts, models and equations embedded in City Water Economics. In more detail: *Section 3* focuses on algorithms and models for the estimation and allocation of costs. *Section 4* deals with the design and estimation of the parameters of different tariff structures. Section 4.1 also provides background information on tariff objectives, design processes and structures. *Section 5* concerns the assessment of output indicators. *Section 6* focuses on the calculation of indicators relevant to the analysis of water management instruments, and *Section 7* describes aspects relating to elasticity analysis, which can be used to analyse the impact of rate increases on output indicators.

1.2 A summary of the City Water Economics functionalities and analysis steps

As mentioned above, City Water Economics is a scoping model, designed to explore (provide "quick answers") to issues pertaining to sustainable cost recovery and suitable tariff structures and cost allocation schemes. It is more aimed towards the screening of alternatives, rather than supporting a detailed tariff or affordability study, which should follow as part of strategic planning.

The steps encompassed in the CWE modelling approach are presented in Figure 31. These concern: (i) Case Configuration, (ii) Definition of the framework for water service provision, (iii) Cost allocation among water service providers, (iv) Definition of pricing schemes, and (v) Calculation of output indicators and sensitivity analysis.

The **configuration of a case** concerns the input of baseline data for a case to be developed and evaluated by the model. Relevant data and parameters concern (a) water flows and infrastructure elements for water supply, wastewater collection and treatment and stormwater management, over a specific timeframe (current or for a future plan), (b) water service areas, and (c) reference data on income and consumption distribution among different population segments in the service areas. The **framework for water service provision** for the area of interest is mapped through the definition of all agents involved in the development, operation and maintenance of water supply, wastewater collection and treatment and stormwater systems, and their respective roles. This expands beyond the simple definition of utilities and authorities concerned with network management and rehabilitation, to also address more complex frameworks, involving agencies/management entities dealing with the management of storage reservoirs and conveyance networks upstream or downstream of the urban water system, and potential institutional reforms.

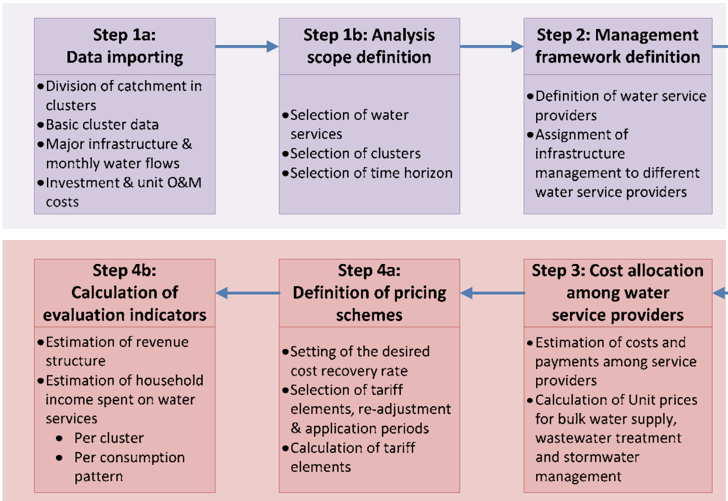


Figure 31: The CWE Case and Scenario analysis steps

Defined scenarios concern the calculation and allocation of capital, operation and maintenance **costs among water service providers**. In this first step of scenario analysis, desired cost recovery objectives can be attained through the estimation of the corresponding bulk prices. These are based on the "user-pays" principle, i.e. the payment for water services received is equal to the cost that corresponds to these services. Bulk prices can also be user-assigned to address the case where these are the output of negotiations or government regulation. **Tariff schemes** for each urban water service can incorporate different elements, depending on overall goals and objectives. City Water Economics incorporates different, widely applicable, methods which can incorporate both fixed and variable charges. Rates are calculated by the model according to desired cost recovery objectives over specific timeframes and periods. Main **output indicators** for scenario evaluation concern: (a) the affordability of water charges, expressed as the annual expenditure and the corresponding income share spent on water services; (b) revenue patterns for water service providers, specifically analyzing the ratio of collected fees in relation to different cost elements; (c) the potential impact of demand elasticities to the range of objectives set; and (d) the rate of return and payback period for decentralized closed-loop systems (raintanks, SUDS, on-site wastewater treatment and reuse etc) and water saving appliances.

2 The concepts behind City Water Economics

Water pricing and cost recovery for water services are receiving increasing attention in both developed and developing countries. In the EU, the implementation of Art. 9 of the Water Framework Directive requires the adequate contribution of water uses to the costs of water services, demanding the allocation of water service costs in an equitable way, that implements the "polluter-pays" principle. In developing countries, the financial sustainability of water services, the affordability of water-related charges, and access to basic water services constitute horizontal policy goals. In the latter case, it is often argued that tariffs should not be the primary instrument to raise the funds required for capacity expansion, as this would substantially raise the costs borne by low-income groups. Nevertheless, even in this case, tariff schemes should raise adequate resources for meeting annual operating and maintenance costs and provide incentives to encourage water saving practices to avoid future, costly supply enhancement alternatives.

The following sections focus on aspects relevant to the policy questions addressed by City Water Economics. They describe issues relating to sustainable cost recovery, financing of water services and strategic plans, and on economic instruments for water management, in order provide the necessary background information on aspects relevant to the model.

2.1.1 Sustainable cost recovery, allocation of costs, and financing

The main concept behind City Water Economics pertains to the assessment of the implications of different forms of institutional organization and of alternative cost allocation schemes towards **sustainable cost recovery**. These are examined from two perspectives: (a) the perspective of those dealing with water service provision at various levels (metropolitan area, metropolitan area subset, river basin) and (b) from the social perspective, with emphasis placed on social equity, affordability and incentives offered by alternative pricing schemes and cost allocation mechanisms.

Sustainable cost recovery, as defined in Rouse (2007), means that costs are recovered so that the entity undertaking water services can achieve and maintain a specified standard of service, both for present and future generations. This level of cost recovery can be achieved wholly through water charges, as in some developed countries, or through a combination of water charges and targeted, reliable, long-term government subsidies. From the financial perspective, the total costs to be recovered include (EC-CIS WATECO, 2002):

- *Operating and maintenance costs:* These costs are those that relate to providing the service and include, amongst others, employment costs, energy costs, chemical costs and the costs of employing third parties. Maintenance costs relate to keeping the assets in serviceable condition throughout their economic life.
- *Capital costs:* These are the costs of the principal and interest payments (and cost of capital as appropriate) associated with expenditure on assets that is externally financed through loans, bonds, equity and also other financial mechanisms. Usually, different organisations have different depreciation policies, e.g. based on historical cost or replacement value, and different depreciation timescales.
- *Administrative costs:* These relate to the costs of regulating the water service, and include costs for monitoring the system, metering, invoicing and revenue collection, etc.

A critical aspect to sustainable cost recovery refers to the cost of maintaining and refurbishing existing assets. For both capital and maintenance costs, an accounting system is needed that makes the required financial provision. This often needs to expand beyond historical cost accounting, and include a thorough assessment of future replacement costs and their adjustments due to technological progress, changes in market prices, inflation, etc.

In the above context, assessments by CWE can focus on improving cost recovery both for current conditions, and for future management plans. They can thus be helpful in examining **financial aspects of strategic plans**, indicating requirements to seek external sources of funding or required tariff reforms to raise the revenue required for capacity expansion and improvement of service standards and coverage. As such, assessments can help in identifying the right mix of taxes, tariffs and transfers (the 3Ts referred to in OECD, 2009) to achieve water and sanitation targets (Box 2).

Box 2: Financing instruments – The OECD 3Ts (OECD, 2009)

Water finance relies on a mix of financing instruments. The costs of water services can be covered by three sources of revenues:

- *Tariffs: users of the water services can cover (part of) the costs of these services. Experience shows that tariffs have different impacts on different water services. Currently, water pricing has only a limited role in stimulating resource allocation, whereas it is used as an instrument to manage demand for water supply and sanitation.*
- *Taxes: Beneficiaries from water services can contribute to the costs of these services, whether or not they use them. However, deciding upon the precise frontiers of the "community of beneficiaries" (local, regional, national, international) can be difficult. For water management, countries tend to favour a watershed (or river basin) approach, as the benefits of improved water use tend to materialise at this level; but other levels or scales may be appropriate for selected services.*
- *Transfers from international donors or from private charities: In OECD (2009), Official Development Assistance has been kept under transfers, as donors are still disbursing most of their aid through projects and programmes, rather than through recipient country budget processes. Another important feature that distinguishes ODA from taxes is that they are levied in foreign countries, rather than nationally and the political and administrative process of securing ODA resources is very different from taxes.*

The 3Ts represent who actually pays for water. Additional sources of finance (public and private loans, bonds and funds provided by public and private investors) can help cover upfront investment costs and thus enable governments to leverage available sources of revenues and, hopefully, reduce financing costs; but they have to be repaid. The 3Ts and the stability of the financial flows they generate determine the creditworthiness of water utilities and hence access to additional sources of finance.

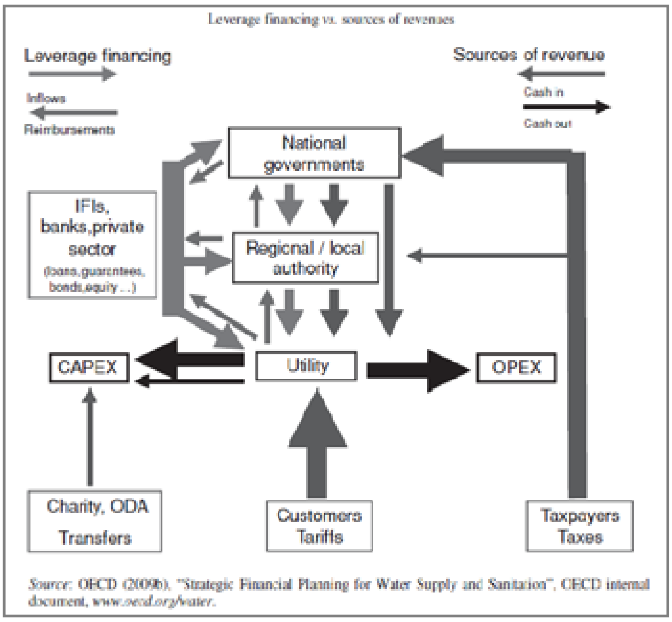


Figure 32: Financial flows to water supply and sanitation

As implied also in Box 2, full cost recovery, in theory, is always guaranteed: total costs could be covered by a broad range of instruments whose extremes are, on the one side, water pricing policies (including environmental charges) and on the other general taxation. In the former case the user will bear the burden of financing the service provision (together with environmental costs), while in the latter case these costs

are split among all tax-payers. Therefore, costs, even those associated with capital investment, are recovered at all times. What remains different, however, is the distribution of costs among the different groups. In this regard, sources of financing for water management operations present different levels of endogeneity. Box 3 highlights that different sets of solutions exist. Generally, the theoretical optimum calls for State financing for components that are public goods, and marginal cost pricing for private-good components.

Box 3: Sources of water supply and sanitation financing (adapted from INECO, 2009)

ENDOGENOUS	***From water users*** • *On individual basis (marginal cost)* • *Compensating among customers according to the charging criteria adopted* • *On a collective base (territorial cross-subsidies)* • *Through ear-marked taxes*
	Cross-subsidies • *From the collectivity* • *Cross-subsidies among services operated by the same authority;* • *Cross-subsidies among users of the same water resource*
	General taxation • *Direct subsidies (grants for new investment; coverage of operational deficits)* • *Indirect subsidies (e.g. low-interest loans, under-pricing of commodities and services supplied by the public sector)*
EXOGENOUS	***Transferred elsewhere as an external cost*** • *To other water users (intra-generational externalities)* • *To next generations (inter-generational externalities: e.g. poor maintenance of assets, public debt for covering operational expenditure)*

The choice among endogenous or exogenous source of finance is determined by several key constraints. First, in most countries, public finance is becoming scarcer. Central and regional governments have limited possibilities to increase public expenditure on public services, such as water and wastewater services. On the other hand, there are several issues that impede financing through water tariffs alone. Firstly, metering is costly; therefore, if elements based on volumetric charges are introduced, and systems have to be placed from scratch (for example in irrigated agriculture in many EU and Mediterranean Countries), total costs to be recovered are increased. Secondly, financing through tariffs alone would have significant distributional impacts, as an increase in tariffs combined with a decrease in public finance availability could make water unaffordable for certain uses. There are several solutions: one would be to introduce cross subsidies among use(r)s; another option concerns water demand management policies, in order to decrease water consumption and, consequently, some of the water service costs borne by the users.

2.1.2 Economic instruments in urban water management

An additional key aspect of the CWE modelling approach concerns incentives towards decentralized solutions. Often, the utilization of alternative water sources within the urban environment (e.g. treated wastewater or stormwater run-off) often requires financial motivation to render such options economically viable. In addition to regulatory measures (e.g. water saving or building standards), **economic instruments**, such as eco-incentives, direct subsidies or significant reductions in the expenditure for water services through tariff reforms, can foster wide implementation and uptake (Box 4).

Box 4: Economic instruments – Definition and classification

Economic instruments refer to mechanisms that create the economic incentives for individuals to freely opt for modifying or reducing their activities, thus indirectly producing an environmental improvement. They encompass a rather diverse toolkit of policies whose main characteristic is that they provide market signals by affecting or modifying relative prices. The aim is to influence the behaviour of consumers, polluters and other economic agents, and provide incentives to them for internalizing the externalities that they may be producing (Robinson and Ryan, 2002). The pertinent literature outlines many ways of classifying economic instruments, depending on their type, function or management issue that they are designed to address, their position along the water cycle (abstraction, discharge, use), the authority that can undertake their implementation, etc. A tentative classification of instruments based on their type is presented in Figure 33.

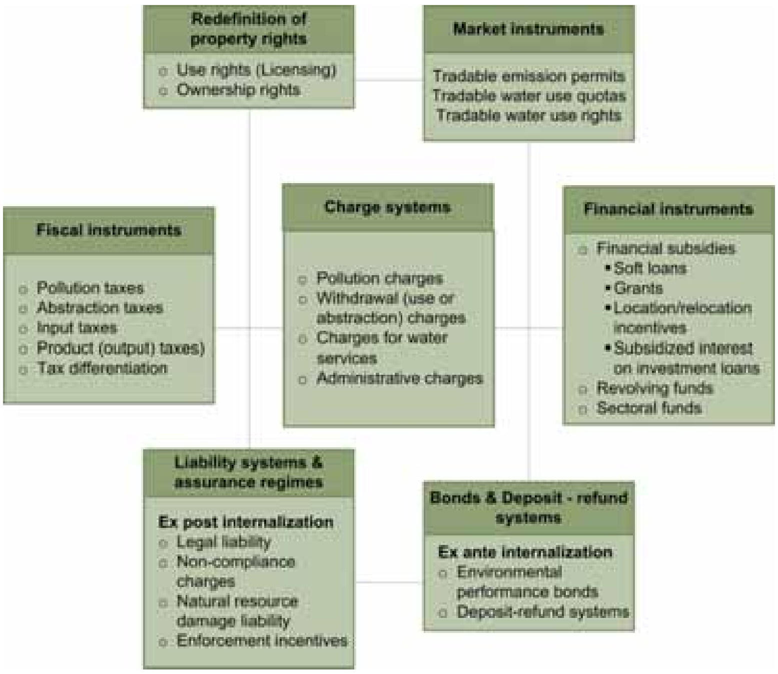


Figure 33: Overview of economic instruments for water management based on their type (adapted from Panayotou, 1994)

Economic instruments relevant to the scope of City Water Economics include (Figure 34):

- Water prices and taxes on water supply;
- Sewerage charges on relevant charges;

- Financial subsidies for water saving measures;
- Fees for stormwater management (drainage).

The model places particular emphasis on water prices and different rate structures, as these constitute the primary instrument for raising revenue towards cost recovery, and for providing incentives for more sustainable water use within the urban environment.

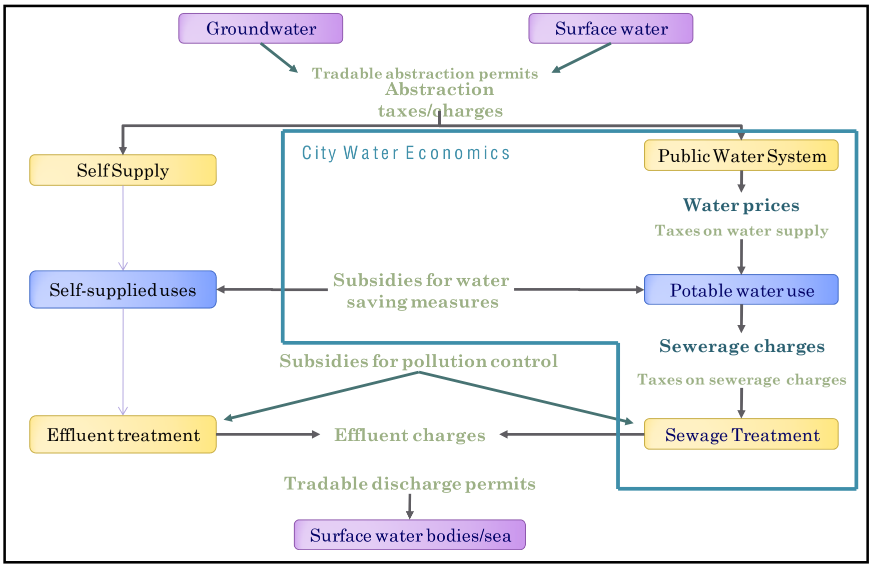


Figure 34: Economic instruments along the water cycle (Kraemer et al., 2003) and the scope of City Water Economics

Furthermore, and as the application of instruments further depends on the way that water services are managed in a given area (i.e. the form of institutional organization), a key element of the modelling approach concerns interactions among the different actors involved in providing water services in an urban catchment.

3 Algorithms and models for cost estimation and allocation

3.1 Main concepts

Within CWE, cost assessments are performed at the level of water service providers, and correspond to the costs incurred for the construction, operation and maintenance of the different infrastructure elements which are managed by the entity concerned, as well as for any payments made to entities for bulk water supply, wastewater treatment and stormwater management.

Cost allocation is thus performed according to the management framework defined for a specific case application, which describes which infrastructure is managed by a water service provider. This framework, which corresponds to the current institutional, organizational and management setting, can be used to model situations where more than one actor is involved in providing water services in a metropolitan area. A typical example is water service provision the Athens Metropolitan area. In this case, water supply infrastructure (dams and conveyance networks) are managed by a separate entity, which provides bulk water supply to the water utility of Athens (EYDAP S.A.). EYDAP S.A. in turn manages distribution networks and treatment facilities in the Metropolitan area, and is responsible for customer

invoicing and billing. Similar situations are also encountered in other European Countries (e.g. Portugal, Spain, France).

As described in the corresponding Section 6.1 of the User Manual, and particularly for the case of payments among water service providers, two options are available:

- The assignment of a common rate for all payments for a specific service; this corresponds to the case where the individual rates are defined externally (e.g. by the State or through ministerial decisions);
- The estimation of rates, to ensure that costs incurred by a specific provider are fully recovered by the provider who manages the infrastructure to provide services to this provider.

In the latter case, the concept for the estimation of rates is based on the "user-pays principle". This involves estimating factors that describe the share of infrastructure costs that should be allocated to a specific provider, and the estimation of the corresponding rates for bulk water supply/wastewater treatment/stormwater management.

The following section describes in more detail the equations and models used for cost estimation and allocation.

3.2 Model equations

Cost estimation and allocation is performed separately for each water service provided by a specific entity (water service provider). The assessment is based on:

- External input data on: (a) flows between infrastructure elements, (b) investment, unit operation and maintenance and fixed maintenance costs.
- The infrastructure management framework, described for the case.

The assessment is based on the assumption that the total volume of water sales for each cluster is equal to the sum of outflows for infrastructure elements of "Type 1" (see Annex I of the User Manual).

Overall, the total cost allocated to a water service provider for a specific year t is calculated by Eq. 3.2.1:

$$TC_{t,prov} = \sum_{ProvIn} Payment_{ProvIn,t} + \sum_{inf} \left(CapCost_{inf,t} + OperationalCost_{inf,t} + FixedMaintCost_{inf,t} \right)$$

In the above equation, TC_t is the total cost allocated to the water service provider, and $CapCost_{inf,t}$, $OperationalCost_{inf,t}$, $FixedMaintCost_{inf,t}$ correspond to the capital, variable and fixed operation and maintenance costs for each infrastructure element managed by the water service provider. $Payment_{ProvIn,t}$ corresponds to the payments made to other water service providers.

The **calculation of capital costs** for depends on the chosen method (simple depreciation or amortization of investment), which is used to calculate the corresponding annual cost over its lifetime. The following equations are used:

$$CapCost_{inf,t} = \begin{cases} InvCost_{inf} * Factor_{inf} \ if \ 0 < t - Construction\,Year_{inf} \leq Lifetime_{inf} \\ 0 \ otherwise \end{cases} \qquad \text{(Eq. 3.2.2)}$$

where $InvCost_{inf}$ is the investment cost in currency units, $Construction\,Year_{inf}$ is the construction year, and $Lifetime_{inf}$ is the lifetime of the infrastructure element in years. $Factor_{inf}$ depends on the assessment method chosen, namely:

- If the chosen method is "Simple depreciation of investment" then:

$$Factor_{inf} = \frac{1}{Lifetime_{inf}} \quad \text{(Eq. 3.2.3.a)}$$

- If the chosen method is "Amortization of capital investment" then:

$$Factor_{inf} = \frac{d*(1+d)^{Lifetime_{inf}}}{(1+d)^{Lifetime_{inf-1}}}$$, where d is the chosen amortization rate. (Eq. 3.2.3.b)

The **calculation of variable operation and maintenance costs** is performed according to Eq. 3.2.4:

$$OperationalCost_{inf,t} = UnitO\&M_{inf} * Flow_t \quad \text{(Eq. 3.2.4)}$$

In Eq. 3.2.4, $UnitO\&M_{inf}$ is the unit operation and maintenance cost, specified for the infrastructure element in the input data file. $Flow_t$ is either the yearly inflow to or the yearly outflow, depending on the type of infrastructure. For water supply infrastructure, it corresponds to the outflow, since O&M costs are measured in currency units/m³ produced, treated, pumped. For wastewater or stormwater management infrastructure, it refers to the inflow to the infrastructure element.

The **calculation of fixed maintenance costs** is based on the value provided in the input file for the infrastructure element.

For each cost element, an annual cost increase is also specified, which can be used to adjust future yearly costs for inflation or price increases, as follows:

$$Cost_t = Cost_{BaselineYear} * (1 + CostIncreaseFactor)^{t-BaselineYear} \quad \text{(Eq. 3.2.5)}$$

where $Cost_{BaselineYear}$ corresponds to investment, unit O&M or fixed maintenance costs provided in the input data file in baseline year prices, whereas the $CostIncreaseFactor$ is specified through the "Annual Cost Growth" parameter (see Section 6.1).

The **calculation of payments among water service providers** is illustrated through the example of Figure 35, for a water supply system involving 3 water service providers. In this case, water abstraction, conveyance and water treatment is undertaken by Provider #1, whereas distribution is undertaken separately by Providers #2 and #3, for Clusters A and B respectively. Water distribution in Cluster C is undertaken by Provider #1. According to the presented scheme, Providers #2 and #3 should pay an amount to Provider #1, corresponding to their share (or part of their share) of the cost incurred for freshwater abstraction, conveyance and treatment. In Figure 35, TC denotes the total cost (capital and operation and maintenance cost) for an infrastructure element in a given year, and $F_{i \to j}$ denotes the flow (outflow) from infrastructure i to infrastructure j.

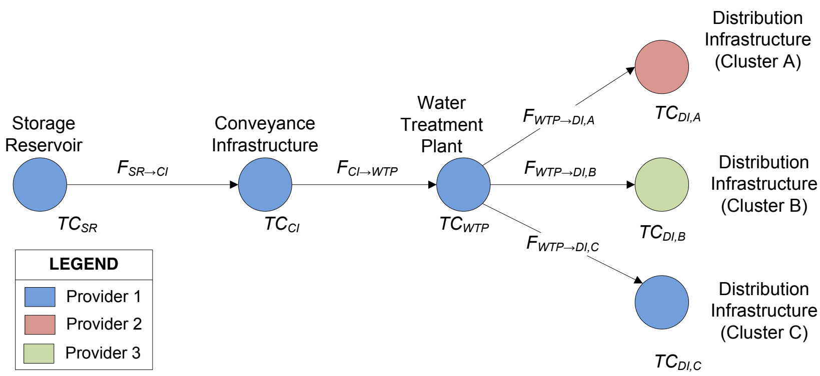


Figure 35: Cost allocation model example

As described in Section 6.1, three options can be chosen. For the **assignment of a default rate**, and for the example of Figure 35, the following equations apply:

- Payment from Provider 2 to Provider 1:
  $Payment_{Prov2 \rightarrow Prov1} = F_{WTP \rightarrow DI,A} * Rate$ (Eq. 3.2.6a)
- Payment from Provider 3 to Provider 1:
  $Payment_{Prov3 \rightarrow Prov1} = F_{WTP \rightarrow DI,B} * Rate$ (Eq. 3.2.7a)
- Total revenue for Provider 1:
  $\sum_{ProvOut} Payment_{ProvOut,t} = (F_{WTP \rightarrow DI,A} + F_{WTP \rightarrow DI,B}) * Rate$ (Eq. 3.2.8a)

In equations 4.2.6a to 4.2.6c, $Rate$ is the assigned default rate, in currency units/m³.

For the **assignment of a default lump sum**, the following equations apply:

- Payment from Provider 2 to Provider 1:
  $Payment_{Prov2 \rightarrow Prov1} = LumpSum$ (Eq. 3.2.6b)
- Payment from Provider 3 to Provider 1:
  $Payment_{Prov3 \rightarrow Prov1} = LumpSum$ (Eq. 3.2.7b)
- Total revenue for Provider 1:
  $\sum_{ProvOut} Payment_{ProvOut,t} = 2 * LumpSum$ (Eq. 3.2.8b)

When **rates are calculated individually** (option c), a first step concerns the allocation of costs among water service providers. In general, this is performed through the application of graph algorithms. For the specific example of Figure 35, and in terms of cost allocation, the following apply:

$$TC_{Prov1 \rightarrow Prov2} = \frac{TC_{SR} + TC_{CI} + TC_{WTP}}{F_{WTP \rightarrow DI,A} + F_{WTP \rightarrow DI,B} + F_{WTP \rightarrow DI,C}} * F_{WTP \rightarrow DI,A} \qquad \text{(Eq. 3.2.6c)}$$

$$TC_{Prov1 \rightarrow Prov3} = \frac{TC_{SR} + TC_{CI} + TC_{WTP}}{F_{WTP \rightarrow DI,A} + F_{WTP \rightarrow DI,B} + F_{WTP \rightarrow DI,C}} * F_{WTP \rightarrow DI,B} \qquad \text{(Eq. 3.2.7c)}$$

where $TC_{Prov1 \rightarrow Provx}$ describes the cost allocated to Provider x from Provider 1.

Subsequently, rates are calculated as follows:

$$Rate_{Prov1 \rightarrow Prov2} = \frac{TC_{Prov1 \rightarrow Prov2}}{F_{WTP \rightarrow DI,A}} \qquad \text{(Eq. 3.2.8c)}$$

$$Rate_{Prov1 \rightarrow Prov3} = \frac{TC_{Prov1 \rightarrow Prov2}}{F_{WTP \rightarrow DI,B}} \qquad \text{(Eq. 3.2.9c)}$$

Revenues and payments are calculated according to Eq. 4.2.6a-4.2.6b, using the calculated rates instead of the default one.

4 Design of tariff schemes

4.1 Background

4.1.1 Tariff functions and design objectives

As noted in the introductory section of this reference manual, water tariffs are a key component for ensuring financially sustainable water services. Despite (political) reluctance to embed the principles of cost recovery, correctly designed tariff schemes can help to ensure long-term sustainability in water

service provision, by providing the resources necessary to operate, rehabilitate and expand water service coverage, and by providing incentives towards demand management and inducing behavioural change.

In addition to adequate cost recovery, affordability is a key criterion in the formulation and design of tariff schemes, especially in developing countries, where infrastructure expansion and improvement is a priority that entails significant investment costs. In these cases, reaching full or at least improving cost recovery can impose significant burden on the poorest segments of society. Affordability concerns, however, are often cited as reason for deferring or dismissing tariff reforms, particularly because these are largely unpopular. This is particularly true in systems where tariffs have been kept at artificially low levels for extended periods of time. To that end, it is noted that affordability should be analysed at local level, and if required, compensating measures (e.g. rebates or external subsidies and aid for poorer households) can be applied in order to not compromise social objectives (OECD, 2009).

Moving towards improved or full recovery of financial costs is particularly required to send the correct signals to consumers. Artificially low (subsidised) water tariffs do not reflect the actual costs of water service provision. Furthermore, they enhance cross-subsidies, as investments or operation and maintenance costs for water service provision need to be funded through the State or local administration budget (and thus from tax revenues or revenue from other services). Although this can be socially acceptable in some cases (e.g. for developing water services in rural, low-income and isolated areas facing water scarcity), the practice decreases transparency in the allocation and use of public funding, and can put additional strain on State finances.

Water tariffs, as any other economic instrument, are designed to meet diverse objectives. The most frequently cited include economic efficiency, fairness in allocating and distributing costs among different customer classes and groups, equity, referring to social implications but also to the perceived fairness of charges set, revenue sufficiency to meet current and future expenditures for water services, et revenue stability, to enable sound financial management and planning, as well as simplicity and understandability, to improve acceptability, enhance transparency and send price signals to users.

Within the context of an overall pricing policy, water tariffs determine the level and pattern of revenue, create incentives, which in turn affect the production and use of water services, and allocate costs among customers, customer groups and over time. To that end, they also influence the value of services received, and on the total cost of production (for example, an increase of volumetric rates can result in a decrease in water consumption, and thus in production and water supply/wastewater treatment costs), and enhance the ability to attract capital, particularly in the case where private investors are involved. Nevertheless, it must be well understood that tariffs, as any other economic instrument, do not operate in a vacuum. As instruments they are most effective when combined with other measures to induce behavioural change (e.g. education and awareness, regulations on water saving standards) and need to be supported with complementary measures, including metering and regulations for transparency in financial management and planning.

Different tariff and rate structures exist, and have been widely applied, according to desired policy objectives and local conditions. The next section briefly introduces the different tariff types and their components, discussing also which of the aforementioned functions can be served by each.

4.1.2 Tariff structures

Water tariffs have the primary goal of recovering costs related with water supply provision; tariff elements are also often designed so as to provide incentives towards more efficient water use and allocation, taking into account that different price structures send different signals to consumers. A fundamental element in determining their structure lies in the consideration that the response of users and customers to economic

incentives is not obvious. On this regard, there is need to carefully understand in each context what the likely outcomes and impacts will actually be. Responses differ according to the target group (e.g. final consumers, producers), presenting also important differences in the short and long run. Therefore, adopting certain measures, such as a temporary increase of water rates in order to face seasonal water stress, will have completely different impacts than in the case in which they are intended to face long-run structural issues.

Several methods exist, all of which have been broadly applied and extensively discussed in numerous policy papers, with regard to their effectiveness, contribution to equitable access, incentive function, management and transaction costs, implementation problems, etc. The following paragraphs briefly outline the main methods, whereas Table 4 (p. 62) summarises their main contribution in relation to ecological sustainability, economic efficiency, financial sustainability and equity/affordability.

In general, a tariff structure is defined by two elements: (a) the type of charges, and (b) the form of volumetric charges (Figure 36).

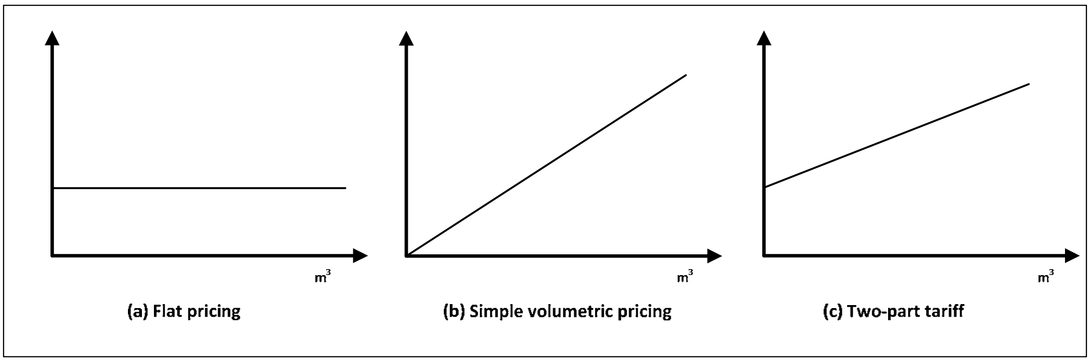


Figure 36: Tariff structures

In **flat pricing,** a charge of a constant fee is set, irrespectively of the water quantity used. Flat pricing methods are widely applied for recovering water service costs, where metering has not been introduced or is extremely difficult and costly to implement. For water supply, the fixed charge can be determined according to the number of customers, the size of the property, the characteristics of connections etc. In all cases, the marginal price of water is 0 (Perry, 2001), and thus no incentives are offered towards water conservation. The main advantage of this method is its simplicity, since it does not require consumption metering, and is thus very easy to implement. Furthermore, it produces fixed revenue and can thus provide stability.

In **simple volumetric pricing**, charges are defined only according to the volumes of water consumed. This structure directly implements the "user-pays" principle, and eliminates cross-subsidies among water users. Nevertheless, simple volumetric pricing cannot guarantee the achievement of cost recovery objectives, as revenues depend solely on water consumption.

In order to minimize risks of insufficient cost recovery, which can jeopardize system expansions and maintenance, **two-part tariffs** are widely used. These include a fixed and a volumetric charge. Fixed charges are designed so as to ensure a minimum level of revenue. Two-part tariffs are one of the simplest pricing methods, and if properly designed, can serve multiple functions (cost recovery, affordability and demand management).

In addition to the above, there are several ways of defining volumetric charges, including uniform rates, decreasing or increasing block rates, and seasonal rates (Figure 37).

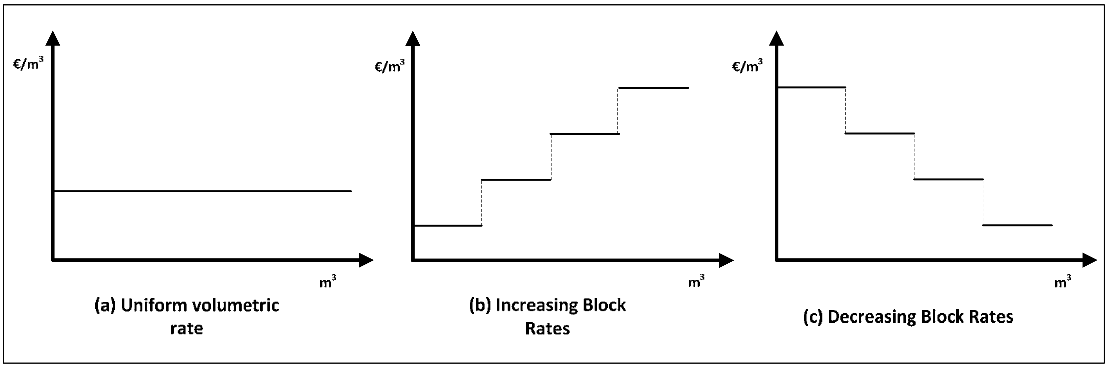


Figure 37: Types of volumetric rates

Uniform rates charge for the quantity of water used at a constant per-unit fee. Uniform rates are easy to apply and easily understandable by consumers. However, employing a constant per-unit fee means that the objectives of equitable access and disincentives to wasteful water use are in conflict.

Decreasing block tariffs (DBTs) charge a volumetric rate that decreases for higher levels of use. They reflect per-unit costs of production and delivery that are reduced as customers consume more water, due to economies of scale. Although in some cases DBRs reflect the actual financial cost of water delivery (e.g. when economies of scale are involved), they offer no incentive for water saving and are not applicable in the case of increasing water scarcity (i.e. when marginal costs for water supply provision are increasing). In some cases, however, they offer incentive to large-scale consumers to connect to public water supply systems, and abandon individual abstractions that can entail significant environmental costs.

Increasing block tariffs (IBTs) apply a volumetric rate that increases for higher levels of use. They are the most popular form of determining volumetric charges in domestic water use, as they offer easier cost recovery than uniform rates, are considered to impose conservation incentives on large users and provide water at an affordable rate to disadvantaged users. On the other hand, they have also been strongly criticized by many researchers in the past years, due to several shortcomings. These, according to Boland and Whittington (2003), can be summarized in the following:

- Difficulties in the definition of the rate for the initial block to ensure access to basic water services;
- Conflict between revenue sufficiency and economic efficiency;
- Lack of simplicity and transparency;
- Unfairness and limited applicability in the case of shared connections (i.e. more than one household sharing the same connection), which is often the case for poorer households in developing countries.

In most OECD countries, water tariffs include a fixed charge, not dependent on consumption, and a volumetric charge, set through one of the volumetric methods described above. The main objective is to secure a minimum amount of revenue to cover water supply costs, while at the same time providing incentive to users towards water conservation. In countries and/or regions experiencing strong seasonality in water demand, **seasonal rates** are also often applied. These are designed so as to recover part of the costs for the additional infrastructure required to supply peak demands, and provide further incentive in water saving (e.g. in outdoor water use or in commercial and tourist facilities).

In most countries, water tariffs for urban water services also include **sewerage charges**, paid for discharges into the sewer system (domestic and other effluents). Sewerage charges have the objective of providing water utilities with the financial resources necessary for wastewater collection and treatment.

The most common practice is that revenues for sewage collection and treatment are largely based on volumetric charges, as applied to public water supply provision. Therefore, there are cases when that the continuing trend toward more incentive-based charging for the public water supply system can lead to more wastewater revenues being recovered through volumetric charging. In addition, volumetric charging reinforces the incentives to use the water supplied more carefully (OECD, 1999).

Stormwater (or drainage) fees are oriented towards raising the revenue required to fund improvements or expansions to drainage networks, and in implementing sustainable drainage options. The dominant practice is to define a fee depending on the area of the property. Fees can vary according to the type of urban development (e.g. high rise, undeveloped residential area, bare property or green space). In recent years, there are cases where the corresponding fees are determined according to the impervious area of a property, determined through aerial photos. This practice achieves a potentially more fair allocation of costs, as these are allocated based on an implicit measure of the stormwater run-off generated by a property, and also provide incentives for the implementation of sustainable urban drainage options.

Figure 38 provides a summary of the interrelations among different elements of a pricing system and specific policy objectives.

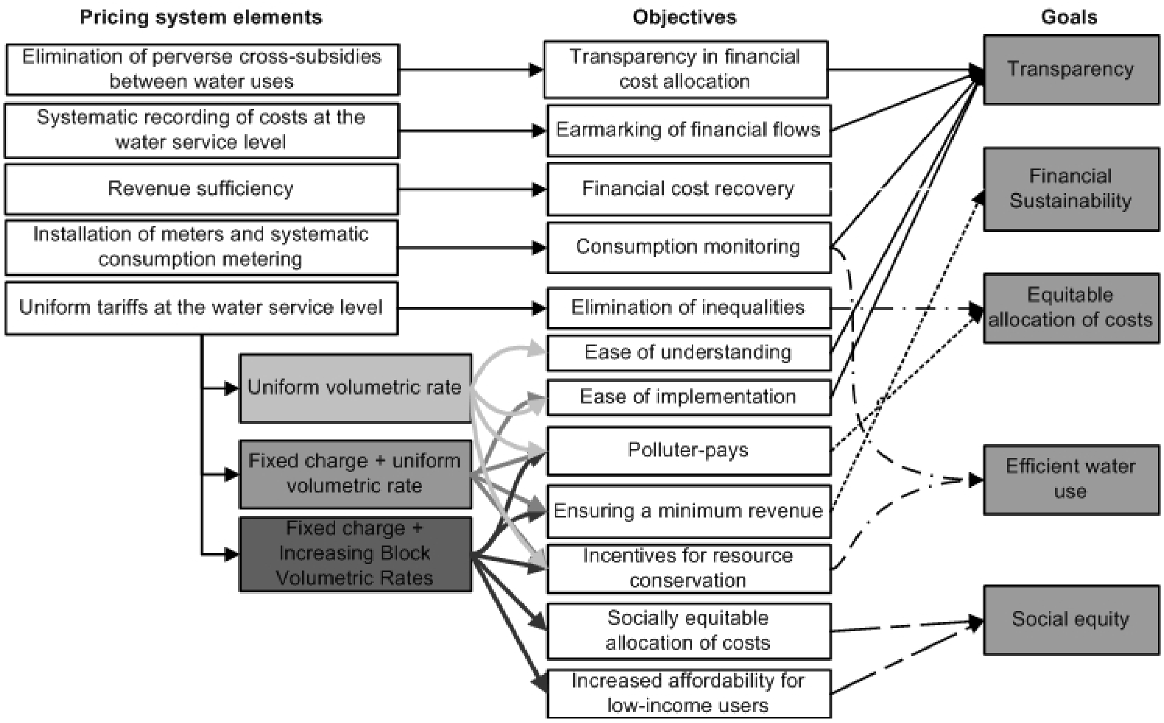


Figure 38: Contribution of pricing system elements to tariff goals and objectives (Chalvatzi et al., 2007)

Table 4: Alternative water tariff structures and performance respect to sustainability targets (OECD, 2009)

	Ecological sustainability	Economic efficiency	Financial sustainability	Equity / affordability
Flat rate/ Uniform license fee	Very poor. No incentives to water saving	Acceptable as a way to recover the fixed cost; inefficient if marginal costs are relevant	Potentially satisfactory, but commitment to cost recovery required Need to avoid the political definition of fees	Very regressive
Non-uniform flat rate	Poor, unless rates are eventually calculated according to specific circumstances (e.g. surface of gardens; swimming pools; water recycling devices)	Acceptable as a way to recover the fixed cost; inefficient if marginal costs are relevant	As above	Potentially good effects, provided that criteria used correspond to personal wealth
Uniform volumetric rate with fixed charge	High, depending on the marginal rate and individual metering	Potentially the best solution provided rates reflect short-run marginal costs (SRMC); particularly suited in case SRMC are constant	Good	Potentially good effects, provided that criteria used correspond to personal wealth
Uniform volumetric rate	As above; higher, since zero fixed charges means higher marginal rates	Not very efficient; inefficiency depends on demand elasticity (the lower the elasticity, the lower inefficiency)	Good	Encourages connection
Uniform volumetric rate with rebates	As above Highest if rebates take into account specific circumstances (e.g. surface of gardens; swimming pools; water recycling devices)	As above; In turn, could be efficient in combination with a positive fixed fee	Good	Progressive and useful for reducing impact on poorer users; Best if rebate is targeted; otherwise, distributive effect depending on income elasticity
Traditional IBT and fixed charge	Highest, provided that metering is individual and marginal rates in the upper blocks are high	Potentially the best solution provided rates reflect short-run marginal costs; particularly suited in case short-run marginal costs are increasing (e.g. .costly extra supply to be purchased)	Good potential for Full Cost Recovery; Attention needed for sudden reforms from flat charges to IBT (effect on demand)	Regressive, according to demand elasticity to income

	Ecological sustainability	Economic efficiency	Financial sustainability	Equity / affordability
IBT with default 1st block and targeted subsidies	Highest, provided that metering is individual and marginal rates in the upper blocks are high	As above	As above	Not very useful; subsidized block not necessarily targeted to the poor
Seasonality on tariffs	Not very useful unless used as a complement to bans for certain uses	Good for providing incentives to reduce demand in peak periods and optimizing capacity use	Generally no effect	Potentially regressive: Poor more likely to be impacted during stress periods

For example, flat rate pricing can ensure revenue stability and is easy to implement, but has no effect on water consumption metering and control and does not contribute to equitable cost allocation. On the other hand, the commonly applied Increasing Block Tariff, combined with a fixed charge, can offer incentives to users; however the emerging problematique questions the ability of the method to convey the right signals to water users and its contribution to the achievement of social objectives, especially with regard to multi-family households (Boland and Whittington, 2003).

A key element in the above Figure concerns transparency. Transparent cost-accounting and recovery means that users can always have access to information related to how much water they have received, how their payments are used and how water tariffs and rates are determined. Furthermore, it means understanding which water services are actually paid for, to which extent, by whom and how, and thus identifying whether external (usually State) subsidies are provided to the water sector, or whether cross-subsidies are paid between categories of users (CIS-WATECO, 2002).

4.1.3 The design process: general premises

In general, the design of tariff structures can be divided in three main steps (AWWA, 2000).

Step 1 concerns the clear definition of goals and objectives. The analysis normally starts with the identification of problems associated with the current tariff structure, and ways through which these can be resolved. In this stage it is important to understand:

- The utility's or the water system's history;
- How customers have responded to existing and previous rate structures, and rate increases;
- The major customer classes and the major water consumers, as well as their characteristics;
- The availability of water resources;
- The level of current and future costs and requirements;
- The socio-economic status and concerns of customers;
- Legal constraints, in setting rate structures, and financial constraints (e.g. potential future reductions of State subsidies or grants).

Next, the water service provider must determine its rate structure objectives, defining also which of the above functions is most important, in light of customer profiles, future revenue requirements and other (legal, financial, technical, administrative) constraints. These objectives will constitute the basis against which alternative rate structures will be evaluated and cross-compared, to select the most appropriate alternative.

Step 2 includes the evaluation of available alternatives. This firstly involves the drafting of a list of alternative rate structures (including who is charged, how often and how much). Secondly, evaluation criteria should be developed to determine how well each alternative performs with regard to objectives set. These need to be preferably evaluated through a quantitative analysis, particularly with regard to those objectives that concern revenue sufficiency and stability, affordability etc. Other evaluation criteria, such as fairness, which are more subjective, can be evaluated through qualitative methods.

Step 3 involves the understanding and communication of outcomes; this involves explaining to a non-technical audience the problems associated with the current rate structure, (new) objectives of rate reforms and the outcomes of the evaluation process. Communication is important to enhance transparency and acceptance of proposed changes.

Key issues in defining the appropriate rate structures concern:

- The availability and quality of data. Key requirements concern past and projected cost records, water sales data per billing period and customer class, revenue data per billing period and type of charge and other customer account data.
- Customer diversity, in order to understand how this influences the expenses and revenues associated with water service provision, and identify, where possible, cross-subsidies among customer classes.
- The seasonality of revenues and costs;
- The ability to send price signals;
- The price elasticity of demand, to assess how customers may respond to changes in prices;
- Weather risks, which may affect both demands placed on the water system and water production;
- Implementation requirements (time required, administrative changes, etc.).

As mentioned above, CWE is rather a scoping model than a tool meant to support a detailed assessment of potential tariff structures. To that end, CWE can be used for exploring the implications of tariff structures, based on a minimal set of data. More detailed assessments, including both quantitative and qualitative assessments, and tools for their communication would be required before a final decision on tariff reforms is made.

4.2 Model equations

Figure 39 presents the process for calculating tariff elements, according to the selected pricing method. Tariffs are designed in order to meet specific revenue requirements, defined by the set recovery rate for financial costs.

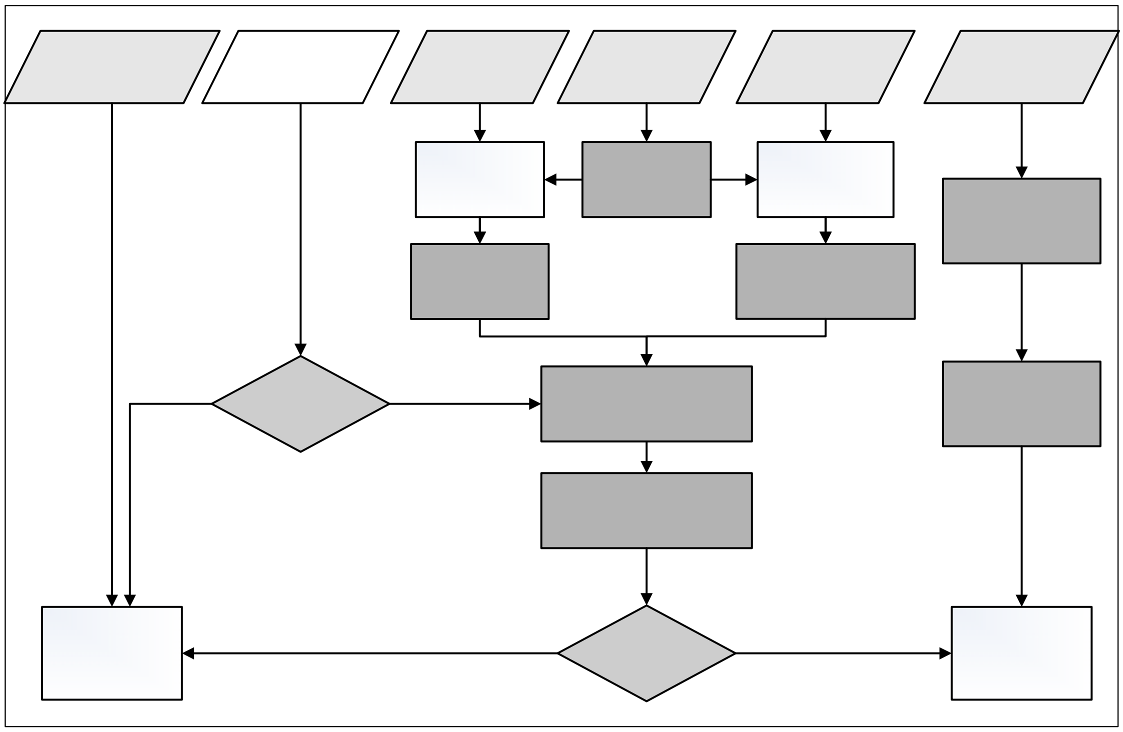


Figure 39: Flowchart for calculating water rates and charges

Tariff elements are designed in order to recover specific cost components, following the recommendations of the OECD (1999), and a simplified approach of the commodity-demand method developed by AWWA (2000).

Data requirements concern:

- Data or projections on water sales
- Data or projections on population, number of households, unit blocks and the average property area;
- Estimation on costs (capital, fixed maintenance costs, operational costs), as described in Section 4 of this manual;
- The distribution of consumption, which takes the form of a Weibull distribution.

Parameters defined by the user concern:

- The desired cost recovery rate;
- The overall design of the tariff structure, including the definition of its components (existence of fixed charges, chosen methods for defining volumetric or variable charges, and the corresponding parameters);
- The definition of billing and re-adjustment periods;
- The charge for new connections to the system.

The design of tariff schemes is performed at the level of water service providers. As such, a scheme can be applied to more than one cluster areas, depending on the defined management framework. In the overall calculation, fixed charges are used to recover costs related to standard expenditures for maintenance and permanent personnel, as well as a share of capital costs. Connection charges are provided as user inputs, considering that they should reflect the cost of connecting a customer to the system, but on the other hand, they should neither be disproportionate to customer incomes, nor meet a considerable share of revenue requirements. All other costs to achieve specified recovery objectives are allocated through volumetric or variable charges, as presented below.

4.2.1 Revenue requirements from volumetric/variable charges

As presented in Figure 39, the first step for the estimation of rates concerns the calculation of revenue requirements from volumetric or variable charges. The estimation follows the same logic for all services (mains water supply, sewerage, drainage), and is undertaken for each water service provider and water service individually. In Eq. 5.3.1 as well as in all subsequent equations in this Section and Sections 4.2.2-4.2.5, all costs and quantities are summed for the period t corresponds to the charge readjustment period (ranging between 1 and 5 years).

$$TCR_{t,prov} = CRR_{Desired,prov} * \left(TC_{t,prov} - \sum_{Provout} Payment_{Provout,t}\right) \qquad \text{(Eq. 4.2.1)}$$

The calculation of the revenue from volumetric charges requires first the estimation of the revenue from new connections and from fixed charges. These are calculated from Eq. 4.2.2 and 4.2.3 respectively:

$$ConRev_{t,Prov} = NewConCharge_t * (Connections_t - Connections_{t-1}) \qquad \text{(Eq. 4.2.2)}$$

$$FixedRevReq_{t,prov} = FixedMaintCost_{t,prov} + ShareCapCostRec * (CapCost_{t,Prov}) \qquad \text{(Eq. 5.3.3)}$$

Fixed charges are calculated by Eq. 4.2.4:

$$FixedCharge_{t,prov} = \frac{FixedRevReq_{t,prov}}{Number\ of\ Connections_t} \qquad \text{(Eq. 4.2.4)}$$

Volumetric revenue requirements are calculated by subtracting revenues from new connections and from fixed charges:

$$VolRevReq_{t,Prov} = TCR_{t,Prov} - ConRev_{t,Prov} - FixedRevReq_{t,Prov} \quad \text{(Eq. 4.2.5)}$$

Subsequently, calculations are differentiated according to the water service and the method chosen for defining volumetric (or variable in the case of drainage) rates.

4.2.2 Volumetric rates for mains water supply

The calculation of volumetric rates varies according to the method chosen:

- The **Uniform Volumetric Rate** is calculated by dividing the volumetric revenue requirements with the total freshwater sales in the cluster areas serviced by the provider:

  $$UVR = VolRevReq_{t,Prov}/TotalSales_{t,Prov} \quad \text{(Eq. 4.2.6)}$$

- For **Increasing or Decreasing Block Rates**, the estimation is based on the calculation of the rate for the first block ($RateBlock_{1,t,Prov}$) according to the rate differentials entered by the user and the consumption pertaining to each block.

  $$RateBlock_{1,t,Prov} = \frac{VolRevReq_{t,Prov}}{Block_1Sales_{t,Prov} + \sum_{i=2}^{Number\ Of\ Blocks} RateDifferential_i * Block_iSales_{t,Prov}} \quad \text{(Eq. 4.2.7)}$$

  In Eq. 5.3.7 the volume of sales pertaining to each block is calculated from the Weibull distribution for consumption. Subsequently, the rates for all other blocks are calculated according to their differentials:

  $$RateBlock_i = RateDifferential_i * RateBlock_{1,t,Prov} \quad \text{(Eq. 4.2.8)}$$

- For the case of **seasonal water rates**, rates are differentiated according to the seasonal pattern of water sales, by estimating differentials for each period with respect to the first one, and determining the rates for the first period, using an equation similar to Eq. 4.2.7.

4.2.3 Rates for sewerage charges

The estimation of sewerage charges and rates follows a similar logic. It involves the calculation of: (i) the total costs to be recovered, (ii) revenue from new connections, (iii) revenue from fixed charges (if applicable), (iv) fixed charges, and (v) revenue requirements from volumetric charges, according to equations 4.2.1 to 4.2.5, using calculated values and parameters for wastewater collection and treatment.

Subsequently, and depending on the method chosen for the volumetric component, the following equations are used:

- For the case where the volumetric component is defined as a **surcharge on the volumetric charge for mains water supply**, the surcharge $SMVC$ is estimated by Eq. 4.2.9:

  $$SMVC = \frac{VolRevReq_{t,Prov}}{\sum_{\mathrm{HH}} VarExp_{HH,WS,t}} \quad \text{(Eq. 4.2.9)}$$

  where $VarExp_{HH,WS,t}$ is the household expenditure for volumetric charges for mains water supply, calculated according to the equations presented in Section 5.

- For the case where the volumetric component is defined as **independent, uniform rate**, based on mains water usage, the rate is calculated by Eq. 4.2.10:

  $$SMVR = \frac{VolRevReq_{t,Prov}}{SMWC * WaterSales_{t,Prov}} \quad \text{(Eq. 4.2.10)}$$

where $SMWC$ is the corresponding percentage, defined by the user and $WaterSales$ is the total volume of water sales in the area(s) where wastewater services are provided.

4.2.4 Drainage fees

The estimation of fixed charges follows a similar logic to equations 4.2.1 to 4.2.5. The variable component is determined according to the method chosen:

- For the case where drainage fees are based on property area, the fee SWF is estimated by Eq. 4.2.11:

$$SWF = \frac{VarRevReq_{t,Prov}}{UBNumber_t * AvgUBArea} \quad \text{(Eq. 4.2.11)}$$

- For the case where drainage fees are based on impervious property area, the fee $SWFI$ is estimated by Eq. 4.2.12:

$$SWFI = \frac{VarRevReq_{t,Prov}}{UBNumber_t * AvgUBArea * ImpAreaShare_t} \quad \text{(Eq. 4.2.12)}$$

5 Assessment of output indicators

5.1 Main concepts

Indicators calculated by City Water Economics for the evaluation of scenarios pertain to two categories:

- Indicators relating to affordability of water services;
- Indicators relating to aspects of financial sustainability in water service provision.

Affordability is assessed both from a macro- and micro-level perspective. Indicators for the entire area depict annual expenditure as share of the average disposable income (macro-affordability assessment). Micro-level analysis includes the calculation of the share of annual disposable income spent on water services at the level of clusters and per income group. They can be used to indicate whether affordability is equally distributed across income groups or neighbourhoods, and to design appropriate compensation measures (e.g. rebates) in case that expenditure exceeds specific thresholds (Table 5).

Table 5: Affordability thresholds (Source: OECD)

	Affordability criterion
OECD	3-5%
EU	3%
US (EPA)	2.5%
IFIs	4%

At the level of water service providers, indicators referring to **financial sustainability and allocation of costs** concern:

- The revenue pattern (structure), which can provide a first indication on revenue stability;
- Cost recovery patterns; although cost recovery is a design criterion in the design of tariff structures, revenue vs. cost inter-annual variability can be important, especially in cases of long re-adjustment periods (>3 years).

Cost recovery patterns are also evaluated at the level of clusters. This type of assessment can be used to map potential cross-subsidies among geographical areas or neighbourhoods, i.e. cases where revenues from a specific area exceed the costs of water service provision.

In all cases, indicators are computed for the entire time horizon and for each water service analysed in the model. Affordability indicators also include the total household expenditure for water services and the share of disposable income spent on these.

5.2 Model equations

5.2.1 Affordability indicators

City Water Economics estimates two indicators relating to affordability:

- The annual expenditure of households for water service;
- The share of disposable income spent for water services.

The assessment is undertaken for each water service (water supply, wastewater collection and treatment and drainage), at the level of individual clusters, and for the whole of the analysed area (average value).

If income groups are fully described with regard to their characteristics (share of water consumption over the total, average property size and disposable income), micro-affordability indicators can also be calculated to show impact on low and higher income households. If no data are provided for income distribution, indicators rather correspond to a macro-level assessment, relating the average income to water service expenditures.

The following paragraphs describe the generic equations for the calculation of relevant indicators for a specific income group and cluster. If income distribution information is not provided, then the average values for disposable income, consumption and property size are used to estimate macro-affordability indicators, according to the same equations.

The annual expenditure of a household ($AnnExp_{HH}$) for a water service x is calculated as the sum of expenditures for all tariff application periods. It includes expenditure for fixed charges $FixedExp_{HH,x,n}$ (if any) and for variable/volumetric charges ($VarExp_{HH,x,n}$):

$$AnnExp_{HH,x} = \sum_{Period=1}^{n} Exp_{HH,x,n} = \sum_{Period=1}^{n} FixedExp_{HH,x,n} + VarExp_{HH,x,Period} \quad \text{(Eq. 5.2.1)}$$

The calculation of the expenditure for fixed charges is common for all water service types:

$$FixedExp_{HH,x} = n * FixedCharge_x \quad \text{(Eq. 5.2.2)}$$

where n is the frequency of tariff application in the year ($n = 1$ for yearly tariffs, $n = 2$ for 6-month tariffs etc.) and $FixedCharge_x$ is the fixed charge estimated for the specific service, tariff scheme and year of assessment.

The estimation of $VarExp_{HH,x,n}$ differs according to the service and the method chosen for defining volumetric/variable charges. The assessment is performed per billing period, and values are then summed to calculate the annual expenditure for volumetric/variable charges.

For mains water supply:

- For Uniform Volumetric Rates, Eq. 5.2.3 applies:

$$VarExp_{HH,WS,Period} = \mathrm{UVR}_{\mathrm{Period}} * HHCons_{Period} \quad \text{(Eq. 5.2.3)}$$

- For Increasing or Decreasing Block Rates, the assessment involves defining the block to which household consumption pertains, denoted below by $Block_y$. Eq. 5.2.4 is used:

$VarExp_{HH,WS,Period} = \sum_{i=1}^{y-1} Block_{i,Period} * Rate_{Block_i,Period} + \left(Block_{y,Period} - HHCons_{Period}\right) * Rate_{Block_y,Period}$ (Eq. 5.2.4)

where $Block$ corresponds to the upper limit of consumption for the consumption range that describes the block and $Rate$ is the applicable rate for the block.

For wastewater collection and treatment:

- If rates are calculated independently, considering a share of mains water consumption as wastewater flow, then

  $VarExp_{HH,SW,Period} = SMVR_{Period} * SMWC * HHCons_{Period}$ (Eq. 5.2.5)

- If volumetric charges are calculated as a surcharge on the mains volumetric charge, then:

  $VarExp_{HH,SW,Period} = SMVC * VarExp_{HH,WS,Period}$ (Eq. 5.2.6)

For drainage:

- If drainage fees are based on property area then:

  $VarExp_{HH,SW} = UnitPropCharge_{SW} * HHPropSize$ (Eq. 5.2.7)

- If drainage fees are based on impervious property area then:

  $VarExp_{HH,SW} = UnitPropImpCharge_{SW} * HHPropSize * ImpAreaShare$ (Eq. 5.2.8)

Subsequently, the share of disposable income spent on water services is estimated as:

$IncomeShare = \frac{AnnExp_{HH,WS} + AnnExp_{HH,WW} + AnnExp_{HH,SW}}{DispIncome}$ (Eq. 5.2.9)

5.2.2 Cost recovery at the level of clusters

The assessment of cost recovery at the level of clusters can be used to depict potential cross-subsidies among different geographical areas (e.g. neighbourhoods, metropolitan area subsets or municipalities, etc.). The assessment requires defining the amount of (i) revenues and (ii) costs at the cluster level.

Revenues at the cluster level are calculated on the basis of the annual expenditure of households for water services, considering also the corresponding number of connections and consumption distribution (for the cases of water supply and sewerage).

Revenues from fixed charges are calculated by multiplying the fixed charge to the number of collected households. Similarly revenue from new connections is calculated by multiplying the connection charge to the new connections to the system for a specific year.

Revenues from volumetric charges are calculated through the following equations:

For mains water supply:

- For Uniform Volumetric Rates, Eq. 5.2.10 applies:

  $RevVar_{WS,Cl,Period} = UVR_{Period} * Cons_{Cl,Period}$ (Eq. 5.2.10)

- For Increasing or Decreasing Block rates, Eq. 5.2.11 is used:

  $RevVar_{WS,Cl,Period} = \sum_{\mathrm{y=1}}^{\mathrm{Number\ of\ Blocks}} VarExp_{HH,WS,Cl,Period,y} * NumberOfHouseholds_{WS,Cl,Period,y}$ (Eq. 5.2.11)

where $NumberOfHouseholds_{WS,Period,y}$ is the number of households connected to the water system whose consumption pertains to $Block_y$, and $VarExp_{HH,WS,Cl,Period,y}$ is the expenditure for volumetric charges for a household pertaining to $Block_y$, calculated through Eq. 5.2.4.

For wastewater collection and treatment:

- If rates are calculated independently, considering a share of mains water consumption as wastewater flow, then
  $RevVar_{Cl,SW,Period} = SMVR_{Period} * SMWC * Cons_{Cl,Period}$ (Eq. 5.2.12)
- If volumetric charges are calculated as a surcharge on the mains volumetric charge, then:
  $RevVar_{Cl,SW,Period} = SMVC * RevVar_{WS,Cl,Period}$ (Eq. 5.2.13)

For drainage:

- If drainage fees are based on property area then:
  $RevVar_{Cl,SW} = UnitPropCharge_{SW} * HHPropSize * HHNumber$ (Eq. 5.2.14)
- If drainage fees are based on impervious property area then:
  $RevVar_{Cl,SW} = UnitPropImpCharge_{SW} * HHPropSize * ImpAreaShare * HHNumber$ (Eq. 5.2.15)

Depending on tariff application periods, an additional sum operation is performed to calculate yearly values.

Costs at the cluster level are calculated following a similar approach to the one described for the allocation of costs among water service providers (Section 2.2). This involves the allocation of costs for joint infrastructure (i.e. infrastructure used to provide services to more than one area) according to the quantities provided/collected/treated.

Subsequently, **cost recovery at the cluster level** is calculated by:

$$TCR_{Cl,x} = \frac{RevFix_{Cl,x}+RevVar_{Cl,x}+RevCon_{Cl,x}}{Cost_{Cl,x}} \quad \text{(Eq. 5.2.16)}$$

5.2.3 Indicators at the level of water service providers

Revenue structure can be useful in assessing revenue stability, and involves the calculation of the following components:

- Revenues from fixed charges;
- Revenues from new connections;
- Revenues from volumetric/variable charges;
- Revenues from services to other water service providers.

The first three categories are calculated from the individual cluster results (see Section 5.2.2) which are summed for the clusters serviced by the corresponding provider.

Revenues from services to other water service providers, and costs incurred are calculated according to the equations of Section 3.2. The annual cost recovery is then calculated by dividing revenues and costs, similarly to Eq. 5.2.16.

6 Price elasticity analysis

6.1 Main concepts

Rate changes can have significant impact on water usage in a given area. In this regard, the assessment of the impact of such changes on water use, and thus on revenues and costs, is required to provide a more

thorough analysis of potential deviations from the desired cost recovery objectives. The responsiveness of water use to price changes is measured through the **price elasticity of water demand**, which denotes the sensitivity of water use relative to changes in the price of water. The price elasticity of water demand is defined as the percent change in demand that would be expected from a small percent increase in price.

OECD (2009) notes that in most countries the price elasticity of drinking water demand by urban households is low. This is because water has no substitutes for basic uses and because the customer exhibits a low level of perception of the rate structure, since water bills typically represent a small proportion of income (Arbués et al., 2003). This is backed up by many studies in different urban contexts, which have found that household water demand in industrialized countries is both price and income inelastic. In these countries, other household characteristics (size and composition), housing characteristics (principal versus secondary residence; garden size, if any; stock of water-using appliances), and weather data are commonly acknowledged as determinants of water use. Furthermore, the analysis of the main determinants of water demand in developing countries suggest that, despite heterogeneity in the places and time periods studied, most estimates of own-price elasticity of water from private connections are in the range of -0.3 to -0.6, close to what is usually reported for industrialised countries (Nauges and Whittington, 2010).

Nevertheless, impacts can be particularly significant if the tariff structure is substantially modified (e.g. through change of pricing method or if a large rate increase is implemented). The pertinent literature is vast and outlines different econometric and statistical methods for estimating price elasticities and analysing user responsiveness to price increases in different contexts. The main considerations that emerge for estimating potential impacts from tariff modifications concern the following:

- Wastewater charges affect the price elasticity results (if usage-dependent sewerage charges are neglected, then this reduces the absolute value of elasticity coefficients).
- Consumers rather react to average rates (rather than marginal ones) and to total bills rather than they do to the rate of the final block of use.
- Rate design affects water use but not necessarily price elasticity. Price elasticities do not vary substantially across uniform, decreasing or increasing block rates.
- Each user class may respond differently to rate changes;
- Consumer education programmes affect price elasticities;
- A key factor is the change in real water prices. Use is more affected by increases in real (adjusted for effect of inflation water rates, rather than by increases in nominal water rates (not-inflation adjustments);
- Usage patterns for large users are generally more price elastic than the patterns of residential consumers.

To account for the potential impact of rate changes on water usage, and thus on key indicators that concern the formulation and analysis of cost recovery schemes, City Water Economics employs a **sensitivity analysis** approach. Recognizing that price elasticities may vary across contexts for different reasons (e.g. level of price increase, location, demand pattern, consumer awareness, etc.) this allows estimating potential impacts for different elasticity values and thus provides a more comprehensive conclusion, particularly in cases where the price elasticity is unknown or relevant information is outdated.

The analysis conducted by the model is based on **average price elasticity**, for the following reasons:

- Under block rate tariffs, it is very difficult to analyse the effect of changes in the intramarginal rates, that is, rates that do not correspond to the current level of consumption (e.g. of rates that

correspond to levels of lower consumption). Furthermore, as the marginal price is not affected by a change in the intramarginal rate, the latter will only affect demand through an income effect;

- Many studies have shown that users respond to average, rather than marginal prices, for the reasons presented above.

The following paragraph presents in more detail the employed approach.

6.2 Model equations

The price elasticity of water demand (e) is defined as:

$$e = \frac{\frac{dQ}{Q}}{\frac{dP}{P}} = \frac{\frac{Q_{new} - Q_{old}}{Q_{old}}}{\frac{P_{new} - P_{old}}{P_{old}}} \qquad \text{(Eq. 7.1)}$$

where Q_{new} denotes the new quantity demanded after a change of the water price from P_{old} to P_{new}, and Q_{old} is the water demand when the water price is equal to P_{old}.

The above equation is used for calculating the new water consumption under modified rates. As the assessment is based on average price elasticity, the model first calculates the average price faced by a household under the old (baseline) and the new tariff scheme. For this purpose, the following are calculated at the level of individual clusters:

- The annual expenditure on volumetric charges for water supply (AVC), according to the equations described in Section 5.2. The calculation is performed both for the baseline and for the formulated pricing scheme.
- The average household consumption in the area concerned, based on the data entered. This consumption corresponds to Q_{old} in the above equation.

Subsequently, the new average household consumption is calculated by solving Eq. 7.1 with respect to Q_{new} .and calculating the average prices by dividing the annual expenditure AVC with the average household consumption.

The new levels of consumption at the cluster level are then used to estimate relevant indicators according to the equations presented throughout this reference manual (levels of water use, costs incurred, revenues raised and achieved cost recovery at the level of clusters and water service providers). Calculations are repeated for the entire range of elasticity values entered by the user, and relevant results are presented in the form of graphs.

7 Analysis of on-site water management interventions

7.1 Main concepts

In addition to the price elasticity analysis, which also offers an estimate of potential demand reductions as a result of changes in tariff structures, City Water Economics also performs an economic analysis of urban water management options, to investigate potential incentives that could be offered by the analysed pricing schemes towards their implementation. Urban water management options that could be analysed in this respect concern water saving appliances and devices and use of alternative water supply sources (e.g. raintanks, treated wastewater, etc.). Furthermore, there is possibility to investigate SUDS, such as green roofs, porous pavements etc.

This analysis requires that data relating to the design of the specific options have already been imported in the model. These concern the amount of water savings, reductions in wastewater outflows and in impervious area resulting from their implementation, and can be obtained through the simulation of these options in other City Water models (e.g. City Water Balance, STORM, etc.).

Indicators that are calculated by the model express the financial viability of the intervention under the examined pricing scheme for an average household (Table 6). They correspond to the calculation of lifecycle costs and economic benefits resulting from the reduction in the annual expenditure for water services. According to these, City Water Economics estimates the amount of subsidy or further incentive required to compensate for any benefit shortfalls or the payback period for the investment, if this is economically viable.

Table 6: Economic Indicators for the analysis of on-site urban water management options

Indicator Category	Indicator	Description
Total savings in expenditure for water services	Savings from the mains water bill	Lifecycle savings from the expenditure for water supply services for an average household (Currency units/household)
	Savings from the wastewater bill	Lifecycle savings from the expenditure for sewerage services for an average household (Currency units/household)
	Savings from the stormwater bill	Lifecycle savings from the expenditure for drainage services for an average household (Currency units/household)
	Total savings	The total reduction in the expenditure for water services (Currency units/household)
Lifecycle Cost	Cost	The lifecycle cost associated with the intervention, including: (a) investment, (b) operation and maintenance costs in present value terms
Required subsidy or payback period	Total subsidy	The amount of subsidy required to make the option financially viable
	Subsidy as share of investment cost	The share of investment costs that need to be subsidized for the option to be financially viable
	Payback period	The option payback period (applicable only when the total reduction in the expenditure for water services is higher than lifecycle costs).

7.2 Model equations

Financial indicators on water management interventions are calculated according to input data entered, and a chosen discount rate, d, for which a sensitivity analysis can also be undertaken.

The **lifecycle cost** LCC for an intervention is calculated by Eq. 7.2.1:

$$LCC = InvCost + \sum_{i=1}^{Lifetime}(O\&M_i + FM_i) * \frac{1}{(1+d)^i} \quad \text{(Eq. 7.2.1)}$$

where $InvCost$ is the investment cost for a household, $O\&M_i$ is the operation and maintenance cost in year i, calculated on the basis of the unit operation and maintenance cost, as entered in the input data file, and the yearly average water consumption or wastewater outflow, FM_i is the fixed maintenance cost and d

is the chosen discount rate. If the time horizon for which data are provided is shorter than equipment lifetime, then missing water consumption or wastewater outflows are calculated as the average value for the timeframe for which data have been provided.

The **yearly savings** from the mains ($SMWB$), wastewater ($SWWB$) and stormwater bills ($SSWB$) are calculated as the difference between the expenditure for water services with and without the intervention. For the first two cases, this involves calculating the reduction in water use for an average household, based on the provided time series of data. For the case of drainage, the assessment is based on the corresponding reduction in impervious area, if this is the chosen method for defining drainage fees.

The **total lifecycle savings** $TLCS$ are then calculated by Eq. 7.2.2:

$$TLCS = \sum_{i=1}^{Lifetime}(SMWB_i + SWWB_i + SSWB_i) * \frac{1}{(1+d)^i} \qquad \text{(Eq. 7.2.2)}$$

The **minimum amount of subsidy** required to make a potential investment financially viable, in present value terms is calculated by Eq. 7.2.3:

$$TS = \begin{cases} LCC - TLCS \; if \; LCC \geq TLCS \\ 0 \; if \; LCC < TLCS \end{cases} \qquad \text{(Eq. 7.2.3)}$$

The **payback period** is an indicator applicable only if total savings exceed lifecycle costs. It is calculated by finding the year when the cumulative sum of total savings becomes greater than the cumulative sum of costs.

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Part III: Application examples

1 Introduction

This Part of the City Water Economics documentation summarizes the main applications of the model within the framework of SWITCH. As outlined in this document's preface, City Water Economics has been applied in three SWITCH Demo cities, Birmingham, Alexandria and Accra.

The application of the model in **Birmingham, UK** was undertaken by Patrick Oldendorf, MSc Student at the École Polytechnique Fédérale de Lausanne, under the supervision of Dr. Marc Soutter. The application was part of an overall study, aimed at assessing Sustainable Urban Drainage Strategies (SUDS) in the Upper Rea catchment. In this study, City Water Economics was used for assessing financial costs and incentives for the adoption of different SUDS.

The application of City Water Economics in **Alexandria, Egypt**, was developed by the National Technical University of Athens, as part of the overall training on City Water Economics within the framework of SWITCH. The application focuses on potable water supply, and has been based on (a) data collected within the framework of SWITCH by CEDARE and (b) other studies undertaken as part of the Strategic Planning Process in the city. The focus has been on assessing potential tariff reforms, according to the objectives of the Alexandria Water Company (AWCO) and on evaluating the incentives offered by current (or potential) tariff schemes towards water saving in households.

The application of the model in **Accra, Ghana,** was developed in collaboration with the University of Abertay, as part of SWITCH WP 1.3, using data from two SWITCH deliverables, developed within the framework of strategic planning for the city. The application was intended to showcase the applicability of the model in different contexts, and addresses: (a) the current framework for water service provision, and (b) a cost recovery scheme, considering the current Strategic Investment Plan (SIP) developed for the city.

The following sections summarize the main inputs, assumptions and results from the application of the model in each area, illustrating the types of results that can be provided, and policy-relevant questions that can be addressed by the model.

2 Assessment of economic instruments for supporting sustainable stormwater management in Birmingham, UK

The application of City Water Economics in the case of the Upper Rea Catchment was part of an overall study, aimed at identifying and assessing suitable stormwater management strategies for the area. The assessment was based on the application of two models, STORM and City Water Economics and of the City Water Information System, within the framework of SWITCH, and was undertaken by Patrick Oldendorf, EPFL. The main objectives of the work concerned:

- The analysis of an integrated water management approach to deal with stormwater flood issues in the area, considering both hydraulic and financial/economic challenges and aspects;
- The combined use of a drainage model (STORM), an economic model (City Water Economics) and a modelling platform (CWIS) to assess the analytical capabilities of each in the specific application case and their inter-operation potential;
- The investigation of the hydraulic and economic effects of sustainable drainage management strategies for the studied area, assessing the flood protection performance and the economic characteristics of each.

This chapter summarizes the outcomes of the assessment, focusing particularly on the application of City Water Economics and the results pertaining to the economic assessment and the evaluation of economic instruments to support proposed SUDS for the area. The chapter is structured in the following way: Section 2.1 provides a brief overview of flood issues in the Upper Rea catchment. Section 2.2 summarizes the SUDS proposed and simulated for the area, and the results obtained through the application of STORM. Section 2.3 presents the first set of results derived from the implementation of CWE for the assessment of the proposed SUDS, whereas Section 2.4 outlines results relating to financial planning and economic incentives towards their implementation.

2.1 Background: Flood issues in the Upper Rea Catchment, Birmingham

The Upper Rea catchment is part of the urban agglomeration of Birmingham in the West Midlands county of England. As the second most populated metropolis in the United Kingdom, the city of Birmingham represented the heart of the country's industrial revolution. Today, and although its industrial importance has declined, the city has developed into a national commercial centre, and a target for many international business investments (Ellis, 2009). Located southwest of Birmingham's city center, the Upper Rea catchment covers an area of about 1,800 ha and hosts a population of roughly 70,000 persons (DEFRA, 2008). The catchment is subject to intense rainfall events, much different than those observed in the rest of the Birmingham metropolitan area. Flood events have been registered since the beginning of the 20th century, with the latest episodes causing severe damage to infrastructures and deterioration in the quality of life of inhabitants.

Figure 40: Flood risk zones in the Upper Rea catchment

The flood system behavior of the region is complex, including peri-urban flooding, river flooding and sewer overflows. Historical records identify several sources that contribute to the occurrence of flood events in the region (DEFRA, 2008; Ellis et al., 2008). The main zones that have been identified as flood-prone are shown in Figure 40, whereas estimates of sewer flooding by DEFRA are presented in Figure 41.

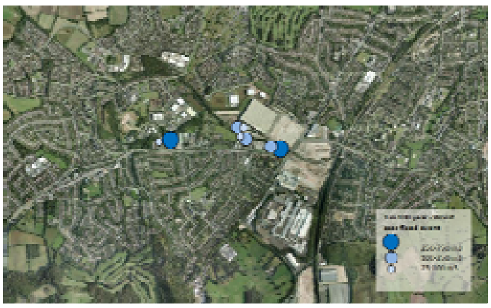

Figure 41: DEFRA estimates for sewer flooding for a 1 in 100 year event (DEFRA, 2008)

2.2 Strategies for sustainable stormwater management

The study concerned the formulation of alternative drainage strategies in the Upper Rea catchment, through the selection, simulation and analysis of different interventions for sustainable stormwater management, involving green roofs, porous pavements, swales, infiltration trenches and detention ponds. Interventions were selected taking into account different constraints relating to the specific surface, soil permeability, and land use function (Figure 42).

Figure 42: Site constraints for SUDS implementation

They were further ranked through Multi-Criteria Analysis, using an adapted matrix from the Daywater Decision Support tool (Shutes, 2006; Sieker et al., 2008), in order to factors relating to hydraulic control, water quality, response to climate change, social and economic issues, risk of failure and integration in urban planning (Table 7).

Overall, three strategies were formulated:

- **Strategy 1**, *No infiltration*, was developed considering the low infiltration potential of the area, and included interventions aimed at stormwater retention and conveyance (green roofs, pervious pavements and swales).
- **Strategy 2**, *Infiltration*, concerned the introduction of relevant interventions in the vicinity of unconstructed open spaces and natural areas, so that overflows would not result in property damage. Treatment chains were also introduced to ensure that pollutants conveyed from asphalted areas do not compromise water quality.
- **Strategy 3**, *Wetland Pond*, in addition to the measures included in Strategy 1, also involved the introduction of a retention pond north of the Longbridge industrial site, receiving all corresponding run-off flows. Consequently, the strategy included conveyance through swales, sedimentation, filtration, and biodegradation in the reservoir pond.

The three Strategies were simulated using STORM, a drainage model which enables the prediction of stormwater runoff and calculates the corresponding flow rates. Within STORM, the distribution of flows is spatially calculated using a one-dimensional approach and is analysed for each hydraulic element that can be implemented in the model. Flood predictions have been investigated over the total period of precipitation events (38 years of hourly rainfall records).

Table 7: SUDS Decision Matrix

Criteria	Indicators	Green Roof	Porous Pavement	Swale	Trench	Detention ponds	Weighting indicators (%)	Weighting criteria (%)
Hydraulic control	Runoff volume reduction	3	3	2	3	1	5	30
	Runoff flow rate control 1/2 year event	3	3	3	3	3	5	
	Runoff flow rate control 1/30 year event	3	3	3	3	3	5	
	Runoff flow rate control 1/100 year event	1	1	3	1	3	15	
Water quality	Total suspended solids	1	3	3	3	2	10	20
	Heavy metals' removal	1	3	2	3	3	5	
	Nutrients' removal	1	3	2	3	1	1	
	Bacteria removal	1	3	2	2	1	2	
	Capacity to treat fine suspended solids and dissolved pollutants	3	3	3	3	1	2	
Response of system to climate change	System reliability and durability	2	3	3	2	3	20	20
Social and economic factors	Maintenance	1	2	3	3	3	5	20
	Costs	1	2	3	3	3	10	
	Community acceptability	3	2	2	2	3	3	
	Habitat creation potential	3	1	2	1	2	2	
Risk of failure and Urban planning	Adoption Status	2	2	3	2	1	5	10
	Building development issues and stormwater regulations	2	1	2	2	1	5	
Total scores		369	428	402	426	303	100	100

Results concerning the Upper Rea Flood Zones 6 and 7 (see Figure 40) are presented in Table 8.

Table 8: Flood predictions for Zones 6 and 7 under the 3 drainage strategies

	Flood zone 6	Flood zone 7
Average flood volume (m^3)		
Strategy 1	88	335
Strategy 2	108	285
Strategy 3	88	0
Maximum flood volume (m^3)		
Strategy 1	474	335
Strategy 2	323	285
Strategy 3	474	0

Overall, Strategy 1 results in a reduction in flood events for the entire sewer system. Sewer flood risks for maximum floods are somewhat further mitigated through Strategy 2, which however increases risks for natural areas, which could also affect the neighbouring commercial zones. In this regard, the average flood volume is slightly increased in comparison to Strategy 1, as impermeable soil characteristics limit the infiltration potential. Strategy 3 shows that no flood event is induced from the Longbridge site stormwater run-off. There are no overflows from the pond itself, and all water collected either infiltrates the soil or evaporates.

2.3 Economic assessment of drainage strategies

The economic assessment of the drainage strategies for the Upper Rea catchment concerned (i) their cost-effectiveness analysis in terms of mitigating flood risks and (ii) the analysis of potential economic instruments (financial incentives and taxes) that could foster their uptake in the selected area. The assessment was performed using the SWITCH *City Water Economics (CWE)* model. Unit cost data for the specific interventions incorporated in each strategy were based on the SUDS Manual, which were further adjusted according to the outcomes of the design stage.

Figure 43 presents the costs of the three strategies over the examined 30-year period. Their corresponding effect (*% maximum flood decrease*) vs. cost is further illustrated in Figure 44.

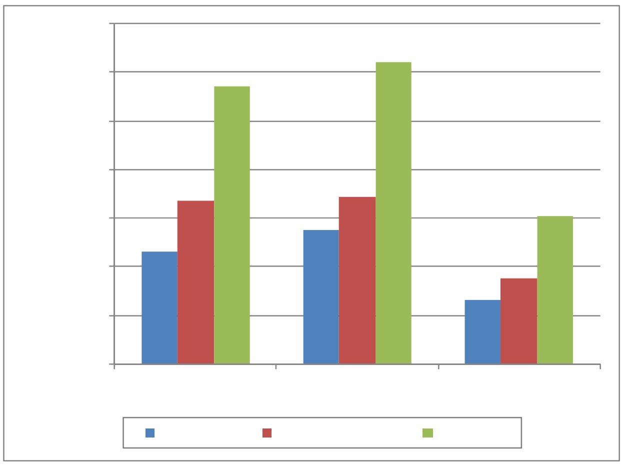

Figure 43: Costs for the drainage strategies costs over the 30-year study period

The analysis of results indicates that Strategy 1 has the smallest effect while entailing significant costs, whereas the higher effectiveness of Strategy 3 corresponds to significantly higher implementation costs, in comparison to Strategy 2. The high costs entailed imply that the choice is to be determined by the corresponding objectives for flood risk mitigation.

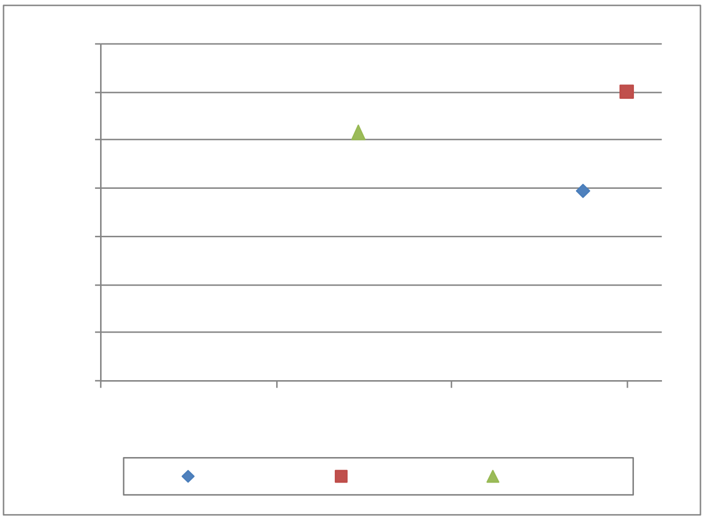

Figure 44: Cost-effectiveness analysis for the 3 drainage strategies

2.4 Financial planning and economic incentives for strategy uptake

Despite the integration of SUDS in the national Directives of the UK, their implementation remains rather sporadic, as these require large investments, which are to be covered through local municipal funding. In this regard, further assessments are required in order to: (i) elaborate a financial plan to raise the resources required for strategy implementation and (ii) analyse incentives to foster the implementation of different stormwater reduction measures by the users.

The financial plan concerned the introduction of a stormwater tax dependent on household impermeable surface, a practice widely applied in Europe to improve cost recovery in stormwater management and provide incentives (Choui et al., 2007). The tax was calculated equal to 1 pound per m^2 of household impermeable surface, in order to integrate the additional drainage infrastructure expenses for the entire catchment. The resulting expenses are represented in Table 9 for each residential unit block type.

Table 9: Stormwater tax per type of residential unit block

No	Unit Block Type	Stormwater tax (£)
1	Residential – Terraced Small Garden	236
2	Residential – Terraced Large Garden	215
3	Residential – Semi-detached small garden	181
4	Residential – Semi-detached large garden	156
5	Residential – Detached small garden	243
6	Residential – Detached large garden	212
7	Residential – Flats	237
8	Residential – Home	210

As the amount of tax can increase rapidly for larger properties, adjustments are required for commercial and industrial zones. Accordingly, the increase of tax for impermeable surfaces can be adjusted to assume lower unit increases, at two thresholds: 100 m^2 and 1000 m^2 (Figure 45). The adopted scheme provides financial motivation for the adoption of SUDS, since establishments that implement SUDS reduce the corresponding impermeable areas. An estimate for a detached home with a small garden (Type 5 in Table 9) is provided in Figure 45.

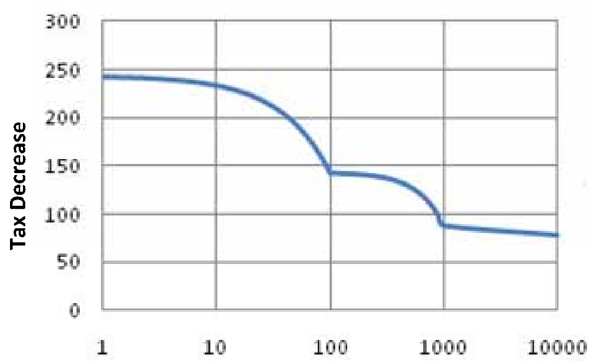

Figure 45: Example of a tax decrease scheme

Nevertheless, the reduction in attributed stormwater taxes does not cover the costs borne by consumers. To that end, additional financial motivation can be offered through subsidies, which can lower the total cost incurred to users. Figure 46 presents the user's tax end cost, with and without the implementation of SUDS, and the amount of subsidies necessary to cover costs borne for the implementation of a green roof or a porous pavement. As depicted in Figure 46, subsidies can adapted for surfaces smaller than 100 m^2, depending on planning objectives.

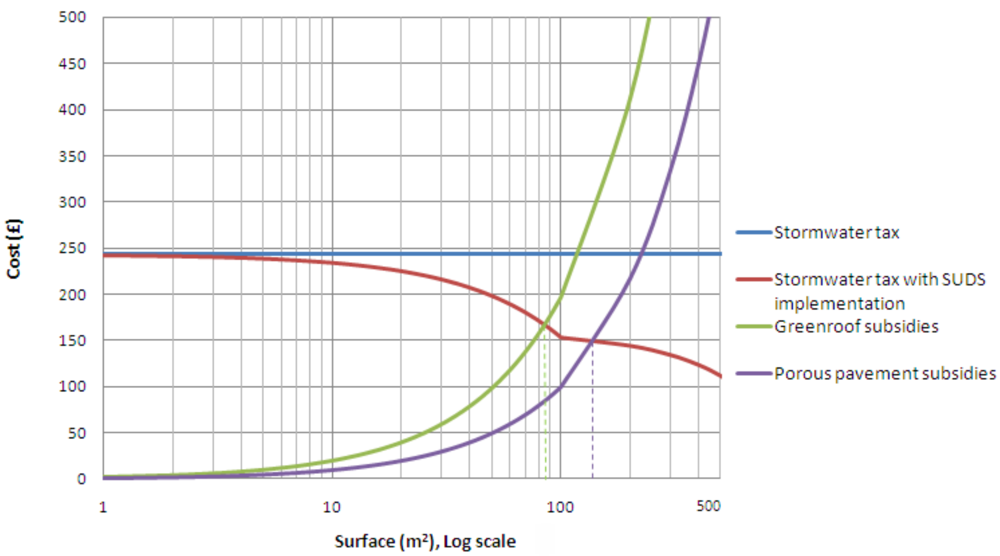

Figure 46: Stormwater costs and SUDS subsidies

As evident, required subsidies also depend on the implemented drainage strategy. Subsidies for green roofs are more important than those for porous pavements. To that end, Figure 46 also reveals the point

when subsidies start to become higher than the actual stormwater tax. Users that implement green roofs become costly for authorities when the implemented surface exceeds 85 m^2. The corresponding threshold for porous pavements is 140 m^2.

In summary, and given the high costs entailed, it can be argued that the choice of a suitable strategy would depend on policy objectives, transfers and financial incentives. An optimal solution would lie between a combination of the (existing) centralized schemes and decentralized management interventions, also considering views and constraints set by local stakeholders and authorities. To that end, the integration of hydraulic, financial, economic and communication tools appears crucial in terms of decision-support and alternatives analysis.

3 Development of tariff schemes for potable water provision in Alexandria, Egypt

As mentioned in the Introductory Section, the application of CWE in the case of Alexandria, Egypt, was focused on developing and evaluating pricing schemes for potable water supply provided by AWCO. Relevant assessments and demonstrations formed part of the training on the City Water suite of tools, and were presented to the local Learning Alliance in September 2010.

The CWE application was based on data from two studies developed by SWITCH to support the Alexandria Strategic Planning process, the Water Demand Management Study (El Din et al., 2010), and the Study on "Whole of System Modelling and Decision Support" (Donia et al., 2010).

3.1 Background and motivation

Urban water management in Alexandria has so far followed a centralized approach focused on supply enhancement and network expansion to provide adequate water supply to the city's inhabitants (current coverage ~ 95%). Potable water supply in the wider metropolitan area is managed by the Alexandria Water Company (AWCO), which also supplies water to the Governorates of Behira and Marsha-Matrouh (Figure 47). The total daily production from the 8 water treatment plants operated by AWCO is about 2.5-3 hm^3/d; of this amount, about 36% corresponds to leakage and unaccounted for water (El Din et al., 2010).

Figure 47: Base map of the areas serviced by the AWCO

The high rate of losses, the high per capita consumption (higher than 200 l/cap/d), and the dependence from Nile waters, which are also used for crop irrigation, underline the need for orienting policies towards water demand management. To that end, examined options within the framework of SWITCH have involved the cost-benefit assessment of leakage reduction programmes, the introduction of incentives for

the installation of water saving appliances, and tariff reforms. The latter, according to the company's objectives, should ensure affordability of water-related charges, while at the same time improving cost recovery and providing incentives towards efficient use. In the above context, the application of City Water Economics focused on two aspects: the preliminary assessment of alternative tariff schemes for improving cost recovery in potable water supply provision and (b) the evaluation of incentives offered by current and potential pricing policies for the installation of water saving appliances in households.

3.2 Data and assumptions

3.2.1 Population and demand projections

CWE was applied for a timeframe of 10 years, using 2007 as the base year, the year for which AWCO has provided relevant information. Developed scenarios for Alexandria within the framework of SWITCH assume for this period significant population growth and expansion of the metropolitan area serviced by AWCO. For the purposes of the CWE application, a simplification was made of the catchment representation undertaken for the application of the Aquacycle and the City Water Balance Models. In more detail, the metropolitan area in CWE was divided in three main sub-areas, namely:

- The "Densely Populated area" of Alexandria;
- The "Suburban area"
- The "Summer Houses" cluster.

Cluster areas corresponding to informal settlements were not considered, as these are in their largest part, not connected to the water distribution system. Information relevant to the above areas was derived from the Aquacycle application study (Donia et al., 2010), and is summarized in Table 10.

Table 10: Base year (2007) data on households and population

Cluster	Densely populated area	Suburban Houses	Summer Houses
Number of Unit Blocks	24,360	17,370	13,206
Number of Households	584,640	138,960	174,648
Permanent Population	2,923,200	694,800	873,240

The development of projections for the period 2008-2017 was based on relevant information provided by the Alexandria Water Company (AWCO). Projections were based on the assumption of a yearly population growth rate of 1.55%, which corresponds to the assumptions of the AWCO 2037 Master Plan and the Business-As-Usual scenario developed within SWITCH. Further to this, and as noted by El Din et al. (2010) it is expected that urban expansion will concern the western and southern outskirts of the current metropolitan area, where population density is currently low. To that end, population for the first two clusters was considered constant for the examined time horizon, under the assumption that further increase of population density and/or expansion in these areas is not possible. It has further been considered that population growth and city expansion will concentrate on the "Summer Houses" cluster, which corresponds to geographical areas towards the outskirts of the metropolitan area. The above are illustrated in Figure 48, which presents the assumed expansion and population growth for each cluster. All new households are assumed connected to the water distribution system.

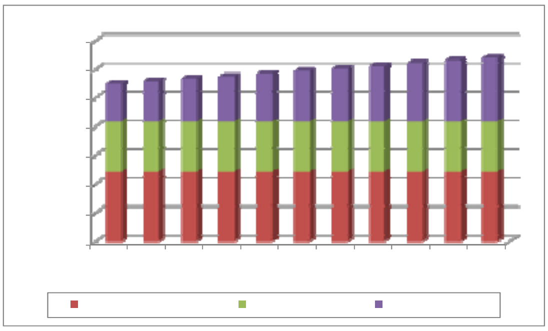 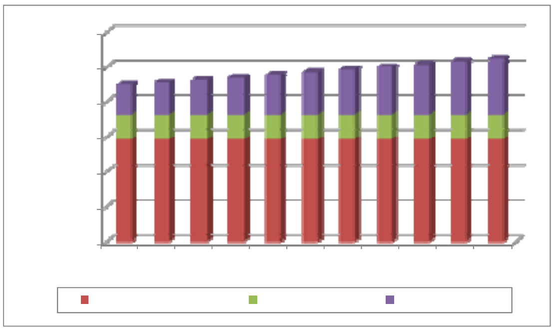

Figure 48: Unit Block (left) and population (right) projections for the cluster areas

Considering that demand projections of the 2037 Master Plan take also into account non-residential demands and are thus based on significantly high consumption rates (300 l/cap/day for permanent population and 500 l/cap/day for seasonal-summer population), relevant demand estimates for City Water Economics have been developed considering a consumption rate of 230 l/cap/day, according to the results of a detailed survey undertaken by AWCO in the Toson Area (Donia et al., 2010). In combination with population estimates, this yields a yearly residential consumption of about 377 million m^3, which reasonably approximates the relevant data of AWCO on water consumption per sector (372.2 million m^3 in 2005/2006, 370.8 million m^3 in 2007/2008 for residential use).

As seasonal population figures for the metropolitan area are not available, monthly projections were developed considering the monthly pattern of the AWCO water production. Corresponding factors, which were subsequently used to derive the monthly consumption profile, are provided in Table 11.

Table 11: Monthly pattern for the estimation of residential water consumption

Month	Water production by AWCO (million m^3)	Monthly share
January	66.42	7.7%
February	59.83	7.0%
March	66.68	7.8%
April	67.38	7.9%
May	72.02	8.4%
June	74.87	8.7%
July	80.17	9.3%
August	83.09	9.7%
September	77.09	9.0%
October	74.89	8.7%
November	68.32	8.0%
December	67.09	7.8%
Total	857.85	100%

Figure 49 presents monthly residential consumption estimates for 2017.

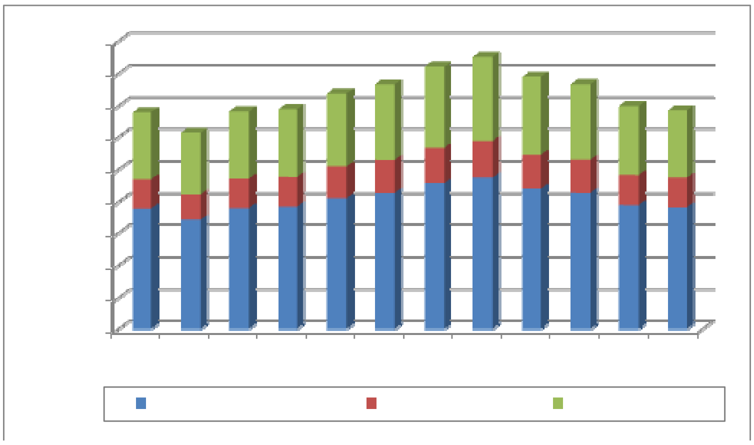

Figure 49: Monthly residential consumption estimates for 2017

3.2.2 Losses and unaccounted-for water

Subsequently, an estimate was made for the total water production required to meet the estimated water requirements. This was based on the current estimate of physical losses, which according to AWCO reaches 36%.

3.2.3 Current costs and future investments

Currently, and according to the Alexandria Water Company the total water production and supply cost is equal to 0.61 EGP/m³. This corresponds to operation and maintenance as well as other variable costs for the water supply system. The amount of future investments is specified in the 2037 Master plan, and concerns interventions and infrastructure development for continuing to provide services at full coverage and high quality. For the concerned time span, the total amount of required investment is (El Din et al., 2010):

- For the period 2007-2012, 875 million EGP.
- For the period 2012-2017, 1020 million EGP.

A share of the above investments is usually funded by the State; the corresponding subsidy is equal to 30-35% of funding requested. Furthermore, not all investment can be attributed to the residential sector of the Metropolitan area, as the Alexandria Water Company also provides water to Governorates in the vicinity, as well as other, non-residential uses (commercial, industrial users, governmental buildings and water exports account for about 40% of water consumption). To that end, and as the scope for the application of CWE was focused on the residential sector, investment costs attributed to residential water use were adjusted to account for: (a) State Subsidies, (b) demands from other water use sectors, which will also bear a part of the corresponding investment costs. CWE outputs with regard to cost estimates for residential water supply by AWCO are presented in Figure 50. Capital costs for each investment plan period have been estimated assuming a 10-year amortization period and an amortization rate of 5%.

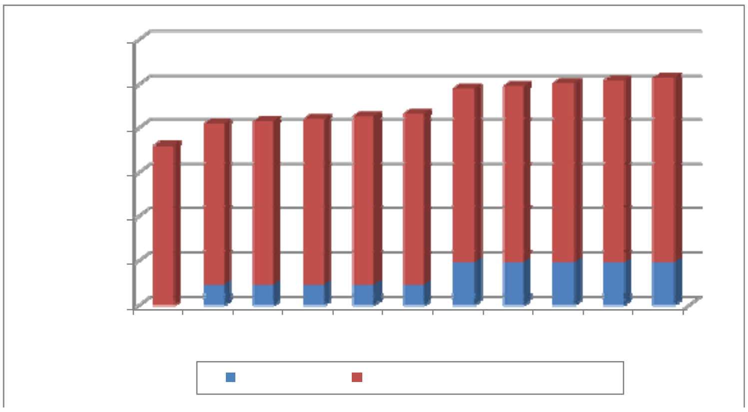

Figure 50: Costs allocated to residential water use

3.2.4 Current tariff structure

The current tariff structure for residential water supply follows an Increasing Block Rate structure, and is presented in Table 12. As discussed below, current rates are perceived as low by the AWCO, which considers that future policies should entail a gradual tariff increase, to discourage wasteful water use and ameliorate cost recovery.

Table 12: Current AWCO tariff for residential water supply

Block (m³/household/month)	Current rate (EGP/m³)
0-20	0.23
21-30	0.25
>30	0.35

3.2.5 Income and demand distribution

One of the objectives of the application of City Water Economics was the assessment of the affordability implications of potential tariff reforms. To that end, one of the main data requirements concerned the distribution of income and consumption among the different population segments. In the absence of information for Alexandria, data were obtained from Egypt-wide statistical information, collected by CEDARE. The corresponding data are presented in Table 13.

Table 13: Annual disposable income and consumption distribution data for Egypt (Source: CAPMAS)

Income Stratum	Annual Disposable Income per HH (EGP/yr)	Households as % of Total Sample	Annual water consumption (m³/HH/yr)
Lower Income Stratum - 1	2,964	0.30%	122
Lower Income Stratum - 2	4,260	0.94%	196
Lower Income Stratum - 3	5,441	2.10%	245
Lower Income Stratum - 4	6,595	3.26%	282
Lower Income Stratum - 5	7,791	5.25%	346
Lower Income Stratum - 6	9,056	6.74%	359
Lower Income Stratum - 7	10,545	7.71%	391
Lower Income Stratum - 8	11,941	8.67%	407

Income Stratum	Annual Disposable Income per HH (EGP/yr)	Households as % of Total Sample	Annual water consumption (m^3/HH/yr)
Avg. Middle Income	19,461	56.20%	517
Avg. High Income	52,290	8.71%	1088

3.3 Analysed Cases

The application of City Water Economics was primarily aimed at:

- Assessing the current tariff scheme, to provide a baseline for comparison purposes;
- Developing and evaluating alternative tariff schemes for potable water supply in the residential sector, in order to ameliorate cost recovery taking into account future investments.

Furthermore, an additional application was developed concerning the analysis of incentives offered by current and alternative schemes towards the installation of water saving appliances in homes.

3.3.1 Assessment of the current tariff scheme

A comparison of revenues vs. costs allocated to the residential sector shows that current tariffs recover only 36.5% of the corresponding costs. Furthermore, and according to the statistical distribution of consumption, the vast majority (~87%) of consumers in Alexandria pertains to the final consumption block. In this regard, most residential consumers face the same rate. This signals a non-equitable distribution of costs among households, as high water consuming households face the same volumetric rate as lower consuming ones. It can further be argued that the incentive function of IBTs is not fully exploited, as the current tariff structure acts similarly to a uniform volumetric rate scheme.

Figure 51 presents the share of household income spent for water supply for each income group.

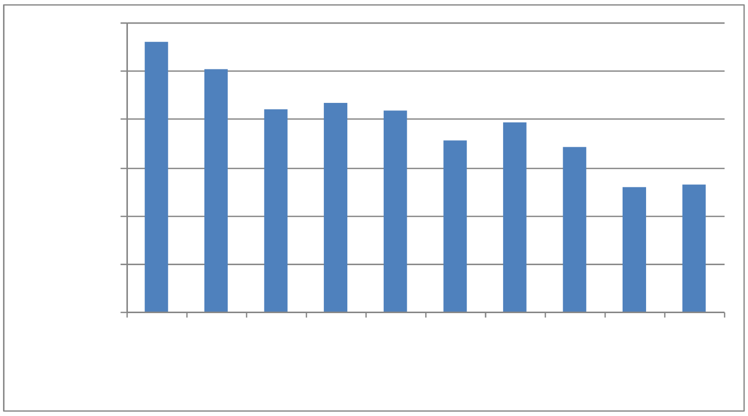

Figure 51: Share of income spent for water services for the current tariff scheme

3.3.2 Design and evaluation of alternative tariff schemes

In order to assess the potential impact of strategies for improved cost recovery, three tariff schemes were evaluated through CWE. All tariff schemes were designed according to the same cost recovery objectives. Targets included 100% recovery of costs for operation and maintenance and 65% for investment costs (the remaining 35% is funded by the State). Furthermore, all schemes included a re-adjustment period of 2 years was introduced to account for changes in costs, population growth and consumption patterns.

In more detail:

- **Scheme #1**, “Adjustment of volumetric rates for improved cost recovery”, concerned the increase of volumetric rates preserving the current consumption blocks, in order to achieve the set cost recovery targets.
- **Scheme #2**, “Change in block tariff structure” included the introduction of two additional consumption blocks and higher variation of the volumetric rates, to achieve a more equitable distribution of costs and preserve affordability of charges faced by low income groups. It further included a fixed charge, to recover 50% of capital costs. To further simplify billing processes, the invoicing period was set at 4 months (instead of monthly) to potentially decrease administrative costs.
- **Scheme #3**, “Seasonal rates” included the additional introduction of seasonal rates for each 4-month period, to account for the large variation between summer and winter water consumption, which requires the development of additional infrastructure (and thus potentially entails higher costs) to cope with peak demands.

The specific objectives of the formulated tariff schemes are summarized in Table 14.

Table 14: Objectives of tariff schemes modeled in CWE

Tariff objective	Implementation in CWE
Improved cost recovery	• Targeted cost recovery rate of 100% for O&M and 65% for investment costs (the remaining 35% is funded by the State) • Readjustment periods to account for changes in costs, population growth and consumption patterns
Enhancement of incentives	• Introduction of additional consumption blocks and higher variation of rates with regard to the first block • Seasonal rates
Affordability	• Higher variation of rates with regard to the first block, so that the largest share of costs is borne by higher income households, also consuming the largest share of the resource
Ease of implementation	• Longer billing periods
Enhancement of revenue stability	• Introduction of fixed charges to recover part of capital costs

The following paragraphs present the individual parameters calculated for each scheme, as well as the annual household expenditure for mains water supply. Section 3.3.2.4 performs a cross-comparison and discusses the affordability implications of the three tariff schemes.

3.3.2.1 Tariff Scheme #1: Adjustment of volumetric rates for improved cost recovery

Figure 52 presents the estimated block rates for achieving the set cost recovery objective. As expected, these are considerably higher than those of the current tariff, reaching 1.2 EGP/m³ for a consumption exceeding 30 m³/month in 2017.

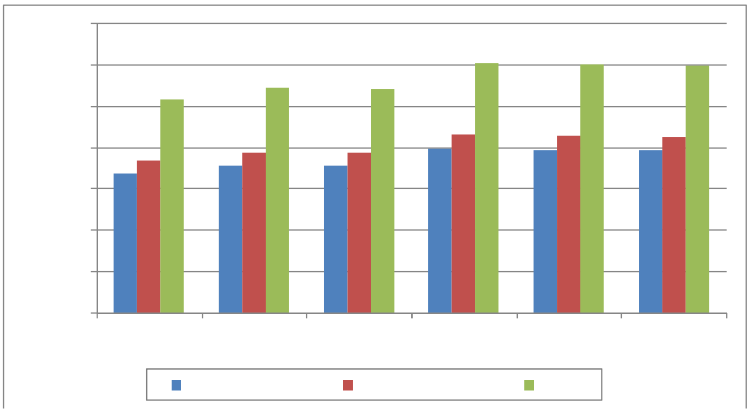

Figure 52: Estimated block rates for Scheme #1 - Adjustment of volumetric rates for improved cost recovery

Figure 53 presents the calculated annual expenditure for water supply services for each income group. For 2007, this amounts to 234 EGP for “Low income group – 8”, 293 EGP for an average income household and to 808 EGP for those of high income. A comparison of the share of income spent on water services reveals that this would rise 1.6% on average for households pertaining to the low income groups, exceeding 2% for the lowest income class. The increase is about 1% for the high income group.

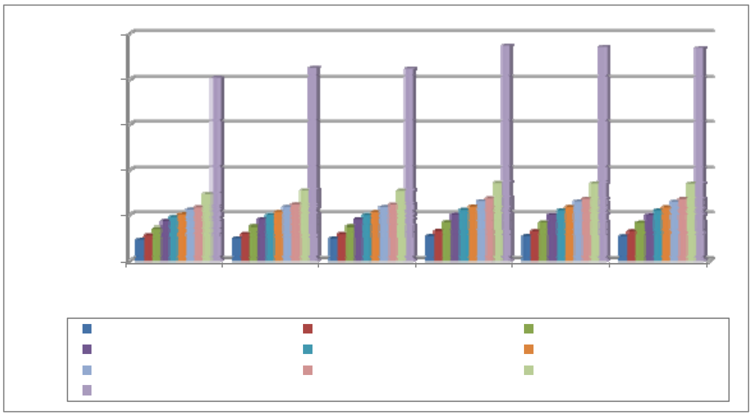

Figure 53: Annual expenditure for water supply services in Scheme #1 - Adjustment of volumetric rates for improved cost recovery

3.3.2.2 Tariff Scheme #2: Change in block tariff structure

The second scheme that was formulated concerned a change in the current tariff structure. In more detail:

- A fixed charge was introduced, to recover 50% of capital costs associated with new investments;
- The overall structure of volumetric charges was reformulated, to include additional blocks and higher rate variations to allow a more socially equitable allocation of costs;
- The invoicing (tariff application) period was changed from monthly to 4-month periods, to achieve a more simplified and easy-to-implement system.

The design of the volumetric tariff elements was performed considering that the first block should correspond to a “lifeline” consumption, which, according to CAPMAS, corresponds to 15 m^3/HH/month (60 m^3/HH/4-month period). The second block was defined considering an average “normal” consumption for a 5-member household of 30 m^3/month (120 m^3/4-month period). The next blocks were defined considering consumption patterns and connections pertaining to each. Details are presented in Table 15.

Table 15: Block Rate design for Tariff Scheme #2 - Change in block tariff structure

Block (m³/4-month period)	Rate variation (% with regard to 1st Block)	Share of Connections (%)	Share of Consumption (%)
0-60	-	0.71	0.20
60-120	120	12.85	7.52
120-190	150	52.49	48.89
190-240	200	28.93	35.85
>240	350	5.02	7.54

Figure 54 and Figure 55 present respectively the estimated fixed charge and volumetric rates. Fixed charges increase after 2007-2008, as the repayment of the first phase of the investment plan is introduced as additional cost to be recovered and escalate to 16.1 EGP/connection after the repayment of the 2nd Master Plan phase is initiated. Their minor decrease in 2011-2012 and after 2014 is due to the increase in the number of connections. Volumetric rates approximate those currently applied for the 1st, lifeline block, being equal to 0.54 EGP/m³ in 2007-2008. Furthermore, volumetric rates for the last block (>180 m m³/4-month period) are estimated at 1.9 EGP/m³, being approximately 80% lower than those of Scheme #1, as a result of the introduction of fixed charges.

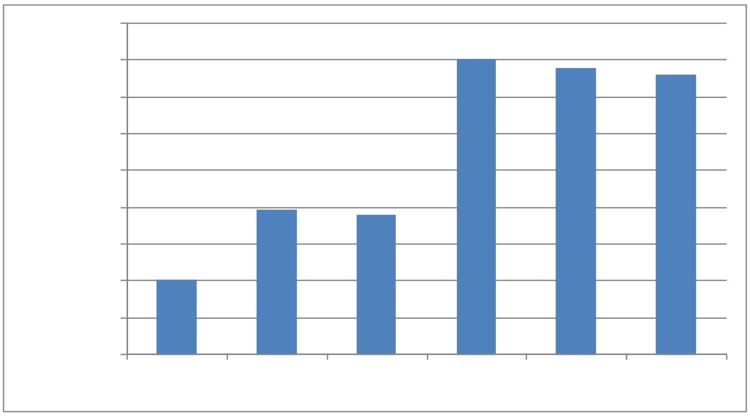

Figure 54: Fixed charges estimated for Tariff Scheme #2 - Change in block tariff structure

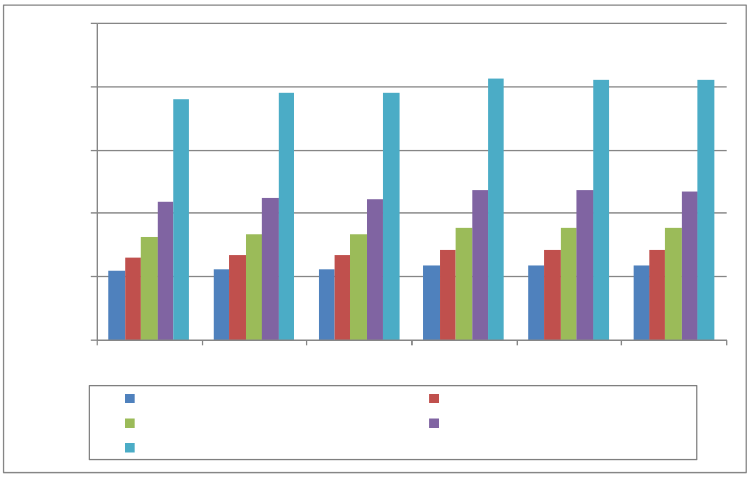

Figure 55: Block rates estimated for Tariff Scheme #2 – Change in block tariff structure

Figure 53 presents the calculated annual expenditure for water supply services for each income group. For 2007, this amounts to 211 EGP for "Low income group – 8", 259 EGP for an income average household and almost 900 EGP for a high income household.

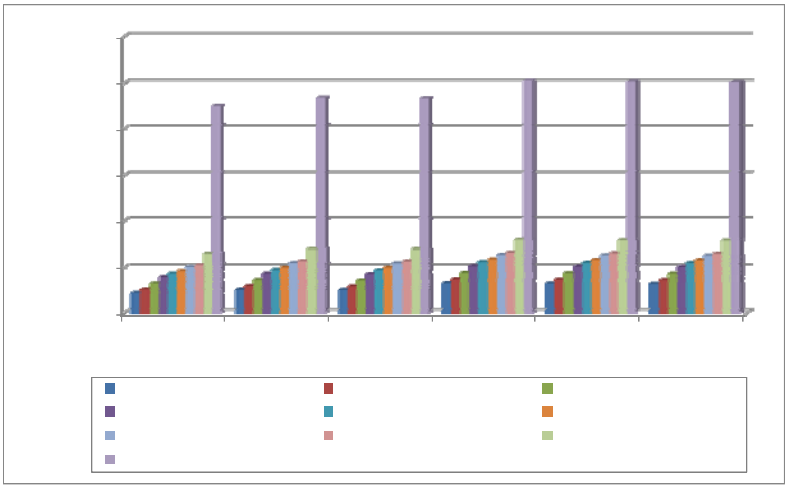

Figure 56: Annual expenditure for water supply services in Scheme #2 – Change in block tariff structure

3.3.2.3 Tariff Scheme #3: Seasonal rates

The third scheme was based on the overall design of Scheme #2, but further included the introduction of seasonal rates, according to the corresponding water consumption pattern. Similarly to Scheme #2, this Scheme also included fixed charges to recover 50% of capital costs. Indicative results on volumetric rates for 2007-08 and 2017 are presented in Figure 57.

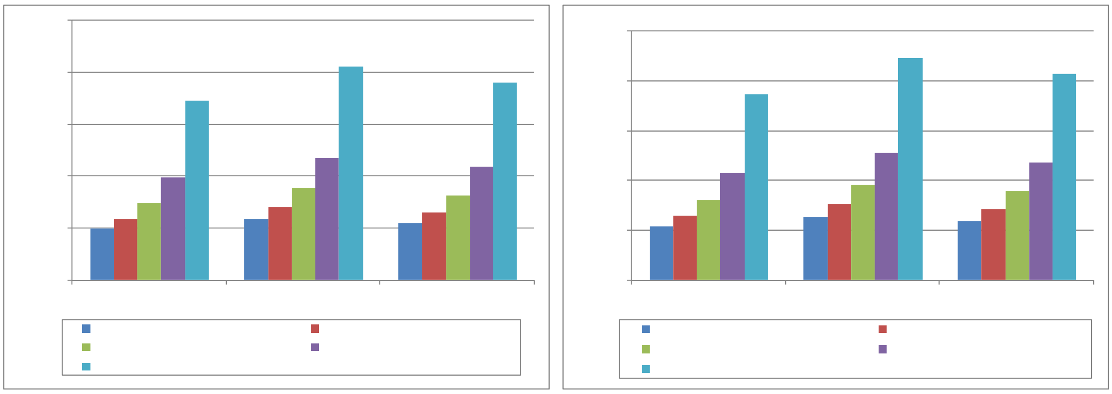

Figure 57: Seasonal volumetric rates for (a) 2007-08 (left) and (b) 2017 (right)

Overall, rates for the 2nd period (May to August) are 20% higher than those estimated for the other periods, in line with the overall variation of consumption. Figure 58 presents the calculated annual expenditure for water supply services for each income group. Overall, expenditure does not vary significantly between Schemes #2 and #3, and estimated figures are only an approximation, as the corresponding estimates are based on the average annual consumption of households pertaining to each income group, and detailed data on the corresponding monthly patterns are not available.

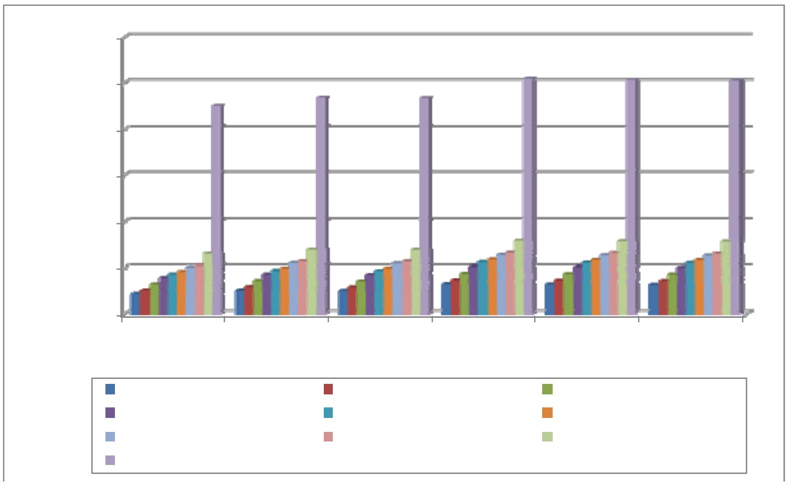

Figure 58: Annual expenditure for water supply services in Scheme #3 – Seasonal rates

3.3.2.4 Cross-comparison and discussion

Figure 59 presents a comparison of the share of income spent on water services for the current and the three analysed schemes for 2007.

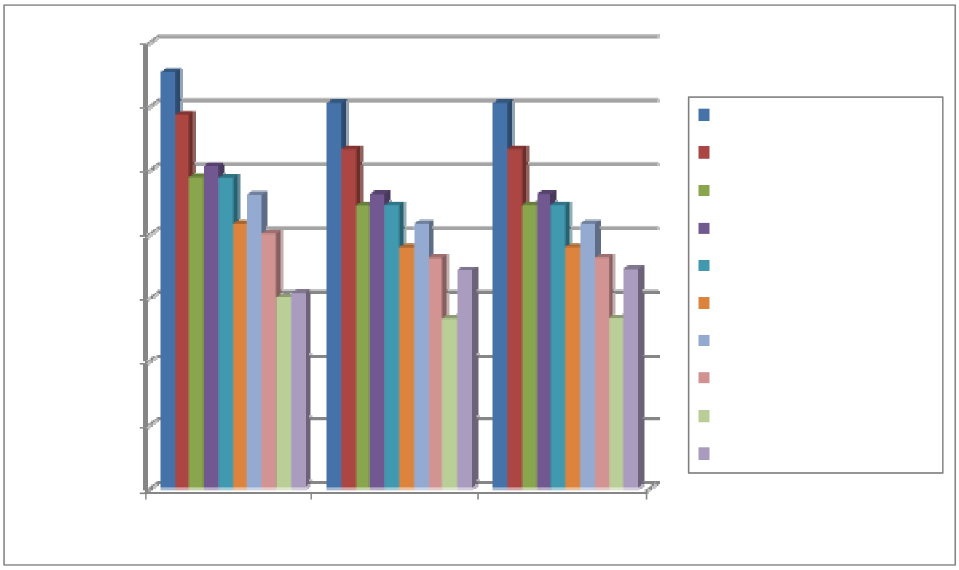

Figure 59: Share of income spent on water services for the three tariff schemes

The following can be noted:

- In all cases, the share of disposable income spent on water supply services is well below the affordability threshold of 5%, and is less than 3% in the majority of cases; it can thus be argued that all schemes produce affordable rates, even if the currently applied 30% wastewater surcharge is included;
- Particularly for the lower income strata, a reform of the current tariff structure, including additional blocks and higher rate variations (allocation of the largest part of the cost to the higher consumption blocks, which correspond to higher income households) could significantly improve affordability of water charges.

Overall, and despite current concerns, it can be supported that improved cost recovery is not an unattainable objective; through an appropriate tariff design, based on more detailed survey data and information, social acceptability and more equitable distribution of costs could be achieved, alleviating the burden from the lower income strata.

3.3.3 Assessment of incentives

A second application of CWE in Alexandria concerned the evaluation of incentives offered by the current and the examined tariff schemes for the installation of water service devices in homes.

This alternative forms part of the SWITCH Water Demand Management Study, by El Din et al. (2010). The study focuses on analyzing alternatives to support water saving. According to the study, the average cost per household would amount to 72 EGP, considering that a device cost of 18 EGP and that 4 devices are required by each. The proposed strategy involves the initial purchase of the equipment by AWCO, and their installation by AWCO personnel. The corresponding costs could be recovered through an additional charge/instalment on the water bill for the concerned households.

In the above frame, the application of CWE was aimed at evaluating whether current and formulated tariff schemes could by themselves offer the required incentive, or whether additional funding and economic support would be required. The assessment is made by calculating the annual savings for a 5-year period for an average household, as a result of the reduction of water consumption and thus of expenditure for mains water supply. Results are presented in Table 16.

Table 16: Incentives of analysed schemes for the installation of water saving devices

Scheme	Household Savings from expenditure for mains water supply (Average household, 2011 values)	Payback period
Current tariff	663 EGP	<1
Tariff Scheme #1	1817 EGP	<1
Tariff Scheme #2	1588 EGP	<1
Tariff Scheme #3	1522 EGP	<1

In all analysed cases, the payback period is less than 1 year, implying that (a) even without tariff reforms, subsidies are not required, (b) a scheme where AWCO subsidizes a smaller share of purchase costs is equally variable, and (c) a tariff reform, combined with information and awareness campaigns could yield results similar to the strategy proposed by AWCO.

4 Cost recovery of strategic plans in the city of Accra

4.1 Introduction

4.1.1 Overview of water supply services in the Greater Accra Metropolitan Area

The city of Accra is located in the Greater Accra Region, which constitutes the smallest region in Ghana. The Greater Accra Metropolitan Area (GAMA) concerns the Accra Metropolitan Area (AMA), the Tema Municipal Area (TMA), and the urban areas in Ga East and Ga West Districts. In 2000, the overall population of the GAMA was somewhat lower than 2.7 million inhabitants.

The Accra-Tema Metropolitan Area is supplied by 2 main systems, the Kpong system on the Volta river and the Weija system on the Densu river, which both produce about 137 million m³/yr. The corresponding water infrastructure is managed by the Ghana Water Company Lmt (GWCL) and its operator, Aqua Vitens Rand Lmt (AVRL).

The GWCL estimated that in 2003 about 60% of the population was not served by direct pipe connections. Most of these people depend on private service providers, who take water either from GWCL-AVRL or from other sources. As a result, within the area there are several water service delivery models, which are differentiated according to the water source and the provided level of service (Figure 60). Households can rely on different service delivery models, which complement each other.

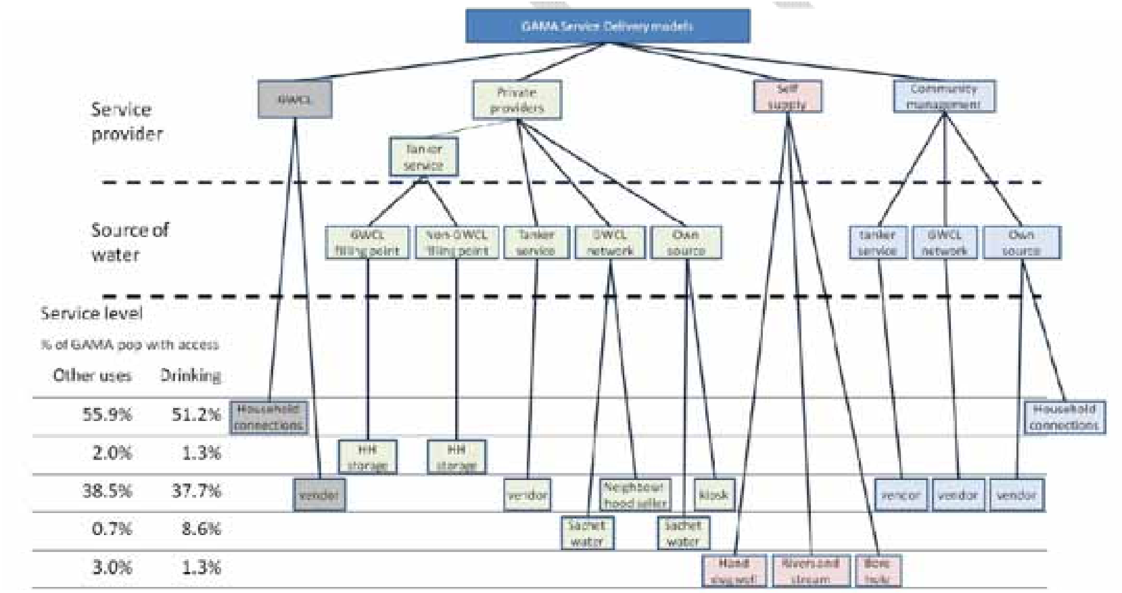

Figure 60: Urban water supply services in the GAMA (Adank et al., 2009)

As summarized by Adank et al. (2009), access to pipe-borne water in Accra is closely related to the degree of urban planning and to the degree of household wealth. Only 28.8% of poor households have indoor pipe connections, compared to 71.1% of medium wealth and 94.8% of high wealth households. However, interviews indicated that regardless of their income, consumers commonly suffer from dry taps and depend on water tanker service and sachet water supply.

4.1.2 A vision and scenarios for the future

The Integrated Urban Water Management Vision for Accra, as described by stakeholders involved in water management in the Greater Accra Metropolitan Area makes explicit reference to the need to ensure access to water supply at an affordable price (Box 5).

Box 5: The Integrated Urban Water Management Vision for Accra (Adank et al., 2010)

In 2030, everyone in the City of Accra (the Greater Accra Metropolitan Area), regardless of economic and social status, will have access to uninterrupted water supply, at an affordable price within a reasonable distance from the house. The water quality of the supplied water will meet Ghana Standard Board criteria. Non revenue water in the GWCL system, caused by physical and commercial losses, will have decreased to 25%.

In 2030, at least 80% of Accra's citizens have access to an acceptable level of sanitation facilities, including flush toilets, KVIPs or good public toilets. Pan and bucket latrines will be phased out. Good sanitation behaviours will be practiced by at least 80% of Accra's citizens. There will be no more open defecation and littering, and hand-washing after toilet use will be common practice. People will willingly pay for waste management. This will have led to a 70% reduction in water and sanitation diseases.

In 2030, Accra will be a cleaner city with a well-functioning drainage system. There will be integrated solid waste management (Collection, transport treatment and final disposal) of solid waste in a sustainable way. At least 90% of the solid waste will be collected. The improved collection of solid waste will have eradicated the dumping of solid waste into small and larger drains. The drains will be free from solid waste, and pollution of the surface waters and the risk of flooding will have reduced. There will be improved productive uses of water for livelihood (micro-enterprises and agriculture), especially through the reuse of stormwater and/or wastewater in urban agriculture.

To facilitate strategy development and denote potential deficiencies of current plans towards the achievement of this vision, the Accra Learning Alliance identified a series of external factors that could influence these, including city population development, economic growth, climate change, political commitment and interference, and public awareness. Narrative scenarios (storylines) focused primarily on population development and economic growth. These can be seen as complementary to existing assessments and projections of water demands, formulated according to different amounts of water requirements per person per day and different population sizes as a basis for the estimation.

4.1.3 The scope for the application of City Water Economics

Within the above context and given data constraints, the application of City Water Economics concerned the current framework of water supply provision in the city of Accra, and the analysis of potential tariff implications for future scenarios.

The application was constrained by limited data availability. While existing reports (Adank et al., 2009 and 2010) provide a comprehensive analysis of costs borne by consumers, little information is available on the actual costs of the system as well as capacity expansions. Relevant data on the GWCL system primarily concern billed water volumes and non-revenue water and no estimates or approximation of current cost recovery levels are provided. Considering the above constraint, the application rather concerns the demonstration of the usefulness and applicability of the model, than the provision of a detailed analysis of tariff schemes to improve cost recovery.

In this respect, the analysed cases presented in the following paragraphs provide an overview of results obtained by the model in relation to future scenarios and strategic directions (Adank et al., 2010), as developed by the SWITCH Accra team.

4.2 Modelled cases

4.2.1 The current situation

As presented in Figure 60, several different water service delivery models are currently operating in Accra. The modelling of the current framework for water service provision through City Water Economics was aimed at pointing out the versatility of the model with regard to its application to different institutional frameworks for water service provision. In the lack of detailed data for specific cost elements (e.g. water production costs for GWCL, transfer or sachet water costs), the assessment was based on reasonable approximations, using readily available information from the corresponding reports.

For the purposes of baseline modelling, the entire metropolitan area of Accra was defined as one cluster area, due to the lack of specific estimates on income distribution and water consumption for metropolitan area subsets (e.g. Tema, Accra West and Accra East) and the application of the same water tariffs/rates across the entire metropolitan area.

Water extraction from the three main water supply sources (the Kpong and Weija systems, and groundwater) was based on the 2007 data included in Adank et al., 2009. Furthermore, and as data on extraction, conveyance and treatment costs from these supply sources were not available, a uniform water production cost of 0.62 GHC/m³ was estimated based on the 2007 published data of the AVRL. In total, three models of water service delivery were assessed:

- Piped water supply from the GWCL distribution network;
- Water provision by tanker operators;
- Water provision by sachet producers.

Table 17 lists the main input data used in the model.

Table 17: Data used for representing the current situation regarding water supply provision in Accra

Type of Information	Data	
Water supply sources	**Water production**	
Kpong system	70,601,510 m^3/yr	
Weija system	61,996,016 m^3/yr	
Groundwater	558,815 m^3/yr	
Cluster area	**Number of Households**	**Number of Unit Blocks**
Accra Metropolitan area	1,156,034	381,678
Cost information	**Costs and rates**	
Water production cost (GWCL)	0.62 GHC/m³ produced	
Rate charged by GWCL to tanker operators and sachet/bottled water producers	1.10 GHC/m³	
Water sales	**Water volume**	
From the GWCL system to tanker operators	633,107 m^3/yr	
From the GWCL system to sachet/bottled water producers	277,927 m^3/yr	
From the GWCL system to households (metered use and standpipes)	28,411,868 m^3/yr	
From the GWCL system to other uses (industrial, commercial, governmental)	24,099,158 m^3/yr	

Figure 61 presents the parameters entered for simulating the current conditions for water provision, where the corresponding cost recovery objective was defined so as to calculate the rates currently paid by consumers to the GWCL and tanker operators.

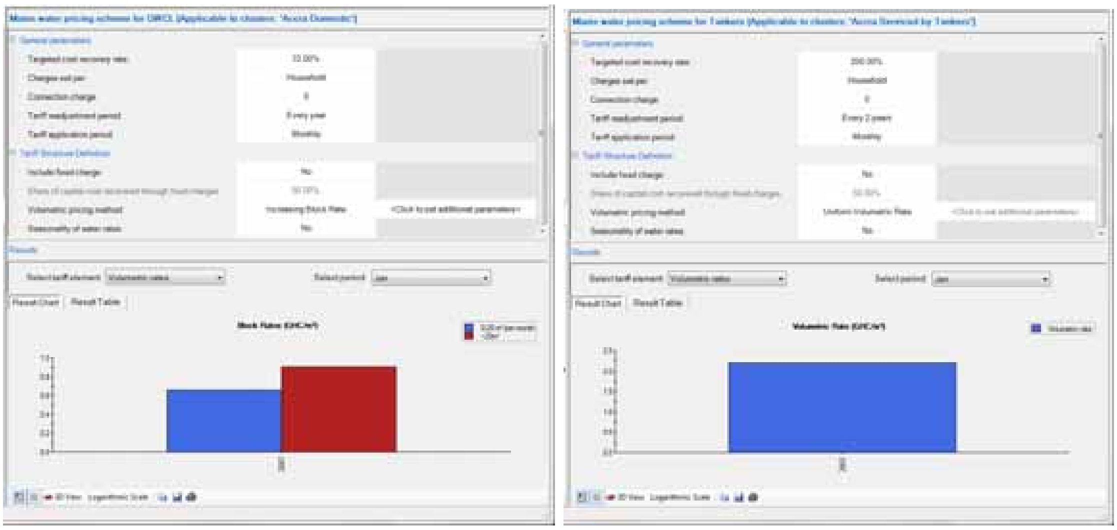

Figure 61: Parameters for simulating the current situation regarding water supply provision in Accra

Figure 62 presents the annual expenditure for a household and the income share spent on water supply services, assuming that the corresponding water supply is provided only from one water supply source. As expected, the income spent when water is provided by other operators is considerably higher than the affordability thresholds. To that end, and as presented in Adank et al. (2010), the "recognition, regularization and regulation of alternative water providers" is a measure required to improve access to water services and affordability, particularly for low income groups.

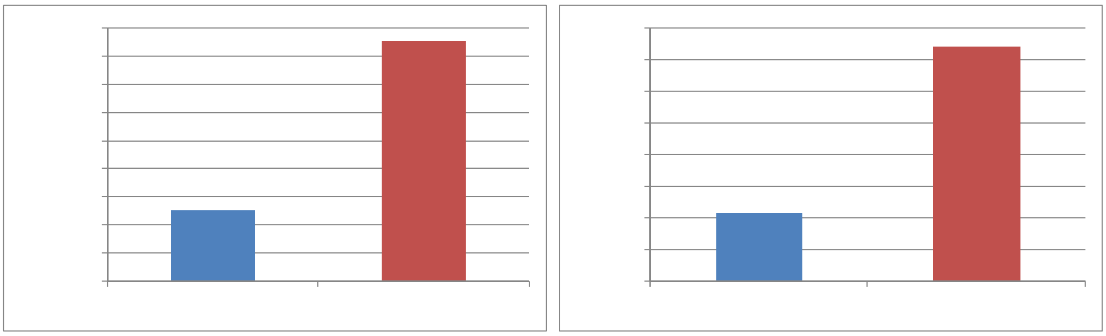

Figure 62: Estimates of annual expenditure on water supply and income share spent on water services for the current framework for water supply provision in Accra

As stated in the introductory section, and due to the limited available information on costs and distribution of water use, the above estimates are only provisional; they are aimed at demonstrating the applicability of the model to different contexts, rather than providing accurate assessments. Further analysis, including data completion and cross-checking of assumptions (in collaboration with local stakeholders and research groups) are required to arrive to more concrete and useful results.

4.2.2 Scenario analysis

As mentioned above, scenarios within the framework of the SWITCH strategic planning process were formulated to depict plausible futures and facilitate the overall process of strategy development, by denoting those factors that are most uncertain and likely to have an impact on urban water services. Scenarios formulated within the framework of SWITCH were narrative storylines, quantified in terms of population growth, urban development and water demand. Despite the above, scenarios did not include quantitative data on future infrastructure investments; to that end, the application of City Water Economics was based on the data provided in the Strategic Investment Plan (SIP), whose review and update is presented in Adank et al. (2010).

The reviewed SIP provided estimates for water demands in the ATMA area by extrapolating information of the 1998 SIP. Population estimates and demand projections are presented in Table 18.

Table 18: Population and Water Demand estimate, according to the SIP (Adank et al., 2010)

	2007	2011	2015	2025
Population Projection	3,705,136	4,247,616	4,869,978	6,857,285
Water Demand (m³/d)	474,465	554,988	647,363	931,746

According to the Strategic Investment Plan, the overall amount of investment required is 844,495,422 US$. This corresponds to the improvement of the performance of the existing treatment plants and the expansion of the treatment facilities, the rehabilitation and extension of the distribution system and the construction of a number of additional standpipes. The planned rehabilitation and extension of the distribution system would decrease leakages in the systems and improve system reliability. Furthermore, accessibility to the system would be improved by the extended distribution network and the construction of a total of 5880 standpipes. According to Adank et al., 2009, a foreign grant of 152,307,692 € has already been provided, to enhance the capacity of the Kpong system, and the corresponding project is expected to be completed by 2013.

For the purposes of future estimates, and given the broad time horizon (2025) the modelling of the 2025 SIP scenario did not include subdivision in clusters. Furthermore, it has been assumed that the foreseen capacity expansion will eliminate the need for private water service provision; thus, and in accordance to the vision, the entire Accra population will have access to piped water supply. Although it can be assumed that community managed systems will continue to exist to a small extent and that (possibly) municipalities at the city outskirts will manage their own infrastructure, for simplicity purposes it has been assumed that both water supply infrastructure and distribution networks will be managed by the GWCL in the entire metropolitan area.

Assuming physical losses of 25% and a small share of non-revenue water of 10% (again under the assumption that interventions will significantly improve the effectiveness of the system, also from a managerial point of view), the total amount of water sold in 2025 would equal 221.06 million m³/yr (i.e. 605,635 m³/d on average).

A key point in the overall estimation of the investment cost allocated to households concerns the share of residential water use (metered) over the total volume of water sales. According to the AVRL data for 2007, this percentage amounts to 55% over the total (Table 19). It can safely be assumed that urban growth and population increase will be accompanied by a similar increase in commercial and industrial water demand, as a result of economic growth. In this regard, investment costs allocated to households were calculated at Table 19.

Table 19: Water consumption in the GWCL system

	Tankers	Metered Dom	Pstand	Standpipe	Sachet	Bottled	Commercial	Industrial	Institution	Institution gov't
Accra East	23,515	8,888,145	600	8,458	0	16,318	5,021,913	778,582	359,690	4,784,606
Accra West	552,215	11,630,279		30,309	0	0	2,253,099	309,486	277,799	483,900
Tema	57,377	7,683,909		170,768	266,669	111,258	3,959,479	4,765,057	125,013	1,160,543
Total Gama	**633,107**	**28,202,333**	**600**	**209,535**	**266,669**	**127,576**	**11,234,491**	**5,853,125**	**762,502**	**6,429,049**

An additional consideration concerns revenues (up to 2025) from new connections. Table 20 provides the corresponding estimate, assuming an average household size of 4.6 persons[2] and a connection charge of 70 GHC (currently this ranges between 80 and 100 GHC). The assumption of lower connection charge is used as an additional measure to facilitate access to the public water supply system, particularly for poorer strata. As seen by calculated figures, the total revenue from new connections is negligible when compared to the total investment costs, and would have very little impact on costs borne by users.

Table 20: Estimation of revenues from new connections

	2007	2025
Connected population	60% of current (2003)	100%
Connected households	483,279	1,490,714
New connections (cumulative)		1,007,436
Revenue from new connections (current prices, cumulative)		70,520,520

Figure 63 presents the total costs allocated to households in 2025, where capital costs correspond to the share of residential water demand over the total, and have been estimated by assuming amortization of investment costs over a 25 year period at an interest rate of 5%.

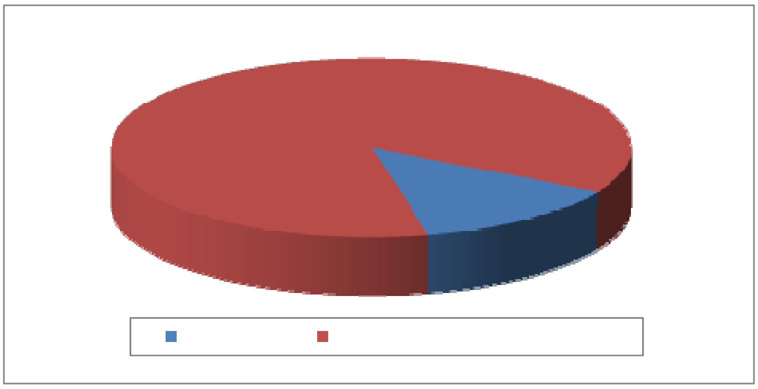

Figure 63: Estimated costs allocated to households (2025), assuming full implementation of the Accra SIP

On the basis of calculated costs, two tariff schemes were formulated, aimed at 100% and 80% recovery of financial costs respectively. In both cases, the lifeline block was defined by assuming a consumption of

[2] Source: Ghana Nation.com web site (http://www.ghananation.com/Greater_Accra/), accessed on 30/12/2010.

70 l/cap/d (as opposed to the current practice where the lifeline block is defined at 20 m³/connection/month – approx. 150 l/cap/d). The other design parameters are presented in Table 21.

Table 21: Design parameters of tariff schemes for future scenarios

Tariff application (metering) period	2 months
Fixed charge	Designed to recover 100% of capital costs
Volumetric method	Increasing Block Rates
Number of blocks	4
Rate Differentials	
Block 1 (lifeline): 0-20 m³/2month period	0%
Block 2: 20-40 m³/2month period	20%
Block 3: 40-80 m³/2month period	80%
Block 4: >80 m³/2month period	100%

Figure 64 presents the estimated fixed charge and volumetric rates for the two cost recovery objectives. Rates for a consumption equivalent of 20 m³/month (40 m³/2-month period) are not considerably higher of those currently applied (0.66 GHC/m³). To that end, it can be argued that improved cost recovery will not impact significantly on charges faced by the majority of water users, provided that efforts are made towards universal metering and reduction of non-revenue water.

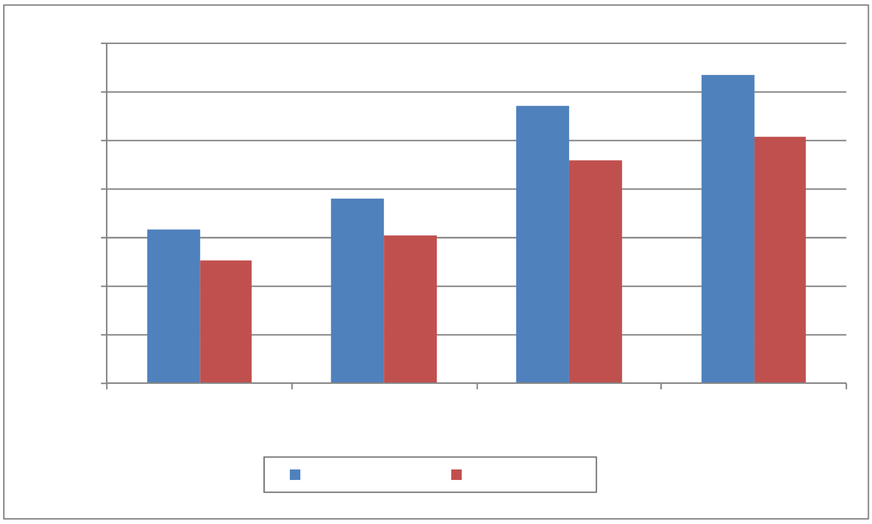

Figure 64: Calculated volumetric rates for water supply in Accra for 2025

The assessment of the affordability of the proposed tariff scheme was estimated assuming an annual income growth rate of 2%. Results are presented in Table 22.

Table 22: Affordability of the 2025 tariff schemes for Accra

Income stratum[3]	100% recovery	80% recovery
Average	3.5%	2.8%
Poor threshold (66% of national income)	5.3 %	4.2%
Hard core poor threshold (25% of national income)	13.9%	11.1%

Despite the fact that the above estimates are indicative (no data on demand distribution among income strata are available), they portray that full cost recovery under the evaluated scenarios cannot be attained, as it would considerably impact on low income groups. To that end, targeted subsidies or rebates towards the poorer households would probably be required in order to maintain charges at affordable levels.

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[3] Income strata are defined as follows: (a) Poor: 25 to 66% of national income; (b) Hard core poor: <25% of national income. The average income stratum is defined as equal to the Ghana wide per capita income for 2007, assuming an annual growth rate of 2% up to 2025.

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