



WatERP

Water Enhanced Resource Planning  
“Where water supply meets demand”

GA number: 318603

WP5: Demand Management System  
D5.5: Water Demand Management System  
and relevant documentation

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<b>Abstract (for dissemination)</b>	<p>This report is part of Deliverable 5.5 and provides all necessary documentation for the WDMS software prototype. The report presents the terms and general concepts behind water demand management and the WDMS in particular, leading to a system’s analysis of management processes along the water supply-distribution chain, by considering knowledge gained from auditing and interacting with WatERP’s Pilot sites. This, in turn, leads to the specification of user requirements and the design of the WDMS software Toolbox. The models and methods used in WDMS are discussed, with reference to the deliverables D5.1 to D5.4, where a more comprehensive description is provided, and the overall WDMS architecture and functionality is described, followed by a description of the actual software development environment and processes.</p>
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<b>Key words</b>	Water demand, Demand management, Water Demand Management System, Water demand forecasting, Similar days model, Economic instruments, Regulatory instruments, Technical measures, Tool for Economic Instruments, Captology, Awareness raising, Persuasive technologies, WaterCity, Water use profiles, Water Use Profiles Registry, Water Use Profiling Tool Registry
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## List of Acronyms

**ACA** - Agencia Catalana de l'Aigua

**AGBAR** – AiGües de Barcelona

**AHP** - Analytic Hierarchy Process

**ATLL** - Aigües Ter Llobregat

**BAU** – Business As Usual

**CAPTology** - Computers As Persuasive Technologies

**DoW** - Document of Work

**DSS** – Decision Support System

**DVGW-TZW** – Deutsche Vereinigung des Gas und Wasserfaches – Technisch-Wissenschaftlicher Verein EV

**EI** – Economic Instrument

**ER** - Entity-Relation

**GUI** – Graphical User Interface

**ICCS** - Institute of Communication and Computer Systems

**MCDM** – Multi Criteria Decision Making

**OMP** - Open Management Platform

**WatERP** - Water Enhanced Resource Planning "Where water supply meets demand"

**WDM** – Water Demand Management

**WDMS**– Water Demand Management System

**WDW** - Water Data Warehouse

**WDW** – Water Data Warehouse

**WUPR** - Water Use Profiles Registry

**WUPT** - Water Use Profiling Tool

## Executive Summary

This report is part of Deliverable 5.5, which includes also the software implementing the “Water Demand Management System” developed by Task 5.5 of WatERP. The prototype is a software Toolbox that finalizes, embeds and integrates the software tools developed by all other tasks of WP5; it also interfaces them with the Open Management Platform (OMP). The Water Demand Management System (WDMS) is one of the principal WatERP components and it represents the culmination and final output of WP5. This report provides all necessary documentation for the WDMS software prototype, as well as a presentation of the concepts behind it and the work done, by Task 5.5, for its development.

The overall objective for WDMS is to provide a comprehensive set of models and tools which would support demand management actions & policies at different levels of the water supply-distribution chain, so as to contribute to the long-term conservation of natural resources, including minimization of water and energy usage, towards sustainable water management. WDMS pursues this objective through a 4-tier approach:

- i. Realizing that the main prerequisite for resource conservation is accurate demand forecasting as an input to critical scheduling & regulation processes along the water chain (so as not to overuse natural or financial resources), WDMS provides a suitable demand forecasting tool. This is aimed specifically at short-term water management processes, since the analysis proved these are critical for resource conservation within WatERP’s context (e.g. water supply regulation, pump scheduling). However, medium to long-term forecasting has not been overlooked; it has been embedded within other tools oriented towards resource planning at a longer time-scale. Interactive use of the tool has also been provided for, to take care of situations requiring direct personal judgement (e.g. scheduling of maintenance operations or special events).
- ii. Going further than daily management operations (as in (i)), long-term planning and formulation of water management policies, measures and regulations require a good working understanding of the components of water demand, the factors that influence it and its trends. WDMS enhances that understanding by providing a water use profiling tool, designed to organize/structure and analyse available information -historical as well as real-time- related to water demand. This is achieved by: (a) providing a Water Use Registry, that disaggregates water demand into its structural components and unit uses and containing multiple information layers of both international reference values and values from recent local measurements; (b) providing analytic functions that allow end-users to explore trends, analyse factors that influence water demand and investigate use profiles and consumption patterns at different spatial and time scales.

- iii. Having formulated a water management policy and considered various alternative tactics and policy instruments for its realization (e.g. aided by knowledge presented in the D5.3 report), a decision-making process has to be carried out for implementing it. For that, WDMS provides a tool for designing, analysing and evaluating various potential demand management policy instruments (economic, fiscal, regulatory and technological). This is based on an end-use/unit use demand prediction model that can also be used to produce instrument-independent (BAU) medium to long-term demand forecasts for resource or infrastructure planning purposes. Through this model, the short as well as the long-term aggregate impacts of policy instruments on water demand are evaluated, providing input to an assessment methodology that models the whole water supply-distribution chain, including all actors and stakeholders, in order to fully account for secondary economic and distributional effects (e.g. changes in costs and revenues) and assess the viability, equity and affordability of potential instruments. The tools can be used both interactively and through a software interface by some other DSS, using the Open Platform's protocols.
- iv. Finally, having in place some medium or long-term water demand management policy and, possibly, a set of policy instruments to implement, a web-based communication tool is provided by WDMS to support that policy from the demand side, i.e. targeted to the water consumer. This tool aims at (a) maximizing the impact of measures by providing relevant knowledge directly to the water consumer (i.e. realization of the rational consumer principle); (b) enhancing the consumer's awareness and persuading towards efficiency in water usage. To that purpose, an awareness raising tool, applying captology and gamification principles and social web approaches, is used to promote the engagement of water users towards water conservation.

The report presents the terms and general concepts behind water demand management and the WDMS in particular, leading to a system's analysis of management processes along the water supply-distribution chain, by considering knowledge gained from auditing and interacting with WatERP's Pilot sites. This, in turn, leads to the specification of user requirements and the design of the WDMS software Toolbox. The models and methods used in WDMS are discussed, with reference to the deliverables D5.1 to D5.4, where a more comprehensive description is provided, and the overall WDMS architecture and functionality is described, followed by a description of the actual software development environment and processes. To understand this document the following deliverables have to be read.

Number	Title	Description
D5.1	Demand forecasting models	This deliverable examines the drivers that influence water demand management and the methodologies available for describing and modelling their relations. It also examines the water demand management requirements of the pilot sites, as well as data availability. This leads to the selection and development of a demand forecasting model and tool.
D5.2	Review of approaches for intelligent water use profiling - Requirements	This Report describes the potential uses and the available approaches to water use profiling. This leads to an analysis of requirements for a profiling tool, which could also support the functionality of WDMS economic tools. The report includes input from the Pilots concerning demand management procedures and the application of demand management instruments, including the measurement of demand elasticity.
D5.3	Tools for assessing economic instruments for water demand management and relevant guidelines & documentation	This Report examines the context, concepts, policy and policy instruments for Water Demand Management. This is followed by an analysis of requirements for procedures and supporting tools fulfilling WatERP objectives in this field. This leads to the development of a water supply-distribution chain model and methodologies for fully assessing WDM policy instruments and, consequently, to the design of a WDM Economic Tool, implementing that model and assessment methodology.
D5.4	Social web-based tools for awareness raising towards demand management	This Report examines approaches and uses of communication tools for water demand management. An approach, based on persuasion concepts employed by existing applications in the water & energy sectors, is selected and enhanced by using captology and gamification principles. It is implemented as a web-based tool targeting the residential water consumer and aimed at providing social motivation to developing a continuous engagement towards water conservation.

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# 1. Introduction

## 1.1 Scope and structure

Task 5.5 concerns the development of a Water Demand Management System that will incorporate the results of all the previous WP 5 tasks. The developed system will allow end-users to explore trends and examine demand forecasts, experiment and analyse different measures and instruments, investigate use profiles and consumption patterns at different spatial scales and promote the engagement of water users towards water conservation, using social web approaches.

This document corresponds to the Deliverable 5.5 “Water Demand Management System and relevant documentation” of Task 5.5. The document is structured as follows:

- **Chapter 2** introduces water demand management and provides an overview of the actions taken by a water utility or a water service provider in order to meet demand and achieve efficient use of available water resources.
- **Chapter 3** presents an analysis of water demand management objectives, goals and user requirements.
- **Chapter 4** focuses on the methodology followed by the different tools developed in the context of WP5 as well as their conceptual design
- **Chapter 5** presents the integration of the WDMS tools into the WatERP environment.
- **Chapter 6** summarises the work undertaken and discusses further work to be done.

The following Appendices complement the document:

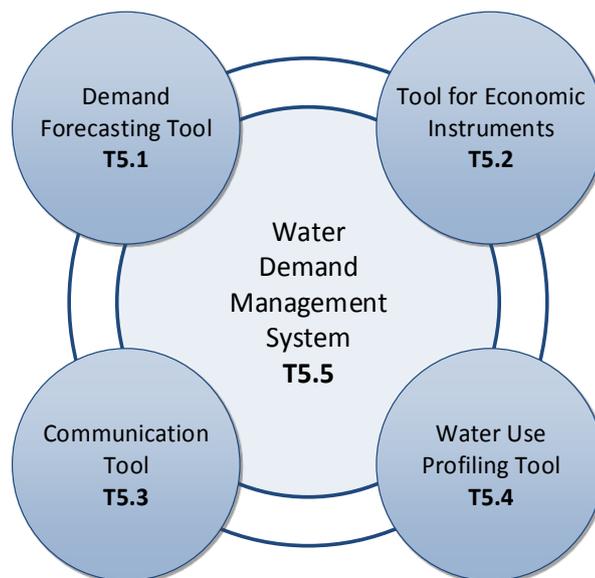
- **Appendix A** provides a description of the demand forecasting calibration tool.
- **Appendix B** presents a detailed printout of the demand forecasting WPS process specification files.
- **Appendix C** presents a detailed printout of the economic instrument WPS process specification files.
- **Appendix D** presents a detailed printout of the profiling WPS process specification files.

## 1.2 Water demand management in the WatERP/WP5 framework

The aim of WP5, as described in the WatERP DoW, is to “provide models and tools to support demand management policies”. Water demand management is aimed at the efficient use of available water resources, particularly in cases of water shortage, due either to limited water availability or to limitations in the capacity of water-related infrastructure.

The main output of WP5 will be the Water Demand Management System (WDMS), which includes a suite of tools that can support the water demand management process by analysing it into individual steps and focusing mainly on the demand component of the process (Figure 1):

- **Demand Forecasting Tool** which will provide demand forecasts per water use sector and at the required level of analysis (T5.1), using the appropriate estimation method.
- **Tool for Demand Management Instruments**, to assess potential instruments for demand management (T5.2), taking also into account cost recovery, cost allocation among actors and including secondary socio-economic impacts.
- **Communication Tool**, for raising public awareness on water use and water saving options (T5.3).
- **Water Use Profiling Tool** (T5.4), for enhancing the understanding of the causes that drive water demand, by organizing, storing and analysing water use information.

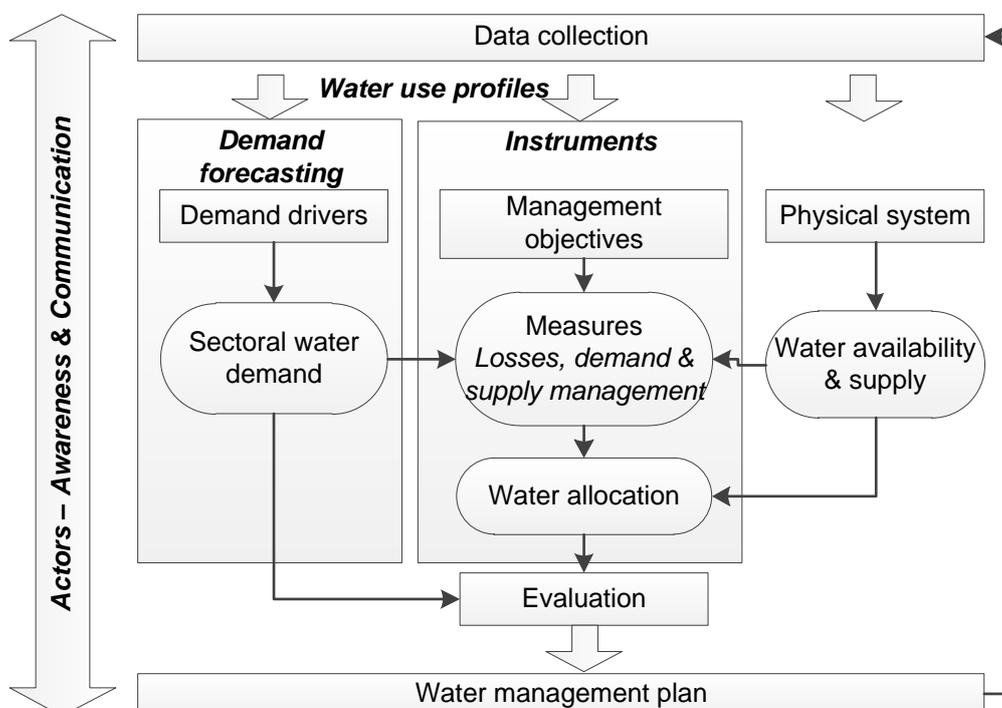


**Figure 1:** The Water Demand Management System as a Suite of Tools.

## 2. Overview: concepts and definitions

Water demand management involves the series of actions taken by a water utility or a water service provider in order to meet demand and achieve efficient use of available water resources. These actions are typically described in a water management plan (Figure 2) and are designed on the basis of:

- Water demand estimates and forecasts. Water demand refers to the volume of water requested by users (e.g. industry, agriculture, urban, hydropower, environment, tourism, etc.) to satisfy their needs. Decisions on resources utilization, infrastructure development, water allocation, and network operation are based on forecasts on demands by sector and their temporal evolution.
- Management objectives. Water managers can select from a wide list of measures in order to achieve a balance between water supply and demand, as well as economic efficiency (i.e. cost recovery of water services), social acceptance and equity, and environmental protection.
- Available data, resources (financial & human resources, technical capacity) and tools, for supporting demand forecasting as well as for the design, implementation and monitoring of demand management measures.
- User awareness of and contribution to the efficient use of water, as a result of social change (e.g. change of habits) and dissemination of water-related information.



**Figure 2:** Conceptual framework of the processes towards the development of water management plans.

## 2.1 Water demand forecasting

Water demand is primarily distinguished according to the type of water use, and can be further analysed according to location (offstream, instream), treatment of water used (raw, potable, reclaimed) and/or the type of end use activities (e.g. livestock, cooling, toilets etc.). Demand is influenced by a number of factors, such as socioeconomic characteristics (population and land use), user profiles, climate and weather conditions, technology used, network efficiency and changes in supply sources (White et al., 2003).

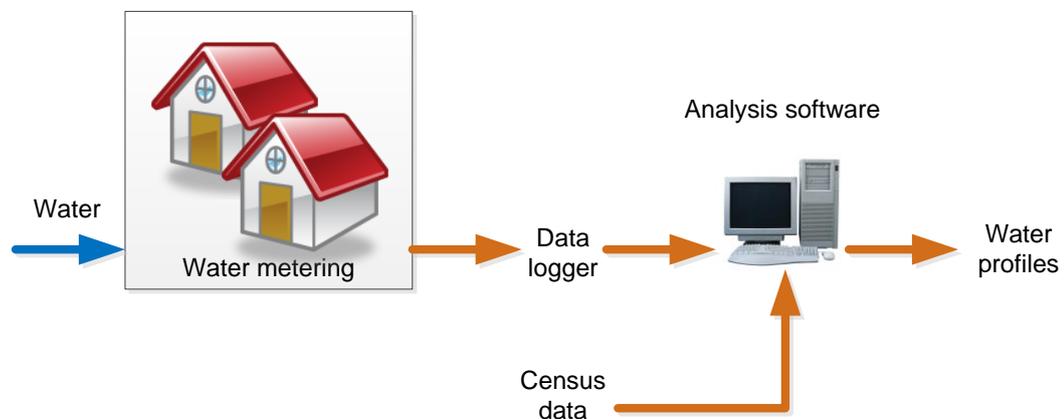
Demand forecasts can be either short-term (present demand) or long-term (future demand), depending on the aim of using forecasts. Short-term forecasting is typically used for supporting the day-to-day operational management of the water distribution infrastructure, and optimizing the use of energy and operational costs for providing water services. On the other hand, long-term forecasts are used for formulating a strategic plan for investing in the development of water infrastructure, allocating water resources among actors, and optimizing water resources usage & minimizing costs of water procurement. Different methods are used for each forecasting type (Table 1), with differing degrees of sophistication (WRDMAP, 2010). The selection of a demand forecasting approach is mainly based on three (3) criteria (Davis, 2003): (i) the purpose of the demand forecast and the level of detail needed by the decision-makers, who will use the water demand forecast information in their water system planning and/or management activities; (ii) data requirements and availability, considering data already available and new data that may need to be collected and their temporal and spatial scales, (iii) available resources, in terms of budget and the time schedule for data collection, model setup and development, and model calibration.

*Table 1: Water demand forecasting in WatERP.*

Time frame	Time step	Demand forecasting methods	Forecasting method in WatERP	Use of forecasting in WatERP
<b>Short-term (from 1 to several months)</b>	Hourly/	Time series analysis	Pattern recognition (similar days approach)	Improve of efficiency of operation of the water network
	Daily	Artificial Neural Networks		
<b>Long-term (several years)</b>	Monthly	Regression analysis	The unit use/ end-use model	Planning & assessment of demand management instruments
		Unit use & end use methods		
		Artificial Neural Networks		

## 2.2 Water use profiling

The development of a water management plan demands for a detailed knowledge of “where, when, (even by whom/why) and how much water is used”, also known as “water use profiles”. The study of water use profiles involves two main processes (Figure 3): (i) the measurement and analysis of water consumption in time and by category and technology used, and (ii) the analysis of socio-economic and other factors that influence the hourly, daily, weekly, even monthly water use pattern. The first process refers to the design and execution of a data collection and analysis method (e.g. metering or water audit). The second concerns demographic-economic information about water users that is typical collected through questionnaire surveys.



### Water use types & indicative end-uses

*Residential:* Bath & showers; Toilets; Washing machines; Water faucets; Garden irrigation; Pools; Other indoor; Other outdoor

*Commercial – Public Buildings:* Toilets and water faucets; Other indoor; Garden irrigation; Other outdoor

*Industrial:* Industrial processes; Toilets & water faucets; Other indoor; Other outdoor

*Agriculture:* Process

**Figure 3:** Schematic representation of the process of developing water use profiles.

Enhanced knowledge of the water use patterns can improve water management, support the development of demand management strategies and increase awareness of water use. Water Use Profiles Registries are thus the core component of a water demand management system, as the data stored in these can be used for demand forecasting (either per capita or per use type water demand, for various time steps) and increasing awareness (e.g. use in communication tools to support functionalities such as user benchmarking, suggesting interventions for water use reduction, etc.).

## 2.3 Instruments for demand management

Demand management measures are classified in four main categories (Table 2). Economic instruments can be applied in order to (i) provide incentives towards water saving and efficient use of water (primary

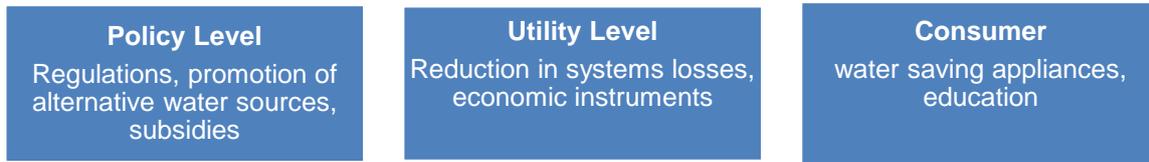
impact), and (ii) raise revenue towards cost recovery (secondary impact). Regulatory instruments can be employed to further strengthen water conservation programmes by providing a (minimum) set of standards that specific users need to comply with or controlling water supply and use in the different use sectors. Technical measures refer to the uptake of water efficient technologies or the improvement of existing infrastructure. Finally, educational/behavioural measures aim at the change of water use habits of the individual users.

**Table 2:** Categories and tools of water demand management (Qdais, 2003).

<b>Economical</b>	<b>Institutional/ Regulatory</b>	<b>Technical</b>	<b>Educational/ Behavioural</b>
Well-designed water tariff system	Legislation and regulations to conserve water	Applying metering to measure consumption	Seminars and workshops
Financial incentives for water conservation	Building and plumbing codes	Leak detection	Media campaigns
Enforcing polluter pays principle	Capacity building of the water institutions	Pressure monitoring and control in the networks	School curriculums
Water allocation through market	Monitoring and controlling of land use	Using water saving devices	Competitions and festivals
	Decentralization and local-level management	Using computer techniques to monitor and distribute water	

An integrated water demand management plan includes a combination of tools, as demand management measures can have either a short-term or long-term impact, can target high priority sectors, and can be implemented or aimed at different actors along the water supply distribution chain (Figure 4). The assessment of demand management instruments, in order to select the appropriate mix of measures, typically involves four main steps:

1. Estimation of its impact on water demand on the basis of water demand estimation and forecasting models that include instrument-related parameters in the model.
2. Calculation of any direct costs needed for implementing the instrument.
3. Evaluation of any secondary economic and distributional effects along the water supply distribution chain, referring mainly to cost and income allocation based on the payments made among actors.
4. Assessment of its overall efficacy, feasibility and usefulness, using indicators such as cost recovery for actors, affordability of tariffs (e.g. percentage of household disposable income spent for water services), need and cost for investment or subsidies.



**Figure 4:** Demand management measures, applicable to the various actors along the water supply chain.

## 2.4 Communication and awareness

Web-based “feedback and persuasion techniques” are used to foster pro-environmental behaviour. Applications, such as tools to record water use for different purposes, are being mainly used by water agencies for improving awareness on water use and informing users about options for more efficient water use. The design of such applications is based on (one of) the following principles:

1. Just-in-time prompts, which remind people of actions that they are predisposed to;
2. Positive or negative reinforcement for promoting the desired behaviour;
3. Social validation, by informing/discussing how other people behave.

Few applications of persuasive technologies have been reported (Table 3). Most of work in this area is largely limited to sensing and feedback at the point-of-consumption and to simple ambient displays, in the context of Human Computer Interaction (HCI) research. Most systems have focused on faucet and shower usage, providing point of use feedback in devices such as the tap and the showerhead.

**Table 3:** Examples of persuasive systems and technologies in the water domain.

System	Brief description
WaterBot (Arroyo, at al., 2005a)	The system utilises ambient visualizations in order to present information on a device that is attached to the sink itself; the information displayed is used to motivate people to turn off the tap when the water is not being used.
CleanSink (Arroyo et al., 2005b)	The system has a small display beside the sink that can persuade people to wash their hands properly by following the directions displayed.
UpStream (Kuznetsov and Paulos, 2010)	It is a custom-designed orb display using a traffic light metaphor, for providing feedback. It lights up in green, orange, and red colors depending on the length of time a faucet or shower is used, relating total usage at that fixture so far for the day.
Show-me (Kappel and Grechenig, 2009)	The system meters and displays the amount of water used during one shower in the form of LEDs assembled on a stick.
Smart Garden Watering (Pearce et al., 2008; Pearce et al., 2009)	It is a web application, helping people water their gardens more efficiently. Through SGW, gardeners’ reasoning about water demand and water supply for their gardens is supported.

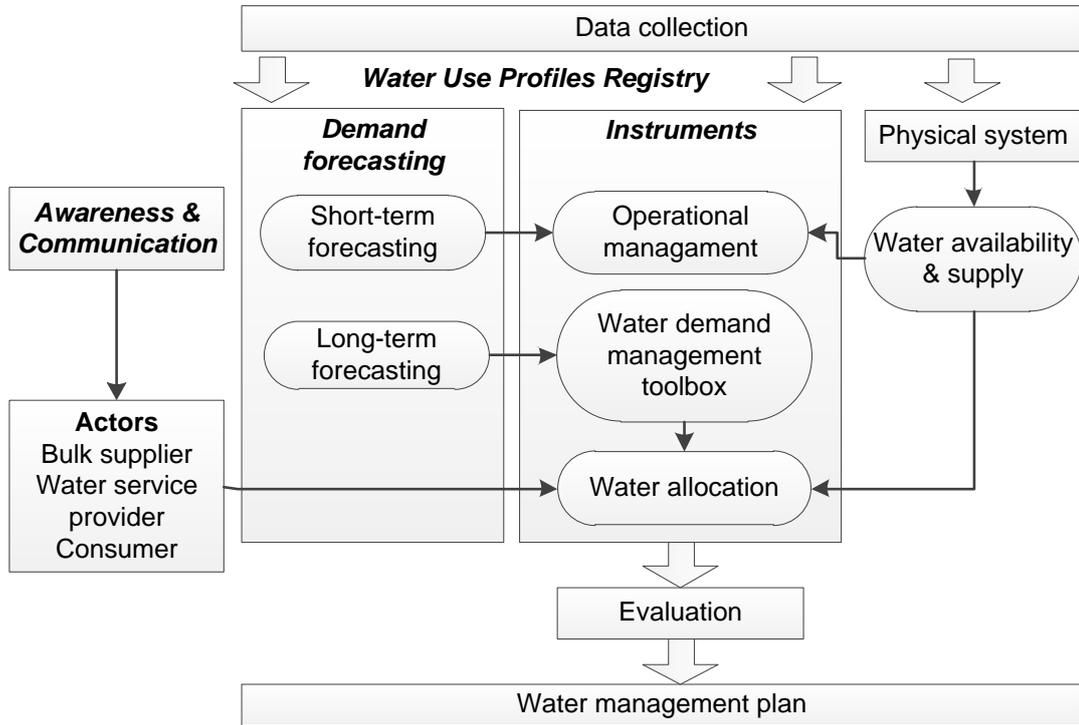
In the framework of an integrated water demand management system, a web-based communication tool can be used to promote engagement and enhance citizen participation in water conservation activities. Emphasis must be given to the adoption of a social proof persuasive strategy, which has a strong influence on user persuasion and behavioural change towards resource conservation activities.

## 2.5 Water demand management system

A Water Demand Management System (WDMS) provides a comprehensive set of models and tools, as such described in sections 2.1 to 2.4, in order to support demand management actions and policies at different levels of the water supply-distribution chain. The system involves a detailed mapping of:

- Actors along the water supply chain. Each actor, through water allocation decisions and the application of demand management instruments, affects the operation of the water system and the behaviour of other actors along the chain. Three main types of actors can be distinguished: (i) The Bulk water supplier, referring to the actor in charge of allocating the available water sources to different water utilities/downstream actors, (ii) The Water service provider (utility), corresponding to the actor responsible for the distribution of water to the different “consumers”, and (iii) The Consumer, corresponding to the final water user.
- Uses in the water system, representing demand nodes with different characteristics and response to demand management instruments. Use profiles, both aggregated (e.g. as demand node) and disaggregated (e.g. as unit use demand), can be used to analyse water use behaviour and plan accordingly demand management actions (measures and awareness/communication tools).

In line with the above, Figure 5 presents the conceptual framework of a WDMS. The main outcome of the WDMS is the value of a set of evaluation criteria (related to water use & economic efficiency, and social affordability) for different demand management options and under given demand forecasts, which can be used by water managers in decision making and the formulation of water management plans.



**Figure 5:** Conceptual framework of a Water Demand Management System.

## 3. Analysis of requirements & software specifications

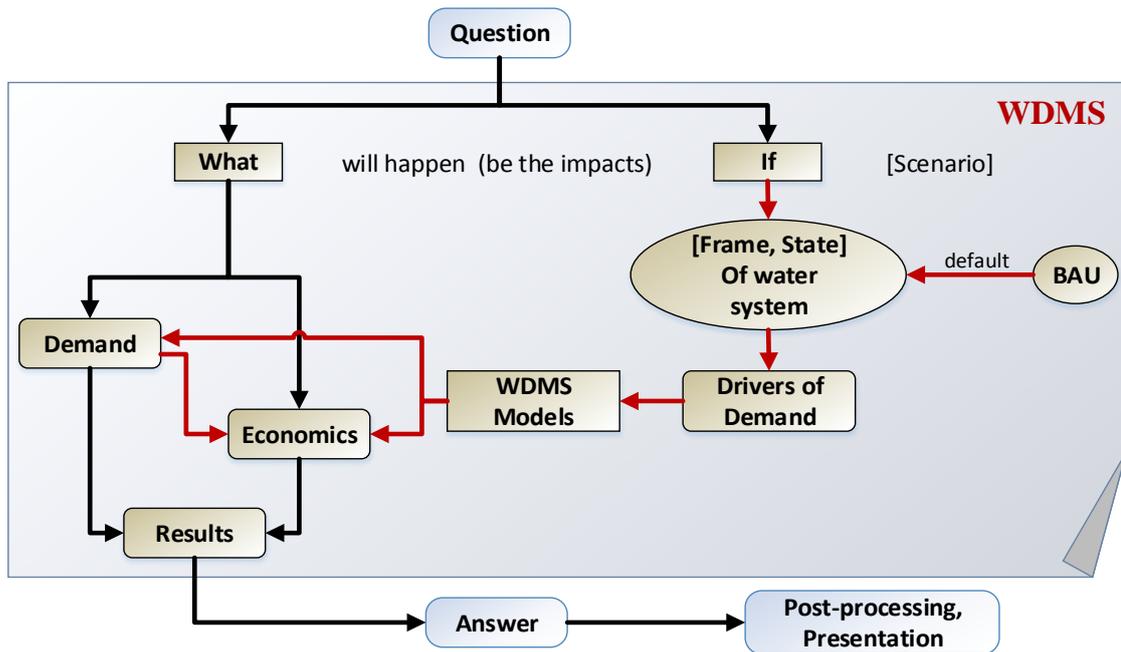
### 3.1 Analysis of water demand management objectives, goals and user requirements

#### 3.1.1 Objectives & Goals

The **overall objective** for WDMS, defines it as a (computational) system that provides a set of models and functions (or tools) which would support demand management actions & policies at different levels of the water supply-distribution chain, so as to contribute to the long-term conservation of natural resources, including minimization of water and energy usage, towards sustainable water management. **Sub-objectives** focus on issues of exploration of historical trends; investigation of water use profiles; analysis of demand drivers & demand forecasting; design & evaluation of policy instruments; raising water users' awareness and their engagement towards water conservation. It may be assumed that such sub-objectives correspond to functions or functional groups or Tools. Such tools were developed, as expected, by tasks 5.1, 5.2, 5.3 & 5.4. It is for this reason that WDMS has been presented, in previous WP5 reports, as a Toolbox, both containing these tools and integrating and extending their functionality.

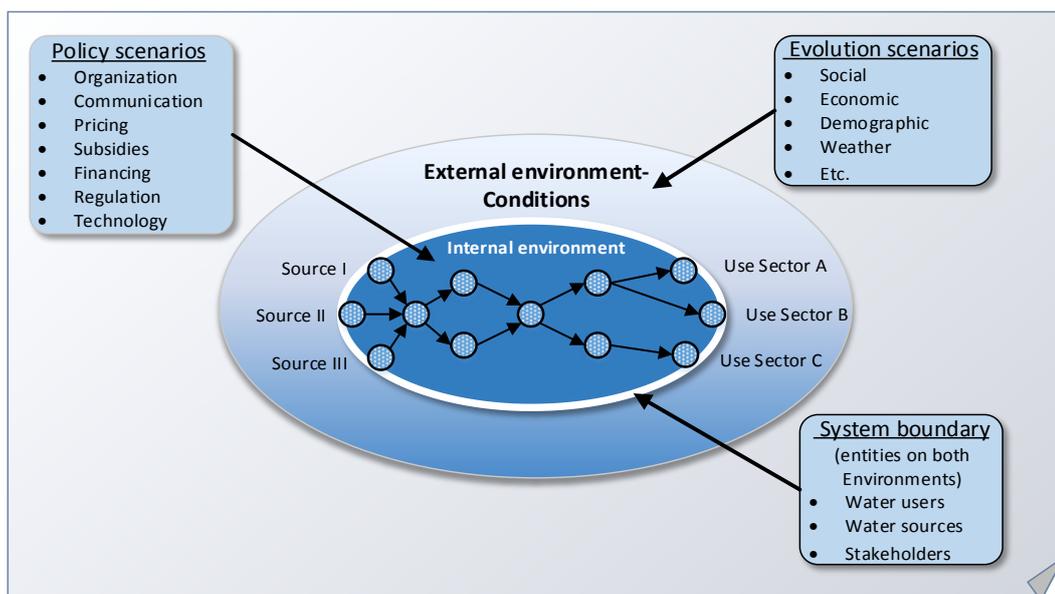
In any case, water demand estimation or forecasting will be considered as the core function of WDMS, since it underlines almost any other function and any water management process/action, to be supported, and is its most essential input. Indeed, since the goal is set to the long-term conservation of resources and since the amount of resources used in any water management process/action depends on the amount of water being used, i.e. on water demand, it may be assumed that the efficiency of the process/action (water, energy, cost, etc. used) increases as the accuracy of demand prediction increases.

From the above definitions, in conjunction with the overall context and objectives of the WatERP project, follows also that (a) WDMS is an information server which (b) provides services (directly or indirectly) to managers at different levels along the water supply-distribution chain of a water region. Thus, WDMS is seen as a server that accepts certain types of queries, to which it provides an answer. The general logical schema of WDMS queries is represented in the following Figure 6.



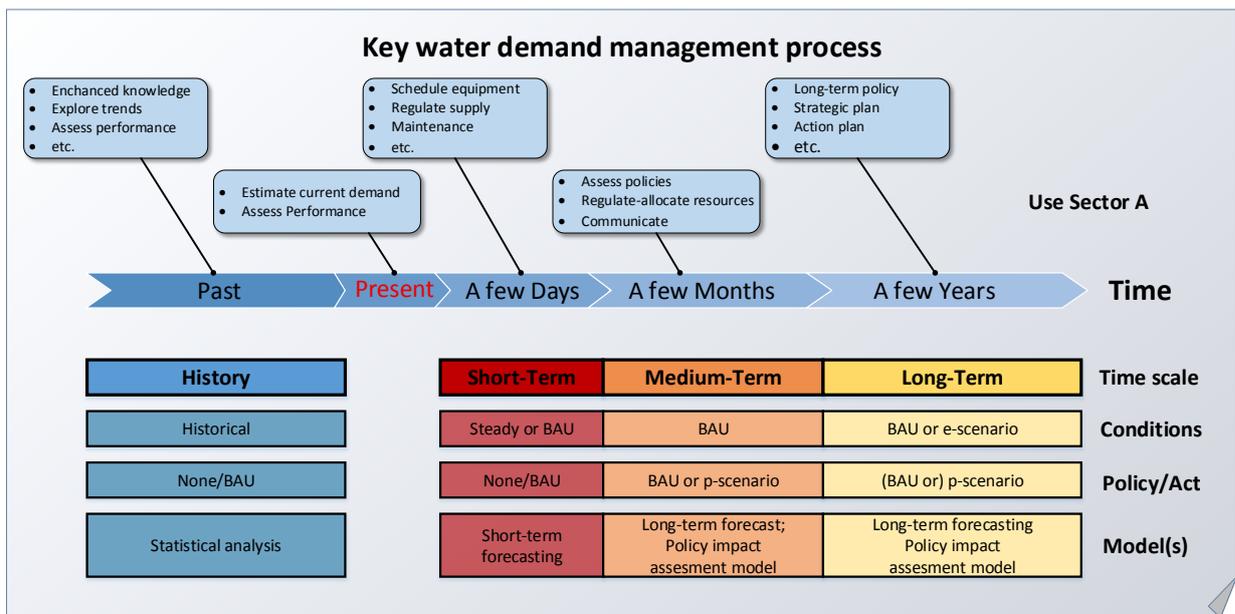
**Figure 6:** General logical schema of WDMS as an information server.

This schema implies that all or most questions which are answered by the WDMS either define explicitly or imply some kind of scenario or hypothesis (what if ...). Such a scenario defines (or implies) the reference frame of the query, i.e. the target state of the water system and its environment. It is within this frame of reference that WDMS users/clients ask for some information about water demand or other water system variables related to or correlated with water demand. In Figure 7, the source and nature of such scenarios/ hypotheses (reference states) are presented, i.e. why and how do they come to be.



**Figure 7:** Environment generating WDMS explicit or implied scenarios / hypotheses.

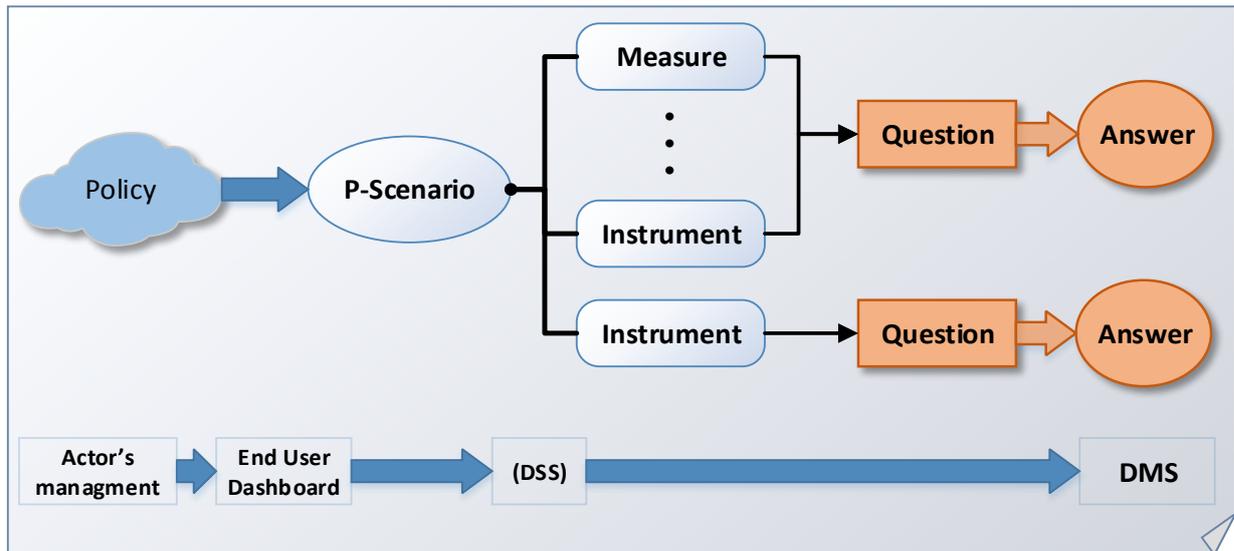
Besides the above topological frame, scenarios are generated by and within the temporal frame of water demand management processes. Various management goals and processes/actions fit within different time scales and cycles and require different approaches using different types of models to provide supporting information, as presented in Figure 8.



**Figure 8:** Temporal relation of WDMS scenarios and management processes.

It can be seen that there are two (2) distinct categories of “scenarios” implicit or explicit in any query:

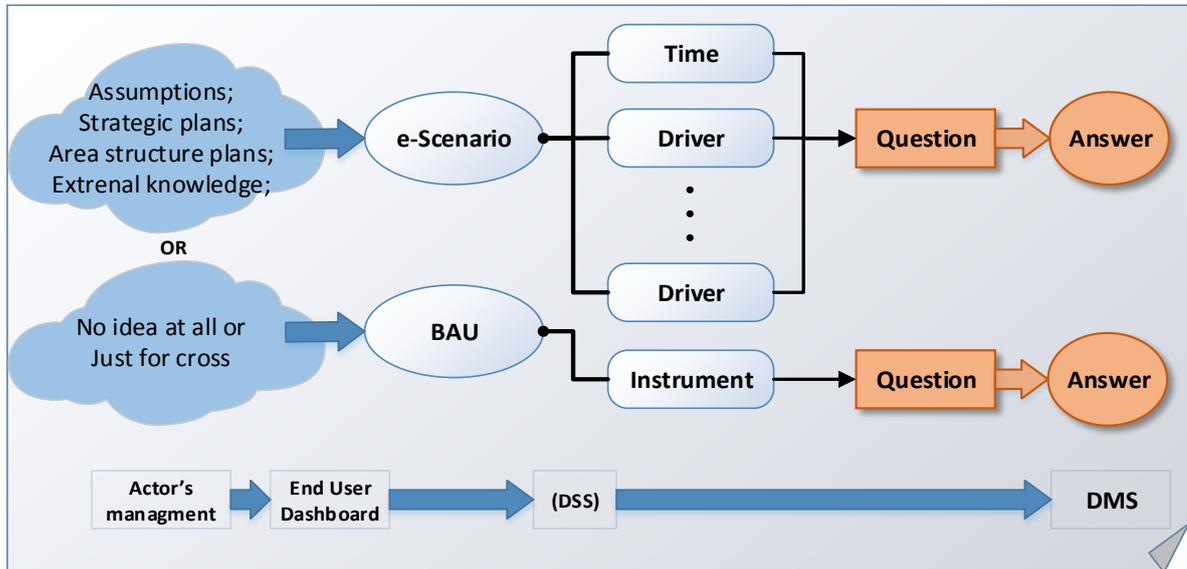
- a. Scenarios referring to the **internal environment** of the water system (the water supply distribution chain itself) and its boundary (e.g. water use technology, water user’s controllable behavioral elements), which express water demand policies or sets of policy instruments (policy scenario or *p-scenario*). Such scenarios express the intension (or potential) of WatERP’s users to intervene in the water system, causing controlled changes in its internal environment, for example pricing policies, subsidization policies, technology uptake policies. A policy has to be converted into a p-scenario in suitable form (e.g. into a tariff structure, for pricing policies) to compose a query to the WDMS, as presented in Figure 9.



**Figure 9:** Derivation of a WDMS query based on a policy-scenario.

- b. Scenarios referring to the **external environment** of the water supply distribution chain and its interfaces (boundary conditions) with the internal environment (e.g. water availability related to rainfall, uncontrollable behavioral elements of water user's). Such scenarios express hypotheses about the evolution (or change) of the external environment (environmental scenario or e-scenario). In this case, WatERP's users may have no volition or potential for intervention to cause the change that the scenario expresses. It just happens, due to external factors and all the user can do is predict it and take it into account. A hypothesis or assumption has to be converted into an e-scenario in suitable form (e.g. into a market structure consisting of water use drivers' levels) to query the WDMS, as presented in Figure 10.

The two types of scenario are not mutually exclusive; they co-exist (implicitly or explicitly) in any query to the WDMS. An implicit scenario expresses either the “do-nothing” or the “business-as-usual” (BAU) cases. A p-scenario can be either a “do-nothing” or a “do-something” case, while an e-scenario can be either a “do-nothing” (i.e. steady state, no evolution) or a “business-as-usual” (i.e. current trends apply) or a “do-something” (i.e. a prediction of change) case. Thus, the expression of both types of scenario in a query to WDMS, requires a query reference framework that includes six (6 = 2 x 3) combinations, as follows:



**Figure 10:** Derivation of a WDMS query based on an environmental-scenario.

The simplest case is the base-case, in which neither a p-scenario nor an e-scenario are expressed in the query, meaning that the external environment is considered to be in a steady state (no change), while a do-nothing policy applies to the internal environment (or the time scale is not long enough for a policy to be implemented and/or take effect). In this case WDMS has to look only on historical data and simple statistical trends (e.g. averages, extrapolations) of a dependent (queried about) model variable, with no explanatory variable (driver) used. Statistics are derived directly from available historical data, without using any explanatory model. This case may represent the base query reference frame for exploring from historical data and deriving knowledge from them. It may also represent a simple approximation of the present state of the system (e.g. current water demand) and/or the reference scenario used for the assessment of a policy. In such a frame of reference, WDMS may need to provide answers to queries such as “*what is the current/next (daily/monthly/yearly) water demand in sector/area/point X?*”.

In a slightly more complex situation, there is no p-scenario (do-nothing policy), but the e-scenario is a business-as-usual (BAU) scenario, meaning that (at least) trends have to be considered, either for the dependent model variable (typically, water demand) and/or its drivers, in order to take into account the normal evolution of the external environment. This type of query may be used for performing short-to-medium term forecasting and/or for the evaluation of the do-nothing reference state (or reference scenario), used for the assessment of a policy. Standard statistical methods can be used to predict the values of model variables and then the

model can be run to provide the requested information. In such a frame of reference, WDMS may need to provide answers to queries such as “*what would be the expected average daily/monthly/yearly water demand in sector/area/point X, after n years?*”. In a much more complex (and important) variation, there is the case that the upcoming needs (typically, 1 to 3 days ahead) have to be predicted, in order to re-schedule operations and/or regulate supplies. In this case, a specialized very short-term forecasting model is used, after predicting the values of its variables by external methods (e.g. weather forecasting). In this sub-case, WDMS would provide answers to queries such as “*what would be the predicted hourly and/or daily water demand in sector/area/point X, for the next n days?*”.

In a little more complex situation, while there still is no p-scenario (do-nothing policy), there does exist a specific e-scenario for the evolution of the external environment, i.e. a specific set of changes of external conditions that can be expressed (Figure 10) as changes of the levels of independent model variables (typically, water demand drivers). These values have to be predicted by using external (to WDMS and/or OMP) methods and tools. Then an explanatory model (incorporating these variables/drivers) can be used by WDMS to predict the level of the dependent variable (typically, water demand). This represents a medium-to-long-term prediction of the information requested, when no demand management action/plan is considered. Such may be the case when future needs have to be evaluated for a do-nothing policy, e.g. to be used as a base reference level. In such a frame of reference, WDMS may need to provide answers to queries such as “*what would be the predicted water demand in sector/area/point X that, (after n years), has undergone change Y?*”.

In the case that there is a specific p-scenario (e.g. a policy instrument) that is proposed for implementation in the near future (short-to-medium-term policy), the external environment can be implicitly considered as unchanged, i.e. no e-scenario is expressed in the query (no change). This means that no water system variables (e.g. water demand) change due to environmental change, but some change due to the impacts of a policy (Figure 9). This change can be thought of as taking place in a medium-term time horizon. An explanatory model (incorporating these policy-affected variables) is used to predict the level of the dependent model variable (e.g. water demand), as well as any secondary impacts (e.g. to water system actors). This represents a medium-term prediction of the information requested. In such a frame of reference, WDMS may need to provide answers to queries such as “*what would be the predicted potential water demand (and/or other impacts) in sector/area/point X, if potential policy Z is applied?*”.

In a more general case, a specific p-scenario is proposed and needs to be evaluated, but this scenario (policy, instruments, action plan) is not considered for implementation in the very near future, but in a long-term future. Alternatively, the full impacts of a policy may need a long time to fully develop. In such a case, the external environment must not be considered to be in a steady state (i.e. e-scenario = do nothing), but it must be allowed to evolve in a BAU direction

(i.e. e-scenario = BAU). Standard statistical methods must be used to predict the values of the independent variable (e.g. demand drivers) and then these values can be introduced into an explanatory model to predict the level of the dependent model variable (e.g. water demand). Finally, the impacts of the p-scenario on the BAU case must be estimated and assessed. This represents a medium-to-long-term prediction of the information requested. In such a frame of reference, WDMS may need to provide answers to queries such as “*what would be the predicted potential water demand (and/or other impacts) in sector/area/point X, after n years, if policy Z is then put into effect?*”.

In the most general case, a specific p-scenario is proposed to be implemented in a specific external environment, significantly different than the present one, i.e. under a specific set of changes of the external conditions (e.g. water users’ populations, habits & user behavior, water availability, economy, etc.). This would mean that an explanatory model (i.e. incorporating variables/drivers that depend on the external conditions) must be used to predict the level of the dependent model variable (e.g. water demand) and, over that, apply an assessment model for the evaluation & assessment of p-scenario impacts. Such a query would be put in the process of long-term planning of resources and/or infrastructure (e.g. a strategic plan). It would not be possible for WDMS to provide a completely automatic answer to such a query, since that would require possibly a full study and depend on specific conditions (e.g. estimation of future water reserves). Following the schemas in Figure 9 and Figure 10, the problem has to be decomposed into three distinct components: (a) prediction of explanatory variables for a demand forecasting model; (b) prediction of water demand for the BAU scenario; and (c) evaluation & assessment of policy impacts. This represents an extended form of a long-term prediction of the information requested. In such a frame of reference, WDMS may need to provide answers to queries such as “*what would be the predicted water demand (and/or other impacts) in sector/area/point X that after n years has undergone change Y, considering that policy Z would be put into effect?*”.

These combinations, defining the WDMS query reference framework, are summarized in Table 4:

**Table 4:** Summary of the WDMS query framework.

CASE (purpose of use)	POLICY SCENARIO	ENVIRONMENTAL SCENARIO	WDMS USE METHODOLOGY
<b>1. Do-nothing at present</b> <b>(get available data; evaluate baseline case)</b>	None (same as BAU)	None	Derive statistics from available historical data; use averages or extrapolation to estimate present demand.

CASE (purpose of use)	POLICY SCENARIO	ENVIRONMENTAL SCENARIO	WDMS USE METHODOLOGY
<b>2. Just BAU (find upcoming needs; do short to medium term prediction)</b>	None (same as BAU)	BAU	Use standard statistical methods to predict values of demand drivers then use demand model for long-term demand forecasting.  (*)In a special, very short-term case, predict model variable values and use a specialized model for very short-term forecasting.
<b>3. External environment evolution / change (evaluate future needs; long-term prediction)</b>	None (same as BAU)	e-scenario	Use external methods & tools to predict values of all e-scenario parameters; use these values to estimate demand model variables and run forecasting model(s) with all variables
<b>4. Medium-term policy (implement a policy now, under current conditions)</b>	p-scenario	none	Use p-scenario to estimate the impact of its policy instruments on demand and on Actors along the water supply-distribution chain.
<b>5. Long-term policy (implement a long-term policy or plan or a policy with long-run impacts)</b>	p-scenario	BAU	Use standard statistical methods to predict values of demand drivers; use these to predict future demand; then use the p-scenario to re-estimate any supply-side policy-affected variables and make an assessment of the policy or action plan.

CASE (purpose of use)	POLICY SCENARIO	ENVIRONMENTAL SCENARIO	WDMS USE METHODOLOGY
<b>6. Strategic plan (implement a policy and/or action plan fitting for a predicted change of the external environment)</b>	p-scenario	e-scenario	Use external methods & tools to predict values of all e-scenario parameters; use these values to estimate demand model driver values; then use the p-scenario to re-estimate any supply-side policy-affected variables and make an assessment of both policy/plan and conditions.

The above analysis helps define the role of WDMS and the framework in which its users may operate and/or require its services, submitting queries to it. It may be noted that WDMS puts particular emphasis in supporting short-to-medium term water demand management processes, occurring in a Business-As-Usual environment (see next section 3.1.2 for more elaboration about this direction). WDMS does aim to support medium- and long-term planning (as defined above). However, it is outside its (at least present) scope to include methods for predicting the evolution of the external environment and evaluating changes of the levels of factors that may influence water demand (e.g. populations of water users, types of crops or products, water using technologies, water using habits & behaviors, weather, water availability, special events, income and production costs factors, etc.). Such changes are either evaluated or hypothesized by the users, as is the standard procedure, by either using external methods and dedicated tools or by obtaining this information from external sources (e.g. Weather Bureaus, Statistics Bureaus, studies, experts). It is for this reason that using WDMS may be a multi-step procedure, with one or more steps carried out independently of the WDMS/WatERP environment. Of course, WatERP's open architecture (OMP) opens up WDMS software services to application developers and allows for the extension of WDMS in a future installation, or even the addition of more WDMS components to the OMP. In this way, custom external procedures might become completely incorporated and automated.

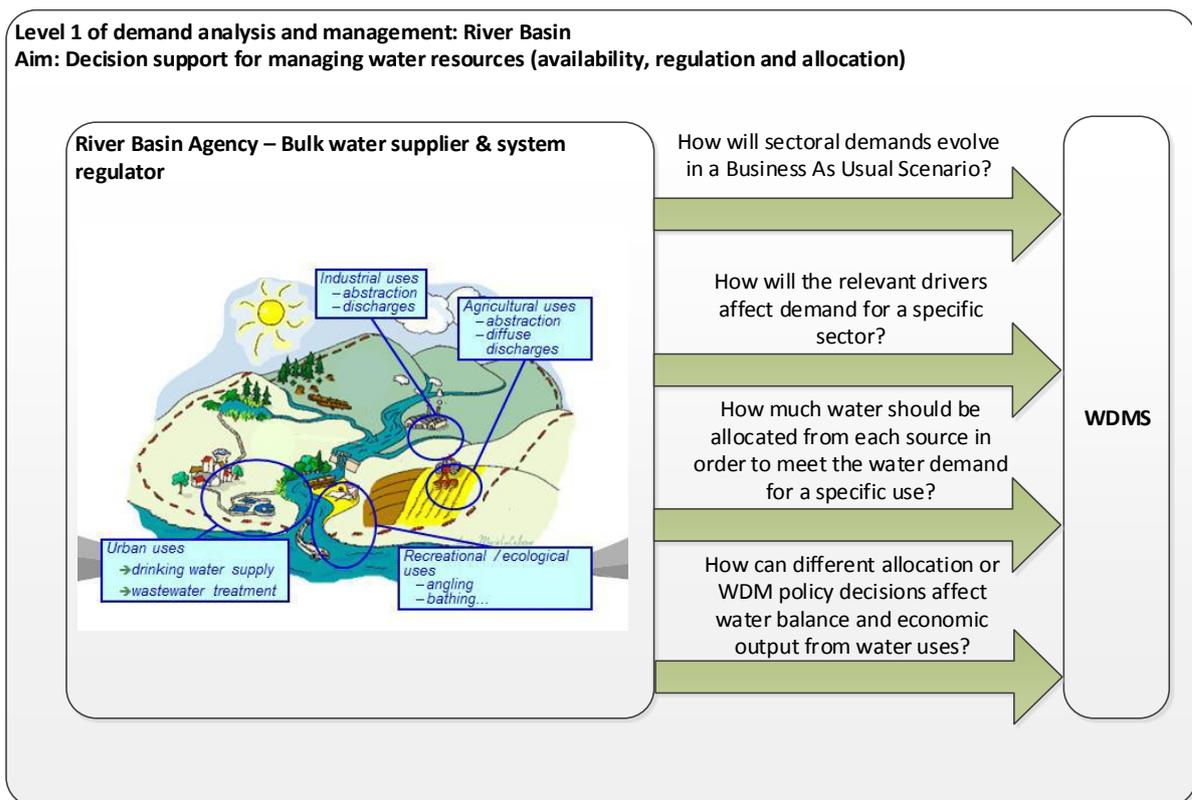
In the following section the potential WDMS users and their requirements will be further exposed, in order to, eventually, define concretely the services that WDMS will provide.

### 3.1.2 Users and User Requirements

The potential WatERP users and their potential requirements have been investigated and analysed, in general and through WatERP's Pilot Sites' participatory procedures, and the results of this analysis

have been reported in deliverables D1.1, D1.2, D1.3, D1.4, D1.5, D6.1 and D7.1. References to the subject, targeted specifically to the design of the WDMS tools, have been made in sections 4.4, 5.3 and 5.4 of D5.1, sections 6.1 and 6.2 of D5.2 and section 7.1, 7.2 and 7.3 of D5.3. This information will be restructured and transferred into the context of an integrated water demand management system.

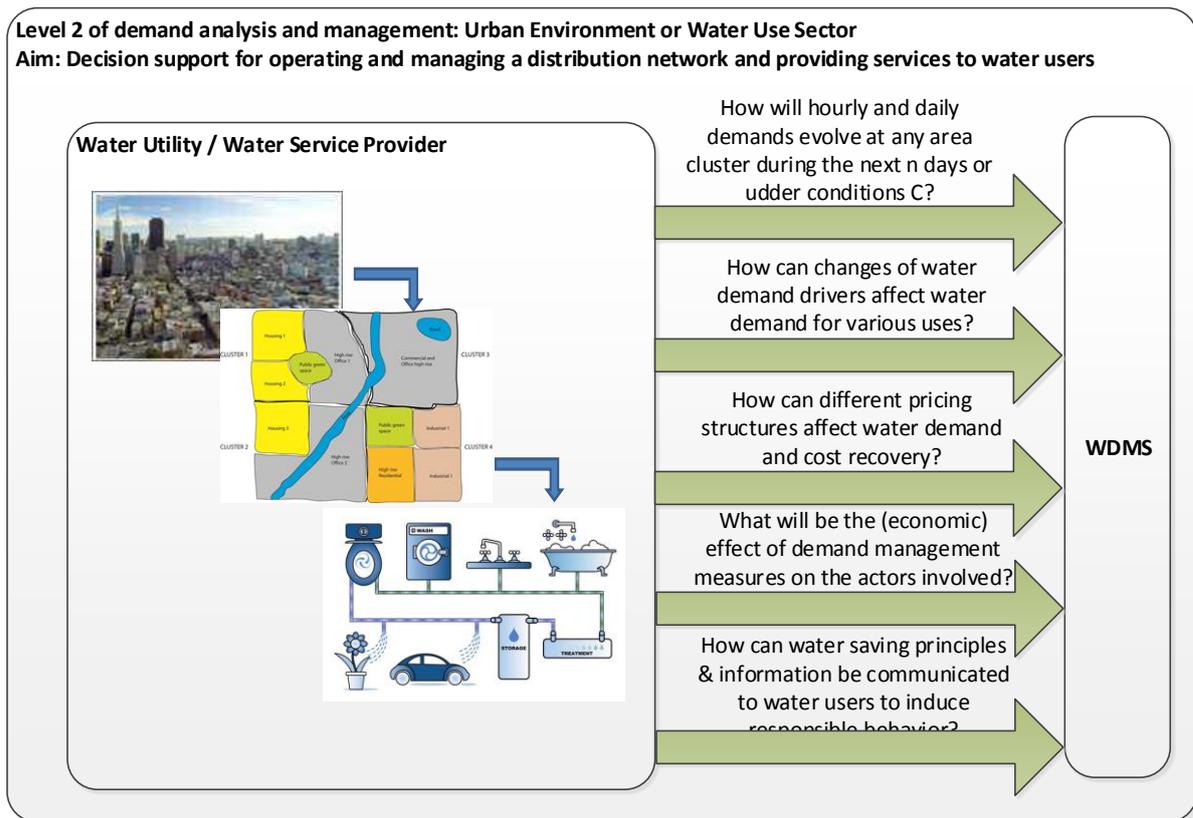
WDMS users may be distinguished into two (2) broad categories, representing the two levels of examining and managing demand and supply along the water supply-distribution chain: (1) the River Basin level and (2) the urban environment or water use sector level. The first category (level 1) focuses mainly on the supply side of the water chain and its most representative water demand management entity can be labelled as a “Regulator Entity” (or River Basin Agency). Management on this level is concerned mainly with issues of water availability, regulation, allocation, environmental sustainability and bulk water supply to the down-stream part of the chain. Accordingly, queries that might be put to WDMS by users at this level, would request information relevant to those issues. The conception of level 1 is exemplified in Figure 11; with some indicative potential questions that management at this level may put, that might need support from WDMS to be answered.



**Figure 11:** Indicative questions asked by level 1 water demand management.

The second category (level 2) focuses mainly on the distribution side of the water chain, i.e. at the water use sectors, most typically at the Urban Environment of water distribution and use. Its most representative water demand management entity can be labelled as a “Water Utility Entity” (or Water

Service Provider or Distributor). Management on this level is concerned mainly with issues of infrastructure management & operation (e.g. optimizing the operation of the distribution network), water allocation to end-user clusters and providing water services to water users. Queries that might be put to WDMS by users at this level, would request information relevant to such issues. The conception of level 2 is exemplified in Figure 12; with some indicative potential questions that management at this level may put, that might need support from WDMS in order to be answered.



**Figure 12:** Indicative questions asked by level 2 water demand management.

WatERP's two Pilot Sites, having quite different characteristics, represent the above two levels (and views) of the water supply-distribution chain. The Ter-Llobregat (Barcelona) Site represents the level 1 view and the Pilot Site partner (ACA) represents a River Basin entity (i.e. Regulator). The Karlsruhe Site represents the level 2 view and the Pilot Site partner (SWKA) represents a Water Utility entity (i.e. is a Service Provider to water users). Interaction with the two sites revealed that both put much higher priority to improving short-term demand management processes, needing WDMS support for such. Naturally, such processes are quite different for the two sites and the respective Actors, due to the fact that they view the Water System from quite different perspectives (i.e. management levels). Level 1 Actor (ACA) puts priority to short-term water allocation/regulation processes, seeking to optimize the use of its water resources; while Level 2 Actor (SWKA) puts priority to the improvement of daily/hourly (thus very short-term) operations for its urban distribution network (e.g. scheduling pump &

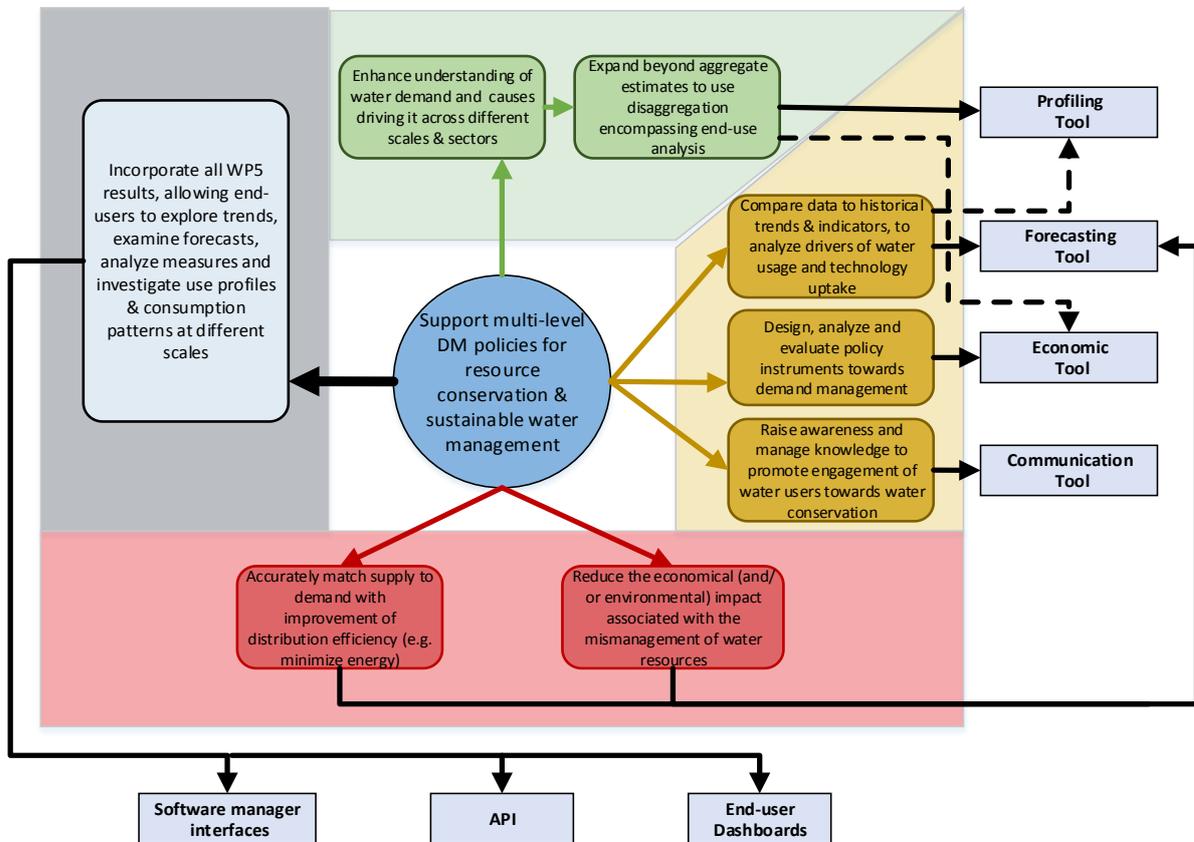
tank/reservoir operation), seeking to optimize energy use and costs through the micro-regulation of water supply (and the corresponding water losses). In addition, ACA, representing a relatively water poor region and much concerned with issues of water availability is interested in investigating / assessing water saving policy instruments; while SWKA, representing a relatively water rich region, puts very low priority on such measures, although it remains interested on assessing the impact of changes in water tariffs on system economics.

It is for such reasons that a WDMS development choice has been to put higher emphasis on short and medium-term water demand management processes, rather than on long-term planning. And it is in this area that WatERP would be, by design, most innovative and effective overall, given its OMP concept, which is supported both by an extensive ontology, WaterML ontology extensions and ontology-enabled data warehouse and also by the handling of real-time data and external information systems through ESI and the MAS architecture. It should be stressed that this WDMS emphasis on supporting short and medium-term processes (with a view to increasing their efficiency and/or effectiveness) may not only produce short or medium-term benefits, but also, through repeated (or continuous) application over a long enough period of time, it may contribute to the long-term conservation of natural resources.

Right from the start -and this has been confirmed by subsequent Project's work so far- it became apparent that WDMS functionality (services) needed to support water demand management processes, by providing answers to questions, such as those presented in above in Figure 11 and Figure 12, can be grouped into four (4) functionality groups. These can be thought off and also be practically implemented as discreet software tools, namely:

- i. A **Forecasting Tool**, that provides accurate water demand forecasts, used to optimize processes as those described above; Further, more process-specific, support for planning or scheduling these processes is provided through a DSS, such as the Water DSS developed in WatERP;
- ii. An **Economic Tool**, used for supporting decisions concerning the formulation and implementation of water demand management policies;
- iii. A **Profiling Tool**, used for understanding the water use side of the water system and planning water demand management policies and strategies; Used also as a data server by the other tools; and
- iv. A **Communication Tool**, used for communicating such policies and inducing water saving behavior to individual water users.

This WDMS functionality and the respective tools, alone or in conjunction with other WatERP components, work towards the realization of the objectives set for WatERP / WP5 and the Water Demand Management System, as exemplified in Figure 13.



**Figure 13:** Overall scheme of WDMS functionality relation to WP5/WDMS purpose & objectives.

These tools have already been designed and tested, as a result of tasks 5.1 to 5.4. Integrating these tools into a WDMS enhances their efficiency and potential, through their interaction and synergies, as well as the sharing of informational and computational resources. It also permits the exposure of their services, both to software developers and end-users, according to a common organized and consistent interface design. Even more importantly, it allows for the implementation of a holistic (multi-stage) water demand management action plan, being able to encourage and support actions & policies at different levels of the water supply-distribution chain. This may be achieved by targeting the four functionality groups, through WDMS integrated environment, for supporting an integrated 4-tier water demand management approach:

- i. Realizing that the main prerequisite for resource conservation is accurate demand forecasting as an input to critical scheduling & allocation-regulation processes along the water chain (so as not to overuse natural or financial resources), WDMS would provide a suitable demand forecasting tool. This is aimed specifically at short-term water management processes, since the analysis proved these are critical for resource conservation within WatERP’s context (e.g. water supply regulation, pump scheduling). Since such processes are multiple and polymorphic, a flexible automatic tool, callable from any external software process as well as

- WatERP's Water DSS, would be provided. Interactive use of the tool would also been provided for, to take care of situations requiring direct personal judgement (e.g. scheduling of maintenance operations or special events).
- ii. Going further than daily management operations (as in (i)), long-term planning and formulation of water management policies, measures and regulations require a good working understanding of the components of water demand, the factors that influence it and its trends. WDMS would enhance that understanding by providing a water use profiling tool, designed to organize/structure and analyse available information -historical as well as real-time- related to water demand. This is achieved by: (a) providing a Water Use Registry, that disaggregates water demand into its structural components and unit uses and containing multiple information layers of both international reference values and values from recent local measurements; (b) providing analytic functions that allow end-users to explore trends, analyse factors that influence water demand and investigate use profiles and consumption patterns at different spatial and time scales.
  - iii. Having formulated a water management policy and considered various alternative tactics and policy instruments for its realization (e.g. aided by knowledge presented in the D5.3 report), a decision-making process has to be carried out for implementing it. For that, WDMS would provide a decision support tool for designing, analysing and evaluating various potential demand management policy instruments (economic, fiscal, regulatory and technological). This is based on an end-use/unit use demand prediction model that can also be used to produce instrument-independent (BAU) medium to long-term demand forecasts for long-term planning purposes. Through this model, the short as well as the long-term aggregate impacts of policy instruments on water demand would be evaluated, providing input to an assessment methodology that models the whole water supply-distribution chain, including all actors and stakeholders, in order to fully account for secondary economic and distributional effects (e.g. changes in costs and revenues) and assess the viability, equity and affordability of potential instruments. The tool would be useable both interactively, through the OMP Dashboards (provided by WatERP) and/or through the software interface by some additional DSS, that might be developed in the future and added to the OMP, using the Open Platform's protocols.
  - iv. Finally, having in place some medium or long-term water demand management policy and, possibly, a set of policy instruments to implement, a web-based communication tool would be provided by WDMS to support that policy from the demand side, i.e. targeted to the water consumer. This tool would be aimed at (a) maximizing the impact of measures by providing relevant knowledge directly to the water consumer (i.e. realization of the rational consumer principle); (b) enhancing the consumer's awareness and persuading him towards efficiency in water usage. To that purpose, an awareness raising tool, applying captology and gamification principles and social web approaches, has been developed to promote the engagement of water users towards water conservation.

This approach allows for the sharing and analysis of information and data across different decision-making levels and spatial scales. It may be noted that, even beyond this 4-tier approach, WDMS would provide support for long-term planning of water resources and infrastructure expansion or update. As mentioned above, such support would be based on the WDMS Profiling Tool, for analysing water use and water demand trends, and on the WDMS Economic Tool for long-term demand forecasting and for developing long-term water demand management policies. Further analysing this approach, the main groups of potential water demand management procedures, which are found to lie within the objectives of WATERP/WDMS, in relation with the WDMS tool functionalities that may support them, can be defined as follows:

**Group A:** Short-term (day-to-day or weekly) management of current water resources, water service providing operations and other related actions, aiming at improving the efficiency of operations and preparing for contingencies:

- i. Optimization of current water supply-distribution operations and minimization of the energy usage in them, by closely matching supply to demand (use of forecasting tool via the DSS);
- ii. Determination of the most suitable, for the foreseeable conditions of the current DM period, water supply (or water resource management) scenario or contingency plan, that minimizes cost and use of valuable water resources (use of forecasting tool via the DSS);
- iii. Investigating possibilities and planning / preparing for various other short-term DM actions and contingencies (e.g. maintenance/closure of facilities/network, preparing for special events, implementation of development/action plans, public or private consultations, etc.) (use of forecasting tool for information purposes, water demand-trends analysis/profiling tool).

**Group B:** Medium-term (seasonal, yearly) or long-term (a few years ahead) planning for managing water resources and ensuring their sufficiency, by implementing measures and actions, aiming at reducing water use and/or financing the water system's sustainability:

- i. Assessment of a proposed DM policy / measure (use of economic tool);
- ii. Determination of the best DM policy / measure for achieving a (demand and/or economic) goal or set of goals (use of economic tool, directly or through external DSS);
- iii. Optimization of a selected/existing DM measure (use of economic tool, directly or through external DSS);
- iv. Planning for a water saving communication policy and setting up for its implementation strategy (use of water use profiling and demand analysis/profiling tool).

**Group C:** Medium-term (seasonal, yearly) to long-term (years ahead) planning of water supply (resources, service operations and infrastructure development) or of water demand regulation (e.g. water users' behavioral modification), aiming at ensuring sustainability and water system operational efficiency:

- i. Provision of knowledge to water-system managers along the supply-distribution chain, about the state of affairs in the system with regards to supply and demand and their internal & external environment, and setting of goals & priorities for long-term development (use water demand analysis/profiling tool, use of economic tool for information only);
- ii. Evaluation of trends in water demand and the rates of consumption and estimation of future needs in water and infrastructure (use water demand analysis/profiling tool, economic tool);
- iii. Design of long-term demand management policies and instruments for achieving demand & economic goals and closing gaps between demand & supply (economic tool);
- iv. The implementation of a communication policy that promotes water saving at the individual consumer unit level by behavior modification (use of communication tool);
- v. Provide information & support to a DM policy or measure through a communication strategy (use of communication tool).

In addition to functionality provided to end-users (water system managers), WDMS needs to provide functionality for internal uses (e.g. interaction between tools, sharing of resources), as well as to software managers responsible for database maintenance, model calibration, etc. This discussion is summarized in Figure 14 which presents the procedural schema (or 'roadmap') for the potential uses to which WDMS functionality might be put to. This schema provides also a bridge to the following section that describes the overall plan for implementing the WDMS and integrating its tools.

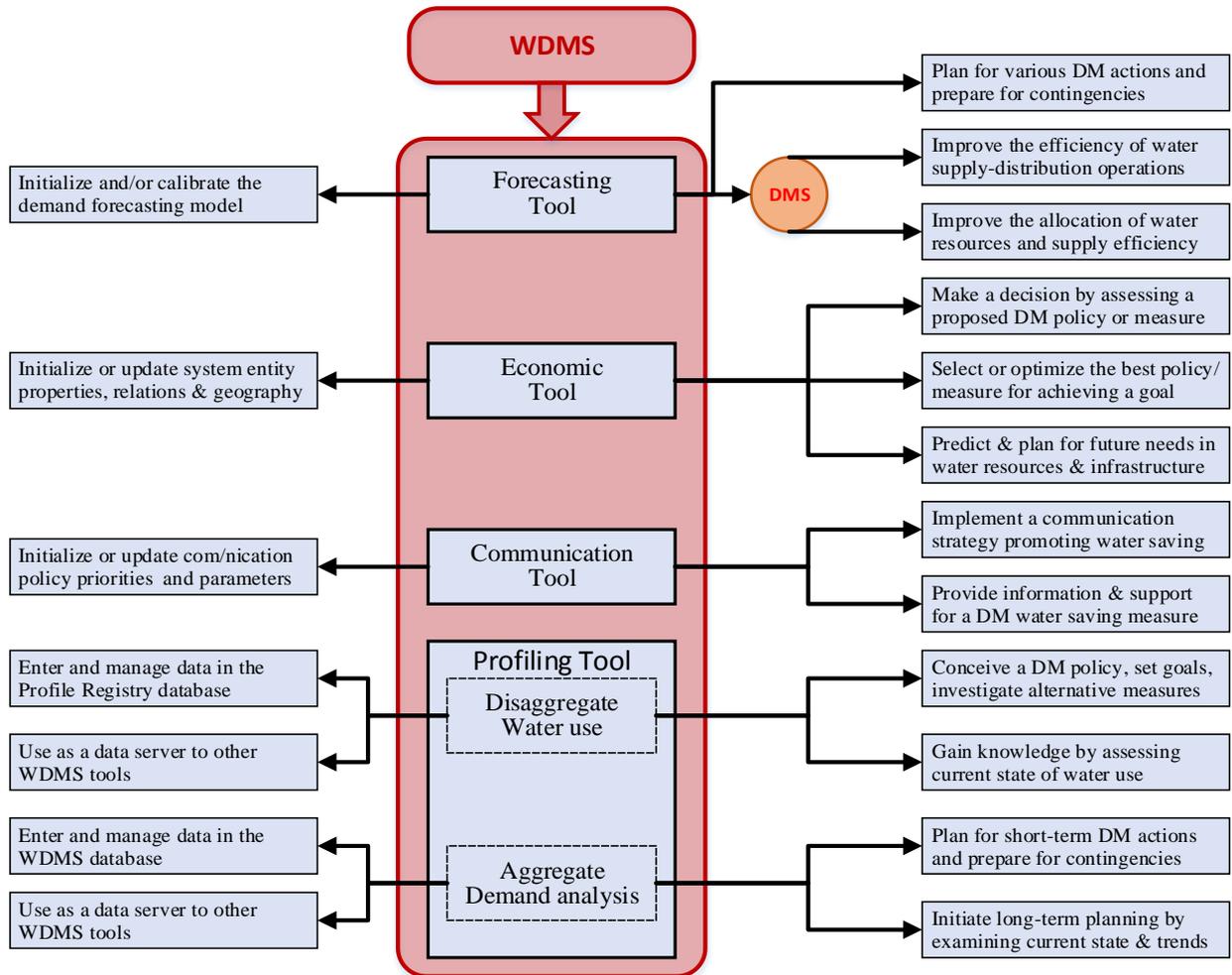
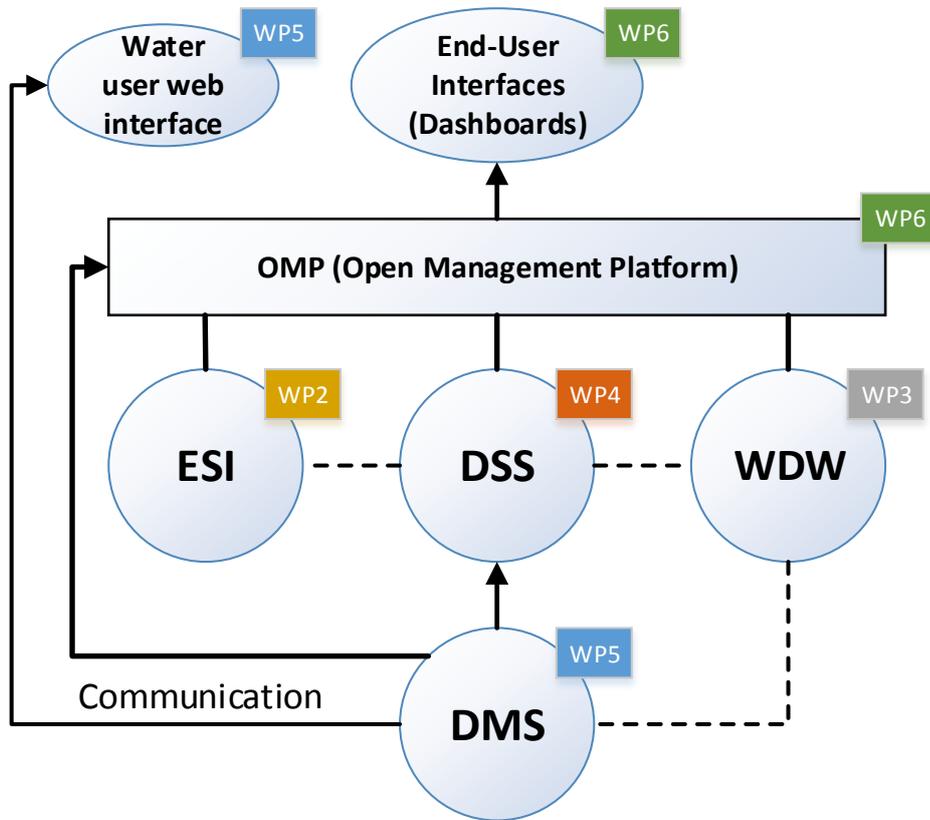


Figure 14: Roadmap to the potential use of WDMS functionality

## 3.2 Plan for filling goals & requirements

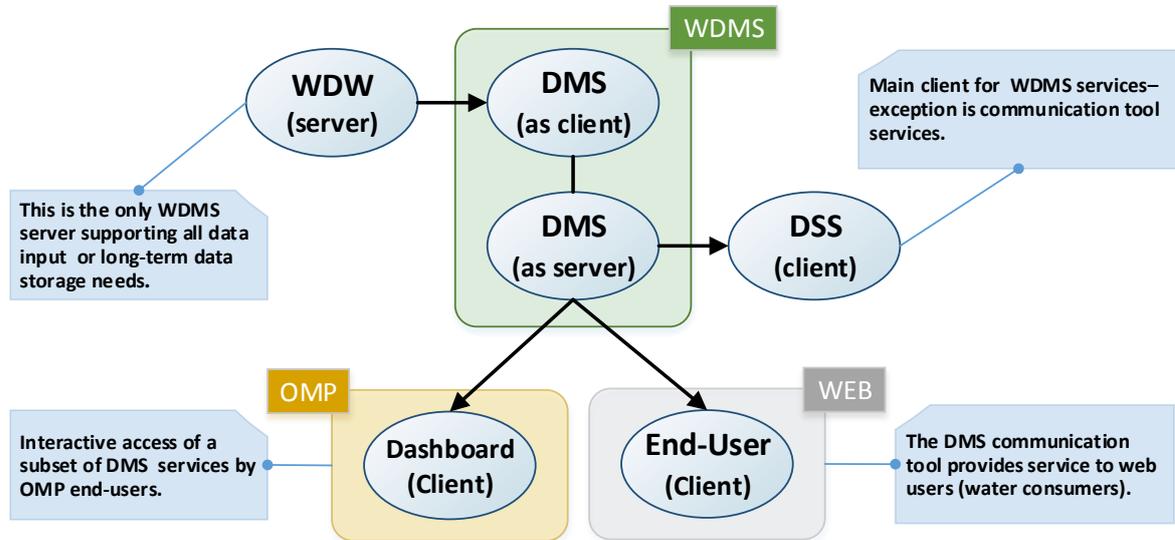
### 3.2.1 The concept & contents of a WDMS Toolkit and its development plan

The Water Demand Management System is one of the main software components of WatERP's Open Management Platform. It provides information services to end-users in three (3) different ways: (a) indirectly through a DSS (such as WatERP's Water DSS); (b) directly through OMP dashboards to OMP end-users (actors & stakeholders along the water supply-distribution chain); and (c) directly to individual water consumer units (this applies especially to the WDMS communication services/tool). This WDMS usage schema is exemplified in Figure 15.



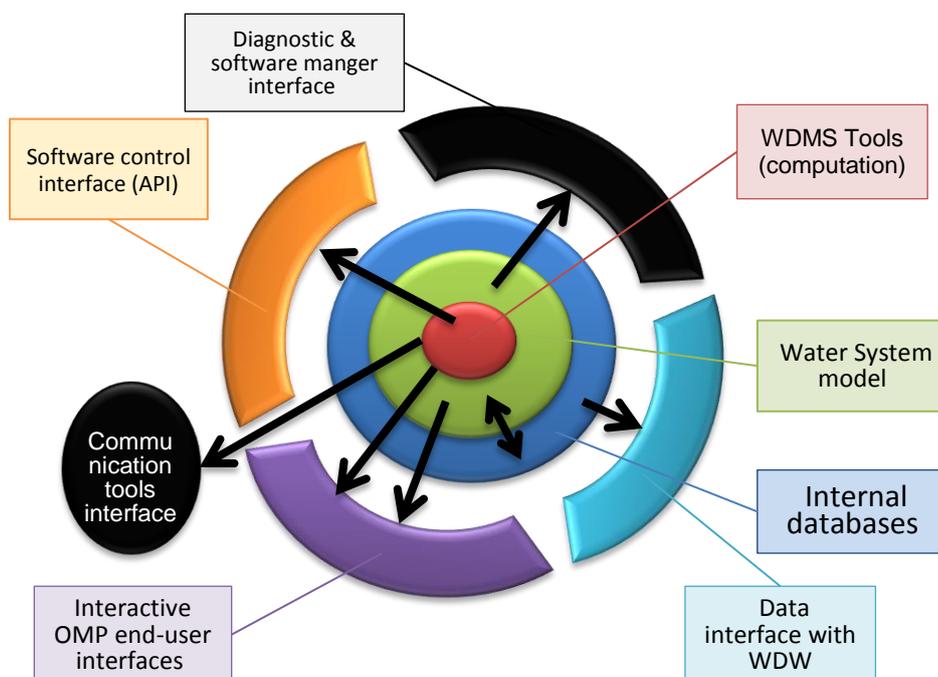
**Figure 15:** Hierarchical schema for WDMS role & provision of services.

WDMS operates and provides its services within a client-server environment enabled by the OMP (through its MAS architecture and its WaterML2 extension). Its main and only software client is this prototype version of OMP is the WatERP Water DSS. In any future implementation and deployment of the OMP it may have additional DSS components (i.e. targeted to other water management processes along the water chain) as clients. It also serves interactively OMP end-users (i.e. actors and stakeholders along the water chain) through dedicated OMP dashboards. Finally its communication tools communicate with water consumers through dedicated web forms (i.e. not through the OMP). The only server WDMS uses is the WDW component that provides data, geographical and statistical services. The general schema of these client-server relations is given by Figure 16.



**Figure 16:** General schema of WDMS client-server relations to other components & end-users.

WDMS has already been defined as a Toolbox, meaning that its functionality is expressed and exported as a set of four (4) functional groups or Software Tools, whose functionality has been briefly described in the preceding section. However, WDMS must be more than a collection of stand-alone tools. There is a matter of shared resources, as well as a unifying overall concept and model (data as well as computational) of the water system. These, combined with the schema of Figure 16, lead to the conceptual structure for WDMS presented in Figure 17.



**Figure 17:** Conceptual structure of WDW software component.

In addition to the core functionality groups discussed previously, which directly contribute towards the WATERP/WDMS objectives, auxiliary WDMS functionality will be required for the following purposes:

- i. enabling the easy access of various classes of potential users/clients to WDMS information and computational services;
- ii. sharing resources between WDMS tools and better integrating the tools into the WDMS; and
- iii. seamlessly integrating the WDMS into the OMP environment.

User access functionality (i) can be further distinguished into four (4) groups:

- OMP end-user (water system actors/stakeholders) oriented;
- Water consumer oriented;
- software management oriented (power user, software administrator, installer, pilot validation);
- application programmer oriented.

Resources sharing & tool integration functionality (ii) can be further distinguished into three (3) groups:

- use of shared data resources (organization, management & maintenance of local data sets);
- use of shared computational resources (common functions, I/O, error handling, help, etc.);
- internal services and communication pipelines for interaction between tools.

OMP integration functionality (iii) can be further distinguished into two (2) parts:

- the 'service layer' that establishes WDMS as a server on the OMP platform, able to provide information services to any client communicating through the platform protocol, as well as able to request and receive information from other OMP servers, as well as its clients;
- the software development and run-time environments of WDMS and its tools, that ensures their compatibility with the OMP environment and their secure operation within it.

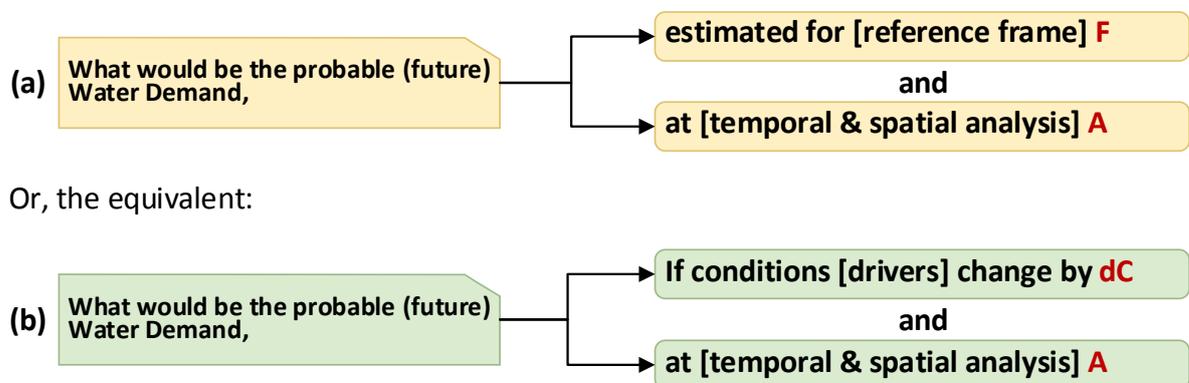
Thus WDMS, as presented in Figure 17., consists of four (4) conceptual layers: (a) the core layer comprises of all four software tools; (b) the unifying water system model layer which is closely coupled with (c) the data layer applying it, that comprises of two local data bases, one for aggregate data (historic consumption related data) and one for disaggregate data (water use profile registry); and (d) the interfaces layer. This last layer, in turn, comprises of: (i) a diagnostic and software managing interface; (ii) the OMP end-user interface (dashboards); (iii) a data I/O interface for internal use; (iv) a software application interface (API); and (v) a communication tool web interface. This discussion clarifies the concept for the integration of all four software tools (developed by tasks 5.1 to 5.4 of WP5) into WDMS and suggests a program for the integration consisting of the following steps:

- recoding the tool prototype software to achieve compatibility with software development and run-time environments;

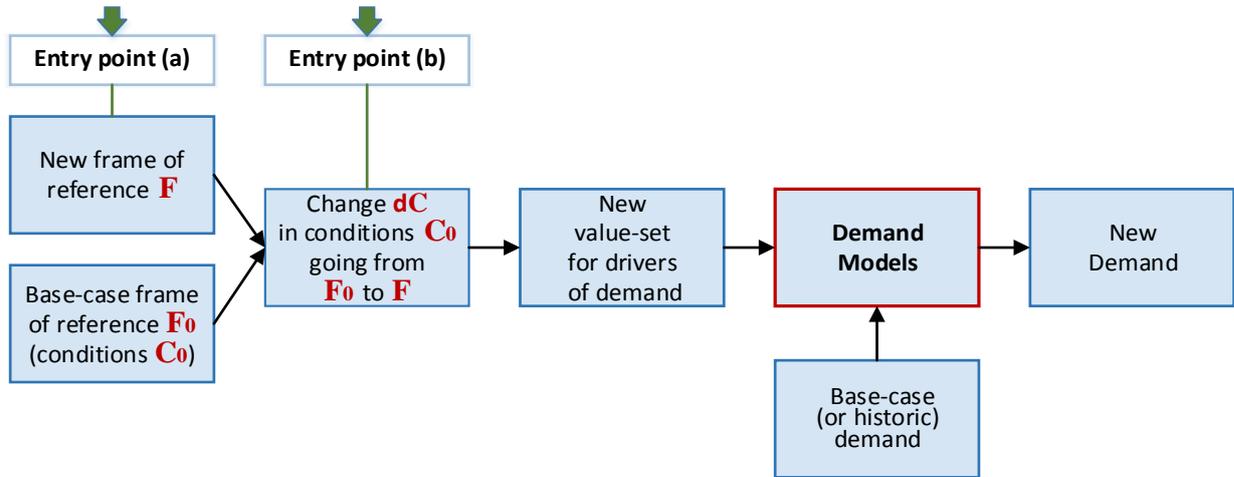
- provide any additional functionality that might be needed for achieving objectives set for WDMS;
- implementing data management processes and the sharing of resources between tools;
- creating a seamless environment for the integration of tools and for the communication (exchange of data or other software services) among them;
- creating a service layer & utilities needed for integrating WDMS into the WATERP environment;
- designing and implementing all user interfaces;
- compiling, testing and validating the software within the OMP environment.

### 3.2.2 Implementation of core water demand management methodologies

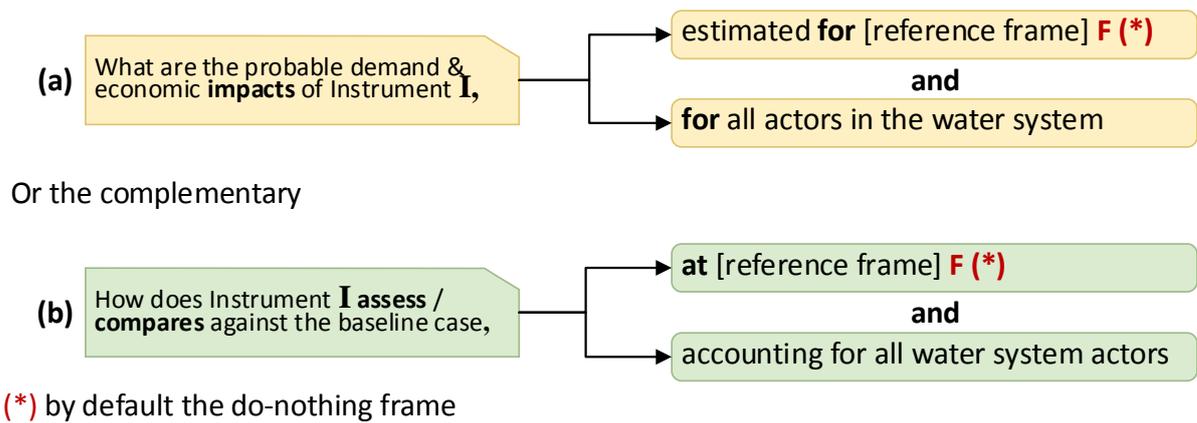
In Figure 11 and Figure 12, some potential questions were listed, that might be asked by actors involved in water demand management. WDMS support consist of providing information used to answer, directly or indirectly, such questions and this is achieved by using (one or more times, or repeatedly) one or more of the WDMS tools. Each one of these tools, can provide answers to a set of basic types of information request. This set of elementary queries constitute the basis (the building blocks) from which most other, complementary or more complex, problems or questions, concerning the management of water demand, may be translated or synthesized. In the following diagrams these sets of basic questions that may be answered by each one of the four WDMS tools are listed, followed by the corresponding generic (i.e. top level) procedural diagrams for answering these questions. In these diagrams, the reference frame of the query (scenario/conditions/time) is symbolized by **F**, the baseline frame by **F<sub>0</sub>**, the temporal & spatial frame of analysis is symbolized by **A**, the conditions (level of drivers) by **C**, the baseline conditions by **C<sub>0</sub>**, a change in conditions by **dC** and a DM policy instrument by **I**.



*Figure 18: Basic questions answered by the WDMS demand forecasting tool.*

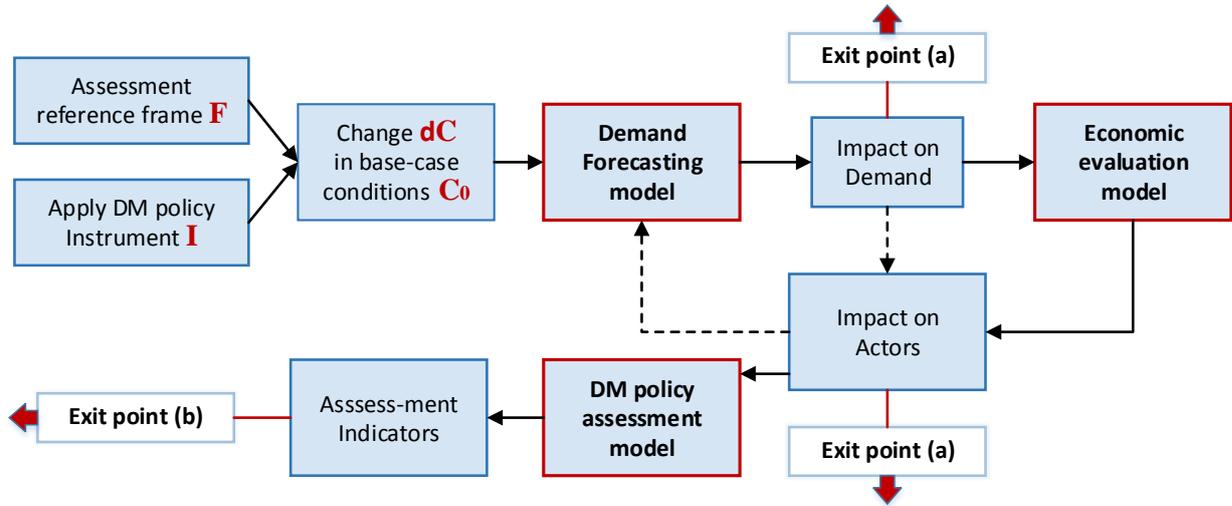


**Figure 19:** Generic procedure for answering questions concerning water demand forecasting.



**Figure 20:** Basic queries answered by the WDMS Economic Tool.

The generic methodological procedure used to provide an answer to such questions is provided by Figure 21.



*Figure 21: Generic procedure for answering questions concerning WDM policy assessment.*

## 4. WDMS Tools – Methodologies and Design

### 4.1 Demand Forecasting Tool

#### 4.1.1 Selection of the WDMS demand forecasting model

There is more than one methodology that might be usable for the purpose of developing a water demand forecasting tool for WDMS. There is no single methodology, which is optimal or even suitable for all forecasting purposes, meaning any and all water sectors, any time range, any change scenario, any time and space resolution or aggregation level. In the context of WP1, the following three alternative methodologies have been implemented and tested into the Pilot Sites.

- **The Unit Use/ End-use analysis method**, based on the disaggregation of total water use into water use units/components. The selected variation of this methodology is especially flexible by allowing for a variable degree of disaggregation and variable sources of unit use data. It can be very successful in providing long-term forecasts for scenario evaluation and as such it provides a good replacement for the regression methodologies which have been rejected from this selection;
- **The Statistical Trends Analysis method**, based on the analysis of time-related variation patterns in historical consumption data in time-series. The selected variation of this methodology incorporates into the model expert knowledge of the Water System by pre-identifying periodicities and short-term trends due to weather conditions and distinguishing them from any persistent trends handled by the usual autocorrelation components of the analysis. It can be very useful in providing short to medium term forecasts at daily or hourly time step, although the method can be easily modified to provide monthly forecasts.
- **The Similar Days method**, follows type (i) pattern recognition methodology, which uses a database driven similarity index estimation to find a set of days similar to the forecast day. The selected variation of this method normalizes the values of the similarity factors which contribute to the index, introduces distinct weights for these factors and automates the calibration process. It can be very accurate in providing short-term and very-short-term (e.g. next day) forecasts in a very fine temporal resolution (daily, hourly or even smaller steps).

The technical evaluation of the three models showed that the **'unit use'** model is more demanding in terms of data requirements, this attribute concerning not the data volume but the data types & sources. Also, this model cannot provide very accurate and/or at a small-time step short-term predictions. However, it can be very flexible in providing long-term forecasts and/or forecasts for non-BAU scenarios. On the contrary, both the **'trends analysis'** and **'similar days'** models need relatively large data volumes, but this data is readily available. Also, they excel in providing accurate short-term

forecasts at a small time-step. However, they are not suitable for providing long-term forecasts and they are not flexible in dealing with non-BAU scenarios. It has been noted, though, that change due to various factors (e.g. water price change) can be easily modeled by provided by specific (external) functions complementary to the models. Finally, it has been noted that the ‘similar day’ model can more readily provide forecasts for time steps less than an hour, while it is also more easily customized to the user’s needs by including more variables and it is more useful in extracting knowledge from this process.

Concluding, the assessment, the ‘**similar days**’ model is selected as the best water demand forecasting modeling solution for the objectives of WatERP. It is further developed to provide a full prototype for both daily and hourly demand forecasts.

#### 4.1.2 The Similar Days Demand Forecasting Model equations

The methodology is based on the ‘similar days’ pattern recognition approach, i.e. on the principle that days having similar conditions (i.e. levels of factors affecting demand) are expected to exhibit also quite similar consumption levels. Future water demand is forecasted by estimating a weighted average of actual historic water consumption data that refer to a set of days in the past, with attributes similar to the forecast day. Thus, the model comprises of two stages. At the first stage, a set [S] of  $N$  days from the recent past, similar enough to the forecast day, are selected on the basis of a number of criteria (i.e. independent explanatory variables of the model). At the second stage, demand is predicted by estimating a weighted average of the recorded historic consumption values for this particular set of similar days, using the formula:

$$d_f = \sum_{i=1}^N w_i c_i \quad (1)$$

where  $d_f$  is the forecasted water demand (daily, hourly or n-minute) for the forecast day  $f$ ,  $c_i$  is the observed water consumption of similar day  $i$  for the same time step and  $w_i$  is the influence (i.e. statistical weight) of similar day  $i$  on the demand forecasted.

Past days are included in the similarity set [S] if they are: (i) sufficiently similar to the forecast day, and (ii) recent enough, so that the basic hypothesis of the model, i.e. the correlation between day similarity and water consumption, holds true.

The similarity set must be large enough to account for sufficient statistical variation of water consumption and small enough, so that outlier values are not included. Past days are considered similar, if their characteristics (similarity factors) are very close to those of the forecast day. A quantitative expression of this concept of similarity is provided by the similarity index. It is calculated using the formula:

$$r_i = \frac{\sum_{k=1}^M v_{ik} v_{fk}}{\sqrt{\sum_{k=1}^M v_{ik}^2 \cdot \sum_{k=1}^M v_{fk}^2}} \quad (2)$$

where  $r_i$  is the similarity index for day  $i$ ,  $M$  is the number of factors influencing demand,  $v_{ik}$  is the mapping value of factor  $k$  for day  $i$  and  $v_{fk}$  is the mapping value of factor  $k$  for forecast day  $f$ . Mapping values of similarity factors are explained in the next paragraph.

The index estimated by formula (2) is a measure of the vector distance of the days  $i$  and  $f$  in the  $M$ -dimensional similarity factor space. It is analogous to a correlation coefficient and its values are assessed similarly. Past days with sufficiently high similarity index values are considered similar to the forecast day and they are included into the similarity set to be used in the demand forecast estimation formula (1). Sufficiently high are values above a pre-defined threshold  $r_c$  (e.g.  $r_i > 0.9 = r_c$ ). This is a model parameter, representing the similarity condition (i), while a second model parameter, representing condition (ii), is the cut-off point in the consumption time-line (i.e. the number of past days  $t_c$  considered for inclusion in [S]) for the similarity set. The values of both parameter are determined during the calibration of the model.

The similarity indices of days included in the similarity set [S] can be used to calculate the relative weights of similar days in formula (1), i.e. weights are linearly analogous to the degree of similarity, according to the following formula:

$$w_i = \frac{r_i}{\sum_{j=1}^N r_j} \quad (3)$$

The methodology has the advantage that, due to the way that the similarity set is compiled, error statistics and confidence levels of the resulting forecast can be directly estimated using standard statistical methods, taking into account that the most probable values and their probabilities (as estimated by the weights  $w_i$  of similar days) have already been calculated. Therefore, risk analysis, on the use of the estimated forecasts in water management procedures, can be easily performed. This can be necessary in some resource optimization cases, where the consequences of a wrong decision could be serious enough.

### 4.1.3 Methodological steps

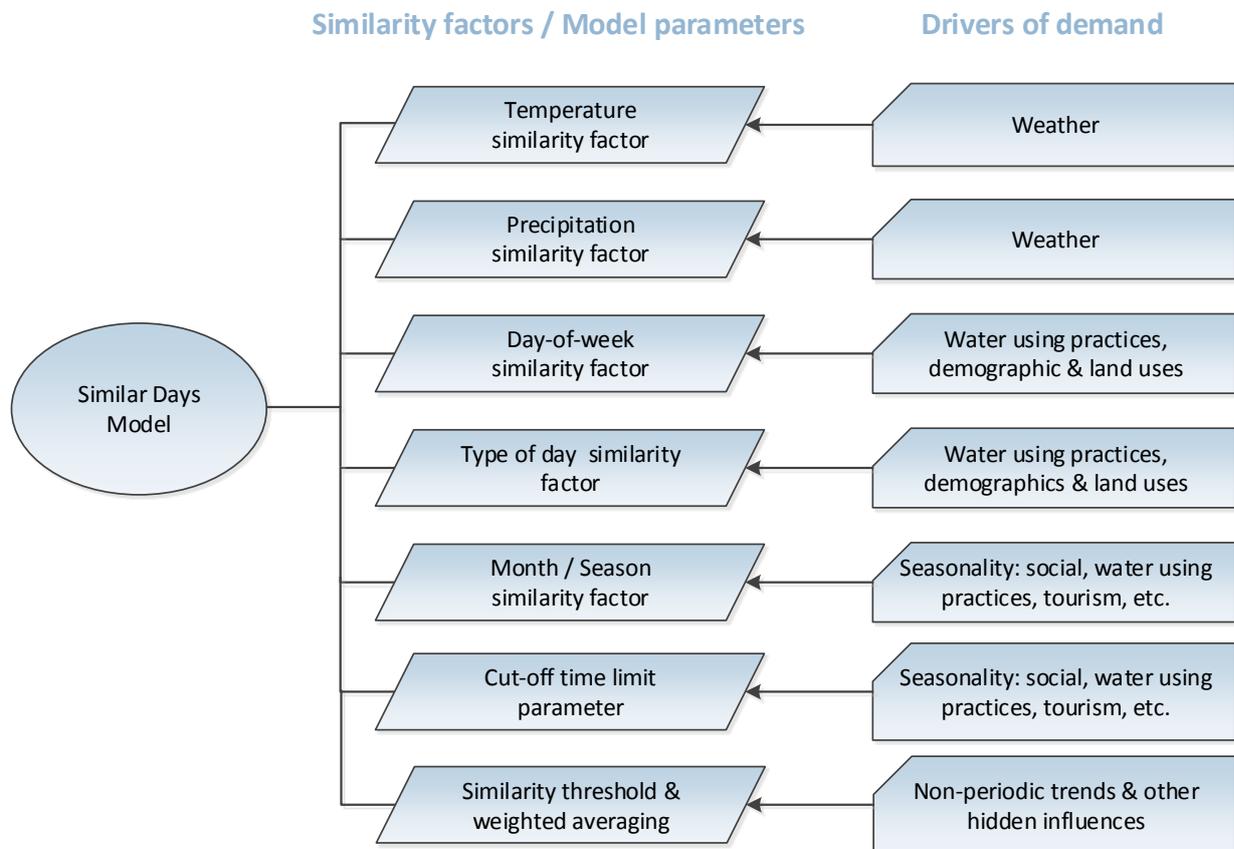
The practical application of the forecasting methodology presented in the previous paragraph can be summarized into ten procedural steps:

1. Identify the factors influencing water demand to be included in the forecasting model.
2. Establish mapping tables, to obtain the range of values for each similarity factor.
3. Compile a time-series of data for consumption and all related similarity factors.
4. Obtain/estimate predictions of the mapping values of similarity factors for the forecast day.
5. Calculate the similarity index for all days in the time-series database, which fall within the cut-off time limit  $t_c$ , using formula (2).
6. Select the set [S] of similar days to the forecasted day, by applying threshold  $r_c$ .
7. Calculate the weights/probabilities of the similar days in [S], using formula (3).

8. Estimate the demand for the forecast day, using formula (1).
9. Estimate error statistics and confidence levels.
10. Perform sensitivity and risk analysis.

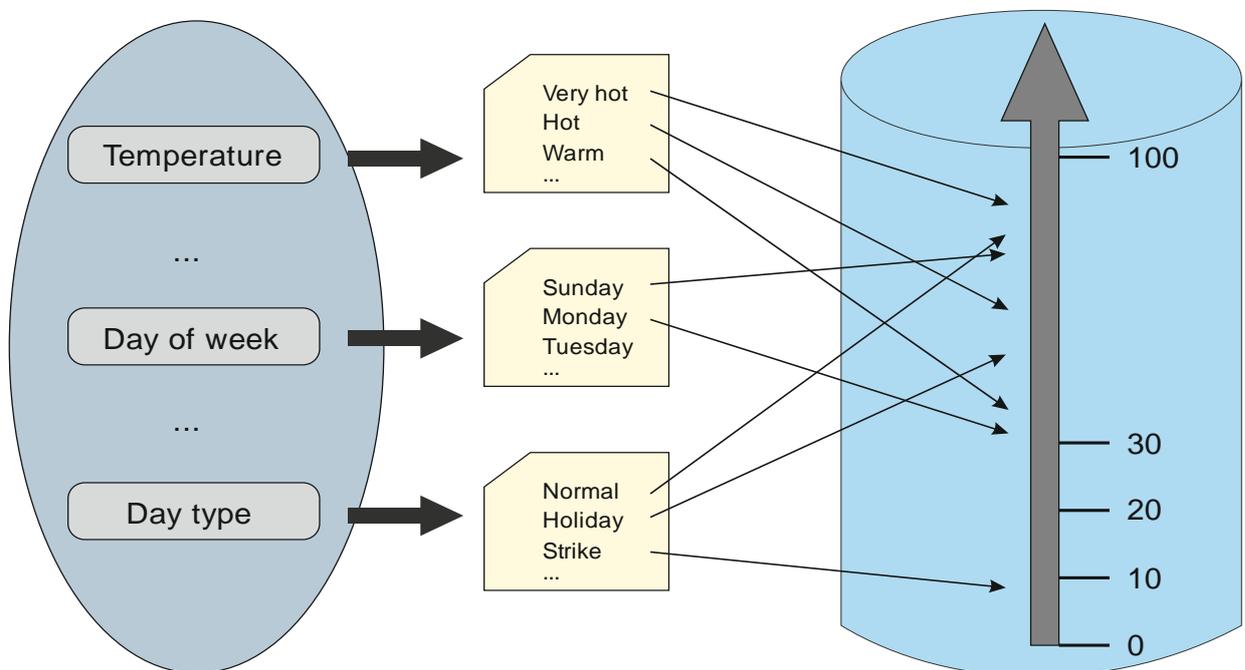
Steps 1 to 3 are implemented during the setup and calibration of the model in a new area, steps 3 to 8 are regular steps performed each time a demand forecast is required and steps 9 and 10 are part of the optional risk analysis phase.

In step 1, a set of similarity factors is selected and incorporated to initialize the mapping table. Such typical factors, expressing the drivers of water demand on a day-by-day basis, are the type of day (e.g. normal day, public holiday, strike, major sports or other special event, etc.), day of the week, month, temperature, precipitation, etc. Selection of factors is done either empirically or through the statistical study of co-variance and they should satisfy two rather obvious criteria of applicability. It should be possible to obtain and update (up to present day) a time-series of historic data values, correlated to the corresponding water consumption, and it should be feasible to predict the value of each factor for the forecast day. The main drivers of demand as expressed in the similar days model through the similarity factors and model parameters are depicted in Figure 22.



**Figure 22.** Similar Days model variables and drivers of demand expressed by them.

Similarity factors can be qualitative or quantitative, taking nominal or numerical values. In order for all factors to be comparable and usable in formula (2), quantitative factors (e.g. temperature) need to be converted into qualitative ones, by subdividing their ranges into numerical intervals and correlating those with discreet day states (nominal values). Every state needs to be mapped to a numerical ranking value in order to be entered in formula (2). This is done in Step 2, where the mapping table is filled with numeric values for each possible state (class) of each factor, in such a way as to capture the importance of each factor and provide a basis for the comparison of days. The mapping of the factor states to ranking values is accomplished by using the statistical distribution of water consumption values for each state of each factor from available time-series data. Figure 23 illustrates the concept of the mapping database (note that the numeric ranking values are normalized in the [0...100] interval). The final mapping values (weights of similarity) are obtained by multiplying the normalized value of each state with a normalized weighting coefficient for each similarity factor. Thus, the relative importance of each factor on water demand prediction is taken into account. Following that and provided that sufficient data have been made available (step 3) and that the factors' values for the forecast day are predicted (step 4), the actual calculation of the forecasted demand (steps 5 to 8) by using formulas (1) to (3), is quite straightforward.



**Figure 23.** Mapping similarity factor values.

#### 4.1.4 Implementation issues

The data required to support the forecasting procedure (steps 3, 4) are composed of three main datasets (water consumption, day characterization and meteorological data). Readily available historical consumption data are used, that should ideally be in a continuous time-series extending from the present up to three years in the past. Note that the time resolution of the forecasts depends only on the resolution of the historical consumption data; thus the described methodology can as easily forecast hourly or n-minute water demand, provided that consumption data of the same resolution (e.g. hourly) are included in the time-series.

Since forecasted demand is calculated directly from historical consumption data, the quantity estimated corresponds exactly to the topological frame of reference of these data. Therefore, the forecast can actually be a prediction of the flow through some node in the water supply-distribution network, where consumption is measured. Forecasts, in addition to regular water use, also incorporate any regular water losses (e.g. leaks, unaccountable water use), since these are incorporated in the historical data. One-off events, such as breaks, unscheduled infrastructure maintenance or supply restriction events, or other abnormal conditions cannot be forecasted (they could be possibly predicted as stochastic events in long-range forecasting, e.g. at a yearly basis). The influence of scheduled events on demand can potentially be predicted by the model, provided that there is sufficient historical data available and that a specific similarity factor is included for this purpose into the model.

The model could be used to forecast as far ahead in time as desired. However, there is a practical limitation, since the time scope is limited by the need to have an accurate forecast of the values of the similarity factors. Since these factors include meteorological conditions, this limits the useful time scope of the model to about 7 days ahead. This is not really a problem, since the model is intended to be used in short-term water management procedure, typically for planning and/or controlling next-day or at most next 48 to 72 hour operations.

## 4.2 Tool for Economic Instruments

### 4.2.1 Overall Methodology

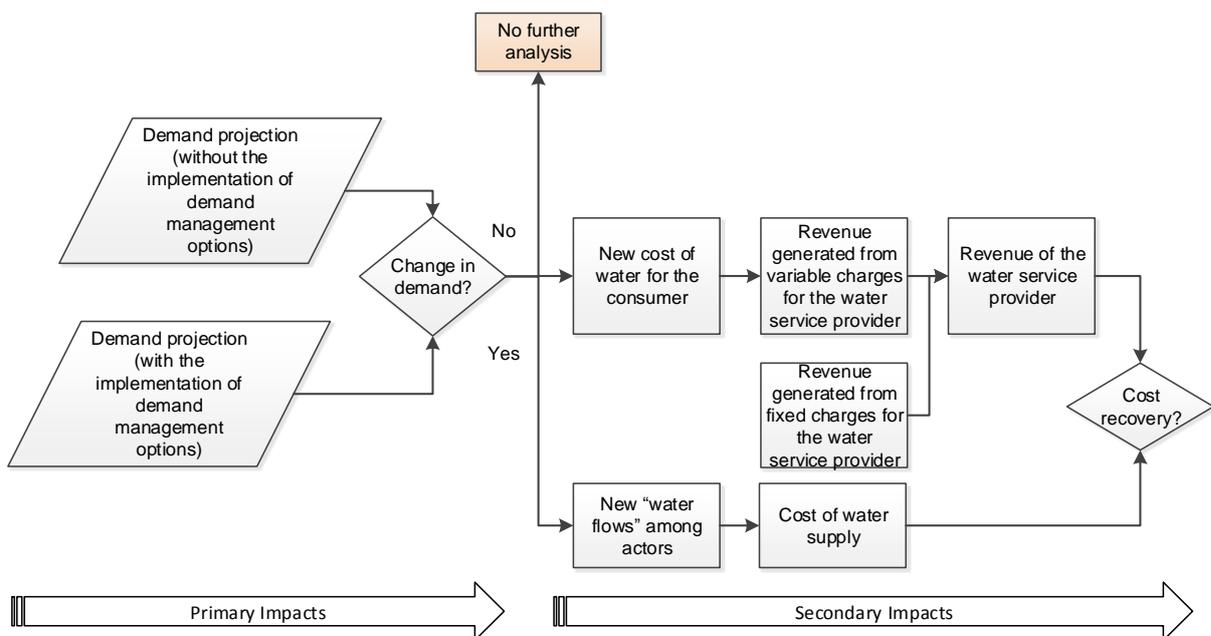
Economic instruments can be applied in order to encourage water saving and efficient use of water (**primary impacts**) and to raise revenue towards cost recovery (**secondary impacts**). The assessment of primary impacts can be achieved through either of the following two approaches:

- A **bottom-up approach**, which assesses benefits and costs for representative users. In this case, benefits correspond to avoided expenditure for water services and costs refer to capital and O&M costs for new technology/equipment. Subsequently, through e.g. agent-based modelling, results can be up-scaled to provide aggregate measures for future water demand.

- A **top-down approach**, whereby area aggregate models are used to assess the impact of instruments on water demand. In this case, price and technology are included as influencing factors in the corresponding demand forecasting models.

Secondary impacts concern potential economic effects along the water supply distribution chain. These impacts are linked to the actors managing the different components of the water supply system (bulk water suppliers, water utilities and consumers), and can be triggered from changes in water demand (through application of economic instruments, standards or other means) at any part of the water supply distribution chain.

The steps encompassed in the modelling approach by the “Tool for Economic Instruments”, for assessing the primary and secondary impacts of a demand management instrument are depicted in the flow chart of Figure 24.



**Figure 24:** Flowchart for the analysis of demand management instruments.

The assessment of primary impacts is based on a top-down approach while the secondary impacts depend on the interactions between the actors in terms of water and financial flows. The main models and methodologies that delineate the overall approach concern:

1. A representation of the institutional framework for water service provision. This concerns the actors in the water supply chain and the interactions among them. It also concerns all the water use entities and their hierarchical structure that will provide the framework for estimating water demand.
2. A long-term water demand projection model that include instrument related parameters. This model forms the basis for estimating the direct impacts (changes in water demand) from the

implementation of one or more demand management instruments. Parameters related to instruments are included as influencing factors in the demand.

3. A set of rules and equations for allocating water service costs and revenues among the different water service providers and to different end-users, allowing the estimation of the secondary impacts.
4. A scenario assessment methodology on the basis of different indicators, which assess the achievement of objectives.

#### **4.2.2 Water System Model**

An important step in developing a methodology for analysing water demand management instruments is the definition of the framework for water service provision in the examined area. This framework is mapped through the definition and modelling of all entities involved in the water supply chain. The water system model includes all the actors involved in the development, operation and maintenance of the water system (bulk water suppliers, water service providers), the water service consumers and their relations. This scheme is expanded and extended to provide for the analysis of user classes, end use activities and appliances. All the information pertaining to the water demand entities, the actors and their interactions is stored in the "Water Use Profiles Registry" (WUPR) of the WDMS and is detailed in section 4.4.2.

#### **4.2.3 Assessing the Direct Impacts of Instruments**

One of the main roles of the water system model is to support the water demand forecasting, required for the assessment of direct impacts of demand management policy instruments. The unit-use/end-use demand forecasting model that is implemented in the "Tool for Economic Instruments" is based on the analysis (disaggregation) of water use in the application area into a progressively finer tree of water use entities, as described in Figure 31. It also provides the framework for modelling the effects of demand management instruments on water demand, by defining appropriate parameters that quantify the influencing factors in the demand.

According to the unit use/end use model, water demand is disaggregated in water use sectors (*s*), in order to assess changes of the water use per sector in the overall water demand. Additionally, every sector will be subdivided in area clusters (*c*), based on socio-economic criteria or on the implementation of different tariff structures. Area clusters are further analysed into user classes (*u*), which differ by water use sector (Table 5).

The disaggregation of demand in water use sectors, area clusters and users classes represent the minimum level of analysis. An optional extended level can also be defined where user classes can be further analysed by end-use activity (*a*) and water use appliances (*ap*), as presented in Table 5. This disaggregation is very important for the analysis of many technical measures.

**Table 5:** Minimum and extended level of analysis for unit-use/end-use model.

Minimum level of analysis			Extended level of analysis	
Sectors	Area Clusters	User classes	Activities	Appliances
Urban	e.g. based on the water source, socio-economic conditions	e.g. single-family, multi-family or low-income, high-income	e.g. shower, toilet, clothes washer, tap	e.g. normal-flow or water efficient shower, half-flush or full-flush toilet, automatic top-loader, front-loader or semi-automatic clothes washer
Industrial	e.g. based on the water source, the existence of organised industrial areas	e.g. production of milk, food processing, metal processing		
Agricultural (Livestock)	e.g. based on the water source	e.g. beef cattle, sheep-goats, chicken		
Agricultural (Irrigation)	e.g. area served by public/common irrigation network vs. self-supply	e.g. arable crops, vegetables, fruits		

The unit-use/end-use water demand model is based on the following formula, providing the water demand for a specific user class:

$$Q_{u,t} = q_{u,t} \cdot N_{u,t} \quad (4)$$

where:

- $Q_{u,t}$  Water demand for user class ( $u$ ), at time period ( $t$ );
- $q_{u,t}$  Per unit use water demand of user class ( $u$ ) at time period ( $t$ ); and
- $N_{u,t}$  Number of units for user class ( $u$ ) at time period ( $t$ ).

Both “per unit use” ( $q_{u,t}$ ) and the “number of units” ( $N_{u,t}$ ) are generic variables, which can take different forms based on the user class and the type of water use unit (person, household, crop area, etc.). The per unit use water demand is estimated by using formula:

$$q_{u,t} = qo_u \cdot f_P(P, e) \cdot f_S(S_A) \cdot f_t(t) \cdot f_I(I, e) \cdot f_w(T, Pr, e^T, e^P) \quad (5)$$

where:

$qo_u$	Per unit use water demand of user class ( $u$ ) at the baseline state;
$f_p(P, e)$	Unit use change factor related to the price of water ( $P$ ) with the corresponding elasticity ( $e$ );
$f_s(S_A)$	Unit use change factor due to alternative supply options;
$f_l(I, e^I)$	Unit use change factor related to the income of consumer ( $I$ ) with the corresponding elasticity ( $e^I$ );
$f_t(t)$	Time variation factor of water demand that expresses the variation of the unit use from the typical average use at the forecasted time period ( $t$ ); and
$f_w(T, P_r, e^T, e^P)$	Factors related to weather condition, such as temperature ( $T$ ) and precipitation ( $P_r$ ), with the corresponding elasticity factors ( $e^T, e^P$ ).

The water demand of user classes, calculated by (4), can be aggregated up to the area clusters, water use sectors and total area, as follows:

$$Q_{c,t} = \sum_{u=1}^{nu_c} Q_{u,t} \quad (6)$$

$$Q_{s,t} = \sum_{c=1}^{nc_s} Q_{c,t} \quad (7)$$

$$Q_t = \sum_{s=1}^{ns} Q_{s,t} \quad (8)$$

where:

$Q_{c,t}$	Water demand for area cluster ( $c$ ), at time period ( $t$ );
$Q_{s,t}$	Water demand for water use sector ( $s$ ), at time period ( $t$ );
$Q_t$	Total water demand at time period ( $t$ );
$nu_c$	Number of user classes ( $u$ ) in cluster $c$ ;
$nc_s$	Number of area clusters ( $c$ ) in sector $s$ ; and
$ns$	Number of water use sectors ( $s$ ).

When the extended level of analysis (see Table 5) has been applied, extra equations can be formulated for the calculation of the per unit water use  $qo_u$  of user classes, based on the disaggregation of water use in activities and appliances:

$$qO_u = \sum_{a=1}^{na_u} qO_a \cdot f_a \quad (9)$$

$$qO_a = \sum_{p=1}^{np_a} qO_p \cdot c_p \quad (10)$$

where:

$na_u$  Number of end use activities ( $a$ ) of user class  $u$ ;

$qO_a$  Water consumption per end use activity  $a$ ;

$f_a$  Frequency of end use activity  $a$ ;

$np_a$  Number of appliances ( $p$ ) for end use activities  $a$ ;

$qO_p$  Water consumption per use of appliance  $p$ ; and

$c_p$  Coverage of appliance  $p$ .

The power of unit-use/end-use model is in the rich set of parameters that can be used to explain the influence of various factors on demand (drivers of demand). Price, technology, consumers income are included as influencing factors and the corresponding parameters can be used to model the application of demand management instruments.

The factors influencing the per unit water use are summarized in Table 6. The table also present the formula expressing the influence of each factor as well as the relevant model parameters. The table include all possible factors and not just those that are used to model the relevant to Pilot Sites instruments.

**Table 6:** Factors influencing the per unit water demand.

Driver	Term in Unit Use Eq.	Description	Expression	Parameters
Price	$f_p(P, e)$	Price change factor	$f_p(P, e) = 1 + \left( \frac{e \cdot (P - P_0)}{P_0} \right)$	$P_0$ : Price at the baseline state $P$ : Price at forecast time period $e$ : Price elasticity
Income	$f_I(I, e^I)$	Income change factor	$f_I(I, e^I) = \left( \frac{I}{I_0} \right)^{e^I}$	$I_0$ : Income at the baseline state $I$ : Income at forecast time period $e^I$ : Elasticity on income

Driver	Term in Unit Use Eq.	Description	Expression	Parameters
Technology	$f_S(S)$	Percentage reduction of water use due to alternative supply options	$f_S(S_A) = (1 - S_A)$	$S_A$ : Percentage coverage from alternative sources
Technology	$qo_u$	Water use related to end use activities	$qo_u = \sum_{a=1}^{na_u} qo_a \cdot f_a$	$qo_a$ : Water use per end-use activity $f_a$ : Frequency of activity
Technology	$qo_a$	Water use related to water use appliances	$qo_a = \sum_{p=1}^{np_a} qo_p \cdot c_p$	$qo_p$ : Water use per use of appliance $c_p$ : Coverage of appliance
Seasonality	$f(t)$	Time variation factor	$f_t(t) = V_{m,t} \cdot V_{w,t} \cdot V_{d,t}$	$V_{m,t}$ : Seasonal variation $V_{w,t}$ : Weekly variation $V_{d,t}$ : Daily variation
Temperature & Precipitation	$f_w(T, Pr, e^T, e^P)$	Weather conditions factor	$f_w(T, Pr, e^T, e^P) = \left(\frac{T}{T_o}\right)^{e^T} \left(\frac{Pr}{Pr_o}\right)^{e^P}$	$T$ : Temperature at forecast time period $T_H$ : Historical average temperature $e^T$ : Elasticity on temperature $Pr$ : Precipitation at forecast time period $Pr_H$ : Historical average precipitation $e^P$ : Elasticity for precipitation $T_o$ : Mean baseline daily temperature $Pr_o$ : Mean baseline precipitation

The demand management instruments that can be assessed using the prototype “Tool for Economic Instruments” are summarized in Table 7, Table 8 and Table 9 for economic, technical and regulatory instruments respectively. The tables present the modelling approach for estimating the changes in the water demand, based on the unit-use/end use model, as well as the data required for assessing direct and secondary effects of each instrument.

**Table 7: Modelling approach and data requirements for economic instruments.**

Instrument	Description	Modelling approach	Data requirements (per cluster)
<b>Water pricing</b>	Change of water tariffs to encourage water saving (and increase cost recovery)	Factor related to the price of water with the corresponding elasticity ( $f_p(P, e)$ ). (see equation <b>¡Error! No se encuentra el origen de la referencia.</b> )	<ul style="list-style-type: none"> <li>• Water tariff</li> <li>• Price elasticity</li> <li>• O&amp;M costs</li> <li>• “Water flows” among actors</li> <li>• Income</li> </ul>
<b>Subsidies for facilitating technology adoption</b>	Government or utility subsidies for inducing the adoption of water saving technologies	Calculation of unit use on the basis of the water use per appliance ( $q_{op}$ ) and the percentage coverage of each type of appliance ( $c_p$ ). (see equations (9) and (10))	<ul style="list-style-type: none"> <li>• Subsidies</li> <li>• % usage of subsidies – adoption of water saving technologies</li> <li>• Water saving potential</li> <li>• Water flow per cycle or use or minute of water saving technology</li> <li>• Cost of appliances</li> <li>• O&amp;M costs</li> <li>• “Water flows” among actors</li> <li>• Income</li> </ul>

**Table 8: Modelling approach and data requirements for technical measures.**

Instrument/Measure	Description	Modelling approach	Data requirements (per cluster)
<b>Efficient irrigation methods</b>	Replacement of old irrigation techniques with new, water saving ones	Factor related to the irrigation efficiency.	<ul style="list-style-type: none"> <li>• % coverage with new, water saving irrigation techniques</li> <li>• Irrigation efficiency (%)</li> <li>• Cost</li> </ul>
<b>Reduction of network losses</b>	Replacement of old network or leakage control (e.g. through metering, pressure control)	Correction factor of total daily demand	<ul style="list-style-type: none"> <li>• % leakage</li> <li>• Replacement cost</li> <li>• Water saving potential</li> <li>• Investment cost</li> </ul>
<b>Recycling and reuse</b>	Partial coverage of water demand with treated	Factor in the equation of water demand related to alternative water supply	<ul style="list-style-type: none"> <li>• Percentage coverage from alternative sources</li> </ul>

	wastewater	sources. ( $f_S(S_A) = (1 - S_A)$ )	<ul style="list-style-type: none"> <li>Investment cost</li> </ul>
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*Table 9: Modelling approach and data requirements for regulatory instruments.*

Instrument/Measure	Description	Modelling approach	Data requirements (per cluster)
<b>Technology standards for water-related equipment/ infrastructure</b>	Setting of standards of water use rate of indoor appliances (e.g. washing machines, toilets)	Calculation of unit use on the basis of the frequency of use of each appliance	<ul style="list-style-type: none"> <li>Water flow per cycle or use or minute</li> <li>Saturation level (%)</li> <li>Cost of appliances</li> </ul>
<b>Water efficiency standards for buildings (building codes)</b>	Setting of standards for the design and construction of buildings so as to minimize the volume of water required	New value for unit use	<ul style="list-style-type: none"> <li>% of buildings constructed according to the new building code</li> <li>Unit use (before and after the new code)</li> </ul>

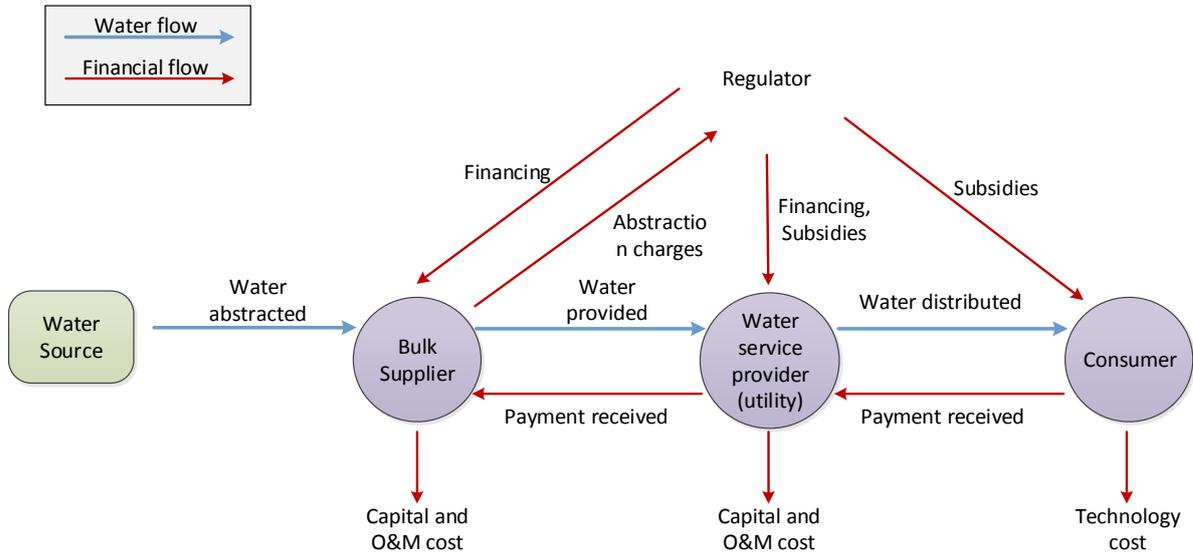
#### 4.2.4 Assessing Secondary Impacts on the Water System Actors

Secondary impacts are linked to the actors managing the different components of the water supply system. Economic interactions among actors are in form of payments for water services. Therefore, any change in water demand due to the application of an instrument (primary effect) will modify the water volume flows between actors and the corresponding financial flows (secondary effects).

Three main types of actors are identified:

- The **Consumer**, corresponding to the final water user. The main cost element of the consumers is the payment (to the corresponding water utility) for water services. Any change (reduction) in water consumption (attributed to the change in water price, the use of water saving appliances etc.) will result to changes in water bills and thus payments to the water utility.
- The **Water service provider (utility)**, corresponding to the actor responsible for the distribution of water to the different “consumers”. The water utility receives payments from consumers (revenue) and typically bears the costs for the operation of the water system and the supply of water from upstream actors. Secondary impacts are related to change in costs and revenues due to changes in billed water volumes.
- The **Bulk water supplier**, referring to the actor in charge of allocating the available water sources to different water utilities/downstream actors. The main economic parameters are abstraction charges and payments received from the downstream actors. Secondary impacts correspond to changes in costs and revenues due to changes in water volumes required downstream and the water quantities abstracted from the various sources.

The interactions among the water system actors, in terms of water and financial flows, are registered in the water system model presented in paragraph 4.2.2, and are presented in Figure 25.



**Figure 25:** Interactions among Water System Actors

### Payments and revenues for water services

These are related to the water volume flows. Considering a constant rate for water (average water price), the total payment of actor  $j$  (consumer or utility) for water services ( $Payment_j$ ) is equal to the sum of payments to actors  $i$  (utility or bulk supplier) providing the water:

$$Payment_j = \sum_i F_{i \rightarrow j} \cdot P_{i \rightarrow j} \quad (11)$$

where:

$F_{i \rightarrow j}$  Yearly water flow from actor  $i$  to actor  $j$ ; and

$P_{i \rightarrow j}$  Average water price.

The total revenue for water services for actor  $i$  (utility or bulk supplier) ( $Revenue_i$ ) is the sum of the payments received from all downstream actors  $j$ :

$$Revenue_i = \sum_j F_{i \rightarrow j} \cdot P_{i \rightarrow j} \quad (12)$$

### Operation 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. They are calculated, for actor  $i$ , according to the following equation:

$$OMCost_i = UnitOMCost_i \cdot \sum_j F_{i \rightarrow j} \quad (13)$$

where:

$UnitOMCost_i$ : Unit operation and maintenance cost (Euro/m<sup>3</sup>); and

$\sum_j F_{i \rightarrow j}$ : The yearly water outflow from actor  $i$ .

### Capital and Investment 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. The following equation is used for the calculation of annual capital cost of an infrastructure element ( $inf$ ):

$$CapCost_{inf} = \begin{cases} InvCost_{inf} * Factor_{inf} & \text{if } 0 < t - Construction\ Year_{inf} \leq Lifetime_{inf} \\ 0 & \text{otherwise} \end{cases} \quad (14)$$

where:

$InvCost_{inf}$ : Total investment cost (Euro);

$Construction\ Year_{inf}$ : The year of construction;

$Lifetime_{inf}$ : The lifetime of the infrastructure element in years; and

$Factor_{inf}$ : Depends on the depreciation method.

If a simple depreciation of investment method is used, then:

$$Factor_{inf} = \frac{1}{Lifetime_{inf}} \quad (15)$$

If an amortization of capital investment method is used, then:

$$Factor_{inf} = \frac{d * (1+d)^{Lifetime_{inf}}}{(1+d)^{Lifetime_{inf}} - 1} \quad (16)$$

where  $d$  is the chosen amortization rate.

#### 4.2.5 Scenario assessment

The assessment of a demand management instrument (or a set of instruments) is based on a number of indicators, expressing both direct and secondary impacts. The indicator chosen for expressing the direct impacts is the **Water Saving Potential**, that provides the reduction in water demand of a consumer as a result of applying the instrument/s. Indicators calculated by the “Tool for Economic Instruments” for expressing the secondary impacts pertain to two categories: (i) indicators relating to **Affordability** of water services and (ii) indicators relating to aspects of financial sustainability in water service provision (**Cost Recovery**).

##### 4.2.5.1 Water Saving Potential Indicators

The water saving potential indicator can be expressed for the whole water system as well as for each consumer.

- The system indicator ( $WSP$ ) is defined as:

$$WSP = Q_o - Q \quad (17)$$

where:

$Q_o$  Total water demand at the baseline state; and

$Q$  Total water demand after applying the instrument, as calculated by the unit-use/end-use model (equation (8)).

- The indicator for a specific consumer  $i$  ( $WSP_i$ ), is similarly defined as:

$$WSP\_CONS_i = \sum_c Q_{o_c} - \sum_c Q_c \quad (18)$$

where:

$Q_{o_c}$  Water demand for cluster  $c$  at the baseline state; and

$Q_c$  Total water demand for cluster  $c$  after applying the instrument, as calculated by the unit-use/end-use model (equation (6)).

The summation in equation (18) is performed over all clusters  $c$  of the consumer  $i$ .

#### 4.2.5.2 Affordability Indicators

Affordability can be assessed both from a macro and micro level. 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.

The Tool for “Economic Instruments” estimates two indicators relating to affordability of water services for the consumers:

- The annual expenditure of consumers for water service, which is expressed as a change from the baseline case:

$$EAF_i = Payment_{o,i} - Payment_i \quad (19)$$

where:

$Payment_{o,i}$  Total payment of consumer for water services at the baseline state; and

$Payment_i$  Total payment of consumer for water services after applying the instrument, as calculated by the unit-use/end-use model (equation (11)).

- The share of disposable income spent for water services:

$$IAFF_i = \frac{Payment_i}{Income_i} \quad (20)$$

#### 4.2.5.3 Cost Recovery

Sustainable cost recovery 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. 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 is assessed for water service providers and bulk suppliers, and is calculated by the following formula:

$$CR_i = \frac{Revenue_i}{CapCost_i + OMCost_i + Payment_i} \quad (21)$$

## 4.3 Communication Tool

### 4.3.1 Overall Methodology

The main goal of the web-based communication tool (WaterCity) is to promote engagement and enhance citizen participation in water conservation activities, through the development of novel Web 2.0 persuasive IT processes incorporating captology principles, game mechanics and social media. Through the developed Web 2.0 persuasive IT processes, it is expected that consumers using WaterCity will develop a continuous engagement towards water conservation, triggering social motivation more efficiently. To this end, **emphasis was given to the social proof persuasive strategy**, which has a strong influence on user persuasion and behavioral change towards resource conservation activities

The goal is to leverage the power of the social proof persuasive strategy when combined with social media and social networking applications with the aim to induce user behavioral change with respect to water conservation. To this end we developed WaterCity, a specifically-designed web application incorporating social networking features, through which households can receive information and feedback about their water consumption, compare their consumption to that of similar others and set and monitor water reduction goals. In WaterCity information and feedback can be presented to users in a variety of engaging and vivid ways and social proof can take on a competitive bent that may reinforce its effect. Moreover, as the application is connected to Facebook, users can spread the word about both their results with respect to water conservation and WaterCity itself through their social networks. By capitalizing on the viral effect of social networking, WaterCity can facilitate the building of a sustainable online regional community of users engaged in water conservation activities. The ultimate goal would be to change not only individuals' attitudes and practices, but also that of the greater community. This is an issue of scale.

In addition to the social proof strategy, the following strategies which have been successfully applied for pro-environmental behavioral change, e.g. for the reduction of CO<sub>2</sub> emissions and the conservation of energy were also considered in the design of the tool:

- **Self-monitoring**, i.e. allowing people to monitor themselves and especially current behavior in comparison to past behavior as the informational and experiential basis for behavioral change, while eliminating the tedium of tracking performance or status.
- **Goal setting/commitment** (consistency), i.e. getting people to commit to future actions, as people feel obligated to commitments when these commitments fulfill three features: They are active, public and voluntary. Self-monitoring is shown to be interactively related to the ability of the consumer to set meaningful goals.
- **Rewards** (conditioning) including gamification: To (virtually) reward target behaviors influences people to perform the target behavior more frequently and effectively.

- **Tailoring**, i.e. the provision of information that is tailored to the individual needs, interests, personality, usage context, or other factors relevant to the individual.

WaterCity incorporates the behavioral change strategies outlined above, with an emphasis **on the social proof strategy**. Each one of the aforementioned persuasion strategies is incorporated into all the layers of the web-based tool, starting from the user interface layer and continuing down to the business logic and data layers.

More specifically self-monitoring was implemented through graphical charts, images and tables allowing the WaterCity user to compare his/her current household water consumption to the water consumption of previous years and months, see water consumption averages and trends and track the status of both current and historical goal achievements. Their current status is communicated to WaterCity users properly through visual means such as graphical charts and images with the aim to eliminate the tedium for them for tracking their performance.

Goal setting was implemented by allowing the users to set goals and define plans towards the achievement of those goals. Plans consist of a pool of specific actions towards water conservation from which the user can choose a subset in order to define a water conservation plan for the next period. For some actions, the user is presented with a percentage representing the estimated water consumption reduction to be achieved if the action is followed. The pool of actions and the estimated water consumption for some actions, were identified as described in section 3.8.

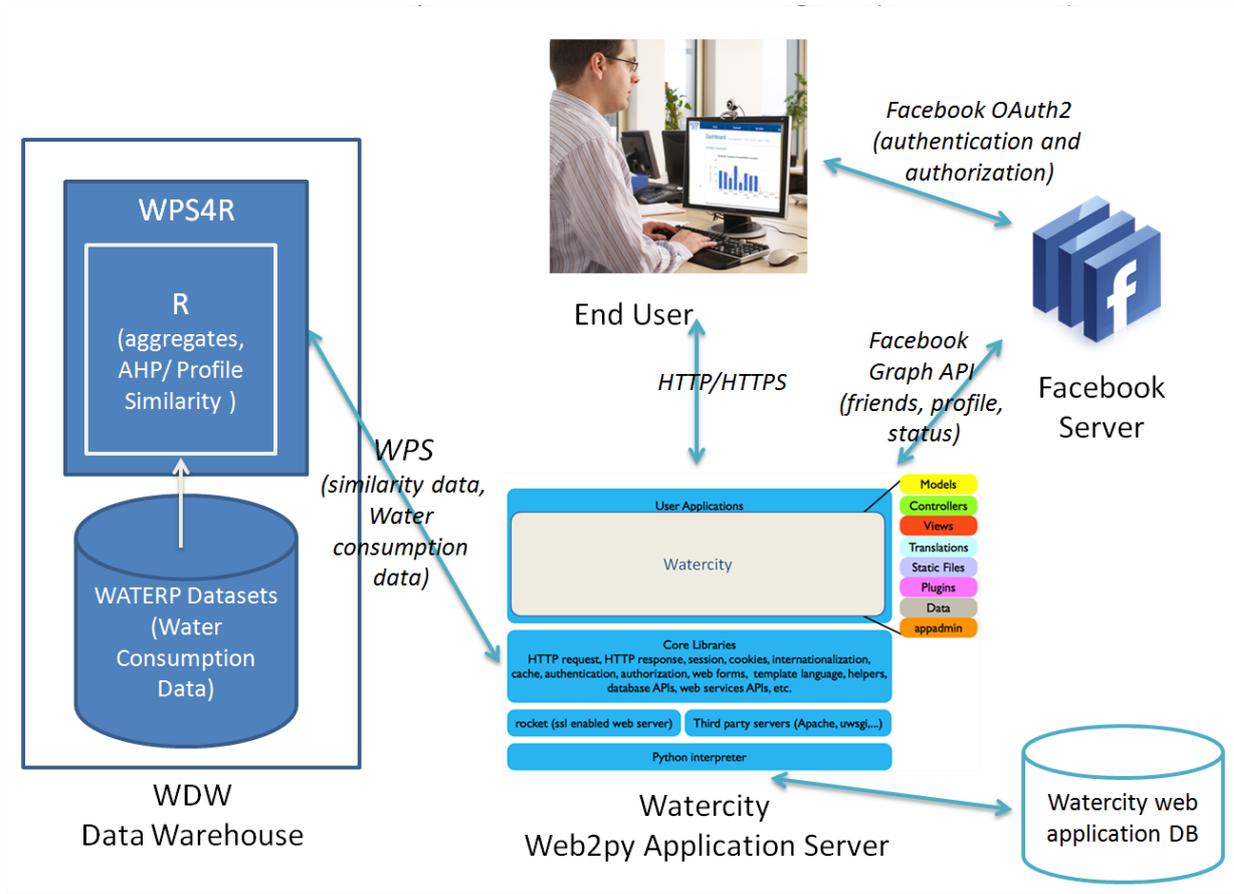
Virtual rewards implemented in the web-based tool are related to recognition. First, a hall of fame was developed listing the top three WaterCity users, which have achieved the highest reduction on their average daily consumption. Second, the average consumption reduction from the previous month is translated to estimate financial savings, so that the user can get a feeling of how his/her efforts for water conservation are translated to financial benefits. Third, a tree graphic was developed that indicates water conservation activity, with the tree accumulating leaves, the more the individual progresses in terms of water conservation.

Tailoring was approached through the personalization of the set of actions explained above, based on the features of the user profile. For example actions related to pools, dishwashers, cloth washing machines, gardens and car washing activities are not shown to users that don't possess these water consumption items in their profile. Moreover, the estimated water consumption reduction percentage per action is also tailored to the individual user profiles by considering the values of the features influencing water consumption for each user.

### 4.3.2 System Architecture

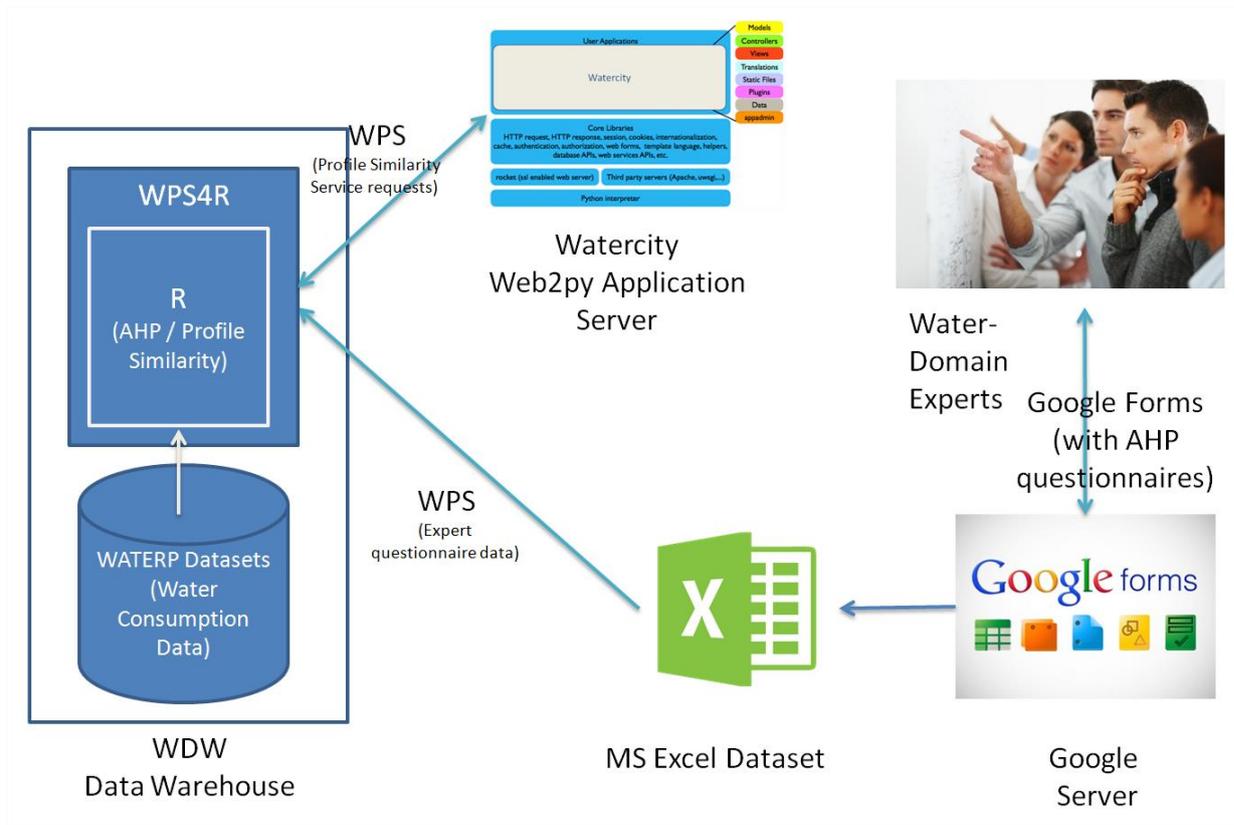
Watercity is a web-based application that has several components each one having different responsibilities inside the system. The following diagrams depict the technical architecture of the

system.



**Figure 26:** Watercity technical architecture - end-user (water consumer) subsystem.

The first diagram (**Figure 26**) depicts the components of the system that implement the functionalities which refer to the end-users of Watercity, the residential water consumers. The end users, using a common web-browser enter the system, put their data about their household, their water bills and goals and the system helps them using many different methods to monitor and lower their water use.



**Figure 27:** Watercity technical architecture - water-expert subsystem.

The second diagram (**Figure 27**) depicts the core components of the system that implement the functionalities which refer to the water-experts. The water-experts contribute data to the system that are used for the calibration of the algorithms implementing user similarity calculation functionalities. In more details the role of each module of the system is the following:

**a) Watercity web2py application**

Watercity is a Python web-application developed using the web2py framework. Web2py is an open-source web framework (released under the LGPL version 3 license) for agile development of secure database-driven web applications.

**b) WDW and WPS4R**

The WPS4R module is part of the WATERP WDW. In Watercity WPS4R is used as a module that implements facilities for complex (and usually long running) computations, such as the assessment of the similarity of user profiles, based on the mixed AHP-weighted user similarity method.

**c) Facebook OAuth2 and Graph API**

The Watercity web-application uses the Facebook platform both for user authentication/authorization and for a set of other services that it provides to social-application developers. Facebook possesses the largest social network. Watercity is a Facebook application hosted on a private server. It utilizes data

stored in Facebook such as user profile data (i.e. name, email, hometown location, photo), the social network of the user (i.e. the friends that use the Watercity app) and the ability to send invitations and notifications from within application in order to provide its services.

#### **d) Google Forms**

With the use of Google Forms water experts provide input to the mixed AHP-weighted user similarity algorithm as explained in section 3.7 of D5.4. This algorithm is implemented in R language and is based on the AHP MCDM method. Google Forms is a free service from Google that provides facilities for creating survey forms and sharing them with other users. Water experts complete online the survey forms, which have been designed (see section 3.7 of D5.4). Their responses are automatically collected in a Google Sheets spreadsheet. This spreadsheet is then exported as file and sent to the R script implementing the AHP-weighted user similarity algorithm.

### **4.3.3 Data Layer**

The data-layer of the application is described with an Entity-Relationship (ER) diagram. This data model is implemented using the Data Access Layer of the Web2py framework in combination with a relational database (the administrator can choose between MySQL, PostgreSQL, SQLite and other database engines). The main entities are depicted in Figure 28.

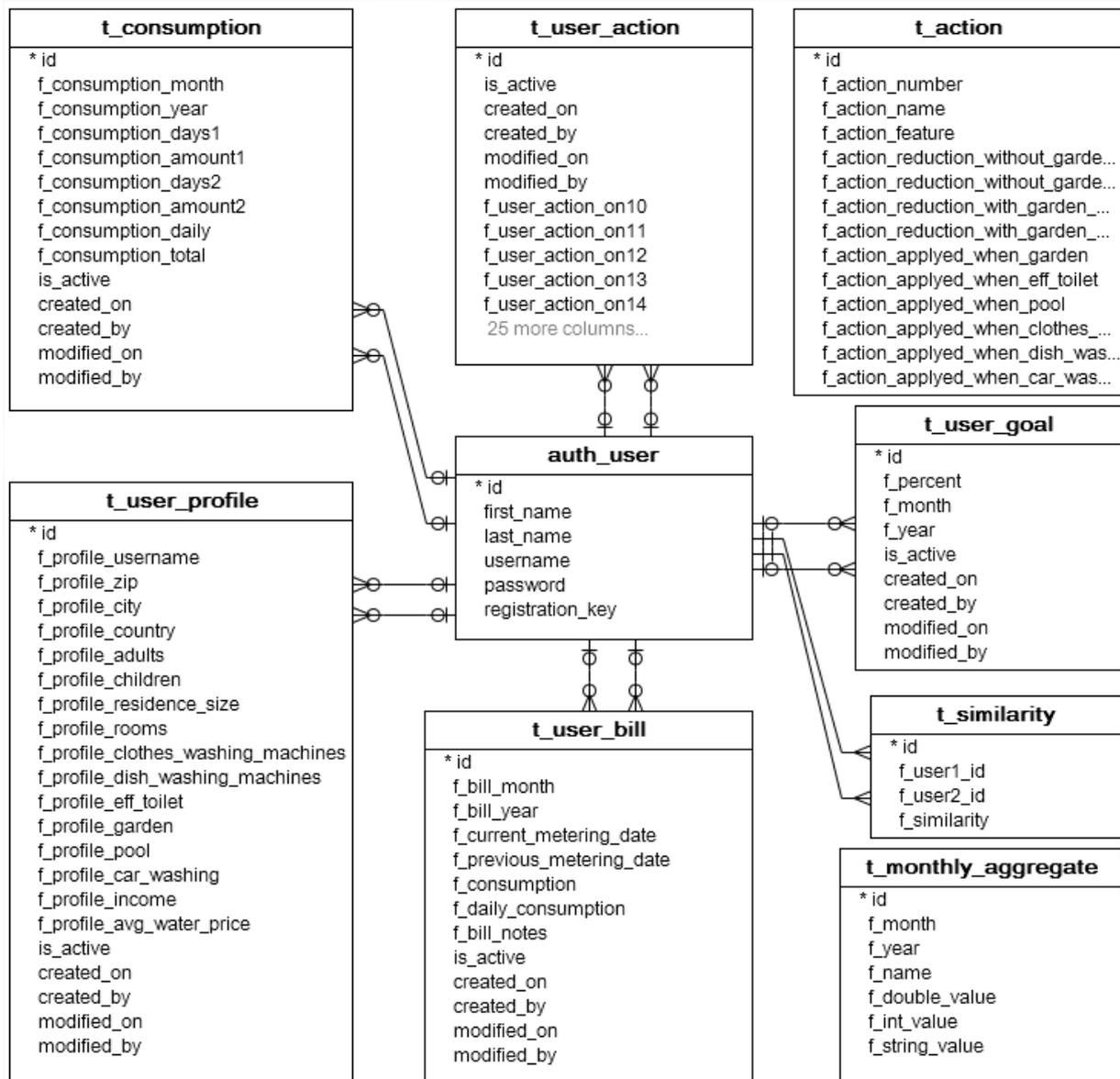


Figure 28: Watercity Data Model.

### 4.3.4 Presentation Layer

The following diagram (Figure 29) provides an overview of the information that is presented in the Watercity web-application.

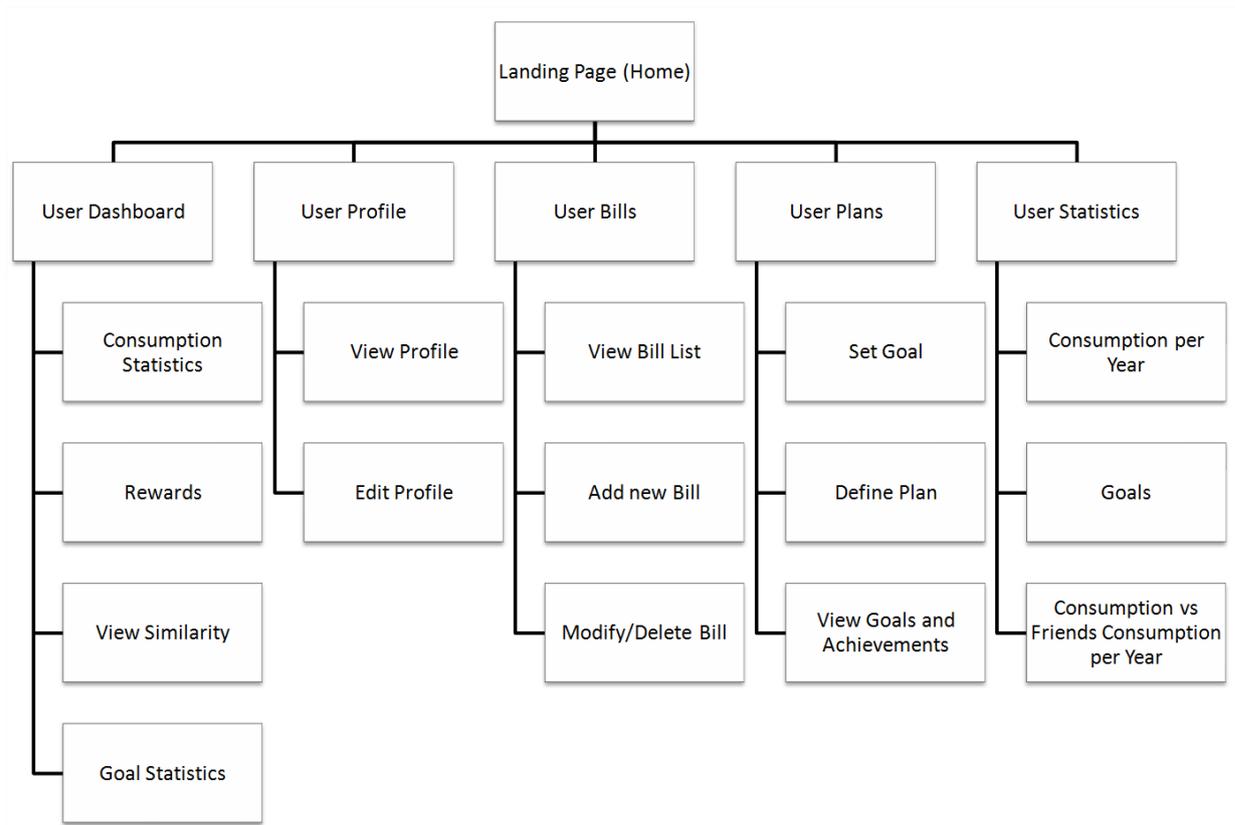


Figure 29: Watercity Information Architecture.

## 4.4 Water Use Profiling Tool

### 4.4.1 Requirements of profiling information in WatERP

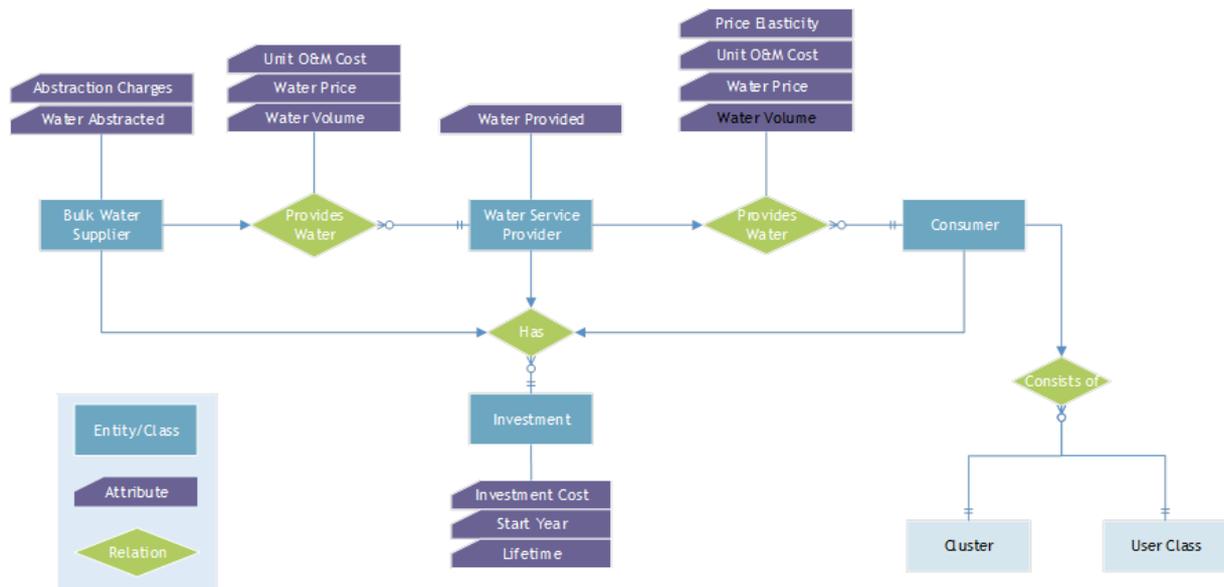
Water use profiling information is essential for supporting the functionalities of WDMS and can also be useful to the end-users of WatERP platform who need to formulate water demand management policies or do long-term planning of water. A **Water Use Profile Registry (WUPR)** has been developed, where data on water demand and water use rates can be stored and retrieved, defining where, when and how much water is used.

The registry includes profiling data along the water supply distribution chain accounting for actors, water use sectors, end-use activities and appliances, discussed in the next paragraph. The information stored in the registry may come from various sources (standards, literature, measurements as well as estimations, smart metering, etc.).

However, not only a comprehensive water use registry need be set-up to organize and store such information, but also a **Water Use Profiling Tool (WUPT)** is included to the WDMS Toolbox for the management, retrieval and analysis of profile information. Its primary function is to support the WDMS demand forecasting and economic instrument tools.

#### 4.4.2 Water system entities

In order to conform to above requirements, the WUPR is structured around the model representation of the water supply and distribution chain. This maps the actors (bulk water suppliers, water service providers and consumers) in the system and their relations (supply-side entities as in Figure 30).



**Figure 30:** Supply-side entities in the water system.

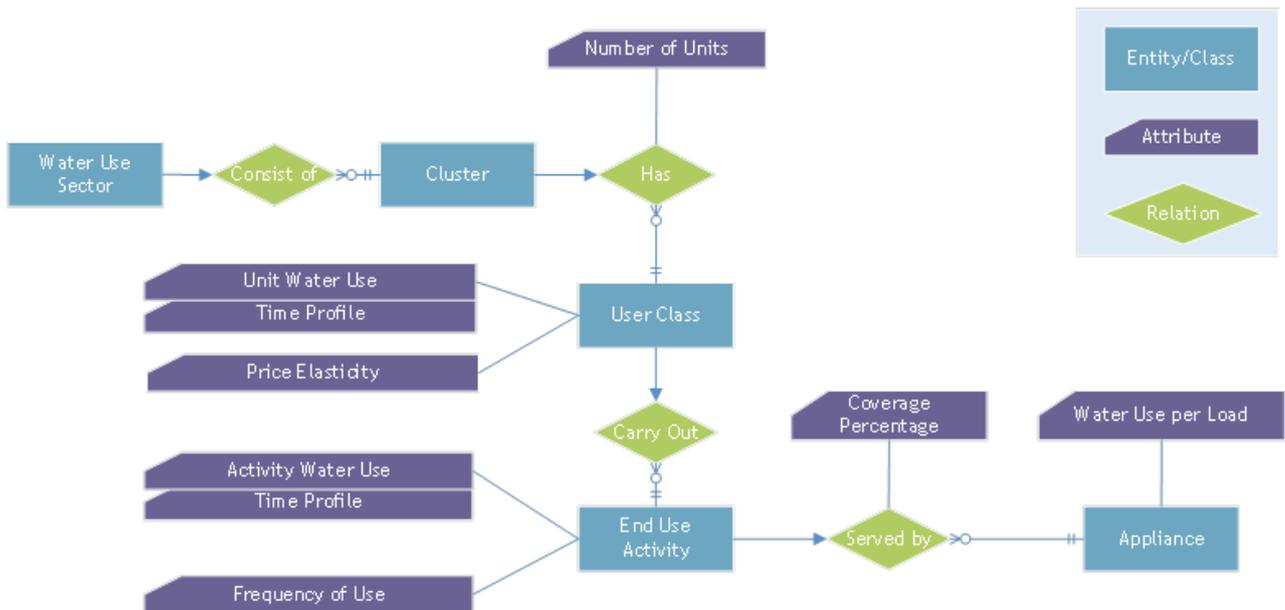
Consequently, the registry includes all entities in the above scheme, as well as their hierarchical and other relations and attributes, starting with actors (which depend on the implementation site and scale) and water use sectors (Urban, Industrial, Agricultural, Livestock, Environmental, Other)

The registry also fits all unit use profile and aggregate consumption data within this hierarchical scheme. Accordingly, this scheme is expanded and extended towards the end-use part (demand-side) to provide for:

- The analysis of users to user categories, depending on the water use sector, e.g.
  - Urban residential: single family house, multifamily house; low income, high income; etc.
  - Agriculture: categorization by crop type
  - Livestock: categorization by animal species
  - Industrial: by site and/or by product type
- The analysis of water use patterns
  - Where (links to area characteristics)
  - When (links to periodicity of activity & weather)
  - How much (consumption volume) water is used per:
    - Use type & User (e.g. residential, household)
    - End-use activity (e.g. washing, irrigation)

- Appliance (e.g. washing machine, potentially even specific brand)

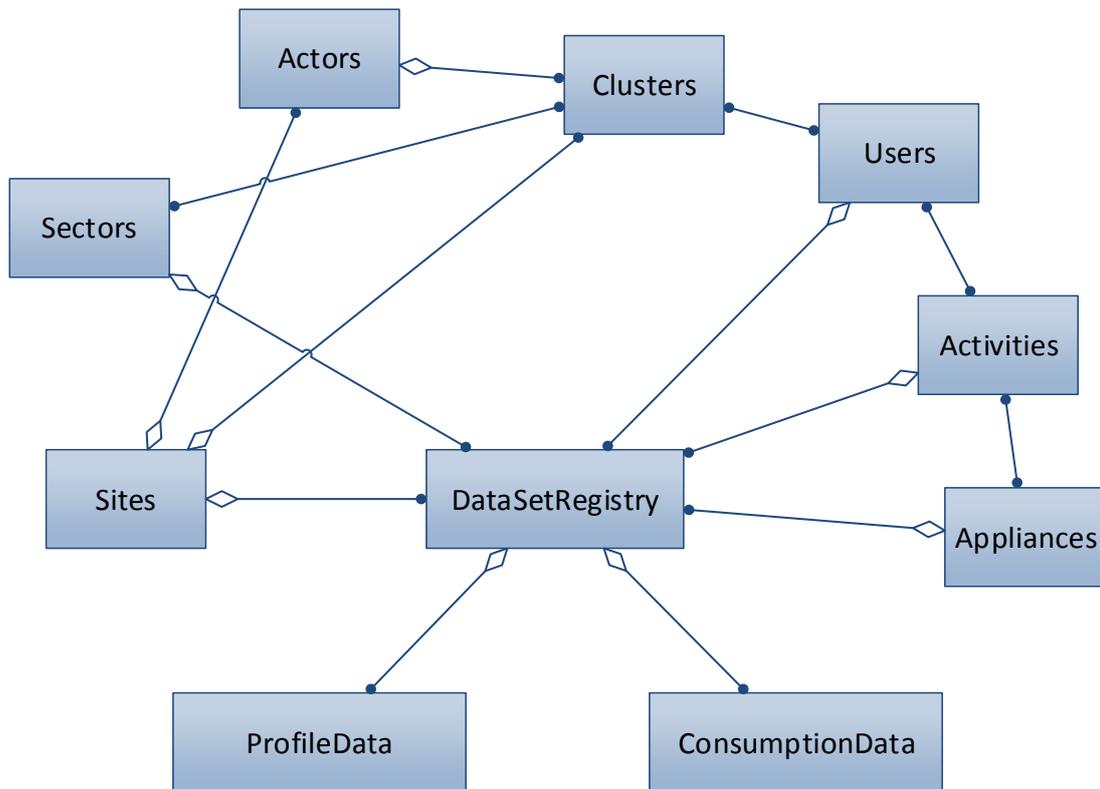
The main demand-side entity classes of the water system, their relationships and their main attributes are presented in the following diagram:



**Figure 31:** Demand-side entities in the water system.

#### 4.4.3 Water Use Profiling Registry database schema

The registry is designed as a special purpose relational database, for which entity-relation diagrams and preliminary table structures are presented. Figure 32 presents the entity-relation (ER) diagram of the database, using IDEF1X notation. The entities and the relationships are realized in database tables, the structure of which is presented in the following paragraphs.



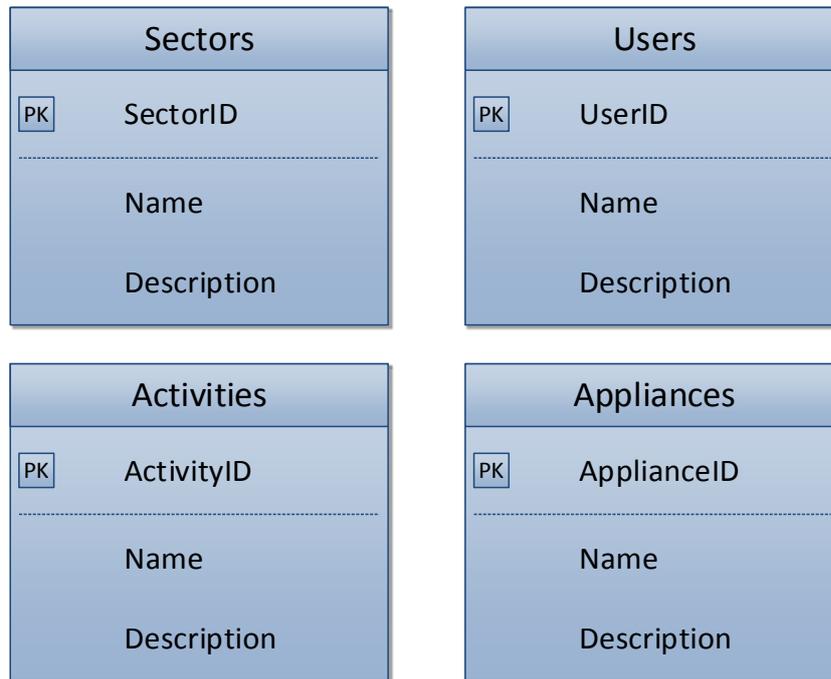
**Figure 32:** Entity-Relation diagram of the database.

### Tables representing key entities

The database tables described in Table 10 represent key entities that exist in every installation of the database. The structure of the tables is presented in Figure 33.

**Table 10:** Description of the tables representing key entities.

Table	Description
<b>Sectors</b>	Stores the water use sectors (domestic, agricultural, industrial...)
<b>Users</b>	Stores the water users (e.g. single family, multi family, industrial site)
<b>Activities</b>	Contains all possible end use activities (e.g. bath, garden irrigation, industrial process)
<b>Appliances</b>	Contains all possible end use appliances (e.g. washing machine)



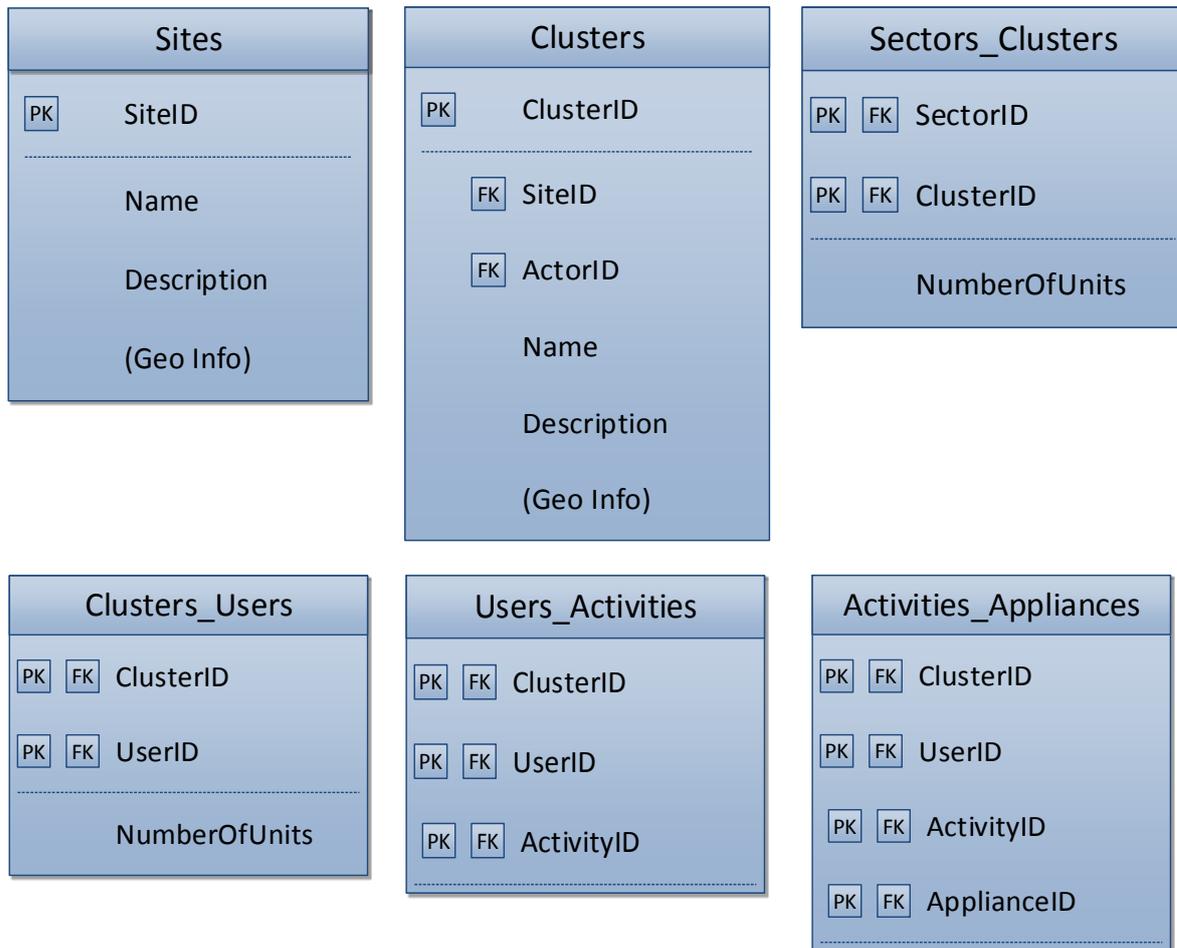
*Figure 33: Structure of the tables representing key entities.*

### Tables representing the water system

The tables of this category store all the entities and relationships that define the characteristic of the water system of an installation site. The description of the tables is presented in Table 11 and their structure is given in Figure 34.

*Table 11: Description of the tables representing the water system.*

Table	Description
<b>Sites</b>	Stores all the sites that are registered in the database. Geographical information may be defined for each site.
<b>Clusters</b>	Stores the clusters of a specific water system. Geographical information may be defined for each cluster.
<b>Sectors_Clusters</b>	Stores the relation between sectors and clusters. A sector is divided in one or more clusters and a cluster belongs to one or more sectors
<b>Clusters_Users</b>	Stores the relation between clusters and users. A cluster contains one or more water users. The number of units per cluster is stored in this table.
<b>Users_Activities</b>	Stores the relation between users and end use activities. A user performs one or more activities.
<b>Activities_Appliances</b>	Stores the relation between end use activities and appliances.



**Figure 34:** Structure of the tables representing the water system.

### Table for registering data sets

Data sets representing water use profile patterns or water consumption time series should first be registered as a unique entity in the database. The registration is performed in the DataSetRegistry table, the structure of which is presented in Figure 35. The main attributes of this table are:

- Keys defining the scope of the dataset (SiteID, SectorID, ClusterID, UserID, ActivityID, ApplianceID).
- The time frame of the data set (Period).
- The Unit of the data values.
- A flag (Level) of the dataset origin (default values from literature or actual measurements).
- Metadata (Source, Sample).
- Information concerning the insertion (CreateDate, CreateBy) and update (UpdateDate, UpdateBy) of the dataset in the database.

DataSetRegistry	
PK	DataSetID
<hr/>	
FK	SiteID
FK	SectorID
FK	ClusterID
FK	UserID
FK	ActivityID
FK	ApplianceID
	Description
	Period (Hour/Day/Month/Year)
	Unit (m3/lit/%)
	Level (Default Values/Literature/Measurements)
	Source
	Sample
	CreatedDate
	CreatedBy
	UpdatedDate
	UpdatedBy

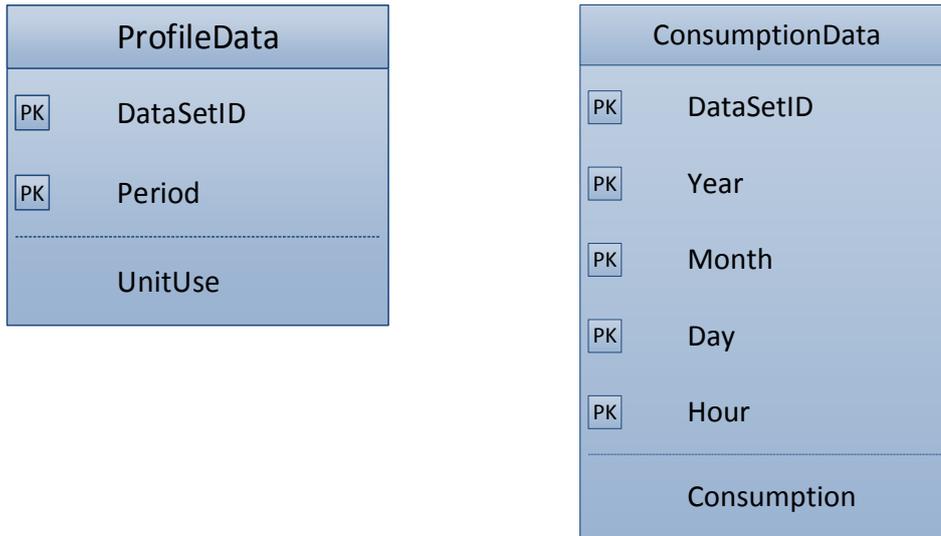
**Figure 35:** Structure of the table for registering data sets.

### Tables storing profile and consumption data

The actual values of the water use profile patterns and water consumption time series measurements are stored in two database tables, as described in Table 12. The structure of the tables is given in Figure 36.

**Table 12:** Description of the tables storing profile and consumption data.

Table	Description
<b>ProfileData</b>	Table used to store water use profile data.
<b>ConsumptionData</b>	Table used to store time series of water consumption.

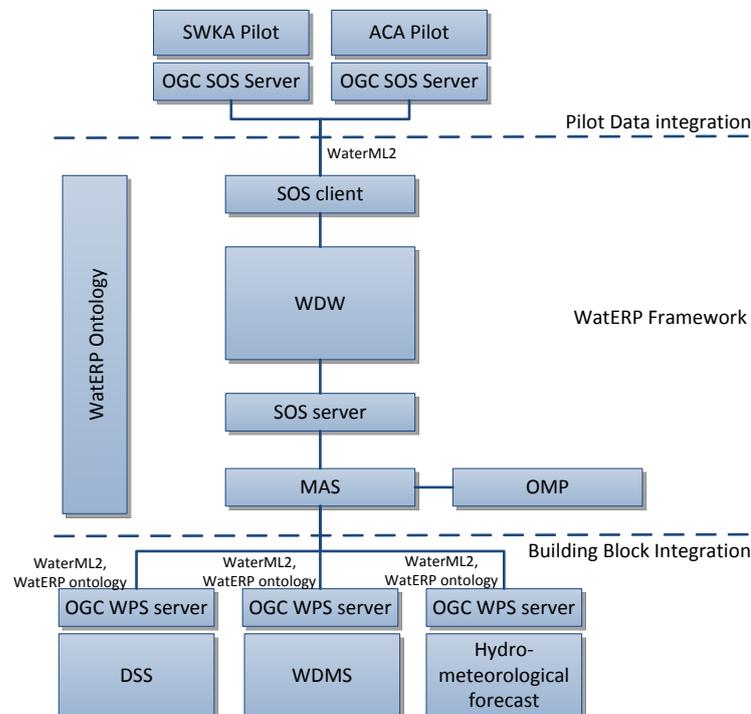


**Figure 36:** Structure of the tables storing profile and consumption data.

## 5. WDMS Integration into WatERP

### 5.1 The WatERP structure

WatERP structure emphasises the interconnection of different applications within the water supply distribution system chain. Basically, it is based on open standard with the aim of homogenizing the communication, and hence to encourage the third parties integration. Mainly, WatERP structure is divided in three layers: (i) pilot data integration, to feel the WatERP system with pilot information; (ii) building block integration, to bind developed applications in the WatERP structure and finally (iii) WatERP framework that is responsible to manage the integrated data and functionalities. These layers are presented in *Figure 37* with the involved components.



**Figure 37:** WatERP structure.

Fundamentally, the building block integration, whose guidelines were presented on D2.3 Open Interface Specification, is based on defining two main issues: (i) communication interface and (ii) data exchange format. OGC® WPS standard interface is used as communication interface because it simplifies the task of making simple or complex computational processing services accessible via web service providing tools for discovering and binding the services. On the other hand, WaterML2, which it is widely supported by the scientific and governmental community, and WatERP ontology, that is based on multiple extended ontologies (HY\_FEATURES, SWEET, OWL-S, ...), are used as exchange data format providing a standard communication format.

Below, the following sections depict the processes implemented in the OGC® WPS for each tool of the WDMS and their exchanged data.

## 5.2 Integrating Demand Forecasting Tool

The implementation and integration of Demand Forecasting Tool involves the following steps:

- Implementing the similar days algorithm to provide water demand forecasts, both for daily and hourly time steps.
- Defining the parameters of the WPS processes in “Process Description” XML files. These files detail the inputs (request) and outputs (response) of the corresponding WPS processes.
- Implementing the WPS processes and integrating into the WatERP system.

The initial prototype of the Demand Forecasting Tool, delivered by D5.1, had been developed in the MathCAD interactive environment, as a means to test and improve the algorithm. This prototype has improved, finalized and recoded in Java, to be compatible with the 52 North WPS server.

Two WPS processes were implemented:

- **HourlyDemandForecastProcess** for hourly water demand forecasting (relevant to Karlsruhe Pilot Site).
- **DailyDemandForecastProcess** for daily water demand forecasting (relevant to Barcelona Pilot Site).

The Tables below summarize the inputs and outputs of the two processes. Complete listings of the corresponding process description files are provided in Appendix B.

**Table 13:** Hourly Demand Forecast Process Inputs/Outputs.

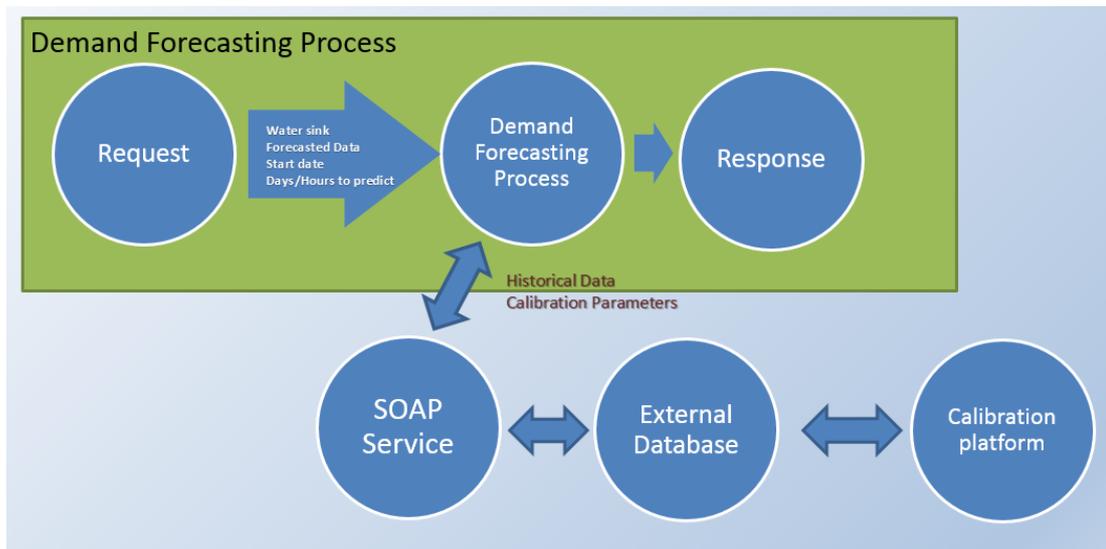
Name/Identifier	Direction	Range	Format	Comments
waterResource	Input	1...N	WatERP ontology	Water resources (sinks) to calculate the demand
dayCharacterization	Input	1	WatERP ontology	Day characterization
dailyAvgTemperatureForecast	Input	1	WaterML2	Daily average temperature for each water resource (sink)
dailyMinTemperatureForecast	Input	1	WaterML2	Daily minimum temperature for each water resource (sink)
dailyMaxTemperatureForecast	Input	1	WaterML2	Daily maximum temperature for each water resource (sink)
dailyPrecipitationForecast	Input	1	WaterML2	Daily precipitation forecast
date	Input	1	Gml	Date to start the prediction in format ISO8601: YYYY-MM-DDThh:mm:ssTZD

Name/Identifier	Direction	Range	Format	Comments
forwardTof	Input	1	Integer	Hours to be predicted
hourlyDemandForecast	Output	1	WaterML2	Predicted demand for each water resource (sink)
hourlyAggregatedDemandForecast	Output	1	WaterML2	Total demand (sum of all predicted demands)

**Table 14:** Daily Demand Forecast Process Inputs/Outputs.

Name	Direction	Range	Format	Comments
waterResource	Input	1...N	WatERP ontology	Water resources (sinks) to calculate the demand
dayCharacterization	Input	1	WatERP ontology	Day characterization
dailyAvgTemperatureForecast	Input	1	WaterML2	Daily average temperature for each water resource (sink)
dailyMinTemperatureForecast	Input	1	WaterML2	Daily minimum temperature for each water resource (sink)
dailyMaxTemperatureForecast	Input	1	WaterML2	Daily maximum temperature for each water resource (sink)
dailyPrecipitationForecast	Input	1	WaterML2	Daily precipitation forecast
date	Input	1	Gml	Date to start the prediction in format ISO8601: YYYY-MM-DDThh:mm:ssTZD
forwardTof	Input	1	Integer	Days to be predicted
dailyDemandForecast	Output	1	WaterML2	Predicted demand for each water resource (sink)
dailyAggregatedDemandForecast	Output	1	WaterML2	Total demand (sum of all predicted demands)

The forecasting provided by the similar days algorithm is based on historical consumption data as well as historical meteorological and day condition data. The historical consumption data are provided by the Water Use Profile Registry, implemented as a relational database, as described in section 4.4.3. Historical meteorological as well as special day conditions are also stored in this database. The population of the database with data from Pilot Sites is performed through the WPS processes developed for the integration of Profiling Tool and described in Section 5.5. However, specific SOAP services (see Figure 38) have been implanted for interfacing the Demand Forecasting Tool with the database of historical data. The complete



**Figure 38:** Demand Forecasting Process and SOAP Service.

A special, web based, tool has been developed for the purpose of reviewing the historical data provided from meteorological stations in the external database and for calibrating model parameters for each Pilot Site. Appendix A provides a description (User's Guide) of the calibration platform.

### 5.3 Integrating Economic Instruments Tool

The implementation and integration of Economic Instruments Tool involves the following steps:

- Formulating the inputs and outputs required by the algorithm defining the parameters of the WPS process in the "Process Description" XML file. This file details the inputs (request) and outputs (response) of the WPS process.
- Implementing the algorithm as a WPS process and integrating it into the WatERP system.

The initial prototype of the Economic Instruments Tool, delivered by D5.3, had been developed in the MathCAD interactive environment, as a means to test and improve the algorithm. This prototype has improved, finalized and recoded in Java, to be compatible with the 52 North WPS server.

The WPS process implemented, **EconomicInstrumentsProcess** is heavily based in the water system WATERP ontologies which are supplied by the OMP for both the demand and the supply side. The table below summarizes the inputs and outputs of the process. A complete listing of the process description file is provided in Appendix C.

**Table 15:** Economic Instruments Process Inputs/Outputs.

Name/Identifier	Direction	Range	Format	Comments
Baseline	Input	1	WatERP ontology	Baseline depicts the bulk suppliers, water utilities, consumers, investments, relations between actors, clusters, sectors, user classes, activities and appliances. It will be used to define baseline water system scenario and the modified water system scenario
Instruments	Input	1	WatERP ontology	Economic Instruments to be applied to baseline scenario – (No additional model objects / only instruments that reduce water used)
EvaluationOfFlows	Output	1	WatERP ontology	Depicts water and financial flow information.
AnnualExpenditure	Output	1	WatERP ontology	Describes the annual expenditure for each consumer for both baseline and instruments scenarios
WaterSavingPotential	Output	1	WatERP ontology	Describes the water saving for each consumer for both baseline and instruments scenarios
AffordabilityIndicators	Output	1	WatERP ontology	Describes the Annual Expenditure of consumers for water services and the share of disposable income spent for water services
CostRecovery	Output	1	WatERP ontology	Describes the cost recovery for each utility and bulk supplier.

The baseline input parameter contains a full description of the water system. It contains bulk water suppliers, the Utilities water suppliers, consumers and clusters (sinks) and the interrelations between them. The Instruments input parameter contains the modified water system scenario. It's the water system scenario after the application of the demand management instruments. Table 16 presents all the information required to describe the water system. A complete listing of how the request input parameters look like is provided in Appendix C.

**Table 16:** Input parameters for water system.

Actors	
<b>ActorID</b>	Uri of the actor
<b>Name</b>	Name of the actor
<b>Type</b>	BulkSupplier, WaterUtility, Consumer
<b>Income</b>	Mean yearly income for consumers (€/year/consumer). This data is needed to be able to calculate the “share of disposable income spent for water services” indicator.
Actors Investments	
<b>InvestmentID</b>	Uri of the Investment
<b>ActorID</b>	Uri of the corresponding Actor.
<b>Name</b>	General name of the investment.
<b>Description</b>	General description of the investment.

<b>InvestmentCost</b>	The total cost of the investment (€)
<b>Lifetime</b>	The lifetime of the investment (in years).
<b>AmortizationRate</b>	The amortization rate (%).
<b>Relations between actors</b>	
<b>FromActor</b>	ActorID for the actor providing water.
<b>ToActor</b>	ActorID for the actor receiving water.
<b>Priority</b>	Priority of the flow (relevant only when an actor receives water from multiple actors).
<b>Net_Loss</b>	Water loss factor for the distribution of water through the water network.
<b>Water Price</b>	Water price (€/m <sup>3</sup> ).
<b>Unit_OM_Cost</b>	Annual operation and management cost per unit of water flow (€/year/m <sup>3</sup> ).
<b>Clusters</b>	
<b>ClusterID</b>	Uri of the cluster.
<b>Name</b>	Cluster name.
<b>SectorID</b>	Sector to which this cluster belongs.
<b>Geometry</b>	GML3/GeoJSON with the polygon definition for this cluster.
<b>ConsumerID</b>	ActorID of the consumer to which this cluster belongs.
<b>Price elasticity</b>	Price elasticity of the cluster. If this value is empty (null) the price elasticity of the corresponding sector is applied.
<b>Sectors</b>	
<b>SectorID</b>	Uri of the sector.
<b>Name</b>	Sector name.
<b>Price elasticity</b>	Price elasticity of the sector.
<b>User classes</b>	
<b>ClusterID</b>	Uri of the cluster to which this user class belongs.
<b>UserClassID</b>	Uri of this user class.
<b>Name</b>	User class name.
<b>UnitDescription</b>	The unit name (family, resident, tonne/day, ...) in business as usual.
<b>Number of Units</b>	The number of units of the user class.
<b>User Water Use</b>	Water use per unit of user class (l/day). When this value is empty, the water use is calculated from the corresponding activities.
<b>Activities</b>	
<b>UserClassID</b>	Uri of the user class to which this activity belongs.
<b>ActivityID</b>	Uri of the activity.
<b>Name</b>	Descriptive name of the activity.
<b>Frequency</b>	The frequency of end use activity (activities/day).
<b>Activity Water Use</b>	Water consumption per end use activity (l/day). When this value is empty, the water consumption is calculated from the corresponding appliances.

Appliances	
<b>ActivityID</b>	Uri of the activity to which this appliance belongs.
<b>ApplianceID</b>	Uri of the appliance.
<b>Name</b>	Descriptive name of the appliance.
<b>Coverage</b>	The percentage coverage of the appliance in the corresponding end use activity.
<b>Appliance Water Use</b>	Water consumption per use of appliance (l/use).

## 5.4 Integrating Communication Tool

This section describes how WaterCity has been or will be integrated with the rest of the WatERP solution, as well as how it will be fed with information. Three different levels of integration are distinguished:

- User interaction integration
- Data integration
- Technical integration

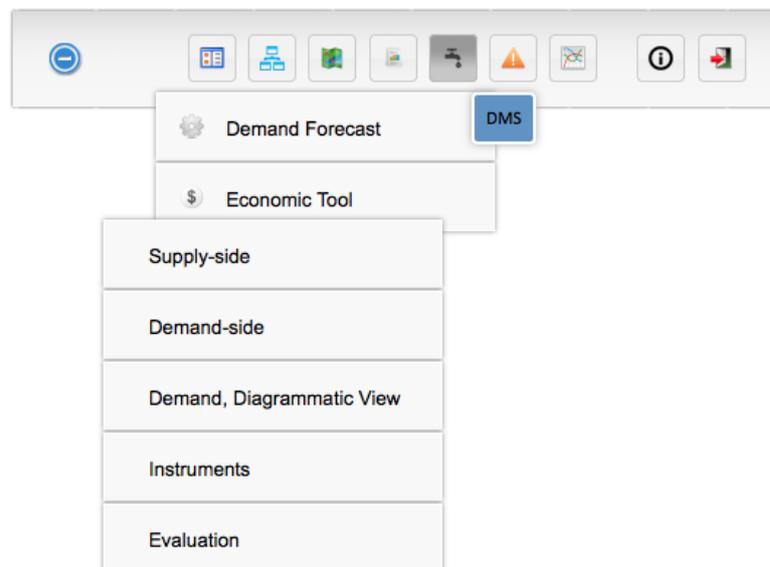
The description of the data level integration includes also information about how WaterCity will be fed with information.

### 5.4.1 User Interaction Integration

WaterCity is part of the water Demand Management System (DMS), therefore it can be part of a water manager's portfolio of methods aiming to manage water demand. In the context of the project, water managers are interacting with the WatERP solution through the user interface of the Open Management Platform (OMP), which exposes the functionalities of both Demand Management System (DMS) and Decision Support System (DSS) to them. Although WaterCity is also including a user interaction interface, it is mainly targeting residential consumers aiming to change their behavior and not water managers. However, WaterCity interaction with water managers is also possible, as considerable configurability is endowed to the former, in terms of a configuration file, so that it can support the latter to configure specific deployments of the application. Aiming at enhancing the usability of the configuration process and achieving a tighter integration between WaterCity and OMP in terms of water manager interaction, we decided to enable the latter to configure WaterCity deployments through the OMP, instead of expecting from them to edit the configuration file directly. In addition to the obvious usability improvements, this approach provides also a better means of access control as the existing OMP user roles and credentials can be used. More specifically, the following process has been defined for configuring WaterCity:

- The water manager logs into the OMP by using his/her existing credentials.

- He/she selects a new menu item called “WaterCity configuration”, that will be added to the part of the OMP interface which is relevant to the DMS, next to “Demand Forecast” and “Economic Tool”, i.e. the other two major components of the DMS (see Figure 39).
- The water manager defines the values of the various WaterCity parameters through an appropriate web form. Parameters may include information such as the city and country of WaterCity deployment, the average water price of that area, the title and subtitle of the application, a short notice to be used by WaterCity at the introductory screen etc.
- The OMP exports a configuration file that includes the values of the parameters provided by the water manager. This file is then imported into WaterCity allowing the latter to read and apply the proper configuration. With respect to the form of the file, it will be a list of entries in the form 'settings.ParameterName = ParameterValue'.



**Figure 39:** Part of the OMP Interface relevant to DMS

## 5.4.2 Data Integration

WaterCity has been integrated with the WatERP Water Data Warehouse (WDW) at the data level, as water consumption data that are available in the latter are fed into WaterCity (e.g. data about monthly average of city consumption per household). With respect to the water consumption data of individual households, these are currently provided to the application by WaterCity users themselves, as they are not available either in the pilot users databases or the WDW. However, as the technical interface between WaterCity and WDW has been already implemented (see also section 5.4.3 below), integration of consumption data at a more detailed level of abstraction (i.e. water consumption data of individual households) could be possible by applying the processing steps of a simple ETL (Extract-Transform-Load) process that extracts data from the WDW, converts the data extracted from its

previous form in the WDW into the form it needs to be in so that it can be placed into WaterCity's database and finally loads it there.

### 5.4.3 Technical Integration

WaterCity has been integrated with the Water Data Warehouse (WDW) at the technical level, through the Web Processing Service (WPS) interface of the WatERP architecture and the design and implementation of a) a Python WPS client at the WaterCity side and b) a set of WPS services at the WDW side, as can be seen in Figure 40. The WPS services implemented exploit the R infrastructure that is part of the WDW, with the aim to expose the following functionality to WaterCity:

- Calculation of similarity between WaterCity users by running the mixed AHP-weighted user similarity method. This functionality is provided by the *WaterCity user similarity service*.
- Ability to run the Analytic Hierarchy Process (AHP) method for calculating feature weights based on expert responses on questionnaires and pairwise feature comparisons from the literature. This functionality is provided by the *AHP service*.
- Provision of water consumption data that are available in the WDW to WaterCity. This functionality is provided by the *water consumption data service*.

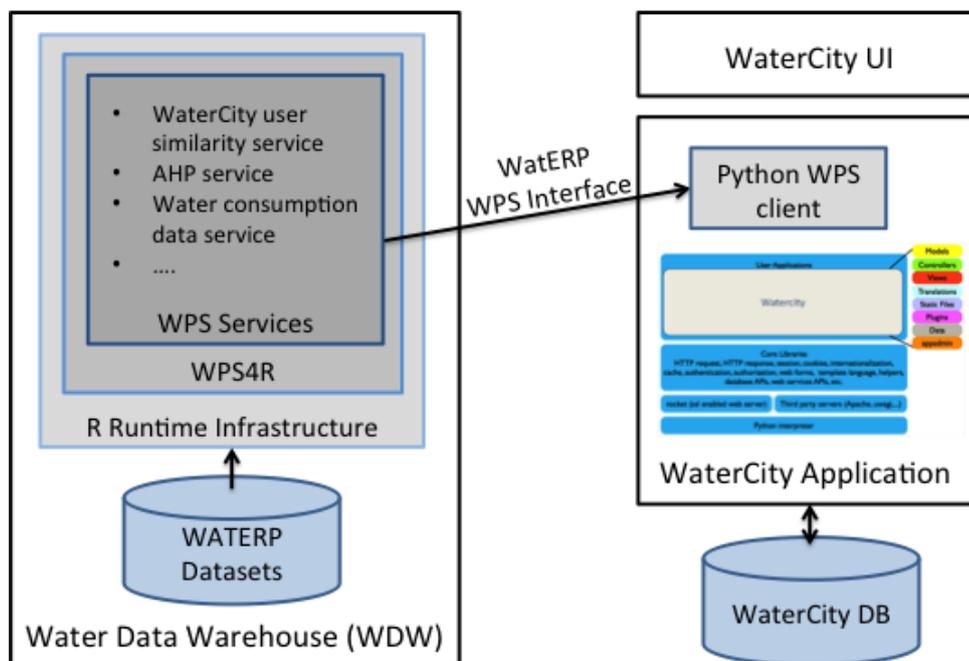


Figure 40: Technical Integration of WaterCity with the WDW

## 5.5 Integrating Profiling Tool

The implementation and integration of the Profiling Tool involves the following steps:

- Implementing a process to implemented to allow water sinks to update an external database with meteorological data and day characterization data.
- Defining the parameters of the WPS processes in “Process Description” XML files. These files detail the inputs (request) and outputs (response) of the corresponding WPS processes.
- Implementing the WPS processes and integrating into the WatERP system.

Two WPS processes were implemented:

- **PopulateSWKAProcess** for populating data relevant to Karlsruhe Pilot Site.
- **PopulateACAPProcess** for populating data relevant to Barcelona Pilot Site.

The Tables below summarize the inputs and outputs of the two processes. Complete listings of the corresponding processes description files are provided in Appendix D.

**Table 17:** *Populate SWKA Process Inputs/Outputs.*

Name/Identifier	Direction	Range	Format	Comments
dailyMinTemperature	Input	1	WaterML2	Daily average temperature for each water resource (sink)
dailyMaxTemperature	Input	1	WaterML2	Daily minimum temperature for each water resource (sink)
dailyAvgTemperature	Input	1	WaterML2	Daily maximum temperature for each water resource (sink)
consumption	Input	1	WaterML2	Measured consumption for each water resource (sink)
dailyPrecipitation	Input	1	WaterML2	Measured precipitation for each water resource (sink)
dayCharacterization	Input	1	WatERP ontology	Day characterization
date	Input	1	Gml	Date of the measured in format ISO8601: YYYY-MM-DDThh:mm:ssTZD
isPopulated	Output	1	Boolean	Confirmation of the data insertion in the database

**Table 18:** *Populate ACA Process Inputs/Outputs.*

Name/Identifier	Direction	Range	Format	Comments
dailyMinTemperature	Input	1	WaterML2	Daily average temperature for each water resource (sink)
dailyMaxTemperature	Input	1	WaterML2	Daily minimum temperature for each water resource (sink)
dailyAvgTemperature	Input	1	WaterML2	Daily maximum temperature for each water resource (sink)

Name/Identifier	Direction	Range	Format	Comments
consumption	Input	1	WaterML2	Measured consumption for each water resource (sink)
dailyPrecipitation	Input	1	WaterML2	Measured precipitation for each water resource (sink)
dayCharacterization	Input	1	WatERP ontology	Day characterization
Date	Input	1	Gml	Date of the measured in format ISO8601: YYYY-MM-DDThh:mm:ssTZD
isPopulated	Output	1	Boolean	Confirmation of the data insertion in the database

## 6. Conclusions and recommendations

This report presents the work done for Task 5.5 (Water Demand Management System), explaining the terms and general concepts behind water demand management, the WDMS framework, the choices made and the options taken thereof, resulting from an analysis of user requirements. It also provides documentation for the prototype WDMS Software Toolbox, including its architecture and functionality, as well as a user's manual (including examples of use) and a programmer's manual.

This Toolbox is the main output of WP5 and one of the main software components of the WatERP Open Management Platform. The role of this component, in WatERP and the OMP, is to act as a server of information concerning water demand and its management. It provides a set of models, tools and functions that support demand management actions & policies at different levels of the water supply-distribution chain, so as to contribute to the conservation of natural resources, including minimization of water and energy usage.

Towards this purpose, the WDMS Toolbox provides four (4) main functionality groups (or "Tools"), namely: (I) Water demand drivers' analysis and short-term demand forecasting; (II) Water use Registry and profiling, including the analysis of water consumption patterns and trends; (III) Design and assessment of water demand management policy instruments, including medium/long-term demand prediction; (IV) Communication with water consumers for awareness raising about water conservation. These functionality groups correspond to a 4-tier approach to demand management: (1) improve day-to-day water management (regulation, scheduling) processes; (2) improve understanding of the water system in order to formulate policies and alternative potential policy instruments; (3) assess and calibrate policy instruments for implementation; and (4) communicate the policy to consumers, increasing its effectiveness. Thus, the comprehensiveness of the WDMS approach is ascertained. The end-users gain access to WDMS functionality through special OMP dashboards.

Tools corresponding to the above functionality groups (I) to (IV) have been developed as first prototypes by tasks 5.1, 5.4, 5.2 and 5.3 respectively. The first prototypes delivered by D5.1 (forecasting tool) and D5.3 (economic tool) had been developed in the MathCAD interactive environment, as a means to test and improve algorithms. In Task 5.5, these first prototypes were improved, finalized and recoded in runtime versions on the WatERP programming platform. Additionally, a demand influencing factor analysis and calibration utility tool has been produced as a supplement to the Forecasting Tool. Finally, all tools have been integrated into the WDMS and a service layer added to let them communicate with other OMP components.

The next step of work on the "Water Demand Management System will consist of finalizing and validating the profiling tool as well as test and validate the economic and profiling tools into the Pilot Sites.

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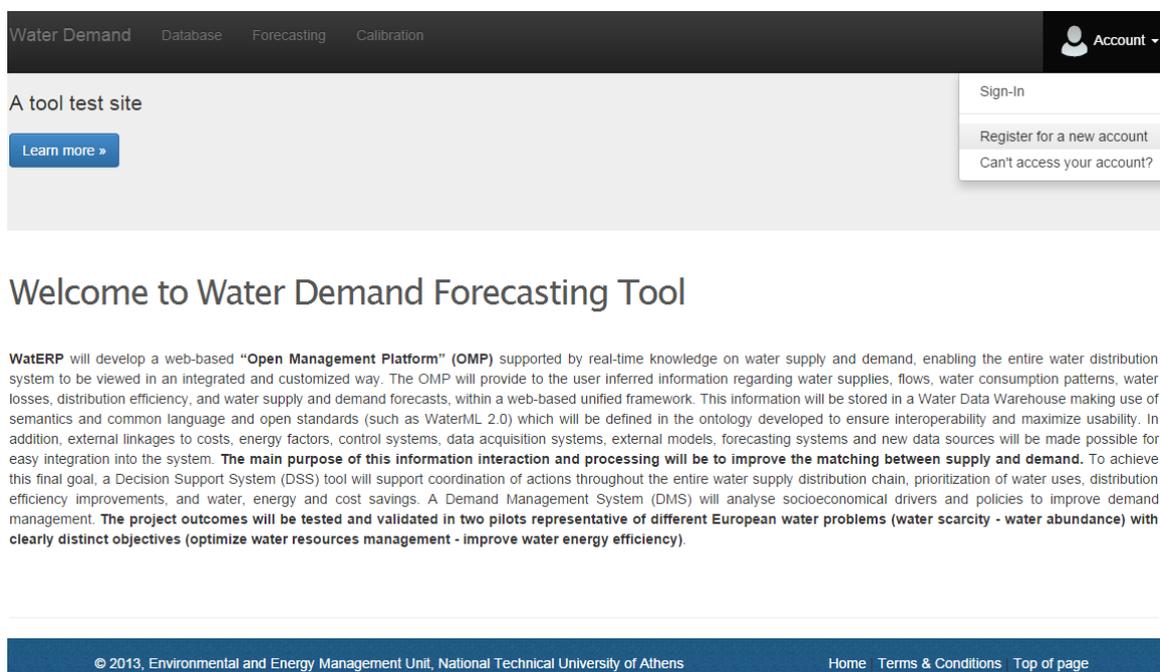
[http://www.euwi.net/files/Cap\\_net\\_EUWI\\_FWG\\_GWP\\_Manual\\_Economics\\_of\\_water\\_FINAL.pdf](http://www.euwi.net/files/Cap_net_EUWI_FWG_GWP_Manual_Economics_of_water_FINAL.pdf)

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## Appendix A: User’s Guide of the Water Demand Forecasting Calibration Platform

For the purpose of model calibration in the conditions of both pilot sites, a special web application has been developed. This Appendix presents a short description of this web application.

The application is an online tool available at <http://environ.chemeng.ntua.gr/WatERP/DF/> (Figure 41) and requires an account (username and password) to use it.



**Figure 41:** Water Demand Management Tool Home Page.

The tool provides three options, presented as links at the top of the page:

- **Database Management** enables the user to add/delete and update demand nodes and related data.
- **Forecasting**, allows the user to make demand forecasts.
- **Calibration**, allows the user to change the parameters of the model.

The three options are described in the following paragraphs.

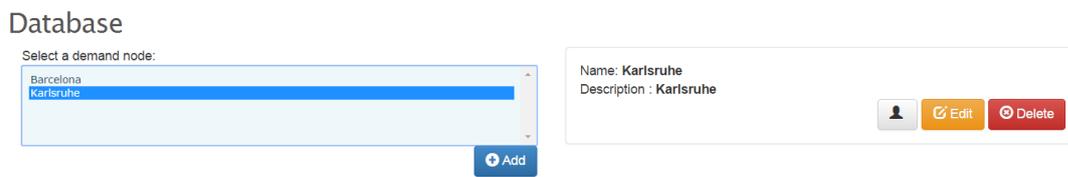
### A.1 Database Management

In order to make a forecast the user has to first fill in the database of the demand node with related data. The Database management screen allows the user to add as many demand nodes as necessary.

This page also allows the creator of the demand node to give rights to other users, permitting them to edit the demand node data and related parameters.

### Demand Node Definition

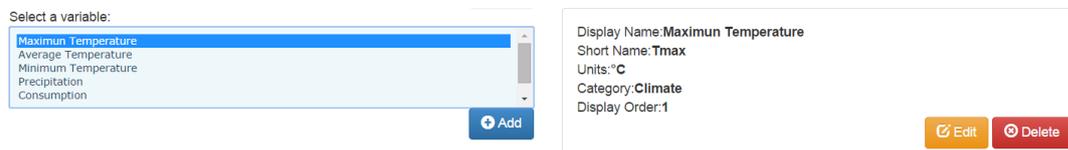
In the “Demand node” list (Figure 42), the user can select the demand node he is interested in, or just create a new one by pressing the “Add” button. Along with the options to “Delete” and “Edit” demand node-specific parameters, other users can be permitted to view or administer the demand node by using the “Users” button.



**Figure 42:** Demand Nodes Management

### Variables Definition

The factors influencing water demand (similarity factors) to be included in the analysis are defined in the “Variables” list (Figure 43). The user can add, delete or edit the attributes of the factors using the corresponding buttons.



**Figure 43:** Variables list

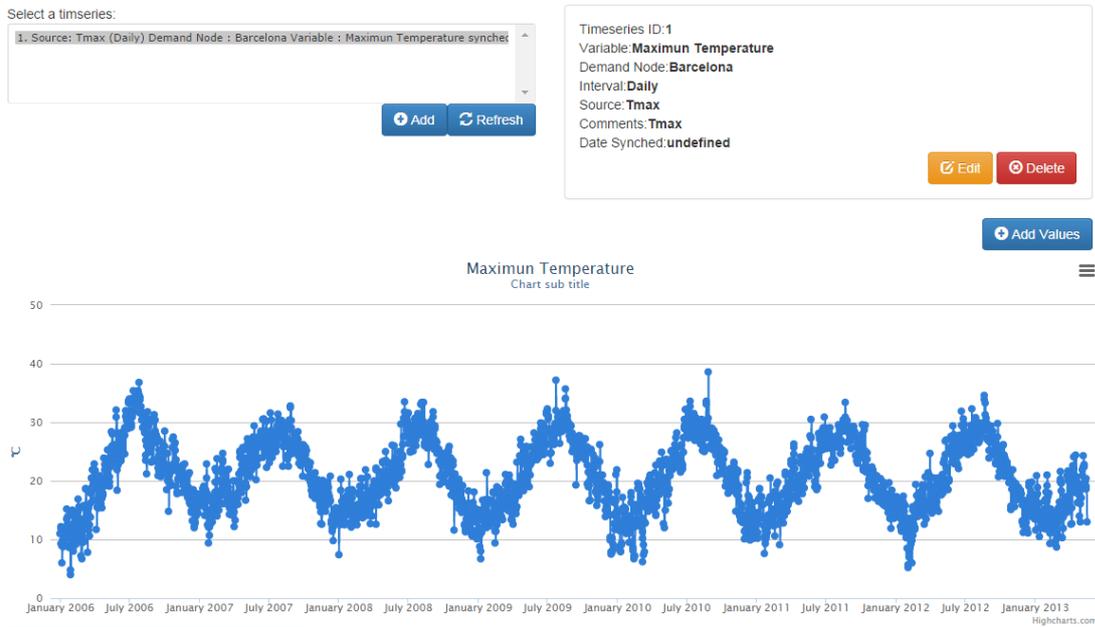
### Historical Data

Having selected a demand node and a variable, the user can create a new time series by pressing the “Add” Button below the time series list (Figure 44).

The “Add Time series” Popup will appear (Figure 45) where the user has to press the “Upload” button and select a MS Excel File containing the actual data. The selected file needs to have a specific structure where each row contains these values:

- Column 1: Time (if you have hourly data) – Valid values range from 00:00 to 23:59
- Column 2: Day
- Column 3: Month
- Column 4: Year
- Column 5: Value (of the selected variable)

After selecting an available Excel file the “Add Time series” Popup will display a preview of the selected worksheet on the left side to assist making the correct selections in the dropdown-menu appearing on the right side of the popup window.



**Figure 44: Time Series Review**

The screenshot shows the 'Add Timeseries' form with the following fields and values:

- Variable:** Maximun Temperature
- Demand Node:** Barcelona
- Source:** (empty text box)
- Comments:** (empty text box)
- Interval:** Hourly

At the bottom right of the form are 'Close' and 'Add' buttons.

**Figure 45: Adding Time series**

## A.2 Forecasting

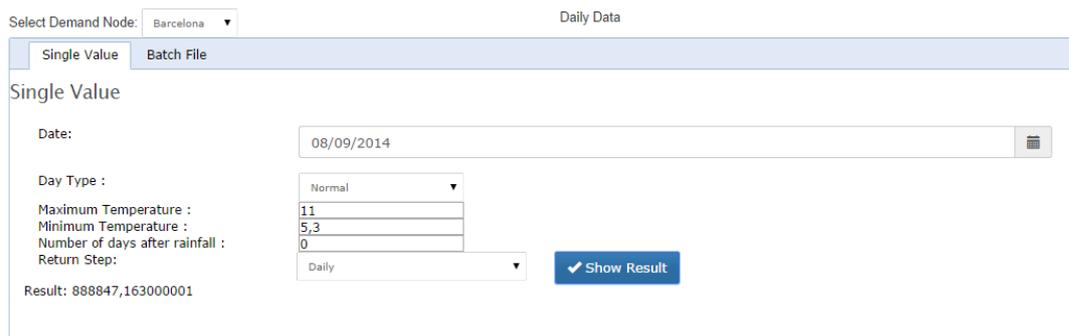
This page enables the user to calculate a demand forecast using the Similar Days algorithm, providing a simple interface.

The user can manually calculate for one date by providing (Figure 46):

- Date (Specified in a daily or - if available - in an hourly time step)
- Day Type
- Minimum Temperature
- Maximum Temperature
- Days after rainfall

The forecasted water demand for the selected parameters is displayed after pressing the “Show Result” button.

### Forecasting



The screenshot shows the 'Forecasting' interface. At the top, there is a dropdown menu for 'Select Demand Node' set to 'Barcelona' and a 'Daily Data' label. Below this are two tabs: 'Single Value' (selected) and 'Batch File'. The 'Single Value' section contains the following fields:

- Date:** A text input field containing '08/09/2014' with a calendar icon on the right.
- Day Type:** A dropdown menu set to 'Normal'.
- Maximum Temperature:** A text input field containing '11'.
- Minimum Temperature:** A text input field containing '5,3'.
- Number of days after rainfall:** A text input field containing '0'.
- Return Step:** A dropdown menu set to 'Daily'.

At the bottom left, the result is displayed as 'Result: 888847,163000001'. A blue button with a checkmark and the text 'Show Result' is located at the bottom right of the form.

**Figure 46:** Forecasting for a single date

Alternatively, the user may choose to upload a specially formatted Microsoft Excel File and get a demand forecast for each row in the file (Figure 47).

## Forecasting

Select Demand Node: Barcelona Daily Data

Single Value Batch File

Batch File

Upload an excel file using the structure of this [example file](#) with values you request

+ Upload XLSX file...

Select Excel File: CalcDemand Show Results

Date	Day Type	Tmin	Tmax	DAR	Demand
1/1/2006 0:0:0	Public Holiday	53	11	0	847773,297
2/1/2006 0:0:0	School Holiday	41	119	0	928878
3/1/2006 0:0:0	School Holiday	48	122	0	928878
4/1/2006 0:0:0	School Holiday	29	93	0	928878
5/1/2006 0:0:0	School Holiday	42	6	0	889594,917
6/1/2006 0:0:0	Public Holiday	39	89	0	928878
7/1/2006 0:0:0	School Holiday	75	10	0	847773,297

**Figure 47:** Forecasting using excel batch file

### A.3 Calibration

The Calibration page enables the user to adjust the parameters of the Demand Forecasting model to the conditions of the site. The following parameters can be defined in this page:

#### Similarity Threshold (Figure 48)

The selection of the days with high similarity is determined by setting up a similarity threshold value. Those days whose similarity is greater than this threshold can be retained, while those less than this threshold are abandoned.

#### Weighting Exponent (Figure 48)

In order to increase the weight of the most similar days an exponent is used in the calculation of weights. In this way, the forecasting demand contains more information about the most similar days, which results in a lower error.

Select a demand node:

- Barcelona
- Karlsruhe

Name: Barcelona  
Description: Barcelona Observatori Fabra (SMC) (For MAB demand)

Parameters

Similarity Threshold:

Weighting Exponent:

Update Parameters

**Figure 48:** Similarity threshold and weighting exponent parameters.

#### Weight Factors (Figure 49)

Weights of the similarity factors are defined by assigning any positive numerical value for each factor. The proposed approach for assigning weights is to define a large weight (e.g. 100) for the most

important factor and then proceed to the next most important factor and define a weight relative to the first factor, until all weights are defined.

## Mapping Weights

Mapping	Weight	
Day Type	100	
Day of Week	50	
Month Of Year	80	
Maximum Temperature	60	
Minimum Temperature	60	
Days After Rainfall	40	

**Figure 49: Defining Weight Factors**

## Mapping of Similarity Factors (Figure 50)

The mapping values of any similarity factor can be defined in this list. The user can add, edit or remove any mapping pair using the list on the right.

### Mapping Pairs

Select a Mapping:

- Day Type
- Day of Week
- Month Of Year
- Maximum Temperature
- Minimum Temperature
- Days After Rainfall

Key	Value	
Normal	40	   
Strike	100	   
Public Holiday	40	   
School Holiday	40	   
World Mobile Congress	80	   

**Figure 50: Defining Mapping Pairs**

## Appendix B: Demand Forecasting Process Description Files

### B.1 Daily Demand Forecasting Process

```

<?xml version="1.0" encoding="UTF-8"?>
<wps:ProcessDescriptions
  xmlns:wps="http://www.opengis.net/wps/1.0.0"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xmlns:ows="http://www.opengis.net/ows/1.1"
  xsi:schemaLocation="
    http://www.opengis.net/wps/1.0.0
    http://schemas.opengis.net/wps/1.0.0/wpsDescribeProcess_response.xsd"
  xml:lang="en-US"
  service="WPS"
  version="1.0.0">
  <ProcessDescription
    statusSupported="false"
    storeSupported="false"
    wps:processVersion="1.0">

    <ows:Identifier>gr.iccs.waterp.dms.process.DailyDemandForecastProcess</ows
:Identifier>
    <ows:Title>Title</ows:Title>
    <ows:Abstract>Abstract</ows:Abstract>
    <DataInputs>

    <Input minOccurs="1" maxOccurs="100">
      <ows:Identifier>waterResource</ows:Identifier>
      <ows:Title>Water resource</ows:Title>
      <ows:Abstract>Water resource with geospatial
position</ows:Abstract>
      <ComplexData>
        <Default>
          <Format>
            <MimeType>text/xml+rdf</MimeType>
            <Encoding>UTF-8</Encoding>
            <Schema>http://www.waterp-
fp7.eu/WatERPontology.owl</Schema>
          </Format>
        </Default>
        <Supported>
          <Format>
            <MimeType>text/xml+rdf</MimeType>
            <Encoding>UTF-8</Encoding>

```

```

        <Schema>http://www.waterp-
fp7.eu/WatERPontology.owl</Schema>
        </Format>
    </Supported>
</ComplexData>
</Input>

<Input minOccurs="1" maxOccurs="1">
    <ows:Identifier>dayCharacterization</ows:Identifier>
    <ows:Title>Day Characterization</ows:Title>
    <ows:Abstract>Day Characterization</ows:Abstract>

    <ComplexData>
        <Default>
            <Format>
                <MimeType>text/xml+rdf</MimeType>
                <Encoding>UTF-8</Encoding>
                <Schema>http://www.waterp-
fp7.eu/WatERPontology.owl</Schema>
            </Format>
        </Default>
    <Supported>
        <Format>
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            <Encoding>UTF-8</Encoding>
            <Schema>http://www.waterp-
fp7.eu/WatERPontology.owl</Schema>
        </Format>
    </Supported>
</ComplexData>
</Input>

<Input minOccurs="1" maxOccurs="1">
    <ows:Identifier>dailyAvgTemperatureForecast</ows:Identifier>
    <ows:Title>Average temperature</ows:Title>
    <ows:Abstract>Average temperature</ows:Abstract>

    <ComplexData>
        <Default>
            <Format>
                <MimeType>text/xml</MimeType>
                <Encoding>UTF-8</Encoding>

    <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
            </Format>
        </Default>

```

```
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  <Format>
    <MimeType>text/xml</MimeType>
    <Encoding>UTF-8</Encoding>

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  </Format>
</Supported>
</ComplexData>
</Input>

<Input minOccurs="1" maxOccurs="1">
  <ows:Identifier>dailyMinTemperatureForecast</ows:Identifier>
  <ows:Title>Minimum temperature</ows:Title>
  <ows:Abstract>Minimum temperature</ows:Abstract>

  <ComplexData>
    <Default>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>

<Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
  </Format>
</Default>
<Supported>
  <Format>
    <MimeType>text/xml</MimeType>
    <Encoding>UTF-8</Encoding>

<Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
  </Format>
</Supported>
</ComplexData>
</Input>

<Input minOccurs="1" maxOccurs="1">
  <ows:Identifier>dailyMaxTemperatureForecast</ows:Identifier>
  <ows:Title>Maximum temperature</ows:Title>
  <ows:Abstract>Maximum temperature</ows:Abstract>

  <ComplexData>
    <Default>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
```

```

<Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
  </Format>
</Default>
<Supported>
  <Format>
    <MimeType>text/xml</MimeType>
    <Encoding>UTF-8</Encoding>

<Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
  </Format>
</Supported>
</ComplexData>
</Input>

<Input minOccurs="1" maxOccurs="1">
  <ows:Identifier>dailyPrecipitationForecast</ows:Identifier>
  <ows:Title>Precipitation</ows:Title>
  <ows:Abstract>Precipitation</ows:Abstract>

  <ComplexData>
    <Default>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>

<Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
  </Format>
</Default>
<Supported>
  <Format>
    <MimeType>text/xml</MimeType>
    <Encoding>UTF-8</Encoding>

<Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
  </Format>
</Supported>
</ComplexData>
</Input>

<Input minOccurs="1" maxOccurs="1">
  <ows:Identifier>date</ows:Identifier>
  <ows:Title>Start date</ows:Title>
  <ows:Abstract>Start date to carry out the forecast</ows:Abstract>
  <ComplexData>
    <Default>

```

```

        <Format>
            <MimeType>text/xml</MimeType>
            <Encoding>UTF-8</Encoding>
<Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
    </Format>
</Default>
<Supported>
    <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
<Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
    </Format>
</Supported>
</ComplexData>
</Input>

<Input minOccurs="1" maxOccurs="1">
    <ows:Identifier>forwardTof</ows:Identifier>
    <ows>Title>Forward time of forecast</ows>Title>
    <ows:Abstract>Daily forward time of forecast</ows:Abstract>
    <LiteralData>
        <ows:DataType ows:reference="xs:integer" />
        <ows:AnyValue />
    </LiteralData>
</Input>
</DataInputs>
<ProcessOutputs>
    <Output>
        <ows:Identifier>dailyDemandForecast</ows:Identifier>
        <ows>Title>Daily temperature forecast for a specific
location</ows>Title>
        <ows:Abstract>Time series with the min, max and average temperature
forecast for aspecified location</ows:Abstract>
        <ComplexOutput>
            <Default>
                <Format>
                    <MimeType>text/xml</MimeType>
                    <Encoding>UTF-8</Encoding>
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    </Format>
</Default>
<Supported>
    <Format>

```

```
<MimeType>text/xml</MimeType>
<Encoding>UTF-8</Encoding>

<Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
  </Format>
</Supported>
</ComplexOutput>
</Output>
<Output>
  <ows:Identifier>dailyAggregateDemandForecast</ows:Identifier>
  <ows:Title>Daily temperature forecast for a specific
location</ows:Title>
  <ows:Abstract>Time series with the min, max and average temperature
forecast for aspecified location</ows:Abstract>
  <ComplexOutput>
    <Default>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>

<Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
  </Format>
</Default>
<Supported>
  <Format>
    <MimeType>text/xml</MimeType>
    <Encoding>UTF-8</Encoding>

<Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
  </Format>
</Supported>
</ComplexOutput>
</Output>
</ProcessOutputs>
</ProcessDescription>
</wps:ProcessDescriptions>
```

## B.2 Hourly Demand Forecasting Process

```

<?xml version="1.0" encoding="UTF-8"?>
<wps:ProcessDescriptions
  xmlns:wps="http://www.opengis.net/wps/1.0.0"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xmlns:ows="http://www.opengis.net/ows/1.1"
  xsi:schemaLocation="
    http://www.opengis.net/wps/1.0.0
    http://schemas.opengis.net/wps/1.0.0/wpsDescribeProcess_response.xsd"
  xml:lang="en-US"
  service="WPS"
  version="1.0.0">
  <ProcessDescription
    statusSupported="false"
    storeSupported="false"
    wps:processVersion="1.0">
    <ows:Identifier>gr.iccs.waterp.dms.process.HourlyDemandForecastProcess</ows:Identifier>
    <ows:Title>Title</ows:Title>
    <ows:Abstract>Abstract</ows:Abstract>
    <DataInputs>

    <Input minOccurs="1" maxOccurs="100">
      <ows:Identifier>waterResource</ows:Identifier>
      <ows:Title>Water resource</ows:Title>
      <ows:Abstract>Water resource with geospatial position</ows:Abstract>

      <ComplexData>
        <Default>
          <Format>
            <MimeType>text/xml+rdf</MimeType>
            <Encoding>UTF-8</Encoding>
            <Schema>http://www.waterp-fp7.eu/WatERPOntology.owl</Schema>
          </Format>
        </Default>
        <Supported>
          <Format>
            <MimeType>text/xml+rdf</MimeType>
            <Encoding>UTF-8</Encoding>
            <Schema>http://www.waterp-fp7.eu/WatERPOntology.owl</Schema>
          </Format>
        </Supported>
      </ComplexData>
    </Input>

    <Input minOccurs="1" maxOccurs="1">

```

```

<ows:Identifier>dayCharacterization</ows:Identifier>
<ows:Title>Day Characterization</ows:Title>
<ows:Abstract>Day Characterization</ows:Abstract>
<ComplexData>
  <Default>
    <Format>
      <MimeType>text/xml+rdf</MimeType>
      <Encoding>UTF-8</Encoding>
      <Schema>http://www.waterp-fp7.eu/WatERPOntology.owl</Schema>
    </Format>
  </Default>
  <Supported>
    <Format>
      <MimeType>text/xml+rdf</MimeType>
      <Encoding>UTF-8</Encoding>
      <Schema>http://www.waterp-fp7.eu/WatERPOntology.owl</Schema>
    </Format>
  </Supported>
</ComplexData>
</Input>

<Input minOccurs="1" maxOccurs="1">
  <ows:Identifier>dailyAvgTemperatureForecast</ows:Identifier>
  <ows:Title>Average temperature</ows:Title>
  <ows:Abstract>Average temperature</ows:Abstract>
  <ComplexData>
    <Default>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
      </Format>
    </Default>
    <Supported>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
      </Format>
    </Supported>
  </ComplexData>
</Input>

<Input minOccurs="1" maxOccurs="1">
  <ows:Identifier>dailyMinTemperatureForecast</ows:Identifier>
  <ows:Title>Minimum temperature</ows:Title>

```

```

<ows:Abstract>Minimum temperature</ows:Abstract>

<ComplexData>
  <Default>
    <Format>
      <MimeType>text/xml</MimeType>
      <Encoding>UTF-8</Encoding>
      <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
    </Format>
  </Default>
  <Supported>
    <Format>
      <MimeType>text/xml</MimeType>
      <Encoding>UTF-8</Encoding>
      <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
    </Format>
  </Supported>
</ComplexData>
</Input>

<Input minOccurs="1" maxOccurs="1">
  <ows:Identifier>dailyMaxTemperatureForecast</ows:Identifier>
  <ows:Title>Maximum temperature</ows:Title>
  <ows:Abstract>Maximum temperature</ows:Abstract>

  <ComplexData>
    <Default>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
      </Format>
    </Default>
    <Supported>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
      </Format>
    </Supported>
  </ComplexData>
</Input>

<Input minOccurs="1" maxOccurs="1">
  <ows:Identifier>dailyPrecipitationForecast</ows:Identifier>
  <ows:Title>Precipitation</ows:Title>

```

```

<ows:Abstract>Precipitation</ows:Abstract>
<ComplexData>
  <Default>
    <Format>
      <MimeType>text/xml</MimeType>
      <Encoding>UTF-8</Encoding>
      <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
    </Format>
  </Default>
  <Supported>
    <Format>
      <MimeType>text/xml</MimeType>
      <Encoding>UTF-8</Encoding>
      <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
    </Format>
  </Supported>
</ComplexData>
</Input>
<Input minOccurs="1" maxOccurs="1">
  <ows:Identifier>date</ows:Identifier>
  <ows:Title>Start date</ows:Title>
  <ows:Abstract>Start date to carry out the forecast</ows:Abstract>
  <ComplexData>
    <Default>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
      </Format>
    </Default>
    <Supported>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
      </Format>
    </Supported>
  </ComplexData>
</Input>

<Input minOccurs="1" maxOccurs="1">
  <ows:Identifier>forwardTof</ows:Identifier>
  <ows:Title>Forward time of forecast</ows:Title>
  <ows:Abstract>Hourly forward time of forecast</ows:Abstract>
  <LiteralData>
    <ows:DataType ows:reference="xs:integer" />

```

```

        <ows:AnyValue />
    </LiteralData>
</Input>
</DataInputs>
<ProcessOutputs>
    <Output>
        <ows:Identifier>hourlyDemandForecast</ows:Identifier>
        <ows:Title>Hourly temperature forecast for a specific location</ows:Title>
        <ows:Abstract>Time series with the min, max and average temperature forecast for
aspecified location</ows:Abstract>
        <ComplexOutput>
            <Default>
                <Format>
                    <MimeType>text/xml</MimeType>
                    <Encoding>UTF-8</Encoding>
                    <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
                </Format>
            </Default>
            <Supported>
                <Format>
                    <MimeType>text/xml</MimeType>
                    <Encoding>UTF-8</Encoding>
                    <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
                </Format>
            </Supported>
        </ComplexOutput>
    </Output>
    <Output>
        <ows:Identifier>hourlyAggregateDemandForecast</ows:Identifier>
        <ows:Title>Daily temperature forecast for a specific location</ows:Title>
        <ows:Abstract>Time series with the min, max and average temperature forecast for
aspecified location</ows:Abstract>
        <ComplexOutput>
            <Default>
                <Format>
                    <MimeType>text/xml</MimeType>
                    <Encoding>UTF-8</Encoding>
                    <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
                </Format>
            </Default>
            <Supported>
                <Format>
                    <MimeType>text/xml</MimeType>
                    <Encoding>UTF-8</Encoding>
                    <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
                </Format>
            </Supported>
        </ComplexOutput>
    </Output>

```

```
</Supported>  
</ComplexOutput>  
</Output>  
</ProcessOutputs>  
</ProcessDescription>  
</wps:ProcessDescriptions>
```

## Appendix C: Economic Instruments Description Files

### C.1 Economic Instruments Process Description File

```

<?xml version="1.0" encoding="UTF-8"?>
<wps:ProcessDescriptions
  xmlns:wps="http://www.opengis.net/wps/1.0.0"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xmlns:ows="http://www.opengis.net/ows/1.1"
  xsi:schemaLocation="http://www.opengis.net/wps/1.0.0
http://schemas.opengis.net/wps/1.0.0/wpsDescribeProcess_response.xsd"
  xml:lang="en-US"
  service="WPS"
  version="1.0.0">
  <ProcessDescription
    statusSupported="false"
    storeSupported="false"
    wps:processVersion="1.0">

    <ows:Identifier>org.ntua.eemru.waterp.process.EconomicInstrumentsProcess</ows:Identifier>
    <ows:Title>Economic Instruments Process</ows:Title>
    <ows:Abstract>The Economic Tool, used for supporting decisions concerning the
    formulation and implementation of water demand management policies</ows:Abstract>
    <DataInputs>
      <Input minOccurs="1" maxOccurs="1">
        <ows:Identifier>Baseline</ows:Identifier>
        <ows:Title>Baseline</ows:Title>
        <ows:Abstract>Baseline depicts the bulk suppliers, water utilities, consumers,
        investments, relations between actors, clusters, sectors, user classes, activities and
        appliances. It will be used to define baseline water system scenario and the modified water
        system scenario.</ows:Abstract>
        <ComplexData>
          <Default>
            <Format>
              <MimeType>text/xml</MimeType>
              <Encoding>UTF-8</Encoding>
              <Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
            </Format>
          </Default>
          <Supported>
            <Format>
              <MimeType>text/xml</MimeType>
              <Encoding>UTF-8</Encoding>
              <Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
            </Format>
          </Supported>
        </ComplexData>
      </Input>
    </DataInputs>
  </ProcessDescription>

```

```

    </Supported>
  </ComplexData>
</Input>
<Input minOccurs="1" maxOccurs="1">
  <ows:Identifier>Instruments</ows:Identifier>
  <ows:Title>Instruments</ows:Title>
  <ows:Abstract>Economic Instruments changes</ows:Abstract>
  <ComplexData>
    <Default>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
      </Format>
    </Default>
    <Supported>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
      </Format>
    </Supported>
  </ComplexData>
</Input>
</DataInputs>
<ProcessOutputs>
  <Output>
    <ows:Identifier>AnnualExpenditure</ows:Identifier>
    <ows:Title>Annual Expenditure</ows:Title>
    <ows:Abstract>Describes the annual expenditure for each consumer</ows:Abstract>
    <ComplexData>
      <Default>
        <Format>
          <MimeType>text/xml</MimeType>
          <Encoding>UTF-8</Encoding>
          <Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
        </Format>
      </Default>
      <Supported>
        <Format>
          <MimeType>text/xml</MimeType>
          <Encoding>UTF-8</Encoding>
          <Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
        </Format>
      </Supported>
    </ComplexData>
  </Output>
</ProcessOutputs>

```

```

</Output>
<Output>
  <ows:Identifier>CostRecovery</ows:Identifier>
  <ows:Title>Cost Recovery</ows:Title>
  <ows:Abstract>Describes the cost recovery for each utility and bulk
supplier.</ows:Abstract>
  <ComplexData>
    <Default>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
      </Format>
    </Default>
    <Supported>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
      </Format>
    </Supported>
  </ComplexData>
</Output>
<Output>
  <ows:Identifier>AffordabilityIndicators</ows:Identifier>
  <ows:Title> 1)Annual Expenditure and 2)Disposable Income Spent </ows:Title>
  <ows:Abstract>Annual Expenditure of consumers for water services and the share of
disposable income spent for water services</ows:Abstract>
  <ComplexData>
    <Default>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
      </Format>
    </Default>
    <Supported>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
      </Format>
    </Supported>
  </ComplexData>
</Output>
<Output>

```

```

<ows:Identifier>EvaluationOfFlows</ows:Identifier>
<ows:Title>Evaluation Of Flows</ows:Title>
<ows:Abstract>Depicts water and financial flow information.</ows:Abstract>
<ComplexData>
  <Default>
    <Format>
      <MimeType>text/xml</MimeType>
      <Encoding>UTF-8</Encoding>
      <Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
    </Format>
  </Default>
  <Supported>
    <Format>
      <MimeType>text/xml</MimeType>
      <Encoding>UTF-8</Encoding>
      <Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
    </Format>
  </Supported>
</ComplexData>
</Output>
<Output>
  <ows:Identifier>WaterSavingPotential</ows:Identifier>
  <ows:Title>Water Saving Potential</ows:Title>
  <ows:Abstract>Describes the water saving for each consumer</ows:Abstract>
  <ComplexData>
    <Default>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
      </Format>
    </Default>
    <Supported>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
      </Format>
    </Supported>
  </ComplexData>
</Output>
</ProcessOutputs>
</ProcessDescription>
</wps:ProcessDescriptions>

```

## C.2 Water System Request Input (used for baseline and modified water systems)

```

<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:WatERPOntology="http://www.waterp-fp7.eu/WatERPOntology.owl#"
  xmlns:geo="http://www.opengis.net/ont/geosparql#"
  xmlns:gml="http://www.opengis.net/ont/gml#"
  xmlns:owl="http://www.w3.org/2002/07/owl#" xmlns:dc="http://purl.org/dc/elements/1.1/"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#">

  <!-- ##### -->
  <!-- Bulk water suppliers -->
  <!-- ##### -->
  <rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Bulk1">
    <rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#BulkWaterSupplier"
  />
    <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Bulk1</WatERPOntology:id>
    <WatERPOntology:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">My
name Bulk 1</WatERPOntology:name>
    <WatERPOntology:income
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">15.0</WatERPOntology:income>
    <WatERPOntology:hasInvestment rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Investment1" />
  </rdf:Description>
  <!-- ##### -->
  <!-- Water Service Providers -->
  <!-- ##### -->
  <rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Utility1">
    <rdf:type rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#WaterServiceProvider" />
    <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Utility1</WatERPOntology:id>
    <WatERPOntology:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">My
name Utiliy 1</WatERPOntology:name>
    <WatERPOntology:income
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">15.0</WatERPOntology:income>
    <WatERPOntology:hasInvestment rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Investment2" />
  </rdf:Description>
  <rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Utility2">
    <rdf:type rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#WaterServiceProvider" />

```

```

    <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Utility2</WatERPOntology:id>
    <WatERPOntology:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">My
name Utiliy 2</WatERPOntology:name>
    <WatERPOntology:income
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">15.0</WatERPOntology:income>
</rdf:Description>
<!-- ##### -->
<!-- Consumers -->
<!--##### -->
<rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Consumer1">
    <rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#Consumer" />
    <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Consumer1</WatERPOntology:id>
    <WatERPOntology:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">My
name Consumer 1</WatERPOntology:name>
    <WatERPOntology:income
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">15.0</WatERPOntology:income>
    <WatERPOntology:hasInvestment rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Investment2" />
</rdf:Description>

<!-- ##### -->
<!-- Investment -->
<!--##### -->
<rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Investment1">
    <rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#Investment" />
    <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Investment1</WatERPOntology:id>
    <WatERPOntology:name
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Network
cost</WatERPOntology:name>
    <WatERPOntology:description
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Cost for network
expansion</WatERPOntology:description>
    <WatERPOntology:lifetime
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">30.00</WatERPOntology:lifetime>
    <WatERPOntology:invesmentCost
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">30.00</WatERPOntology:invesmentCo
st>
    <WatERPOntology:amortizationRate
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">30.00</WatERPOntology:amortization
Rate>
</rdf:Description>

<rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Investment2">

```

```

<rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#Investment" />
<WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Investment2</WatERPOntology:id>
<WatERPOntology:name
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Appliances
cost</WatERPOntology:name>
<WatERPOntology:description
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Procurement of new
equipment</WatERPOntology:description>
<WatERPOntology:lifetime
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">30.00</WatERPOntology:lifetime>
<WatERPOntology:invesmentCost
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">30.00</WatERPOntology:invesmentCo
st>
<WatERPOntology:amortizationRate
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">30.00</WatERPOntology:amortization
Rate>
</rdf:Description>
<!-- ##### -->
<!-- Clusters -->
<!-- ##### -->
<rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Cluster1">
<rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#Cluster" />
<WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Cluster1</WatERPOntology:id>
<WatERPOntology:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Cluster
1</WatERPOntology:name>
<WatERPOntology:pertains rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#SWKA_Sink1" />
<WatERPOntology:hasConsumer rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Consumer1" />
<geo:hasGeometry rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Cluster1Geometry" />
<WatERPOntology:hasSector rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Sector1" />
<WatERPOntology:priceElasticity
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">25.00</WatERPOntology:priceElasticit
y>
<WatERPOntology:hasUserClass rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#UserClass1" />
<WatERPOntology:hasUserClass rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#UserClass2" />
</rdf:Description>

<rdf:Description rdf:about="http://www.waterp-
fp7.eu/WatERPOntology.owl#Cluster1Geometry">

```

```

<rdf:type rdf:resource="http://www.opengis.net/ont/gml#Polygon" />
<WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Cluster1Geometry</WatERPOntology:
id>
<geo:asGML rdf:datatype="geo:gmlLiteral">38.966556999999995 -77.008232
38.966556999999995 -77.008233 38.966556999999995 -77.008234 38.966556999999995 -
77.008236</geo:asGML>
<geo:asWKT rdf:datatype="geo:wktLiteral">38.966556999999995 -77.008232
38.966556999999995 -77.008233 38.966556999999995 -77.008234 38.966556999999995 -
77.008236</geo:asWKT>
<geo:spatialDimension
rdf:datatype="http://www.w3.org/2001/XMLSchema#integer">2</geo:spatialDimension>
<WatERPOntology:srsName
rdf:datatype="http://www.w3.org/2001/XMLSchema#String">urn:ogc:def:crs:EPSG:4326</WatER
POntology:srsName>
</rdf:Description>

<!-- ##### -->
<!-- Sector -->
<!-- ##### -->
<rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Sector1">
<rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#WaterUse" />
<WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Sector1</WatERPOntology:id>
<WatERPOntology:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Sector
1</WatERPOntology:name>
<WatERPOntology:priceElasticity
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">25.00</WatERPOntology:priceElasticit
y>
</rdf:Description>
<!-- ##### -->
<!-- User classes -->
<!-- ##### -->
<rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#UserClass1">
<rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#UserClass" />
<WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">UserClass1</WatERPOntology:id>
<WatERPOntology:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Single
family city house</WatERPOntology:name>
<WatERPOntology:unitDescription
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">family</WatERPOntology:unitDescripti
on>
<WatERPOntology:numberOfUnits
rdf:datatype="http://www.w3.org/2001/XMLSchema#integer">2.00</WatERPOntology:numberOfUnit
s>

```

```

    <WatERPOntology:waterUseUnit
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">22.30</WatERPOntology:waterUseUnit>
    <WatERPOntology:carryOutActivity rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#Activity1" />
    <WatERPOntology:carryOutActivity rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#Activity2" />
    </rdf:Description>

    <rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#UserClass2">
    <rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#UserClass" />
    <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">UserClass2</WatERPOntology:id>
    <WatERPOntology:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Single
family suburban house</WatERPOntology:name>
    <WatERPOntology:unitDescription
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">resident</WatERPOntology:unitDescription>
    <WatERPOntology:numberOfUnits
rdf:datatype="http://www.w3.org/2001/XMLSchema#integer">3</WatERPOntology:numberOfUnits>
    <WatERPOntology:waterUseUnit
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">25.30</WatERPOntology:waterUseUnit>
    <WatERPOntology:carryOutActivity rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#Activity1" />
    </rdf:Description>
    <!-- ##### -->
    <!-- Activities -->
    <!-- ##### -->
    <rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Activity1">
    <rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#Activity" />
    <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Activity1</WatERPOntology:id>
    <WatERPOntology:name
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Bathing</WatERPOntology:name>
    <WatERPOntology:frequency
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">2.5</WatERPOntology:frequency>
    <WatERPOntology:waterUseActivity
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">2.5</WatERPOntology:waterUseActivity>
    <WatERPOntology:hasAppliance rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#Appliance1" />
    </rdf:Description>

    <rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Activity2">
    <rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#Activity" />

```

```

    <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Activity2</WatERPOntology:id>
    <WatERPOntology:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Toilet
use</WatERPOntology:name>
    <WatERPOntology:frequency
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">2.5</WatERPOntology:frequency>
    <WatERPOntology:waterUseActivity
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">2.5</WatERPOntology:waterUseActivit
y>
    </rdf:Description>
    <!-- ##### -->
    <!-- Appliances -->
    <!-- ##### -->
    <rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Appliance1">
    <rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#Appliance" />
    <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Appliance1</WatERPOntology:id>
    <WatERPOntology:name
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Shower</WatERPOntology:name>
    <WatERPOntology:coverage
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">10</WatERPOntology:coverage>

    <WatERPOntology:waterUseAppliance
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">3.5</WatERPOntology:waterUseAppli
ance>
    </rdf:Description>

    <!-- ##### -->
    <!-- Relations (Bulk water suppliers - Water service providers) -->
    <!-- ##### -->
    <rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Bulk1Utility1">
    <rdf:type rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#WaterManagementFlow" />
    <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Bulk1Utility1</WatERPOntology:id>
    <WatERPOntology:hasProvider rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Bulk1" />
    <WatERPOntology:hasConsumer rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Utility1" />
    <WatERPOntology:priority
rdf:datatype="http://www.w3.org/2001/XMLSchema#integer">1</WatERPOntology:priority>
    <WatERPOntology:netLossFactor
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">10.50</WatERPOntology:netLossFact
or>
    <WatERPOntology:waterPrice
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">10.00</WatERPOntology:waterPrice>

```

```

    <WatERPOntology:omCost
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">10.00</WatERPOntology:omCost>
    </rdf:Description>

    <rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Bulk1Utility2">
    <rdf:type rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#WaterManagementFlow" />
    <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Bulk1Utility2</WatERPOntology:id>
    <WatERPOntology:hasProvider rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Bulk1" />
    <WatERPOntology:hasConsumer rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Utility2" />
    <WatERPOntology:priority
rdf:datatype="http://www.w3.org/2001/XMLSchema#integer">1</WatERPOntology:priority>
    <WatERPOntology:netLossFactor
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">10.50</WatERPOntology:netLossFact
or>
    <WatERPOntology:waterPrice
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">10.00</WatERPOntology:waterPrice>
    <WatERPOntology:omCost
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">10.00</WatERPOntology:omCost>
    </rdf:Description>

    <rdf:Description rdf:about="http://www.waterp-
fp7.eu/WatERPOntology.owl#Utility1Consumer1">
    <rdf:type rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#WaterManagementFlow" />
    <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Utility1Consumer1</WatERPOntology:
id>
    <WatERPOntology:hasProvider rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Utility1" />
    <WatERPOntology:hasConsumer rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Consumer1" />
    <WatERPOntology:priority
rdf:datatype="http://www.w3.org/2001/XMLSchema#integer">1</WatERPOntology:priority>
    <WatERPOntology:netLossFactor
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">10.50</WatERPOntology:netLossFact
or>
    <WatERPOntology:waterPrice
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">10.00</WatERPOntology:waterPrice>
    <WatERPOntology:omCost
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">10.00</WatERPOntology
:omCost>
    </rdf:Description>

```

```

<rdf:Description rdf:about="http://www.waterp-
fp7.eu/WatERPOntology.owl#Utility2Consumer1">
  <rdf:type rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#WaterManagementFlow" />
  <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Utility2Consumer1</Wa
tERPOntology:id>
  <WatERPOntology:hasProvider rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Utility2" />
  <WatERPOntology:hasConsumer rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Consumer1" />
  <WatERPOntology:priority
rdf:datatype="http://www.w3.org/2001/XMLSchema#integer">1</WatERPOntology:pr
iority>
  <WatERPOntology:netLossFactor
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">10.50</WatERPOntology
:netLossFactor>
  <WatERPOntology:waterPrice
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">10.00</WatERPOntology
:waterPrice>
  <WatERPOntology:omCost
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">10.00</WatERPOntology
:omCost>
  </rdf:Description>
</rdf:RDF>

```

### C.3 Evaluation of Flows Request Output

```

<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:WatERPOntology="http://www.waterp-fp7.eu/WatERPOntology.owl#"
  xmlns:qudt="http://data.nasa.gov/qudt/owl/qudt#"
  xmlns:owl="http://www.w3.org/2002/07/owl#" xmlns:dc="http://purl.org/dc/elements/1.1/"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#">

  <!-- ##### -->
  <!-- Bulk water suppliers -->
  <!--##### -->
  <rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Bulk1">
    <rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#BulkWaterSupplier"
  />
    <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Bulk1</WatERPOntology:id>
    <WatERPOntology:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">My
name Bulk 1</WatERPOntology:name>

```

```

    <WatERPOntology:income
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">15.0</WatERPOntology:income>
    </rdf:Description>

    <!-- ##### -->
    <!-- Water Service Providers -->
    <!-- ##### -->
    <rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Utility1">
        <rdf:type rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#WaterServiceProvider" />
        <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Utility1</WatERPOntology:id>
        <WatERPOntology:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">My
name Utility 1</WatERPOntology:name>
        <WatERPOntology:income
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">15.0</WatERPOntology:income>

    </rdf:Description>

    <rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Utility2">
        <rdf:type rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#WaterServiceProvider" />
        <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Utility2</WatERPOntology:id>
        <WatERPOntology:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">My
name Utility 2</WatERPOntology:name>
        <WatERPOntology:income
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">15.0</WatERPOntology:income>

    </rdf:Description>

    <!-- ##### -->
    <!-- Consumers -->
    <!-- ##### -->
    <rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Consumer1">
        <rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#Consumer" />
        <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Consumer1</WatERPOntology:id>
        <WatERPOntology:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">My
name Consumer 1</WatERPOntology:name>
        <WatERPOntology:income
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">15.0</WatERPOntology:income>
    </rdf:Description>

    <!-- ##### -->
    <!-- Water Flows -->

```

```
<!-- ##### -->
<rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#WFBulk1Utility1">
  <rdf:type rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#WaterManagementFlow" />
  <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">WFBulk1Utility1</WatERPOntology:id
>
  <WatERPOntology:hasProvider rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Bulk1" />
  <WatERPOntology:hasConsumer rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Utility1" />
  <WatERPOntology:hasObservation rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#OWFBulk1Utility1Demand1YearBaselineDemandPrediction" />
  <WatERPOntology:hasObservation rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#OWFBulk1Utility1Demand1YearInstrumentsDemandPrediction" />
</rdf:Description>

<rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#WFBulk1Utility2">
  <rdf:type rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#WaterManagementFlow" />
  <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">WFBulk1Utility2</WatERPOntology:id
>
  <WatERPOntology:hasProvider rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Bulk1" />
  <WatERPOntology:hasConsumer rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Utility2" />
  <WatERPOntology:hasObservation rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#OWFBulk1Utility2Demand1YearBaselineDemandPrediction" />
  <WatERPOntology:hasObservation rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#OWFBulk1Utility2Demand1YearInstrumentsDemandPrediction" />
</rdf:Description>

<rdf:Description rdf:about="http://www.waterp-
fp7.eu/WatERPOntology.owl#WFUtility1Consumer1">
  <rdf:type rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#WaterManagementFlow" />
  <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">WFUtility1Consumer1</WatERPOntol
ogy:id>
  <WatERPOntology:hasProvider rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Utility1" />
  <WatERPOntology:hasConsumer rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Consumer1" />
```

```

    <WatERPOntology:hasObservation rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#OWFUtility1Consumer1Demand1YearBaselineDemandPrediction"
 />
    <WatERPOntology:hasObservation rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#OWFUtility1Consumer1Demand1YearInstrumentsDemandPredictio
n" />
  </rdf:Description>

  <rdf:Description rdf:about="http://www.waterp-
fp7.eu/WatERPOntology.owl#WFUtility2Consumer1">
    <rdf:type rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#WaterManagementFlow" />
    <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">WFUtility2Consumer1</WatERPOntol
ogy:id>
    <WatERPOntology:hasProvider rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Utility2" />
    <WatERPOntology:hasConsumer rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Consumer1" />
    <WatERPOntology:hasObservation rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#OWFUtility2Consumer1Demand1YearBaselineDemandPrediction"
 />
    <WatERPOntology:hasObservation rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#OWFUtility2Consumer1Demand1YearInstrumentsDemandPredictio
n" />
  </rdf:Description>

  <!-- ##### -->
  <!-- Financial Flows -->
  <!-- ##### -->
  <rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#FFUtility1Bulk1">
    <rdf:type rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#FinancialManagementFlow" />
    <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">FFUtility1Bulk1</WatERPOntology:id>
    <WatERPOntology:hasInvestor rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Utility1" />
    <WatERPOntology:hasBeneficiary rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Bulk1" />
    <WatERPOntology:hasObservation rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#OFFUtility1Bulk1Payment1YearBaselinePaymentPrediction" />
    <WatERPOntology:hasObservation rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#OFFUtility1Bulk1Payment1YearInstrumentsPaymentPrediction" />
  </rdf:Description>

```

```
<rdf:Description rdf:about="http://www.waterp-
fp7.eu/WatERPOntology.owl#FFConsumer1Utility1">
  <rdf:type rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#FinancialManagementFlow" />
  <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">FFConsumer1Utility1</WatERPOntolo
gy:id>
  <WatERPOntology:hasInvestor rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Consumer1" />
  <WatERPOntology:hasBeneficiary rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Utility1" />
  <WatERPOntology:hasObservation rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#OFFConsumer1Utility1Payment1YearBaselinePaymentPrediction"
/>
  <WatERPOntology:hasObservation rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#OFFConsumer1Utility1Payment1YearInstrumentsPaymentPredictio
n" />
</rdf:Description>

<rdf:Description rdf:about="http://www.waterp-
fp7.eu/WatERPOntology.owl#FFConsumer1Utility2">
  <rdf:type rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#FinancialManagementFlow" />
  <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">FFConsumer1Utility2</WatERPOntolo
gy:id>
  <WatERPOntology:hasInvestor rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Consumer1" />
  <WatERPOntology:hasBeneficiary rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Utility2" />
  <WatERPOntology:hasObservation rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#OFFConsumer1Utility2Payment1YearBaselinePaymentPrediction"
/>
  <WatERPOntology:hasObservation rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#OFFConsumer1Utility2Payment1YearInstrumentsPaymentPredictio
n" />
</rdf:Description>

<!-- ##### -->
<!-- Observations -->
<!-- ##### -->
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## C.4 Evaluation of Expenditures Request Output

```

<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:WatERPOntology="http://www.waterp-fp7.eu/WatERPOntology.owl#"
  xmlns:qudt="http://data.nasa.gov/qudt/owl/qudt#"
  xmlns:owl="http://www.w3.org/2002/07/owl#" xmlns:dc="http://purl.org/dc/elements/1.1/"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"

  <rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Consumer1">
    <rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#Consumer" />
    <WatERPOntology:id
    rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Consumer1</WatERPOntology:id>
    <WatERPOntology:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">My
    name Consumer 1</WatERPOntology:name>
    <WatERPOntology:income
    rdf:datatype="http://www.w3.org/2001/XMLSchema#double">15.0</WatERPOntology:income>
  </rdf:Description>

  <rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#FFConsumer1">
    <rdf:type rdf:resource="http://www.waterp-
    fp7.eu/WatERPOntology.owl#FinancialManagementFlow" />
    <WatERPOntology:id
    rdf:datatype="http://www.w3.org/2001/XMLSchema#string">FFConsumer1</WatERPOntology:id>
    <WatERPOntology:hasInvestor rdf:resource="http://www.waterp-
    fp7.eu/WatERPOntology.owl#Consumer1" />
    <WatERPOntology:hasBeneficiary rdf:resource="http://www.waterp-
    fp7.eu/WatERPOntology.owl#Utility1" />
    <WatERPOntology:hasBeneficiary rdf:resource="http://www.waterp-
    fp7.eu/WatERPOntology.owl#Utility2" />
    <WatERPOntology:hasObservation rdf:resource="http://www.waterp-
    fp7.eu/WatERPOntology.owl#OFFConsumer1Payment1YearBaselinePaymentPrediction" />
    <WatERPOntology:hasObservation rdf:resource="http://www.waterp-
    fp7.eu/WatERPOntology.owl#OFFConsumer1Payment1YearInstrumentsPaymentPrediction" />

```

</rdf:Description>

```
<rdf:Description rdf:about="http://www.waterp-
fp7.eu/WatERPOntology.owl#OFFConsumer1Payment1YearBaselinePaymentPrediction" >
  <rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#Observation" />
  <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">OFFConsumer1Payment1YearBaseli
nePaymentPrediction</WatERPOntology:id>
  <WatERPOntology:hasPhenomenon rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Payment1Year"/>
  <WatERPOntology:hasProcedure rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#BaselinePaymentPrediction"/>
  <WatERPOntology:hasObservationResult rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#ORFFConsumer1Payment1YearBaselinePaymentPrediction"/>
</rdf:Description>
```

```
<rdf:Description rdf:about="http://www.waterp-
fp7.eu/WatERPOntology.owl#ORFFConsumer1Payment1YearBaselinePaymentPrediction" >
  <rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#SpecificValue" />
  <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">ORFFConsumer1Payment1YearBasel
inePaymentPrediction</WatERPOntology:id>
  <WatERPOntology:value
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">200000000</WatERPOntology:value>
  <qudt:unit rdf:resource="http://data.nasa.gov/qudt/owl/unit#EuropeanMonetaryUnit" />
</rdf:Description>
```

```
<rdf:Description rdf:about="http://www.waterp-
fp7.eu/WatERPOntology.owl#OFFConsumer1Payment1YearInstrumentsPaymentPrediction" >
  <rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#Observation" />
  <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">OFFConsumer1Payment1YearInstru
mentsPaymentPrediction</WatERPOntology:id>
  <WatERPOntology:hasPhenomenon rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Payment1Year"/>
  <WatERPOntology:hasProcedure rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#InstrumentsPaymentPrediction"/>
  <WatERPOntology:hasObservationResult rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#ORFFConsumer1Payment1YearInstrumentsPaymentPrediction"/>
</rdf:Description>
```

```
<rdf:Description rdf:about="http://www.waterp-
fp7.eu/WatERPOntology.owl#ORFFConsumer1Payment1YearInstrumentsPaymentPrediction" >
  <rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#SpecificValue" />
```

```

    <WatERPOntology:id
    rdf:datatype="http://www.w3.org/2001/XMLSchema#string">ORFFConsumer1Payment1YearInstr
    umentsPaymentPrediction</WatERPOntology:id>
    <WatERPOntology:value
    rdf:datatype="http://www.w3.org/2001/XMLSchema#double">16000000</WatERPOntology:value>
    <qudt:unit rdf:resource="http://data.nasa.gov/qudt/owl/unit#EuropeanMonetaryUnit" />
    </rdf:Description>

</rdf:RDF>

```

## C.5 Water Saving Potential Indicators Request Output

```

<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:WatERPOntology="http://www.waterp-fp7.eu/WatERPOntology.owl#"
  xmlns:qudt="http://data.nasa.gov/qudt/owl/qudt#"
  xmlns:owl="http://www.w3.org/2002/07/owl#" xmlns:dc="http://purl.org/dc/elements/1.1/"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"

  <rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Consumer1">
    <rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#Consumer" />
    <WatERPOntology:id
    rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Consumer1</WatERPOntology:id>
    <WatERPOntology:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">My
    name Consumer 1</WatERPOntology:name>
    </rdf:Description>

    <rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#WFConsumer1">
      <rdf:type rdf:resource="http://www.waterp-
      fp7.eu/WatERPOntology.owl#WaterManagementFlow" />
      <WatERPOntology:id
      rdf:datatype="http://www.w3.org/2001/XMLSchema#string">WFConsumer1</WatERPOntology:id>
      <WatERPOntology:hasProvider rdf:resource="http://www.waterp-
      fp7.eu/WatERPOntology.owl#Utility1" />
      <WatERPOntology:hasProvider rdf:resource="http://www.waterp-
      fp7.eu/WatERPOntology.owl#Utility2" />
      <WatERPOntology:hasConsumer rdf:resource="http://www.waterp-
      fp7.eu/WatERPOntology.owl#Consumer1" />
      <WatERPOntology:hasObservation rdf:resource="http://www.waterp-
      fp7.eu/WatERPOntology.owl#OWFConsumer1Demand1YearBaselineDemandPrediction" />
      <WatERPOntology:hasObservation rdf:resource="http://www.waterp-
      fp7.eu/WatERPOntology.owl#OWFConsumer1Demand1YearInstrumentsDemandPrediction" />
      </rdf:Description>

```

```

<rdf:Description rdf:about="http://www.waterp-
fp7.eu/WatERPOntology.owl#OWFConsumer1Demand1YearBaselineDemandPrediction">
  <rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#Observation" />
  <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">OWFConsumer1Demand1YearBaseli
neDemandPrediction</WatERPOntology:id>
  <WatERPOntology:hasPhenomenon rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Demand1Year"/>
  <WatERPOntology:hasProcedure rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#BaselineDemandPrediction"/>
  <WatERPOntology:hasObservationResult rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#ORWFConsumer1Demand1YearBaselineDemandPrediction"/>
</rdf:Description>

<rdf:Description rdf:about="http://www.waterp-
fp7.eu/WatERPOntology.owl#ORWFConsumer1Demand1YearBaselineDemandPrediction">
  <rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#SpecificValue" />
  <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">ORWFConsumer1Demand1YearBase
lineDemandPrediction</WatERPOntology:id>
  <WatERPOntology:value
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">20.4</WatERPOntology:value>
  <qudt:unit rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#hm^3" />
</rdf:Description>

<rdf:Description rdf:about="http://www.waterp-
fp7.eu/WatERPOntology.owl#OWFConsumer1Demand1YearInstrumentsDemandPrediction">
  <rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#Observation" />
  <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">OWFConsumer1Demand1YearInstru
mentsDemandPrediction</WatERPOntology:id>
  <WatERPOntology:hasPhenomenon rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#Demand1Year"/>
  <WatERPOntology:hasProcedure rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#InstrumentsDemandPrediction"/>
  <WatERPOntology:hasObservationResult rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#ORWFConsumer1Demand1YearInstrumentsDemandPrediction"/>
</rdf:Description>

<rdf:Description rdf:about="http://www.waterp-
fp7.eu/WatERPOntology.owl#ORWFConsumer1Demand1YearInstrumentsDemandPrediction">
  <rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#SpecificValue" />
  <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">ORWFConsumer1Demand1YearInstr
umentsDemandPrediction</WatERPOntology:id>

```

```

    <WatERPOntology:value
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">14.4</WatERPOntology:value>
    <qudt:unit rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#hm^3" />
  </rdf:Description>

</rdf:RDF>

```

## C.6 Affordability Indicators Request Output

```

<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:WatERPOntology="http://www.waterp-fp7.eu/WatERPOntology.owl#"
  xmlns:qudt="http://data.nasa.gov/qudt/owl/qudt#"
  xmlns:owl="http://www.w3.org/2002/07/owl#" xmlns:dc="http://purl.org/dc/elements/1.1/"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#">

  <rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Consumer1">
    <rdf:type rdf:resource="http://www.waterp-fp7.eu/WatERPOntology.owl#Consumer" />
    <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Consumer1</WatERPOntology:id>
    <WatERPOntology:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">My
name Consumer 1</WatERPOntology:name>
    <WatERPOntology:shareValue
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">0.5</WatERPOntology:shareValue>
  </rdf:Description>

  <rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Utility1">
    <rdf:type rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#WaterServiceProvider" />
    <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Utility1</WatERPOntology:id>
    <WatERPOntology:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">My
name Utility 1</WatERPOntology:name>
    <WatERPOntology:shareValue
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">0.75</WatERPOntology:shareValue>
  </rdf:Description>

  <rdf:Description rdf:about="http://www.waterp-fp7.eu/WatERPOntology.owl#Utility2">
    <rdf:type rdf:resource="http://www.waterp-
fp7.eu/WatERPOntology.owl#WaterServiceProvider" />
    <WatERPOntology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Utility2</WatERPOntology:id>
    <WatERPOntology:name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">My
name Utility 2</WatERPOntology:name>

```

```

    <WatERPontology:shareValue
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">0.25</WatERPontology:shareValue>
    </rdf:Description>
</rdf:RDF>

```

## C.7 Cost Recovery Indicators Request Output

```

<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:WatERPontology="http://www.waterp-fp7.eu/WatERPontology.owl#"
  xmlns:owl="http://www.w3.org/2002/07/owl#"
  xmlns:dc="http://purl.org/dc/elements/1.1/"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#">

  <rdf:Description rdf:about="http://www.waterp-
fp7.eu/WatERPontology.owl#Bulk1">
    <rdf:type rdf:resource="http://www.waterp-
fp7.eu/WatERPontology.owl#BulkWaterSupplier" />
    <WatERPontology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Bulk1</WatERPontology
:id>
    <WatERPontology:name
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">My name Bulk
1</WatERPontology:name>
    <WatERPontology:costRecoveryValue
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">0.25</WatERPontology:
costRecoveryValue>
  </rdf:Description>

  <rdf:Description rdf:about="http://www.waterp-
fp7.eu/WatERPontology.owl#Utility1">
    <rdf:type rdf:resource="http://www.waterp-
fp7.eu/WatERPontology.owl#WaterServiceProvider" />
    <WatERPontology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Utility1</WatERPontol
ogy:id>
    <WatERPontology:name
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">My name Utiliy
1</WatERPontology:name>
    <WatERPontology:costRecoveryValue
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">0.75</WatERPontology:
costRecoveryValue>
  </rdf:Description>

```

```
<rdf:Description rdf:about="http://www.waterp-
fp7.eu/WatERPontology.owl#Utility2">
  <rdf:type rdf:resource="http://www.waterp-
fp7.eu/WatERPontology.owl#WaterServiceProvider" />
  <WatERPontology:id
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Utility2</WatERPontol
ogy:id>
  <WatERPontology:name
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">My name Utiliy
2</WatERPontology:name>
  <WatERPontology:costRecoveryValue
rdf:datatype="http://www.w3.org/2001/XMLSchema#double">0.55</WatERPontology:
costRecoveryValue>
  </rdf:Description>
</rdf:RDF>
```

## Appendix D: Profiling Process Description Files

### D.1 Populate SWKA Process

```

<?xml version="1.0" encoding="UTF-8"?>
<wps:ProcessDescriptions
  xmlns:wps="http://www.opengis.net/wps/1.0.0"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xmlns:ows="http://www.opengis.net/ows/1.1"
  xsi:schemaLocation="
    http://www.opengis.net/wps/1.0.0
    http://schemas.opengis.net/wps/1.0.0/wpsDescribeProcess_response.xsd"
  xml:lang="en-US"
  service="WPS"
  version="1.0.0">
  <ProcessDescription
    statusSupported="false"
    storeSupported="false"
    wps:processVersion="1.0">
    <ows:Identifier>gr.iccs.waterp.dms.process.PopulateSWKAProcess</ows:Identifier>
    <ows>Title>Title</ows>Title>
    <ows:Abstract>Abstract</ows:Abstract>
    <DataInputs>
      <Input minOccurs="1" maxOccurs="1">
        <ows:Identifier>dailyMinTemperature</ows:Identifier>
        <ows>Title>Minimum temperature</ows>Title>
        <ows:Abstract>Minimum temperature</ows:Abstract>

        <ComplexData>
          <Default>
            <Format>
              <MimeType>text/xml</MimeType>
              <Encoding>UTF-8</Encoding>
              <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
            </Format>
          </Default>
          <Supported>
            <Format>
              <MimeType>text/xml</MimeType>
              <Encoding>UTF-8</Encoding>
              <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
            </Format>
          </Supported>
        </ComplexData>
      </Input>

```

```

<Input minOccurs="1" maxOccurs="1">
  <ows:Identifier>dailyMaxTemperature</ows:Identifier>
  <ows:Title>Maximum temperature</ows:Title>
  <ows:Abstract>Maximum temperature</ows:Abstract>

  <ComplexData>
    <Default>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
      </Format>
    </Default>
    <Supported>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
      </Format>
    </Supported>
  </ComplexData>
</Input>
<Input minOccurs="1" maxOccurs="1">
  <ows:Identifier>dailyAvgTemperature</ows:Identifier>
  <ows:Title>Average temperature</ows:Title>
  <ows:Abstract>Average temperature</ows:Abstract>
  <ComplexData>
    <Default>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
      </Format>
    </Default>
    <Supported>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
      </Format>
    </Supported>
  </ComplexData>
</Input>
<Input minOccurs="1" maxOccurs="1">
  <ows:Identifier>consumption</ows:Identifier>
  <ows:Title>Consumption</ows:Title>

```

```

<ows:Abstract>Consumption</ows:Abstract>
<ComplexData>
  <Default>
    <Format>
      <MimeType>text/xml</MimeType>
      <Encoding>UTF-8</Encoding>
      <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
    </Format>
  </Default>
  <Supported>
    <Format>
      <MimeType>text/xml</MimeType>
      <Encoding>UTF-8</Encoding>
      <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
    </Format>
  </Supported>
</ComplexData>
</Input>
<Input minOccurs="1" maxOccurs="1">
  <ows:Identifier>dailyPrecipitation</ows:Identifier>
  <ows:Title>Precipitation</ows:Title>
  <ows:Abstract>Precipitation</ows:Abstract>
  <ComplexData>
    <Default>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
      </Format>
    </Default>
    <Supported>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
      </Format>
    </Supported>
  </ComplexData>
</Input>
<Input minOccurs="1" maxOccurs="1">
  <ows:Identifier>dayCharacterization</ows:Identifier>
  <ows:Title>Day Characterization</ows:Title>
  <ows:Abstract>Day Characterization</ows:Abstract>
  <ComplexData>
    <Default>
      <Format>

```

```

        <MimeType>text/xml+rdf</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://www.waterp-fp7.eu/WatERPOntology.owl</Schema>
    </Format>
</Default>
<Supported>
    <Format>
        <MimeType>text/xml+rdf</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://www.waterp-fp7.eu/WatERPOntology.owl</Schema>
    </Format>
</Supported>
</ComplexData>
</Input>
<Input minOccurs="1" maxOccurs="1">
    <ows:Identifier>date</ows:Identifier>
    <ows:Title>Date</ows:Title>
    <ows:Abstract>Date</ows:Abstract>
    <ComplexData>
        <Default>
            <Format>
                <MimeType>text/xml</MimeType>
                <Encoding>UTF-8</Encoding>
                <Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
            </Format>
        </Default>
        <Supported>
            <Format>
                <MimeType>text/xml</MimeType>
                <Encoding>UTF-8</Encoding>
                <Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
            </Format>
        </Supported>
    </ComplexData>
</Input>
</DataInputs>
<ProcessOutputs>
    <Output>
        <ows:Identifier>isPopulated</ows:Identifier>
        <ows:Title>Database is populated</ows:Title>
        <ows:Abstract>Returns if the information has been added on the
database</ows:Abstract>
        <LiteralOutput>
            <ows:DataType ows:reference="xs:boolean" />
        </LiteralOutput>
    </Output>

```

```

    </ProcessOutputs>
  </ProcessDescription>
</wps:ProcessDescriptions>

```

## D.2 Populate ACA Process

```

<?xml version="1.0" encoding="UTF-8"?>
<wps:ProcessDescriptions
  xmlns:wps="http://www.opengis.net/wps/1.0.0"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xmlns:ows="http://www.opengis.net/ows/1.1"
  xsi:schemaLocation="
    http://www.opengis.net/wps/1.0.0
    http://schemas.opengis.net/wps/1.0.0/wpsDescribeProcess_response.xsd"
  xml:lang="en-US"
  service="WPS"
  version="1.0.0">
  <ProcessDescription
    statusSupported="false"
    storeSupported="false"
    wps:processVersion="1.0">
    <ows:Identifier>gr.iccs.waterp.dms.process.PopulateACAProcess</ows:Identifier>
    <ows:Title>Title</ows:Title>
    <ows:Abstract>Abstract</ows:Abstract>
    <DataInputs>
      <Input minOccurs="1" maxOccurs="1">
        <ows:Identifier>dailyMinTemperature</ows:Identifier>
        <ows:Title>Minimum temperature</ows:Title>
        <ows:Abstract>Minimum temperature</ows:Abstract>

        <ComplexData>
          <Default>
            <Format>
              <MimeType>text/xml</MimeType>
              <Encoding>UTF-8</Encoding>
              <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
            </Format>
          </Default>
          <Supported>
            <Format>
              <MimeType>text/xml</MimeType>
              <Encoding>UTF-8</Encoding>
              <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
            </Format>
          </Supported>
        </ComplexData>
      </Input>
    </DataInputs>
  </ProcessDescription>
</wps:ProcessDescriptions>

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        </Supported>
    </ComplexData>
</Input>
<Input minOccurs="1" maxOccurs="1">
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    <ows:Title>Maximum temperature</ows:Title>
    <ows:Abstract>Maximum temperature</ows:Abstract>

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                <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
            </Format>
        </Default>
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                <Encoding>UTF-8</Encoding>
                <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
            </Format>
        </Supported>
    </ComplexData>
</Input>
<Input minOccurs="1" maxOccurs="1">
    <ows:Identifier>dailyAvgTemperature</ows:Identifier>
    <ows:Title>Average temperature</ows:Title>
    <ows:Abstract>Average temperature</ows:Abstract>
    <ComplexData>
        <Default>
            <Format>
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                <Encoding>UTF-8</Encoding>
                <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
            </Format>
        </Default>
        <Supported>
            <Format>
                <MimeType>text/xml</MimeType>
                <Encoding>UTF-8</Encoding>
                <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
            </Format>
        </Supported>
    </ComplexData>
</Input>

```

```

<Input minOccurs="1" maxOccurs="1">
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  <ows:Title>Consumption</ows:Title>
  <ows:Abstract>Consumption</ows:Abstract>
  <ComplexData>
    <Default>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
      </Format>
    </Default>
    <Supported>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
      </Format>
    </Supported>
  </ComplexData>
</Input>
<Input minOccurs="1" maxOccurs="1">
  <ows:Identifier>dailyPrecipitation</ows:Identifier>
  <ows:Title>Precipitation</ows:Title>
  <ows:Abstract>Precipitation</ows:Abstract>
  <ComplexData>
    <Default>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
      </Format>
    </Default>
    <Supported>
      <Format>
        <MimeType>text/xml</MimeType>
        <Encoding>UTF-8</Encoding>
        <Schema>http://schemas.opengis.net/waterml/2.0/waterml2.xsd</Schema>
      </Format>
    </Supported>
  </ComplexData>
</Input>
<Input minOccurs="1" maxOccurs="1">
  <ows:Identifier>dayCharacterization</ows:Identifier>
  <ows:Title>Day Characterization</ows:Title>
  <ows:Abstract>Day Characterization</ows:Abstract>

```

```

    <ComplexData>
      <Default>
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          <Encoding>UTF-8</Encoding>
          <Schema>http://www.waterp-fp7.eu/WatERPontology.owl</Schema>
        </Format>
      </Default>
      <Supported>
        <Format>
          <MimeType>text/xml+rdf</MimeType>
          <Encoding>UTF-8</Encoding>
          <Schema>http://www.waterp-fp7.eu/WatERPontology.owl</Schema>
        </Format>
      </Supported>
    </ComplexData>
  </Input>
  <Input minOccurs="1" maxOccurs="1">
    <ows:Identifier>date</ows:Identifier>
    <ows:Title>Date</ows:Title>
    <ows:Abstract>Date</ows:Abstract>
    <ComplexData>
      <Default>
        <Format>
          <MimeType>text/xml</MimeType>
          <Encoding>UTF-8</Encoding>
          <Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
        </Format>
      </Default>
      <Supported>
        <Format>
          <MimeType>text/xml</MimeType>
          <Encoding>UTF-8</Encoding>
          <Schema>http://schemas.opengis.net/gml/3.1.1/base/gml.xsd</Schema>
        </Format>
      </Supported>
    </ComplexData>
  </Input>
</DataInputs>
<ProcessOutputs>
  <Output>
    <ows:Identifier>isPopulated</ows:Identifier>
    <ows:Title>Database is populated</ows:Title>
    <ows:Abstract>Returns if the information has been added on the
database</ows:Abstract>
    <LiteralOutput>

```

```
<ows:DataType ows:reference="xs:boolean" />
</LiteralOutput>
</Output>
</ProcessOutputs>
</ProcessDescription>
</wps:ProcessDescriptions>
```