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Interactive water services: The WATERNOMICS approach

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Abstract

WATERNOMICS focuses on the development of ICT as an enabling technology to manage water as a resource, increase end-user conservation awareness and affect behavioral changes. Unique aspects of WATERNOMICS include personalized feedback about end-user water consumption, the development of systematic and standards-based water resource management systems, new sensor hardware developments, and the introduction of forecasting and fault detection diagnosis to the analysis of water consumption data. These services will be bundled into the WATERNOMICS Water Information Services Platform. This paper presents the overall architectural approach to WATERNOMICS and details the potential interactive services possible based on this novel platform.

Keywords: Interactive water services; decision support; gamification; linked data; fault detection;

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1. Introduction

Global energy and water demand is expected to rise 40% over the next 20 years [1]. The World Economic Forum has cited "The Water Supply Crises" as a major risk to global economic growth and environmental policies. By 2025, 1.8 billion people will live in water scarce regions and two thirds subjected to water stress. In Europe, 20-40% of water is being wasted due to poor infrastructure, consumer negligence and lack of proper resource management.

The root cause behind many of these problems is, up until now, that water has not been adequately considered as a resource. The result is that our water infrastructure, business models, and behaviours at all levels of the water value chain reflect this fact. Subsequently, the drive to develop and implement ICT in the sector is lagging. However, there is the significant opportunity to accelerate the development and implementation of ICT-based water awareness, management and conservation solutions by following best practices and lessons learned from the energy markets.

With this background, the goal of the WATERNOMICS project is to provide personalised and actionable information about water consumption and water availability to individual households, companies and cities in an intuitive and effective manner at a time-scale relevant for decision making. Access to this information will increase end-user awareness and improve the quality of the decisions from decision makers regarding water management and water government.

2. Project Objectives

The broad objectives of this project are as follows:

Table 1. WATERNOMICS objectives

Objective	Description
Awareness	Promote ICT enabled water awareness to the public using airports and water utilities as pilot examples. The platform will engage consumers in new, interactive, and personalized innovations that bring water efficiency to the forefront and leads to changes in water-use behaviour
Methodology	Introduce demand response and accountability principles (water footprint) in the water sector. WATERNOMICS proposes a standards-based methodology for the design of ICT-based water management programs at the corporate and municipal levels.
Interactive Water Information Services	Integrate real time water usage related information from meters, sensors, data analysis (leak and fault detection), and hydro-meteorological information. WATERNOMICS will offer these water information services and decision support systems to end-users in an intuitive and high impact platform. Personalized information services will be developed and delivered to end users and decision makers via dashboards, smartphone applications and web portals
Analysis	To develop and demonstrate fault detection diagnosis rules for water networks using consumption data, historical benchmarking, equipment benchmarking, and simulation methods. WATERNOMICS will also develop novel low-cost leak detection methods for water networks.
Decision Support Systems	To empower corporate decision makers and municipal area managers with a water information platform together with relevant tools and methodologies to enact ICT-enabled water management programs
Business Models	To make possible new water pricing options and policy actions by combining water availability and consumption data
Impact	Through a combination of the above data analysis, decision support, and personalized information services, to reduce water consumption, water peak consumption, and the energy distribution loads attributed to water.

3. WATERNOMICS Platform

The proposed objectives will be accomplished with minimal disruption to existing information infrastructure. The objective is to expose the data within existing systems, but only link the data when it needs to be shared. Representing water usage data within a linked data format allows it to be easily combined with linked data from other relevant domain silos. The main components of the initial envisioned architecture, (Fig. 2), are (i) water usage metering and monitoring on existing systems, (ii) a linked water dataspace consisting of a linked data cloud & support services, and (iii) the resulting water management applications.

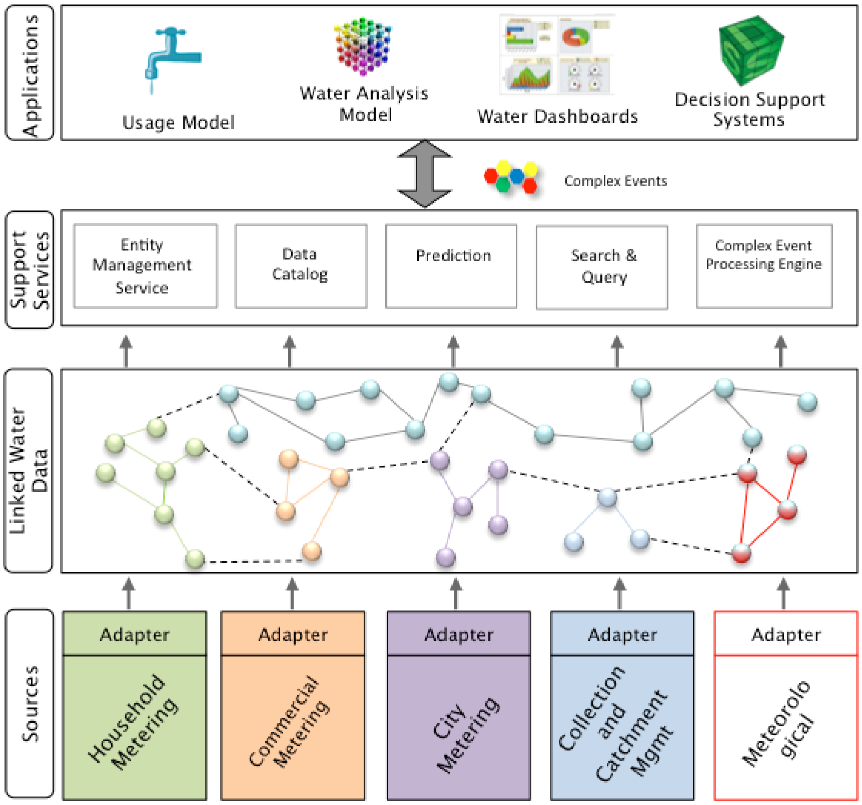

Fig. 1: WATERNOMICS Platform

Sources: At the bottom of the architecture are the existing operational legacy information systems. These include existing household water meters, pumping station monitoring, meteorological data etc. Data adapters will convert this information to RDF (Resource Description Framework) in order to standardise, contextualise and link each individual data source. This process transforms multiple legacy data formats and lifts it to the dataspace.

Linked Water Data: The linked dataspace [2] links data at the information-level by focusing on the conceptual similarities between information, as has already been successfully applied to solve similar problems within the Building Management [3] and the Energy Management [4] domains. This is achieved by following an entity-centric approach that focuses on the concepts that exist within the systems, for example, business entities like buildings, rooms, employees, products, and equipment. Entities within the dataspace are enriched with data from multiple systems resulting in a cloud of interlinked resources. The resulting 'Linked Water Cloud' is rich with knowledge and semantics about water usage performance indicators, and thus forms the basis for a real-time water usage analytics and other applications with the help of *support services.*

Support Services: Dataspace support services are designed to simplify the consumption of the linked data cloud by encapsulating common services for reuse

Water Usage and Management Applications: At the top of the architecture are the water usage and management applications that consume the resulting data and events from the linked water data. Such applications will include personalized water dashboards presenting real-time actionable information on water usage, availability and pricing. They will also include a set of decision support systems at company and city level that facilitate the decision making process in terms of water usage related decisions and policies. For the household level such applications will also include interactive games based on the real-time data encouraging best practice in water usage and management at household level.

4. Applications

The WATERNOMICS platform forms the basis for the delivery of a number of key services, as outlined in the project objectives:

Fig. 2: WATERNOMCIS applications

4.1. Water Analysis Services

Analysis applications will use the rich data provided by the WATERNOMICS platform to provide additional insight into the performance of the underlying systems.

Water Usage Prediction Models: An operational real-time forecasting system of water availability will be developed to increase awareness at the household level during periods of water scarcity. The forecast of water availability will be transformed into an indicator that shows to the household consumer, the current need for efficient water use. The service will analyse previous water usage and availability and will forecast water usage and availability for a specified forecast horizon.

Hydro-meteorological Drought Forecast: WATERNOMICS will provide hydro-meteorological forecasts for indicators of water availability, to promote water use efficiency during dry spells. The main advance with respect to state-of-the-art hydro-meteorological forecasting methods, is that WATERNOMICS will provide probabilistic forecasts. These forecasts will show the range of predicted variables, e.g. rainfall or water level, with their probability distribution [5], [6]. The main advantage of a probabilistic forecast is that early warning signs can be provided to water utility companies. Outliers are explicitly part of the decision support [7]. Low chance/high impact events will no longer surprise companies, as they will be provided with ample lead times. This is especially of interest where citizen awareness has to be built up before an actual crisis hits.

Leak Detection / Fault Detection and Diagnosis (FDD): Leak detection is an active effort to pinpointing the exact position of a leak. Due to the fact that these activities are costly, water utilities concentrate on reducing water losses by detecting and locating leaks generally in the main pipes of the distribution network. In addition, current methods for leak detection are mainly based on acoustic principles [8]. WATERNOMICS will investigate a number of novel methods for leak detection, at both small scale (residential, business users) and large scale (municipal / regional distribution networks). This work will be based on a number of recent technological advances in this area which may enable cheaper, more cost-effective fault identification for a multitude of use-cases. These may include, but are not limited to:

- Citizen reporting - crowdsourcing: A standard procedure that water utilities use to deal with damages in the distribution network is to allow citizens reporting visible water leaks by phone.

- Leak detectors at household level: A number of devices have been proposed to detect leakages at household level. On such device uses electric sensors that are activated once excess water (e.g. from a leak) is detected.
- Smartphone apps: During the night, we will monitor the sound in the pipes at and near household level, when the phones are charging, the back-ground noise is low and the pressure in the system is high. It is expected that leaks from the pipes in the streets can also be detected by these devices, allowing for an accurate leakage mapping of the entire network

In addition, WATERNOMICS will build on the experience of fault detection and diagnosis in other industries, such as detection of leaks and component failures in HVAC Heating, Ventilation and Air-Conditioning) systems [9]–[11].

4.2. Interactive Water Information Services

There is already a number of studies on how interactive water information and natural resources consumption information services deployed in households might help on affecting family behaviour and how such systems should be designed to be more effective. Salazar et. al. [12] present a mix of various multimedia tools that use eco-visualizations, cartoon characters and narratives to affect family behaviour based on the parent-children relationship. Makonin, Pasquier and Bartram [13] present a system of ambient displays for showing consumption information for electricity water and natural gas. They exploit three different approaches in information visualization to investigate which ones are more effective in changing users' behaviour. In fact, there are already a number of cases where households, companies and cities are exploiting the benefits of smart water metering grids and their real-time water usage services. One such case is the software utilities and the smart metering infrastructure developed by Oracle[*] utilities which helps water supply companies to meet demand and end users to manage their water usage effectively. iQuatic[†] water monitoring is another example of such an application making easier to monitor water usage in real-time through a specially designed information platform. At city level, New York City[‡] where wireless meters are installed in their water supply network in order to help city officials to track water use in real time.

WATERNOMICS will exploit a number of different persuasive technologies for affecting users' behaviour, targeting not only end-user behaviour change at a household level, but also at company and city level. The effects of personalized and customizable solutions at these levels will also be investigated.

4.3. Decision Support Systems

Decision support systems for water are typically in systems for strategic decisions and those for operation and maintenance [14]. Strategic decisions concern long-term investments and public policy [15]. The decision support system of WATERNOMICS focuses mainly on efficiency gains through improved operation and maintenance.

For operational decision making, many different approaches exist, from simple Proportional Integral Delay control [16], to more complex decision support tools such as Model Predictive Control [17] and Stochastic Dynamic Programming [18]. There are already decision support systems for drinking water supply, and WATERNOMICS will build on these existing systems. An important scientific and practical improvement over present decision support systems is that we will take uncertainties into account. Inclusion of uncertainty in decision support needs careful communication and visualisation. A mere graph of the probability density function is usually not immediately understood by operational decision makers. Instead, colour coding and percentile reporting will be developed. The true innovation will be that we will not "simply" design another operational method. Instead, scientists and stakeholders will be engaged within WATERNOMICS in a continuous dialogue in order to close the gap between existing academic knowledge (advanced algorithms) and the water supply process (daily practice). Closing this gap will be based on the analysis of information demand [19].

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[*] http://www.digitalopportunity.org/news/thailand-to-launch-e-service-to-monitor-water-use/
[†] http://www.noveda.com/solutions/water-management/iquatic-water-monitoring
[‡] http://www.fastcompany.com/1669508/nyc-begin-tracking-water-use-real-time-wireless-meters

5. Demonstration

The WATERNOMICS platform will be deployed on three pilot sites, capturing a variety of end-use activities, applications and climates:

Table 2. WATERNOMICS demonstration pilots.

Pilot Type	Audience	Climate	Tariffs	Existing Metering	No. Users	Existing Leak Detection
Domestic / Public	Public employees, students and households	Temperate coastal climate	Flat water	Limited water metering	~ 1,500	None
Municipal	Households, micro businesses, and the municipal utility	Mediterranean	Flat water	Changeover underway to new sensors with telemetry	~50	None
Corporate	Management teams and employees in a commercial setting	Humid subtropical climate	Flat water and wastewater	Limited to none	~20	None

5.1. Domestic / Public

Water used by households is typically 60 - 80% of the public water supply across Europe [20]. Water efficient domestic appliances, such as washing machines or dishwashers, have already contributed towards reducing water usage. However, more significant steps must be taken in order to increase people's awareness of water issues and change their behaviour towards a more sustainable water usage. The use of water for personal hygiene accounts for about 60% of water used by households [20]; the majority of domestic water is used for showering / bathing and toilet flushing (Fig. 3).

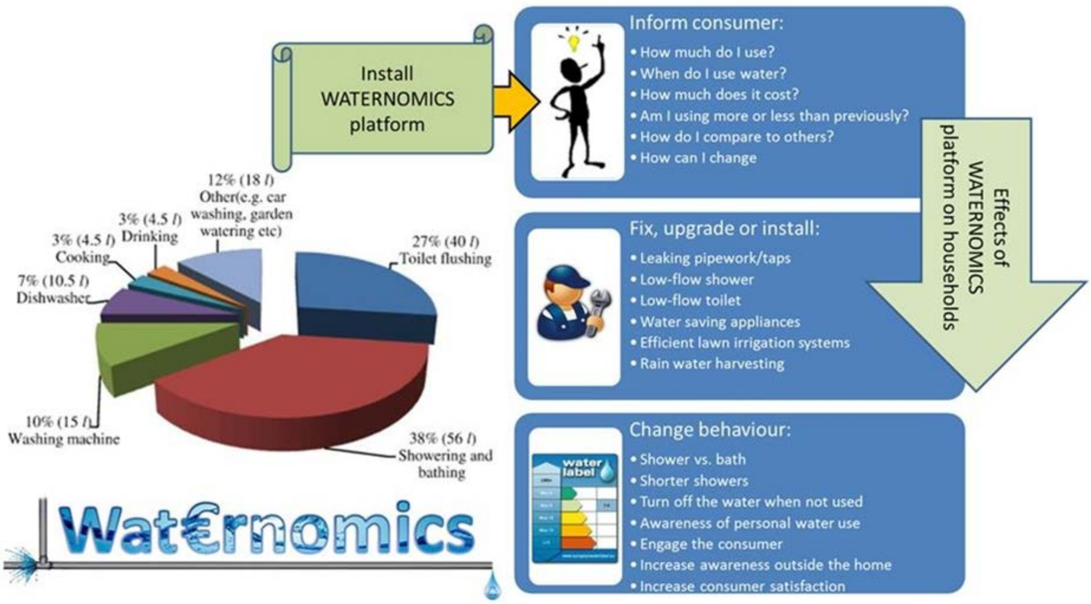

Fig. 3: Domestic water consumption per capita per day (Ireland 2006) (left) and the interaction of the WATERNOMICS platform with domestic consumers (right)

This pilot will be used to demonstrate and validate the innovative WATERNOMICS Platform for domestic water users. Through the deployment of innovative ICT consumers awareness of water issues will be increased in order to shift their typical behaviour towards a more sustainable water usage model. The pilot study will also demonstrate the efficacy of WATERNOMICS in significantly improving and increasing the interaction between householders and utilities.

5.2. Municipal

This pilot will demonstrate, at a district metered area level, the WATERNOMICS Platform in a municipality. For many municipalities they are both a major water provider but also a major water user. About 20% of water abstraction is accounted for by municipalities/public water supplies [20]. Key challenges for municipalities include variations in demand, multiple consumer types, high demand periods due to festivals, concerts, tourism etc., changing demographics, leaks in supply infrastructure etc.

As with many municipalities in Europe and indeed internationally planned key water saving initiatives at the municipal level include (i) the ability to change consumer behaviour, (ii) raise awareness and (iii) reduce non-revenue water. Other initiatives such as rainwater harvesting and grey-water re-use can often follow when consumer and supplier awareness is high.

5.3. Corporate

This pilot will explore the deployment of innovative ICT and off the shelf ICT under the constraint of a fixed value investment to validate the WATERNOMICS Platform, enact data analysis techniques, and quantify water, energy and CO2 savings. The commercial pilot has an annual water consumption of about 700,000 m^3, and an annual water cost of approximately €385k. At present there is a lack of metering and inability to track water losses and wastages within the system. Lack of metering also prevents providing feedback or incentive to its sub concessionaires about their consumption (demand management). For example, sub concessionaries in a non-metered area may be billed based on a group average and not on their individual consumption.

6. Conclusions

The research task in WATERNOMICS is to develop a systematic and standards-based methodology for the design and implementation of an ICT-based water management system. This research, combined with the demonstrator activities, will help WATERNOMICS address key technical challenges, including:

Table 3. WATERNOMICS key issues to be addressed.

Type	Description
Technical	Sensor locations, measurements, communication architecture and consequences are appropriate for district metering
Reporting / Communication	Decide on relevant metrics and key performance indicators to collect
Economic / Infrastructural	Analyze costs and benefits – how does this affect existing infrastructure (e.g. wastewater treatment)? What is the priority listing and cutoff lines for different levels of investment?
Water management model	Develop new tariff structures which building on data made available through the platform
Management & Processes	Research methods for assigning management responsibilities and incentives. Methods for gauging consumer reaction to new processes and business model.
Certifications	Methods for engaging with existing carbon credits, ISO, or other certifications
Savings	Specific features of WATERNOMICS platform that can produce further savings

WATERNOMICS emphasizes the use of demonstration activities and wide-ranging stakeholder involvement to ensure that developments within the project will have a broad impact across the water sector; from consumers to business and municipalities to water utilities. The novel architecture proposed within the project will give consumers, commercial end-users and water utilities unprecedented access to interactive and relevant information on their water supply and/or consumption activities. Furthermore the WATERNOMICS platform will engage the water users and decision makers of tomorrow in water resource management through innovative water awareness games.

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