VALIDATION METHODOLOGY

The design of SmartH2O case studies

SmartH2O

Project FP7-ICT-619172

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Summary of this report: .... D7.1 Validation methodology. This report contains the methodology used to conduct the Swiss and UK case studies. It defines the KPI to be measured.

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SEVENTH FRAMEWORK PROGRAMME

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Executive Summary

This deliverable describes the methodology employed by SmartH2O to validate the impact of the project in the case studies.

A brief description of the context of the two case studies is first provided: the district of Tegna, in Switzerland, where 400 meters are being installed, and the cities of Swindon and Reading in the London area, where 2500 meters are available. The methodology aims to be general enough to be extended also to new case studies, in urban areas of the EU.

The objectives of the introduction of the SmartH2O Platform are then illustrated: the ability to better understand consumer behaviour, a reduction in the consumption of water due to increased awareness, a reduction in the consumption of water due to the effect of innovative pricing strategies, and, finally, the impact on the efficiency of water utilities. A set of key performance indicators to measure the objectives is provided.

The deliverable then describes the validation methodology adopted to assess the effective impact of the SmartH2O platform and to verify that the proposed KPIs have been subject to a significant change before and after the use of SmartH2O. This methodology describes how the users in the case studies are selected and how the dimensions of the test and the control groups are determined. The statistical analyses to be performed are also outlined.

The validation plan is finally presented in greater detail. The plan describes the sequence of steps that will be performed to deploy the SmartH2O platform in the case studies, to involve a set of alpha testers, to revise and correct potential software problems, and to test the pre-release of the platform (beta testing). The plan then lists the actions that will be performed to involve users and to collect the necessary data to compute the KPIs. The validation plan is also enriched by a risk contingency plan addressing the problems that will be most likely to occur and proposing a strategy for limiting the adverse consequences.

1. Introduction

The SmartH2O project addresses the following major research challenge:

> ***Quantifiable evidence of water savings by increased awareness and dynamic pricing schemes****. Thanks to the smart metering technology used in the project and models of consumer behaviour, the impact of the demand management policies will be predicted and potentially measured using state of the art methods.*

This research challenge must be verified through **validation in the real world**. For this reason, we will deploy the SmartH2O platform in two case studies, in two different European contexts: a megacity (London, UK) and a sparsely populated area (Canton Ticino, CH).

This deliverable is an output of Task 7.1 of Workpackage 7 which designs a methodology to conduct the case study, carefully analysing and reviewing the key performance indicators to be measured in the case studies, and the data collection and reporting methodologies to be employed.

1.1 The Swiss case study

The Swiss Case study is located in Tegna, one of the three districts of the small municipality of Terre di Pedemonte, in the Locarno region. While Terre di Pedemonte has 1139 inhabitants (as of 31.12.12), in Tegna there are 756 (in the remaining two districts there are 696 inhabitants in Cavigliano and 1137 in Verscio). In Tegna 400 smart meters are being installed by the SmartH2O partner SES to monitor the water consumption at the house inlet.

Unlike the UK case study where smart meters were previously installed, in Switzerland meters are installed as part of the SmartH2O project, with the twofold benefit of enabling the project team to set up an interesting case study and allowing the project partner SES to develop an expertise on multi-metering water and electricity data. In Figure 1 two typical installations are presented: on the left panel, a single household, where the smart water meter (the white box at the bottom) is linked via a data transmission dongle to the smart electricity meter, which communicate the data to the utility data centre, which in turn transmits them to the SmartH2O database. On the right panel, a multi-family building, which is bulk metered for water. The smart water meter is not even in the picture, as it is attached to a pipe outside the building. In Tegna 300 buildings are single family, while 100 are multi-family.

Figure 1: Two typical installations in the Swiss case study: single family (left) and multi-family (right).

In the Swiss case study we expect to find the following users' features:

- Peri-urban / rural area.
- A sizable number of swimming pools.
- A sizable number of single family houses with gardens.
- Water price is less a concern due to both the average income of the user group and the availability of water.
- Environmental concern and social responsibility are rather high.

Such assumptions will be verified after psychographic data will be collected during the first phase of the validation (year 2 of the project).

1.2 The UK case study

The UK case study is located in Reading, a medium sized city in the vicinity of London. Reading has 155'698 inhabitants (2011 census). The SmartH2O partner TWUL has been running smart meter experiments in Reading and Swindon since 2011. TWUL is planning to deploy 3 million smart meters in the Greater London area by 2020. Reading will be a first test site of the technology that will be used for the large scale deployment and it will consist of 2500 smart meters.

In the UK case study we expect to find the following users' features:

- Urban area.
- A sizable number of single family houses with gardens.
- Water price is a real concern for some users with medium to low income.
- Environmental concern and social responsibility are rather high.
- Water scarcity is an issue and users can be sensitive to that.

Such assumptions will be verified after psychographic data will be collected during the first phase of the validation (year 2 of the project).

1.3 The objectives: the baseline, the impact and validation

We will benchmark the impact of the SmartH2O project using the objectives we stated in the Description of Work:

1. Understanding consumer behaviour.
2. Conserving water by raising social awareness.
3. Saving water by dynamic pricing schemes.
4. Improve the efficiency and business operations of water companies.

In Section 2, we detail the key performance indicators (KPI) associated with each objective. In Section 3, we describe the methodology to validate them, which is based on the principles of Experimental Design and Statistical Inference. We also describe how we define the baseline, in order to measure the impact. Note that to be comparable, the baseline data needs to be collected with the same metering infrastructure we are using in SmartH2O, and for this reason the first part of the trials will be devoted to the collection of the baseline data.

Finally, in Section 4 we detail the plans to perform the validation studies, explaining which releases of the SmartH2O platform will be used in the different trials.

2. The SmartH2O objectives

2.1 Objective 1: Understanding consumer behaviour

A major objective of the SmartH2O project is to analyse smart meter data at medium and high resolution in order to understand and possibly predict consumer behaviour.

The project activities aiming understanding consumer behaviour are concentrated in work package 3 (User modelling), work package 4 (Saving water by social awareness), and work package 5 (Saving water by dynamic water pricing).

WP3 will deliver:

1. User clustering and classification algorithms: psychographic variables, such as the household size, the number of residents, the income and education level, the number of appliances and their type, will be correlated to water consumption in order to produce an estimate consumption pattern based on the most relevant user features. The models will be cross-validated by splitting the observational times series into a training (calibration) and a testing (validation) subset. Preliminary results are available in D3.2 (First user behaviour models).
2. End use disaggregation algorithms: given the aggregate water consumption at a given sampling rate, the end uses by single fixture (e.g. shower, gardening, bath, etc.) are reconstructed. As in the previous case, models will be validated with a holdout cross-validation approach. Preliminary results based on energy data are available in D3.2 (First user behaviour models).
3. District level models of aggregate behaviour: an agent-based simulation model will be used in order to assess the potential impact of water saving policies and instruments, from awareness campaigns to price signals. The agent based model incorporates the explicit models of behaviour generated by WP4 and WP5 as described below. The simulated consumers' behaviour will be compared with data collected on the field, thus providing a quantitative assessment of the validity of the simulation model.

WP4 will deliver model of social interaction and determination of actions to stimulate water savings. These actions will be used as an additional feature in the classification algorithm described above.

WP5 will deliver an understanding about how consumers might respond to price changes over short (daily) or seasonal (e.g. Summer-Winter) time frames. It will investigate and experiment with how they might respond to price changes when associated with smart metering programs (where the consumer is provided frequent updates on consumption) and also how consumer's attitudes towards pricing changes might be impacted by social gaming or other use of personal technology.

In Figure 2 and Figure 3 we describe the two main steps in the validation of the classification algorithms. In a first trial (see Section 3.2), we will collect data of current user behaviour, as measured by the smart meters. A first data subset will be used to calibrate the algorithm (at least one month of data) and a second subset will be used to validate the model. This approach is represented in Figure 2.

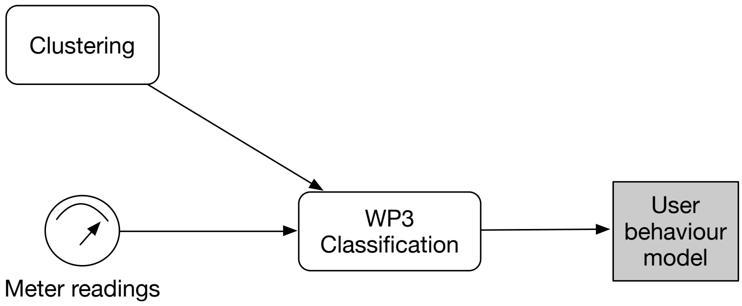

Figure 2: Classification of user behaviour before the deployment of the SmartH2O platform.

Table 1: Benchmarks for models predicting water customers' behaviours.

Reference	Title	Region	Resolution	Drivers considered	Validation
Benn2013	ANN-based residential water end-use demand forecasting model	Australia	household	Geo-spatial + economic + psychographic variables	R^2 = 0.41
Magg2015	Water demand management in times of drought: What matters for water conservation	United States	household	Geo-spatial + economic + psychographic variables	R^2 = 0.48
Makk2015	Novel bottom-up urban water demand forecasting model: Revealing the determinants, drivers and predictors of residential indoor end-use consumption	Australia	household	Economic + psychographic variables	R^2 = 0.85-0.95
Blokk2010	Simulating residential water demand with a stochastic end-use model	The Netherlands	household	Psychographic variables	ME = 5%, RMSE = 9%, R^2 = 0.94
Gato2007	Temperature and rainfall thresholds for base use urban water demand modelling	Australia	urban	Geo-spatial variables	R^2 = 0.8
Pole2010	Seasonal residential water demand forecasting for census tracts	United States	Census track	Geo-spatial variables	RMSE = 12%

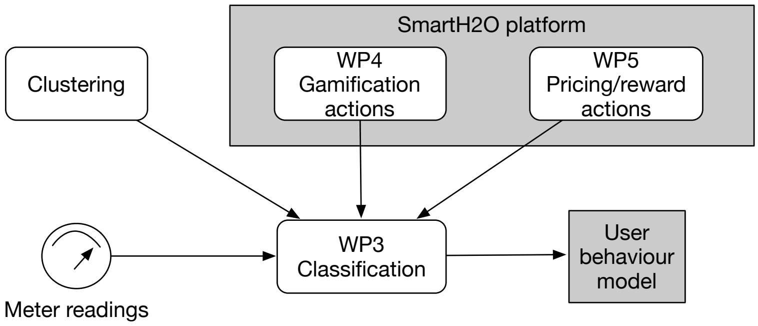

Figure 3: Classification of user behaviour after the deployment of the SmartH2O platform.

In Figure 3 we represent the classification flowchart after the deployment of the SmartH2O platform, where users start receiving inputs and suggestions on how to reduce their water consumption. As in the previous case, we will first record data to classify the user behavior, also based on the response to the suggested water saving actions. Subsequently, we will collect data to validate the previously obtained model.

For both models (pre and post SmartH2O) we will measure the following **key performance indicator (KPI)**:

- **KPI_1: Average error between the expected and measured water consumption**. More specifically the Mean Square Error (MSE) will be computed to assess the accuracy, with no distinction between under- and over-estimation of the user consumption attitude. The indicator will be computed at the household level.
    - Target value for the KPI: a MSE not greater than 20% per day in the case of a single household.
    - The main benchmark studies that propose predicting models for water consumption at the household level are reported in Table 1.

The aggregate consumption model, which is implemented using an agent-based modelling paradigm, will be validated using the same strategy: the data collected before the deployment of the SmartH2O platform will be used to calibrate and validate the simulation model. After the deployment of the platform, the model will be re-calibrated and re-validated.

The KPI to be used in this case is the same as above, but with a different target:

- **KPI_2: Average error between expected and measured consumption**. The indicator will be computed at the district level to evaluate the model performance, when the behavior of multiple users is used to predict the aggregate consumption.
    - Target value for the KPI: a MSE not greater than 10% in the case of a district composed by at least 50 households.
    - In Table 2 we present a brief review of previous studies where the ABM paradigm has been employed to model residential water demand. These studies represent the current benchmark against which we will test our performances.

Table 2: Benchmarks for agent based simulation for modelling residential water demand.

Reference	Title	Region	ABM Model	Data	Simulation period	Validation
Chu2009	Agent-based residential water use behavior simulation	Beijing	Residential Water Use Model (**RWUM**)	Disaggregated	1985-2030	R^2=0.818

	and policy implications: A case-study in Beijing city					
Down2000	Understanding Climate Policy Using Participatory Agent-Based Social Simulation	Thames region of England	**FIRMA Thames** (1st version)	Aggregated	1970-1996	no
Bart2001	Policy modelling with ABSS: The case of water demand managemen	Thames region of England	**FIRMA Thames** (2nd version)	Disaggregated	NA	stakeholders validation
Rixo2006	Exploring Water Conservation Behaviour through Participatory Agent-Based Modelling	-	"**MEME** model"	Aggregated	730 days	no
Atha2005	A Hybrid Agent-Based Model for Estimating Residential Water Demand	Thessalo-niki (GR)	**DAWN**	Aggregated	1994-2000	no
Tseg2009	Tsegaye, S., and K. Vairavamoorthy (2009). Agent-Based Modeling to Estimate Residential Water Demand and to Explore Optimal Demand Side Water Management strategies	-	**DAWN** inspired	Aggregated	60 months	no
Lope2005	Urban Water management with artificial societies agents: the FIRMABAR simulator	Barcelona (ES)	**FIRMABAR** (1)	Aggregated	10 years	stakeholders validation
Gala2009	An agent-based model for domestic water management in valladolid metropolitan area	Valladolid (ES)	**FIRMABAR** (2)	Aggregated	40 quarters	stakeholders validation
Erns2005	Shallow and deep modeling of water use in large, spatially explicit, coupled simulation system	Upper Danube basin	**DANUBIA**	Disaggregated	2011-2040	no
Link2013	An Agent Based Model of Household Water Use	USA / NL	"Single household model"	Disaggregated	1 year	5-15% aggregated data. much worst when taking into account disaggregated data.

2.2 Objective 2: Conserving water by raising awareness

SmartH2O leverages on increasing consumer awareness to stimulate a more responsible use of water. This objective is achieved by introducing persuasive technology principles [Fogg2002] in order to modify users' behaviour.

The users will be involved using the following approaches, as described in Deliverable D4.1 - First social game and implicit user information techniques:

1. a physical board game stimulates the users to reflect on their daily water habits, and thanks to its mobile app extension, invites them to register on the SmartH2O platform.
2. The SmartH2O water utility customer portal will provide an intuitive and easy to grasp interface displaying the current and historical water consumption (see Deliverable D2.2 - Final requirements).
3. According to the clustering of the users, as generated by the WP3 model, specific water saving actions are proposed.
4. According to the availability/scarcity of water specific water saving signals can be sent to the users.
5. User interaction is fostered by the social component of the SmartH2O platform. The user can see his/her position in a leaderboard, and s/he can be stimulated to improve his/her position.

The SmartH2O platform will therefore generate a number of inputs (also named factors) that can impact water consumption:

- Feedback on current consumption, compared to average values.
- Gamification actions that motivate the users to increase their ranking.

The impact of the usage of the platform will be assessed by checking the average water consumption per user **before** (the baseline) and **after** the adoption of the SmartH2O social game and gamification components, the number of users playing the game, their willingness to change their behaviour and the level of awareness they have gained regarding their behaviour.

The key performance indicator (KPI) used to monitor this objective is:

- **KPI_3: Water saved per capita per period**: we will measure/obtain the past water consumption over a meaningful long period in order to consider seasonal variations (the first trial lasts 4 months as described in section 3.2). This amount of water will be contrasted with the amount used over a similar (in terms of season and extreme events) period after the introduction of SmartH2O. The period should be long enough to include enough time for potential *rebound effects* to set in. We will identify a control group of consumers at the district level and we will measure the effective consumption after the actual introduction of the proposed policies.
    - Target value for the KPI: it is expected to depend heavily on typology of the sample households. We expect a smaller saving for environmentally friendly households, who have already a high level of awareness. We assume that a 5% overall saving would be a success, but we expect a greater saving in drought periods (if they will occur during the testing phase), where we aim to a reduction of 20%.
    - Benchmark studies that assess water savings by raising environmental awareness are reported in Table 3.

Table 3: Benchmarks for water savings by raising environmental awareness.

Authors	Title	Region	Water Saving
Will2010	Alarming visual display monitors affecting shower end use water and energy conservation in Australian residential households	Australia	27% for shower consumption and 3% for total citywide consumption
Davi2014	Water-saving impacts of Smart Meter technology: An empirical 5 year, whole-of-community study in Sydney, Australia	Australia	6.4%
Inma2006	A review of residential demand-side management tool performance and influences on implementation effectiveness	Australia, United States, Europe	Average 10%
Maye2004	Tampa water department residential water conservation study: the impacts of high efficiency plumbing fixture retrofits in single-family homes	United States	15.6%
Ampt2013	'Ask' is the new 'nudge' and 'choice' causes 'spill over' – lessons from effective behaviour change programs in Australian cities	Australia	20%
Anda2013	Smart Metering Infrastructure for Residential Water Efficiency: Results of a Trial in a Behavioural Change Program in Perth, Western Australia	Australia	9%

2.3 Objective 3: Saving water by dynamic pricing schemes

Smart metering enables new approaches for European water utilities to interact with their customers and charge them for services. Dynamic prices, i.e. prices that change over time, could potentially better reflect the real financial and environmental cost of public water supply. It also presents an opportunity to change how water users view water consumption in relation to those around them (other consumers) and the environment.

WP5 will deliver the following:

1. A review of pricing instruments tailored for relevance to a smart metering project. This will include a literature review of pricing policies used or considered in European states and a review for England and Switzerland (or Italy) on case-studies assessing user attitudes towards metering and smart meters. The review will consider pricing models that would require smart metering and interactive media.
2. The effectiveness of traditional (pricing only) mechanisms on water consumption will be evaluated through a meta-analysis of past estimates of price elasticity of demand focusing on European studies.
3. A user survey on attitudes towards economic incentives to water conversation, that is, prices and rewards, will be deployed in the case of the Swiss study.
4. Proposed new dynamic pricing mechanisms for smart metered systems: given smart meters and new opportunities for consumer interaction through smart media, new possibilities for dynamic pricing will emerge. We will propose and detail new pricing and consumer interaction models to fill this gap. Other schemes will include critical peak pricing, peak time rebate and time-of-use rates, i.e, approaches that encourage discretionary consumption during off-peak times (at daily and seasonal scales) will be

investigated. Finally, including pricing structures where consumer price is linked to short and/or long-term water scarcity will be investigated.

5. Impact of smart metering on the overall supply-demand assessment of water resource systems: this will investigate the impact more or less effective dynamic pricing schemes could have on the over-all water balances. Implications in terms of removal of water from the environment, operating cost reduction, carbon implications will be assessed.
6. Experimental economics: we will design and conduct experiments within workshop settings with water consumers, ideally with participants and non-participants of smart metering programs linked to SmartH2O, to validate our estimates of consumer views and behaviors towards smart metering and its use for dynamic pricing. Alternatively, workshops will be held with users of the platform early on and after a year of usage. Workshops will test how use of the platform changes attitudes towards smart metering pricing schemes, smart metering and perception of water's value and of the utility water provider. Detailed water use profiles will be passed through various pricing schemes to simulate their financial impact. Exercises and quizzes will be designed to elicit preferences and perceived simplicity/fairness. Results will allow utilities to better understand customer acceptability of smart metering for charging customers and the acceptability of various dynamic pricing schemes. These will help utilities makes better pricing scheme choices and improve customer communication about smart metering and its link to pricing.

Key performance indicator:

- **KPI_4: Percentage of customers expressing intention to voluntarily adopt a dynamic pricing scheme if available**. The goal is to measure and understand changes in attitudes towards smart-meter enabled dynamic pricing. A customer fairness/acceptability index for smart-meter based pricing will be designed and informed from a range of questions, exercises, and games delivered in a workshop setting. Some of these will involve observed interaction of customers using the app and data stored on it. Others will involve more traditional questions and tests. The index change will be measured with customers that have or not had access to the SmartH2O platform or with the same customers at initial and late stages of its use. This will depend on which is more likely to get a larger group. We will also estimate the combined impacts of dynamic water pricing and user awareness, to verify if the interactions of these two signals can be cooperative or competitive.
    - Target value for the KPI: we are hoping for a statistically significant rise in the positive perception of dynamic pricing schemes and the intention to voluntarily adopt such a pricing scheme if available. A successful target would be a 5% increase in customer's stated intention to adopt this scheme. This would be related to customer's estimation that they would be able to adapt their consumption and get pay less for water whilst reducing their carbon/energy footprint.
    - Benchmark studies that assess water savings by dynamic and variable pricing mechanisms are reported in Table 4. It has to be noted that dynamic pricing has never been attempted in the water sector, where other pricing mechanisms, such as increasing block rates, are more common.

Table 4: Benchmarks studies for water savings achieved by implementing dynamic and variable pricing schemes.

Authors	Title	Region	Sector	Results
Baer2013	Do Increasing Block Rate Water Budgets Reduce Residential Water Demand? A Case Study in Southern California	US	Water	Reduction 18% at least
Faru2011	Dynamic pricing of electricity in the mid-Atlantic region: econometric results from the Baltimore gas and electric company experiment	US	Energy	Reduced peak usage in the range of 18% to 33%
Faru2013	Dynamic pricing of electricity for residential customers: the evidence from Michigan	US	Energy	Reduced peak period by 15.9 %
Faru2010a	Household response to dynamic pricing of electricity: a survey of 15 experiments	US	Energy	3%-6% drop in peak demand under time-of-use rates and 13%-16% under peak pricing tariffs
Fisc2008	Feedback on household electricity consumption: a tool for saving energy?	26 projects from ten countries: USA (three), Japan (two), Northern and Western European countries (Denmark (four), Finland (two), Germany (two), Netherlands (one), Norway (three), Sweden (six), Switzerland (one), UK (two)	Energy	Typical savings between 5 to 12%
Nwc2011	Effectiveness and impacts of water pricing reforms	Australia	Water	Reduction is usage between 15 to 25%
Ofge2011	Energy Demand Research Project: Final Analysis	UK	Energy	10% drop in peak demand
Faru2010b	The impact of informational feedback on energy consumption—A survey of the experimental evidence	US	Energy	Time-of-use and critical-peak pricing (in combination with direct feedback) reduce peak and critical demand by 5% and 30% respectively
Faru2005	Quantifying Customer Response to Dynamic Pricing	US	Energy	Time-of-use rates produce peak reductions in the region of 5%

2.4 Objective 4: Improve the efficiency of water utilities

We expect the SmartH2O platform to bring not only benefits to the end users, but also to the water utilities.

In order to validate the impact on the business of water utilities, we will measure the following key performance indicators (KPIs):

- **KPI_5: Peak-period reduction of water consumption**: this indicator will be measured by comparing the historical data of peak water consumption in the two case studies with the data monitored after the introduction of SmartH2O.
    - Target value for the KPI: 10 to 20% water consumption reduction for the customers actively participating in the SmartH2O platform.
- **KPI_6: Energy saving for pumping water**: another indicator that can indicate considerable savings in costs for the water utility. Energy cost covers nearly half of water utility budget. Reducing water consumption has a direct effect on energy cost.
    - Target value for the KPI: we expect to achieve a 2% decrease in the energy used for pumping water in the Swiss case study, where pumping is not so relevant because of the hilly location, while a larger decrease (5%) could be expected in the UK case study.
- **KPI_7: Reduction in CO2 emissions**: an indicator strictly connected to energy savings. CO2 emissions by drinking water production are only due to energy consumption for water distribution and water use. A reduction in the latter implies a reduction in the former.
    - Target value for the KPI: more or less the same reduction observed for energy consumption, with a dependence on the type of power source used for pumping equipment.
- **KPI_8: Reduction in Waste Water Treatment**: by reducing water consumption SmartH2O will also reduce wastewater and associated treatment. In our case studies, a wastewater treatment plant eventually processes the consumed water, so there is no need to set up additional metering to identify the fraction of water being treated.
    - Target value for the KPI: it is the same as the KPI for the Water saved per capita per period objective, a reduction of around 5%, which could be up to 20% in drought periods.
- **KPI_9: Investments avoided**: it is the total amount of money that has not been spent over a given period thanks to reduction in water consumption. It is difficult to measure, but this indicator helps to assess how reduced water consumptions prevented the building of new infrastructures.
    - Target value for the KPI: we expect that a reduction of 5 to 20% of water consumption can lead to a large reduction of investment in infrastructures, up to 50% in the best cases.

Benchmark studies that assess water savings by dynamic pricing mechanisms are reported in Table 5.

Table 5: Benchmarks studies on improving the efficiency of water utilities by smart metering technology.

Authors	Title	Region	Sector	Results
Hled2009	How Green Is the Smart Grid?	US	Energy	Reduced CO2 emissions by between 5 and 16%
Ofge2006	Smart Meters : Commercial, Policy and Regulatory Drivers	UK	Energy	Results with smart prepayment meters in Northern Ireland have shown a 3% energy saving. A 1% saving would equal 8% of the UK's domestic CO2 target
Prat2010	The Smart Grid: An Estimation of the Energy and CO2 Benefits	US	Energy	12% expected reductions in electricity and CO2 emissions by 2030

3. The overall validation methodology

The validation methodology of SmartH2O is based on the concept of controlled experiment. In synthesis, we define a number of experiments we will perform in order to assess the impact of the various SmartH2O platform features on the case studies.

For each experiment, we need to:

1. Define the sample size and define the size of the control group; verify the statistical distribution of the sample and ensure that the sample is representative of the universe.
2. Define the duration in time of experiment.
3. Prepare the data collection infrastructure. Make sure that data are collected in a reliable and reproducible manner.
4. Identify the factors (controllable variables and parameters) and the responses (performance indicators) of the experiment. Design the experiment in order to optimise the data collection effort.
5. Perform a statistical analysis on the experiment outcomes and compile a short report.

3.1 The sample size

The sample size will be determined after the launch of the SmartH2O platform in each case study. Only then it will be known how many users will be willing to engage with the Water Utility Customer Portal and the Games Platform. Given that the number of potential adopters is approximately 400 families in Switzerland and 2500 families in the UK, we expect approximately 40 to 80 families and 100 to 400 families respectively.

According to the work of [Noor2010] the minimum sample size to detect a 10% reduction of consumption and assuming a standard deviation of 40 litres in consumption and an alpha level for the significance test of 5% and a power equal to 0.8, is 40. In case the reduction we want to detect is 5%, then the sample size grows up to 160 elements. As it might be possible that only 100 adopters will be joining in the Swiss case study, only savings greater than 10% can be observed. Smaller savings could be observed only in the UK case study. The control groups will be then created selecting among the users who did not register to use the SmartH2O platform. The control groups will be thus totally uninfluenced by any measure or action channelled through the SmartH2O platform. Moreover the users in the control groups will not receive other information on their consumption than the regular yearly water bills.

Note that this choice creates a selection bias, as we will have only people who are intrinsically motivated to save water in our test group. This is a side effect, which is expected as SmartH2O plays the role of an enabler of intrinsic motivation. Moreover, the SmartH2O platform requires an intrinsic motivation of the user to continue the interaction and to accept the various challenges posed by the gamification approach. Also, the participation in gamification experiments and tests has always been voluntary, and it is expected to be so in the future. It might even be impossible to get a uniform sample of users, including users not motivated in saving water, as these users would stop using the platform after a very few days. It has also to be considered that the case studies are limited in size, and we have to make realistic assumptions on how many users will be willing to participate in the study. In case the adoption rate will turn out to be much higher than expected, we will introduce a randomization component in the selection of the new users [Duf2007], but only after we have reached our sample sizes targets, as described in Table 6.

Table 6: Sample sizes in the two case studies.

Case study	*Installed meters*	*Expected adopters*	*Min. sample size of the test group*
Tegna (CH)	400	40 to 100	40
Reading (UK)	2500 (est.)	100 to 400	40

3.2 The trials

In order to gather the necessary data to validate the research questions of the SmartH2O project we have planned a total of 4 trial periods. A trial is a period of time during which the user actions and behavior are observed and collected. The trial periods have been selected in order to take into account impact of climate in the different seasons, even if there might be considerable variability within a season.

S1 - Summer trial, part 1: Switzerland and United Kingdom, July 2015 - September 2015

This initial trial is used to tune the validation methodology and test the data collection infrastructure. The first month of the trial will also be used to create the baseline data set that describes the behaviour of the users before the deployment of the SmartH2O apps and tools.

W1 –Winter trial, part 1: Switzerland and United Kingdom, November 2015 - January 2016

In the case studies the data will be used to create a new data set to be compared later with the sample obtained in a similar period (trial starting in November 2016).

S2 - Summer trial part 2: Switzerland and United Kingdom, July 2016 - September 2016

In this trial we gather a data set useful to compare consumption with the previous similar period in the Swiss and UK case studies (July 2016 vs July 2015).

W2 - Winter trial 2: Switzerland and United Kingdom, November 2016 - January 2017

In this final trial we gather a data set useful to compare consumption with the previous similar period in the Swiss case study and in the UK case study (November 2016 vs November 2015). The final validation report will be heavily based on this trial, as we expect that during this trial the users had access to the full functionalities of the SmartH2O platform.

In Table 7 we summarise the tests that will be performed to validate the SmartH2O platform.

Table 7: The trials to be performed.

Trial #	*Case study*	*Period*
S1	CH/UK	July 2015 – Sept 2015
W1	CH/UK	Nov 2015 – Jan 2016
S2	CH/UK	July 2016 – Sept 2016
W2	CH/UK	Nov 2016 – Jan 2017

3.3 The data collection infrastructure

According to the SmartH2O architecture, described in detail in D6.2 (Platform architecture and design), water consumption data are continuously fed into the SmartH2O database by the water utilities. This happens thanks to the Smart Meter Data Manager Component, a software component that parses the data files received from the water utility and feeds the SmartH2O database.

The SmartH2O data model (see D3.1 Databases of user information) can accommodate data measured at different temporal resolution.

In the Swiss case study data are collected every hour; the progressive meter readings, in cubic metres with a precision up to the third digit (i.e. litres), are sent daily to the SmartH2O platform.

In the UK case study, measurements will be made every 15 minutes. The measurement unit will be cubic metres with a precision up to the third digit. The readings will also be sent daily to the SmartH2O platform.

In the SmartH2O database each smart water meter is identified by a unique id, which is totally anonymous. The geographical information associated with the meter ID is coarse: it will be possible to know whether the meter is in Switzerland or in the UK. For the Swiss case study, being the case study location limited in its dimension, there will be no further information on its location. For the UK case study, the meter will be associated with a water district, which is defined by the water utility, and it comprises from 5 to 6 postcode areas, on average.

The samples will be composed of those users who choose to create an account on the SmartH2O platform and to participate to our experiments. The meter id of those users will be then associated with their user id in the SmartH2O platform. The association can take place in a totally anonymous way thanks to an anonymisation table maintained by the water utility.

Table 8: Meter ID mapping table.

Customer ID	*True meter ID*	*SmartH2O meter ID*
1234	CH_AQU_1234	431242445
…	…	…

The data contained in Table 8 are managed by the water utility. The water utility knows the “Customer ID” and the true meter ID. On the basis of this information, the water utility generates an anonymised “SmartH2O meter ID”, which is uniquely mapped to the “True meter ID”. This “SmartH2O meter ID” is transmitted to the SmartH2O platform, together with the meter readings.

When the SmartH2O platform will be launched in each case study, the water utilities will send their customers a communication (either by standard mail or by email) inviting them to join the experimentation phase. In this letter, the users will receive the SmartH2O meter ID. This is the only information they need to create an account on the SmartH2O platform and to associate their newly created account with their own meter readings. From then on, the users will be able to add more data in their profile, for instance regarding the composition of the household, the number of appliances, their type, etc. The data will then stored in an SQL database, allowing for fast retrieval and processing to compute the key performance indicators defined in Section 2.

3.4 Identification of the factors and the responses

During the validation period a number of experiments will be run in order to evaluate the impacts of the various water saving actions proposed to the users. In order to map the SmartH2O terminology to the common terminology used in the context of experimental design [Goos2011], the actions are the *factors*, and the impacts are the *responses*.

In the SmartH2O platforms there will be many actions (factors) that can influence the response of the users. We have categorised the possible actions as:

- Gamification actions.
- Rewards and pricing actions.

A preliminary description of these actions is presented in D2.2 (Final requirements). In short, the gamification actions comprise all the interactions the user has with the Water Utility Customer Portal, with the Gamification Engine and with the Games Platform (see D6.2). Through these components the SmartH2O platform will try to increase the awareness of the customer on his/her consumption and it will propose possible actions to reduce and manage it. The rewards and the pricing actions are aimed at stimulating the user behaviour with respect to potential monetary gains and losses.

The responses that we will observe are the expected impacts of the SmartH2O platform adoption, which will be measured by means of the key performance indicators introduced in the previous sections and summarized in Table 9.

Table 9: Summary of the key performance indicators.

KPI	Description	Target
KPI_1	Average error between the expected and measured water consumption	MSE<20%
KPI_2	Average error between expected and measured consumption	MSE<10%
KPI_3	Water saved per capita per period	5%
KPI_4	Percentage of customers expressing intention to voluntarily adopt a dynamic pricing scheme if available	5%
KPI_5	Peak-period reduction of water consumption	10-20%
KPI_6	Energy saving for pumping water	2%
KPI_7	Reduction in CO2 emissions	2%
KPI_8	Reduction in Waste Water Treatment	5%
KPI_9	Investments avoided	5-20%

3.5 Statistical analyses

In order to evaluate the significance of the impact of the adoption of the SmartH2O platform in the two case studies, we will conduct a number of experiments, following the theoretical prescription of Experimental Design.

3.5.1 Single factor experiment

A first experiment will be based on a single factor: the presence or the absence of feedback provided by the SmartH2O platform.

This is the simplest experiment we will run and it is also the most meaningful to validate the impact of the SmartH2O platform.

On the basis of the collected data, we will run a significance test for the difference of the mean consumption for the SmartH2O users against the control group.

This test will be performed using the entire sample during the second and the third trial.

3.5.2 Two factor experiment

A second experiment will be based on two factors: the presence or absence of gamification signals and the presence or absence of pricing/reward signals. This is a simple factorial experiment where we want to assess the four configurations displayed in Table 10.

Table 10: The four configurations of the two factor experiment.

		Pricing/rewards	
		Present	Absent
Gamification	Present	*Configuration 1*	*Configuration 2*
	Absent	*Configuration 3*	*Configuration 4*

We expect the two factors to interact, as the presence of gamification might impact the effect of price/reward signals, as it might have already exploited most of the ability of the user to reduce his/her water consumption. In other words, the presence of a factor might inhibit the other, as they are unlikely to be additive. This is a common sense hypothesis, which we want to assess with this experiment.

This test will be performed using the sample data produced during the third and fourth trials.

3.5.3 Multiple factor experiment

Finally, if the dimension of the sample sizes will allow, we will try to run a multiple factor experiment, by which we will try to infer the impact of single gamification actions. In this experiment, we focus on gamification rather than on prices and rewards, since the type of gamification actions are more diverse, and it might be worth to evaluate which type of interaction with the user is more effective.

We will adopt 2^k factorial design schemes to identify the statistically significant factors in our experiment.

This test will be performed using the data produced during the fourth trial.

4. The Validation Plan

The validation plan describes, for a generic test site, the set of tests that will be run and how they will be prepared, run, and concluded. We also describe the expected results of the tests, referring to the expected impact.

4.1 Validating the SmartH2O platform

In order to validate the impact made by the SmartH2O platform in the case studies a series of actions have to be performed, for each version of the prototype.

1. Release of a version of the SmartH2O Platform.
2. Deployment of the new version in the case study.
3. Promotion of the SmartH2O platform.
4. Test of the SmartH2O Platform:
    - measurement of impacts;
    - evaluation of software capability.
5. Assessment of the test outcomes:
    - update of the platform release plan in order to incorporate deviations from the expected software capability delivery plan.

The above test cycle will be repeated for four main releases of the SmartH2O platform: initial release (Month 12), second release (Month 18), third release (Month 24), fourth release (Month 30). The fifth and final release, being issued at Month 36 will not be subject to test within the scope of the project.

As the SmartH2O platform is an ongoing project the release tests will be superimposed to the four trials we have described in 3.2 producing Table 11, which describes what is being tested and when.

In summary, we will test:

- Release 1 during the first Summer trial (S1);
- Release 2 during the first Winter trial (W1);
- Release 3 during the second Summer trial (S2);
- Release 4 during the second Winter trial (W2).

Note that each trial lasts three months. Trial S1 and W1 are run nearly consecutively, apart for one month where the platform is upgraded and a new promotion campaign is launched. The same happens for Trial S2 and W2, while there is a longer delay between W1, which ends in January 2016 and the start of S2 in July 2016. During this period the consumer behaviour will be continuously collected, as the platform will not be switched off during the duration of the project, but no promotion campaigns will be run, so we will observe the decay rate of the active participation, as the number of users stopping using the platform per month in absence of external stimuli.

Table 11: Features to be tested per release and per trial.

	Release 1 (M12 – Apr 15)	***Release 2 (M18 – Sept 15)***	***Release 3 (M24 – Mar 16)***	***Release 4 (M30 – Sept 16)***
S1 (Jul15-Sept15)	Test of data transfer from Utility to SmartH2O. Test user access to consumption data in the non Gamified platform. Creation of baseline data set. Initial tests on user classification data.	Not Available (N/A)	N/A	N/A
W1 (Nov15-Jan 16)	Not used (N/U)	Functional test of first prototype of Agent Based Modelling. Assessment of performance of user classification algorithms (Objective 1, part 1). Assessment of effects on awareness and water conservation (Objective 2).	N/A	N/A
S2 (Jul 16 – Sept 16)	N/U	N/U	Assessment of performance of user classification algorithms (Objective 1, part 1). Assessment of performance of water consumption at district level by ABM (Objective 1, part 2). Assessment of impact of social awareness (Objective 2) and of dynamic pricing (Objective 3) on water conservation.	N/A
W2 (Nov 16- Jan 17)	N/U	N/U	N/U	Assessment of performance of user classification algorithms (Objective 1, part 1). Assessment of performance of water consumption at district level by ABM Objective 1, part 2). Assessment of impact of social awareness (Objective 2) and of dynamic pricing (Objective 3) on water conservation. Assessment of impact on efficiency of water utilities (Objective 4).

4.2 Risk management plan

The risk management plan describes what happens during the validation of the SmartH2O platform in face of unexpected results

4.2.1 Software risks

Risk type: issues with data quality.

Typical scenario: data from the smart meter is missing and/or unreliable.

Assessment: according to the hardware solution used to assimilate smart meter data transmission errors can arise.

Solution: errors and problems in data collection can be automatically detected by the smart meter data connector component and corrective actions can be implemented by the water utility.

Risk type: issues with software quality.

Typical scenario: because of bugs and errors in the customer facing application, the user grows dissatisfied and abandons the project.

Assessment: as SmartH2O is a development project it cannot be ruled out that the initial releases (R1 and R2) of the platform will be prone to errors.

Solution: motivate the user to continue the participation using psychological arguments about the relevance of the project for the well-being of the community, highlighting the positive features that are working in the platform, and mentioning that bugs are continuously fixed. Implement a ticketing system that can be easily accessed by the end users.

Risk type: issues with quality of delivered results.

Typical scenario: the user classification algorithm has a low performance, the district level predictions are mostly wrong.

Assessment: the quality of the algorithm output of SmartH2O depends on the quality of the available data provided as input. It can be expected that a sub-standard performance can be observed when few users participate and the algorithms don't have enough training data.

Solution: the user involvement will have to be increased, possibly organising competitions with real prizes and rewards for customers.

4.2.2 User risks

Risk type: Issues with protection of privacy.

Typical Scenario: the user is reluctant to enter personal data during the registration phase.

Assessment: The data gathered from social media and from personalized equipment (smart meters etc.) are privacy sensitive.

Solution: The SmartH2O project will ensure a proper privacy policy. All data that are possibly dealing with privacy sensitive data will be assessed and appropriate steps will be taken. Anonymisation of data before entering the data warehouse and before use by the SmartH2O solutions will be a standard procedure.

Risk type: Protection of sensitive data from cybercrime.

Typical scenario: hackers will try to penetrate the SmartH2O servers to gain sensitive user data.

Assessment: There is growing concern in the EU for the dangers of cybercrime. These can aim their attacks at the drinking water production and distribution.

Solution: The SmartH2O framework will, next to the protection of privacy sensitive data, also focus on the overall protection of the data system. The most up-to-date ICT solutions for the protection against cybercrime will be incorporated in the development. Moreover, all data in the SmartH2O server are anonymised.

Risk type: Not enough users participate.

Typical scenario: after an initial phase in which a substantial number of users sign up and register on the SmartH2O platform, after a couple of weeks most of them have stopped using it.

Assessment: the Social Awareness app requires a critical mass of users to provide a meaningful amount of data.

Solution: the participation of users will be monitored after the deployment and a multi-level contingency plan will be put in action, in case the participation does not satisfy the requirements. Such a multi-level plan comprises dissemination actions at different level of impact (and cost).

- Dissemination through own students: the involved universities dispose of a very large base of students in the target territories. These communities have a large spread potential, since they are forms by young people with high mobility and digital activity levels.
- Dissemination through partner projects: the involved universities have projects at national level that already target very large educational and social communities. These projects target young students and their schools to have a far reaching effect on their families and local communities at large. They will be surely interested in joint-activities on socially sensible matters such as public good sustainable use, and will be contacted for cross dissemination.
- Dissemination through specialized media companies: all the consortium members have relationships with media companies active in the sustainability and environment protection sectors. Contacts will be taken in case of need for building up dissemination tools and campaigns over such already well-established thematic channels.

5. Conclusions

In this deliverable we have presented the methodology to be used to validate the outcomes of the SmartH2O project.

During the validation activities we want to ascertain that:

The SmartH2O approach, based on the increased awareness of customers on their consumptions by mean of social media and of dynamic pricing, has a real impact on water consumption and on the efficiency of water utilities.

The SmartH2O classification algorithms are able to model the individual customer behaviour, especially in response to the above awareness stimuli. At the same time, the aggregated behaviour, implemented as an agent based simulation model, reflects the effects of social interactions promoted by the use of the platform.

Finally, we want to make sure that the software products and artefacts produced during the project lifetime function properly and that can be successfully deployed in the case studies, thus confirming the potential exploitability of the SmartH2O platform in a real world context.

To these means, we have proposed in this deliverable a Validation Plan articulated in 4 trials spaced during the project lifetime, which will test 4 releases of the SmartH2O platform. During each one of these trial/platform tests, the impact of the platform will be tested using the key performance indicators associated with the four main objectives: Understanding consumer behaviour; Conserving water by raising social awareness; Saving water by dynamic pricing schemes; Improve the efficiency and business operations of water companies.

Finally we have presented a risk plan in order to highlight the most likely problems that could occur during the validation of the SmartH2O platform, the foreseen consequences, and the expected contingency actions to be performed.

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