ADVANCED MEASUREMENT OF WATER CONSUMPTION

Efficient management of the integral water cycle is linked to the measurement of user consumption. advanced measurement, based on cutting-edge technologies, tools and methodologies, is another step towards the protection of water resources and the environment in general. CANAL DE ISABEL II, S.A.M.P.

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INTRODUCTION

The measurement of water consumption is an essential element for the proper management of the resource. It is especially relevant in countries with water scarcity, but it undoubtedly brings clear benefits in those that a priori do not have drought problems. Therefore, in supplies that lack measurement of the consumption made by users, one of the best practices to gain efficiency in management is the installation of water meters.

There are currently different types of water meters in the international market. The knowledge of their behaviour (principles of operation, durability...) is important in order to choose the most appropriate equipment for each case …

Likewise, it is convenient to segment users according to what and how they use water, since the operating regime of the water meters will be different in each case.

An advanced measurement of water consumption is based, first and foremost, on the pursuit of metrological excellence.

On the other hand, in current times, with the relevant advance of communications and the expansion of new technologies worldwide, the digitization of operations is ceasing to be an extra only accessible to societies of highly developed economies to be incorporated as a basic in many societies. Increasingly competitive prices and standard information transmission systems applicable to a multitude of "use cases" (water meters, pressure and temperature sensors, etc., both in the water sector and in other sectors), mean that today when the implementation of new water consumption measurement equipment is considered, digital equipment with remote reading is already considered as a starting option.

The remote reading of water meters provides massive information and in real time, which brings multiple benefits both for the managers of the supplies and for the users themselves. However, although the current environment is favourable to digitization, it must be borne in mind that this entails associated costs that need to be analysed.

Both the costs and benefits associated with remote water meter reading can vary depending on the country/geographical area, the hydraulic system available, as well as the specific conditions of the area concerned.

The feasibility for the implementation of remote water meter reading in a given supply system will depend on the relationship between the associated costs for its deployment and operation, versus the benefits linked to the massive provision of information that water meters with remote reading provide.

In any case, the measurement of water consumption is a must. And this is because whether or not water is scarce, the protection of the environment requires responsible consumption of it and all other resources associated with its production and discharged back into the channels after use. The degree of metrological excellence of the equipment to be installed, as well as its level of digitalization and automation of the operations that can be implemented in each supply will depend on the specific conditions of the same.

This document presents three basic aspects that make up an advanced measurement of water consumption, and they are:

1. The measurement of water consumption.

    - Some general criteria or recommendations will be presented that can serve as a guide when choosing the most appropriate type of water meter for each situation.
    - A methodology will be detailed to guarantee a solvent performance of the water meters from the metrological point of view, which implies the metrological control that is made by the competent authority in each area, as well as the convenience of carrying out specific controls that can be carried out by the supply manager.

2. The use of the information provided by the remote reading of water meters.

    - In the field of the managers of the integral cycle of supply.
    - In relation to the benefits that can be derived from it for citizens.

3. The cost/benefit analysis of solutions with remote water meter reading, which will validate the applicability or not of it according to the area and its conditions.

The document refers to the methodology used by Canal de Isabel II, operator of the integrated water cycle in the Community of Madrid, on cold water measurement for urban use.

Therefore, the type of water meters exposed, the applicable regulations, as well as the methodologies presented should be considered exclusively as a reference, and in no case can they be directly extrapolated to other countries or sectors, since the supply conditions, degree of development of each society and value of water according to its scarcity, significantly condition the type of management that can be carried out.

This document contains the reflections of the author based on her experience in the management of the measurement of water consumption in Canal de Isabel II, which she presents in good faith, in case they are of interest to other supply managers. Therefore, its content must be considered within the scope of the opinion on good practices or general ideas that may be useful when making a measurement of water consumption for users.

CHAPTER I: MEASUREMENT OF WATER CONSUMPTION

1. Water meters in the Spanish market

Next, general basic aspects about the water meters in the Spanish market for the measurement of cold water are exposed.

1.1. Measurement technologies: Principles of operation

A. **Mechanical water meters:** they contain mechanical moving components that are used for the measurement of water consumption.

1. Speed water meters. They can be of various types:
    - ✓ Single jet
    - ✓ Multiple jet
    - ✓ Woltman
    - ✓ Proportional
    - ✓ Tangential

2. Volumetric water meters

In the case of mechanical water meters, totalizers can be mechanical or electronic.

B. **Static water meters:** They do not contain mechanical moving components and water consumption is measured with different technologies that give rise to different types of static water meters. The most commonly used are ultrasonic and electromagnetic ones.

In the case of static water meters, the totalizer is electronic.

1.2. Metrological aspects: Flow rates, range and measurement errors

As specified in Annex VIII of Royal Decree 244 / 2016 [2], it is defined:

- ✓ *“Minimum water flow rate (Q1): the smallest water flow rate at which the water meter provides indications that meet the maximum permissible error requirements.*
- ✓ *Transition water flow rate (Q2): value of the water flow rate that lies between the minimum and the permanent water flow rate and in which the water flow rate range is divided into two zones, the "upper zone" and*

the "lower zone." Each zone corresponds to a characteristic maximum allowed error.

- ✓ *Permanent water flow rate (Q3): highest water flow rate at which the water meter can operate satisfactorily under normal use conditions, i.e. under steady or intermittent flow conditions.*
- ✓ *Overload water flow rate (Q4): highest flow rate at which the water meter can operate satisfactorily for a short period of time without suffering deterioration.”*

The technical parameters that define a water meter are:

- Q_3: Permanent flow rate
- R: Ratio (Q_3/Q_1)

Permanent flow rate Q_3				
1,0	1,6	2,5	4,0	6,3
10	16	25	40	63
100	160	250	400	630
1000	1600	2500	4000	6300

Table 1: Permanent flow rates Q_3, according to UNE-EN 14154 ISO 4064:2014

Range of measurement R									
						40	50	63	80
100	125	160	200	250	315	400	500	630	800

Table 2: R ranges of measurement available

The rest of flow rates of the error curve of a water meter are determined by:

Q_2=1,6 Q_1

Q_4= 1,25 Q_3

The Spanish legislation establishes as maximum permitted errors ±5% for flows between Q_1 y Q_2, and ±2% for flows between Q_2 y Q_4.

The higher R is, the greater measurement range with errors admitted by legislation the water meter will have.

For a given installation, the maximum flow rate expected therein is considered to define the permanent flow rate Q3 of the meter to be used. But once said flow rate has been selected, the choice of high R ratios will depend on the need to capture consumption at low flow rates, such as leaks in the pipes and in the elements of said installation.

In short, for a water meter to measure well, it is necessary to previously establish the expected flow ranges at which a certain type of user is going to consume. Domestic users have very different consumption patterns than those of industrial users, or irrigation, for example. Likewise, different types of home users have differentiated patterns.

In the case of domestic users, there are published consumption patterns that can be used as a reference and starting point in the dimensioning and choice of the most appropriate type of water meter.

2. Measurement errors and the principle of operation

Water meters that are marketed in Spain for use in the measurement of consumption on which a commercial transaction is to be applied, must be subject to the metrological control of the State.

In this sense, regardless of their operating principle, all of them present measurement errors before being installed in the supplies, which must comply with current legislation.

Once the water meters are installed in the supplies, and throughout their useful life, in accordance with current Spanish legislation, errors in service must be maintained. And this is where the principle of operation does affect. The aging of the water meters causes them to modify their errors in service, reaching the maximum ranges allowed by legislation.

In order to properly monitor compliance with metrological legislation, it is very convenient to carry out controls on the water meters. The following sections describe the controls carried out by Canal de Isabel II.

On the other hand, the principle of operation, as well as the range of flow rates in which a meter can operate, is closely linked to the metrological ratios that can be achieved with each technology.

The choice of one type and another of meters will depend on the circumstances of the supply and the objectives pursued in terms of measurement.

3. The ageing of the water meters

According to various research carried out in the water supply sector in Spain, and the experience of Canal de Isabel II, the ageing of water meters depends on multiple factors. Among them, the following can be highlighted:

- The **flow rate** that passes through the water meters. The higher the flow rate, the earlier the equipment ages.
- The **age** of the water meter. The age is in many cases linked to the volume of water that has passed through the equipment. However, depending on the operating principle of the meter, with low flow rate, the meter may age depending on the quality of the water. Water with high amounts of suspended particles can damage meters prematurely. Likewise, the hardness of the water is a risk factor for the aging of the meters.
- The **installation**. The way in which the water meters are installed also has a very significant influence on their aging, as well as on the accuracy of the measurement. It is important to respect the installation instructions provided by the meter manufacturers. The installation of equipment on farms is frequently done with inclination. In this case, and depending on the inclination threshold, the mechanical water meters will be affected in their performance.
- The **operating regime** of the water meters affects their aging and even their premature failure. Permanently exceeding the maximum flow rate Q4, for which the meter is designed, means its breakage. In this sense, an adequate dimensioning of the meters is essential in order to adapt in the best possible way the operating flow rates of the meter to the expected consumption pattern of the users.

In Spain, the legislation considers the ageing of water meters. In accordance with the provisions of article 8.3 of the Metrology Law (Law 32/2014 [1]), for those instruments in which the cost associated with the metrological control of instruments in service is similar or higher than the replacement cost of the instrument, a useful life is established.

And specifically, in paragraph 4, of Annex III of ICT/155/2020 [3], it is regulated that:

"In accordance with the provisions of article 8.3 of Law 32/2014, of December 22, developed by article 16.2 of Royal Decree 244/2016, of June 3, the useful life of clean water meters and water meters for other uses will be twelve years".

4. Choice of the type of water meter

The type of meters must be chosen according to the conditions of use and environment, as well as the availability of water resources in the area, linked to the value of water.

In order to choose the type of water meter, a preliminary technical study on the measurement needs in the supply area concerned will be necessary.

4.1. The influence of the location of the water meters, their way of installation and water quality

The type of location in which the meter is located and how it is installed also significantly determines the choice of the most appropriate type of meter. For example, certain types of meters are affected by the position, reducing their metrological ratio if it has been installed rotated or has an inclination, due to the variation in the operating conditions of the mechanical components for measuring the volume of water.

Additional issues such as the influence that the position of valves and elements attached to the water meter may have on the measurement accuracy must also be considered when choosing, being always advisable to opt for U0D0 meters, given the usual lack of space in the locations where the meters are installed.

Likewise, it is also necessary to consider the quality of the water (suspended solids, hardness of the same ...) when choosing the most convenient type of water meter, to avoid premature failures in the equipment due to encrustations and deposits.

The non-permanent operating regime of water in the distribution network is another element to be taken into account. It is advisable to test the performance of water meters in this type of regime.

4.2. The importance of the segmentation of users

The realization of an adequate segmentation of users according to the use they make of water will help the decision making of the type of water meter that best suits each type of consumer.

The classification of users can be very general, establishing large groups (domestic, industrial, commercial) or more specific, disaggregating into subgroups (domestic in single-family housing with irrigation, domestic in flats ...) with delimitation of the consumption patterns of each group of users with similar behaviours against the use they make of water.

The flow demanded, the operating regime of the meter ... is different for each type of users, so it is interesting to make a segmentation of users as refined as possible when choosing the water meter that best suits each situation.

The following classification is the most usual in urban water uses:

- Domestic uses: They have simpler and more uniform patterns. The variation of the volume consumed depends largely on the number of inhabitants of the house and external uses (gardens and/or swimming pools).
  - Detached house with or without pool and/or garden area.
  - Multiple flats (floors in height) with a single community water meter.
  - Housing (floors in height) with individual water counter.

- Commercial uses: They present specific patterns to their activity, although they can be grouped thematically into groups of similar uses, differentiated in turn by their volumetry in, for example, number of beds, rooms ... and, in general, capacity for commercial use.
  - Hospitals
  - Hotels
  - Restaurants/Bars
  - Schools
  - Etc.
  - Industrial: Present specific patterns to their activity in an individualized way.
- Urban irrigation: Its pattern varies depending on the irrigation schedule, the type of garden and the irrigation system.

In all cases, it is very important to contemplate the existence of a regulatory deposit that laminates the patterns of consumption. The consumption pattern of the users is in these cases completely conditioned by the filling regime of the tank.

4.3. The usefulness of remote reading

When you have a remote water meter reading system that allows you to have hourly information of consumption in quasi-real time, it is possible to make much more specific consumption patterns of each segment of customers, making sub-segmentations that allow you to adjust even better the gauge of the most appropriate water meter to each group and subgroup of users, as well as adjust the most convenient metrological ratio to each one.

4.4. The choice of water meters in Canal de Isabel II

Canal de Isabel II, as a public company, has among its objectives to ensure maximum attendance at tenders and the choice of the type of water meters is largely conditioned by this. In general, the technical specifications set out in the tender documents for the purchase of water meters do not impose a specific hydraulic operating principle, leaving the possibility open to tenderers who can offer speed, volumetric or static water meters. It is true that the quality of the water in the Community of Madrid is excellent and the conditions of installation and environment are not demanding, so any of these principles offers good metrological results.

On the other hand, the tender documents establish minimum compliance criteria that are aligned with current legislation, and technical improvement criteria that seek to acquire products with the best metrology according to the use of the supply and the measurement needs of Canal de Isabel II. All this to guarantee an excellent measurement of the consumptions made by the users and on the basis of which the billing is made to them for the integral cycle services provided. Therefore, one of the most outstanding aspects is to ensure that the water meters maintain their error curve as close to zero and without favouring any of the parties (neither undercounting, nor overcounting).

For domestic users, for small and medium diameters (15 to 40 mm.), Canal de Isabel II has traditionally installed speed water meters, mostly single jet, and volumetric. With the technological advance in the latest generations of static water meters, this technology has also been incorporated into the measurement of consumption to this type of users. Regarding metrological ratios, it seeks to combine an accurate measurement of the usual consumptions in this segment of customers, at medium flows, with the capture of very low flows, which would correspond to leaks in the facilities of the users. To do this, counters from R200 are installed as an essential minimum.

With regard to water meters in large diameters (50 to 300 mm.) for users with high flow demand, in commercial and industrial uses, Canal de Isabel II is installing static water meters with high dynamic range (R500 or higher). And this in order to capture the widest possible range between low flow rates and high flow rates with the least measurement error.

For the case of uses in fire connections (diameters greater than 40 mm.), although Canal de Isabel II was traditionally installing Woltman water meters, it has evolved towards static water meters, which do not have any type of mechanism that, due to clogging, can prevent the flow of water, and where, in addition, load losses are minimized. Both advantages of this type of meters help reduce the risk of interruption in the water supply or the lack of pressure necessary for the fire protection system to be activated in the building serviced by the water connection.

4.5. Conclusions on the choice of the water meter

As stated, there are multiple factors to be taken into account in the choice of the most appropriate typology and characteristics that a water meter must have to achieve metrological excellence in a given supply.

It cannot be said that there is the "perfect water meter" of universal use, since all of them have advantages and disadvantages according to the situation.

It will be the supply manager who must evaluate the specific circumstances that must be considered in order to make the choice of the water meters that best adapt to them.

The price of the water meter varies according to its type and technical characteristics. Although it has not been discussed in this section, it is an essential aspect to consider when choosing the meter, but not the only one. A proper balance between the performance of the water meter and its price should lead to the choice of the most advantageous solution from a global point of view.

In Chapter III, some general guidelines on the cost-benefit analysis of an advanced measurement of water consumption will be indicated.

5. Metrological control of water meters in Spain

When metrological excellence is sought as an objective, it is important to guess the type of water meter to be installed in a given supply, but the existence of control by the competent authorities is essential, as well as a commitment of the supply managers to work collaboratively in the achievement of this objective.

5.1. Metrological control of the State

The applicable legislation in Spain is the following:

- Spanish Constitution: Article 149.1.12ª.

- Law 32 / 2014 of 22 December on Metrology.
- Royal Decree 244 / 2016 of 3 June 2016 implementing Law 32 / 2014, which transposes Directive 2014/31/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to the marketing of measuring instruments (recast).
- Order ICT/155/2020, of 7 February, which regulates the metrological control of the State of certain measuring instruments.

In accordance with the provisions of Article 7 of Chapter III of Law 32/2014 [1]:

> *"In accordance with the regulations of the European Union and with the resolutions of the International Organization of Legal Metrology, the **metrological control of the State** is the set of activities that contribute to guaranteeing the certainty and correctness of the result of the measurements, regulating the characteristics that the instruments, means, reference materials, measurement systems and computer programs related to the measurement must have; the appropriate procedures for their use, maintenance, evaluation and verification; as well as the typology and obligations of the intervening agents."*

In accordance with what is specified in article 8, of Chapter III of Law 32/2014 [1]:

> *"The instruments, means, reference materials, measurement systems and computer programs **that serve to measure or count and that are used** for reasons of public interest, public health and safety, public order, protection of the environment, **protection or information to consumers and users**, collection of taxes, calculation of tariffs, fees, administrative sanctions, performance of judicial experts, **establishment of basic guarantees for fair trade**, and all those that are determined with regulatory character, will be subject to the metrological control of the State in the terms established in its specific regulations."*

> *"Regulations will establish the **marking and sealing regime** for measuring instruments and systems subject to metrological control, which must provide clear and precise information to citizens, consumers and users and the inspection authorities on their assessment of conformity and verification status".*

That is, in Spain, water meters as instruments on which the billing of consumption is based are subject to metrological control by the State and must be clearly marked and sealed for users.

The metrological control of the State comprises a phase of conformity assessment and a phase of metrological control of the instruments in service.

5.1.1. Metrological control of the State: Assessment of the conformity

In accordance with Article 9 of Chapter III of Law 32/2014 [1]:

"In the conformity assessment phase, compliance with the regulatory requirements that instruments, apparatus, means, reference materials and measuring systems must meet in their first use is checked."

In accordance with Article 7 of Chapter III of Royal Decree 244/2016 [2]:

"The conformity assessment phase of the State metrological control shall apply to measuring instruments prior to their being placed on the market and put into service, using the conformity assessment procedures set out in Article 10.2 and developed in annex I or in the specific regulation for measuring instruments."

In this respect, the legislation allows different options for the assessment of the conformity of water meters. The supply manager will have to verify that the manufacturer of the water meter he is purchasing is in possession of modules B+D (type examination plus conformity to type based on quality assurance of the production process), B+F (type examination plus conformity to type based on instrument verification) or H1 (conformity based on full quality assurance plus design examination).

In order for a water meter to be marketed and put into service, it must comply with the provisions contained in legislation, which will be recorded by means of a conformity marking. When a meter manufacturer draws up a declaration of conformity, he shall assume responsibility for the compliance of the meter with the applicable legal requirements.

5.1.2. Metrological control of the State: Instruments in service

In accordance with Article 9 of Chapter III of Law 32/2014 [1]:

"The metrological control phase of instruments in service may comprise, as appropriate in each case, verifications after repair, verifications after modification and periodic verifications. This phase aims to check and confirm that a measuring instrument or system in service maintains compliance with regulatory requirements consistent with the original ones".

In accordance with Article 7 of Chapter III of Royal Decree 244/2016 [2]:

"The metrological control of the State of the condition of measuring instruments in service may include verification after repair or modification and, or, periodic verification. The prohibition of repair of certain measuring instruments and fix their useful life in a maximum time can also be established".

In accordance with Article 19 of Chapter IV of ICT155/2020 [3]:

"The maximum permissible errors of instruments for which a service life is established shall be those set out in their conformity assessment."

The metrological control of the State includes the surveillance of the market, through the adoption of measures to carry out checks on the water meters marketed in order to verify the conformity of these.

5.2. The metrological control in Canal de Isabel II

5.2.1. Metrological control before the installation of the water meters

Although there is metrological control by the competent authorities, supply managers can also carry out additional metrological checks before installation.

This control can be carried out by sampling at the reception of the batches of the water meters, through tests carried out by an approved laboratory (usually managed by the supplier itself).

Metrological control at Canal de Isabel II, prior to the installation of the water meters, is carried out through tests carried out in the Canal laboratory, a collaborator of the Spanish Metrology Centre and a calibration laboratory accredited by ENAC (National Accreditation and Certification Entity), as a prior reception control. They are as follows. Ref. [4]:

- Full curve: The purpose of the test is to verify the four flow rates referred to in the applicable standard (R.D.). 244/2016 [2]), together with Q4/4 and Q4/10.
- Full curve after ageing. The purpose of this test is to verify the behaviour of the water meter after subjecting it to aging cycles.
- Starting flow of the water meters: The purpose of the test is to verify if the meters total volume under minimum conditions of pressure and flow.

- Immunity to magnetic fields: It is intended to verify the behaviour of the water meters under the affectation of a specific magnetic field.

In the event that suppliers have offered improvements in the minimum required benefits, they are also tested to verify their compliance, which may be, Ref. [4]:

- Improvement of errors in the full curve required by legislation.
- Water meter start-up at very low test flow rates below the minimum required.
- Improvement in errors with the affect of a specific magnetic field.
- Improved repeatability: when the maximum difference between the errors obtained in the full-curve tests is less than or equal to ±0,5%
- Improvement of minimum required R=Q3/Q1 ratio.

With this, it is possible to select the best water meters, adapted to the needs of Canal de Isabel II.

Figure 1: Metrology laboratory of Canal de Isabel II

5.2.2. Metrological control of the water meters in service

The behaviour in service phase is very relevant, and especially the maintenance of the maximum permitted errors according to metrological legislation.

During the service phase, Canal de Isabel II carries out sampling of the metrological behaviour of water meters in two areas:

- On the farms where the water meter is installed: The verification is carried out by a Canal team specialized in the Technical Inspection of the Measurement Set under a procedure accredited by ENAC, and which includes the verification of measurement errors of the water meter installed, through the use of a ramp with a standard water meter.

- In the Canal laboratory: The verification of the water meter, once removed from the farm, is carried out by the specialized team in the laboratory, accredited by ENAC.

The purpose is to evaluate the ageing of the water meters and the maintenance over time of the services offered by the manufacturers of water meters.

In this sense, when Canal detects deviations from these errors, it rectifies the billing for water consumption issued to its customers and replaces the water meter. Therefore, the commitment of meter suppliers to the metrological excellence of the equipment they sell, through the appropriate guarantees, is essential.

CHAPTER II: REMOTE READING OF WATER METERS

1. Selection of the most appropriate communication technology

1.1. The case of Canal de Isabel II

Canal de Isabel II has always been at the forefront of technology. It was one of the pioneers in monitoring the supply network. In the 80s it began to capture signals from flow meters, levels of tanks and reservoirs... to evolve over the years to the capture of signals in a multiplicity of sensors both in supply and sanitation and reuse.

The supply network at Canal de Isabel II is sectorised and data on incoming flows to each sector is available in near real time. However, the consumption of users is available every two months, after a process of face-to-face reading by staff who must travel to the farms to obtain the data.

In summer 2016, the 3GPP published the NB-IoT (Narrow Band-IoT) standard. This new technology was presented as the first capable of meeting the requirements of Canal de Isabel II, among which were:

- Be a standard.

Proprietary solutions usually generate undesirable dependencies in public management.

- Be offered in the communications market under a regime of free competition.

Free competition is sought for tenders of products (water meters) and services (connectivity).

- Have a guarantee of future continuity.

The investment necessary for the implementation of meters with remote reading can only be carried out if there is a guarantee of continuity in the provision of the connectivity service during at least the years that the amortization of said investment lasts.

- Be efficient from an energy point of view.

According to the legislation on metrological matters in Spain, the water meters have a useful life of 12 years, and the capacity of the batteries installed in them must enable communication during that period.

- Have good geographical coverage.

Canal de Isabel II provides integrated water cycle services in 179 municipalities of the Community of Madrid, scattered throughout its territory, in urban areas and in more isolated rural areas. It is not feasible to have different capabilities in connectivity that imply differences in availability of services linked to remote water meter reading information between customers of different municipalities.

- Have a good penetration of the signal.

The water meters in the CAM are located mostly in cabinets on the facade of buildings, but also in manholes or in basements where the level of radiofrequency coverage is degrading.

In January 2017, Canal de Isabel II launched a public announcement inviting all communications operators using NB-IoT, as well as all manufacturers of devices (water meters) to test the technology for its possible application to remote meter reading.

After the signing of the corresponding collaboration agreements, over the following years different pilot tests are developed, installing equipment in the field in difficult environments for the purposes of radio communications, which are subjected to different operational tests, including stress tests. Likewise, laboratory tests are carried out, to know the technology, the advantages and limitations of it.

Trials and field tests were focused on verifying the performance of the equipment against:

- Energy Efficiency
- Geographic Coverage
- Signal Penetration

The results of the pilots being satisfactory, the NB-IoT technology is validated for its application in the remote reading of water meters in the Community of Madrid.

The main reasons for choosing this technology were:

- It's a standard. It is not a proprietary solution.
- It is offered by the mobile communications market under free competition. Free participation in tenders for the acquisition of products and services is guaranteed.
- It has a guarantee of continuity, as the NB-IoT service is configured within the 5G spectrum and remote reading of water meters is one of the many use cases for this technology.
- It allows communication over an already deployed infrastructure and with massive and shared use cases, which minimizes costs of both first implementation and maintenance and operation …
- It is efficient from the energy point of view, which allows durability of the water meters according to their useful life of 12 years …
- It has good geographical coverage, both in large municipalities and in small and more isolated municipalities.
- It has a good signal penetration even in basements and indoor locations, reaching almost all of the water meters.

NB-IoT applied to the remote reading of water meters is a homogeneous and efficient solution at regional level, for all municipalities in the Community of Madrid.

1.2. Considerations in the choice of communication technology

By its very nature, linked to 5G communications, and based on the remote water meter reading implementations being carried out in Spain and other countries, NB-IoT is proving to be one of the most promising technologies for its application to multiple use cases in the water sector itself in Spain and in other sectors and countries.

However, the choice of the technology that best adapts to each situation and environment is not something obvious or homogeneous.

When it comes to incipient or innovative technologies, it is advisable to test them beforehand in order to verify their applicability to the use case in question. In addition, the more in-depth the previous studies, the pilot tests in the field and the performance tests that are carried out, the greater guarantee of success the solution that is chosen for its implementation will have.

Another important factor when it comes to choosing the technology is the analysis of the ecosystem that supports it. In the case of NB-IoT, being within the 5G environment, linked to a multiplicity of applications in mobile telephony and IoT, and its universality worldwide, it benefits from the robustness of the entire 5G system (components, software elements, infrastructures, suppliers, standardization by international organizations, future evolutions and innovation ...).

In short, each supply manager, depending on the conditions and the environment in which he finds himself, will choose one or another technology. As a summary, and based on the experience of Canal de Isabel II, some aspects that can be considered as support for decision-making in the choice of a communications technology for remote water meter reading are listed:

- ✓ Existence of an infrastructure already deployed, operated and maintained by specialists in IoT connectivity, in order to save costs and gain efficiency in the operation of said infrastructure.
- ✓ Support by solvent organisms for an adequate support to the technological evolutions that always exist in this type of technologies.
- ✓ Standard solution, with maximum universality in the evolution of components and associated software solutions.
- ✓ Guarantee of continuity of the solution in the future, since the water meter must be amortized at least during its metrological useful life.
- ✓ Good geographical coverage and good signal penetration, with the cleanest possible spectrum of interference, in order to receive the information of the water meters in quasi-real time in all the deployed devices.
- ✓ Low battery consumption, as it is equipment that must align its duration with the metrological useful life.
- ✓ Good protection and ability to adapt to the evolution of legislation on cybersecurity.

2. Selection of the technical solution for remote reading of water meters

Parallel to the choice of communications technology, it is necessary to define the technical solution to implement Remote water Meter reading. This will depend on the type of facilities that exist in the supply, as well as the type and state of the existing water meters in the park.

In the case of Canal de Isabel II, the water meters are configured in the following typologies:

- Water meters in concentration arrangement (batteries of meters located in rooms for this purpose).
- Isolated water meters (usually located at the edge of the property, in cupboards on the facade or manholes on public roads, but also inside buildings).

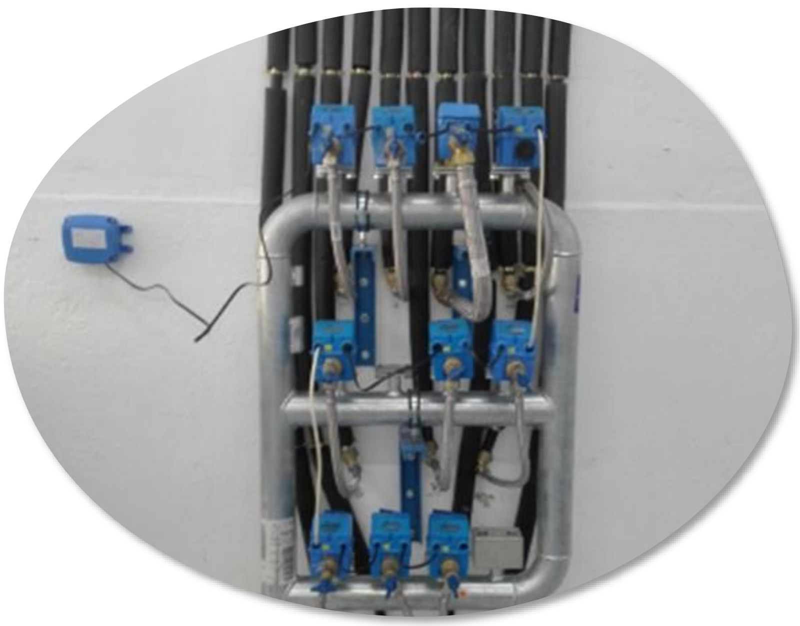

Figure 2: Water meters in concentration arrangement (batteries)

Figure 3: Water meters in isolated arrangement

The number of water meters in Canal de Isabel II is currently estimated at 1.59 million meters with the following distribution:

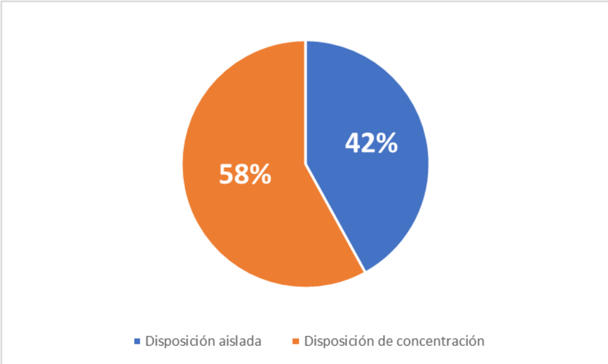

Figure 4: Distribution of water meters in Canal by type of installation

Canal de Isabel II had spent years looking for technologies that would allow the digitization of all its operations. For this reason, it began years ago, carrying out campaigns to replace mechanical water meters and installing electronic water meters in the meter batteries. In this way, and as it has been, when the appropriate communications technology was available, this solution would allow the remote reading of all the water meters already installed in the batteries in a fast and efficient way.

In this technical solution of automatic reading, prior to remote reading, the communication between the meters of the battery is carried out through a standard communication bus described in Standard UNE-82326:2010, linked to a concentrator. The reader, in person, interacts with the concentrator and automatically downloads the readings of the water meters of the entire battery in its reading terminal to be subsequently transmitted to the Canal information system. This system has made it possible to gain efficiency in the reading of water meters, evolving from a manual reading to a mechanical meter, to an automatic reading to a system of electronic meters, eliminating reading errors, which were very frequent in the batteries of mechanical meters.

Therefore, the technical solution chosen for the remote reading of water meters in battery is through a new concentrator that incorporates NB-IoT technology and that is responsible for collecting the readings of all the meters of the bus and sends them through NB-IoT to the Canal servers. It is an efficient way of Remote Reading due to the savings associated with the data transmission of several water meters grouped in a single communication package, but, in addition, in the case of Canal, the investments necessary for the implementation of Remote Reading are reduced to the replacement of only a small part of the meters in batteries that are still mechanical, and to the installation of new concentrators with integrated NB-IoT..

The technical specifications of concentrators for remote reading can be consulted in the procurement documents published in file 162/2020 [5].

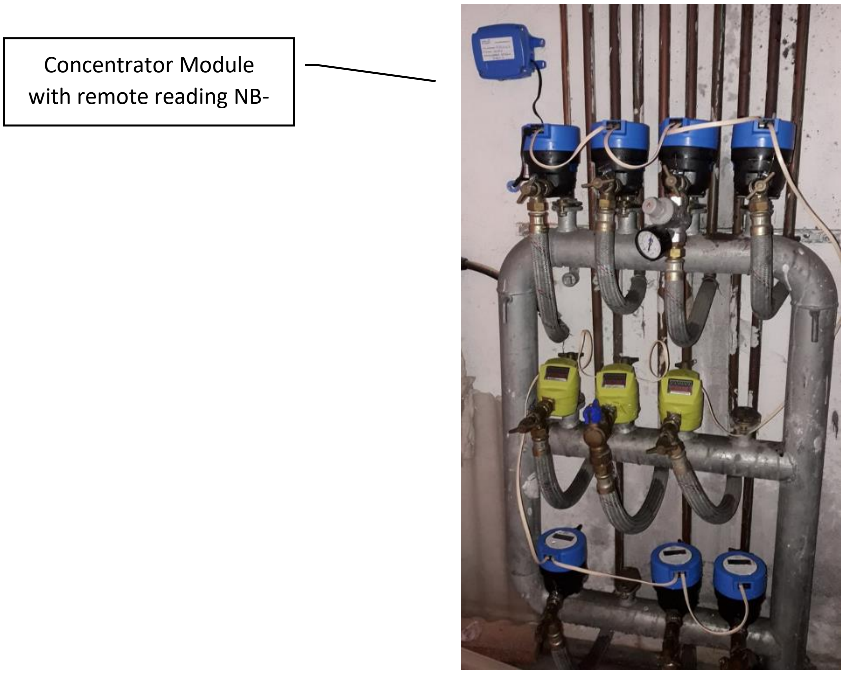

Figure 5: Distribution of electronic water meters in bus UNE-82326:2010 and NB-IoT concentrator

In the case of water meters in an isolated arrangement, the Canal de Isabel II park consists of mechanical meters. After several analyses carried out on the different solutions existing in the market for the implementation of Remote Reading in this configuration, the following technical solution was decided, which differs depending on the diameter of the water meter:

- For small water meters (diameters 15, 20, 32 and 40 mm.): NB-IoT is integrated into the meter itself, which provides numerous advantages linked to the fact that it is a compact solution. It is easily integrated into the accommodation, quick and easy installation and maintenance, which results in cost savings, robust in terms of integrity and security of information ... etc.

Figure 6: Electronic counter with integrated NB-IoT

The technical specifications of meters with NB-IoT integrated into the meter itself can be found in the procurement documents published in dossier 74/2022 [4].

- For medium and large water meters (diameters 50 mm. and above): Remote reading by concentrator incorporating NB-IoT. The location of these meters, many of them in manholes, makes the conditions in front of humidity are demanding, so installing the communication equipment as close to the grade of the public road, minimizes the risk of breakdown, always recommended when dealing with high price meters.

3. Type of data that can be dumped from a water meter with remote reading

The basic data provided by a water meter are the reading indices. By difference between them, the consumption recorded in the meter in a given period is obtained. Traditionally, supply managers manage bimonthly or quarterly consumptions in most of the supplies. Consumption is only controlled with less frequency in those users where, either because they are large consumers or because of their strategic nature, it is convenient to follow up more frequently. And all this for the cost of face-to-face reading.

With the implementation of remote water meter reading, it is now possible to have consumption practically in real time. The frequency required (hourly consumption, every fifteen minutes, every five minutes ...) will depend on the need for such information for the intended use.

For example, if you want to make very detailed studies on water uses, you will have to increase the frequency of availability of these consumptions. Likewise, if you want to use the information to generate warnings, for example, of high flow leaks, real-time consumption will be the most convenient.

However, it is necessary to evaluate the cost of having a huge volume of information, both from the point of view of investment in water meters and cost of communications (the greater and more frequent availability of information, the greater the cost), and of the management and processing systems of said information.

In the case of Canal de Isabel II, and considering the current state of technology, it has been established as the main use case to have daily time information from the previous day. This information is sufficient for most of the applications in which Canal needs the data to improve efficiency in supply management and also for most of the services that can be offered to customers.

In addition to this main use case, with hourly information and daily transmission, Canal will establish some additional use cases by doing statistical sampling in different groups of users, to advance in the knowledge of water uses and in the improvement of the management of the integral cycle, where the frequency and immediacy of the information will have to be greater (every 15 and 5 minutes).

In the future, when technology allows it in an economical way, it will be possible to advance in the availability of information in real time and in a general way for all users.

On the other hand, depending on the type of water meter, it can offer additional information to consumption, such as maximum and minimum flow rates, flow histograms, leakage suspicion alarms, alarms about the state of the batteries, pressure measurement, temperature measurement ... In this sense, each supply manager will decide the usefulness of this type of variables and its implementation or not in all or in certain types of users.

On the other hand, water meters, in addition to consumption information and other hydraulic parameters, provide information on engineering metrics linked to communications, which will also need to be treated for proper management of the remote reading system. Early detection of incidents in communications is essential in the good performance of the remote reading solution.

4. Processing of the remote reading data of water meters

Once the data that the water meters are able to provide reach the servers of the supply manager, it is necessary to treat it efficiently to convert it into useful information. This involves several steps ...

4.1. Control of the information. Middleware of operation

The operation middleware is the platform where the remote water meter reading information arrives and has an essential role as an intermediate element of reception of said information, both of the meter readings and of all the engineering metrics associated with communications.

It is, therefore, the control system of the remote reading efficiency and the tool that allows the management of the remote reading system.

In addition, in the incipient stage of development of products linked to the remote reading of water meters, manufacturers handle protocols that are not standard, it is necessary to incorporate and manage in a common way for all of them. As the development of NB-IoT products and services progresses, more and more standards will be generated that will facilitate management.

4.2. Big-data systems

Once the information is validated in the operation Middleware, it is loaded into the corresponding repository for the treatment and consolidation of it according to a data model, from where an appropriate treatment will be made to the application that is going to be carried out.

For this, tools for processing large volumes of data (big-data) are essential, as well as servers that can provide adequate support for an agile management of information.

Therefore, within the remote reading system it is essential to have the evolution of information systems, with the associated investment that this entails. It is useless to have near-real-time consumptions if they are not transformed into useful information, which is unthinkable without an adequate infrastructure of the systems and associated applications.

Likewise, it is necessary to incorporate new professional profiles and evolve existing ones so that the potential of remote reading information can be exploited, which is not always easy.

Information analytics is being developed at Canal de Isabel II in parallel with the field deployments of water meters with remote reading. This allows the models to be compared with a small group of users in order to subsequently evolve them in a controlled way when the implementation is complete.

4.3. Artificial Intelligence

Every day we hear new news of applications of artificial intelligence, which may make us think that it is something already present in the day-to-day operations, and specifically, something already almost implanted in the management of supplies.

Currently, at Canal de Isabel II, the evolution towards models using artificial intelligence is still a long way off. It is undoubtedly a challenge to address, and the information provided by remote water meter reading is essential to achieve it, but previously it is necessary to take some steps, such as consolidating the advanced analytics of remote meter reading information, which is what Canal de Isabel II is working on at the moment.

5. Benefits of the information provided by remote reading of water meters

Regarding the benefits of the digitalization of supplies, and specifically referring to the information provided by remote water meter reading, there are two different areas:

- The management of the integral water cycle: The availability of data in quasi-real time (schedules, for example), allows advanced analysis of efficiency in the water distribution networks themselves, allowing a reduction of unnecessary losses of the water resource itself, and of all those costs linked to its production and purification (energy costs, reagents ... and environmental).
- Customer/user management: The detailed knowledge of the consumption pattern allows users to limit themselves in irresponsible or sumptuous consumption. In addition to personalized awareness campaigns, tariff systems can be established focused on a more efficient demand management. On the other hand, with the information provided by the Remote Reading of water meters, new services and utilities can be offered to citizens not related to the water sector, but yes, for example, with alert systems against unwanted housing occupations, to give just one example.

Remote water meter reading takes on meaning when the information it provides is used to improve day-to-day management of a scarce resource, water.

Among the first utilities of the information that will be implemented in Canal, we can mention the feeding of the existing hydraulic models, transforming them already into digital twins, in order to detect anomalies in the water networks early that allow resource savings, optimization in demand management, and improvement in the operations of the integral cycle, which will result in greater efficiency of the necessary investments.

In the field of citizens, Canal will provide useful information for better self-management of consumption, as well as a catalogue of new value-added services. A new model of relationship with the client is structured, much closer.

6. Methodology for the implementation of a remote water meter reading project

When the time comes to address a remote water meter reading implementation project, it is convenient to apply methodologies that comprehensively address the project.

In the case of Canal de Isabel II, the following methodology has been followed for the development, implementation and operation of remote meter reading. The model can be summarized in the following ten essential heading:

1. Analysis of the information that a water meter with remote reading can provide, reflecting on its usefulness and valorisation of the expected benefits.
2. Study and selection of available technologies that allow the remote reading of water meters. The choice will depend on the circumstances of each supply, with special importance on the availability of connectivity technologies in the area.
3. Definition of the technical solution to be implemented in the supplies, which will vary depending on the type of connections, the form of measurement of consumption and

contractual relationship with the users that each Supply has, as well as the technical configuration and state of the park of water meters that exist in it.

4. High level planning, which includes a technical feasibility analysis and the deployment model.

   4.1. Technical feasibility analysis, through the study of the real availability in the market of equipment (water meters and concentrators) with the required technical characteristics.

   4.2. Deployment model of the solution to be implemented, which can be integral or phased. In the case of Canal de Isabel II, with an innovative and emerging technology in the market, a phased deployment model has been chosen, in order to obtain the following benefits:

   - ✓ Ensuring maximum attendance at tenders, giving the possibility for suppliers who were not prepared to bid in the first procurement procedures, to prepare adequately and bid in the following ones.
   - ✓ Taking advantage of technological improvements that may arise, in order to incorporate them in those tenders in which they were already available.
   - ✓ Reduction of the risk against possible inefficiencies in the first equipment offered to the market and in the processes of implementation of a very massive solution in the Canal.
   - ✓ Boosting the market for the search for massive solutions that reduce overall costs in the global remote water meter reading solution.

5. Impact of the project on the company's resources, studying the need for parallel developments in information and communications systems (big data, artificial intelligence, information security...), organizational change, evolution of professional profiles, etc.

6. Economic study of the project, through the analysis of expected costs and benefits of remote water meter reading.

7. Strategic feasibility analysis, where all the factors that intervene in the final decision making about the convenience or not of addressing the remote water meter reading project are analysed globally.

8. Strategic feasibility analysis, where all the factors that intervene in the final decision making about the convenience or not of addressing the remote water meter reading project are analysed globally.

9. Implementation and maintenance in the field of the solution: connected water meters, including the development of information systems supporting the entire remote reading solution.

10. Use of information to improve the efficiency of the management processes of the integral water cycle in the company and to establish a new model of relationship with customers, based on this information.

CHAPTER III: COST/BENEFIT ANALYSIS IN THE MEASUREMENT OF WATER CONSUMPTION

1. Introduction

The measurement of water consumption is considered a necessary operation in any supply, whether the water resource is scarce, or if there is an abundance of water in the area.

The mere measurement of consumption encourages users to make responsible consumption. If, in addition, it is complemented by a tariff system for the supply and/or sanitation services provided, which promotes water savings and penalizes sumptuous or disproportionate consumption, the management of water resources will be sustainable and respectful of the environment.

In addition, the remote reading of water meters allows to improve the efficiency of the management of supplies, being an effective tool for locating leaks and water losses in distribution networks and encouraging the user, through the information provided, to a more sustainable consumption.

The type of measurement that can be done in each case, basic or advanced applying the latest technologies, will depend on the state of development of the area in question, the water situation of the same and the value of the water.

In case the supply manager does not consider the implementation of remote reading, obviously in the economic model the costs and benefits associated with it will not be taken into account.

The following sections present in a very general way the main costs and benefits of the implementation of an advanced measurement. The cost/benefit ratio to achieve the economic balance and self-sufficiency of the system chosen by each supply manager will depend on the monetary valuation that corresponds in each case and that will be very variable depending on the circumstances of each supply. In short, the case study that corresponds to a certain supply is not valid for another.

Therefore, this chapter proposes concepts that can be included in the economic study on the feasibility of a measurement project, and specifically advanced measurement considering remote water meter reading, but they are not coded, due to their variability depending on the circumstances of each supply.

2. Analysis of costs

The cost model varies depending on the implementation or not of remote reading.

On the other hand, considering that the implementation of remote reading is decided, the associated costs vary depending on the remote reading management model that is decided.

There may be models such as "integral service," "disaggregated" models, and intermediate models between both extremes, where the costs will be similarly "aggregated" under a global price offered by the providers of the integral service, or where the costs will be "disaggregated" under prices of different suppliers of products and services, plus the costs of the management itself carried out directly by the supply operator.

Some management models for the remote reading of water meters are briefly described below:

A. Model "integral service of management of remote reading information": Everything is contracted with a third party, including the analysis of the information generated by the water meters with remote reading, as well as the new services to clients that can be derived from this information.

B. "Remote reading service" model: The provisioning of equipment, the deployment in the field of these and the sending of information, as well as the maintenance of the remote reading system, is contracted with a third party. The supply operator receives the remote readings in real time from the supplier during the years of duration of the contract, but reserves the performance of the analysis of the information and manages its use including the new services associated with remote reading for customers.

C. Model "provisioning of water meters and associated connectivity service": The provision of water meters with remote reading as well as the associated connectivity service is contracted with a third party, being the supply manager who controls how the performance of the remote reading system is being carried out, in order to verify compliance with the provisions of the contract. This includes the monitoring of engineering parameters from a metrological and communications point of view.

   The use of information through advanced analytics, which allows an improvement in the efficiency of the supply, as well as a change in the management of customers are made by the supply operator.

   It is the management model that Canal de Isabel II has chosen for the first generation of remote reading equipment, as it allows to work collaboratively with the supplier in order to gain knowledge in an innovative technology such as NB-IoT, and to be able to exploit the possibilities of the remote reading system chosen both in its current performance and in its future evolution.

D. "Disaggregated" model: The different products (meters, concentrators ...) are contracted with different suppliers, as well as the different services that make up the remote reading system (connectivity ...), with the supply operator being responsible for its correct interoperability and operation.

Below, the main costs to be included in the economic viability model of the water consumption measurement project are indicated, which, depending on the management model chosen, will be imputed in an aggregated or disaggregated way.

In the case of a supply without remote water meter reading:

1. Costs of deploying equipment in the field:
   - Cost of the equipment (whose price will vary depending on the characteristics and typology of the meters chosen).
   - Cost of metrological control prior to the installation of the water meters, in order to verify compliance with the maximum permitted errors, in accordance with current legislation, and to verify the specified technical characteristics of the meters.
   - Cost of the installation of the meters in the water supply connections.

2. Operating and maintenance costs of the water meter park, in service:
   - Cost of metrological control of water meters in service, in order to verify the maintenance over time of the characteristics of the meters and carry out a control of their ageing …
   - Cost of maintenance of the water meter park (cleaning of filters, replacement and repair of keys and associated parts....)
   - Cost of water meter reading (personnel who must travel to the farms to obtain the reading indices).
   - Cost of monitoring the water meter park (personnel who must travel to the farms to verify the causes of consumption outside the expected range for a certain supply or operating anomalies of the meters themselves)

3. Costs of information analytics and management of customer complaints:
   - Cost of personnel dedicated to the analysis of the consumptions obtained from the readings (bimonthly, quarterly ...) prior to the issuance of the invoice for water consumption.
   - Cost of personnel dedicated to the management of claims for water consumption billing.

4. Other costs:
   - Cost of water lost in leaks not detected early.
   - Cost of inefficiencies of the supply management system, such as inadequate dimensioning of the water meters due to precise ignorance of the consumption patterns of the users, or those inefficiencies linked to the estimation of consumption when it is not possible to have the reading of water meters inside farms, …

In the case of a supply that has a remote water meter reading system, the most relevant constants to consider are the following:

1. Costs of deploying equipment in the field:
   - Cost of the equipment (whose price will vary depending on the characteristics and typology of the water meters chosen), which will be higher than the cost of the equipment without remote reading.
   - Cost of metrological control prior to the installation of the water meters, in order to verify compliance with the maximum permitted errors, in accordance with current legislation, and to verify the specified technical characteristics of the meters.
   - Cost of controlling the performance of communications prior to the installation of water meters.
   - Cost of the installation of the water meters in the water supply connections.

2. Operating and maintenance costs of the water meter park, in service:
   - Cost of metrological control of water meters in service, in order to verify the maintenance over time of the characteristics of the meters and carry out a control of their ageing.
   - Cost of controlling the performance of connectivity in service, in order to verify that the communication parameters are maintained in a desired range, so that the information offered by the water meters arrives according to the established use case and the durability of the batteries of the equipment is not affected by unnecessary retries or other undesired effects.
   - Cost of maintenance of the water meter park (cleaning of filters, replacement and repair of keys and associated parts, …).
   - Cost of communications for remote reading (NB-IoT connectivity in the case of Canal de Isabel II).
   - Cost of monitoring the water meter park, which will be greatly reduced compared to a traditional model without remote reading.

3. Costs of advanced analytics of the information offered by water meters with remote reading and management of customer claims:
   - Cost of personnel dedicated to the analysis of the consumptions obtained from the remote readings, prior to the issuance of the bill for water consumption and for its use in the new utilities derived from said information.
   - Cost of personnel dedicated to the management of claims for water consumption billing, which will be much lower than in the traditional model without remote reading.

4. Other costs associated with remote reading systems:
   - Cost of development or acquisition of an operation middleware for the implementation of remote reading and for its maintenance, which includes the monitoring of communications and the attention of incidents in them, preferably in an automated way and integrated with the commercial system itself.
   - Cost of acquisition of new systems, such as new information storage spaces and applications for the treatment of large amounts of data (big-data).

- Cost of the evolutionary development of the existing systems (Commercial System, Virtual Office and Economic Management System) for the implementation of the benefits associated with the remote reading of water meters.
- Annual cost of newly recruited personnel with the new professional profiles necessary for the exploitation of remote reading information (data scientists, …).
- Cost of training for the evolution of existing personnel towards profiles more focused on the management of a remote reading system.
- Cost of training and implementation of a new digitalization culture in the company and in the customers themselves.

3. Analysis of benefits

This section will focus on the expected benefits of remote water meter reading.

In case of not having remote reading, the benefits are related to the control exercised over the uses of water in order to be able to bill users for the services provided with sufficient guarantee both for the supply manager and for the user himself. This should be related to the value of water in the area concerned.

Regarding the benefits derived from water meter reading, an analysis is carried out from two different areas. On the one hand, from the improvement of operations related to the management of the integral water cycle and, on the other hand, contemplating the new services that can be offered to citizens.

In the field of water resource management, some of the expected benefits are:

- Knowledge of consumption patterns to reduce leaks and fraud in the distribution networks.

  The remote reading of water meters helps to detect leaks and unauthorized consumption, as it allows water balances to be carried out by sectors with greater precision, by knowing the hourly consumption of users (sector outputs) that are compared with the inputs to the sector.

  Likewise, the remote reading of water meters allows to generate comparative consumption patterns by groups of customers. This information is very useful especially for users with inefficient consumption patterns who, being aware of it, will establish saving measures.

  And all this allows:

  - Increased guarantee of supply: Supply capacity in the face of population increases or in situations of drought (climate change).
  - Resource savings, with reduction of water treatment, storage and distribution costs, as well as, after its use, its subsequent collection and purification, before its return to the natural environment. Reduction of costs in reagents, energy ….
  - Reduction of costs of obtaining the resource by more expensive systems (pumping). The savings in volume of water that is necessary to inject into the system also entail the savings linked to being able to dispense with water resources of more expensive production (for example, the need for extraction

of groundwater or water sources of poorer quality at source that require more expensive treatments …).

  - Improvement against environmental impacts. Reduction of carbon footprint by reductions in unnecessary water treatments (reagents, energy...), and by the digitalization itself (reduction of reader vehicles on the road).
  - More refined adjustment of the hydraulic model, with optimization of the dimensioning of the supply system and improvement of the demand estimation system. Possibility of digital twins. This leads to savings in investments due to unnecessary oversizing of hydraulic infrastructures (tanks, pipes, treatment stations).
  - Creation of descriptive models in the first place and predictive models later for demand management, being able to make a forecast of investments for the infrastructures that are necessary with sufficient time in advance.

At the user level, some of the expected benefits are:

- In its application to the services provided: Knowledge of consumption patterns: Improvement in the model of detection of anomalous consumptions.
  - Early detection of leaks in internal networks.
  - Control and optimization by the customers of their own consumption habits. Reduction of inefficient consumption.
  - Comparison between groups of similar customers:
    - Personalization of notices and awareness campaigns.
    - Detection of possible fraud.
- In its application to the provision of new value-added services:
  - Consumption warnings in the absence of the customer (e.g. early detection of illegal occupation).
  - No-consumption warnings when there should be (for example, tracking of the elderly).
- In its application to the tariff models:
  - Flexibility for billing in time slots that in turn allow an optimization of the Canal hydraulic system.
  - Billing according to a responsible use of the resource, linked to environmental protection.

The benefits listed are only the first ones that can be considered. The very process of implementation of remote reading and its exploitation, together with the rapid evolution of information processing tools, will open up new opportunities that are not yet contemplated today.

Each water supply or operator, depending on their specific circumstances, may consider one or the other benefits. Likewise, the weight that each of them has in the economic balance of the project varies for each situation (different models of hydraulic infrastructures, their state, variation in customer expectations, etc.).

4. Analysis cost/benefit

This section summarizes, in a simplified way, the main concepts that can be used in the cost/benefit analysis in a system with remote reading.

4.1. Costs:

- Cost of equipment (water meters and concentrators) and its installation.
- Cost of communications (connectivity).
- Cost of development of existing systems and new information systems for the implementation and operation of the remote reading system.
- Cost of personnel focused on a model with remote reading.
- Cost of implementing a new digitalization culture.

4.2. Benefits:

All of them are related to the ability of remote water meter reading to offer a much greater volume of information (1,460 times greater, in the case of use of time information).

1. **Tangible benefits**

- ✓ Reduction of production, transport, distribution and purification costs of water by reducing leaks and inefficient consumptions.
- ✓ Reduction of the carbon footprint by reductions in unnecessary water treatments (reagents, energy...), and by the digitalization itself (reduction of reader vehicles on the road).
- ✓ Elimination of the annual expenditure on water meter reading.
- ✓ Improvement in the accuracy of the billing issued to customers, due to the disappearance of the consumption estimate.
- ✓ Reduction of the costs of handling complaints.
- ✓ Reduction of the monitoring costs of the meter park.
- ✓ New services provided to customers.
  In order to detect customer needs that can be satisfactorily covered with the information provided by remote reading, it is interesting to conduct opinion surveys. In this way, the portfolio of services to be offered to users and, consequently, the benefits derived from remote reading are significantly enriched. Its valuation will depend on the strategy of each company.

2. **Intangible benefits**

Difficult to quantify economically, the main challenge is to establish an evaluation methodology, sufficiently objective to be able to derive realistic figures from it.

Another option is to consider intangible benefits as an unquantified add-on, provided that the tangible benefits themselves enable the economic viability of the project.

Among the intangible benefits are:

- ❖ Optimization of the management of demand.
- ❖ Increase in the guarantee of supply.
- ❖ Reduction of water stress.
- ❖ Increase in the satisfaction of the client.

In the case of supplies that do not have water meters with remote reading, the mere fact of installing meters represents a very significant change towards an efficiency path …

Consumption control is essential in any supply, whether or not there is a shortage of water resources, because it involves saving and reducing all resources (including energy) linked to the production, transport, distribution and purification of water …

In this case, the cost-benefit analysis is simplified in terms of the concepts to be considered.

CHAPTER IV: REFLECTIONS ON THE ADVANCED MEASUREMENT OF WATER CONSUMPTION

Due to the growing population, climate change and the increasingly evident scarcity of water resources, an efficient management of the water cycle is essential.

The first measure to be implemented is the installation of equipment that measures the consumption of users individually.

The existing water meters on the market have different measurement principles and technical characteristics that make them more or less suitable for use in different locations and patterns of water consumption.

However, being more or less correct the choice of the type of water meter to be installed, as well as the frequency and the moment in which the managers of the supplies have the information that the meters provide, the most important fact is to have measurement.

Once the users' consumption is known (quarterly, bimonthly, daily, hourly ...) different actions can be carried out focused on improving supply management, as well as being able to influence the consumption habits of the users themselves. One of the traditional systems is to adjust the tariff system so that it becomes itself a demand management tool, but there are many other actions that can be carried out, such as citizen awareness campaigns, among others.

And for this, the knowledge of the form and moment in which users consume is very relevant. The greater the granulometry of information on consumption, the more focused and personalized will be the actions that supply managers can carry out.

Therefore, since the measurement of the consumption of end users is an essential factor for a good management of the water cycle, the advanced measurement by remote reading of water meters that allows the managers of the supplies and the users themselves to have information with increasing frequency, for example, hourly information in practically real time, make the connected meter an element of first order.

Systems such as the Remote Reading of meters, taking advantage of their information, allow reducing the water that is needed, reducing leaks and inefficient consumption, with its unnecessary expenses of water and resources associated with its production, distribution and purification, such as energy, while reducing the necessary investments in the hydraulic infrastructures associated with the management of the water cycle.

The main objective of an advanced measurement of water consumption is the reduction of this, either by reducing leaks or by the realization of a more responsible consumption by users.

And this because the provision of water suitable for human consumption and its discharge to public channels after use, entails associated costs of energy, reagents ... for its production, transport and purification.

The optimization of water consumption implies an overall improvement in the availability of water resources and general protection of the environment.

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