Phyn Plus: New approach to water management in homes

Introduction

United Nations projects that 68% of world population will live in urban areas by 2050. It is also anticipated that global water use will increase by 20–30% during the same period [1]. This will put considerable pressure on the performance and capacity of urban water distribution systems, both in terms of the municipal infrastructure and in terms of managing water distribution and use within buildings.

Many European consumers do not consider water as a scarce resource. This is in particular the case in northern parts of Europe with relatively dense population and relatively high access to water resources. This traditional frame of mind has influenced consumer behaviour, construction technology choices and building management practices in a way that has not been favourable to water efficiency.

It should be noted, however, that while there is on average abundant access to freshwater resources in Europe (long-term average of 3 500 m³ per inhabitant and year), these are both highly variant and unevenly distributed in time and geographically. According to the European Environmental Agency, this resulted during 2015 in 33% of the European population to be exposed to water stress conditions. [2]

A European Commission's estimate [3] from 2014 states that "in about half of the Member States, more than 20% of clean drinking water is lost in the distribution network before it reaches consumers' taps, while for some Member States the proportion is as high as 60%". A EurEau study from 2017 puts the mean value of distribution losses in EurEau member countries to 23% of distributed water and 2 171 m³/kilometre of network/year [4]. Unnecessary consumption due to hidden or catastrophic leakages in water systems within buildings is a much less studied topic, but it is an established fact that water damage due to leakage is one of the largest sources of insurance claims from building owners. Consequently, most insurance companies will provide a discount to insurance payments if a leak detection system is installed.

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Higher standards of living have changed water demand patterns in Europe. This is reflected mainly in increased domestic water use, especially for personal hygiene. Most of the water use in households is for toilet flushing, bathing and showering, and washing machine and dishwashing (**Figure 1**). The proportion of drinking water for actual cooking and drinking purposes is minimal, compared with the other uses of potable water. [5], [6]

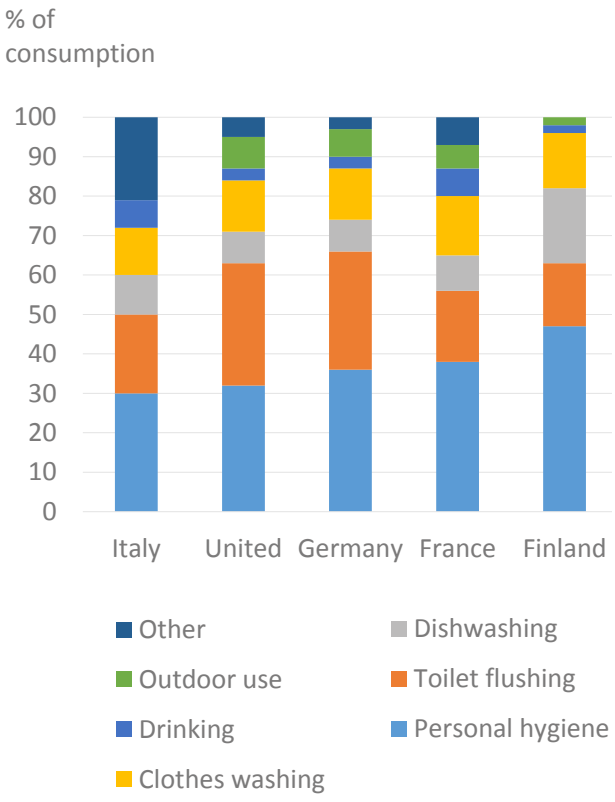

Figure 1. Household water use by activity in selected European countries [6].

The consumer problem

Current investment in developing, maintaining and upgrading water distribution systems within buildings and in communities is unfortunately not on the level required to sustain efficient and reliable water distribution and resource management. This is the case both in developed economies - such as most of Europe and North America – and particularly in emerging and developing economies in Asia, Africa and Latin America.

While there is a clear need for more efficient and affordable water management tools and practices for building owners and occupants, a strikingly low level of development effort by the industry has addressed this need. This is partially related to the value and unit price of consumed water: as the initial resource is free of charge to water suppliers, the consumer price of water has remained relatively low and consequently incentives to invest in water management practices have been low.

With the rapid increase in environmental awareness, and with the more frequent water shortage or water stress situations occurring also in different parts of Europe, there is now also a clearly emerging need from the consumers' and building owners' side for solutions to water management, in particular intelligent detection of hidden leaks and other unnecessary water consumption.

The consumer requirements for such solutions are relatively clear:

- Cost effectiveness: the value provided by detecting unnecessary consumption needs to be in acceptable relation to the cost of detection, including technology costs, installation, maintenance and use;
- Ease of installation and compatibility: the solution needs to be easily retrofitted to existing installations, in order to have sufficient coverage across the whole installed based of plumbing systems; also, installation technologies, sensoring and measurement technologies, and interfaces of these technologies need to be compatible with varying market and installation practices across Europe;
- Predictive performance: in order to have actual value for a leakage detection and water use analytics system, it needs to be capable of predicting leaks before catastrophic failures in the network actually occur;
- Intuitive guidance: in addition to providing technical detection of leaks and other unnecessary consumption, a relevant technology will also provide feedback and guidance to end consumers on consumption patterns, ways of influencing unnecessary consumption, the impact of alternative changes to the water bill, etc.

According to a consumer survey carried out in early 2019 across 500 respondents in Finland [7], there is a clear demand for efficient solutions meeting these requirements. A third of the survey respondents expressed concern regarding the condition of their home plumbing system and showed interest in purchasing water monitoring equipment. Every tenth respondent had already installed a leakage detection device. For most of the respondents the maximum acceptable cost of such an installation was 500 euros.

Most attractive water monitoring features identified in the survey were leakage detection (24% of respondents), water quality monitoring (14%), the possibility to remotely shut off the water (14%) and monitoring total water use (13%). Approximately 8% of the respondents were interested in monitoring and disaggregating water use between different consumption points in the home.

The technological solution: intelligent water fingerprinting

When a faucet or other water outlet connected to the plumbing system is opened or closed the pressure within the piping system fluctuates in a particular way. The Phyn Plus technology measures pressure in the network 240 times a second to track these individual pressure variations at one single installation point, typically adjacent to the main water meter (**Figure 2**). The data collected from pressure measurements is analysed by an artificial intelligence algorithm capable of detecting and learning the individual fingerprints of each outlet connected to the system.

The first two to four weeks after installation is a learning period for the artificial intelligence algorithm. A typical learning period requires approximately 1,000 opening and closing events to learn and double check the different combinations of water outlets in the building.

This leads to a unique feature of the technology. As every faucet (or any other water-using device in the plumbing

Figure 2. The Phyn Plus unit is installed at the main water inlet of the house and monitors the pressure fingerprints of each consumption point from this single location.

system) causes a distinctive set of pressure variations, the artificial intelligence of the Phyn Plus application identifies which water outlet is being used. As the system learns the fingerprints of the outlets connected to the system during their daily use, it will also recognise exceptional situations when the pressure fingerprints deviate from those that have already been identified. These cases are highly likely to be a either leaks or other types of unintended water use and will cause an alarm (or a prompt for action) to be sent to the homeowner.

A further unique feature of the pressure fingerprinting technology is that it can identify such anomalies even when several water outlets are being use simultaneously. This is due to the fact that the individual pressure fingerprints never occur exactly at the same moment, and the 240 measurements per second frequency is sufficient to separate the openings and closings of individual faucets.

The algorithm is also able to provide early warnings of freezing in cold climate plumbing systems. Ice crystal formation causes particular kinds of pressure variations which can be recognised by the system. As such variations are detected, the system is shut off remotely if the risk of freezing is evident.

The Phyn Plus hardware itself does not store monitoring data. It communicates with a dedicated cloud service via the homeowner's Wi-Fi connection. Data stored in the cloud is used to provide consumers with aggregated insights on water use and benchmarking data on a completely anonymized basis. Through the availability of data from multiple installations around the world, Phyn Plus includes a preset basic pool of fingerprints to make the learning period shorter and more effective.

The system also performs a daily plumbing condition check that will reveal even the smallest leaks. The user can select at which times these checks are carried out, preferably at times when water is normally not used, for example during very early morning hours. During the condition check water supply is shut off for 45 seconds. The system monitors the development of the pressure level in the system and reacts to very small reductions in pressure implying even the smallest leaks in the system.

Open innovation as implementation approach

The concept behind Phyn Plus was created approximately ten years ago at the University of Washington. Similar technology had already been successfully used to monitor electricity consumption in buildings based on voltage and current fingerprints of individual appliances. A research group at the University of Washington embarked on a study regarding the application of the same approach to monitoring water systems.

Fundamental research and evaluation of the technology concept led to patents based on successfully applying the methodology to water monitoring. At this point Belkin, an American corporation specialised in consumer electronics, mobile device accessories, IoT and network technologies, entered the partnership. Belkin has long experience in smart home appliances and their technology capabilities provided a good

Table 1. *Comparison of technical features of Phyn Plus and alternative leak detection technologies.*

	Leak sensors	Leak sensors + Shut Off	Connected device + Shut Off	Smart Water assistant + Shut Off (Phyn Plus)
Automatic shut off	X	✓[1]	✓[2]	✓[3]
Real time notification via app	X/✓	X/✓	✓	✓
Low risk of false alarms	✓	X	X	✓
Daily diagnostic on drip leaks (Plumbing Check)	X	X	✓	✓
Immediate leak detection	X/✓[7]	X	X	✓
Freeze detection	X/✓[4]	X	X/✓[5]	✓[6]
Fingerprinting / Water consumption by fixture	X	X	X	✓
Water left running alert	X	X	X	✓
One device for the entire home	X	X	✓	✓

1 Automatic Shut off only on preset aggregate values (total flow, consumption per day etc.)

2 Automatic Shut off only on aggregate values - adjustable remotely or historical patterns

3 Automatic Shut off triggered by any not recognized water event (no preset)

4 Freeze detection limited, based on room temperature

5 Freeze detection limited, based on water temperature

6 Freeze detection based on pressure, water & outside temperature algorithm

7 If sensor placed in the place where leak happens

platform for taking the technology from a laboratory concept to a first industrial prototype.

However, introducing a new technology to the plumbing market is not the same thing as developing and launching a new consumer electronics product. Uponor's experience in plumbing system development and access to the plumbing market provided the final missing piece of the puzzle.

As the technology for online plumbing system performance monitoring was something new for both Belkin and Uponor, a separate and dedicated joint venture seemed to be the best solution for finalising the technology development and for introducing the technology to the market. This led to Phyn being established as an independent company in 2016, with currently equal ownership stakes in the joint venture shared between Uponor and Belkin.

This setup is a prime example of open cross-industry innovation in practice. The final commercial implementation of the technology would not have been possible without the combination of basic scientific development capabilities, knowhow in consumer electronics, IoT and machine learning, and long experience and insight to the design, installation and management of plumbing installations.

Lessons learnt from pilot installations

Since 2018 the Phyn Plus technology has been available on the North American market. During 2019 it has also been launched in selected European markets, and it was introduced in Europe during the ISH trade fair in Frankfurt in March 2019.

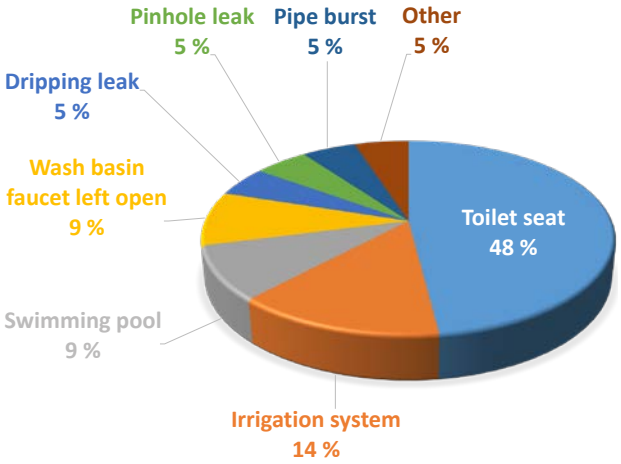

Figure 3. Distribution of leaks and unintended water consumption identified during the Phyn Plus pilot installation period.

Before launching the technology, a pilot installation and testing program was carried out in North America. The program covered 300 single family home installations and one full year of system operation.

During the pilot test period Phyn Plus detected 65 leaks in the 300 test cases, with an accuracy of 99%. The leaks detected ranged from catastrophic pipe bursts to pinhole leaks and faucets accidentally left open by children. (**Figure 3**)

Phyn Plus is in its first stage available for single family and semi-detached houses. The technology has considerable potential also in apartment and non-residential buildings, but it requires further development to apply to more complex network layouts. According to current planning it will be developed and launched to these more requiring segments during 2021. ■

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