Smart Cities Research

Table of Contents

Smart Cities & Smart Water

“Smart water” is one of six components that define a smart city; the others include energy, mobility, buildings, public services and integration. **The goal of these efforts is to make the city more sustainable and efficient and effectively improve quality of life.**

Figure 1. Smart City Sectors

Obstacles & Statistics

Water loss management is becoming increasingly important as supplies are stressed by population growth or water scarcity. Many regions are experiencing record droughts, and others are depleting aquifers faster than they are being replenished. Less than 1 percent of the earth’s water is available for use in homes, farm fields, and businesses. Climate change is expected to shrink freshwater supplies further, bringing water shortages to one-third of all counties in the Lower 48 states. Yet billions of gallons of water are wasted each day across the United States due to leaky pipes, inefficient fixtures, and thirsty landscaping. Smart, cost-effective solutions can reduce this waste and ensure that people have plentiful water supplies for generations to come. (Source)

Water systems are often overlooked yet are critical components of energy management in smart cities, typically comprising 50 percent of a city's total energy spend. Energy is the largest controllable cost in water/wastewater operations yet optimizing treatment plants and distribution networks has often been overlooked as a source of freeing up operating funds by cash-strapped municipalities. Once facilities are optimized and designed to gather meaningful and actionable data, municipal leaders can make better and faster decisions about their operations, which can result in up to 30 percent energy savings and up to 15 percent reduction of water losses. (Source)

While a survey of the water industry shows that 33% of utilities are interested in real-time control and big data system analytics, water utilities have predominantly not harnessed these technologies, due to several challenges associated with managing and analyzing big data. Technological gaps, workforce challenges, and community disengagement undermine the alignment of critical municipal management priorities with the analysis and application of smart water data. Installing data analytics systems can worsen data deluge, which is a serious challenge for municipalities, utilities, and their constituencies. The ubiquity of different types of sensors and data collection mechanisms obscures the issues with frequency and a synchronicity of data collection, the types of data generated, and gaps in datasets. Utilities that have installed smart meter systems need support to make sense of and apply data for decision-making, and applications are lacking that would demonstrate that the use of smart systems will support long-term sustainability and urban planning goals. (Source)

The increase in the volume, velocity and contaminants in stormwater runoff has caused a crisis in receiving water bodies. Harmful algal blooms, associated with anthropogenic inputs of nutrients, have resulted in unsafe drinking water, impaired fisheries and damage to recreational waters. As such, managing pollutant loadings from urban stormwater has become one of our most pressing environmental challenges.

Expansion and upsizing of gray infrastructure are perhaps the most common solutions to coping with increased runoff resulting from changing weather and land use. Aggressive climate adaptation via traditional tools may lead to overdesigned gray infrastructure, which conveys water too quickly to streams, leading to floodplain encroachment, increases in runoff volumes, and stream erosion. To preserve stream stability and ecological function, advances in stormwater science are calling for traditional peak attenuation designs to be replaced with those that reduce stream erosion during smaller, more frequent storms. As communities seek more resilient and adaptive stormwater solutions, novel and nontraditional alternatives to new construction must be considered. (Source)

Internet of Things (IoT)

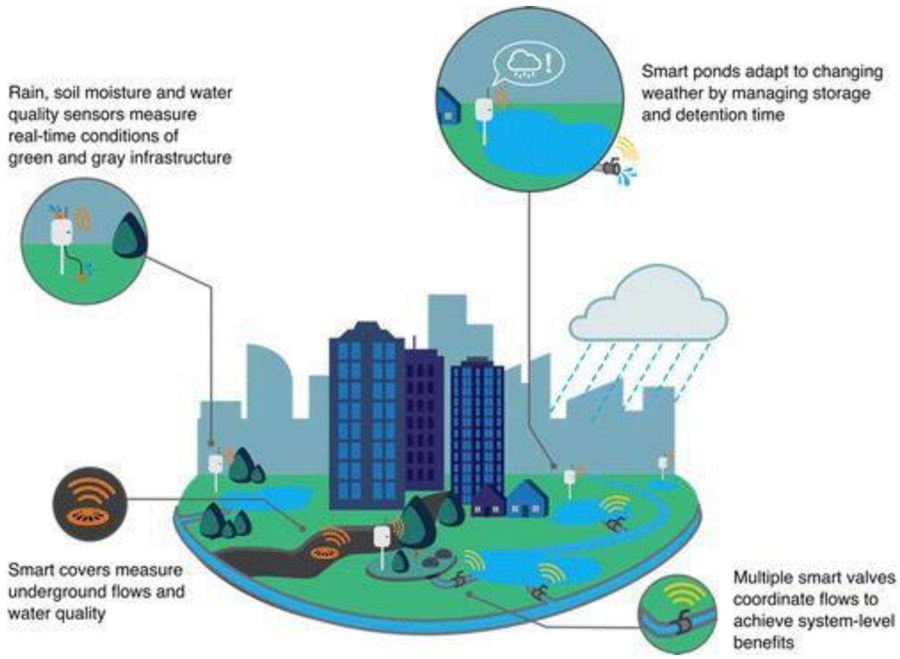
The past decade has witnessed significant advances and reduction in the cost of novel sensors, wireless communications and data platforms. In large, much of this development has accompanied the recent boom on the Internet of Things (IoT), a technological movement that promises to build the next generation of interconnected and smart buildings and cities. The IoT can connect personal smart devices with faucets and pipelines that are embedded with sensors, actuators, and network connectivity to collect and report real- time information about water consumption, quality, and losses.

The stormwater sector has been slow in its adoption of these technologies, especially in the context of high-resolution and real-time decision-making. Present uses of sensors range from regulatory compliance to performance studies of individual stormwater facilities. These technological advances have the potential to become highly transformative, however, by enabling stormwater infrastructure to evolve from static to highly adaptive. By coupling the flow of water with the flow of information, modern stormwater infrastructure will adapt itself in real-time to changing storms and land uses, while simultaneously providing a highly cost-effective solution for cities that are otherwise forced to spend billions on stormwater reconstruction. (Source)

Smart Water & Smart Water Systems

Smart water points to water and wastewater infrastructure that ensures this precious resource - and the energy used to transport it - is managed effectively. Smart water generally refers to a holistic approach to managing water and the infrastructure systems surrounding its sourcing, treatment and delivery. A smart water system is designed to gather meaningful and actionable data about the flow, pressure and distribution of a city's water. Further, it is critical that that the consumption and forecasting of water use is accurate.

By recognizing anomalies in consumption patterns for both the utilities and end users, cities can optimize and eliminate water waste and cost in delivery. The high-energy demand of a city's water treatment and delivery networks are often underestimated, meaning that improving operational efficiency through actionable data will reduce greenhouse gas emissions and cut costs simultaneously.



Smart Water Management

Smart Water Systems

A smart water system is designed to gather meaningful and actionable data about the flow, pressure and distribution of a city's water. The goal is to know what the accurate consumption is and forecasting of water use. Incorporating smart water technologies allows water providers to minimize non-revenue water (NRW) by finding leaks quickly and even predicatively using real-time SCADA (Supervisory control and data acquisition) data and comparing that to model network simulations. A city's water distribution and management system must be sound and viable in the long term to maintain its growth and should be equipped with the capacity to be monitored and networked with other critical systems to obtain more sophisticated and granular information on how they are performing and affecting each other.

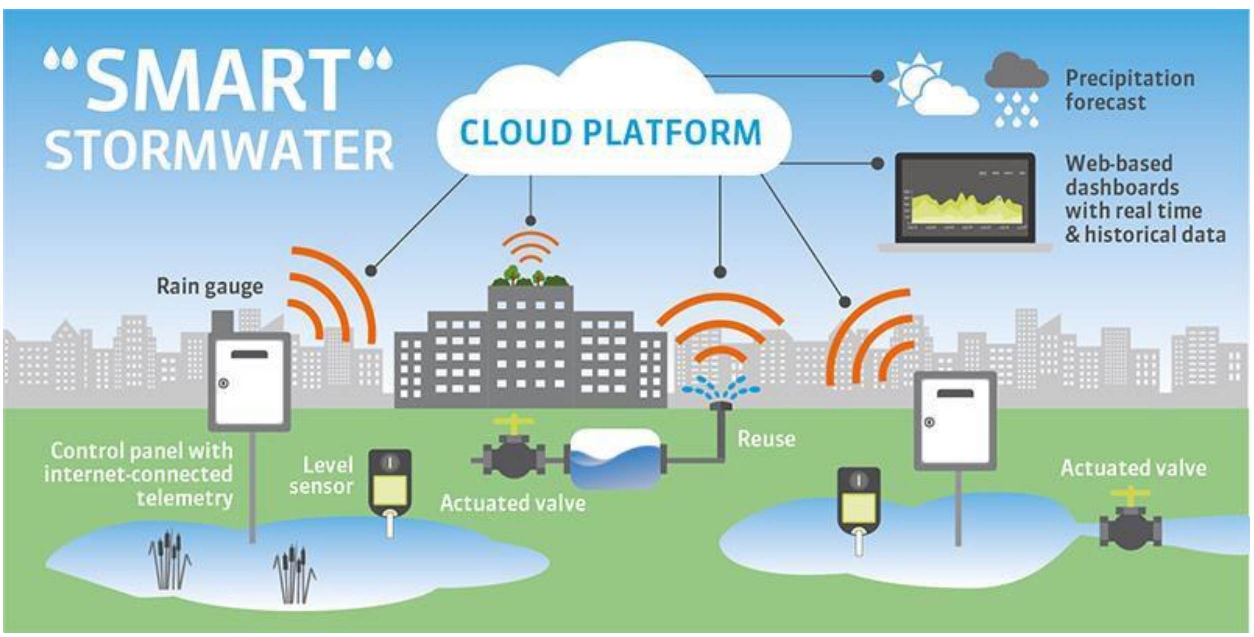
A smart water solution has 5 components:

1. Physical Component
    a. Pipe / Pumps / Reservoirs / Valves
2. Sensor Component
    a. These are the devices that contain the sensors to capture the data (e.g. water quality, temperature, pressure, consumption, etc.)
3. Collection and Communication
    a. Data collected from the sensors and transmitted to the information systems via the network infrastructure
4. Data Management and Display
    a. Data processing and presentation of the data collected
5. Data Analysis
    a. Analytics tools ‘slice and dice’ the data to generate dashboards for the decision-making process and consumer notification

Smart Stormwater Systems

“Smart” stormwater systems will transform cities into coordinated and real-time controlled treatment plants. Retrofitting existing stormwater elements with sensors and controllers will allow them to change their configuration to maximize watershed-scale pollutant removal.

Retrofitting stormwater systems with sensors and controllers will allow cities to be operated as real-time, distributed treatment plants. Unlike static infrastructure, which cannot adapt its operation to individual storms or changing land uses, “smart” stormwater systems will use system-level coordination to maximize watershed pollutant removal and treatment. Considering the current funding mechanisms for stormwater, especially in the United States, the cost of retrofitting will provide a more budget-conscious alternative to new construction while achieving similar or better water quality outcomes. (Source)



Existing stormwater infrastructure is ordinarily passive and often serves a limited purpose. The design and construction of these systems rely on fixed configurations and pre-determined static flow scenarios to provide a single management objective (i.e., remove or drain stormwater from developed areas as quickly as possible). Once constructed, these systems require perpetual operation and maintenance (O&M), with limited future benefit; in fact, they often act as a liability as we continue to pay for antiquated benefits while modern-day costs increase. New stormwater management systems face the same design and construction limitations as existing systems because they rely on the same passive design methodology and implementation to achieve current regulatory requirements.

Continuous monitoring and adaptive control (CMAC) systems provide a practical solution to enhance the performance and value of existing stormwater infrastructure while increasing the efficacy and efficiency of new infrastructure. The CMAC technology integrates information from field-deployed environmental and water-level sensors, actuated valves, and telemetry enabled control panels with cloud-based control systems, and real-time weather forecast data to directly monitor performance and actively control stormwater storage and flows. **CMAC systems are adaptive and more efficient, converting stormwater infrastructure into an asset, instead of a liability, even when considering the long-term O&M costs. Through CMAC, existing stormwater infrastructure can be enhanced, or repurposed, new stormwater infrastructure can provide better benefits, and both can provide a higher ROI.** (Source)

Stormwater Management System Challenges

Three significant challenges face current stormwater management systems.

1. **Measuring and Reporting Performance**—communities need accurate reports on performance to meet regulatory compliance requirements.

Regulatory agencies will soon require communities to provide consistent, accurate and reliable data on the performance of their stormwater systems to demonstrate compliance. Collecting, collating, and reporting this data is currently not feasible due to limited resources and technology. CMAC technology provides the necessary data for accurately recording and reporting on stormwater infrastructure performance. These systems obtain high-quality performance data, efficiently collated and readily reported to regulators. **Continuously monitoring stormwater systems provides a reduction in regulatory risk and increased compliance**. Thus, CMAC provides an efficient and cost-effective method for achieving regulatory compliance.

2. **Operations and Maintenance**—reducing ongoing costs and achieving sustained performance.

Current periodic or schedule-driven O&M activities are inefficient and typically result in higher maintenance costs. CMAC technology allows communities to manage their stormwater infrastructure more proactively and efficiently through targeted O&M activities. Because CMAC provides targeted O&M based on data-driven decision making, the systems are more efficient and better maintained, thus reducing cost.

Data-driven analysis and decision making dramatically improve many routine O&M activities and schedules, increasing uptime and decreasing O&M costs. Adaptive and proactive maintenance through the integration of asset management tracking systems allows the community to maintain assets, addressing their needs before they fail. System performance information is integrated into maintenance contractor workflows and work order management; **this integration helps target maintenance requirements, minimizing unplanned maintenance and associated downtime by alerting staff when a facility is operating outside its expected performance limits or specifications.**

3. **Beyond Single-Purpose Management**—communities need solutions that are adaptive and scalable to address changing watershed conditions and meet desired stormwater management outcomes.

CMAC technology also helps communities adapt to changing conditions, unlocking the potential to achieve multiple stormwater management goals and outcomes. Facilities that integrate CMAC can now meet many performance metrics, instead of one or two. Function and performance are easily modified, with minimal capital cost, adapting to changing climatic and hydrologic conditions. CMAC allows the system to meet its intended performance measures and scale or adjust to new ones.

- For example, by installing smart technology and hardware communities can enhance or convert existing stormwater infrastructure, improving water quality and significantly expanding capacity. In new facilities, active and dynamic control of system performance meets stormwater management objectives more efficiently by simultaneously measuring quantity, volume, and quality control. CMAC allows stormwater infrastructure to accomplish more with less—using a much smaller physical footprint, thus reducing land acquisition (or loss of developable space) and construction costs.

Forecast-based real-time flow control of both connected and distributed stormwater infrastructure allows for adaptive management—the technology integrates information from field-deployed sensors with real-time weather forecast data to directly monitor performance and actively control stormwater storage and flows. **Improved metrics and performance reporting via centralized, cloud-based control systems help communities predict and plan for O&M costs and comply with regulatory requirements.** Continuous monitoring and adaptive control technology allow communities to accurately record and report performance data and metrics, operate and maintain their infrastructure systems and components more efficiently, and achieve stormwater management and associated regulatory compliance targets while reducing capital and operating costs. (Source)

Examples

- Using the IBM Bluemix Platform and a network of sensors, a team reused storm water to irrigate local plant life, reducing the amount sent straight to the river. (Source)
- How the IoT Can Help Communities Better Manage Stormwater (Source)
- Monitoring combined Sewer Systems in Philadelphia (Source)
- Five Cities using innovative green tech to manage stormwater runoff before it hits the drain (Source)
- Smart Stormwater products (Source)
- Many existing studies focus on the real-time control of stormwater basins and ponds, which are some of the most common elements in a stormwater system. (Source) (Source) (Source)
- Real-time control of a retrofitted detention pond showed that the removal of Escherichia coli was improved by strategically retaining water for 24 h after a storm rather than allowing the water to flow though the pond as originally designed. (Source)
- The Potential of Knowing More: A Review of Data-Driven Urban Water Management (Source)

Funding

One of the biggest obstacles to any capital-intensive project is access to funding. To update our aging water infrastructure with the most current technologies, tens of billions will need to be spent through both public and private investment. **Juniper Research estimates $15 billion will be invested in software alone by 2021.** In addition, smart sensors need power to take readings, creating a huge new source of energy demand. There are also significant issues of privacy to address and whether all this data and information should be available to the public. This decade, cities around the world will invest $108 billion in smart city infrastructure, such as smart meters and grids, energy-efficient buildings and data analytics, according to Navigant Research. (Source)

Potential Funding Sources

Energy Saving Performance Contracts: As cities and municipalities look to achieve smarter water, there are several options available to help them get started. One very effective path is through leveraging energy-saving performance contracts (ESPCs).

- **ESPCs** are a form of a public-private partnership (PPP or P3), a financial model that capitalizes on the flexibility and resources of the private sector to pay for energy-saving capital upgrades using future energy savings. (Source)
    - The initial investment is provided by the private financial community, and services are delivered by energy service companies (ESCOs).
    - The financier is paid from the accrued energy savings, with the ESCO guaranteeing the savings amount.
    - An ESPC starts with an energy audit. After identifying opportunities and quantifying the potential savings, the ESCO recommends any number of

energy conservation measures, such as equipment retrofits, pumping optimization, demand monitoring and control, and/or load-shedding and cogeneration which will save energy through more efficient operations.

- Energy Savings Performance Contracting: Guidelines for Developing, Staffing, and Overseeing a State Program. (Source)

Sources

https://www.waterworld.com/articles/print/volume-29/issue-12/water-utility-management/smart-water-a-key-building-block-of-the-smart- city-of-the-future.html

https://sia.planning.unc.edu/project/smart-water-iot/

https://www.environmentalleader.com/2018/04/water-wise-the-role-of-water-management-in-the-smart-city-revolution/ https://www.nrdc.org/issues/promote-urban-water-efficiency

http://bwsmartcities.businessworld.in/article/Effective-Water-Management-Indispensable-for-smart-cities-/09-05-2018-148681/

https://pubs.rsc.org/en/content/articlehtml/2017/ew/c6ew00211k

https://www.smartcitiesdive.com/ex/sustainablecitiescollective/tech-updates-how-design-stormwater-drainage-system/1163433/ https://www.ibm.com/blogs/internet-of-things/managing-storm-water/

https://pubs.acs.org/doi/pdf/10.1021/acs.est.5b05870 https://www.nrdc.org/issues/water-smart-cities