pipeon

Robotics and AI for Sewer Inspection & Maintenance

Policy Brief 1

From Inspection to Prevention: How autonomous sewer robotics can advance Europe's Zero Pollution ambition

WP9 – Dissemination and outreach

Author: Water Europe

Date: July 2026

Funded by
the European Union

PIPEON (Robotics and AI for Sewer Pipe Inspection and Maintenance) is a four-year Horizon Europe project bringing together 12 partners from six countries to develop autonomous robots and AI able to work continuously inside live sewer networks.

The project is developing autonomous robots and AI able to move across different pipe surfaces and conditions, for continuous sewer inspection and maintenance, targeting up to 30% fewer sewage spills into rivers and reduced inspection costs and time. Three water utilities, Gemeente Heusden[1] (Netherlands) and the Bærum[2] and Hitra[3] municipalities (Norway), are hosting case-study networks so results are validated under real operating conditions.

Currently, the EU Agenda includes several hooks for Pipeon to provide inputs:

- The deployment of the different actions under the Water Resilience Strategy[4] (WRS). This strategy is the new narrative that we have to embed in the position. PIPEON shall demonstrate how it can contribute to the objectives set in the WRS.
- The current discussion on the Digitalisation Action Plan, expected in Q4 2026 as one of the 50 actions under the WRS. This communication document of the EU Commission will focus on leakage reduction, agile water management, particularly for utilities.
- The implementation of the ZeroPollution Action Plan[5] (ZPAP). The previous Commission developed an action plan to reach zero pollution in Europe. PIPEON has been financed under this objective, and hence it could demonstrate its benefits.
- The implementation of the Urban Wastewater Treatment Directive[6] (UWWTD). The EU expert group for the UWWTD is currently working on several guidance documents to facilitate the implementation of the new directives. Some opportunities could pop up during the discussion. As Water Europe is a member of the EU expert group, we can facilitate the dissemination of PIPEON's perspective.

This first policy brief translates the activities described in Section 2.2 of the Grant Agreement, related to *T9.1 Communication, Outreach and Dissemination*, which requires the project to develop 3 policy briefs. It focuses on PIPEON's contribution to

- the 2030 objectives of the Zero Pollution Action Plan (ZPAP),
- the revised Urban Wastewater Treatment Directive (UWWTD).

Ultimately, PIPEON supports the implementation of the WRS, of the Water Framework Directive[7], and promotes the sustainability of wastewater utilities as critical infrastructures whilst protecting the environment.

The recast UWWTD and the Water Resilience Strategy both call for better monitoring, digitalisation and green/blue infrastructure planning, opening a near-term window to embed robotics-enabled evidence into compliance practice. However, PIPEON shows that without early regulatory attention, robotics-enabled evidence risks staying outside official compliance and reporting frameworks, slowing adoption by risk-averse utilities and their regulators.

[1] PIEPON, Case study 1
[2] PIPEON, Case study 2
[3] PIPEON, Case study 3
[4] European Commission, Water resilience strategy, 2025
[5] European Commission, Zero Pollution Action Plan
[6] EUR-LEX, Directive (EU) 2024/3019 concerning urban wastewater treatment
[7] EUR-LEX, Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (Water Framework Directive), 2026

The internal discussion with PIPEON consortium also demonstrates the importance to focus on standards, particularly the ATEX one[8]. Considering the technicity of the topic, the next policy brief will focus on this topic to reach the specific audience that it requires.

Therefore, this brief sets out **six recommendations** for EU policymakers to help sewer robotics and AI contribute to the different strategies and the implementation of the UWWTD:

PIPEON Recommendations

1. **Recognise robotics and sensor-based data as valid evidence in Integrated Urban Wastewater Treatment Plans**
2. **Set common data and interoperability standards for AI-based sewer defect detection**
3. **Embed autonomous inspection and predictive maintenance in the Water Resilience Strategy's digitalisation actions**
4. **De-risk early investment for utilities adopting robotics-enabled maintenance**
5. **Feed robotics-enabled evidence into the Zero Pollution Monitoring and Outlook framework**
6. **Clarify EU standards and regulatory requirements to remove barriers to the uptake of innovative robotic solutions, particularly for smaller utilities**

Autonomous inspection robots and distributed sensors could help utilities detect defects, blockages and pollution risks earlier, if EU support combines deployment with interoperable data, safety assurance and procurement guidance. PIPEON supports the creation of an EU pathway for trusted autonomous sewer inspection and maintenance that demonstrably reduces pollution risk, improves worker safety and directs scarce capital toward the highest-value interventions.

[8] Directive 2014/34/EU relating to equipment and protective systems intended for use in potentially explosive atmospheres

1. Introduction

Europe is entering an important implementation phase for water policy in which better knowledge of underground infrastructure, digitalisation and more preventive asset management can directly support several EU objectives:

- The recast Urban Wastewater Treatment Directive (UWWTD) introduces stronger requirements for wastewater collection and integrated urban wastewater management, including measures addressing storm-water overflows and urban runoff.
- The Water Resilience Strategy (WRS) calls for accelerated digitalisation and the uptake of artificial intelligence in the water sector, , while its forthcoming Digitalisation Action Plan (DAP) provides an opportunity to translate this ambition into a practical toolbox for utilities.
- The Zero Pollution Action Plan (ZPAP) requires further progress in preventing pollution at source and strengthening the evidence available to monitor progress towards the EU's pollution-reduction objectives.

These policy developments have a common operational requirement: utilities need better and more actionable information about the condition and performance of wastewater collection networks (sewers). Europe operates an estimated 3.2 million km of sewers, yet the condition of a significant proportion of this buried infrastructure remains poorly known. Inspection still relies heavily on CCTV surveys and manual image assessment, limiting the frequency and coverage of inspection and making it difficult to build an up-to-date picture of network condition.

This information gap has direct consequences for EU water-policy objectives. Defects and blockages can contribute to wastewater spills and flooding, while infiltration through damaged pipes unnecessarily increases the volume of water transported and treated by wastewater treatment plants. Conversely, exfiltration can release untreated wastewater into surrounding soil and groundwater. For utilities, incomplete knowledge of the network can therefore translate into higher operating costs, inefficient investment and reactive maintenance rather than prevention.

PIPEON aims to provide a practical response to this gap. By combining autonomous sewer robots, multi-sensor inspection, artificial intelligence, infrastructure mapping and robotic intervention, PIPEON aims to move sewer management from intermittent inspection towards continuous, risk-based and preventive maintenance. Its added value is not simply the development of a new inspection robot. It is the creation of a pathway from better underground information, earlier identification of risks, targeted intervention, and measurable reductions in pollution and infrastructure failures.

This approach can support EU policy implementation in several concrete ways. For the UWWTD, robotics-enabled condition data could strengthen the evidence available for integrated urban wastewater management plans and measures addressing storm-water overflows. For the WRS and its DAP, PIPEON provides a concrete use case for AI, autonomous inspection, digital infrastructure mapping and predictive maintenance in water utilities. For the ZPAP, earlier identification of blockages, infiltration, exfiltration and structural defects can support pollution releases to the environment and provide evidence on the effectiveness of preventive interventions. The approach may be particularly relevant for smaller utilities, which face expanding regulatory obligations while often having more limited capacity to deploy extensive permanent monitoring infrastructure.

However, technological capability alone will not ensure uptake. If robotics-generated information is not recognised within regulatory and reporting practices, if data are not interoperable, or if safety, cybersecurity and conformity requirements remain unclear, utilities may have limited incentives to adopt these technologies. Early investment can also be difficult to justify while the market and regulatory frameworks are still developing.

This brief sets out six recommendations for EU policymakers to create an enabling framework for robotics-enabled sewer inspection and maintenance:

PIPEON Recommendations
1. **Recognise robotics and sensor-based data as valid evidence in Integrated Urban Wastewater Treatment Plans**
2. **Set common data and interoperability standards for AI-based sewer defect detection**
3. **Embed autonomous inspection and predictive maintenance in the Water Resilience Strategy's digitalisation actions**
4. **De-risk early investment for utilities adopting robotics-enabled maintenance**
5. **Feed robotics-enabled evidence into the Zero Pollution Monitoring and Outlook framework**
6. **Clarify EU standards and regulatory requirements to remove barriers to the uptake of innovative robotic solutions within buried pipe networks, particularly for smaller utilities**

2. What PIPEON is building: contributions to the Zero Pollution Action Plan

The EU ZPAP calls for pollution to be prevented and reduced at source, supported by better monitoring, digital solutions and more effective implementation of environmental legislation. PIPEON contributes to this agenda by addressing a hidden source of risk: ageing sewer networks whose condition is often poorly known and whose failures can release untreated wastewater into rivers, soils and urban environments.

PIPEON's added value lies in connecting inspection directly to intervention. The project is developing an integrated system of autonomous robots[9], manipulators[10], sensors, artificial intelligence and sewer-network models that can identify defects and blockages, install flow monitors and support maintenance decisions. This could allow utilities to act before network deterioration becomes an overflow, leakage or flooding incident. Robotics can help utilities move from incomplete and intermittent knowledge of sewer networks towards dynamic infrastructure mapping and risk-based asset management, while detecting infiltration and exfiltration, reducing reliance on extensive fixed monitoring infrastructure, lowering maintenance costs and enabling more targeted investment. These benefits may be particularly significant for smaller utilities, provided that EU regulatory and standardisation frameworks facilitate rather than inadvertently hinder uptake.

−30% sewage spills into rivers	**10×** more sewer covered per day	**24h+** continuous autonomous operation	**10×** lower inspection cost

From intermittent inspection to practical evidence

Current sewer inspections often depend on CCTV systems and human interpretation. Coverage is consequently limited, while observations can be inconsistent or difficult to combine with hydraulic and asset-management data.

PIPEON is working on a new inspection system that uses visual, acoustic, ultrasonic, and inertial measurements. Machine-learning methods will analyse this data to find and identify defects in areas where GPS is not available and where the scenery looks the same[11]. A key added value of robotic inspection is its capacity to progressively map and update knowledge of buried sewer infrastructure, including its location, geometry and condition. This is particularly valuable where existing asset records are incomplete or outdated and provides the information base for digital twins, risk-based maintenance and targeted investment.

For the Zero Pollution agenda, this creates four forms of added value:

1. Improved mapping and updating of sewer-network assets and their condition
2. Earlier identification of conditions that can contribute to blockages, infiltration, exfiltration, sewer failure and storm-water overflows.
3. Better targeting of maintenance expenditure toward assets presenting the greatest pollution and service risks.
4. A stronger evidence base for integrated urban wastewater management planning, regulatory reporting and pollution-prevention investment.

[9] PIPEON, *Deliverable D2.3. Tardigrade concepts*, 2025
[10] PIPEON, *Deliverable D2.5. Manipulator Concepts*, 2025
[11] PIPEON, *Deliverable D2.3. Tardigrade concepts*, 2025

From detection to pollution prevention

PIPEON goes beyond monitoring alone. Its robotic manipulators are being developed for tasks such as installing flow sensors and removing light blockages[12]. Docking infrastructure[13] is intended to support charging, data transfer and repeated deployment, while risk-aware mission planning will help robots operate safely in inaccessible networks.

This inspection-to-intervention chain is the project's principal contribution to pollution prevention at source:

Detect earlier → assess risk → intervene selectively → verify the outcome

Removing a blockage before it causes an overflow or repairing a defect before it develops into a major failure[14], can be more effective and less disruptive than responding after pollution has occurred. Particularly, detecting and locating infiltration can help utilities reduce the unnecessary conveyance and treatment of groundwater, while identifying exfiltration can help prevent untreated wastewater from reaching soil and groundwater. PIPEON therefore complements investment in treatment capacity and green or blue infrastructure by improving the performance of the collection network that carries wastewater to treatment.

Supporting the implementation of EU water policy

PIPEON can provide practical evidence to support the implementation of the recast UWWTD, particularly for integrated urban wastewater management plans and measures addressing storm-water overflows. It also supports the European WRS's emphasis on infrastructure modernisation, digitalisation and AI.

The project's relevance to the ZPAP extends across five areas:

ZPAP priority	PIPEON contribution
Prevent pollution at source	Earlier detection and removal of conditions that may lead to spills, leakage or flooding
Strengthen monitoring	Higher-frequency, multi-sensor information about buried sewer assets
Use digital solutions	AI-supported defect classification, autonomous navigation, mapping and digital twins
Improve implementation	Decision-ready evidence for maintenance planning, investment and wastewater-management plans
Enable a just and safe transition	Reduced exposure of workers to confined, corrosive and potentially hazardous sewer environments

Proving environmental added value

PIPEON targets a 30% reduction in sewer-overflow spills, at least 24 hours of autonomous operation, ten times more distance inspected per day and an order-of-magnitude reduction in inspection costs.

The project will establish its added value through staged laboratory and field validation. Environmental assessment should trace the complete pathway from robotic inspection to maintenance action and measurable network outcomes. Relevant indicators include:

- Defects and blockages are correctly detected and classified
- Inspection coverage, frequency and cost
- Time between detection and intervention

[12] PIPEON, *Deliverable D2.5. Manipulator Concepts*, 2025
[13] PIPEON, *Deliverable D2.4. Docking station concept,* 2025

[14] PIPEON, *Deliverable D2.3. Tardigrade concepts*, 2025; D2.4. *Docking station concept,* 2025

- Blockages removed and failures prevented
- Changes in overflow frequency, duration or pollutant-load proxies
- Worker exposure avoided
- Energy use and whole-life environmental costs
- Data interoperability and utility uptake

PIPEON can help the Zero Pollution Monitoring and Outlook framework assess not only whether pollution is declining, but which digital and operational interventions produce credible reductions. Its central added value is therefore not simply a new sewer robot: it is a tested pathway from better underground information to earlier maintenance and lower pollution risk.

3. Recommendations

PIPEON's concept-stage evidence and the current EU implementation window point to six near-term actions. They can be advanced through transposition, guidance, standards, programme design and monitoring.

1. **Recognise robotics and sensor-based condition data as valid evidence in Integrated Urban Wastewater Management Plans.**
   The UWWTD should explicitly accept continuous robotic and AI-based inspection as valid evidence for the risk assessments data - not only periodic CCTV surveys - and storm-overflow monitoring, so utilities can plan investment around real condition data rather than assumptions.

   Acceptance should depend on transparent methods, traceability and human oversight, not on a requirement to use one inspection technology.

2. **Set common data and interoperability standards for AI-based sewer defect detection.**
   Robotic inspection will only be trusted across borders if defect codes, metadata, confidence scores and exchange formats are comparable. European standardisation organisations should:
   - Assess how EN 13508-2 and related sewer-condition coding standards can accommodate or be complemented by autonomous, AI-based and multi-sensor inspection, including requirements for defect localisation, sensor-derived condition data, confidence scores and interoperable data exchangeDevelop a light-touch interoperability standard for autonomous sewer inspection data
   - Keep safety conformity requirements clearly separated from data-performance claims: aligning data interoperability and equipment certification work from the outset would spare manufacturers a costly second compliance pass

3. **Embed autonomous inspection and predictive maintenance in the Water Resilience Strategy's Digitalisation Action Plan.**
   The upcoming Digitalisation Action Plan should:
   - Name autonomous inspection, sensor fusion, digital twins and predictive maintenance as relevant use cases
   - Promote interoperable and reusable data
   - Include smaller utilities in testing, capacity-building and procurement guidance

4. **De-risk early investment for utilities adopting robotics-enabled maintenance.**
   Early adopters face technology, procurement and integration risk before project-level benefits are fully demonstrated. Horizon Europe follow-on actions, EIB water-sector financing and cohesion-policy programmes should:
   - Make robotics-enabled inspection and maintenance eligible where projects include measurable performance, workforce transition, cybersecurity, interoperability and whole-life-cost criteria

5. **Feed robotics-enabled evidence into the Zero Pollution Monitoring and Outlook framework.**
   The 2025 Zero Pollution Monitoring and Outlook shows the value of comparable evidence for tracking progress. Ahead of the 2030 outlook, the ZPSP should:
   - Define how validated project data on blockages, overflow risk, avoided spills, and inspection performance can complement, not replace, official environmental monitoring

6. Clarify EU standards and regulatory requirements to remove barriers to the uptake of innovative robotic solutions, particularly for smaller utilities

Uncertainty around the application of EU regulatory, safety, cybersecurity and technical requirements can slow the deployment of innovative robotic solutions, particularly for smaller utilities. Some existing safety standards and risk-assessment approaches may not yet be fully adapted to the specific characteristics of autonomous and robotic solutions operating in wastewater infrastructure, particularly regarding exposure and risk assessment. This can create uncertainty for utilities and technology providers and impose disproportionate barriers on smaller utilities and innovative SMEs. The European Commission, Member States and relevant standardisation bodies should:

- Cl Clarify how cybersecurity and critical-infrastructure resilience requirements apply to connected robotic systems and the sensitive infrastructure data they generate, while ensuring requirements remain proportionate to the risks involved.
- Review and, where necessary, update relevant safety standards and exposure/risk-assessment approaches to ensure they are fit for innovative and autonomous robotic applications in wastewater environments (e.g. ATEX Directive 2014/34/EU, and its guidance).
- Ensure that conformity assessment, safety and technical requirements are proportionate to the actual risks of robotic applications, avoiding unnecessary regulatory and certification burdens that could hinder uptake by smaller utilities or market entry by innovative SMEs

There are an estimated 3.2 million km of sewers in Europe, but their condition is often unknown due to reliance on manual CCTV image analysis. This leads to failures such as property flooding and wastewater spills. PIPEON will develop robotic and AI technologies for autonomous sewer inspection and maintenance. These rugged robots operate in harsh sewer environments, navigating various surfaces and handling wastewater.

Equipped with dexterous manipulators, they install flow monitors and remove blockages. Advanced sensors and AI algorithms enable navigation, anomaly detection, and risk-aware mission planning. Designed for long operation, they significantly reduce inspection costs, providing utilities with abundant data for timely maintenance. By swiftly clearing blockages, PIPEON aims to cut sewage spills into rivers by 30%, supporting Europe's zero-pollution goals. The project brings together leading scientists, SMEs, and water utilities to drive innovation and practical application.

pipeon

Robotics and AI for Sewer Inspection & Maintenance

Funded by
the European Union