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WATERWISE

WATERWISE - Advancing Water Sustainability in the Green Transition: European Educational Initiative

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TRANSNATIONAL RESEARCH AND HYDROSTRATEGY

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Centro Studi AMIStaDeS APS Ricerca, Analisi e Formazione in Affari Internazionali

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Introduction

1.1 Background

The global context is experimenting an increasing intensification of issues related to the management of water resources.

The consequences of climate change and human activities on a global scale indicate that the demand for fresh water, energy and food will grow significantly in the coming decades. **Climate change** is pressuring natural resources and water supply systems, intensifying water scarcity in many regions. This increase is driven not only by population growth, but also by the resulting degradation, economic and urban development. Growing urbanization, the extension of intensive agriculture, and unsustainable consumption patterns have amplified demand, resulting in many areas - both in developed and developing countries – facing an unprecedented water crisis.

A detailed examination of the global scenario reveals that the **Mediterranean area** is among the most vulnerable to the consequences of climate change. The region is experiencing a 20% faster rate of warming than the global average. This is leading to a general deterioration of ecosystem conditions and a reduction in precipitation levels, while southern Europe could suffer a reduction of up to 30%.

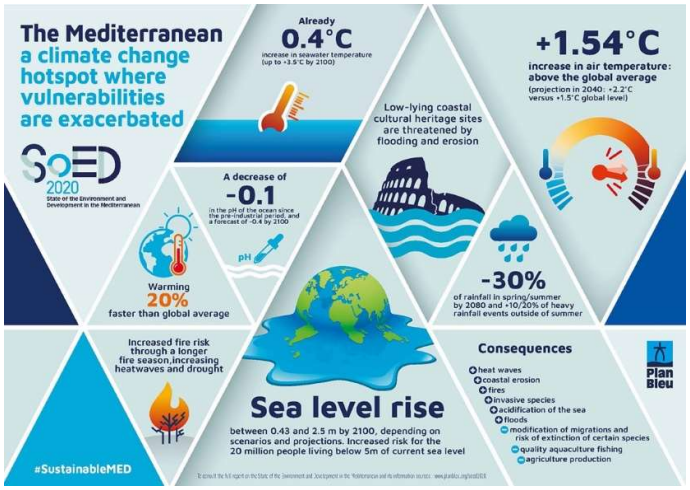

Figure 1 - Climate change in the Mediterranean[1]

[1] UN environment Programme, *Climate change in the Mediterranean*: https://www.unep.org/unepmap/resources/factsheets/climate-change

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The Mediterranean region is exposed to new climate-related threats. These include the emergence of mega-droughts, defined as droughts of exceptional duration, intensity and spatial expansion.

Finally, dry-hot compound events, whose effects are worse than the sum of the impacts of drought and urban heat islands separated in time, have also become a concern. The conjunction of these risks, associated with climate change, may not only pose a threat to the natural environment and the land but also to society in economic and health terms, affecting water resources, energy management and food security.

In response to the challenges posed by adverse climate change scenarios, escalating water scarcity, rapid urbanisation and mounting pressure from agriculture, there is an increasing motivation to enhance **collaboration between the Mediterranean countries**. This collaboration wants to address the diverse strategic needs that impact the entire region.

Considering these challenges, leaders and institutions have intensified their economic, political and diplomatic bonds through various initiatives that are focused on promoting regional cooperation by enhancing existing platforms, financial commitments and operational programmes. A key aspect of these activities is the management of water resources.

As an example, the Union for the Mediterranean (UfM) is an organisation that works to establish and strengthen relations between Mediterranean countries on water issues through its *Regional Water Platform*, which is a forum that brings together governments and stakeholders in working groups dedicated to finance, climate adaptation and the water-energy-food-ecosystems nexus.

Moreover, the Partnership for Research and Innovation in the Mediterranean Area (PRIMA) represents the primary scientific cooperation programme between Europe, North Africa and the Middle East, encompassing 19 countries. This collaboration provides support for innovative projects in the domains of water, agriculture and sustainable food systems.

In this context, the European Union has begun to build a regulatory framework to manage and innovate the water resource management sector, with the aim of respecting the environment and fighting the effects of climate change.

In order to better adapt and coordinate water resource management on the European continent, the new European Commission, which took office in 2024, appointed Jessica Roswall as Commissioner for Environment, Water Resilience and the Circular Economy for the first time in its history.

In June 2025, the European Commission presented the European Strategy for Water Resilience with the aim of addressing the growing pressures on water resources caused by pollution, climate change and increased demand.

The areas of intervention of this new strategy concern ensuring water security, access to clean water and a sustainable water economy, improving water efficiency and promoting nature-based solutions.

1.2 Objectives and Impacts

This research aims to conduct a detailed analysis of hydro-strategic policies and strategies in the three European countries involved, Italy, Spain, and Cyprus. Although the three countries belong to the European Union, they present very different climatic, geographical, and socio-political characteristics that significantly influence water resource management.

A comparative and multidisciplinary analysis of the context in each country will help identify both shared challenges and differences in water management policies and practices. The research will also investigate the advantages of new technologies, including artificial intelligence, that play a fundamental and innovative role in water management. At the same time, this policy paper will restore the importance of raising awareness and training both the public and professionals on the centrality of water resources in a global sustainability context. To achieve the stated objective, the hydro-strategy research will undertake an analysis of the most effective hydro-strategic policies and strategies for European countries, identifying transnational approach and opportunities for international cooperation.

This multidisciplinary analysis aims to generate several impacts in the various sectors involved in water management:

- Scientifically speaking, this research aims to advance knowledge within the context of water resource management, through the examination of current issues and strengths in Italy, Spain, and Cyprus.

This will generate practical indications of sustainable approaches to water management that could be applied in other contexts.

- The research also attempts to ensure better delivery of tangible benefits for public policy, industry, society and the environment. This will help policymakers take additional considerations regarding the economic and social implications of water management policies. This may lead to the implementation of policies that protect vulnerable communities and encourage sustainable economic progress.
- For the industrial sector, the adoption of innovative technologies will improve water efficiency in strategic sectors such as agriculture, energy, and manufacturing. Indeed, the implementation of innovative technologies, such as AI informed water monitoring, can enable industries to optimize their water consumption, save costs, and respect company and legal environmental regulations.

The analyses will assist to better support the evolution of new water management technologies encouraging both investments, and ultimately the generation of green jobs.

- The outputs from the research point to raise public awareness about water conservation and sustainable management while promoting the sustainability of water resources and ecosystems.
- The Hydro-diplomacy strategies identified through the research aim to increase cooperation between countries enhancing frameworks for fair and sustainable water management at an international level. These cooperative political strategies could encourage policy coherence as they will encourage governments to align energy, water and food policies.

In synthesis, the research intends to serve as a foundation for improving and integrating academic and professional education in the field of water resource management across Europe.

The goal is stimulating greater collaboration between universities, research institutions, and industry stakeholders, driving innovation and continuous improvement in water management practices.

1.3 Methodology

As already mentioned, the policy paper and the identification of the hydro-strategies have a multidisciplinary character. For this reason, it has been adopted a multiscale approach, including a variety of academic and scientific disciplines, such as economics, sociology, agronomy, international law, geopolitics, artificial intelligence, and the history of international relations.

This interdisciplinary method enables a holistic analysis of water resource management systems in the three countries, identifying their strengths and weaknesses in order to develop effective and innovative strategies to be applied in national systems and in international cooperation in the water sector.

The analysis employed both quantitative methods for data-based interpretations, and qualitative ones for depth of understanding.

The research has carried out a sectorial perspective along with a conceptual approach in order to investigate the relationships between sustainable and innovative practices as well as relationships across domains. In the legal domain, the analysis combined comparative, interdisciplinary and legal methods. For the international cooperation component, analysis was undertaken as historical, interdisciplinary and international relations research in order to reveal the diplomatic tools to use in water sector.

1.4 Structure

The structure of the research endeavours to reflect its multidisciplinary approach, which seeks to analyse the various sectors that constitute the water management system. The objective is to furnish a comprehensive and lucid portrayal of the domains of intervention and innovation within the water sector.

The analysis of the **regulatory framework** has two principal aims. Firstly, it seeks to present the national legislative structure, which includes not only the regulatory framework itself, but also the hierarchical organisation of the institutions involved and their respective competences. Secondly, it is concerned with the identification of the nature of the decision-making process.

In order to understand each country's management capacity, climate resilience and technological level, the research devotes a section to **key infrastructures**, focusing on efficiency and vulnerability indicators.

This analysis helps to reflect the country's level of infrastructure governance, from the decision-making process to the strategic implementation of the project, as well as the level of equity and access to water for communities.

Subsequently, the research focuses on analysing **a series of indicators** useful for understanding the efficiency and vulnerabilities of each country, providing an overview of each sector considered, from environmental and economic sustainability to the social sphere, to the commitment of industry and the technology sector to sustainable water resource management.

The identification and development of sustainable practices and strategies for water management must not only refer to the structure, state capacity and processes implemented in the various sectors, but must also reflect climate projections and the need to limit the effects of climate change and human intervention. Consequently, the research dedicates a section to the scenarios and challenges confronting the water sector in the context of **climate change**, which is exerting a particularly severe impact on the Mediterranean region. These insights provide the framework for the study and identification of **efficient hydro-strategies** that can have sustainable and long-term benefits for the various sectors involved in the research, identifying opportunities for **cooperation** at an international level, by disseminating **European know-how and management models.**

Water Governance and Regulatory Framework

1. Spain

1.1 Legislative System

Spanish legal framework for the management of water is grounded in Roman Law and medieval norms, later codified by the Laws of the Indies and brought into the Spanish legislative model in Latin America. The first modern legislation appeared in 1866 and 1879 when the regulations concerning the source and use of public waters were issued, and disposition of waters were legislated in a manner that laid the groundwork for their exploitation of supply, irrigation, and industrial use.

The most significant advance in this sector was the 1978 Constitution and the subsequent Law 29/1985, which was replaced by the Consolidated **Text of the Water Law** (*Texto Único de la Ley de Aguas*) approved by Royal Legislative Decree 1/2001. This text is still regarded as the primary legislation in this field, although it has been amended on multiple occasions to ensure compliance with European Union law.

The **Water Framework Directive** (WFD, 2000/60/EC), which was transposed into national legislation in 2003, introduced fundamental concepts such as river basin management, stringent ecological quality objectives, strategic planning cycles and cost recovery.

The regulatory framework of Spain has evolved in accordance with the transposition of European legal acts at the national level.

The 2000 Directive was supplemented by Directive 2020/2184/EU on the quality of water intended for human consumption and Directive 2007/60/EC on the assessment and management of flood risks, transposed through **Royal Decree 865/2003** and the related risk management plans.

The national regulatory framework is characterised by its articulation into specific laws and decrees. In terms of drinking water, in addition to the *Texto Refundido de la Ley de Aguas* (TRLA), which regulates the use and management of water resources, the registration of water concessions and the management of water registers, **Royal Decree 3/2023** establishes the health criteria of water used for human consumption.

Law 10/2001, meanwhile, sanctions the National Hydrological Plan and establishes the requisite provisions for its compliance. Furthermore, **Law 21/2013** establishes the process to evaluate the environmental impact at the level of plans, programmes and projects for water.

In the domain of wastewater treatment and reuse, the **Royal Decree 1620/2007** indicates quality standards and permissible uses, while **Law 7/2022** set up the framework for the sustainable management of waste and contaminated soil including the control of microplastics.

The principle that the *"polluter pays"* is established under **Law 26/2007** which also establishes environmental responsibilities.
Most recently, the **Royal Decree 1085/2024** sets, on the one hand, the technical and health conditions for the use of treated water; on the other, it pursues the sustainable management of water resources and the protection of human health and the environment.

A distinctive feature of the Spanish model is its management by river basin, through the establishment of ***Confederaciones Hidrográficas*** (basin authority). These public bodies administer inter-municipal waters by developing Hydrological Plans for each basin every six years. These plans regulate water use in that particular river basin and set environmental and resource management objectives.

Water resources of a single Autonomous Community are up to the **regional agencies**, like the *Agència Catalana de l'Aigua (ACA)* and the *EPSAR* in the Valencian Community.

At the central level, the water policy at the national level is guided by the ***Ministerio para la Transición Ecológica y el Reto Demográfico*** *(MITECO)*, and its planning process is supported by the **Dirección General del Agua** (DGA).

The regulatory framework has been further reinforced by the development of **drought and flood risk management plans** which are considered as critical tools in adapting and managing the water system to the worst impacts of climate change. From an economic and financial perspective, water is recognised as a public resource. However, the use of water is subject to the **payment of fees and tariffs** that are intended to cover some of the costs (capital and operational) associated with the infrastructure and services to provide water. Nevertheless, that fees and tariffs do not fully cover costs at present.

The Spanish water law is founded on the **principle of scarcity**, emphasising robust public intervention and planning, while demonstrating openness to adaptable instruments such as the market for usage rights and inter-basin water transfers.

The the centrality of planning, the process of digitisation of institutions that make data and information on water resources clear and accessible, together with the progressive adaptation of economic mechanisms, collectively constitute a modern legal and institutional laboratory for integrated water resource management.

1.2 Key actors, institutions, and decision-making processes

In Spain, water governance is characterised by **a multi-level and polycentric system**. The various responsibilities for the management of water resources are, therefore, divided among different institutions and bodies.

At the European level, the EU Commission imposes regulatory constraints and guidelines through directives, such as the WFD, regulations, as well as co-financing infrastructure programs and projects. On 4 June 2025, the European Commission presented the Water Resilience Strategy, a multi-objective plan to achieve resilient and sustainable water management on the European continent.

At the state level, the **MITECO** has various responsibilities, outlining national water and environmental policy, coordinating inter-basin hydrological plans and ensuring compliance with EU directives. Within MITECO itself, the **DGA** operates as the technical authority for water planning and regulatory supervision.

At the regional level, the **Autonomous Communities** have the management competence of the internal basins, so they are often supported by the work of their own water agencies (for example the Agència Catalana de l'Aigua in Catalonia, or the Entidad Pública de Saneamiento de Aguas Residuales in the Valencian Community).

The **Confederaciones Hidrográficas** are also responsible for technical, administrative and supervisory tasks, such as the preparation of water management plans for basin demarcations, the authorisation of water uses, the supervision of concessions, quality control and the management of water crisis situations.

At the local level, **municipalities and provincial councils** are responsible for the supply and distribution of drinking water, sewerage and wastewater treatment, often through regional or private operators.

In Spain, the decision-making process in water management includes all the actors involved and interested in the control and administration of water quantity and quality. The main actors include the institutions seen so far: MITECO and the Council of Ministers for inter-basin projects, the Confederaciones for basin planning, the Autonomous Communities for regional policies, local governments for operational implementation, and stakeholders such as farmers, companies, NGOs and citizens.

Thanks to European funding programs, Spain is implementing several projects, at the local level, to improve, expand and raise awareness of the participatory and collaborative system in the decision-making process in water management involving the territorial community.

1.3 Water management plans and national strategies

The main decisions on water management take place through the drafting every six years of the **Basin Management Plans**. The governance of these plans is strengthened by two key processes.

On the one hand, **public participation** is guaranteed by formal six-month consultations and sectoral and territorial meetings with regional authorities, national agencies and stakeholders; on the other hand, the **Strategic Environmental Assessment (SEA)** allows sustainability to be integrated into final decisions.

Subsequently, there is a public consultation period, of at least six months, in which citizens, associations and users can send comments that are collected, evaluated and integrated into the revised plans, and accompanied by a justification for the changes accepted or rejected, before final approval by MITECO.

The monitoring process, coordinated by the *Confederaciones Hidrográficas* and MITECO, allows the continuous collection of data on the quantity and quality of water, with periodic reports transmitted to the European Commission every six years and published to ensure transparency. The update of the plans takes into account the data and observations collected, as well as the progress achieved and new needs arising from climate change, technological developments and regulatory updates.

These plans, drawn up for each river basin, have as their main objective the achievement and maintenance of the **"good ecological and chemical status"** of all surface and groundwater, in compliance with the European Water Framework Directive.

The Spanish planning cycle, currently in its third year (2021–2027), includes phases of diagnosis of the status of water bodies through monitoring networks, identification of pressures, definition of objectives and preparation of a Programme of measures. This document must respond to several objectives: pollution reduction and hydro morphological improvement, satisfaction of water demand for agricultural, industrial and urban uses, protection from extreme events (droughts and floods) and strengthening of governance and knowledge.

Alongside the Hydrological Plans, Spain has specific management tools in extreme event contexts, such as **the Drought Management Plans** *(Planes de Sequías),* which not only establish progressive early warning and emergency scenarios, but also provide for implementation measures of restrictions on use, activation of alternative sources and awareness campaigns.

The entire system integrates with cross-cutting national strategies, such as the **National Plan for Adaptation to Climate Change** and the **National Action Program against Desertification**, ensuring a coherent and dynamic approach to water management in Spain.

2. Italy

2.1 Legislative System

The breadth of potential implications related to water means that, both legislatively and administratively, the topic falls within multiple and varied areas of jurisdiction.

In Italy, legislative powers are generally divided between the State and the Regions, as established by **Article 117 of the Constitution**, as defined in 2001. This definition primarily reserves matters of strategic importance to the State. The same article subsequently provides for a series of matters subject to concurrent legislation between the State and the Regions. All matters not included among those under exclusive State jurisdiction and those under concurrent State-Region jurisdiction are reserved for regional legislative jurisdiction.

Based on the above-described division framework, the State has exclusive legislative competence in the "protection of the environment, ecosystems, and cultural heritage", a topic that also includes the management framework of water resources as environmental assets.

Legislative power is shared between the State and the Regions in various sectors that may involve the use and management of water, such as **land management, health care, civil defense, energy production/distribution, ports, navigation networks, and the enhancement of environmental assets**. In matters of concurrent legislation, legislative power rests with the Regions, except for the determination of fundamental principles, which is reserved for state legislation.

It should be added that Italy has five regions with special statutes: Aosta Valley, Trentino-Alto Adige, Friuli-Venezia Giulia, Sicily, and Sardinia. These enjoy additional legislative powers, which may include the independent management of water resources.

The fundamental provisions of the Constitution can be found in:

- **Article 9**, which establishes, among other things, that the Republic protects the environment, biodiversity, and the ecosystem, also in the interest of future generations;
- **Article 43**, paragraph 1, which provides that economic activity may not be conducted in a manner that harms the environment;
- **Article 43**, paragraph 2, which assigns to the law the task of establishing appropriate programs and controls to ensure that public and private economic activity is directed and coordinated for social and environmental purposes.

The issue of water as a vital element for human survival, which should be recognized as a constitutional right, has yet to find a shared and viable solution in Italy.

A repeal referendum was held in 2011, however, in which voters prevented the privatization of local water services, thus affirming the principle that water is a common good and must be free from private profit.

The key legislative text currently governing water is the Environmental Code, **passed in 2006 following EU directives**. The Code introduces an analytical classification of water and the morphological and territorial assets associated with it, and defines the planning, programming, and implementation activities. It establishes a highly detailed framework of responsibilities at various levels, assigning them to:

- Prime Minister and the Committee of Ministers for Soil Conservation;
- Interministerial Committee for Ecological Transition;
- Minister of the Environment and Land and Sea Protection;
- State-Regions Conference;
- Higher Institute for Environmental Protection and Research;
- Regions;

- Municipalities, provinces, including their consortia or associations, mountain communities, land reclamation and irrigation consortia, mountain catchment basin consortia, and district basin authorities;
- permanent district observatories on water use.

The Code first establishes river basin districts. These are territorial units that group together multiple river basins and serve as the basis for integrated water resource management. In Italy, they were established in implementation of the **European Union's Water Framework Directive 2000/60/EC**, which promotes environmental planning at the basin scale to ensure the qualitative and quantitative protection of water. Their functions can be summarized as follows:

- coordination of water planning and soil conservation;
- management of hydrogeological and flood risks;
- promotion of the sustainable use of water for agriculture, industry, and civil consumption;
- development of Water Management Plans and Flood Risk Management Plans.

Seven river basin districts have been established: Eastern Alps, Po River, Northern Apennines, Central Apennines, Southern Apennines, Sardinia, and Sicily. The districts correspond to the district basins, consisting of geographical areas defined on the basis of the hydrographic network, which include one or more river basins and constitute the territorial unit of reference for the integrated management of water resources. In practice, they are the natural "containers" through which rivers, streams, and tributaries flow, and where water use and protection are planned. The districts are managed by the District Basin Authorities, which coordinate water policies between regions and local authorities and include multiple river basins: a single river basin is the area attributable to a single main watercourse (e.g., the Po River basin).

A particularly important area regulated by the Code is the protection of water from pollution, for which it establishes:

- the general principles and responsibilities of state, regional, and local administrative bodies;
- the methods for identifying and pursuing the environmental quality objective;
- the inventory of releases from diffuse sources, discharges, and losses;

- the requirements for analysis methods and the definition of average values;
- the quality objectives for specific purposes;
- the definition of certain waters according to a specific purpose.

Other relevant aspects regulated by the Code include the protection of water bodies and the related regulations on discharges and environmental violations, which are associated with significant administrative and/or criminal penalties.

The third section of the Code regulates the management of water resources and the general principles it must adhere to, identified in the public ownership of infrastructure up to the point of delivery and of all surface and groundwater, the balance of the water budget, and resource conservation.

Regarding the management of the integrated water service, the Code regulates:

- the organization of water services based on the optimal territorial areas defined by the regions;
- the area plans;
- the procedures for awarding the service;
- the relationship between the area governing body and the entities managing the integrated water service;
- the powers of control and substitution;
- the integrated water service tariff;
- water transfer works and interventions.

2.2 Key actors, institutions, and decision-making processes

In Italy, powers, responsibilities, and decision-making levels regarding water are distributed in a highly fragmented manner, as illustrated below.

The **national government** develops general guidelines and coordinates national environmental and water policies through the Ministry of the Environment and Energy Security (MASE), which is responsible for water resource protection and soil conservation.

The **regions** have legislative and administrative powers over water resource management, according to the framework of responsibilities outlined in the previous paragraph. The main functions concern the definition of regional water plans and the regulation of Optimal Territorial Areas (ATO).

The **municipalities**, in addition to mandatory participation in the EGA (see below), ensure the approval of urgent projects, participate in territorial planning, and monitor the proper functioning of the integrated water service, in collaboration with the management bodies.

District Basin Authorities: There are seven of them, located in each of the river basin districts (Po River, Eastern Alps, Northern Apennines, Central and Southern Apennines, Sicily, and Sardinia). They coordinate the planning and protection of surface and groundwater.

Area Governing Bodies (EGA): These are public bodies that manage the ATOs and entrust the Integrated Water Service (SII) to operators. They coordinate collection, distribution, sewerage, and purification.

Water service operators, which may be public, private, or mixed, operate under a concession regime with operational management responsibilities.

Citizens and associations can participate in decision-making processes through participatory evaluation tools, as provided for by Article 118 of the Constitution, which will be further explained in the following paragraph.

2.3 Water management plans and national strategies

Considering the distribution of legislative and administrative powers, the Ministry of the Environment and Energy Security (MASE) is responsible for developing national water strategies.

The strategic issues identified at the ministerial level are:

- the implementation of EU water protection and efficiency policies;

- the involvement of all stakeholders (institutions, organizations, citizens, etc.) in water issues;
- the promotion and implementation of circular economy measures;
- the initiation of recovery processes using unconventional resources, primarily desalination and wastewater reuse;
- the improvement of the integrated water service, consisting of all public aqueduct, sewerage, and purification services in a specific territorial context;
- the quality of water for human consumption;
- the environmental quality of water;
- river basin governance and coordination of district river basin authorities;
- permanent observatories on water use;
- the protection of the sea and coasts;
- the mountain catchment basins;
- the challenges posed by droughts and weather events.

In terms of implementing EU policies, the European Union recently launched the "European Strategy for Water Resilience." EU Directive 2024/3019 already provided, in addition to incentives for agricultural reuse, highly significant targets for the treatment and reuse of urban wastewater by 2035–2045.

Wastewater reuse, as mentioned, is also a key strategic objective of the Ministry. In this regard, the strategy of the Ministry of the Environment and Energy Security fits fully within the framework of the ecological transition and the circular economy. The national authority is working to implement **European directives** and, in particular, to implement the **European regulation** establishing minimum requirements for the reuse of treated wastewater in agriculture. It also plans to reform national regulations to introduce a risk-management approach, expand the scope of uses, redefine the categories of responsible parties, and safeguard water quality through improved controls and inspections. Recognizing that the reuse of purified water, while already significant, presents significant regional disparities, the Ministry aims to standardize practices and incentivize recovery and reuse nationwide, including through PNRR funding and collaboration with local authorities.

Regarding water waste, MASE has outlined a multifaceted strategy to address the issue, modernizing the system, reducing losses, and promoting sustainable management of the resource. The key elements are:

- Reducing management fragmentation, reducing the number of over a thousand local managers, often small and poorly structured, to approximately one hundred operators;
- Modernizing networks to reduce water losses by renovating aqueducts, introducing the use of smart sensors, and improving preventative maintenance;
- enhancing international cooperation: in this regard, mention should be made of the Water Coalition during the G7 Climate, Energy, and Environment Summit, promoted by Italy itself for the adoption of joint strategies to combat the effects of climate change;
- integration with the National Strategy for Sustainable Development within the framework of circular and resilient economy practices, in line with the UN 2030 Agenda Goals;
- promotion of environmental education, public participation, and technological innovation.

3. Cyprus

3.1 Legislative System

Being water management a major issue for the Government and the people of Cyprus, national laws and policies related to water resource management have been adopted by the authorities of the island since long time. Worth to be mentioned are:

- **Cyprus Water Law (Cap. 222)**: Core legal framework that declares all water resources public and defines ownership, access, and administrative control.
- **Water Pollution Control Law (106(I)/2002)**: Governs the discharge of pollutants into water bodies, including permitting and enforcement.
- **Integrated Water Management Law (79(I)/2010)**: Introduced to ensure national compliance with the EU Water Framework Directive.
- **Urban Waste Water Treatment Law (N.106(I)/2002)**: This law transposes the EU Urban Wastewater Treatment Directive (91/271/EEC) into Cyprus legislation. It regulates the collection, treatment, and discharge of urban wastewater and sets specific obligations for municipalities and sewerage boards regarding infrastructure, environmental permits, and compliance monitoring.

A correct and sustainable management of water concerns also require appropriate policies governing water use in industries. This important sector responds to some *ad hoc* regulations:

- The use of water in industrial sectors in Cyprus is regulated under the mentioned Water Law (Cap. 222), which governs water ownership, abstraction, and allocation across all sectors.
- The **Water Pollution Control Law (106(I)/2002)** sets out requirements for permits and standards related to wastewater discharge. Industries are required to obtain water abstraction permits from the Water Development Department and discharge permits from the Department of Environment.
- Oversight is shared between the Ministry of Agriculture, Rural Development and Environment, which leads national water policy, and the Department of Environment, which ensures compliance with environmental standards.
- While there is no dedicated legislation mandating circular water use, Cyprus's National Water Strategy and related EU initiatives actively encourage industrial sectors, particularly tourism and agriculture, to adopt water-saving practices such as reuse systems and closed-loop processes.

3.2 Key actors, institutions, and decision-making processes

The decision-making processes in the Republic of Cyprus are carried out by the following relevant authorities:

- The Water Development Department (WDD): This is Cyprus's central water authority, responsible for policy implementation, infrastructure (dams, desalination plants), and management of water resources.
- The Department of Environment: Handles pollution monitoring and environmental permitting, including for water discharges.
- Local water boards and municipalities: These bodies are legally responsible for water supply and sewerage systems at the local level, such as the Nicosia Water Board.
- The Ministry of Health oversees drinking water quality, while the Geological Survey Department monitors groundwater and aquifers.
- Civil society organizations and the general public.

3.3 Water management plans and national strategies

Water-related decisions are coordinated by the WDD, which drafts national strategies and coordinates implementation. Policies, which regard debates, approvals, implementation, and public participation, are reviewed through stakeholder consultations, in line with EU Water Framework Directive requirements. Local authorities are consulted on infrastructure and service delivery. Public participation occurs through published consultations, hearings, and digital feedback channels.

Several water management plans are adopted and regularly monitored and reviewed, among which a national plan, a watershed-specific plan, and one for drought and flood prevention). They are:

- River Basin Management Plans (RBMPs)
- Drought Management Plans
- Flood Risk Management Plans

These plans are monitored through a national network of hydrological stations and environmental data collection. The WDD reviews and updates RBMPs every six years, incorporating feedback from environmental agencies, municipalities, and public consultation sessions. Plans are aligned with EU requirements and climate projections.

4. Spain, Italy and Cyprus. Summary of Evidence in Differences and Best Practices

Spain represents the most advanced and integrated national model. Its strength lies in a coherent and mature legislative framework aligned with EU directives and a basin-based governance structure. The Texto Refundido de la Ley de Aguas (TRLA) and the Royal Decree 1/2001 define water as a public good managed through **Confederaciones Hidrográficas**, which operate at the river-basin scale. The system's coordination by MITECO ensures national strategic alignment, while Autonomous Communities retain control over internal waters.

Major best practices include:

- River basin management integrating ecological, social, and economic goals.

- Public participation in decision-making, with formal consultation phases during hydrological planning.
- Comprehensive drought and flood risk management plans, integrated into climate adaptation policies.
- Progressive digitalization of hydrological data and transparent public access systems.

Weaknesses remain limited cost recovery and financial sustainability due to tariffs below actual service costs, though Spain's water pricing framework supports equitable access and environmental protection.

Italy's model is characterized by technical richness but structural inefficiencies. The **Integrated Water Service** (*Servizio Idrico Integrato*) governs collection, distribution, and treatment through varied local operators, mostly public. Infrastructure is extensive but obsolete - with 42% network water loss and an average pipeline age exceeding 50 years. Public investment remains low (circa 1-2% of total spending), and governance fragmentation among 82% small local providers hampers efficiency.

However, Italy's best practices concern:

- Advanced hydropower infrastructure and a strong dam network offering significant resource storage capacity.
- A growing emphasis on reuse and recycling in line with EU circular economy strategies, though actual reuse (4%) lags behind Spain's 35%.
- Regionalized quality monitoring and Water Management Plans (PGDAC) promoting urban water efficiency and greywater reuse.
-

Italian resilience policies, while still emerging, aim to modernize infrastructure, promote rainwater and wastewater recovery, and strengthen inter-level coordination between local and national authorities.

Cyprus exhibits a compact but highly EU-compliant governance model, reflecting intensive water scarcity pressures. The **Water Law (Cap. 222)** and **Integrated Water Management Law (79(I)/2010)** establish water as a public resource managed under the Water Development Department (WDD). The system's integration with EU directives is complete, including the Urban Wastewater Treatment Law and Water Pollution Control Law, ensuring alignment with quality standards and international compliance.

Distinctive best practices include:

- A centralized governance framework with strong inter-ministerial coordination under the WDD, ensuring strategic consistency.
- Systematic desalination and reuse programs tailored to national scarcity conditions.
- Continuous public and stakeholder consultation aligned with the EU Water Framework Directive.
- Advanced data monitoring networks linking hydrological and environmental quality parameters.

Challenges persist due to dependency on non-conventional sources (desalination and reuse) and limited industrial-scale circularity, though the governance model's coherence and transparency surpass the Mediterranean average.

Dimension	Spain	Italy	Cyprus
Governance Model	Multi-level, polycentric; basin authorities (CHs) key instruments	Fragmented, locally administered with limited national coordination	Centralized under WDD with clear administrative hierarchy
Legal Framework	Mature, comprehensive, aligned with EU directives (WFD, flood, and reuse laws)	Legislative coverage strong but enforcement and coordination weak	Fully harmonized with EU law; Water Law ensures coherence
Public Participation	Formal consultation and public involvement during basin planning	Regional-level and limited citizen engagement	Systematic participation through structured consultations

Dimension	Spain	Italy	Cyprus
Reuse of Water	35% (EU-leading performance)	4% (significant lag)	Expanding reuse and desalination to counter scarcity
Financial Sustainability	Partial cost recovery; tariffs cover some service costs	Chronic underinvestment; financial inefficiency	Stable funding via centralized planning; EU-supported programs
Institutional Strength	Strong coordination among MITECO, DGA, and regional agencies	Weak coordination and project completion rate (11%)	Cohesive inter-ministerial management with monitoring capacity

Table 1: Trilateral Comparison of Evidence and Best Practices Between Spain, Italy and Cyprus

Water Infrastructure and Management Systems

1. Spain

1.1 Key Infrastructures

The supply and distribution of Spanish water resources rely on a **massive infrastructure system** that serves as pillar of water management, especially in a context of strong territorial imbalances and frequent periods of water scarcity. Spain's water infrastructure system is one of the most advanced and diversified in Europe, combining engineering tradition with the ability to adapt and resilience to climate change.

Spain ranks fifth in the world, after China, the United States, India and Japan, in terms of the number of water infrastructures, with **more than 1,225 major works** surveyed by the DGA (2023).

Among the most important structures are **dams and reservoirs**, whose total storage capacity is estimated at about 56,000 hm^3. This volume of water is a crucial resource for agricultural, energy and urban uses.

Among the main examples are the *La Serena Reservoir* (3,220 hm^3, Badajoz), the largest in the country, the *El Atazar Reservoir* which feeds Madrid, and the *Yesa dam* in Navarre, essential for the irrigation of the Bardenas Canal.

Irrigation, covering over 3.5 million hectares (MAPA, 2023), is the largest and most strategic use, while hydropower production, accounting for about 20% of national renewable electricity production, represents another key sector (REE, 2022).

The **management** of these infrastructures is mainly assigned to the ***Confederaciones Hidrográficas***, which operate at the basin level and integrate these infrastructures into the cyclical hydrological planning envisaged by the Basin Hydrological Plans.

A decisive role is also played by the ***Estaciones de Tratamiento de Agua Potable*** (ETAP), which guarantee the quality of water reserved for human consumption, in accordance with European Directive 2020/2184, through multi-stage processes (pre-treatment, coagulation-flocculation, filtration, disinfection) and, increasingly, advanced treatments such as activated carbon, reverse osmosis or ozonation to counteract emerging contaminants (drugs, microplastics, endocrine disruptors). Among the most important plants are the ETAP in *Valmayor* (Madrid), the *Sant Joan Despí* and *El Prat* (Barcelona), equipped with ozonation systems and membranes. Quality is monitored by MITECO, with strict controls and ISO certifications (9001, 14001) that attest to its sustainability.

Another central component is the **wastewater treatment stations** (EDAR or WWTPs).

Spain counts on 2,000 operating units that guarantee the treatment of wastewater of more than 90% of the urban population (Eurostat, 2022). Many of the Spanish plants include tertiary processes, which allow the reuse of treated water in agriculture, for urban and industrial uses, strengthening the circular economy strategy. Leading examples include the *Murcia Este WWTP*, which provides regenerated water for agriculture in one of the driest areas of the country, and the *Pinedo plant* in Valencia, known for its high efficiency in nutrient treatment.

The Spanish Recovery and Resilience Plan has activated new investments with the aim of digitizing and making plants more resilient.

Finally, Spain stands out as a state at the forefront of the production and use of unconventional water sources. **Desalination** has reached a capacity of more than 700 hm^3/year (INE, 2022), making the country the world leader after Israel. Large plants such as *Torrevieja* (Alicante, 80 hm^3/year) and *Carboneras* (Almería, 42 hm^3/year) supply water to cities and crops in arid coastal areas. At the same time, Spain is second in the world for **the reuse of reclaimed water**, with the region of Murcia reusing up to 98% of treated water, followed by Alicante and the Balearic Islands.

1.2 Performance and efficiency indicators

The complexity and diversification of the Spanish infrastructure system are assessed by **efficiency indicators** that determine the quality of service, the sustainability of the infrastructure and the overall management of resources. These indicators promote more transparent water management oriented towards continuous improvement, with a view to adapting to climate change.

The urban distribution system supplies about 4 billion cubic meters of water per year, with an overall treatment and storage capacity (drinking water treatment plants, tanks and distribution networks) generally adequate to cover water demand. However, large territorial and climatic disparities remain, particularly in the south-eastern regions, where water scarcity and demographic pressure put a strain on supply and distribution networks.

A critical issue of the Spanish infrastructure system is represented by the indicator of **network losses** (Non-Revenue Water), which in Spain exceed an average of **22%** of the water introduced into the distribution systems. In cities with modernised infrastructure, such as Madrid and Barcelona, losses are between 10 and 15%, while in rural areas with outdated networks they can exceed 30%.

In recent years, digitalisation and network renewal programmes have been launched in support of the increase in efficiency, often with the support of European funds, through the installation of smart meters, real-time monitoring, pressure control and pipe replacement.

For performance evaluation, Spain adopts benchmarking systems and sustainability indicators such as **SIBEA** (Sistema de Indicadores y Benchmarks de AEAS), which make it possible to monitor and compare the performance of water operators. Key parameters include energy efficiency per cubic metre distributed, volume of water reused, continuity of service and coverage of the population served.

1.3 Vulnerabilities and Resilience

Performance and efficiency indicators allow to identify the structural, managerial and climatic vulnerabilities of infrastructures through which it is possible to identify and implement measures and intervention programs.

Spain faces increasing **climate vulnerability**, characterized by heavier but less frequent rainfall and prolonged droughts, putting pressure on dams, pipelines and distribution systems (IAHR–Spain Water–CICCP Conference, 2024). Spain faces severe levels of water stress and desertification with estimates indicating that by 2050, half of the population could experience disruptions in water supply if incisive measures are not taken [2].

Another critical issue is represented by **obsolete infrastructure**, especially dams and main pipelines, which require maintenance and rehabilitation. The economic sustainability of the Spanish water sector is threatened by **water tariffs below the EU average** (about half) and a structural debt estimated at €100 billion. In addition, **poor public-private integration and low administrative adaptability** represent additional vulnerabilities that limit the ability to attract investments and innovations.

Despite these vulnerabilities, Spain demonstrates strong resilience and innovation capabilities in the water sector. MITECO, CEDEX and the DGA promote a vision oriented towards the sustainability, digitalisation and multifunctionality of infrastructure.

The main fields of action include:

- the digitization of water systems for more efficient and predictive management;
- the increasing use of unconventional resources;

[2] WWF, *España será uno de los países europeos con mayor riesgo de sufrir estrés hídrico en menos de 30 años si no se toman medidas:* https://www.wwf.es/?61600/Espana-sera-uno-de-los-paises-europeos-con-mayor-riesgo-de-sufrir-estres-hidrico-en-menos-de-30-anos-si-no-se-toman-medidas

- the development of the National Programme for Hydraulic Energy Storage, which integrates water management with the energy transition through hydroelectric and pumped storage;
- the development of hybrid physical-numerical models for the planning and safety of hydraulic works, promoted by CEDEX.

2. Italy

2.1 Key Infrastructures

Italy, due to its complex geography and uneven population distribution, has developed a complex and diversified water system over time. Here is an overview of the main infrastructures.

First and foremost, the national and regional aqueducts, the most important of which are the Peschiera aqueduct, one of the largest in Europe, serving Rome and part of Lazio; the Sele-Calore aqueduct, essential for Naples and surrounding areas; and the Sardinia Aqueduct, a strategic network for the region, which has limited water resources.

There are also important dams and artificial reservoirs. These include the **Bilancino Dam**, an essential resource for Florence and Mugello; the **Ridracoli Dam**, which serves Romagna and part of the Marche; and numerous reservoirs in southern Italy, used for irrigation and water supply in particularly arid areas.

As for hydroelectric power plants, there are **4,860 active plants**, concentrated primarily in the Alpine region. The regions with the highest installed capacity are Lombardy, Trentino-Alto Adige, and Piedmont.

Finally, wastewater treatment plants are worth mentioning: in particular, despite being below capacity and unevenly distributed across the country and the region, the **more than 18,000 wastewater treatment plants are noteworthy**.

Regarding water management systems, the integrated water service (SII) is significant and fundamental. It includes collection, supply, distribution, sewerage, and purification. Water is publicly owned, but its management varies. There may be a single public operator, a jointly managed company with public and private capital, or municipalities that directly manage the service. Management by entirely private companies is extremely rare.

2.2 Performance and efficiency indicators

Performance and efficiency indicators for water management can be identified as follows. Measuring water losses in the distribution network indicates the percentage of water lost before reaching the end user. The national average is around 42.4% (as of 2022). This highlights one of the most critical aspects regarding the efficiency of the network.

Sewer coverage indicates the percentage of the population served by adequately efficient sewer systems. In Northern Italy, service coverage is up to 97.9% (Valle d'Aosta), while Sicily and Calabria are below 77%.

The user satisfaction index demonstrates the perception of water quality and the water service. In the North, satisfaction **exceeds 90%**; in the South and on the islands, it is **below 70%**, with peaks of dissatisfaction **exceeding 33%**.

The water rationing assessment indicates the number of days in a year in which water supply was suspended or reduced. The worst cases were Agrigento (208 days) and Trapani (180 days). Drinking water withdrawal and consumption account for the total volume withdrawn for civil use: 9.14 billion m^3 in 2022.

Wastewater management provides information on the added value generated by this specific process: **€6 billion in 2022**, equal to 25% of national environmental spending.

The quality of water bodies is monitored at least every three years by the regions with the aim of also assessing the chemical and ecological status of surface and groundwater.

Finally, other strategic approaches are implemented through water management plans (PGDAC), which, updated every six years, include quality objectives and improvement measures. From this perspective, efficiency evaluation processes are also adopted in the urban and building context, aimed at promoting the reuse of rainwater and greywater, reducing consumption and improving the water cycle.

2.3 Vulnerabilities and Resilience

In Italy, the main water vulnerabilities arise from a combination of structural, climatic, and management factors. The most significant issues are listed below.

Much infrastructure is obsolete and inefficient due to aging water networks: approximately **22% of pipes are more than 50 years old**, while large reservoirs have an average construction age of 58 years. Water losses amount to approximately **6.5 billion cubic meters** due to poorly maintained pipes. Uncontrolled discharges affect at least one watercourse, posing a serious risk of pollution from microplastics, heavy metals, and pathogens.

Vulnerabilities are also caused by climate change and drought. Precipitation has been significantly reduced in recent decades, especially in the South and the islands. Extreme events, such as floods and droughts, are associated with **90% of natural disasters**. Severe droughts can be described as recurrent: in the last five years, nine periods of very serious water shortages have occurred, with estimated costs of around **€30 billion**.

Management and investment shortcomings are also evident. Public investment in particular is low: only 1% to 2% of public spending has been allocated to water systems over the last 20 years. Projects are sometimes partial or interrupted: only 11% of projects financed by the European Regional Development Fund for Water Resources have been completed. Management is disjointed due to the lack of shared strategies for water storage, distribution, and reuse.

Environmental and health implications are also significant. Water pollution is frequent, as malfunctioning sewer systems and urban runoff cause contamination that threatens public health and ecosystems. Emissions from the water sector contribute approximately 10% of global greenhouse gas emissions, highlighting the need for more sustainable practices.

In terms of resilience, Italy attaches strategic importance to mitigating and solving the wastewater problem, whose incremental reuse would inevitably have a positive impact. According to data from the Water Observatory pub**lished by Intesa Sanpaolo and Acea, in Italy** only 4% of treated wastewater is actually reused. This figure highlights a significant shortfall compared to the rest of Europe, where the average reuse rate is 20%, with peaks of 35% in Spain. Furthermore, in Italy, treatment is deemed safe at 70%.

The main problems related to wastewater are the widespread presence of inadequate plants, in terms of size and technical or technological characteristics, and the slowness of bureaucratic authorization procedures. This results in a shortage of treatment and reuse.

Looking ahead, addressing and resolving these problems would first and foremost facilitate greater access to water for the production system, thereby reducing the burden on industry and agriculture and facilitating profitable and productive reuse solutions. It would also make it possible to address climate and drought crises more effectively and catch up with countries with similar economic potential. All of this within a framework of greater compliance with European directives.

Reuse obviously concerns refined water, that is, water purified and further treated to achieve quality standards that make it safe to reuse for non-potable purposes, such as agricultural irrigation, particularly of cultivated fields, greenhouses, and nurseries; industrial use for cooling systems and for technical cleaning; urban cleaning, such as washing public spaces; and irrigation of urban greenery.

The reuse of wastewater is certainly important and essential as it contributes to achieving significant water savings, reducing drinking water consumption and preserving natural reserves for priority uses, starting with human consumption. It reduces pollution by preventing chemicals, nutrients, and pathogens from entering rivers and seas, and improves environmental quality. It is a factor in economic sustainability as it reduces water supply costs for agriculture, industry, and urban services. It protects ecosystems: reduced withdrawals from rivers, lakes, and aquifers mean greater ecological balance and greater protection of biodiversity. It increases climate resilience by strengthening communities' adaptability, ensuring supplies even in difficult times.

Another challenge to address to increase resilience is the high level of water waste in the Italian water supply system, among the highest in Europe.

Updated data on water waste show that **42.4%** of the drinking water introduced into urban networks is lost before reaching residents. This is due to obsolete and inefficient infrastructure and a lack of management coordination, as **82%** of water providers are small public entities, often lacking technical and financial resources. A lack of user awareness of water conservation also plays a role.

The system is therefore generally geared, as a result of the main vulnerabilities and critical issues identified, to promote investments in network modernization and efficiency and to increase the use of monitoring technologies. In addition to wastewater recovery, rainwater harvesting is also considered important.

The aim is also to achieve more coordinated governance between local and national authorities and to raise awareness among the economic and productive sectors of a culture of water conservation by encouraging consistent practices and behaviors.

3. Cyprus

3.1 Key Infrastructures

Cyprus has developed a complex and adaptive water infrastructure system, especially to deal with its frequent droughts and limited natural water availability. Among these, dams water treatment plants, distribution networks, and unconventional water sources are essential to grant water needs to population, agriculture, industry and tourism.

The most critical component is the Southern Conveyor Project, which transfers water from western dams to central and eastern regions. The country also operates five large desalination plants that produce most of the drinking water for cities and coastal areas. Recently, fifteen more desalination plant have been given to Cyprus as a gift by the United Arab Emirates.

Over 100 small and medium-sized dams and reservoirs collect rainwater during the wet season, while an expanding network of wastewater treatment plants allows for the reuse of treated water, mainly in agriculture. These systems are actively managed by the WDD and local water boards.

3.2 Performance and efficiency indicators

The water regulations in Cyprus have reached a good level of effectiveness through an integrated and adaptive Water Resource planning which fully respect the compliance with EU water quality targets. A sensitive reduction in groundwater over-extraction is implemented as well as an increase in wastewater reuse for irrigation. Recycling water for different uses is now considered an imperative action in Cyprus.

An idea of the efficiency of the water policies is given by data on water flow, network losses, and supply capacity:

- **Water Flow and Storage**

- Reservoir Capacity: Cyprus operates 108 dams and reservoirs with a combined storage capacity of approximately 330 million cubic meters.
- Current Storage Levels: As of early 2025, reservoir levels have dropped to around 24.6% of their total capacity, attributed to consecutive dry winters.
- Groundwater Recharge: The natural aquifer recharge is estimated at 300 million cubic meters annually, with about 70 million cubic meters flowing to the sea and 100 million cubic meters emerging from springs.

- **Non-Revenue Water (NRW)**
  - National Average: Non-revenue water, which includes losses due to leaks and unauthorised consumption, is estimated at 20% to 30% in urban areas.
  - Recent Improvements: Pilot projects have achieved annual water savings of 1 million cubic meters, equating to a 4.8% reduction in water entering the network.
- **Water Supply Capacity**
  - Desalination Plants: Cyprus currently operates four large desalination plants with a combined daily production capacity of approximately 220,000 cubic meters.
  - Mobile Units: To address immediate shortages, the country has received 15 mobile desalination units from the UAE, collectively adding about 15,000 cubic meters per day to the supply.
  - Future Expansion: Plans are underway to construct two new permanent desalination plants by 2030, aiming to further enhance water security.

3.3 Vulnerabilities and Resilience

One of the country's strengths is the centralized role of the Water Development Department (WDD), which ensures consistent planning and implementation across regions. Analysis, studies, research of solutions, projects and initiatives are the everyday work of WDD.

Nevertheless, there are still gaps, particularly at the local level, where enforcement and technical capacity can be limited.

Public understanding and engagement on water issues also remain relatively low outside urban areas. Strengthening local capacity and increasing public communication would help to improve these aspects. In particular, specific training courses, continuous monitoring of the local water issues, international cooperation with regions experiencing similar problems, and giving budget priority to water issues could be significantly helpful to overcome weaknesses.

Integrated Indicators for Sustainable Water Governance

1. Spain

1.1 Environmental indicators

The environmental indicators of water in Spain are used **to monitor and analyse the ecological and chemical status of water bodies**, as well as the **impacts of human activities and climate change** on aquatic ecosystems. These procedures are based on a strict regulatory framework that integrates European directives (Water Framework Directive 2000/60/EC, Directive 2020/2184/EU on human consumption, Directive 2008/105/EC on priority environmental parameters and Directive 2013/39/EU on emerging contaminants) and Spanish Royal Decrees (Royal Decree 487/2022 and 742/2013, which regulate the quality criteria for water intended for human consumption and wastewater control procedures, respectively).

The implementation of this regulatory framework makes it possible to establish monitoring networks to determine that data on the chemical and ecological quality of water bodies are consistent with European and Spanish standards.

According to the most recent data from the European Environment Agency (EEA, 2024) and Spain's River Basin Management Plans (RBMPs), **about 34% of surface water bodies achieve good ecological status, while about 75% have good chemical conditions**.

The main pollutants are nutrients (nitrogen and phosphorus) from intensive agriculture, which cause eutrophication, organic matter and pathogens, derived from insufficient purification and, in some sections, heavy metals and industrial substances. Groundwater generally shows better quality, but is vulnerable in agricultural and mining areas, where nitrates and trace metals are recorded.

Despite these problems, Spanish waters are habitat for a rich biodiversity consisting of endemic species of fish, amphibians and invertebrates, migratory birds and aquatic plants.

Key challenges to biodiversity include habitat fragmentation, invasive species, pollution and alterations in water flow.

To counter these threats, national and European initiatives, such as the Natura 2000 network, are active for river conservation and restoration aimed at protecting sensitive ecosystems and species.

1.2 Economic and Legislative indicators

The Spanish water management system operates according to a **decentralised model**, where competences are distributed between national, regional and local authorities, with direct effects on funding mechanisms and the implementation of water policies.

The average cost of drinking water in 2022 was €1.97/m^3 (excluding VAT), with strong regional differences: higher rates in Catalonia and Madrid (around €2.20/m^3) and lower in less populated regions such as Extremadura (less than €1.50/m^3) (AEAS, 2022).

The **financing** of the Spanish water sector **combines public resources, EU funds and private investments.**

The National Plan for Purification, Sanitation, Efficiency, Savings and Reuse (DSEAR 2022-2027) provides for investments of over 22.8 billion euros, of which about 7 billion from European cohesion funds, to modernize treatment plants, promote reuse and improve the efficiency of systems.

The Recovery, Transformation and Resilience Plan (PRTR) allocates €1.7 billion to digitalisation and water reuse, while private capital covers around 25% of total investments, mainly in desalination plants and industrial reuse technologies.

According to INE and OECD data, 70% of investments in water infrastructure come from public funds, while 30% are of private origin, mainly through management concessions for urban supply and purification. Investments in infrastructure and management improvements have generated annual savings of around €450 million and created more than 80,000 jobs in the water sector (AEAS, 2021).

However, the European Environment Agency (EEA) estimates that the economic costs of pollution and water scarcity could reach €2 billion per year, generating negative impacts in agriculture, tourism and public health.

Overall, Spain stands out for its Mediterranean **leadership in investments in reuse and desalination technologies**, which are crucial for water security and climate resilience.

1.3 Social indicators

The evaluation of the complex and transversal water resource management system also passes through the analysis of the social condition in water management: **condition and equity in access and use of resources and level of participation in the decision-making process**.

Spain has a level of access to water and sanitation services that is close to 100% of the population (INE, 2022). However, some territorial disparities persist. In urban areas, access to treated and safe drinking water exceeds 99%, while in rural areas it varies between 95% and 97%, where infrastructure is more aged. Average household consumption is steadily decreasing - around 128 litres per capita per day in 2022 - evidence of growing common awareness and greater water efficiency.

Public awareness of water scarcity and climate change is particularly high in the south of the country, where national campaigns, such as *"Ahorrar Agua"* promoted by the MITECO, have played a key role in promoting more sustainable behaviour. Although national legislation provides for the participation of citizens in water planning, their effective involvement is still limited. Educational and awareness-raising initiatives are often fragmented and on a local scale, with uneven results across regions.

Barcelona and Valencia, for example, are introducing smart meters and digital apps to monitor consumption, detect leaks and encourage a more efficient use of resources.

These technological tools represent progress towards a more inclusive, conscious and technologically advanced water management, capable of strengthening social resilience in the face of increasing water scarcity.

1.4 The role of Industry and Production System

Water is a strategic resource, not only for the environment and society, but also for the Spanish production system, **directly influencing the productivity, competitiveness and sustainability of key sectors**.

Agriculture is the sector that uses water the most, absorbing **about 70% of national water consumption**, mainly directed to intensive irrigation (INE, 2023).

This is followed by the **energy sector**, which uses **between 10 and 15% of water resources** for cooling heating systems, and the **manufacturing industry**, which is responsible for a further **8-10% of total consumption**, particularly in the textile and chemical sectors. **Tourism** also contributes significantly to water demand, with seasonal peaks in coastal and island areas (Balearic and Canary Islands), where supply often depends on desalination plants and reuse systems.

From an environmental point of view, **industrial activities remain a source of pressure on water quality**: according to the European Pollutant Release and Transfer Register (E-PRTR), discharges of wastewater containing nitrates, phosphates and organic compounds require constant monitoring. However, several industries are adopting circular economy strategies and advanced technologies to reduce their water footprint. *Heineken España*, for example, has reduced its consumption by 43% thanks to leak detection and process optimization systems, while *Cosentino* (Almería) reuses 99% of its process water, creating an almost closed cycle. *Iberdrola* also invests in desalination and reuse of wastewater, limiting freshwater withdrawals for energy production.

An increasingly important aspect is **virtual water.** Spain is an exporter through agricultural products such as vegetables, fruit and wine, with an estimated **volume of more than 30 billion m^3 per year** (Chapagain & Hoekstra, UNESCO-IHE, 2020). This data highlights the strong dependence of the country system on water resources for its economic competitiveness and the need to integrate the concept of water footprint into industrial and commercial policies. The increasing adoption of **ESG standards and certifications** such as ISO 14046 is helping to improve transparency and sustainable water management in production processes, strengthening the role of industry as a key player in the transition to a more water-efficient economy.

1.5 Technological and Digital tools for Water Management Evaluation

Water management in Spain is experimenting a profound transformation thanks to the **integration of advanced technological and digital tools**, which allow an increasingly precise, efficient and sustainable resources assessment.

Water companies and authorities are adopting standards such as ISO 14046, which measures the water footprint of production processes, promoting water reuse and industrial efficiency. Technologies such as membrane reactors (MBRs) and reverse osmosis enable wastewater treatment and recycling, reducing the need for fresh water, especially in the food, textile, and beverage industries.

At the same time, the adoption of smart water meters and smart water networks allows real-time monitoring of consumption, automatic detection of leaks and optimization of operations.

At the territorial level, Spain uses **remote sensing technologies and GIS systems**, such as the *Sistema de Información del Agua* (SIA), integrated with satellite data from the European Space Agency's Copernicus programme, to monitor soil moisture and irrigation management in the most sensitive agricultural areas, such as Andalusia and Castilla-La Mancha. The use of **Artificial Intelligence** (AI) and **machine learning** by institutions enables predictions on water demand and detection of leaks in the distribution network, while **IoT sensors** installed by operators such as *Suez España and Aqualia* constantly monitor water flows, pressure and quality, reducing leaks by up to 20%.

Further innovations include **digital twins, virtual models of water systems** that simulate operating conditions in real time, enabling predictive maintenance and analysis of extreme climate scenarios.

The integration of this data within cloud-based **Decision Support Systems** (DSS), coordinated by the MITECO, ensures faster and more informed management of emergencies such as droughts or floods. Together, these technologies represent the core of water management in Spain, based on digitalization, sustainability and resilience.

2. Italy

In Italy, sustainable water management is generally monitored through a set of integrated indicators, many of which are defined in the context of the **Water Management Plan and Goal 6 of the United Nations 2030 Agenda**.

The Water Management Plan uses the DPSIR (Driving Forces, Pressures, State, Impact, Response) model to classify environmental indicators. Some key indicators include the percentage of ecological status of river, coastal-marine, and transitional water bodies, the percentage of chemical status of water bodies, the number of water bodies in good or high status, anthropogenic pressures (discharges, withdrawals, land use), the efficiency of the sewerage and purification network, and management responses such as investments, intervention plans, and governance.

ISTAT monitors nine official indicators as part of Goal 6 "Clean water and sanitation." These include sewerage service coverage, which measures the percentage of the population served; the efficiency of drinking water distribution networks; per capita drinking water withdrawal; the quality of inland and marine waters; and integrated water resource management. For the latter, Italy has significantly improved, moving from 55 to 78 on a 0/100 scale between 2017 and 2023.

Also important are the indicators related to **Measure 4 of the PNRR**, which monitors the effects of investments aimed at improving the ecological and chemical quality of water, management at the river basin level, more efficient allocation between urban, agricultural, and industrial sectors, mitigation of hydrogeological risks, and protection of aquatic biodiversity.

An important document that contains a significant set of water-related indicators is the **ISPRA** National Hydrological Balance. This is a technical-scientific tool that assesses the natural availability of water resources in Italy on a monthly and annual basis. It is used to monitor and manage water at the national and regional levels. It estimates precipitation, evapotranspiration, renewable water availability, and drought and aridity indicators.

It contains maps and tables of the hydrological balance components from 1951 to 2023, as well as monthly and annual historical series at the national, regional, and river basin district scales. It also includes indicators such as the FAO-UNEP aridity index, the hydro-climatic balance, and drought indicators calculated on various time scales. It is important because it supports water planning and sustainable resource management, helps understand the effects of climate change and drought, and provides useful data for agriculture, energy, environmental protection, and risk management.

2.1 Environmental indicators

Environmental indicators for sustainable water management are essential tools for monitoring and controlling the state of water resources, enabling public policies to be guided accordingly. They are defined in various regulatory and strategic contexts, including the **Water Management Plan, Legislative Decree 152/2006, and Goal 6 of the 2030 Agenda**.

Among these indicators, the ecological and chemical status of water bodies is particularly important, indicating the percentage of surface water bodies in good ecological status and the percentage of water bodies in good chemical status. It provides a classification based on biological, chemical, and hydromorphological parameters.

The pressures and impacts of urban and industrial discharges are monitored in terms of quantity and quality, providing information on water withdrawals for civil, agricultural, and industrial use, and on land use in the respective river basin. Hydrogeological risk and the frequency of extreme events are also monitored.

A significant indicator is the efficiency of water services: it measures sewerage coverage in terms of the percentage of the population served, the efficiency of the distribution network, including water losses, and the purification capacity of urban wastewater.

Data on integrated water resource management are also important, highlighting coordination between local, regional, and national authorities and the integration of water management and land-use planning.

Finally, information on consumption and per capita withdrawal is also significant, reporting the liters of drinking water supplied per inhabitant per day and the total volume withdrawn for drinking purposes.

2.2 Economic and Legislative indicators

The economic and legislative indicators relating to water reflect complex, multilevel management, with significant environmental, social, and economic implications and diversities.

Among the economic indicators, the "Added value of the water sector" is used: in 2022, wastewater management generated approximately **€6 billion** in added value, equal to 25% of national environmental spending. The number of water service providers is also taken into account: in 2022, there were more than 2,000 for civil use.

Water losses are indicative, with a national average dispersion of 42.4%. Regarding sewerage and purification coverage, Northern Italy excels, as evidenced by the Aosta Valley, where sewerage coverage is 97.9%, while Sicily and Calabria remain below 80%. Finally, significant information is provided by mineral water consumption: 82.6% of Italians consume bottled water, with peaks of 92% in Umbria, often due to distrust in the quality of tap water.

Regarding legislative indicators, first and foremost is Agenda 2030 - Goal 6, in relation to which Italy monitors equitable and sustainable access to water as part of the "Sustainable Development Goals," with a focus on efficiency, safety, and resilience. This is followed by EU Directive 2020/2184, which strengthened monitoring and transparency requirements regarding drinking water quality, promptly implemented in Italy with various regulatory updates. Also relevant are the Galli Law (Law 36/1994), which introduced the concept of "Integrated Water Service" and defined the Optimal Territorial Areas (ATO), as well as Legislative Decree 31/2000, which regulates the quality of water intended for human consumption and which was integrated by the Ministerial Decree of 14 June 2017, with the provision that the Water Safety Plans (PSA) also be based on risk analyses along the entire supply chain.

2.3 Social indicators

Social indicators relating to water reflect aspects related to access, quality, management, and perception of water resources. The main ones are listed below.

Regarding access and availability, drinking water withdrawal is monitored: in 2022, 9.14 billion cubic meters of water for drinking purposes were withdrawn, 91% of which was managed by specialized operators. Water rationing is also monitored: in 2023, a third of southern Italian cities adopted rationing measures, with extreme cases such as Agrigento (208 days of suspension).

Regarding water quality, significant data is provided by the microbiological and chemical tests performed regularly by the Ministry of Health, as well as by the "Water Safety Plans" (PSA), introduced in 2017, which provide a risk-based approach throughout the water supply chain.

In terms of services and infrastructure, sewerage coverage is significant, reaching 94.6% in the Northwest, while in Sicily it stands at 76.5%. The level of wastewater management is also significant.

2.4 The role of Industry and Production System

Italian industry plays a crucial role in the management and use of water resources, both as a consumer and as a promoter of innovation and sustainability.

Regarding the economic and productive impact, water accounts for **19% of Italy's GDP**, enabling an industrial and service supply chain that generated €367.5 billion in added value in 2022. In this context, water-intensive manufacturing companies - such as textiles, chemicals, metals, paper, plastics, and agri-food - produced €252.1 billion in added value, again in 2022. A total of approximately 333,000 companies are involved in the water supply chain, with **3.5 million employees** involved in some way in a conceivable extended water supply chain.

The most affected economic, productive, and service sectors are agriculture, the leading sector in terms of water withdrawals, accounting for 56% of the total; Industry, which accounts for 13% of total water consumption, with peaks in Lombardy, Emilia-Romagna, and Veneto. Finally, energy, which uses water for the production and distribution of electricity, gas, and steam.

In short, the entire Italian production system is likely to influence, in the immediate future and also in the medium and long term, the sustainable management of wastewater and the ecological transition, with significant technological innovation.

2.5 Technological and Digital tools for Water Management Evaluation

Technological evolution, especially in the digital context, and now following the emergence of artificial intelligence, is also beginning to have a significant impact on the management and governance of water resources in Italy, with significant results in the monitoring, evaluation, and optimization of the entire water cycle. For example, some of the most significant tools currently in use are listed below, for which investments are planned under the PNRR, which has allocated funds to digitize 25,000 km of new water networks, as well as programs such as REACT-EU, which promote the districting and digital tracking of networks.

Regarding digital technologies and tools for water management, the following can be mentioned:

- Smart Water Networks: these are intelligent water networks with IoT sensors for real-time monitoring of water flow, pressure, and quality: they enable the detection of leaks, spills, and any other operational anomalies;
- Big Data and Data Science, geared towards predictive analytics to plan maintenance interventions and optimize resource use. They are important tools for strategic decision-making, especially when linked to the evaluation of environmental and management data;
- Artificial Intelligence, using algorithms to simulate water scenarios, forecast consumption, and manage emergencies. It is also used to control flow and wastewater quality;
- Smart Metering, or the use of intelligent meters to monitor domestic and industrial consumption, especially for informed and transparent water management;
- GIS systems and ground-penetrating radar, with digital mapping of water and sewerage networks: they are useful for precisely locating faults and for land-use planning;
- Satellite technologies for monitoring surface and groundwater: they are an excellent tool for hydrogeological management of territories and for preventing water-related risks;
- Blockchain and cybersecurity technologies, which enable data traceability and digital infrastructure security. They are essential for ensuring the completeness and integrity of information and defense against intrusions or attacks;
- Digital Twins, or digital twins of water infrastructure for running simulations, experiments, and virtual tests. They enable the prediction of potential issues and optimization of operational processes.

Regarding future water resource management projects, Italy is investing vigorously in the modernization of the water system: future projects focus on sustainability, resilience, and digitalization. Below is a list of some of the most significant.

OSWI 2025: is an Integrated Water Service Observatory, a research and consulting initiative that analyzes priority investments in the water sector and aims to generate economic, social, and environmental benefits through modern infrastructure and innovative financing strategies.

PNRR investments for water. In this regard, the National Recovery and Resilience Plan has allocated over €1.8 billion for water projects, of which **€771 million for drinking water, €500 million for irrigation, and €571 million for mixed use**. The objectives are to improve access to safe water, reduce losses, digitize networks, and ensure sustainability.

The initiatives address primary water infrastructure. These include 75 projects to strengthen and complete diversion, storage, and supply systems, while enhancing issues related to climate resilience, security of supply, and overcoming the emergency scenario. Particular attention is paid to Southern Italy, with the completion of large, unfinished plants.

In summary, the key themes of future projects are, in short, digitalization, sustainability, territorial equity, and climate adaptation.

3. Cyprus

3.1 Environmental indicators

Cyprus maintains generally a high water quality, particularly along its coastlines. According to the European Environment Agency, 99.3 percent of monitored coastal bathing waters met “excellent” quality standards in 2023. Inland waters, however, present more challenges. The 2021 River Basin Management Plan (RBMP) reported that only 48 percent of surface water bodies achieved “good” ecological status, largely due to nutrient pollution from agriculture and urban runoff. A constant effort is necessary in order to reach and maintain a high quality of internal waters, also having in mind the protection of biodiversity.

In terms of biodiversity, in facts, several freshwater ecosystems in Cyprus are under stress. For instance, eutrophication in lakes like **Paralimni** and **Oroklini** has affected sensitive species, reducing aquatic diversity and encouraging the growth of algae and invasive plants. Key habitats such as salt marshes and coastal wetlands are monitored under Natura 2000, with documented declines in water bird populations due to habitat disturbance and changing hydrological conditions.

3.2 Economic and Legislative indicators

A national study conducted in 2022 found that Cyprus's municipal water tariffs generally reflect the full cost of supply, including infrastructure and treatment. For household users, the average water price is **approximately €1.20 to €2.00 per cubic meter**, depending on the municipality and consumption tier. In contrast, irrigation water costs about **€0.17 to €0.24** per cubic meter, heavily subsidized by the government to support the agriculture sector.

The benefits of public investment in water infrastructure are substantial. Projects such as the Southern Conveyor Project and large-scale desalination plants have reduced the country's dependency on rainfall and improved supply reliability. A 2023 loan agreement with the European Investment Bank allocated €100 million for wastewater network upgrades and flood protection, expected to improve service for over 500,000 residents and reduce environmental impacts.

Private sector involvement remains limited, but private hotel groups and agri-cooperatives have independently funded grey water reuse systems and smart irrigation technologies.

3.3 Social indicators

Access to safe drinking water in Cyprus is nearly universal, with 99.9 percent of the population connected to improved water supply systems according to Eurostat. However, territorial inequalities still exist, particularly in remote villages and mountainous regions where supply interruptions are more frequent due to aging infrastructure and limited maintenance capacity.

A 2021 survey by the Cyprus Energy Agency found that over 65 percent of residents in urban areas are aware of water conservation policies, but this drops to around 40 percent in rural communities. Public engagement programs, such as WDD's "Save Water" campaign, have improved awareness in schools and municipalities, but evaluations show mixed success in changing long-term behavior.

3.4 The role of Industry and Production System

As everywhere in the world, also in Cyprus water constitutes an essential element for agriculture, energy, manufacturing, and tourism.

In Cyprus, agriculture is the predominant consumer of water resources, accounting for approximately 70% of total water use. This significant demand is primarily due to irrigation needs for crops such as citrus fruits, potatoes, and vegetables. Despite its substantial water consumption, agriculture contributes a relatively small portion to the national economy, highlighting the importance of improving water use efficiency in this sector.

The domestic sector follows, utilizing about 20% of the country's water resources. This includes household consumption and municipal services.

The tourism industry, a vital component of Cyprus's economy, consumes around 5% of the total water supply. With over 4 million tourist arrivals recorded in 2024, the sector places considerable seasonal pressure on water resources, particularly during the summer months.

Industrial activities, including manufacturing and energy production, account for approximately 1% of water usage. Water in these sectors is primarily used for processing, cooling, and cleaning purposes.
The reliance on desalination has increased to meet the water demands across all sectors. Currently, Cyprus operates several desalination plants, collectively producing a significant portion of the country's potable water supply. This shift towards non-conventional water sources underscores the need for sustainable water management practices across all industrial sectors.

Companies are quite aware of the importance of water in the industrial context of Cyprus and continuously work towards new solutions and industrial best practices. Many of them optimize their water resource usage. Among these:

- **<u>Aphrodite Hills Resort</u>**

Aphrodite Hills Resort in Paphos uses treated wastewater for irrigating its golf course and landscaped areas. This practice is part of the resort’s participation in sustainable water management efforts promoted by the Cyprus Sustainable Tourism Initiative (CSTI).

CSTI confirms that treated effluent reuse is implemented by several hotels and resorts to reduce reliance on potable water, especially during the dry season.

- **Lanitis Bros Ltd**

Lanitis Bros, the official bottler of Coca-Cola products in Cyprus, has been recognised for its environmental initiatives as part of the Coca-Cola Hellenic Bottling Company (CCHBC). In its sustainability reports, CCHBC documents the use of water-saving technologies and adherence to ISO 14001 environmental management standards, including water efficiency targets and internal audits. Although the Cyprus facility is not profiled in detail, it is included in group-wide performance assessments.

- **Cyprus Sustainable Tourism Initiative (CSTI)**

CSTI supports the tourism sector in adopting environmentally responsible practices. It provides guidance and support for implementing grey water recycling, smart irrigation, and low-flow water fixtures in hotels across Cyprus. CSTI collaborates with businesses to reduce water consumption and has showcased best practices through EU-funded programs and case studies.

- **Cyprus Agricultural Research Institute (ARI)**

The Cyprus Agricultural Research Institute conducts applied research on drip irrigation, deficit irrigation, and fertilizing irrigation techniques. These methods are widely promoted by the Institute to improve water use efficiency in agriculture, particularly in vineyards, citrus orchards, and vegetable crops. ARI also collaborates with EU research programs focused on precision agriculture.

These best practices can be replicated given some appropriate and necessary conditions:

- **Ezousas Artificial Groundwater Recharge**: To replicate this project, several key conditions must be met. First, there must be a reliable source of treated wastewater with adequate quality for aquifer recharge. The area also needs suitable hydrogeological conditions, such as permeable soils and aquifers that allow efficient infiltration and storage. Institutional capacity is essential to monitor water quality and maintain the infiltration infrastructure. Finally, regulatory support and public acceptance are critical, especially where the recharged groundwater is used for agriculture.
- **Smart Irrigation for Key Crops**: Replication of this approach requires access to accurate satellite imagery, weather data, and local crop models to generate effective irrigation schedules. Farmers must have basic digital tools (e.g., smart phones) and be open to using new technologies.

- It's also essential to have extension services or training programs that help farmers interpret and apply the data. In regions with similar crops and climate conditions, the system can be adapted with relatively low upfront investment, especially where public or cooperative support exists.

3.5 Technological and Digital tools for Water Management Evaluation

The necessary research for solutions to water issues in Cyprus has pushed the authorities of Nicosia and the local governments to enhance the use of technological and digital tools to improve the water management, like the Geographic Information System (GIS), the Remote Sensing, the Decision Support Systems (DSS), and the Internet of Things sensors (IoT).

Geographic Information Systems (GIS) and Remote Sensing

GIS is widely used in Cyprus for spatial analysis and planning in water management. One prominent example is a study of the Yialias River basin, which applied GIS to assess how urban expansion and agricultural changes have increased flood risk. By integrating land use data with hydrological models, researchers identified specific areas where runoff has intensified, informing local flood mitigation planning. GIS is also used by the Water Development Department for infrastructure mapping and monitoring water quality trends.

Remote sensing tools

Remote sensing tools have been used in Cyprus to monitor surface water availability and drought impacts. For instance, satellite imagery from the Sentinel and Landsat programs is processed to detect changes in reservoir levels and vegetation stress across agricultural zones. These data support national drought early warning systems and guide water allocation during dry seasons.

Decision Support Systems (DSS)

An intelligent hybrid DSS was developed by researchers in Cyprus to optimize water use in semi-arid environments. This system combines real-time meteorological inputs, hydrological models, and user demand data to support operational decisions. It was piloted in scenarios involving agricultural water allocation and seasonal planning. The model helps simulate water demand and supply imbalances and supports policy testing under various climate and land use conditions.

Internet of Things (IoT) Sensors

Cyprus-based innovation center CyRIC has introduced smart water management solutions using IoT. Their platform includes wireless sensors that measure flow, pressure, and leakage in real time. These systems have been tested in urban distribution networks and agricultural settings to detect leaks and monitor usage. One notable application is in greenhouses, where sensors track soil moisture and automate irrigation to reduce water waste.

Country	Water Infrastructure & Management	Efficiency & Performance	Vulnerabilities	Resilience & Adaptation Measures
Spain	Over 1,225 major works including large dams and reservoirs (total storage ~56,000 hm^3); advanced ETAP potable water treatment plants; ~2,000 wastewater treatment plants with high reuse; world leader in desalination (>700 hm^3/year) and reclaimed water reuse (up to 98% in Murcia). Basin management by Confederaciones Hidrográficas.	Average Non-Revenue Water loss ~22%; urban supply about 4 billion m^3/year; benchmarking via SIBEA; digital monitoring and network renewal underway.	Climate-related risks: prolonged droughts, desertification, floods; aging infrastructure requiring maintenance; water tariffs below EU average; sector debt ~€100 billion; low public-private integration.	Strong digitalization of systems; expanding unconventional water sources; hydroelectric and energy storage integration; hybrid modeling for infrastructure safety; focus on sustainability and multifunctionality.
Italy	Complex aqueduct networks (e.g. Peschiera), ~4,860 hydroelectric plants mainly Alpine; over 18,000 wastewater plants unevenly distributed; Integrated Water Service managed mainly by	Non-Revenue Water loss extremely high (~42.4%); sewer coverage varies (high in North, low in South); user satisfaction >90% in North, <70% elsewhere; wastewater	Aging infrastructure (22% pipes older than 50 years), significant water losses (~6.5 billion m^3 annually); incomplete projects (11% completion rate of EU-funded); pollution risks; low investment (1–2%	Emphasizing wastewater reuse and rainwater harvesting; urban and land use planning reforms; increasing monitoring tech adoption; strengthening governance between

Country	Water Infrastructure & Management	Efficiency & Performance	Vulnerabilities	Resilience & Adaptation Measures
	numerous small public entities.	reuse very low (~4%).	public spending); drought and flood risk high with costs ~€30 billion in 5 years.	local and national levels.
Cyprus	108 dams and reservoirs (~330 million m^3 capacity); Southern Conveyor Project; 4 large desalination plants plus 15 mobile units; expanding wastewater reuse; centralized Water Development Department manages infrastructure.	NRW losses 20–30%; reservoir levels low (~24.6% capacity); desalination daily capacity ~220,000 m^3; wastewater treatment coverage high (~98%).	Severe water scarcity and drought; high dependence on desalination and unconventional sources; low public engagement beyond urban areas; limited local enforcement capacity.	National Adaptation Strategy focused on efficiency improvements, nature-based solutions, restoration, centralized crisis response; plans for new desalination plants by 2030.

Table 2: Comparative Summary of Water Infrastructure and Management Systems in Spain, Italy, and Cyprus

Environmental challenges and Climate Change

1. Spain

1.1 Projections

Reports released by the IPCC, data shared by the EU's Copernicus missions and climate projections from the Spanish Meteorological Agency (AEMET) paint a picture of **significant changes in Spanish weather patterns due to climate change**. In general, seasonal patterns are projected to shift, with earlier springs, longer summers and shorter winters, potentially altering ecological and agricultural cycles.

According to AEMET, the **average temperature** in the country **has already risen by 1.7 °C since 1960**, and projections indicate that this trend will continue to intensify in the coming decades[3].
Overall projections for the period 2081–2100 compared to 1850–1900 estimate an increase of between 1.4 °C in the best-case scenario and 4.4 °C in the worst-case scenario, accompanied by an increase in potential evapotranspiration[4].

Projections of annual precipitation show a decline of up to 20–30% in many regions, especially in the south and south-east, with more marked reductions in summer and slight increases in winter in the north. However, rainfall is expected to be **more concentrated and extreme**, increasing the possibility of flash floods such as the DANA phenomena that hit Valencia in October 2024, killing 228 people and devastating more than 20 municipalities.

The predictable consequences of these changes include the so-called **mega-droughts** - that appear as longer, more frequent and more intense drought - generating negative impacts on agriculture, water availability and forest ecosystems; just think of the devastating fires in Castilla y León and Galicia in the summer of 2025.

Correspondingly, **heatwaves** will be more intense and longer lasting as the one recorded in July 2022 in Andalusia, with temperatures exceeding 45 °C. These intense temperatures, which are concentrated in urban centres, pose a risk to public health, especially for vulnerable individuals such as the elderly and children.

Furthermore, **rising sea levels** are pressuring on the country's coastlines, particularly in the Ebro Delta, worsening erosion, flooding and saltwater intrusion into aquifers.

[3] AEMET, *El informe sobre el estado del clima en 2020 en España muestra que fue el año más cálido y se dispararon los récords de calor:* https://www.aemet.es/es/noticias/2021/05/informe_estado_clima_2020
[4] IPCC 6, *Sixth Assessment Report:* https://www.ipcc.ch/assessment-report/ar6/

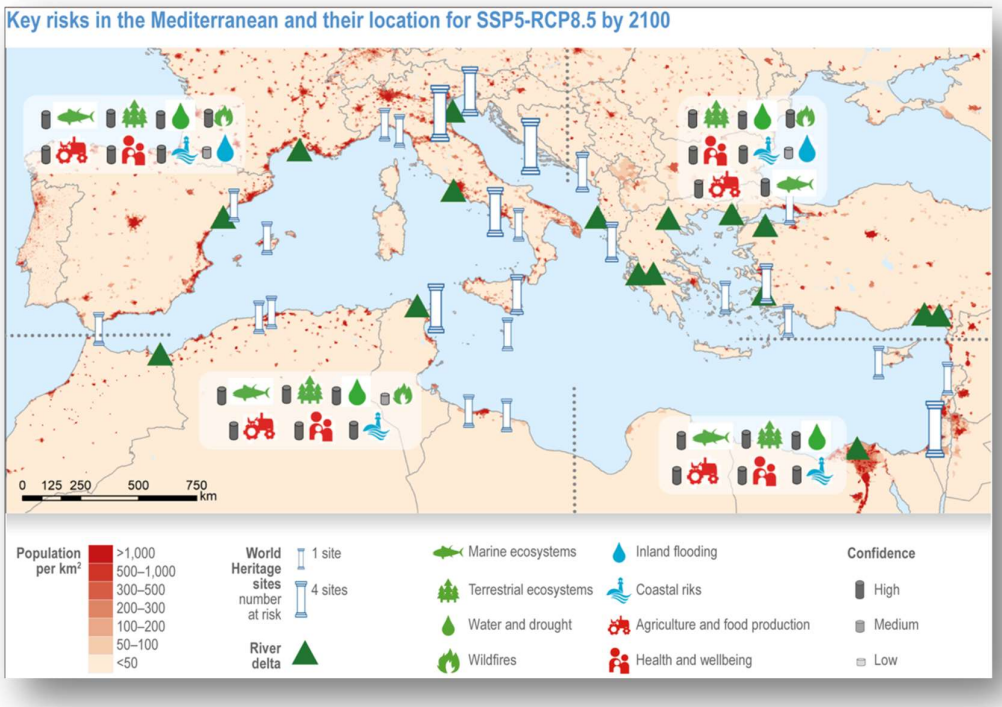

Figure 2 - Key risks in the Mediterranean and their location across the Mediterranean region[5]

1.2 Vulnerabilities

The previously exposed scenario on climate projections in a context of climate change evidently places Spain in a situation of vulnerability in relation to the availability of water resources.

First of all, renewable **water resources will be reduced** especially in the south and east of the country (notably the Guadalquivir, Segura and Júcar basins), due to the decrease in precipitation and the increase in temperatures, while the increase in evapotranspiration will rise the agricultural and ecological demand for water.

[5] Figure CCP4.7 in Ali, E., W. Cramer, J. Carnicer, E. Georgopoulou, N.J.M. Hilmi, G. Le Cozannet, and P. Lionello (2022). Cross-Chapter Paper 4: Mediterranean Region. *IPCC*. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

Drought events will put stress on irrigation systems, hydroelectric production and water supply, also aggravating the deterioration of water quality due to lower dilution capacity; higher temperatures and more frequent **fires** will increase the load of sediments and contaminants in water bodies.
Like natural resources, **infrastructure** will be increasingly exposed to climate change. Urban drainage systems risk being overburdened in intense rainfall by exposing cities to flooding; heat waves impair construction and transportation materials, while dams, reservoirs and water treatment plants will become less reliable due to altered hydrological regimes and damage caused by extreme events.

The **vulnerabilities of the water sector due to climate change also affect economic and social domains.** Agriculture will face increased water stress, damaging production and quality.

The tourism sector will potentially be able to suffer income losses due to strong heat waves, water scarcity which would make supply and distribution more difficult; similarly, ski resorts are exposed to reductions in attendance in the Pyrenees and Sierra Nevada due to the decrease in the snow season.

The energy sector may risk a decline in hydroelectric production, in the cooling process for thermal power plants. As already anticipated, public health will be threatened by rising temperatures that create nighttime heat waves with tropical (>20 °C) and scorching (>25 °C) nights, aggravating mortality from cardiovascular, respiratory, kidney or mental diseases, especially among the elderly, children and outdoor workers.

Biodiversity and ecosystems will come under severe pressure from dwindling surface and groundwater resources, so that the survival of some species will be at risk; as fires increase there will be a reduction in forest cover, decreeing habitat destruction and a reduction in CO2 absorption capacity.

1.3 Adaptation Strategies

Spain is facing the cross-cutting challenges posed by climate change. As already partially mentioned, in order to address the various impacts, Spain has already introduced a range of adaptation strategies in different sectors, with the aim of reducing risks and strengthening the resilience of the country and its communities.

The **Plan Nacional de Adaptación al Cambio Climático** (PNACC) 2021–2030 promotes the integration of climate risks into planning and decision-making processes, the improvement of climate data forecasts and early warning systems, and coordination between the various levels – ministries, regional governments and stakeholders.

The **2021 Climate Change and Energy Transition Act** also imposes legal obligations to incorporate climate change adaptation in urban planning, water policy, coastal protection and infrastructure design.

As previously stated, within the domain of sustainable water management, river basin management plans and drought and flood risk management plans represent pivotal components for the promotion of prevention and adaptation strategies.

Among the priorities for addressing structural water scarcity, caused by a combination of low rainfall and high-water demand from intensive agriculture (as in the communities of Murcia and Almeria), Spain has adopted an integrative approach by developing various **diversification strategies**.

In order to optimise water use, several experiments have been conducted using innovative agronomic and irrigation techniques [6] in various Spanish institutes, such as IRTA and CEBAS-CSIC in Murcia.

More efficient water management also requires more **modern irrigation systems**, such as sprinkler and localised systems, encouraging a reduction in water consumptive use and avoiding a cycle that risks creating greater water consumption.

The so-called *Jevons paradox* occurs when the modernisation of irrigation, which is more accessible, efficient and economical, leads to an increase in the area to be irrigated and therefore in the amount of water needed to meet the water requirements of crops.

In Spain, the application of **precision irrigation** is encouraged in order to ensure more sustainable water use, as it respects the real needs of the crop.

[6] https://www.irta.cat/es/investigacion/proyectos/?programa=68785; CEBAS-CSIC: Reutilización de aguas residuales en la agricultura de áreas urbanas y periurbanas (REOPTIMA); Intelligent Reclaim Irrigation System (IRIS); Sustainable Use of Irrigation Water in the Mediterranean Region (SIRRIMED); Sustainable Orchard Irrigation for Improving Fruit Quality and Safety (IRRIQUAL)

This type of system relies on sensors that measure sap flow, trunk diameter fluctuations, thermography, soil matric potential at different depths and the water status of the plant to optimise the timing and quantity of water to be applied.

Similarly, remote sensing techniques using drones and satellites are used to determine water requirements, any water stress and variability in cultivation, supporting irrigation decisions.

In addition to precision irrigation, the use of **deficit irrigation and controlled deficit irrigation** is becoming increasingly widespread. These agronomic techniques aim to achieve water efficiency by reducing the amount of water supplied to plants, either in a controlled or uncontrolled manner, during specific periods of their phenological cycle.

The CEBAS-CSIC research centre in Murcia has carried out research projects on various crops, including lemons, mandarins, peaches, olives and pistachios, to identify the best phenological period for applying deficit irrigation with reused water and to analyse the product according to the principles of productivity and quality, achieving very optimistic results.

Alongside the study and application of more efficient irrigation techniques, Spain is a European leader in the use of unconventional water resources, including for irrigation purposes.

The **utilisation of wastewater for irrigation** – and for urbanistic purposes - constitutes a further method employed in Spain to regulate water resources and exploit its various advantages, including the supply of nutrients present in reclaimed water (including nitrogen and phosphorus), greater reliability and regularity of the available water flow, and energy savings. This approach obviates the need for additional water supplies from areas further away than where the water regeneration plant is located.

In the context of reusing reclaimed water, it is imperative to acknowledge the potential health risks involved. To address this necessity, the development and implementation of risk analysis and assessment protocols, manuals and guides is essential. These tools – provided at international level from FAO and WHO - grounded in the principle of multiple barriers, serve as preventative management mechanisms. In order to further reduce health risks and protect agricultural production, progress is being made towards greater diversification and alternation of water sources of different qualities: reclaimed, desalinated and fresh water.

At present, 3,500 Hm^3/year are treated in Spain, of which 450 Hm^3/year are reused; 57% of this volume is reused in eastern Spain, and 98% is used for irrigation. Murcia, for instance, has achieved a rate of 102 Hm^3/year [7].

Another sector in which Spain stands out for its performance and innovation is **desalination**. Spain has 765 desalination plants (360 for seawater and 405 for brackish water), with an estimated annual production of around 600 Hm^3, which is essential in areas such as the Segura basin and the Canary Islands[8]. Large plants include Torrevieja, Valdelentisco and Águilas/Guadalentín.

The main use is for urban supply, especially in tourist areas, but desalinated water, often mixed with other water sources to reduce the presence of boron, is also used in agriculture to improve water efficiency. In particular, in the coastal areas of the arid Mediterranean region, and especially in south-eastern Spain, water demand is growing rapidly, driven by intensive agriculture and the tourism industry. The risks of desalination are well known and include depletion of aquifers, marine intrusion, loss of water and soil quality, damage to river ecosystems and wetlands, and even the sustainability of the land uses concerned.

The issue of groundwater exploitation is a matter to which Spain is devoting scientific and technological energy. The intensive or uncontrolled exploitation of these waters has the potential to engender a number of environmental issues and to diminish the available water supply. The Geological and Mining Institute of Spain (IGME), a national centre of the CSIC, an agency under the Ministry of Science, Innovation and Universities, has expressed concern over the state of groundwater bodies in the country. According to the latest hydrological plans, 44% of these bodies are in poor condition[9]. The disorderly exploitation of groundwater can pose a series of direct or indirect problems of a technical, environmental, social, economic, administrative and legal nature.
A highly effective economic water management tool in the face of overexploitation has been the **artificial recharge of aquifers**, which in Spain is still in its initial or experimental stages.

[7] Ministerio de Medio Ambiente y Medio Rural y Marino, *Evaluación ambiental estratégica del plan nacional de reutilización de aguas regeneradas:* https://cdn-portal-miteco-stage.adobecqms.net/content/dam/miteco/images/es/2009_p_006_documentoinicio_tcm30-97960.pdf
[8] AQUAE Fundación, *Plantas desaladoras en España:* https://www.fundacionaquae.org/wiki/plantas-desaladoras-en-espana/
[9] CSIC, *El IGME alerta del preocupante estado del 44% de los acuíferos de España* – 2024: https://www.csic.es/es/actualidad-del-csic/el-igme-alerta-del-preocupante-estado-del-44-de-los-acuiferos-de-espana

The concept of artificial aquifer recharge encompasses a multifaceted approach to water management, serving not only as a storage system but also as a strategy for mitigating the impact of marine intrusion. It functions as a system for the recovery and regeneration of wetlands, a technique for controlling erosion and desertification, and an effective method of water recovery.
In an era of growing concern regarding the availability of water resources, artificial aquifer recharge devices are being presented as a significant alternative to conventional water management systems in planning documents.
The implementation of a collaborative water conservation strategy, encompassing both water regeneration and reuse, in conjunction with AR systems, would signify an enhancement that would be capable of addressing the escalating demand for water.

Finally, **adaptive forest management** is a crucial approach to sustainable water resource management, integrating biodiversity conservation and improving water quantity and quality. In some areas, reducing tree density increases blue water availability and reduces the risk of fires, while balancing the goal of carbon capture. In this field, decision support models such as HYDROBAL, which simulates the water balance of forest ecosystems, particularly in semi-arid areas, are essential for assessing the impact of forest management on hydrological processes such as evapotranspiration, surface runoff and deep drainage.

The Mediterranean region is the most vulnerable to the effects of climate change.
In view of the worrying data, it is in the interests of Europe and the countries in the area to **strengthen cooperation and the exchange of data, information and know-how**, as well as **research opportunities** in the field of adaptation and resilience strategies.

Implementing this mutual collaboration cannot be the result of political cooperation alone, but also of the efforts of research institutes and bodies, as well as associations and platforms capable of creating multilateral contexts involving authorities, researchers and civil society.

2. Italy

2.1 Projections

In Italy, forecasts regarding environmental challenges and climate change outline certain critical issues but leave room for better management through targeted interventions. Below are some of the issues at stake.

Regarding climate change, the potential impacts and related future scenarios include rising temperatures; the expected increased frequency of extreme events such as heat waves, droughts, floods, and forest fires; the health risks resulting from heat waves and water scarcity; and the impact on agricultural productivity.

Among the priority environmental challenges, we can first identify decarbonization: Italy aims to reduce greenhouse gas emissions **by 55% by 2030** compared to 1990 levels, in line with the European Green Deal. This is followed by the need to adopt circular economy processes, in which separate waste collection, with subsequent waste recycling, is already well underway, although critical issues remain in the management of hazardous waste and land use. Biodiversity protection is also of considerable importance: to make it effective, coordinated actions are needed to conserve all natural assets to mitigate the threats posed by urbanization and the infrequent nature of initiatives undertaken to date.

Regarding energy transition and sustainability, Italy aims to achieve **30% of its energy mix from renewable sources by 2030** and has included in its National Strategic Plan 2023–2027 a target of 25% organic agricultural land by 2027, which is ahead of the European target. In terms of monitoring, ISPRA monitors 21 key environmental indicators, including air quality, land use, emissions, and water management. Finally, regarding governance, Italy aims for integrated policies based on a cross-sectoral and multilevel approach, involving regions, local government bodies, and citizens.

2.2 Vulnerabilities

In Italy, the main climate vulnerabilities arise from a combination of geographic, urban, and infrastructural factors that make the region particularly exposed to the impacts of climate change. The critical issues are numerous and significant.

Regarding hydrogeological risk and flooding, it should be noted that, according to ISPRA, over 7,400 municipalities are at risk of landslides or floods. Extreme events are much more frequent than in the past, particularly watercourse overflows affecting densely urbanized areas, while rainfall is increasingly concentrated in short periods, resulting in overloaded sewer systems.

Regarding heat waves and drought, a further increase in so-called tropical nights (**minimum temperatures above 20°C**) is expected. The south of the country is particularly vulnerable to prolonged drought, with impacts on agriculture and water resources.

Coastal erosion is also a significant concern, with nearly 18% of coastlines affected, and rising sea levels are threatening infrastructure, coastal ecosystems, and urban settlements.

Significant vulnerabilities relate to infrastructure that was not designed to withstand extreme weather events, with a high risk of damage and service disruptions, partly due to the lack of an integrated approach combining climate data, hydrogeological risk, and infrastructure priorities.

Certain vulnerabilities are significant according to sectoral classifications. These include agriculture, exposed to water stress, loss of productivity, and emerging plant diseases; population health, with an increase in heat-related diseases and air quality; and tourism, with an impact on seasonality and the attractiveness of destinations.

All of these vulnerabilities are at the heart of "Mission 2" of the PNRR, aimed at ecological transition and climate resilience.

2.3 Adaptation Strategies

Climate change has also led to an increase in adverse weather events in Italy, particularly in the quality and intensity of precipitation, which is increasingly episodic but also increasingly severe.

First and foremost, a more effective climate change adaptation strategy is needed. This strategy, though only slowly being implemented, includes:

- land management aimed at strengthening urban and regional planning to reduce the vulnerability of the most exposed areas, such as those prone to flooding or landslides;
- the use of European investments: the EU has allocated at least 30% of its 2021–2027 budget to climate objectives, including adaptation measures. Similarly, the European Investment Bank has increased its support for adaptation to 15% of its financing through 2030;
- achieving climate neutrality by 2050, reducing emissions and improving resilience to climate change;
- a capacity to respond to extreme events, with strengthened warning systems and rapid intervention in the event of weather emergencies and collaboration with scientific and meteorological bodies to predict and mitigate impacts.

It is clear that current phenomena affect various areas and regions unevenly, given the country's diverse climate vulnerabilities. Response capacities also differ depending on the respective levels of preparedness, both in terms of planning and the organization of emergency relief structures. The development of intervention and response practices, however, faces objective and difficult-to-overcome obstacles, such as complex and time-consuming bureaucratic procedures that slow down the implementation of national policies and measures; poor coordination between different administrative levels; inconsistent planning among the various competent bodies; scarcity or incompleteness of available data for different territorial areas; and insufficient funding sources with limited capacity to engage private resources. All this despite alarming data: in 2023, the increase in events compared to the previous year stood at between 130 and 140%, and the economic damage between 1980 and 2020 is estimated to amount to **approximately 90 billion euros**.

Generally and comprehensively, the country is moving toward climate change adaptation strategies through more careful management of urban areas and land, with planning and subsequent interventions in the most vulnerable and exposed areas; the identification of areas at highest hydrogeological risk, based on the probability of floods, overflows, and landslides; The use of European funds within the framework of the European Union's decisions regarding allocations for the 2021/2027 period, while the European Investment Bank has increased its support for climate change adaptation, raising financing to 15% through 2030.

At the national level, strategies follow and align with the European Union's objectives, particularly regarding climate neutrality - that is, achieving a balance between greenhouse gas emissions caused by human activities and their removal from the atmosphere - as well as resilience to climate change. To this end, Italy has defined the "National Energy and Climate Plan," which expires in 2030 and is currently being updated. This plan defines energy and climate policies within the context of the national contribution to the EU's common sustainability objectives. The plan's objectives include decarbonization, with the aim of reducing greenhouse gas emissions; energy efficiency, to rationalize and improve overall energy use; the development of renewable energy sources such as solar, wind, and hydroelectric; energy security to ensure continuity of supply, including through diversification; and finally, the improvement of the internal energy market by promoting various forms of competition and more effective and functional integration within the European context. The plan involves ministries, regions, municipalities, public bodies such as ENEA, GSE, and ISPRA, businesses, and citizens, through public consultations.

Another pillar of the national strategy is research and innovation, prioritizing and encouraging investments in clean and sustainable technologies. In this regard, significant progress has been made as a result of international political events: the Ukrainian crisis has prompted a rethinking of energy supply sources, which led to the REPowerEU plan, which dedicates a specific chapter to the "Recovery and Resilience Plan to accelerate the green transition and improve energy security."

Regarding more specific prevention activities related to the effects and damage caused by precipitation events such as heavy rain, floods, hailstorms, and thunderstorms, initiatives are undertaken at various institutional, administrative, and territorial levels. The Civil Protection Department manages the weather alert system, which, in the run-up to forecasted events, issues communications defining risk levels (green, yellow, orange, red), each of which is associated with prevention and intervention measures of varying nature and intensity. Each municipality must prepare a plan to manage hydrogeological and meteorological emergencies. Of particular importance are the activities of organizations such as ISPRA (nationally) and ARPA (regionally), which analyze the territory both for preventive purposes, to identify high-risk areas and predict extreme events, as well as to propose mitigation measures.

Structural projects are also underway at various levels, such as the construction of retention basins and flood channels; the consolidation of slopes and river banks; and the maintenance of basins and river courses.

Education and awareness campaigns play an important role. In this regard, the government's "I Don't Risk" campaign, which promotes best practices in the event of extreme weather events, is worth mentioning. It is important to raise awareness among the population by distributing guides and informational materials on what to do before, during, and after various phenomena. Regarding floods and inundations, the plan suggests preventive initiatives and measures for all economic operators and the public, including building maintenance; behaviors to be followed when an alert is issued; Conduct to be maintained in the event of a specific event; measures and behavioral practices to be adopted once the event has passed.

A particular case study in reducing the effects of adverse weather events is the "Less Risk in Tuscany" project, designed to strengthen the hydraulic and hydrogeological safety of the regional territory. Key elements of the plan include the established objective of reducing the risk of floods and landslides through training, planning, and collaboration between agencies; the training program, consisting of a series of meetings aimed at technicians, administrators, volunteers, and citizens; and the topics covered: hydraulic and urban planning, embankment issues and watercourse maintenance, territorial resilience practices, and awareness-raising in schools. The plan relies primarily on training and engagement, involving the Civil Protection Department, firefighters, geologists, architects, engineers, journalists, and students. It includes the awarding of prizes to virtuous municipalities that, by demonstrating good practices, will receive incentives in regional tenders. Specifically, a focus has been identified on the city of Prato, chosen as the starting point for the project, as it was severely impacted by recent and significant flooding. This is all part of a framework of institutional collaboration and social participation between the Region, municipalities, schools, and associations, enhancing the cultural profile of an initiative that aims to change the way citizens and institutions perceive and address risk.

3. Cyprus

3.1 Projections

The global climate change is producing changes in weather patterns everywhere; in Cyprus as well issues connected to the new climate situation are worsening. Climate models project that Cyprus will experience significant warming and reduced precipitation in the coming decades. By mid-century, average temperatures are expected to rise by approximately 3 to 5°C, with potential increases up to 7°C by the end of the century. Annual precipitation is projected to decrease by 10–50%, exacerbating existing water scarcity issues.

3.2 Vulnerabilities

Cyprus's water resources are particularly susceptible to climate change due to the island's semi-arid climate, which naturally limits water availability. Projected decreases in precipitation and increases in temperature are expected to reduce surface water availability and exacerbate groundwater depletion. These changes pose significant risks to agriculture, which relies heavily on irrigation, and to the overall water supply infrastructure.

Since the beginning of its history Cyprus has been vulnerable to water stress due to its dry climate and unpredictable rainfall. But recently, due to climate change, things got worse. One of the most severe episodes occurred in 2008, when the country faced an extreme drought that left reservoirs nearly empty. In response, authorities were forced to import drinking water by ship from Greece, highlighting just how fragile the water system was at the time.

Since then, significant progress has been made to strengthen resilience. The country has expanded its network of desalination plants, ensuring a more stable supply of drinking water that is less dependent on rainfall. At the same time, treated wastewater is increasingly reused for agriculture, helping to reduce pressure on natural freshwater sources.

The Water Development Department now conducts regular assessments to understand how climate change is likely to affect water availability.

These reviews look at trends like declining rainfall and higher temperatures, and they guide long-term infrastructure planning. While flooding is not as frequent a threat as drought, Cyprus has also put in place risk management strategies in areas more prone to sudden storms and runoff, especially in urban and coastal zones.

Together, these efforts have made Cyprus better prepared for future water crises, but ongoing adaptation is needed as climate pressures continue to grow.

3.3 Adaptation Strategies

Adaptation strategies are a key factor to face the new climate situation, and the phenomena that stem from it, like drought and floods.

To address these challenges, Cyprus has developed a National Adaptation Strategy focusing on enhancing water efficiency, protecting water quality, and integrating climate resilience into water policy. Key measures include improving water infrastructure, promoting sustainable water use, and employing nature-based solutions to mitigate flood impacts. Efforts are also being made to restore hydrological continuity and reduce artificial land use to enhance ecosystem storage capacity.

Country	Water Management & Governance	Key Infrastructures	Efficiency & Strengths	Main Vulnerabilities	Adaptation Strategies
Spain	Basin-level management; strong EU integration; coordinated national-regional planning	Advanced dam/reservoir network; top-tier desalination; widespread reclaimed water use	High reuse rates; diversified sources; climate-resilient upgrades	Declining water resources (esp. SE); droughts, mega-droughts; aging infrastructure; increased floods	Precision irrigation, modern urban drainage, aquifer recharge, forest-water management, integrated risk planning
Italy	Fragmented, mainly municipal	Extensive dams & hydro plants; large aqueducts;	Strong hydroelectric capacity;	High water loss (esp. South); frequent	Urban and land use planning reforms, EU-

Country	Water Management & Governance	Key Infrastructures	Efficiency & Strengths	Main Vulnerabilities	Adaptation Strategies
	systems, multilevel governance, slow integration of climate policy	growing but lagging WWTP network	good sewer coverage in North; increasing use of EU funds	floods/landslides; aging assets; slow project execution	funded adaptation, improved integration, risk management systems
Cyprus	Centralized under Water Development Dept.; full EU compliance; proactive climate planning	Dams/reservoirs; large desalination plants; expanding wastewater reuse	Secure urban supply via desalination and reuse; rapid crisis adaptation; stable monitoring	Drought, low rainfall, depleted reservoirs; high vulnerability to climate change; reliance on unconventional sources	National Adaptation Strategy; efficiency improvements, nature-based solutions, restoration, long-term crisis focus

Table 3: Comparative Overview of Water Management and Climate Adaptation in Spain, Italy, and Cyprus

Strategies for Sustainable Water Planning and Management

1. Spain

1.1 Adaptive strategies

Climate change and human activities are progressively altering the hydrological cycle, leading to the exposure to extreme events, as droughts and floods, that will become more frequent and intense.

This issue requests an immediate shift toward a **culture and application of integrated and adaptive risk management**, aimed at creating flexible and resilient approaches to ongoing changes in the environment.

The management of extreme events cannot be relied exclusively on infrastructure; it is necessary to build an **integrated and combined model** that includes prevention measures, knowledge and risk preparation, not only at the political level but also at the social level.

The **risk management cycle** extends from initial mitigation to temporary repairs (reconditioning) and final reconstruction, aimed at strengthening future resilience. There is therefore a need to move from a reactive crisis model to a proactive risk management model.

Spanish flood and drought risk management plans take an integrated and resilience-based approach that involves the various sectors concerned, from the political system and land management to information and community participation.

The culture of prevention in flood management involves not only structural interventions – such as the construction of dams and bypass channels – and the implementation of nature-based solutions – for example, lowering floodplains, rehabilitating wetland habitats, green roofs and permeable urban paving – but also sustainable land-use planning and a system for alerting, intervening and raising public awareness. In this matter, recent events, such as the DANA in Valencia, have shown that a lack of communication can have disastrous consequences in terms of destruction and death.

In the event of drought, demand management is crucial, with a focus on reducing consumption and improving the efficiency of distribution systems. In this context, nature-based solutions, such as the renaturalisation of vegetation, are considered effective solutions for runoff control and impact mitigation. For droughts, scientific research is key to enhancing prevention, technological innovation and cross-cutting management of the phenomenon.

Index measures such as the Standardised Precipitation Evapotranspiration Index (SPEI), for example, give a more precise and sensitive picture for monitoring and predicting drought conditions.

At the core of any climate change adaptation strategy has to be **a strong understanding and awareness of risk** - which is dynamic and continuously changing - in all its components: hazard, exposure, vulnerability, and capacity to act.

The **Sendai Framework for Disaster Risk Reduction** gives a global framework identifying priorities for action as understanding risk, strengthening governance, investing in risk reduction, and improving preparedness.

Climate change also requires a change of perspective in managing water resources, where availability and quality are threatened, not only by climate effects but the effect of human activities.

Integrated Water Resources Management (IWRM) is emerging as the most effective approach, promoting a holistic vision that reconciles environmental, economic and social objectives, recognising the interconnection of water issues with other sectors. This approach is based on the European Water Framework Directive, which seeks to balance economic, social and environmental needs to ensure sustainability and resilience.

1.2 Economic and Financial instruments

Economic and financial policies and instruments play an important role not only in supporting sustainable and transversal water resource management, but also in achieving collective objectives, while promoting resilient water use.

Today's challenge is to balance supply management, based on traditional infrastructure solutions, with demand management, which aims at efficiency and equity in water use and pricing.

Economic policies must seek, on the one hand, to **encourage innovation and resilient practices** with a view to supporting the circular economy; on the other hand, they must **counterbalance any negative impacts**. To this end, Spain can rely not only on regional and national subsidy mechanisms, but also on the various funds, strategies and the Common Agricultural Policy of the European Union. In the economic sphere, Spain applies various financial instruments to promote sustainable and resilient water policies.

Pricing policies are key to encouraging more efficient and responsible water use, as stated in the WFD, although high tariffs can generate negative impacts on employment and income, compromising the principle of equity.

Insurance, especially against the risk of extreme events, is another economic mechanism that can promote adaptation and risk mitigation through risk-based pricing, while reducing public compensation costs, as demonstrated by the cases in Castilla-La Mancha and Murcia.

In terms of **public and private investment**, Spain has encouraged the modernisation of irrigation systems through its Sustainable Irrigation Programme, with the aim of increasing water efficiency.

The challenge, as mentioned above, is to limit and discourage the increase in cultivated land, which would lead to greater water use. This risk can be reduced through economic instruments such as funding conditionality measures or, alternatively, incentives to guarantee ecosystem services.

In river basins such as the Duero and Ebro, **payments for ecosystem services** are being implemented on a trial basis, encouraging landowners and stakeholders to manage natural ecosystems in a way that protects water quality and quantity (Spanish Ministry for Ecological Transition, 2022).

In regions such as Murcia and Castilla-La Mancha, which suffer from severe water shortages, **water markets and banks** have been set up to allow the voluntary reallocation of water flows in response to both cyclical and structural changes in the availability of the resource.

In the banks, users are subject to the action of a regulatory body, which plays a centralising role in operations by acting as the sole and mandatory intermediary in all transactions.

Finally, in line with the EU's climate and sustainability objectives (EIB Annual Report, 2023) and to align with the European Investment Bank's support for **green bonds**, Spain has begun to use these innovative financing methods to fund water infrastructure projects.

1.3 Application of AI

Technological advances have enabled artificial intelligence to become a fundamental tool for the **digital transition of water management**, evolving from a reactive to a predictive model.

The strength lies in its ability to **process enormous amounts of heterogeneous data**, such as climate models, water uses and network conditions, which ensure improved decision-making processes. AI allows **dynamic models** for water use to be developed, responding more quickly and efficiently to different management needs, for instance, climate risk prediction, distribution service optimisation and infrastructure anomaly detection.

To this end, technologies such as **digital twins, virtual models** that simulate water systems in real time to optimise maintenance and analyse future scenarios, or even **sensor data analysis** and the use of **chatbots** based on natural language processing (NLP) to assist users in saving water, can be employed.

A concrete example of the application of AI in water resource management in Spain is the prescriptive management of Barcelona's sewerage network, where data- and AI-based models are used to predict sediment accumulation and dynamically plan maintenance.

Another case study is the use of drones with deep learning and artificial vision algorithms in the Ebro Delta to detect apple snail eggs, which is beneficial for the control and maintenance of the aquatic ecosystem.

The Catalan company *Eurecat* stands out in this field applying the concepts of sustainability and circular economy to the development of new technologies for improving the entire water cycle, which increases the competitiveness of many business sectors while benefiting society as a whole.

The centre has also laboratories and pilot plants, scientific equipment and data processing centres that enable it to tackle the present and future challenges of water management.

As a support for smart and effective water management, **Decision Support Systems** (DSS) can be relied upon. These integrate models, similar to forms of artificial intelligence, are capable of analysing and managing the complexity of water resource systems. These tools allow all elements relevant to basin management to be integrated: natural resources, infrastructure, multiple uses (agricultural, urban, industrial, recreational), environmental and economic aspects. Through simulation and optimisation models, DSSs provide the possibility to predict system behaviour, evaluate planning and management alternatives, analyse future scenarios and resolve conflicts between users.

The efficiency and security of these systems result from providing a scientific and transparent basis for political debate, helping decision-makers and stakeholders to build a shared vision and strategy.

In Spain, for example, the AQUATOOL system is widely used for the development of river basin management plans and the National Hydrological Plan. It has been used at the local level to resolve conflicts in the Júcar river basin and for the coordinated management of complex infrastructure such as the Tajo-Segura transfer.

1.4 Social participation

The implementation of IWRM requires a **participatory and dynamic approach**, involving users, planners, decision-makers and stakeholders with the ultimate aim of ensuring social acceptability and sustainable application of the strategies. The OECD has outlined the principles that should guide water resource management, and one of the pillars is trust and engagement, i.e. **collaborative governance**.

This approach aims to improve coordinated action through platforms for dialogue between the actors and sectors involved and to embrace the concept of **multi-level governance**, in which everyone is responsible for participating in decisions at all levels through various instruments, thus strengthening the sense of shared responsibility.

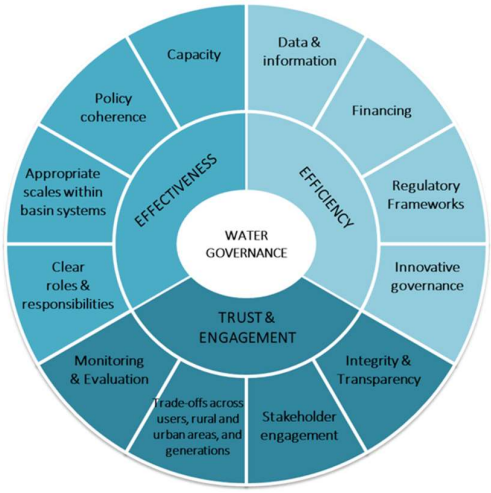

Figure 3 - The OECD Principles on Water Governance

The **Irrigation Communities** (*Comunidades de regantes*) are one of the main mechanisms for social participation in water management in Spain. These are public law entities that organise irrigators for the collective use of water for irrigation, regulating distribution, maintenance and contributions.

There are currently around 7.200 such entities,[10] managing over 70% of the national irrigated area (more than 3.7 million hectares). Although communities of irrigators are a valuable tool for participatory and collaborative management, they face new challenges, such as increasing water scarcity, the impacts of climate change, regulatory fragmentation and the need to strengthen transparency, training and technological tools to ensure the fair and effective participation of all members.

Thanks to the two EU funding programmes LIFE and Horizon Europe, Spain has launched several projects, not only at the infrastructural level, but also in the field of participatory and collaborative water governance.

Proyecto SUD'EAU ("Sustainable and participatory local management of water and rivers in south-western Europe"), promoted by the Navarre region, is an emblematic example of the application of the participatory process at the local level in the decision-making process for improving river areas and reducing flood risks (Lower Arga and Lower Aragon).

In order to promote local and regional initiatives for sustainable and participatory water management, in the context of the implementation of the WFD, a network of entities has been created for participation in sustainable water management.

Likewise, the institutions participating in the project have sought to increase knowledge about the technical and training tools of reference for the development of future actions in the field of sustainable water use, river basin management and local participation in water management. To this end, these information and training tools and the reference experiences in water and river management identified have been implemented on a pilot basis in the selected areas.

[10] FENACORE, *Una asociación apolítica para la defensa de los intereses y derechos del agua:* https://fenacore.org/fenacore/#:~:text=As%C3%AD%2C%20la%20mayor%C3%ADa%20del%20regad%C3%ADo,de%20Regantes%20existentes%20en%20Espa%C3%B1a.

National campaigns like "*Ahorrar Agua*" (Save Water), promoted by the Ministry for the Ecological Transition (MITECO), play an important role in educating citizens on sustainable water use and climate change impacts.

Several urban centres, including Barcelona and Valencia, have begun to adopt digital tools to encourage more direct user involvement through smart meters and mobile apps that monitor consumption, identify leaks and promote water-saving behaviour.

As mentioned, although the WFD requires citizen participation in water resource management planning, effective and direct public involvement remains limited in many areas. Awareness-raising initiatives are often localised, resulting in disparities in dissemination and involvement across the country.

2. Italy

2.1 Adaptive strategies

In Italy, adaptation strategies for the planning and sustainable management of water resources are implemented at various territorial levels: **national**, **regional**, and **local**. They primarily aim to counteract the negative effects of climate change, such as drought, flooding, and coastal erosion. Here are the main ones.

The national strategy is consistent with the European approach defined by the **Water Framework Directive (2000)**, which establishes a common basis for the protection and sustainable management of water resources.

This is a very important legislative act that values water as a heritage to be protected, recognizing that pollution and water management do not stop at national borders, thus requiring a coordinated response at the European level. Its main objectives are: protecting and improving the quality of surface water (rivers, lakes, coastal waters) and groundwater; achieving "good ecological and chemical status" of water within specific deadlines; managing water by river basins, transcending administrative and national boundaries; Promote sustainable water use, also considering the impacts of climate change.

It follows the principle of an integrated approach, as management is based on river basins, transcending political boundaries. It provides for public participation, involving citizens and stakeholders in management plans.

It is based on the criterion of monitoring and planning, with each Member State responsible for preparing river basin management plans and related programmes of measures. It also aims to prevent and reduce pollution, with particular attention to hazardous substances and discharges.

The Framework Directive is accompanied by other specific directives, which concern groundwater (2006), floods (2007), drinking water (1998), bathing water (2006), and nitrates (1991).

The European Directive was followed, for Italy, by the National Strategy for Adaptation to Climate Change (SNAC). This is Italy's guiding document for addressing the impacts of climate change, promoting adaptation actions at the national, regional, and local levels. It was approved in 2015 by the Ministry of the Environment. Its primary objective is to reduce the vulnerability of natural, social, and economic systems to climate impacts. It also aims to increase the resilience of local areas and communities and integrate adaptation into sectoral policies (**agriculture, health, transportation, energy**). Finally, it promotes scientific knowledge and climate change monitoring. The Strategy's priority areas of intervention are water resource management, prevention of hydrogeological instability, biodiversity protection, urban and infrastructure adaptation, public health and climate impacts, agriculture, and food security. The SNAC served as the basis for the **National Plan for Adaptation to Climate Change (PNACC)**, approved in December 2023, which defines concrete actions and operational tools to implement the strategy.

Water safety plans are adopted to assess risks throughout the entire water supply chain, from source to tap. They are recommended by the World Health Organization (WHO). In Italy, they are mandatory by law pursuant to European Directive 2020/2184 on drinking water.

The primary objectives of the plans are primarily aimed at **preventing contamination of drinking water** at every stage of the water system. They also include the identification and assessment of risks throughout the entire supply chain, including collection, treatment, and distribution. They then define corrective and control measures to ensure the sanitary safety of water and protect public health by anticipating problems before they occur.

The plans are structured around several key components, starting with an analysis of the water system with mapping of infrastructure and processes.

They also include an assessment of chemical, microbiological, and physical hazards and risks, and monitoring programs that define the parameters to be monitored, their frequency, and the tools used, along with corrective actions if limits are exceeded. Each plan is complemented by a communications project aimed at engaging institutions, operators, and citizens. The plans must be adopted by integrated water service managers, municipalities, local health authorities, and control and supervisory authorities.

Water-saving technologies, used in efficient irrigation systems, wastewater reuse, and rainwater harvesting, are of primary importance for adaptation strategies. There is also a growing awareness of the need for planning that takes into account scenarios of water scarcity and stress, with increased intersectoral collaboration between agriculture, urban planning, civil protection, and the environment.

Regarding concrete initiatives for improved water management, two issues must be considered of utmost importance and must be addressed decisively and resolutely: wastewater reuse, as discussed previously (sections 2.3 and 3.4), and desalination.

Desalination is still not widespread in Italy, but is **attracting growing interest** due to the increase in droughts. Currently, it represents only 0.1% of freshwater abstraction, with approximately 340 active plants, primarily on the smaller islands. Most plants use reverse osmosis, an efficient and less energy-intensive technique than thermal distillation. It presents significant challenges, such as high energy consumption and brine disposal: the salt residue is difficult to manage and can have environmental impacts. These limitations have so far hindered large-scale development. However, future prospects are encouraging. The government has established an inter-ministerial group to address the drought emergency, and desalination is among the solutions being considered. To streamline processes, plants that integrate multiple techniques to improve sustainability and costs are being studied. Finally, streamlining the relevant regulations is essential.

2.2 Economic and Financial instruments

In Italy, the planning and sustainable management of water resources relies on a series of economic and financial instruments, integrated at the national and European levels. Public funding and strategic investments stand out, primarily those provided by the PNRR, which allocates over **€4 billion in funding for water management**.

These are complemented by the European Structural Funds (ERDF, EAFRD), which support regional projects for water efficiency, sustainable irrigation, and the protection of aquatic ecosystems. The LIFE and Horizon Europe programs also finance innovative projects for water resilience, water reuse, and network digitalization. Public support aimed at reducing network losses, wastewater treatment, and plant modernization by 2026 is also important.

In terms of water economic management, we can consider certain decision-support tools, such as "DSS" (Decision Support Systems) models: these are software that integrate environmental, climate, and socioeconomic data to simulate scenarios and optimize decisions. They are used for cost-benefit analyses, multi-criteria assessments, and uncertainty management. Geographic information systems serve similar purposes, mapping vulnerabilities, river basins, and critical infrastructure.

Also noteworthy are certain regulatory and pricing mechanisms, such as water pricing based on the "polluter pays" principle, which incentivizes virtuous behavior and funds environmental improvement interventions. Also noteworthy in this regard are environmental contributions and concession fees, applied to withdrawals from water bodies and discharges, with the aim of ecological rebalancing.

The WISE (Water Information System for Europe) system, which consists of a European platform for monitoring water quality and quantity, and finally the activities of the District Basin Authorities aimed at coordinating water planning at the territorial level, support the economic management of water.

2.3 Application of AI

In Italy, too, artificial intelligence (AI) is significantly innovating the planning and sustainable management of water resources, offering advanced tools to address challenges such as water scarcity, network efficiency, and climate resilience. Below are some of the key applications already operational in various river basin districts and as part of pilot projects, supported by PNRR funds and European programs.

In the field of hydrological monitoring and forecasting, AI-based predictive models have been introduced that analyze meteorological, hydrological, and environmental data to anticipate droughts, floods, and changes in river basins. Early warning systems are also being implemented to improve responsiveness to extreme events, reducing damage and optimizing operational responses.

Work is also underway to optimize water networks, as AI enables the automation of distribution network management, detecting leaks, anomalies, and inefficiencies in real time, while intelligent algorithms support predictive maintenance, reducing costs and waste.

In the agricultural management and irrigation sectors, AI systems are being used to optimize water use, adapting irrigation volumes to climate conditions and crop needs. They promote precision agriculture practices, reducing water stress and improving yields.

Finally, Italian water utilities are using AI to automate low-value-added processes, freeing up resources for strategic activities, improving cash flow management, invoicing, and data quality control.

2.4 Social participation

Social participation in the planning and sustainable management of water resources is recognized as a key element in ensuring equity, transparency, and effectiveness. The involvement of citizens and communities is strategic. This begins with public consultations in River Basin Plans, which then activate participatory processes in **Water Management Plans**, in line with European directives. Local working groups are also promoted: in this regard, the SUWANU Europe project, funded by the European Union, promotes the safe reuse of treated wastewater for agricultural irrigation. Awareness campaigns are also growing in number and quality, with various regional and national projects promoting environmental education and awareness of the value of water.

With a view to both social inclusion and territorial cohesion, participatory management of purified water has been launched in some communities: treated water is reused in agriculture through shared agreements, transforming it into a "community" resource. The involvement of trade associations is also noteworthy. In this regard, Confindustria's paper "From Emergency to Water Efficiency: The Confindustria Document for the Sustainable Management of Water Services" is cited, which aims to overcome territorial disparities, especially in the South, where management is often entrusted to local authorities with less investment capacity.

Increasing awareness of water-related issues is a crucial challenge. This can be supported by digitalization, as the use of water management platforms can foster broader and more informed participation. And, above all, it can help overcome persistent territorial disparities between North and South by actively involving the population.

3. Cyprus

3.1 Adaptive strategies

Cyprus is actively embracing a range of innovative techniques and emerging technologies in order to optimize its hydrological resources, addressing the challenges posed by water scarcity and climate change. Among these:

- **Advanced Desalination Technologies**: To combat water shortages exacerbated by consecutive dry winters, Cyprus is expanding its desalination capacity. The government plans to upgrade five existing permanent desalination plants, increasing their capacity by up to 50%, and construct two new permanent plants in Moni and Dhekelia through public-private partnerships. Additionally, Cyprus is deploying mobile desalination units to supplement water supply during peak demand periods.
- **Wastewater Reuse**: Cyprus is a European leader in the reuse of wastewater for irrigation, promoting a circular approach to water management. Treated wastewater is utilised for agricultural purposes and green areas, adhering to EU best practices and stringent treatment requirements to ensure safety and environmental compliance.
- **Smart Irrigation Systems**: The agricultural sector in Cyprus is adopting smart irrigation systems that leverage remote sensing and Internet of Things (IoT) technologies. These systems monitor soil moisture and crop water requirements in real-time, enabling precise irrigation scheduling and reducing water wastage. A case study demonstrated the effectiveness of such systems in optimising water use for crops like citrus, olives, and potatoes.
- **Water Quality Monitoring**: Innovative IoT-based devices are being employed to monitor water quality parameters, such as pH, conductivity, and temperature, in real-time. These devices facilitate proactive water management by predicting potential issues and ensuring the safety of water resources.
- **Water-Sensitive Urban Design** (WSUD): Cyprus is exploring WSUD principles to integrate the urban water cycle into urban planning and design.

This approach includes the use of permeable pavements, green roofs, and rain gardens to manage stormwater, reduce runoff, and enhance groundwater recharge, contributing to sustainable urban water management.

- **Drip Irrigation in Agriculture**: Drip irrigation is widely used in Cypriot agriculture to deliver water directly to plant roots, minimising evaporation and runoff. This system is particularly common in citrus groves and vegetable farming, where water use is high and efficiency is essential. According to the Ministry of Agriculture, drip systems have helped reduce irrigation water use by up to 30 percent compared to traditional methods.
- **Greywater Recycling in Tourism**: Hotels in areas like Limassol and Ayia Napa have adopted greywater systems that collect and treat water from showers and sinks for reuse in toilet flushing and landscape irrigation. This significantly reduces freshwater demand in the tourism sector, especially during peak travel months.
- **Closed-Loop Cooling in Manufacturing**: In industrial facilities, particularly beverage and food processing plants, closed-loop systems are used for equipment cooling. These systems recycle water within a contained process, reducing the need for continuous freshwater intake and minimising wastewater discharge.
- **Reverse Osmosis in Desalination**: Desalination plants in Cyprus use reverse osmosis (RO) membranes with energy recovery units to produce potable water efficiently. These technologies are optimised for local conditions and have significantly improved energy-to-output ratios over the last decade, helping industries secure reliable water supplies during droughts.
- **Smart Metering and Leak Detection**: Smart meters have been installed in industrial zones and commercial properties to monitor water consumption in real time. Coupled with automated leak detection systems, they help companies identify and address inefficiencies promptly, reducing non-revenue water and operational losses.

These innovative techniques and technologies are integral to Cyprus's strategy for sustainable water management, enhancing resilience against climate variability and ensuring the efficient use of hydrological resources.

3.2 Economic and Financial instruments

Financial instruments around water in Cyprus is a remarkable element to take into consideration. In particular tools such as water taxes, fiscal incentives, and payments for ecosystem services give a picture of the economic value of water in the island.

Water Pricing Structure

Cyprus uses a progressive water pricing system that encourages water savings and helps cover infrastructure costs. The system is made up of both fixed and variable fees:

- Fixed Annual Charges: These make up about 30% of total revenue from water bills.
- Variable Consumption Charges: These account for the remaining 70%, with the rate increasing as consumption rises.
- For households, the variable rate typically ranges between €1.40 and €5.40 per cubic meter, depending on how much water is used. Agriculture and commercial sectors are subject to similar tiered pricing, tailored to their usage needs.

Anyone using groundwater for farming or commercial purposes must install a metering system. There's a €765 installation fee and an annual €143 metering fee for each water source. These tools help ensure water is not being extracted excessively or without oversight.

Green Taxation Initiatives

As part of its environmental strategy and EU-funded recovery plan, Cyprus is rolling out new green tax measures aimed at improving water and energy sustainability. These include:

- Water Scarcity Charge: A proposed €0.01 per cubic meter levy on water use, intended to discourage waste and help pay for future water infrastructure projects.
- Carbon Taxation: A gradual plan to introduce carbon taxes on fuels that are not already part of the EU Emissions Trading Scheme, as a way to lower emissions and promote cleaner alternatives.

These steps are part of a broader move to use financial tools to drive better environmental outcomes and shift behavior toward conservation.

Payments for Ecosystem Services (PES)

While Cyprus does not currently have formal PES schemes, the concept is recognized as a potential tool for promoting ecosystem conservation. PES involves compensating landowners or resource managers for maintaining or enhancing ecosystem services, such as water purification and flood control. The government and stakeholders are exploring opportunities to implement PES programs, particularly in areas critical for water resource protection.

3.3 Application of AI

AI technologies are the future also for systems applied to improve water management performance. Cyprus takes it seriously in order to find efficient solutions to the water issues.

Smart Infrastructure Monitoring and Control

The KIOS Research and Innovation Center of Excellence at the University of Cyprus, in collaboration with Imperial College London, is developing AI-driven systems to enhance the monitoring and management of water networks. These systems utilize real-time data from sensors to detect anomalies, predict failures, and optimize water distribution, thereby improving efficiency and resilience in the face of challenges such as climate change and infrastructure aging.

AI-Enabled Leak Detection and Pressure Management

The SmartWater2020 project, coordinated by KIOS, focuses on minimizing water loss in Cyprus and Crete through the deployment of innovative technologies. This includes the installation of sensors, valves, and meters in water supply systems, all integrated with smart monitoring software. The system employs AI algorithms to detect leaks and water quality issues promptly, as well as to manage pressure control, thereby reducing water losses and enhancing the reliability of water supply networks.

AI for Agricultural Water Management

A study published in Scientific Reports presents an AI-based approach to optimize irrigation needs for specific crops in Cyprus. By calculating daily crop evapotranspiration for citrus, olives, and potatoes, the model assists in efficient water resource management, crucial for the agricultural sector in the Mediterranean region affected by climate change and drought events.

Digital Twins for Water Quality Monitoring

The DigiWATER project, funded by the Cyprus Research Promotion Foundation, aims to develop a digital twin for AI-enabled water quality monitoring and decision support in water distribution networks. This system integrates real-time data and AI analytics to provide actionable insights, enhancing the management and safety of water resources.

3.4 Social participation

Cypriot citizens participate in water management through public awareness campaigns, community involvement in local issues like water loss and conservation, and participation in cross-community initiatives with Greek Cypriots and Turkish Cypriots to address water scarcity as a shared challenge.

While individual actions are crucial for water conservation, the success of broader water management relies on improved coordination between authorities, the implementation of comprehensive water management plans, and a shift towards collaborative solutions that involve citizens alongside government and expert Public Awareness and Education.

In particular, the Water Development Department (WDD) conducts efforts to raise public awareness about water scarcity, emphasizing the need for careful use and conservation to protect future water supplies.

Community board representatives and citizens respond properly to these appeals and participate in discussions about water management issues, such as the need to reduce water losses from the distribution network. Citizens fully support solutions like desalination, improving water efficiency, and the construction of water dams and tanks to manage water resources.

Another form of social participation refers to the involvement of students through educational programs. Programs like "Alter Aqua" have distributed educational materials to primary and high schools, teaching Cypriot teachers and students about water management in a cross-thematic way to foster understanding and promote sustainable water use.

Industrial and Agricultural Water Use

1. Spain

Spain's water economy is dominated by agriculture, with irrigation shaping both volumes and spatial patterns of use, while industry relies on a mix of direct abstraction, public supply, and growing inputs from desalination and reclaimed water. Official planning figures compiled by the Ministry for the Ecological Transition estimate total national water demand at roughly 32,000 hm^3 per year in 2021; of this, about 80.5% is for irrigation and agrarian uses, around 15.5% is for urban supply, and the remainder covers industrial uses, confirming the structural primacy of agriculture in Spain's water balance.

Applying those shares to the ministry's demand benchmark implies approximately 26,000 hm^3 for agriculture in a normal planning year, with industry accounting for a small single-digit percentage in comparative terms.

The agricultural footprint is visible on the ground. According to the national **ESYRCE field survey**, irrigated land reached **3,713,936 hectares in 2023, down 1.52% from 2022 and 4.23% from 2021** in a drought-stressed cycle. Technology mix matters: localized (principally drip) irrigation already covers 2,140,233 hectares, or 57.63% of all irrigated area, while gravity systems have fallen to 19.44%, and sprinkler and center-pivot account for 14.73% and 8.21% respectively. This reflects a **long, policy-driven modernization** that has shifted Spanish irrigation toward higher efficiency, crop quality, and yield stability while curbing conveyance losses.

Regionally, irrigated land is concentrated in **Andalusia** (1,057,191 ha, 28.47% of the national total), **Castilla-La Mancha** (593,320 ha), **Castilla y León** (456,620 ha), and **Aragón** (404,004 ha), with the **Valencia Region**, **Extremadura**, **Catalonia**, and **Murcia** comprising most of the remainder. These distributions mirror both historical infrastructure and crop specialization: herbaceous cereals in Ebro basin districts sustain gravity shares in Aragón and Catalonia, while high-value woody crops and horticulture in the south and east favor drip.

The composition of agricultural demand is therefore a function of both area and method. Localized systems reduce application losses and enable precise fertigation, but aggregate volumes remain high because Spain's irrigated agriculture drives a large share of farm output and export value. Peer-reviewed synthesis places agriculture at over four-fifths of Spain's consumptive water use, broadly consistent with ministerial accounts; at the same time, episodic droughts have forced acreage and allocation adjustments that propagate through agri-food value chains. In 2023-2024, prolonged deficits in Catalonia translated into production and labor disruptions in water-sensitive sectors such as viticulture, exemplified by furloughs at Freixenet amid emergency restrictions, illustrating how hydrological stress can transmit into industrial employment and regional GDP.

Industrial water use in Spain is more **heterogeneous** and, as a share of national abstraction, much **smaller** than agriculture.

Manufacturing relies partly on self-abstraction (where available) and partly on public networks, with subsectors such as food and beverages, paper, chemicals, and basic metals exhibiting higher water intensities, while many advanced manufacturers are relatively light users per euro of value added. At EU scale, cooling water for electricity generation dominates non-agricultural abstraction; Spain's profile is more balanced due to the power mix and plant siting, but the structural point - that industrial abstraction is significantly below agricultural use - holds. Recent public communication from the national broadcaster, drawing on basin authorities' **2018-2021** ledgers, places industry at roughly 5-6% of water use, with urban supply around 15%, consistent with the ministry's planning snapshot.

Two non-conventional resources cushion both farm and factory: reuse and desalination. Spain has long been a **European leader in water reuse**, with around **400-450 hm^3 per year** of reclaimed volumes documented in ministerial statistics and river-basin reporting. A regulatory update aligned with EU rules has moved forward to tighten quality assurance by use category and to require promotion plans, accelerating upgrades in regions like Murcia where agricultural reuse is already embedded in irrigation districts. These streams increasingly support high-value horticulture and industrial processes requiring fit-for-purpose water, thereby reducing pressure on aquifers and surface allocations.

Desalination now underpins economic water security along Spain's Mediterranean arc. In the Segura River Basin District alone there are thirteen seawater reverse osmosis plants, including **Torrevieja**, **Valdelentisco** and **Águilas**, whose outputs are blended into both urban and irrigation grids and, in some cases, serve industrial parks. Project-level documentation shows further units sized specifically to cover industrial growth and municipal deficits - such as Sagunto's plant designed to supply households and industry - indicating how industrial development strategies in water-stressed provinces are now explicitly coupled to non-conventional supply. While energy costs and brine management remain constraints, falling PV prices and grid decarbonization are improving the life-cycle footprint of desalinated water, which, when targeted to high-value uses, can be economically rational despite higher unit costs than traditional sources.

National statistics on municipal utilities complement this picture by setting the baseline for networked demand and prices.

The latest INE "Suministro y Saneamiento del Agua" release reports average household consumption at **128 liters per person per day in 2022 and a unit water cost of €1.92/m^3 across Spain**. For industry connected to public supply, these tariffs shape process-water substitution and recycling incentives, while the spread of digital metering and loss control funded under the PERTE for the Digitalization of the Water Cycle is improving allocation efficiency at the interface between cities, farms, and factories.

Aspect	Data/Description
National water demand (2021)	≈ 32,000 hm^3/year total
Share used for agriculture	~80.5% (≈26,000 hm^3/year)
Irrigated land (2023)	3,713,936 hectares
Change from previous year	Down 1.52% from 2022, down 4.23% from 2021 (drought cycle)
Main irrigation methods	Drip: 57.63%, Gravity: 19.44%, Sprinkler: 14.73%, Center-pivot: 8.21%
Main regions (2023)	Andalusia (1,057,191 ha, 28.47%), Castilla-La Mancha (593,320 ha), Castilla y León (456,620 ha), Aragón (404,004 ha)
Agriculture proportion of water use	Over 80% (four-fifths), main driver of Spanish consumptive water use
Drought impact (2023-2024)	Production and labor disruptions, e.g. Catalonia viticulture

Aspect	Data/Description
Water reuse (reclaimed volumes)	400–450 hm^3/year (leading in Europe; mainly Murcia region)
Desalination support	Mediterranean coast (e.g., Segura Basin, Torrevieja, Valdelentisco, Águilas plants integrated into irrigation)

Table 4: Spanish Agricultural Water Use: Key Figures and Regional Trends

2. Italy

Italy's water economy is bifurcated between a structurally water-intensive agri-food system and a diversified industrial base that has reduced unit water demands but still abstracts large absolute volumes in European comparison. On the civil side - the interface that conditions industrial intake from public networks - the latest **Istat** census reports **9.14 billion m^3** withdrawn for public water supply in 2022, equivalent to 424 liters per person per day at capture; only a marginal 0.1% of this potabilization volume comes from desalination, confined to plants in Sicily and Tuscany, underscoring how limited non-conventional resources remain within Italy's overall supply mix.

Irrigated agriculture anchors total consumptive use. CREA's synthesis places irrigated area at roughly **2.5 million hectares out of about 13 million cultivated nationally**, with a decade-long expansion concentrated in the North-East (+28%) and minimal growth in the Islands, a geography that mirrors both resource availability and crop specialization. The public irrigation service monitored by SIGRIAN - some **600 consortia** operating **43,000 kilometers** of conveyance - delivers water to about 60% of irrigated land, while the remainder is self-supplied by farms from groundwater and surface water sources. An infographics-based consolidation of Istat's 2020 farm census shows a split that is operationally important for drought response: approximately 60% collective service, 24% autonomous abstractions from aquifers, and 13% autonomous surface withdrawals, with the balance in residual categories. The census also documents that in the 2019/2020 agrarian year more than one-third of irrigated area relied on on-farm self-provisioning, an indicator of how many holdings need direct access to wells or private intakes when allocations tighten.

Method and crop mix drive the intensity and timing of farm demand. In the **Po Valley**'s rice and forage districts, surface methods such as *scorrimento* and *sommersione* remain prevalent, especially in Lombardy where regional planning artefacts still list these as the dominant techniques; by contrast, high-value horticulture and orchards in central and southern regions have progressively shifted toward pressurized systems and drip, leveraging fertigation and precise scheduling to stabilize yields under variable supply. This duality means Italy cannot be characterized by a single "efficiency" trajectory: modernization is advanced in fruit-vegetable chains while gravity and flood remain agronomically and ecologically functional in paddy landscapes, albeit with different return flows and salinity risks. The last comprehensive national quantification of irrigation volumes - around **11.6 billion m^3 for the 2009/2010 season** - pre-dates several modernization cycles; newer administrative datasets emphasize areas and sources rather than volumes, but the spatial picture is clear: collective networks supply the majority of hectares and shape peak-season hydrographs in the northern plains.

Industrial water use is more heterogeneous and has decoupled from value added over two decades, but Italy still abstracts conspicuously in EU rankings. A national review by Italy for Climate documents **a 53% cut in industrial withdrawals between 2000 and 2019** alongside marked efficiency gains per unit of gross value added; even so, industrial abstractions remain on the order of eight billion m^3 per year in recent comparative years, the highest absolute figure among EU peers, and are complemented by roughly six billion m^3 for power-plant cooling in 2017, a component that fluctuates with the generation mix and hydrological conditions. The same report details how the 2022 drought depressed hydroelectric generation by about 37% year-on-year, amplifying the exposure of energy-related water uses to climate variability and, indirectly, the exposure of water-dependent industries to power system stress.

Non-conventional resources are expanding, but from a small base. Direct reuse of treated effluents remains structurally underexploited relative to technical potential: sector diagnostics from the Blue Book 2023 show that only about **4% of reclaimed wastewater is directly reused in agriculture** against a feasible near-term **potential around 23%**, a gap explained by fragmented governance, quality assurance upgrades under the EU reuse regulation, and uneven investment capacity across consortia. Industrial water reuse is already practiced in complex sites - refining and petrochemicals, food and beverage, pulp and paper - where tertiary and advanced treatments reliably deliver process and cooling water, but national accounting still lacks a consolidated annual volume.

On desalination, trade and technical sources converge on an installed production near 650,000 m^3/day across municipal and industrial plants, a scale equal to roughly **0.24 billion m^3/year if fully utilized**; Istat's 0.1% share in civil withdrawals confirms that, system-wide, desalinated water is still marginal compared with withdrawals from surface and groundwater.

The drought sequence culminating in 2022 translated water stress into real economy impacts. Producer organisations estimated aggregate agricultural losses on the order of six billion euros that year - roughly ten percent of national agro-food output - with steep yield declines reported for water-sensitive cereals such as maize and durum wheat; while such figures are advocacy-driven and ex-post, they capture the magnitude of exposure concentrated in the Po basin and northern Apennines when snowpack and spring rains fail. ISPRA's hydrological balance update shows that 2023 saw a rebound in precipitation to about **924 millimeters nationally after the 2022 minimum near 719 millimeters**, yet total renewable availability still sat 18.4% below long-term means, signaling a structural downward drift superimposed on high interannual volatility. For water managers and firms, the implication is that both the mean and the variance of supply are shifting in directions that stress legacy allocation rules and design assumptions.

Across sectors, high losses and retail-side inefficiencies complicate the picture. Istat's civil-use ledger notes roughly 37,400 abstraction points nationwide in 2022 and documents the long-recognized distribution losses that cause delivered volumes to lag far behind withdrawals; those losses translate into elevated gross abstraction requirements for towns and for industries connected to public supply, blunting the savings achieved through on-site recirculation and process optimization. Where industry self-abstracts, particularly in water-intensive subsectors like paper, food processing, basic chemicals, and metals, investments in closed-loop cooling, reuse of tertiary effluents, and switchovers to lower-quality sources have reduced intake per unit output, yet absolute withdrawals remain locally significant in river stretches already stressed by irrigation. In this context, the governance footprint of the 600 irrigation entities and their storage and conveyance assets becomes macro-critical for balancing farm and factory demands during peaks.

The strategic reading that emerges is pragmatic rather than rhetorical. Italy's agriculture will continue to dominate consumptive water use because of irrigated area, crop mix, and summer phenology, but its marginal cubic meter can be made more productive and predictable via metered pressurization where agronomically appropriate, modernization of surface districts where gravity is ecologically and economically justified, and basin-scale scheduling anchored in crop water productivity rather than entitlements alone. Industry will continue to lower specific water intensities and expand reuse, yet regional concentrations of absolute abstraction require local compacts with basin authorities and consortia to smooth peaks and share drought burdens. Civil systems will need leak reduction and tariff reforms to shrink withdrawals and fund the digitalization and redundancy that a more variable climate demands. The data points are consistent even when drawn from different ledgers: **9.14 billion m^3 withdrawn for civil use in 2022** with only **0.1% from desalination**, **irrigated land near 2.5 million hectares** with about 60% supplied by collective networks and a sizable minority self-provisioned, industrial withdrawals cut by roughly half since 2000 yet still near the top of the EU in absolute terms, and a reuse share that remains far below technical potential. In short, the Italian system is adapting, but aligning the scale of adaptation with the scale of hydrological change will require converting today's pockets of excellence - pressurized irrigation districts, industrial water loops, tertiary-quality reuse - into the national norm.

Aspect	Data/Description
Total cultivated area	~13 million hectares
Irrigated agricultural area	~2.5 million hectares
Share of irrigated area supplied	≈60% by public irrigation consortia, ≈24% autonomous aquifers, ≈13% autonomous surface withdrawals
Irrigation infrastructure	~600 consortia, 43,000 km conveyance network
Main regions of expansion	North-East Italy (major growth), minimal on Islands

Aspect	Data/Description
Irrigation methods	Surface techniques (*scorrimento*, *sommersione*) dominant in Po Valley rice/forage districts; drip and pressurized systems (fertigation) in central/southern regions and orchards
Non-conventional water sources	Only ~0.1% of civil supply from desalination (plants in Sicily and Tuscany); direct reuse in agriculture ≤4%, potential up to 23%
Recent irrigation volume	Last comprehensive estimate: ~11.6 billion m^3 for 2009-2010 season
Drought impact (2022)	Agricultural losses ≈ €6 billion (≈10% agro-food output); strong impact on Po basin, cereals, and water-sensitive crops
Trend summary	Irrigated agriculture anchors Italian consumptive water use, crop mix and modernization drive efficiency but surface techniques remain prevalent in key districts, water stress and drought are increasing

Table 5: Italian Agricultural Water Use: Structure, Methods, and Recent Trends

3. Cyprus

Cyprus's water economy is shaped by structural scarcity, a tourism-heavy demand profile, and a deliberate pivot toward non-conventional resources that now underpin both cities and farms. On the supply side, the island relies on a dense dam network with around **315 million m^3 of storage**, but multi-year rainfall deficits and rising temperatures have eroded reservoir reliability; as of 1 September 2025, storage had fallen to about 14.7% of capacity after one of the driest winters in decades.

To secure urban and productive uses, **desalination** - introduced in **1997 and progressively expanded** - has become the backbone of municipal supply, with five large plants and additional mobile units bringing installed output to roughly **235,000 m^3/day** and covering about 70% of drinking water needs in 2025. New temporary and planned permanent units in Limassol, Paphos and at the Moni power station reflect a strategy to meet peak summer demand from residents and tourists while reserving scarce surface stocks for irrigation.

Water use is dominated by agriculture, though precise shares vary by year as allocations track hydrology. A consolidated national snapshot indicates irrigation and landscape watering account for around **160 million m^3 annually**, roughly 59% of overall demand, with domestic uses near 29%, tourism 5%, livestock 3.3%, and industry about 3%. These proportions align with longer-run assessments that place agriculture near 60-70% of withdrawals, with the domestic/municipal sector in the 20-30% range and industry very small in comparative terms. Sectoral pressures **are amplified by seasonality**: irrigation peaks in the dry summer, coinciding with tourism surges that can raise per-capita hotel water consumption several-fold compared with resident baselines, magnifying urban system loads and pushing desalination to sustained high utilization.

The physical footprint of irrigated farming is material but tightly managed. The **2020 Census of Agriculture** reports **381,250 decares of irrigable** land (≈38,125 ha), with **266,076 decares actually irrigated (≈26,608 ha)**. Historical inventories show roughly 35,000 ha irrigated in the early 2000s, with groundwater supplying the majority of plots and surface water serving the remainder; the current pattern remains mixed, but policy has steered areas toward more efficient systems as part of rural development programming that targets technology upgrades on roughly a tenth of irrigated land. Crop choice and method drive volumetric demand: permanent crops and high-value horticulture have progressively adopted pressurized and drip systems for scheduling and fertigation, while groundwater-dependent districts face salinity risks that are mitigated in part by managed aquifer recharge using reclaimed effluent.

Non-conventional resources, **reclaimed wastewater** in particular, are the critical bridge between agricultural demand and hydrological limits. Cyprus is a European leader in reuse: Commission tracking reports that **86.6% of treated urban wastewater is reused**, while Water Development Department presentations document that about **97% of effluent is recovered**, with 22.6 million m^3 directed to agriculture in 2021.

Reuse occurs both directly (pressurized distribution to farms) and indirectly through aquifer recharge, governed by stringent national quality standards aligned with **EU Regulation 2020/741** that took effect in June 2023. This portfolio reduces pressure on dams and wells, buffers drought cuts in irrigation allocations, and helps stabilize yields in water-sensitive value chains.

Industrial withdrawals are modest at the national scale but locally significant, especially in energy and food-processing clusters that must operate through summer peaks. Industry's share of total water demand is on the order of three percent in recent syntheses, with an additional five percent attributed to tourism as a distinct, water-intensive economic function. The small national share conceals critical point loads where **industrial estates, ports, and power assets** coincide with constrained municipal grids; Cyprus's recent deployment of mobile desalination at sites including **Limassol Port and the EAC Moni power station** exemplifies how industrial continuity is being decoupled from variable surface inflows via dedicated non-conventional supplies.

The management framework couples engineered supply with adaptive allocation. The Water Development Department's long-running approach differentiates between "demand" and "use" to adjust entitlements during dry spells; in extreme years, deficit-irrigation cuts of up to 70% have been implemented to preserve priority urban supplies, a policy made more tenable as desalination and reuse scale up. The island's Water Utilization Index - **near 73%** - underscores structural stress and the need to police losses, reduce groundwater over-draft, and maintain environmental flows. Policy documents and recent ministerial briefings point to continuing investments in leakage control, boreholes as emergency reserves, and hotel-level desalination subsidies to protect a sector that accounts for roughly **13.5% of GDP** while avoiding further drawdown of public networks.

Quantitatively, the trajectory is clear. Total demand on the order of **260–300 million m^3 per year** is increasingly met by a blend of surface storage, groundwater, desalination at **~235,000 m^3/day**, and reclaimed effluent with more than twenty million m^3/year routed to farms. Agriculture remains the anchor load at roughly three-fifths of withdrawals, yet its marginal cubic meter is progressively supplied by tertiary-treated water and, in drought years, by reallocation of dam releases conserved through urban desal reliance. Municipal systems are evolving toward full non-conventional coverage in normal years, which in turn allows surface stocks to be prioritized for irrigation when hydrology permits.

Industry retains a small but strategic footprint, increasingly buffered by site-specific desal capacity. In practical terms, Cyprus's model is to use **desalination to secure households and commerce**, **reclaimed water to stabilize agriculture**, and **reservoirs and aquifers as flexible buffers** - an allocation architecture that has allowed the island to support tourism growth and high-value agriculture despite a drying climate, but that will require sustained investment and vigilant environmental oversight (not least on brine management) as capacities expand.

Aspect	Data/Description
Water availability and supply	Structural scarcity, dense dam network (315 million m^3 storage), heavy use of desalination since 1997; storage at ~14.7% capacity as of Sept 2025
Desalination and reuse	5 large plants plus mobile units; covers ~70% of municipal drinking water (2025); reclaimed urban wastewater reuse rate: 86.6% (2021: 22.6 million m^3 to agriculture)
Total water demand	260–300 million m^3/year
Agriculture's share in water use	Accounts for 59–70% of national demand (~160 million m^3/year for irrigation/landscape watering)
Irrigable area	38,125 ha (2020), 26,608 ha actually irrigated; majority supplied by groundwater
Main irrigation methods	Drip/pressurized systems for permanent crops and horticulture; mixed surface/groundwater sources
Water allocation and policy	Adaptive system reallocates during droughts (irrigation cuts up to 70% in extreme years); non-conventional sources prioritized

Aspect	Data/Description
Seasonal and economic pressures	Irrigation peaks in summer with tourism surges; hotel consumption multiplies municipal loads
Major crops and trends	High-value crops, adoption of efficient fertigation; managed aquifer recharge mitigates groundwater salinity risk
Environmental and sustainability focus	Continued investment in leak control, borehole reserves, and recycling technology; strict national and EU water reuse quality standards

Table 6: Cyprus Agricultural Water Use: Scarcity, Strategies, and Innovations

Social Participation and Education

1. Spain

Spain's approach to social participation and education in water management is anchored in the **Water Framework Directive (WFD)** but has evolved into a dense ecology of basin-level consultation, school-to-workforce education, and citizen volunteerism. Legally, the WFD established a right - and an obligation - to inform, consult, and enable active participation in river-basin planning; that shift, documented by Iberian scholarship, helped move the policy regime beyond a purely hydraulic paradigm toward one that integrates ecological, socio-economic and territorial considerations with public input. In practice, Spain's river basin authorities (*Confederaciones Hidrográficas*) run multi-stage engagements through the planning cycle, publishing initial documents, convening workshops, and opening six-month public consultations for the 2022–2027 river basin management plans, thus formalizing participation windows where users, municipalities, NGOs, and citizens can submit observations and shape priorities.

Evidence of this institutionalized participation appears in the public records of individual basin plans. The Cantabrian basin's "*Anejo XI - Participación Pública*" sets out a detailed timeline that mirrors the WFD process - active engagement during the drafting of initial documents, followed by the six-month public display of the draft plan and its strategic environmental assessment from 23 June to 22 December 2021 - and logs meetings, inputs and consultation milestones; similar annexes and notices in the Duero, Júcar and Guadiana basins document working tables, sectoral sessions and stakeholder comments incorporated into the final texts approved in early 2023. Even where debate is polarized, such as on ecological flows linked to the Tajo-Segura transfer, the public record shows the intensity of submissions and counter-submissions from ***regantes***, **regional governments**, **academics** and **civil society** - an indication that basin planning has become a public forum as much as a technical exercise.

Beyond formal planning, Spain has built large-scale education pipelines that normalize water literacy from primary school through vocational pathways. In the **Community of Madrid**, the *Canal Educa* program – which is run by *Fundación Canal* in collaboration with *Canal de Isabel II* - trained **55,556 students** and **2,496 teachers** in the **2024/25 school year** alone, combining classroom activities with guided visits to treatment plants and dams; over the last decade it has sensitized more than **446,000 students and educators**. Complementary institutional outreach includes technical visits to Canal de Isabel II facilities - around 2,000 institutional and academic visitors in 2023 - used to diffuse best practice on the urban water cycle, energy efficiency and circularity. These figures illustrate a scale at which school-age awareness becomes a feeder for future technicians and municipal staff while also shaping household conservation behaviors.

Volunteerism and citizen science extend this learning into stewardship and monitoring. The national "*Programa de Voluntariado en Ríos*," coordinated by **MITECO** and basin confederations, fosters hands-on conservation, riverbank restoration and local diagnostics, and is replicated by basin-specific programs such as the Duero's volunteer initiative and Cantabrian subsidies that mobilize associations to assume shared responsibility for river health. Parallel NGO and civic platforms - WWF Spain's volunteer schemes and "*Proyecto Ríos*" in Cantabria - train citizens to collect data, remove litter, identify invasive species and report pressures, effectively turning public awareness into periodic, measurable contributions to river status. Media coverage of municipal clean-ups and science-based litter audits, from the Río de la Miel to the Jarama, signals how these campaigns have migrated from niche events to recurring community practices that combine education with data for local authorities.

There remain challenges that Spain's participatory machinery does not automatically solve. Researchers and editorial analyses note that participation in the Iberian context historically leaned toward organized user groups rather than broader civil society, and basin processes still grapple with representativeness, the **technical opacity** of some dossiers, and imbalances in the capacity to submit evidence-rich comments. Yet the procedural scaffolding is robust - public drafts, recorded sessions, annexes that report engagement, and clear consultation calendars - and the **scale of education** and **volunteerism** has grown to a point where awareness is continuously refreshed in classrooms, at facility open days, and along river corridors. As a result, public engagement in Spain's water governance is no longer episodic; it is embedded in statutory planning cycles and reinforced by large-footprint education programs and citizen stewardship networks that keep the conversation alive between plan approvals.

2. Italy

In Italy, social participation and education around water management unfold along three mutually reinforcing tracks: the formal consultation architecture mandated by the **Water Framework Directive**, the voluntary, place-based governance of River Contracts, and a broad civic-educational ecosystem that stretches from school programs run by multiutilities to citizen-science campaigns. On the first track, the **2021-2027 river-basin planning cycle** has institutionalized information, consultation, and "active participation" throughout the process. Draft documents are published in advance, public comments are invited and recorded, and basin authorities organize dedicated sessions with citizens, municipalities, user groups, and businesses. The Directive's transposition into national law has made public presence a structural element in setting objectives, measures, and priorities, and national monitoring treats participation as a process indicator rather than a communications add-on.

The second track is bottom-up and territorial: River Contracts have become Italy's operative laboratory of "**water democracy**." From the Po basin to Apulia and Sicily, hundreds of Contract processes have been launched, with many already signed and under implementation. The national platform hosted by the environment ministry not only catalogs cases; it also offers **training modules for technicians and local officials**, which has turned River Contracts into a practical school of multi-stakeholder negotiation, alignment with river-basin plans, and co-design of measures for re-naturalization, flood-risk reduction, ecological quality, and multiple uses.

Several regions have formalized periodic assemblies and technical support lines so that these pacts are not episodic projects but stable components of water planning and territorial policy.

Public awareness and education provide the social bandwidth that makes participation effective. Large multiutilities run multi-year school programs that combine classroom learning with guided visits to treatment plants, reservoirs, and laboratories, normalizing the language of efficiency, reuse, and water quality for tens of thousands of students each year. Long-standing initiatives in central and northern Italy bring science workshops into secondary schools, while metropolitan utilities in **Lombardy** and **Emilia-Romagna** periodically open facilities to students, researchers, and residents, turning the urban water cycle into a hands-on learning experience. These pipelines do more than "raise awareness": they seed basic competence, influence study choices, and create cohorts of future technicians, administrators, and informed users.

Active citizenship converts attention into data and stewardship. National volunteer campaigns on rivers, beaches, and lakes generate independent water-quality observations and litter audits, highlighting persistent wastewater and stormwater bottlenecks at river mouths and urban shorelines. Annual clean-up mobilizations engage hundreds of municipalities and large numbers of volunteers, extending care to riverbanks and canals and providing simple, replicable metrics that local authorities can act upon. Environmental protection agencies amplify this civic signal with official monitoring and continuous public reporting, which not only validates concerns but also channels them into regulatory and investment cycles.

Professional training and regulatory transparency close the loop. Alongside River Contract modules for practitioners, sector regulators and local authorities run consultations when updating tariffs and service standards for the integrated water service, embedding user listening into the regulatory calendar. Basin authorities and regions pair river-basin and flood-risk plans with **technical workshops** and **thematic tables** that translate complex dossiers into choices that non-specialists can understand and scrutinize. Even land-reclamation and irrigation consortia—often perceived as "back-stage" infrastructure managers—now run school programs, public talks, and competitions to explain how collective irrigation, drainage, and biodiversity protection underpin water security for both cities and agriculture.

Taken together, Italy's trajectory shows that public engagement is not a procedural ornament but a form of social infrastructure. The growth and consolidation of River Contracts, the steady flow of students through plants and laboratories, and the longitudinal citizen datasets produced by volunteer campaigns all build an informed demand for ecological quality, efficiency, and resilience. Well-known challenges remain - ensuring representativeness in participatory fora, narrowing technical-capacity gaps between territories, and maintaining stable resources for education - but the center of gravity has shifted. Water governance is no longer defined solely by the hydraulic work that is built; it is increasingly defined by the competent community that requests it, monitors it, and, with growing frequency, co-designs it.

3. Cyprus

Cyprus approaches social participation and education in water management through a mix of legally mandated consultation, long-running school outreach, and a dense web of civic and NGO initiatives that convert awareness into action. On the statutory side, the **Water Development Department (WDD)** runs multi-stage public participation for River Basin Management Plans under the Water Framework Directive. For the current planning cycle, the first consultation phase ran for six months (June-December 2019), included an open conference on 18 December 2019, and invited 141 identified stakeholders; the process logged 16 external attendees at the launch meeting and analyzed 11 submitted questionnaires, with lessons fed back into the planning timeline. The 3rd River Basin Management Plan and its Programme of Measures were subsequently approved by the Council of Ministers on 11 November 2023, anchoring participation within an updated national framework for 2023–2027.

Education and awareness start early and are institutionalized. Since 2007, WDD and the Ministry of Education have run scheduled school campaigns - "Water in Cyprus" - backed by online materials ("The WDD in Schools") and World Water Day activities. The ministry also integrates a dedicated water module within environmental education at the elementary level, signaling that "water conscience" is treated as a core competency rather than an occasional theme.

Hands-on public education is reinforced by dedicated institutions. The Water Museum in Limassol, established by the Water Board of Lemesos and inaugurated in 2008, combines historic infrastructure with an outdoor educational playground and structured programs from kindergarten to university.

It reports thousands of student visits annually and, since 2011, serves as Cyprus's national organizer for the **Stockholm Junior Water Prize**, turning youth curiosity into research-based projects and international exposure.

NGO platforms scale participation and give it a voice. **CYMEPA** implements the international Young Reporters for the Environment programme in Cyprus, enabling students to investigate local water and environmental issues and communicate solutions through journalism, photography, and video - an approach that blends environmental literacy with media skills and public advocacy.

Volunteerism and citizen stewardship translate awareness into measurable outcomes. The nationwide "**Let's Do It! Cyprus**" clean-up campaign mobilized more than **25,000 volunteers** in a single week and expects over 30,000 participants across the 2023-2024 cycle, with historical participation surpassing 250,000; these actions generate litter audits and coastal data that feed municipal and national conversations about water quality and waste. Complementary initiatives such as "Keep Our Sand and Sea Plastic Free" document results at the micro-scale - over 110 kilograms of waste removed across a series of beach cleanups in summer 2024 - keeping public attention focused between planning milestones.

Targeted training complements broad awareness. Beyond school outreach, Cyprus has used farmer-facing media and seasonal campaigns - weekly TV and radio segments, a "Water Week," school visits and competitions - to socialize efficient irrigation and drought-time practices. Parallel technical capacity building comes from the "Mission Water" programme (GWP-Med with the Coca-Cola system in Cyprus), which from 2013-2018 reports **83,621 beneficiaries, 280 teachers trained, 30 technicians trained, and an estimated 40,273 m^3 of water collected**, reused, or saved annually through greywater and rainwater systems in public sites, schools, and sports facilities—linking pedagogy with tangible water savings.

Participation also has a confidence-building dimension in the island's bi-communal context. Under the auspices of the Environment Technical Committee, the "Awareness Raising Measures for Water Saving" project - implemented by AKTI Project and Research Centre with the Turkish Cypriot Chamber of Environmental Engineers - pioneered joint outreach and practical conservation messaging, demonstrating how shared water challenges can seed cooperation across communities.

Viewed together, these elements show a system where consultation obligations create predictable windows for public input, sustained school and museum programs build the next generation's "water conscience," and civic campaigns keep water visible in daily life. The architecture is not only procedural; it is cumulative: **stakeholder workshops, classroom modules, youth reporting, clean-ups,** and **technician trainings** each add layers of competence and legitimacy. In a water-scarce, tourism-intense island, that social infrastructure is as critical as any pipe or plant because it sustains the behavioral, technical, and collaborative habits needed to navigate tighter hydrological margins year after year.

Country	Social Participation	Education and Awareness	Volunteerism & Civic Action	Notable Programs/Examples
Spain	Institutionalized through the Water Framework Directive, extensive basin-level consultations, multi-stage public engagement and input on river basin plans; participation includes citizens, NGOs, sectoral groups, municipalities, and is documented with clear calendars and public records.	Water literacy from primary school to vocational level; initiatives like Canal Educa (55,556 students, 2,496 teachers in 2024–25, over 446,000 in last decade), technical visits, classroom integration, and field experiences; skills for	Expansive volunteerism and citizen science (Programa de Voluntariado en Ríos, local clean-ups, WWF, Proyecto Ríos); activities include river restoration, monitoring, species identification; outputs feed municipal action and	Canal Educa, Programa de Voluntariado en Ríos, technical visits, basin authority consultations.

Country	Social Participation	Education and Awareness	Volunteerism & Civic Action	Notable Programs/Examples
		future water professionals and household conservation.	media attention.	
Italy	Multi-track system: EU-mandated information/consultation (WFD), participatory River Contracts, and national, regional, and municipal stakeholder forums; River Contracts are bottom-up governance labs with periodic assemblies, technical modules and multi-stakeholder negotiation.	School programs by multiutilities, guided visits to water infrastructure, science workshops, campaigns; student awareness influences study choices and future roles as water professionals; large footprint in central/northern Italy.	National volunteer campaigns for river, beach, lake clean-ups, independent monitoring; citizen-driven datasets shape local action and policy, active involvement by environmental agencies (reporting, validation).	River Contracts, school programs, multiutility lab visits, clean-up mobilizations.

Country	Social Participation	Education and Awareness	Volunteerism & Civic Action	Notable Programs/Examples
Cyprus	Public participation structured by Water Development Department (WFD), stakeholder consultations for River Basin Management Plans, outreach to targeted groups and NGOs; multi-stage, open conferences, feedback channels.	Long-term school outreach (since 2007), dedicated Water Museum programs, Water in Cyprus curriculum, World Water Day, youth competitions (Stockholm Junior Water Prize), integration as core competency in primary schools.	Large-scale clean-up campaigns (Let's Do It! Cyprus: 25,000+ volunteers/week, 250,000 historical participation), Young Reporters for the Environment, Keep Our Sand and Sea Plastic Free, Mission Water for technical skill-building.	Water Museum, Young Reporters for the Environment, Let's Do It! Cyprus, Mission Water.

Table 7: Social Participation and Water Education: Approaches in Spain, Italy, and Cyprus

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Transnational Cooperation and Governance

1. Spain

Spain actively participates in international cooperation for the **sustainable water management**, especially in the field **of transboundary water resources**, due to the shared nature of several river basins with neighbouring countries.
Indeed, Spain shares various transboundary watercourses, including the Tagus (Tajo) Douro (Duero), Guadiana, and Miño rivers, as well as the Ebro basin, which requires cooperation mechanisms with neighbouring France and Andorra.
The country adheres to several international treaties and frameworks that aim to ensure the sustainable and equitable use of shared water resources.

A fundamental agreement is the **Albufeira Convention**, which Spain and Portugal signed in 1998 to set the principles and mechanisms for cooperation in the protection and sustainable use of transboundary river basins. The agreement includes regular data exchange, joint management bodies, and requirements for minimum ecological flows and for drought or hydrological stress periods.

In addition to bilateral treaties, Spain is involved in various **European Union water initiatives**, such as the WFD, which requires Member States to cooperate on the management of international river basin districts.

Spain is also a signatory to the **UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes** (Water Convention), which promotes integrated water resources management across borders and the prevention of transboundary impacts. Although originally a pan-European framework, this convention has become global and reinforces Spain's commitment to international best practices.

Spain relies on its international development cooperation agency, **AECID**, to export know-how, opportunities and support to other countries in the field of sustainable water resource management.
Many initiatives are being carried out to guarantee the right to access water and sanitation systems, as well as the availability of water for agriculture: projects in the Philippines and the Palestinian Territories, the **MASAR initiative**, a specific programme that aims to benefit from the experience and prestige of Spanish administrations in water management in the Mediterranean region.

In this regard, AECID's most ambitious commitment to achieving SDG 6 is the **Cooperation Fund for Water and Sanitation in Latin America and the Caribbean**, which has already benefited 4.3 million people on the continent. Work in this area focuses on expanding the coverage of basic water, sanitation and hygiene services, promoting the development of infrastructure for access to basic services, strengthening institutions and promoting public policies.

Spain also participates in the European Union's **EUROCLIMA programme** in the areas of urban water and energy efficiency. These actions have aimed to mitigate the impact of climate change in Latin America and the Caribbean by strengthening institutional capacities and regulatory frameworks.

As the central focus of all its actions, the AECID is committed to improving **integrated water resource management** by supporting water governance, which means that both people and institutions can maintain infrastructure and its costs in the long term[11]. In recent years, the Fund has worked on designing and implementing specific indicators to measure the relationship between programmes and environmental protection from an IWRM perspective.

As a result of these new indicators, the Fund's programmes have carried out 541 specific actions to protect water resources and produced 376 technical documents, guides and procedures based on an integrated water resource management approach. In addition, more than 63,000 people have attended workshops and awareness-raising sessions on this topic [12].

Spain's active participation in international cooperation activities in the field of water management represents its commitment to the International Water Strategy of the Ministry for Ecological Transition and Demographic Challenge that is written with the vision of a world with water security and access to water and sanitation. This **'International Water Strategy'**[13] is based on the vision, mission and strategic objectives for water resource management and on Spain's experience in foreign policy, which exports the Spanish model and principles of water management.

[11] AECID, Agua y Saneamineto: https://www.aecid.es/agua-y-saneamiento

[12] AECID, Gestión Integrada de los Recursos Hídricos: objetivo prioritario del Fondo del Agua y elemento crucial para la protección medioambiental: https://www.aecid.es/web/aecid-fcas/w/gestion-integrada-de-los-recursos-hidricos-objetivo-prioritario-del-fondo-del-agua-y-elemento-crucial-para-la-proteccion-medioambiental

[13] MITECO, Convenios y acuerdos internacionales: https://www.miteco.gob.es/es/agua/temas/convenios-acuerdos-internacionales.html

2. Italy

Italy is actively involved in numerous transnational strategies and international cooperation initiatives for the sustainable management of water resources and adaptation to climate change. These are implemented within multilateral initiatives, through the definition of an Italian strategy for inclusion in scenarios and through participation in cooperation projects.

Regarding multilateral initiatives and global commitments, the following are significant:

- the **Water Coalition** (G7 Climate, Energy and Environment), launched with Italian support: it promotes joint strategies to address the effects of climate change on water, with a focus on biodiversity and environmental degradation;
- the **United Nations Water Conference** (New York, 2023): Italy has signed 18 voluntary commitments, nine of which are managed by the Ministry of the Environment and nine by the Ministry of Foreign Affairs, for a total value of $6 billion. The funds are primarily earmarked for cooperation in the Balkans and Africa, as part of the Mattei Plan;
- the **Euro-Mediterranean Water Forum** (Rome, 2026), a strategic hub that places Italy at the center of the international dialogue on water governance in the Mediterranean;
- the Second Ministerial Meeting on Water of the Union for the Mediterranean (2026), which aims to strengthen cooperation between Mediterranean countries on issues such as wastewater reuse and climate resilience.

Italy's strategic vision is primarily contained in:

- **Three-Year Programming and Direction Document 2024-2026**, with which the Ministry of Foreign Affairs promotes cooperation based on peer-to-peer dialogue, mutual respect, and convergence of interests. Italy presents itself as a bridge between Europe, Africa, and the Middle East, enhancing physical, digital, and energy connectivity;
- **PNACC - National Plan for Adaptation to Climate Change**, which includes 361 specific actions, many of which are related to water management and international cooperation.

Some significant cooperation opportunities include:

- bilateral and regional projects: Italy collaborates with partner countries for the shared management of river basins, water reuse, and ecosystem protection;
- partnerships with UN and EU agencies, aimed at fostering synergies with international donors and multilateral bodies for sustainable development and water security;
- empowering water as an instrument of peace: in line with UN campaigns, Italy promotes water management as a lever for stability and conflict prevention, especially in vulnerable contexts.

3. Cyprus

Transnational cooperation appears to be essential in tackling water issues in regions poor in water. For this reason, Cyprus actively engages in international and regional frameworks that support the sustainable and cooperative management of water resources, particularly in response to shared challenges in the Mediterranean region. The Country is member of several agreements, among which:

- **UN Watercourses Convention (1997)**

  Cyprus is a party to this UN treaty, which promotes the equitable and sustainable use of international watercourses and cooperation between riparian states.

- **Helsinki Convention (1992)**

  Also known as the UNECE Water Convention, it supports the protection and sustainable use of transboundary watercourses and aquifers. Cyprus participates as a cooperating state within the UNECE framework.

- **Union for the Mediterranean – Water Agenda**

  Cyprus contributes to UfM regional efforts for integrated water resource management in the Mediterranean, focusing on resilience to climate change and water scarcity.

- **Eastern Mediterranean Tripartite Cooperation (Cyprus-Greece-Israel)**

  Though focused on energy, this cooperation includes elements of water management such as joint desalination projects and regional water security planning.

- **Med ECC& Horizon Projects**

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Cyprus participates in EU-funded regional research projects on water sustainability and climate impact in the Mediterranean basin.

Guidelines for a National Hydro-Strategy for Europe, informed by Spain, Italy, and Cyprus

Europe requires a hydro-strategy that is legally robust, basin-centric, climate-literate, and socially anchored. Spain, Italy, and Cyprus provide **three complementary archetypes** for building such a frame: a mature river-basin planning state with advanced reuse and desalination; a large, institutionally complex country confronting legacy losses and uneven service quality while mobilizing major recovery investments; and a structurally water-scarce island that has normalized non-conventional resources, centralized planning, and targeted social engagement. Drawing from these systems, a European hydro-strategy should couple the new EU Water Resilience agenda with country-level operational standards that make resilience measurable in governance, infrastructure, economics, and society.

The constitutional layer must begin by reiterating water as a public resource governed at the scale of river basins, with planning cycles aligned to the Water Framework Directive and national codifications that make ecological objectives, cost recovery, and risk management justiciable rather than aspirational. **Spain**'s consolidated **Water Law** and **basin authorities** show how river-basin management plans, strategic environmental assessment, and six-month participation windows can be routinized, with state and regional agencies sharing clear, non-overlapping mandates and the central ministry holding coherence across basins and transfers. The same scaffold integrates drought and flood plans and iterates every six years, with monitoring obligations and public registers to ensure transparency. Any European strategy should internalize this cadence and its instruments - drafts, formal consultation, reasoned replies, and final adoption - so that water policy is cyclic, documented, contestable, and data-led.

At the level of institutions and decision rights, polycentric governance must be made legible. Spain demonstrates a workable division of labor across the environment ministry and its water directorate, basin confederations, autonomous community agencies for internal basins, and municipalities for service operation; public funding streams and cohesion instruments then bind the pieces to common targets for reuse, desalination, and digitalization.

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The lesson is not to copy Spain's territorial design wholesale, but to **codify a European minimum standard** for who does what, when, with what data, and under which accountability tests, including how local tariffs, inter-basin projects, and emergency measures are debated and approved.

A national hydro-strategy must be explicit about the structural role of non-conventional resources. **Cyprus** has securitized its municipal demand with **base-load desalination and scaled treated-effluent reuse** as a standing agricultural water source. The country's water development authority plans, runs, and expands this portfolio in concert with surface storage and transfers, updating river-basin, drought, and flood plans with public consultation on six-year cycles. It quantifies capacity and losses in one frame - dam storage near 330 million m^3, seasonal drawdown, non-revenue water typically in the 20-30 percent band, and desalinated output above two hundred thousand cubic meters per day - so that allocation, emergency cuts, and investment are argued on numbers rather than impressions. A **European strategy** should adopt this **accounting discipline**, requiring each member state to publish, in comparable terms, its storage, secure yield, desalination and reuse capacities, aquifer recharge, and real losses, and to tether drought triggers and sectoral allocations to those metrics.

Performance benchmarking needs to mature from scattered indicators to a unified European dashboard. Spain's operator benchmarking (**SIBEA**) already tracks energy per cubic meter, reuse volumes, service continuity, and coverage; Italy's statistical system reports national losses, rationing days, and the added value of wastewater management; Cyprus publishes integrated supply and loss data while pairing them with coastal and inland quality results. A continental hydro-strategy should mandate a **harmonized set of performance ratios** - physical losses as a share of system input, energy intensity of supply and treatment, liters per capita per day in households, fraction of effluent meeting tertiary standards and reused, and continuity indices - reported at least annually, open-data by default, and tied to corrective action plans where thresholds are breached.

Infrastructure policy must resolve the tension between legacy networks and climate-ready assets. **Italy**'s experience - over forty percent system losses on average, stark regional disparities in sewer coverage and user satisfaction, and rationing events in the most fragile provinces - illustrates how deferred maintenance, fragmentation of operators, and aging pipes compound the **cost of climate shocks**.

Italy's recovery plan now earmarks targeted capital for drinking water, irrigation, and mixed uses, with a programmatic emphasis on digitalization, leak control, and completion of unfinished works, especially in the South. A European strategy should follow that lead by conditioning cohesion and recovery funds on loss-reduction roadmaps, pressure management and district metering, and pipeline replacement rates, with audited milestones that unlock tranches only when real losses decline and service continuity improves.

The financial architecture must be candid about the capital gap and tariffs. Spain's sector under-recovery, with tariffs below the EU average and a structural investment debt near the hundred-billion-euro mark, still sustains a large program for purification, efficiency, savings, and reuse through a blend of public, EU, and private participation. The policy implication is that national hydro-strategies should publish full-cost curves and define how much is recovered via tariffs versus grants, which parts of the cycle are priority candidates for blended finance, and how private capital is de-risked for desalination, industrial reuse, and digital retrofits, all while maintaining lifeline consumption blocks and social protections.

Resource diversification and circularity must be treated as core security instruments, not optional add-ons. Spain's world-leading reuse in arid regions and large coastal desalination hubs, Italy's imperative to lift reuse from a low baseline, and Cyprus's near-structural reliance on desalinated and regenerated water together argue for a European policy that fixes reuse targets by basin typology, streamlines permitting under the EU reuse regulation, and funds tertiary upgrades and agricultural conveyance where they deliver the greatest avoided abstraction. The strategy should also normalize managed aquifer recharge as a storage, quality, and anti-intrusion tool; Spain's planning documents already flag artificial recharge for overdrawn bodies and coastal belts, and this technique should migrate from pilot to portfolio across Mediterranean and Atlantic basins, accompanied by quality monitoring and liability rules.

Drought and flood governance must shift from crisis choreography to conditional playbooks. Spain's drought plans define phased indicators and measures, and its flood-risk plans integrate **land-use**, **warning**, and **civil protection**; Cyprus ties emergency allocations to live storage and desalination ramp-ups; Italy's **hydro-climate diagnostics** identify recurrent shortages and costly extremes that demand anticipatory infrastructure and operational rules.

A European hydro-strategy should therefore require every basin to pre-publish its drought stages, triggers, curtailment ladders, and alternative supply activations, and to test those rules with table-top exercises involving utilities, irrigators, and cities before the dry season, while flood plans should condition urban permits on permeability, storage, and conveyance standards.

Digital water must be mainstreamed as an efficiency and transparency spine. Spain's investment plans dedicate funds to **digital networks**, **smart metering**, **real-time pressure management**, and **leak analytics**; Cyprus demonstrates how IoT sensors and decision-support can optimize irrigation and quality control at small scale; Italy's modernization agenda elevates telemetry and control as pillars of loss reduction. The European strategy should require operator-level digital twins for major systems, mandate smart metering penetration thresholds in large utilities and irrigation districts, and standardize cybersecurity and data interoperability so that basin authorities can see aggregate flows, abstractions, and discharges without months-long reporting lags.

Quality and ecology demand a twin-track program: systematic compliance with chemical and microbiological standards and restoration of **hydromorphology** where status lags. Spain's monitoring shows that only about a third of surface bodies reach good ecological status while chemical status is stronger, and it pinpoints nutrients from agriculture and episodic shortfalls in sanitation as leading pressures; Cyprus pairs **excellent coastal bathing performance** with inland bodies still suffering from eutrophication. A European hydro-strategy must therefore align farm policies, urban wastewater upgrades, and river restoration, including nutrient budgets by sub-basin, tertiary treatment where receiving waters require it, reconnection of floodplains and removal or bypass of barriers, and explicit biodiversity indicators linked to Natura 2000 objectives.

Social participation and education are not decorative; they are operational risk controls. Spain's formal basin consultations, public records of comments and responses, and municipal-to-national programs of awareness and volunteerism show how legitimacy and data can be produced outside the plant fence. Italy's "**water democracy**" through River Contracts and large-footprint school programs run by utilities convert literacy into co-design and scrutiny of plans. Cyprus couples national campaigns with museums, school curricula, and island-wide clean-up mobilizations, transforming awareness into routines that support drought discipline and reuse acceptance.

A European strategy should therefore mandate minimum participation standards per basin, require education tracks in utility licenses and agricultural extension, and support citizen-science networks that feed comparable data to agencies. Participation must be evaluated on representativeness and uptake, not just on the existence of meetings.

Industry and agriculture must be addressed through sector-specific compacts rather than generic exhortations. Spain's legal and financial ecosystem already recognizes reclaimed water for farms, pilots aquifer recharge in stressed bodies, and advances adaptive forest management to rebalance evapotranspiration and blue water in semi-arid zones. Italy's industrial and agricultural users sit atop a leaky, uneven municipal base and therefore stand to gain most from loss reductions, tertiary expansions, and standardized permits for reclaimed uses, while tariff and grant design should back rapid conversion of green spaces, industry cooling, and greenhouse irrigation to non-potable sources. Cyprus shows how tourism and food processing can normalize greywater, drip irrigation, and reuse without compromising public health when oversight and monitoring are strong. The European strategy should codify sectoral pathways with dated milestones: hectares converted to drip and deficit irrigation, factories certified to reuse standards, tourism hubs with on-site reuse and leak-free internal networks, and forestry measures that demonstrably increase baseflow and reduce fire risk without sacrificing carbon goals.

Economic instruments have to correct signals without eroding equity. Spain's evidence on average drinking-water prices, regional dispersion, and the scale of public-EU-private co-financing suggests a triad: keep lifeline tariffs and social funds that secure affordability, price discretionary and non-essential uses to reflect scarcity and externalities, and deploy smart subsidies for conversion to reuse, desalination where it is least-cost secure, and digital loss reduction with payments on verified savings. Italy's recovery allocations illustrate how national treasuries can prime these shifts where local fiscal space is thin, provided disbursement is conditional on transparent milestones. Cyprus's tariff structure and state support to agriculture demonstrate how to balance cost recovery with strategic subsidies when irrigation is a livelihood and food-security concern, while avoiding perverse incentives that entrench inefficient crops or methods.

Climate adaptation must be the organizing logic, not a concluding chapter.

Spain's vulnerability profile - heavier but less frequent rains, prolonged droughts, desertification risk - demands adaptive planning that fuses **hydraulics**, **nature-based solutions**, and **storage** for both water and energy, including pumped hydro as an enabler of variable renewables. Italy's **diagnostics** - heat, drought, flood, coastal erosion, and infrastructure stress - argue for **integrated siting rules**, **resilience standards** for water plants, and **climate-conditioned maintenance budgets**. Cyprus's **adaptation pathway - desalination expansion**, s**marter irrigation, risk mapping for sudden storms, and the integration of water-sensitive urban design** - shows how small systems can harden quickly if governance is centralized and metrics are public. A European hydro-strategy should therefore require that every basin plan include a quantified climate stress test to 2050 and 2080, a no-regret portfolio that clears today on cost-benefit grounds, and a set of options with clear go/no-go triggers as climate signals cross thresholds.

Measurement, verification, and learning must close the loop. Spain's periodic basin reports to the Commission, Italy's national hydrologic balance and SDG-aligned indicators, and Cyprus's six-yearly plan updates together suggest how to institutionalize reflexivity. The European hydro-strategy should require an open, versioned data room for each basin, with time-series on abstractions, quality, losses, reuse, desalination, energy intensity, and customer outcomes; independent audits of operator data; and ex-post evaluations of drought and flood episodes that feed the next cycle. Institutions should be asked to publish not only what worked but also what failed, with reasons and corrections documented in the following plan.

Finally, hydro-diplomacy and skills pipelines deserve explicit status as enabling systems. The Mediterranean cooperation platforms catalogued in the Spanish analysis - **Union for the Mediterranean** and **PRIMA** - should be operationalized as exchange and funding gateways for reuse retrofits, aquifer recharge design, and digital water pilots across EU and neighbor basins. In parallel, member states should be asked to commit to multi-year education and training tracks that start in schools, pass through vocational institutes and universities, and culminate in operator certification and continuous professional development for basin managers, utility engineers, irrigators, and city planners. The objective is not a communications gloss but a durable expansion of Europe's "water competence," because resilience requires people who can run, maintain, and improve the very systems policy imagines.

If adopted in this integrated form - legally precise, institutionally clear, infrastructure- and digital-forward, economically honest, ecologically grounded, socially mobilized, and climate-directed - a National Hydro-Strategy for Europe will not simply add another plan to the shelf. It will convert the best of Spain's basin governance and reuse leadership, Italy's modernization drive and indicator discipline, and Cyprus's non-conventional backbone and centralized resilience into a common operating system that protects ecosystems, secures households and industry, and keeps Europe's water economy viable in a hotter, drier century.