# **AG-WaMED** | Advancing non conventional water management for innovative climate-resilient water governance in the Mediterranean Area

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Deliverable 4.2.2.d

# National policy document for NCW upscaling - Spain

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| **Abstract** | The present report is produced as deliverable for the task 4.2 of AG-WaMED,Integrated Watershed Management Plans and NCW out-scaling. The document contributes to the development of national policy frameworks for upscaling non-conventional water (NCW) uses in selected Mediterranean countries. It addresses the emerging concept of water transition, understood as a shift towards more sustainable governance and use of water resources. Through a systematic literature review, the study develops a conceptual framework that identifies the key barriers and drivers of water transitions. It applies this framework to a case study of a living lab (Spain) to analyze upscaling processes at the national level. The findings inform future policy recommendations and contribute to broader Mediterranean-scale strategies for NCW deployment. | | |
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# Introduction

This document is intended for the development of Deliverable 4.2.2.5, "National policy documents for NCW upscaling (Italy, Spain, Egypt, Tunisia, Algeria, D34)." Subsequently, the results will also contribute to sub-task 4.3.1, “Policy document for upscaling and out-scaling NCW at the Mediterranean scale (M20-34).”

In the face of increasing global water scarcity driven by the combined effects of climate change and water appropriation regimes, transitioning to more sustainable water governance and usage has become a critical issue for our societies (Brudge 2005, 2007). The objective of this document is to collect data to compare the upscaling processes of NCW at the national level. In a narrower sense, the 'scaling out' process can be defined as the expansion of innovations to a larger group of actors, 'scaling up' as the implementation of political and legal changes, and 'scaling deep' as the enactment of profound cultural and institutional changes (Breaught et al. 2021).

These processes involve water transition, a new key concept in water governance. While several countries around the world claim to be engaging in water transitions, often framed by governments as a promise of success for moving towards water sustainability, the conditions necessary to achieve these objectives need to be better identified. Indeed, local administrations and organisations face obstacles or barriers of various kinds that can prevent, hinder, or slow the implementation of these transitions (Heiberg, Truffer, and Binz 2022; Sixt, Klerkx, and Griffin 2018).

In the field of research, the concept of water transition has been used by several scholars (Sullivan et al. 2017; Hartman et al. 2017; Travassos and Momm 2022). It has become an operational framework for analysing the transformation of water governance, as it implicitly incorporates the idea of a rupture towards more sustainable water uses (Eggimann et al. 2018; Novalia, Rogers, and Bos 2021). Much of this research falls within Sustainability Transition Studies. In the water domain, transition refers to the success of social or technological innovation that leads to the creation and implementation of institutional and technological changes to improve the sustainability of the water system (Hartman et al. 2017).

Although the notion of water transition is increasingly employed in scientific research and public policies, it has not been critically examined from the perspective of water governance research. We have not found any articles within this field that propose defining the contours of this concept. No research has yet undertaken a synthesis of the main empirical barriers and drivers of water transition implemented worldwide. We aimed to fill this gap by defining the boundaries of this concept through a systematic meta-analytical approach (Van Houtven 2007) in the literature on water transitions. By conducting a comprehensive analysis of this phenomenon, we identified the barriers that hinder water transitions globally, as well as the drivers that facilitate their deployment.

This paper is structured in three sections. First, we explain our methodology, which involves literature review. We then present the conceptual framework that we developed by identifying the barriers and drivers of water transitions. Finally, we present the results of applying this framework to a case study of a living lab. This application helps to understand the upscaling processes of NCW at the national level.

# Methods

Based on a literature review on "water transitions", we have identified the main barriers and drivers to water transitions. We develop a conceptual framework of these barriers and drivers to then identify them in each living lab for understanding the up-scaling process of NCW.

## Literature review

This research relied on a systematic meta-analytical approach (Van Houtven, 2007). This method uses empirical evidence to identify common points and causal mechanisms that contribute to the construction of notions or theories (Oberlack and Eisenack 2014, Wolfram and Kienesberger, 2023). Meta-analytical approaches are increasingly used to address global and regional patterns of socio-environmental change (Author et al. 2017). By capturing these processes, it bridges the gap between global assessments, which often lack detailed case studies.

Our research is based on systematic case selection and theory-grounded coding. First, the text corpus was constructed by consulting articles published between 2014 and 2024 from two databases: Social Sciences and Humanities Proceedings (ISI WOS) and Scopus "Social Sciences." The search was conducted by combining several keywords (see Table 1).

*Table 1. Keywords used for article research. Source: Authors, 2024.*

| **WOS Social Science** | | |
|---|---|---|
| **Search string** | **Hits** | **Date** |
| "sustainab* system" AND Water | 14 | 08-dic |
| (sustainab* AND socio*techn*) AND Water | 46 | 08-dic |
| "sustainability transition*" AND Water | 140 | 08-dic |

| | | |
|---|---|---|
| (sustainab* AND transition*) AND Water | 1006 | 08-dic |
| (sustainab* AND [niche* OR regime*]) AND Water | 458 | 08-dic |
| (sustainab* AND pathway*) AND Water | 535 | 08-dic |
| (“system transition*” OR “system transformation*”) AND Water | 41 | 08-dic |
| (system* AND [transformation* OR transition*]) AND Water | 1615 | 08-dic |
| (system* AND [niche* OR regime*]) AND Water | 653 | 08-dic |
| (system* AND [niche* OR regime*] AND [transformation* OR transition*]) AND Water | 145 | 08-dic |
| (system* AND pathway*) AND Water | 770 | 08-dic |
| (system* AND pathway* AND [transformation* OR transition*]) AND Water | 142 | 08-dic |
| ([transformation* OR transition*] AND socio*techn*) AND Water | 50 | 08-dic |
| ([transition* OR transformation*] AND pathway*) AND Water | 235 | 08-dic |
| (“transition stud*” OR “transition theor*” OR “transition approach*”) AND Water | 31 | 08-dic |
| ([niche* OR regime*] AND socio*techn*) AND Water | 28 | 08-dic |
| (pathway* AND socio*techn*) AND Water | 7 | 08-dic |
| **SCOPUS Social science** | | |
| **Search String** | **Hits** | **Date** |
| “sustainab* system” AND Water | 56 | 08-dic |
| (sustainab* AND socio*techn*) AND Water | 31 | 08-dic |

| | | |
|---|---|---|
| “sustainability transition*” AND Water | 64 | 08-dic |
| (sustainab* AND transition*) AND Water | 731 | 08-dic |
| (sustainab* AND [niche* OR regime*]) AND Water | 522 | 08-dic |
| (sustainab* AND pathway*) AND Water | 375 | 08-dic |
| (“system transition*” OR “system transformation*”) AND Water | 30 | 08-dic |
| (system* AND [transformation* OR transition*]) AND Water | 2066 | 08-dic |
| (system* AND [niche* OR regime*]) AND Water | 1372 | 08-dic |
| (system* AND [niche* OR regime*] AND [transformation* OR transition*]) AND Water | 147 | 08-dic |
| (system* AND pathway*) AND Water | 642 | 08-dic |
| (system* AND pathway* AND [transformation* OR transition*]) AND Water | 86 | 08-dic |
| ([transformation* OR transition*] AND socio*techn*) AND Water | 26 | 08-dic |
| ([transition* OR transformation*] AND pathway*) AND Water | 184 | 08-dic |
| (“transition stud*” OR “transition theor*” OR “transition approach*”) AND Water | 34 | 08-dic |
| ([niche* OR regime*] AND socio*techn*) AND Water | 10 | 08-dic |
| (pathway* AND socio*techn*) AND Water | 4 | 08-dic |

After removing duplicates, we reviewed the titles of the results (n = 2184) to check whether they were concerned about water resources or drinking water. During this first screening, a large number of publications had to be excluded due to terminological overlaps but lacking relevant content (e.g. ocean, fish in rivers, and maritime transport). Second, the abstracts of the remaining articles (n = 350) were examined according to two criteria: first, whether the article mentioned governance issues, and second, whether the issue of change or transition reflected in the title was substantiated. Third, for the selected articles (n = 74), we reviewed the full text by reading the introduction, methodology, and results to verify that the article's analysis focused on a case study of water transition, even if the author did not necessarily use this term. This resulted in a corpus of 52 publications. We then coded the articles on Atlas-TI to describe these studies by identifying the theoretical framework, object of analysis (innovation, regime, or other), and use of hydrological data. Next, we sought to outline the contours of water transitions according to their application domains and geographical characteristics (country, space, and scale). Finally, we identified textual elements referring to barriers or drivers of transition.

# Theorical framework proposal

In this section, we present the barriers and drivers identified from the literature review. For each of them, we provide a definition.

## Barriers of water transitions

The analysis of the corpus identified eight types of barriers to water transition in 26 articles (Table 2).

*Table 2. Presentation of eight barriers to water transition. Source: Authors, 2024.*

| | **Barriers** | **Definition** | **References** |
|---|---|---|---|
| 1 | Intersectoral barrier | Lack of relationships between actors at different levels, absence of individuals, collective, and technical synergies, and/or emergence of conflicts around an innovation. | (9) Ward and Butler 2016; Hess 2018; Liu and Jensen 2018; van Welie et al. 2018; Savini and Giezen 2020; Novalia, Rogers, and Bos 2021; Heiberg, Truffer, and Binz 2022 ; Nilsson and Blomkvist 2021; Travassos y Momm 2022 |
| 2 | Political barrier | Lack of clear political support for local initiatives, absence of participation and consideration of local needs, and international orientation by funders towards policies and projects unsuitable for Southern regions. | (7) Acheampong, Swilling, and Urama 2016; Ward and Butler 2016; Silvestri et al. 2018; Sixt, Klerkx, y Griffin 2018; Yasmin, Farrelly, and Rogers 2018; Afghani, Hamhaber, and Frijns 2022; Travassos y Momm 2022 |

| | | | |
|---|---|---|---|
| 3 | Institutional barrier | Institutional fragmentation and internal coordination problems, strong institutionalization of the existing sociotechnical regime entrenched in daily institutional practices and logics. | (6) Herslund et al. 2018; Kundu et al. 2018 ; Sixt, Klerkx, y Griffin 2018; Suleiman 2021 ; Helgegren et al. 2021 ; Pakizer et al. 2023 |
| 4 | Economical barrier | Lack of visualization of the benefits and economic viability of the innovation compared to established regimes, or costs too high relative to demand uncertainty. | (6)<br>Domènech et al. 2015; Xu et al. 2016; Ward y Butler 2016; Kundu et al. 2018; Silvestri et al. 2018; Sixt, Klerkx, y Griffin 2018 |
| 5 | Normative barrier | Regulatory obstacles produced by legal frameworks or poor definition of laws leading to interpretation issues. | (5) Baigorrotegui, Parker, y Estenssoro 2014; Domènech et al. 2015; Ward y Butler 2016; Liu y Jensen 2018; Afghani, Hamhaber, y Frijns 2022 |
| 6 | Technical barrier | Inadequate infrastructure, difficulties in use or malfunction of the innovation. | (4) Domènech et al. 2015 ; Kundu et al. 2018 ; Eggimann et al. 2018 ; Nilsson y Blomkvist 2021 |
| 7 | Cognitive barrier | Lack of knowledge to use or maintain new technologies. | (4) McConville et al. 2017; Liu y Jensen 2018; Suleiman 2021; Afghani, Hamhaber, y Frijns 2022 |
| 8 | Behavioral barrier | Failure to consider contexts (practices, habits, beliefs) in developing innovation and the economic, social, and environmental benefits it can provide. | (3) Kundu et al. 2018; Silvestri et al. 2018; Afghani, Hamhaber, y Frijns 2022 |

The most recurrent type of barrier-to-water transition is the intersectoral barrier. This refers to situations where there are no relationships between actors (social, institutional, political, and economic) at different levels, or there is a lack of synergies and alignments to support innovation. It also refers to the presence of resistance or conflict regarding innovation. The second type is political barriers. In this case, the lack of political support for local initiatives, failure to consider the needs of local populations, and implementation of ill-suited projects by international donors and organisations hinder water transitions. The third type is institutional barriers, which are linked to institutional fragmentation and coordination problems among institutional actors or excessive institutionalisation of the existing sociotechnical regime, generating path dependence situations.

The fourth type is economic barriers. The lack of visibility of benefits and economic viability of innovation, compared to established regimes, as well as high costs relative to demand uncertainty and market existence, can hinder water transitions. The fifth barrier is normative barriers, referring to the obstacles produced by the current legal and regulatory frameworks. A lack of clarity in law definitions can also create difficulties in local interpretation and hinder water transition. The sixth is technical barriers related to difficulties in using innovation due to poor design or malfunction. Dependence on centralised infrastructure which is unsuitable for local practices, can also hinder transition. The seventh type is cognitive barriers: a lack of knowledge to use or maintain new technologies can slow water transitions. Finally, behavioural barriers to water transitions are linked to disregard for contexts (practices, habits, and beliefs) in which innovation can be adopted, as well as economic, social, and environmental benefits.

## Drivers of water transitions

The analysis of the corpus identified eight types of water transition drivers in 28 articles (Table 3).

*Table 3. Presentation of eight drivers of water transition. Source: Authors, 2024.*

| | **Drivers** | **Definition** | **References** |
|---|---|---|---|
| 1 | Shared vision driver | The existence of a common vision that shifts collective perception towards a new regime or widespread adoption of innovation. | (7) Fam et al. 2014; van der Voorn and Quist 2018; White et al. 2019; Lennartsson et al. 2019; Criqui, 2020; Miörner et al. 2022; Mguni et al. 2022 |
| 2 | Cognitive driver | The creation and assimilation of knowledge to enhance policy orientation; the presence of professional knowledge to support innovation; individual and social learning to change practices. | (7) Hoolohan et al. 2019; Criqui, 2020; Herrfahrdt-Pähle et al. 2020; McConville et al. 2022; Mguni et al. 2022; Binz et al. 2016 ; Blomkvist et al. 2020 |
| 3 | Institutional driver | The existence of formal and informal institutions to drive experimentation, a coherent and flexible framework, and multiple institutional mechanisms to | (6) Werbeloff et al. 2017; Wutich et al. 2020; Herrfahrdt-Pähle et al. 2020 ; Ampe et al. 2021; Pollachi et al. 2023; Nastar 2014 |

| | | | |
|---|---|---|---|
| | | facilitate regime change and support this transition. | |
| 4 | Individual driver | The presence of a promoter who uses their influential power to support the transition, particularly from the beginning of the process and to steer towards regulatory framework change. | (6) Werbeloff et al. 2017; Wutich et al. 2020; Ampe et al. 2021; Pollachi et al. 2023; Travassos and Momm 2022; Nastar 2014 |
| 5 | Networks drivers | The existence of networks with actors located at other scales to support innovations, their diffusion, or scaling up. | (5) Lieberherr and Truffer 2015; Mguni et al. 2022; da Conceição et al 2023; Dobre et al. 2018; Nastar 2014 |
| 6 | Political driver | Political support from state actors and coherence of public policy instruments to support the transition. | (5) Sullivan et al. 2017; García Soler et al. 2018; Hoolohan et al. 2019; Karimi et al. 2021;<br>Suleiman et al. 2020 |
| 7 | Normative driver | Legal support through the presence of clear and strict regulatory measures, and assistance to stakeholders for their proper implementation. | (3) Werbeloff et al. 2017; Hartman et al. 2017;<br>Suleiman et al. 2020 |
| 8 | Economic driver | The existence of financial support from various stakeholders and demand or market to support the innovation. | (3) McConville et al. 2022;<br>Binz et al. 2016 ; Suleiman et al. 2020 |

The most common driver of water transition is sharing a common vision among different actors. This refers to the existence of a collective vision built in collaboration among stakeholders that generates a change in perception, favouring a new sociotechnical regime. User support (both public and consumer) is also a key element in adopting innovation and supporting transitions. The second type is cognitive drivers. In this case, the creation and assimilation of knowledge improves policy orientation, and decision-making accelerates water transitions. Additionally, improving professional knowledge (2) and individual learning to integrate the use of innovation are key elements in their development.

The third type of driver, institutional, is linked to the existence of formal and informal institutions that can drive experimentation, a coherent and flexible framework, and several institutional mechanisms that can provide a solid foundation for water transitions. The fourth category refers to individual drivers. The presence of promoters, leaders with particular skills, and creative minds who use their influence to support the transition is key. This role is particularly important if engaged early in the transition process towards changing regulatory frameworks.

The fifth driver is associated with the existence of networks. The presence of contact and relationships with actors at other scales supports innovation, diffusion, and scaling up. Political drivers refer to the importance of political support from state actors as well as the integration and coherence among different public policy instruments to support the water transition. The seventh type of driver is legal: legal support for innovations and regime changes through strict and clear regulatory measures and the training of officials and managers for their proper application strengthens the success of transitions. Finally, economic drivers are linked to the financial assistance required for innovation development, as well as the formation of demand by users, and thus, a market for further development.

# Barriers and drivers in Spain

In this section, we aim to analyze the barriers and drivers identified for the case of Spain. These were derived from two main sources: the responses to the guidelines provided to the countries (a methodology specific to this deliverable) and the inputs from Deliverable 4.1.1, Integrated Governance and Policy Analysis Report.

## Barriers

### *Intersectoral Barrier: Coordination Strengths and Economic Conflicts*

According to stakeholders in the Segura Basin and Campo de Cartagena, there is strong collaboration among water sector actors, developed over years of addressing water scarcity challenges. These actors have implemented collaborative strategies and maintain good institutional relationships. However, challenges persist in coordinating desalination projects, which are promoted at the national level, while the necessary infrastructure for water distribution is often developed by regional or local authorities, or even by farmers themselves. Stakeholders note that budget restrictions frequently delay projects, reducing their effectiveness .

A key economic conflict arises around the cost of desalinated water. While urban water managers can pass costs onto consumers, farmers must compete in open markets with producers who have access to significantly cheaper water sources. This creates a major challenge for agricultural irrigation, as desalinated water is often too expensive for competitive farming. Additionally, desalinated water cannot be used exclusively for irrigation due to its chemical composition. Stakeholders indicate that mixing different water sources is necessary to maintain adequate water quality for agricultural use.

Despite frequent cooperation among institutions, broader water policies remain fragmented. Reports highlight that hydrological planning and territorial management operate separately, preventing a truly integrated approach to water governance.

## Political Barrier: Conditional Support and Policy Conflicts

Stakeholders report that political support for desalination initiatives exists but is often theoretical. While desalination is promoted, its full potential is not utilized due to difficulties in securing users willing to pay the high cost of desalinated water when cheaper conventional resources are available. As a result, in times of scarcity, conventional water sources are already depleted, and desalination cannot fully cover demand.

Political alignment between national, regional, and local governments influences how local needs are considered. When governments at different levels belong to the same political party, local needs are better integrated. However, political conflicts arise when national and local authorities follow opposing policies, particularly regarding intensive agriculture. Stakeholders indicate that local governments, regardless of political orientation, generally support the agricultural sector, while national authorities that seek to limit agricultural expansion tend to overlook local priorities.

At the EU level, stakeholders express concerns about unequal trade regulations. While European farmers must comply with strict environmental standards, food imports from non-EU countries are not subject to the same requirements. Farmers argue that traceability and regulatory equivalence should apply to imported products to ensure fair competition.

Regarding drought management, reports indicate that plans exist but lack clear criteria for selecting measures. Although implementation mechanisms are outlined, the cost-effectiveness of different options is not always assessed, making it difficult to prioritize the most efficient solutions during drought periods.

## Institutional Barrier: Coordination Challenges and Pricing Disparities

It is possible to identify three major institutional coordination challenges related to the use of desalinated water in agriculture. First, while desalination plants are relatively easy to build, the necessary storage, transportation, and distribution infrastructure is much more complex and depends on multiple administrative bodies, making coordination difficult. Second, managing the supply and demand of desalinated water presents challenges. Desalination facilities must operate continuously at full capacity to remain efficient, yet demand fluctuates—it is low in normal years due to the availability of cheaper conventional water and insufficient during drought periods when demand surpasses production capacity. Institutional coordination is necessary to balance these fluctuations. Third, the pricing structure of desalinated water is a significant obstacle. While urban consumers can absorb higher costs, agriculture struggles with the high cost of desalinated water. Farmers with historical water rights access cheaper conventional sources, while those dependent on desalinated water bear the full cost of infrastructure amortization and maintenance. This disparity in water pricing creates market dysfunctions, as all farmers compete in the same market despite vastly different water costs.

Additionally, reports highlight inconsistencies in National Hydrological Planning, particularly between the Segura and Tagus River Basin Management Plans, where conflicting water use policies and demands create uncertainty for the agricultural sector. The absence of a national strategy to provide alternatives to the water crisis exacerbates this issue, increasing uncertainty for farmers who rely on water transfers and desalination.

While efforts are being made to promote desalinated water use in agriculture, institutional practices do not fully address economic barriers, and pricing disparities remain a major constraint to widespread adoption.

## Economic Barrier: High Costs, Demand Uncertainty, and Market Imbalances

The Living Lab representatives indicate that desalinated water is the most expensive resource available, leading to highly uncertain demand. When conventional water sources (such as groundwater or water transfers) are available at a lower cost, desalinated water remains unsold, compromising the financial viability and amortization of desalination plants. However, in drought years, demand increases significantly, and both urban suppliers and farmers are willing to pay high prices. This demand fluctuation poses a major management challenge, which, according to the representatives, requires economic instruments to stabilize prices over time.

In the Segura Basin, conventional water resources are almost fully exploited, and in some cases, such as groundwater, they have reached overexploitation. According to the representatives, while desalination and urban water reuse are the only viable alternatives, their high cost limits adoption in agriculture. Farmers relying on desalinated water must cover the full cost of infrastructure amortization, whereas those with historical water rights access significantly cheaper resources, creating competitive imbalances in agricultural markets.

Previous reports (4.1.) highlight additional financial challenges, including the high energy cost of desalination and its greenhouse gas emissions. While urban users generally accept higher water tariffs to comply with the Water Framework Directive (WFD), concerns remain about social sustainability and the risk of water poverty. Additionally, the rising cost of desalinated water impacts farmers, who, according to reports, will lose 27 cubic hectometers per year due to reduced water transfers, forcing them to increase reliance on desalination at significantly higher costs.

To ensure the long-term viability of desalination, the Living Lab representatives suggest implementing price stabilization mechanisms similar to those used in the electricity market, where costs are distributed across different supply sources. They also propose improving energy efficiency and promoting the use of renewable energy to reduce production costs and make desalinated water more affordable for agricultural use (Living Lab responses, Project Deliverables).

## Normative Barrier: Legal Framework and Pricing Mechanisms

There are no direct regulatory obstacles to desalination projects, but the legal framework for water rights creates indirect challenges (Living Lab responses). In Spain, naturally flowing waters are considered public domain, whereas desalinated water is privately owned. Seawater, before desalination, falls under maritime public domain, requiring authorization or concession from the Administration. Once desalinated, its use is outside the concession regime of the Water Law. However, if desalinated water is mixed with public water sources (e.g., rivers, reservoirs, or aquifers), its use may require a water concession.

The pricing mechanism for desalinated water is identified as the main regulatory challenge affecting its adoption in agriculture. Since most desalination plants have been developed and operated by public administrations, they must recover investment and operational costs through legally established pricing systems. This results in higher water prices for farmers compared to conventional water sources. Many farmers consider the cost of desalinated water excessive and choose not to use it when lower-cost alternatives are available .

## Technical Barrier: Infrastructure Limitations and Water Quality Issues

The current infrastructure is adequate for desalinated water production, but distribution remains a significant limitation. While urban areas generally have the necessary transport systems to integrate desalinated water into municipal supply networks, agricultural areas lack sufficient distribution infrastructure to reach all potential users. Since desalinated water is typically a complementary resource, shortages in conventional water sources occur in various locations, many of which are not connected to desalination plants, making access difficult. Additionally, because desalinated water is available at sea level, its distribution across agricultural regions requires significant pumping infrastructure.

Technical issues related to water quality also pose challenges. Desalinated water contains low levels of essential nutrients such as calcium, magnesium, and sulfate, requiring fertilizer adjustments to avoid nutrient deficiencies in crops. Additionally, sodium and chloride residues can accumulate in the soil over time, reducing permeability and fertility, while boron levels may not always be sufficiently reduced during desalination, making it potentially toxic for certain crops.

Energy dependence is another major limitation. The high electricity consumption of desalination plants makes the cost of water vulnerable to energy price fluctuations, increasing its economic burden on farmers. Additionally, brine disposal and $CO_2$ emissions have raised environmental concerns, particularly from environmental organizations. Reports highlight that desalination consumes 3.5 to 4 times more energy than water transfers, further increasing costs and carbon emissions. The underutilization of desalination plants during periods of low demand can also drive up fixed costs, worsening financial sustainability.

To address these issues, solutions include mixing desalinated water with conventional sources, when possible, and linking desalination plants to renewable energy sources to improve cost efficiency and reduce environmental impact.

## Cognitive Barrier: Technical Knowledge and Capacity-Building Needs

Farmers in the Campo de Cartagena Irrigation District are technically well-prepared to manage the challenges associated with desalinated water use. They possess the necessary knowledge to adjust irrigation and fertilization practices when transitioning to desalinated water, ensuring efficient use of the resource. Although lack of training is not considered a major barrier, stakeholders suggest that capacity-building programs could be beneficial in preventing soil degradation linked to long-term desalinated water use. Such programs could focus on best practices for maintaining soil health and improving water management strategies to enhance sustainability.

## Behavioral Barrier: Perceptions, Economic Constraints, and Environmental Criticism

Local practices, habits, and beliefs in Campo de Cartagena are generally supportive of desalination projects, as the long history of water scarcity has convinced farmers of the importance of desalinated water for sustaining agriculture. Farmers are willing to manage water quality challenges, such as mineral deficiencies or potential soil impacts, and local irrigation systems are highly technological, allowing for the necessary adjustments in fertilization and irrigation protocols. However, the main challenge remains economic, as desalinated water is significantly more expensive than conventional sources, and current subsidies or financial aid are insufficient to incentivize its adoption.

Efforts to integrate technological solutions into desalination projects have been accompanied by programs addressing cultural adaptation, economic feasibility, and social acceptance, which have successfully engaged communities and incorporated desalinated water into existing agricultural systems. However, reports highlight strong criticism of desalination from an environmental perspective, particularly regarding brine disposal, high energy consumption, and $CO_2$ emissions. Additionally, desalination has been linked to urban expansion and real estate market interests, particularly along the Mediterranean coast before the 2008 crisis, where investment in desalination was seen as part of broader infrastructure financing strategies rather than purely as a water security measure.

While increasing desalination appears to be a viable option, reports emphasize that its feasibility depends on economic and environmental factors, such as reducing energy costs, minimizing $CO_2$ emissions, and ensuring that desalinated water is mixed with conventional sources to improve water quality and reduce soil degradation risks.

Table 4. Main Barriers to water transition in Spain

| | **Barriers** | **Definition** | **Description** |
|---|---|---|---|
| 1 | Intersectoral barrier | Lack of relationships between actors at different levels, absence of individuals, collective, and technical synergies, and/or emergence of conflicts around an innovation. | Strong collaboration exists among water sector actors, but budget constraints and investment delays limit effectiveness. Economic conflicts arise from higher desalinated water prices for farmers compared to urban consumers, impacting adoption. |

| | | | |
|---|---|---|---|
| 2 | Political barrier | Lack of clear political support for local initiatives, absence of participation and consideration of local needs, and international orientation by funders towards policies and projects unsuitable for Southern regions. | Political support for desalination is often theoretical, with challenges in fully utilizing desalination plants. Political alignment between national and local governments influences policy implementation, and EU regulations on agricultural sustainability create market disadvantages for Spanish farmers. |
| 3 | Institutional barrier | Institutional fragmentation and internal coordination problems, strong institutionalization of the existing sociotechnical regime entrenched in daily institutional practices and logics. | Coordination challenges arise due to the need for additional infrastructure to distribute desalinated water, pricing disparities among water users, and inconsistencies in National Hydrological Planning between river basins. |
| 4 | Economical barrier | Lack of visualization of the benefits and economic viability of the innovation compared to established regimes, or costs too high relative to demand uncertainty. | High desalination costs make water demand unstable—low in normal years and high in droughts. Farmers face unequal water pricing, with those using desalinated water paying higher costs than those with historical water rights. Energy prices further affect affordability. |
| 5 | Normative barrier | Regulatory obstacles produced by legal frameworks or poor definition of laws leading to interpretation issues. | No direct regulatory obstacles exist, but water rights frameworks create complexity. Desalinated water is privately owned, while public water mixing requires additional concessions, complicating access. Pricing regulations require full cost recovery, discouraging agricultural use. |
| 6 | Technical barrier | Inadequate infrastructure, difficulties in use or malfunction of the innovation. | Sufficient production capacity exists, but distribution networks for agriculture are insufficient. Water quality issues (low minerals, sodium, boron) require careful management to avoid soil degradation. Desalination is energy-intensive, increasing reliance on electricity. |
| 7 | Cognitive barrier | Lack of knowledge to use or maintain new technologies. | Farmers are technically well-prepared for desalinated water use. While training is not a major barrier, capacity-building programs could help prevent soil degradation |

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| | | | from long-term desalinated water use. |
| 8 | Behavioral barrier | Failure to consider contexts (practices, habits, beliefs) in developing innovation and the economic, social, and environmental benefits it can provide. | Farmers accept desalinated water as necessary but struggle with high costs. Environmental concerns focus on brine disposal and high $CO_2$ emissions. Desalination investments have also been linked to urban expansion interests along the Mediterranean coast. |

# Drivers in Spain

## Shared Vision Driver: Strong Support for Desalinated Water, but Economic Barriers Persist

In Spain, particularly in the Campo de Cartagena Irrigation District, there is a strong, shared vision among most actors regarding the importance of desalinated water for agriculture. Farmers recognize desalinated water as a key solution to water scarcity and environmental degradation, and there are very few stakeholders who oppose its use.

This common vision has facilitated collective adoption of desalination technology. However, the high cost of desalinated water remains a major challenge. Many farmers struggle to afford it, making them less competitive in both domestic and international markets. Despite this economic barrier, the shared vision has mobilized stakeholders to actively seek solutions.

The Campo de Cartagena Irrigation District has demonstrated a strong commitment by consistently applying for annual water concessions from desalination plants such as Valdelentisco, Torrevieja, Escombreras, and Mojón. These applications reflect the clear demand and willingness to integrate desalinated water into agricultural practices, even though not all requests have been granted due to resource limitations.

At the policy level, there is still a lack of integration between hydrological and territorial planning. Water policies remain fragmented across different administrations, making it difficult to fully realize a coordinated approach to desalinated water management. A more comprehensive and integrated strategy could further strengthen the effectiveness of this shared vision.

## Cognitive Driver: Integration of Knowledge and Learning in Desalination Policies

Murcia’s approach to desalination policy is strongly based on knowledge integration, scientific research, and stakeholder engagement. The development and implementation of desalination strategies in the Campo de Cartagena region rely on continuous learning and adaptation to ensure technological advancements align with agricultural demands, environmental concerns, and economic viability.
Several mechanisms facilitate knowledge creation and dissemination. Public-private partnerships between desalination plants, regional water agencies, and agricultural cooperatives play a crucial role in testing new policies before their full implementation. Institutions such as the Water Observatory provide professionals with updated data on water availability, aiding in decision-making and planning. Additionally, pilot projects explore technological improvements, including reverse osmosis optimization, boron removal, and water blending techniques. The Escombreras desalination plant serves as a key testing ground for these innovations, contributing to the broader adaptation of desalinated water use.

## Institutional Driver: Research Institutions and Policy Coordination Supporting NCW Implementation

In Murcia, multiple institutions play a central role in supporting the experimentation and innovation necessary for the integration of desalinated water into agriculture. Research centers such as the Centro de Edafología y Biología Aplicada del Segura (CEBAS-CSIC) provide critical studies on desalinated water quality, soil interactions, and crop adaptation, enabling policymakers to base decisions on scientific evidence. Universities, including the Universidad Politécnica de Cartagena (UPCT) and the Universidad de Murcia (UM), collaborate with government agencies and farmers to refine irrigation techniques and optimize nutrient management strategies. Additionally, the Instituto Murciano de Investigación y Desarrollo Agrario y Alimentario (IMIDA) conducts applied research on agricultural water management, focusing on the integration of desalinated water into irrigation systems.

Institutional mechanisms supporting the installation and management of desalinated water include Murcia’s government-led coordination efforts. Regular meetings between desalination plant operators, researchers, and farmers help align policies with on-the-ground realities. Public engagement in decision-making is encouraged through stakeholder workshops, transparent communication on water tariffs, and discussions about environmental and economic aspects of desalination. Real-time water quality monitoring through the SAIH and SAICA networks ensures compliance with regulatory standards and agricultural needs, further strengthening policy refinements.

Despite these institutional efforts, challenges remain at the national level. The inconsistency of National Hydrological Planning has led to a lack of coordination between the Segura and Tagus River Basin Management Plans, creating conflicts over water allocation and demand management. The absence of national policies and long-term action plans exacerbates uncertainty in the agricultural sector, highlighting the need for a more integrated approach to water governance.

## Individual Driver: Leadership and Pioneering Efforts Shaping Desalination in Spain

The adoption of desalination in Spain has been an evolving process shaped by multiple actors rather than a single influential figure. The first desalination plants were introduced in the Canary Islands, where water scarcity made them necessary for urban supply. These early facilities demonstrated the viability and reliability of desalination technology, leading to gradual improvements in performance and cost reduction. Over time, this facilitated its expansion to other regions and applications beyond urban water supply. A significant turning point was the introduction of the AGUA plan (Actions for the Management and Use of Water), a national initiative that led to the widespread construction of seawater desalination plants along the Mediterranean coast to mitigate water scarcity.

In Murcia’s Campo de Cartagena, early adoption of desalination for agriculture faced skepticism due to concerns over high costs, water quality, and crop viability. However, pioneering farmers within irrigation cooperatives tested desalinated water on high-value crops such as tomatoes, peppers, and lettuce. Their successful experiences helped build confidence, reduce resistance among other farmers, and ultimately increase demand for desalinated water. This grassroots adoption played a crucial role in integrating desalinated water into the region’s irrigation practices.

A key figure in agricultural water management in Spain was José Manuel Claver Valderas, former president of the Sindicato Central de Regantes del Acueducto Tajo-Segura (SCRATS). Claver was a strong advocate for securing water resources for farmers in southeastern Spain, particularly in Murcia. He actively participated in legal and political efforts to maintain water transfers and defend farmers' rights, navigating complex disputes over water allocations. His leadership helped ensure stability in water supply policies for the region’s agriculture.

Despite these efforts, the high cost of desalinated water remains a challenge, especially for farmers who face rising production costs. The transition to desalination has resulted in increased urban water tariffs, following the principle of full-cost recovery and the Water Framework Directive (WFD). While urban users generally accept higher prices for reclaimed water and its environmental benefits, the affordability and social sustainability of these increases must be considered. Additionally, the energy-intensive nature of desalination has led to concerns over electricity costs and carbon emissions. If desalination plants operate below full capacity, fixed costs remain high, potentially increasing financial burdens for both farmers and public administrations (Deliverable 4.1.).

The success of desalination in Spain demonstrates how leadership, early adoption, and government policy can drive the uptake of non-conventional water sources. However, ongoing challenges related to cost, energy use, and social equity must be addressed to ensure long-term sustainability.

## Networks Driver: Multi-Level Collaboration in Desalination Adoption in Spain

Technology providers such as Aqualia, Acciona, and Sacyr Water play a crucial role in advancing desalination technology by working closely with local authorities to enhance efficiency and reduce energy costs. Meanwhile, SCRATS (Sindicato Central de Regantes del Acueducto Tajo-Segura) represents farmers and actively engages in policy discussions regarding desalinated water pricing, quality, and allocation.

These networks have significantly contributed to the diffusion and successful implementation of desalination technology. Irrigation communities (Comunidades de Regantes) collaborate with knowledge providers to train farmers on the proper use of desalinated water, particularly in nutrient management to prevent soil degradation. Murcia's regional government, the Spanish national government, and the European Union fund workshops and pilot programs demonstrating best practices for desalinated water use. Extension services from the Department of Agriculture offer real-time guidance on key challenges such as boron removal, blending strategies with other water sources, and optimizing fertilization.

Collaboration across local, regional, and national levels enhances the development and implementation of desalination in Murcia:

- National Level: The Spanish government provides subsidies and regulatory frameworks that make desalination a viable alternative. Strategic investment from national infrastructure programs such as the AGUA Plan facilitated the construction of technologically advanced and energy-efficient desalination plants. Coordination with the European Union ensures access to funding from initiatives like the EU's Green Deal and climate resilience programs.
- Regional Level: The Murcia regional government coordinates policy and resource allocation, acting as a mediator between local needs and national policies. Regional institutions optimize water distribution by integrating desalinated water with other resources, such as groundwater and water transfers. Organizations like SCRATS negotiate water management strategies to ensure desalinated water complements traditional sources.
- Local Level: Municipal governments and local water authorities oversee the integration of desalination plants into existing water supply networks, engaging with agricultural stakeholders and urban consumers to address concerns over water pricing and quality. Public-private partnerships fund small-scale desalination projects and promote efficiency in water distribution.

The multi-scale collaboration between these actors ensures that desalination is not only a short-term solution but also a sustainable and integrated component of Murcia's long-term water strategy.

## Political Driver: Policy Evolution and Conflicts in Desalination Adoption in Spain

State actors in Spain have demonstrated varying degrees of political support for the transition to desalination models in Murcia, shaped by competing perspectives on water management strategies. Historically, the Spanish government has promoted desalination as a key solution to address water scarcity in southeastern regions like Murcia. In 2004, the government introduced the AGUA plan, emphasizing the construction of desalination plants along the Mediterranean coast to mitigate water shortages. This initiative marked a shift from previous strategies that relied heavily on water transfers from other basins, such as the Ebro River.

In recent years, the national government has continued investing in desalination infrastructure. A significant investment of over €200 million has been allocated to enhance desalination and water reuse capabilities, aiming to guarantee food security and combat drought. This plan includes doubling resources from water reuse and desalination. However, regional authorities in Murcia have often favored water transfer systems over desalination, citing cost concerns. They argue that water transfers are a more economical solution compared to desalination, which involves higher energy consumption and costs. This preference has led to tensions between regional and national policies, as regional leaders advocate for maintaining and enhancing water transfer agreements to support the agricultural sector.

Spain has introduced multiple policy instruments to support the shift toward desalination. One of the most significant is the DSEAR Plan (Spanish acronym for Purification, Sanitation, Efficiency, Savings and Reuse). This governance instrument aims to integrate improved methodologies into hydrological planning (2022-2027), focusing on water purification, sanitation, and reuse. The DSEAR Plan aligns with European Green Deal policies and Spain's ecological transition strategies.

One of the key aspects of the current policy framework is the strategic mixing of desalinated water with other sources to reduce costs and balance mineral content, making it more suitable for agricultural use. In Murcia, desalinated water is combined with groundwater, river water (Tagus-Segura transfer), and reclaimed water to optimize its efficiency and economic viability.

In addition to water diversification strategies, Spain is promoting circular economy initiatives linked to desalination. Research is being conducted on reusing desalination by-products, such as brine management strategies, to enhance sustainability.

A key example of a policy action that has driven desalination adoption is the AGUA Plan, launched in 2004 as an alternative to the National Hydrological Plan (PHN) of 2001, which initially focused on large-scale water transfers from the Ebro River. The AGUA Plan aimed to secure water supply in scarcity-prone areas in eastern and southeastern Spain without resorting to extensive transfers. Instead, the plan promoted alternative resources, including desalination, water reuse, and irrigation modernization. It led to the construction of desalination plants in key provinces such as Murcia, Almería, and Alicante. The plan also encouraged water reuse for agriculture and industry, improved irrigation efficiency, and the recovery of overexploited aquifers.

Despite these advances, regional resistance to desalination due to economic concerns and competing interests in water transfers remains a major challenge in fully integrating desalinated water into Murcia’s water management strategies.

Additionally, wastewater treatment and water reuse remain problematic in Spain. According to the European Commission, the state of wastewater treatment in Spain is currently unsatisfactory. In 2018, the Court of Justice of the European Union imposed a fine of €12 million on Spain for non-compliance with the 1991 Directive on wastewater treatment. Two major problems were identified:

- Deficiencies in urban wastewater collection and treatment, with parameter values below mandatory requirements.
- Failure to incorporate tertiary treatment in all populations over 10,000 inhabitants.

To address these issues, the Spanish government has developed a national program aimed at resolving wastewater treatment deficiencies while increasing the use of reclaimed water. This program includes investments in wastewater treatment plants, distribution infrastructure, and water quality regulation measures to facilitate the potential use of reclaimed water by agricultural, recreational, and urban users.

While these policy measures demonstrate significant commitment to expanding non-conventional water (NCW) sources, coordination gaps, regulatory challenges, and cost concerns still limit the widespread adoption of desalination in Spain.

## Normative Driver: Legal Framework for Desalination in Spain

Spain has established a clear legal framework to facilitate the implementation of desalination models, but challenges remain in terms of economic viability and regional political alignment. At the European level, the EU Water Framework Directive (2000/60/EC) encourages sustainable water management, under which desalination projects must meet environmental and energy efficiency criteria.

At the national level, the Water Law (Ley de Aguas, 1985, updated 2001) recognizes desalination as a legitimate water source, allowing the Spanish government to regulate and promote its use. The National Hydrological Plan (PHN, 2001) initially focused on water transfers, but later incorporated desalination as a strategic alternative, particularly after the 2004 repeal of the Ebro River transfer plan.

At the regional level, Murcia's Regional Water Strategy supports desalination as part of a mixed water resource model, balancing groundwater, desalinated water, and inter-basin transfers. While desalinated water is legally available for agriculture, cost issues often limit widespread use, leading to regional debates over affordability.

Regulatory measures play a crucial role in helping stakeholders adopt and implement desalination models in Spain, particularly in Murcia. These measures provide legal clarity, financial support, environmental safeguards, and operational guidelines, ensuring that desalination is both feasible and sustainable.

Legal framework: The legal recognition of desalination as a key water resource integrates it into long-term water planning.

Financial support: The Spanish government, with EU support, provides subsidies and funding mechanisms (e.g., EU Green Deal, NextGenerationEU) to make desalination financially viable.
Environmental safeguards: Clear permitting processes ensure that desalination projects meet national and EU environmental standards, reducing bureaucratic delays.
For the agricultural sector and farmers, clear regulations define how much desalinated water can be used for irrigation, ensuring fair distribution. Subsidies and financial incentives help farmers afford desalinated water, which is significantly more expensive than traditional sources. Regulatory frameworks allow for a mix of desalination, groundwater, and inter-basin transfers, ensuring stable water access.

## Economic Driver: Financial Support and Market Demand for Desalination in Murcia

Several types of financial support from different stakeholders help back desalination models in Murcia, ensuring their viability and sustainability. These sources include EU funding, government subsidies, private sector investments, and public-private partnerships (PPPs).

- EU Funding: Spain receives EU grants for sustainable water infrastructure, particularly under the Cohesion Fund and European Regional Development Fund (ERDF). The European Investment Bank (EIB) provides low-interest loans to support water infrastructure projects, including desalination plants in southeastern Spain.
- Spanish Government Support: The Spanish government provides direct subsidies for desalination infrastructure through programs like the National Hydrological Plan and the Plan AGUA (2004), which initially funded large desalination projects. Recently, the government allocated €200 million for desalination and water reuse projects to combat drought and improve water security. Given that desalination is energy-intensive, the government also offers electricity price subsidies to reduce operational costs for desalination plants.
- Private Sector Investments and PPPs: Private companies collaborate with the government to finance, build, and operate desalination plants. Examples include contracts with companies like Acciona Agua and Aqualia, which manage desalination plants along the Mediterranean coast. Financial institutions and water technology firms invest in desalination innovations, improving cost-efficiency and sustainability.
- Water Pricing and Agricultural Subsidies: Water utilities distribute desalination costs across different users (households, industries, and farmers) to make water more affordable. The government and EU offer agricultural subsidies to help farmers cover the cost difference between desalinated and transferred water.

There is a strong and growing market demand for desalination in Murcia, driven by agriculture, urban water needs, and climate change pressures. Murcia is one of Spain's most important agricultural hubs, producing fruits, vegetables, and export-oriented crops. Farmers need a stable water supply, especially as traditional sources (groundwater and Tajo-Segura transfers) become less reliable. Desalination offers a drought-resistant alternative, but high costs remain a barrier for widespread agricultural use.

- Urban and Industrial Needs: Cities like Murcia and Cartagena are expanding, increasing demand for reliable drinking water. The tourism sector, food processing, and other industries require a steady water supply, which desalination can provide.
- Water Transfers and Policy Shifts: As water transfers become more controversial, desalination appears as a necessary long-term solution.

Key Economic Incentives and Financial Resources Supporting Desalination:

- Several economic incentives and financial resources have played a crucial role in enabling the adoption of desalination solutions in Murcia. These include national policies, EU funding, and private-sector investments, helping to offset the high costs of desalination.
- Government Water Price Subsidies: In 2023, water prices for farmers were lowered to €0.34–€0.40 per cubic meter to make desalinated water more competitive with other sources.
- Electricity Cost Reduction: The high energy cost of desalination is a major challenge, so Spain provides electricity subsidies to reduce operational costs.
- Government Investment in Infrastructure: In 2023, the Spanish government allocated €200 million to improve desalination and water reuse infrastructure in southeastern Spain, including Murcia.

Table 5. Main Drivers to water transition in Spain

| | **Drivers** | **Definition** | **Description** |
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| 1 | Shared vision driver | The existence of a common vision that shifts collective perception towards a new regime or widespread adoption of innovation. | There is a shared vision regarding the importance of desalination for agriculture in the Region of Murcia. However, the high cost of desalinated water remains an obstacle to its widespread adoption. Farmers and the Campo de Cartagena Irrigation District have actively promoted desalination, but the allocation of water resources continues to be insufficient. |
| 2 | Cognitive driver | The creation and assimilation of knowledge to enhance policy orientation; the presence of professional knowledge to support innovation; individual and social learning to change practices. | Murcia has developed a knowledge-based approach, integrating scientific research, stakeholder participation, and adaptive policy frameworks. There are training programs for farmers, real-time monitoring systems, and pilot projects aimed at optimizing the use of desalinated water. However, challenges remain in assessing the economic |

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| | | | profitability of the measures adopted. |
| 3 | Institutional driver | The existence of formal and informal institutions to drive experimentation, a coherent and flexible framework, and multiple institutional mechanisms to facilitate regime change and support this transition. | Several institutions such as CEBAS-CSIC, UPCT, UM, and IMIDA support research and innovation in water management. The regional government of Murcia coordinates regular meetings with desalination plant operators and farmers to adjust policies. However, the lack of coherence between national and regional water management plans generates uncertainty |
| 4 | Individual driver | The presence of a promoter who uses their influential power to support the transition, particularly from the beginning of the process and to steer towards regulatory framework change. | There is no single individual clearly identified as the main promoter of desalination; rather, it has been an evolutionary process shaped by the contributions of multiple actors. Local leaders have influenced the acceptance of desalination by demonstrating its viability for high-value crops. Figures such as José Manuel Claver Valderas have played a key role in defending the water rights of the agricultural sector. |
| 5 | Networks drivers | The existence of networks with actors located at other scales to support innovations, their diffusion, or scaling up. | Networks such as SCRATS and irrigation associations have facilitated the dissemination of desalinated water use. Technology companies like Aqualia and Acciona collaborate with local authorities to improve efficiency and reduce costs. Multilevel coordination between municipal, regional, and national governments has been key to ensuring the viability of desalination. |
| 6 | Political driver | Political support from state actors and coherence of public policy instruments to support the transition. | The Spanish government has promoted desalination as a key strategy through the AGUA Plan and the DSEAR. At the regional level, political support varies; Murcia has favored water transfers over desalination due to concerns about energy costs. There is ongoing tension between national |

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| | | | and regional policies regarding the most appropriate water strategy. |
| 7 | Normative driver | Legal support through the presence of clear and strict regulatory measures, and assistance to stakeholders for their proper implementation. | There is a clear legal framework that facilitates desalination, supported by the EU Water Framework Directive and the Spanish Water Law. However, high costs and political debates over equitable access to water remain key challenges. Regulations such as the National Irrigation Plan aim to integrate desalination with other water resources. |
| 8 | Economic driver | The existence of financial support from various stakeholders and demand or market to support the innovation. | Desalination in Murcia benefits from various financing mechanisms, including government subsidies, European funds, and public-private partnerships. The EU and the Spanish government have allocated significant resources to improve desalination and water reuse. Nevertheless, high operational and energy costs remain major barriers to its widespread adoption in the agricultural sector. |

# Conclusions: Constraints and Enabling Conditions for the Expansion of NCW in Spain

## Barriers: Fragmented Governance, High Costs, and Socio-Environmental Tensions

The development of non-conventional water (NCW), particularly desalination, in Spain is shaped by significant structural barriers that restrict its widespread adoption, especially in agriculture. While there is long-standing collaboration among water sector actors in regions like Murcia, the governance framework remains fragmented. A lack of coordination between national policies and regional planning—such as those concerning the Segura and Tagus River Basins—contributes to uncertainty, especially for farmers who must navigate inconsistent regulations and shifting water allocations.

Economic constraints are central to these challenges. The high operational and energy costs of desalinated water make it the most expensive source available, and its demand fluctuates sharply between drought and non-drought years. This variability undermines financial sustainability and makes cost recovery mechanisms difficult to implement equitably. Farmers with access to conventional sources pay significantly less, generating competitive imbalances in agricultural markets and reducing incentives to transition toward desalinated water. In addition, the current pricing structure, which requires full cost recovery, discourages adoption in the agricultural sector, where margins are tight and subsidies insufficient.

The legal framework, while supportive in principle, also introduces complexity. Desalinated water's classification as private property—distinct from conventional public water sources—creates complications when it is blended with public waters, often requiring additional concessions. Furthermore, infrastructure limitations hinder the equitable distribution of desalinated water to rural areas, and its chemical composition raises technical challenges such as soil salinization, nutrient deficiency, and boron toxicity in crops.

While technical capacity and knowledge among farmers are generally high, particularly in the Campo de Cartagena, the economic viability of long-term desalinated water use remains uncertain. Behavioral and environmental factors also play a role: public perception of desalination is shaped by concerns over energy use, $CO_2$ emissions, and brine disposal. Moreover, desalination has been historically linked to urban expansion along the Mediterranean coast, further complicating its social and political acceptance. These interwoven economic, institutional, technical, and normative factors constitute persistent barriers that limit the broader deployment of NCW solutions in Spain.

## Drivers: Knowledge-Based Governance, Stakeholder Coalitions, and Policy Innovation.

Despite these structural constraints, Spain—particularly the Region of Murcia—offers several promising drivers for the advancement of non-conventional water strategies. A shared vision has emerged among agricultural stakeholders regarding the role of desalination in securing water supplies under increasing climate stress. This collective awareness, reinforced by the leadership of local irrigation cooperatives and figures like José Manuel Claver Valderas, has helped legitimize and normalize the use of desalinated water in agriculture.

Institutionally, Spain has developed a robust infrastructure for research and technical support. Organizations such as CEBAS-CSIC, UPCT, UM, and IMIDA play central roles in developing applied solutions for integrating desalinated water into agricultural practices. Their research has supported the adaptation of irrigation and fertilization methods, ensuring environmental compatibility and crop viability. Coordination mechanisms, such as regular meetings between desalination plant operators, researchers, and farmers, foster policy dialogue and continuous learning. These processes are supported by real-time monitoring systems and demonstration projects that test innovations before scaling them up.

Policy initiatives like the AGUA Plan and the DSEAR provide a legal and financial framework that enables investment in desalination infrastructure and water reuse. National support, including €200 million in recent investments, is complemented by European Union funding and electricity subsidies aimed at reducing desalination's energy footprint. At the regional level, Murcia's strategy of mixing desalinated water with other sources—such as groundwater and transferred water—offers a pragmatic model for improving water quality and lowering costs.

The presence of multi-level networks has also been essential. SCRATS, irrigation communities, and technology providers like Aqualia and Acciona collaborate with public authorities to implement efficiency measures, develop training programs, and expand infrastructure. These partnerships help bridge the gap between innovation and implementation, reinforcing political and social support for NCW strategies.

While significant tensions remain—especially between regional and national governments over preferred water management models—the gradual institutionalization of desalination as a core component of Spain's water governance system reflects the potential of integrated, knowledge-based approaches. Strengthening these drivers through more cohesive planning, stable financial instruments, and environmental safeguards will be essential to overcoming the current barriers and ensuring the long-term viability of NCW in the Spanish context.

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