



Playing with Water: A Value Case for Gamified Water Resilience in Alfândega da Fé, Portugal

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Abstract

This contribution explores the case of Alfândega da Fé, Portugal, using a value case approach. It is based on a project completed in the course Water System Design: Learning from the Past for Resilient Water Futures, offered by the UNESCO Chair Water, Ports and Historic Cities team based at TU Delft. The article argues that by adopting an innovative water management strategy and engaging the community through gamification, Alfândega da Fé can become a sustainable city adapted to future environmental needs, with reduced and more responsible water consumption, aligned with current legislation and SDGs. Based on the value case approach, the article shows how we can learn from the past, make connections between water systems and connect to the local environment to achieve a more resilient, sustainable and inclusive water system. The plan is based on the creation of an interactive water services platform for local people designed to increase general knowledge about water and enable the local population to play an important role in water consumption and enhancing water reuse.

Policy Recommendations

- Integrate gamification, like digital games and interactive storytelling, in local and regional water policy to engage citizens, honor cultural water heritage and drive water-saving behaviors.
- Partner cultural institutions, water utilities, municipalities, and educational organizations to co-create heritage-based games that align policy objectives with community values.
- Water stress driven by climate change, overextraction and seasonal variability makes wastewater a vital resource; cutting potable water use and expanding reuse relieves pressure on freshwater sources.

KEYWORDS

droughts
water management
gamification
values
water consumption

WATER VALUES



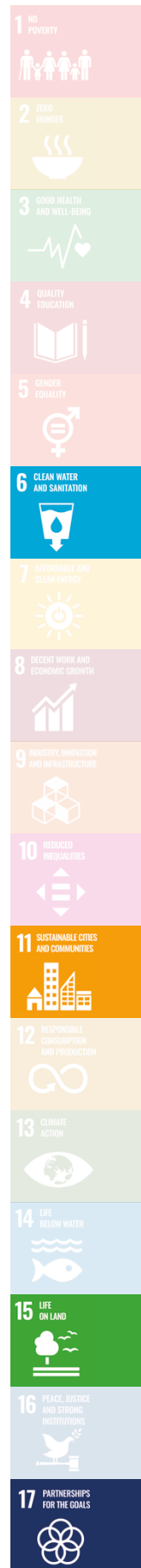
CLIMATE



Csb: Warm-summer Mediterranean climate



< Fig. 1 Sambade dam, during a period of very low water levels and water scarcity (Source: Joao Camelo, 2022).



Introduction

Alfândega da Fé, a small municipality in northern Portugal, spans 320 km² and is home to around 4,300 residents. In an arid region, since the late twentieth century the town has built multiple water infrastructures to tackle recurring droughts. It has adopted practices to ensure reliable drinking water and support agricultural irrigation. Yet, future challenges demand a more resilient water system.

Climate change has introduced many new water challenges, and stand-alone technological interventions cannot sufficiently address complex social, cultural and economic aspects of the problem. Changing water patterns will affect everyone and every structure. How we manage water depends on local conditions, spatial and social developments and cultures as well as decisions made long ago (Hein et al. 2024). Engaging values, based on new tools and methodologies that account for local particularities and acknowledge historic path dependencies, are fundamental to designing sustainable and inclusive water systems (Hein 2022).

As explored in the 2024 TU Delft course *Water System Design: Learning from the Past for Resilient Water Futures*,¹ this article takes a value-based approach to Alfândega da Fé, demonstrating how gamification can be used to revitalize traditional water knowledge, engage rural populations and promote sustainable practices through interactive storytelling and by using digital tools. It connects cultural memory and environmental stewardship, aligned with regional development and climate adaptation.

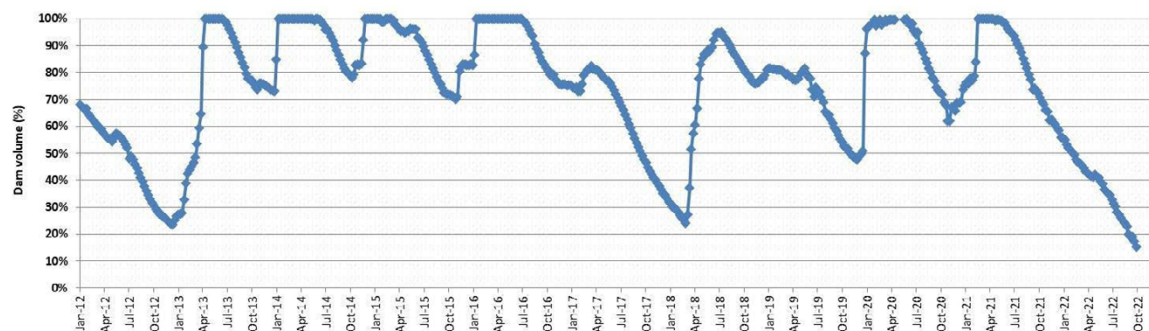
A gamification approach offers a novel and scalable solution to bridge the gap between awareness and action. By transforming water-saving behaviors and cultural heritage into interactive experiences, gamification can foster civic participation, reinforce local identity and promote sustainable consumption. The value case lies in its ability to translate complex water challenges into accessible, motivating formats - aligning with EU policy goals on public participation, heritage valorization and climate adaptation. The Alfândega da Fé case illustrates how playful digital tools can activate community knowledge, support behavioral shifts and contribute to integrated water governance in vulnerable rural territories.

Place and Context

Alfândega da Fé has complex and diverse water systems and many interconnections between them. The provision of drinking water has been the main focus of the water system, alongside the use of water for agriculture and irrigation. These two water uses have come into a constant conflict, especially in recent years, due to water scarcity. The demand for water, aggravated by recent climate change, has led to the establishment of multiple water sources, specifically dams and related pumping stations and networks.

For a long time, the municipality has created water infrastructures for community use, namely for drinking, irrigation and recreation. Examples are small wells and the Estevainha and Camba dams. In 2001, a new water management entity – Aguas do Norte – was established in line with the national drinking water

1. "Water System Design: Learning from the Past for Resilient Water Futures," <https://online-learning.tudelft.nl/courses/water-systems-design-learning-from-the-past-for-resilient-water-futures/>.



^ Fig. 2 Graphical representation of the water volume available in Sambade dam (Source: Joao Camelo, 2024. Based on the SNIRH - Sistema Nacional de Informação de Recursos Hídricos - database).

strategy, which consisted of centralizing all existing wells and creating a single drinking water system with Sambade dam as the main water source. The goal was to be more efficient in terms of quantity and quality of the water supplied. This new entity also promised more transparency and to possess a greater ability to achieve sustainability objectives.

Due to droughts in recent years, new infrastructure has been built and added to the system, through Aguas do Norte, and inter-connections have been made between systems that previously were devoted exclusively to irrigation and other agricultural purposes. One example is a new water treatment plant in Esteveinha and the connection of this system with the water network supply in the city of Alfândega da Fé.

Fig. 2 represents the Sambade dam volume available from 2012 to 2022. It shows the three water scarcity seasons in the last decade and a half: 2012, 2018 and 2022.

In 2016, the Ministry of Environment and Energy built a hydroelectric plant on the Sabor River. While it supplies power nationwide, the municipality also uses the river for tourism and recreation. In 2023, Aguas do Norte tapped it to provide drinking water to Torre de Moncorvo

during a drought, highlighting its future potential to support regional water systems.

The massive use of water bodies for drinking water, followed by a good process-oriented approach, has completely solved the problems of water for this purpose. However, it created a negative impact on the use of water for irrigation and agriculture. In fact, conflicts with other stakeholders have worsened and persist nowadays.

For example, in the 2022 periods of water scarcity, Sambade and Esteveinha dams dropped to 27 per cent and 35 per cent capacity, respectively, threatening both urban water supply and agricultural irrigation. Alfândega da Fé was among 50 locations in Trás-os-Montes receiving truck-delivered water, affecting over 8,000 residents due to depleted supply systems (PortugalResident 2022). The following adaptive measures were also taken (24 Notícias 2022):

- Irrigation reserves were repurposed: Authorities redirected water from Esteveinha (intended for agriculture) to Sambade for human consumption, including installing mobile treatment units.
- Contingency planning: Local government is working with Águas do Norte and the Min-

istry of Environment to secure funding and implement drought resilience strategies, including public awareness campaigns.

Recent projects like I-ReWater (Interreg Sudoe 2021) and GreenValue (CITAB 2022) demonstrate that reclaimed water and biosolids (from Alfândega da Fé's wastewater treatment plant) can support both sustainability and agricultural resilience. By integrating these efforts with EU Directive 2020/2184 on the quality of water intended for human consumption and Portugal's "Water that Unites" strategy (Portal da Água 2025), this value case gains relevance and practicality.

Ecosystems, Flows and Networks

In the Water System Design course, we used a CANVAS tool to highlight the main flows and relationships between different components on a system-centered representation of this specific territory, inspired by the work of Vereecke and

colleagues (2022). This mapping shows the importance of water for the purpose of irrigation/agriculture, displaying all the stakeholders and the connections among them. We can see the "conflict relationship" between the two main uses of the water bodies – for drinking water or for irrigation/agriculture. The analysis led to the finding that the relationship between the three direct stakeholders, which are Aguas do Norte, the municipal government and agricultural associations, should be maintained and strengthened, especially to safeguard the purposes of the water bodies in that region. Also, the design made it possible to identify the local water-dependent industries (olive oil and wine).

The potential water source of the Sabor River is also very important. Its focus is on producing electricity for all the country, but it can also boost tourism in the region. This water body fulfills multiple roles, it can substantially support other subsystems - for example, by supplying raw water to adjacent systems during droughts.



^ Fig. 3 Water systems and their connections in the Alfândega da Fé study case (Source: Joao Camelo, 2024. Basemap from © OpenStreetMap, licensed under the Open Database License [ODbL]).



^ Fig. 4 Reused water produced at Alfândega da Fé wastewater treatment plant is used to irrigate almond crops (Source: Joao Camelo, 2024).

Reclaimed water from the local treatment plant can bolster drinking water systems or serve agriculture and irrigation needs, presenting viable interventions in times of drought.

Strategy: Taking into Account Legislation and the SDGs

The initiative Right2Water (Parks 2014) emphasizes that marginalized communities still lack reliable access to drinking water. In line with SDG 6 (clean water and sanitation) of the UN's 2030 Agenda, Directive (EU) 2020/2184 – adopted into Portuguese law as Decreto-Lei

nº 69/2023 – sets clearer water quality standards, boosts awareness of water losses due to neglected infrastructure and makes water quality information easily accessible online in customizable formats.

SDGs can also be used as a framework to rethink management of water systems. Developed as part of an exercise in the course, fig. 7 identifies the directly related SDGs, indirectly related ones and not related ones. This exercise is used to identify potential values that can improve the value proposition of a system. The current system prioritizes SDG 6 and integrates SDG 3 (health and well-being) and SDG

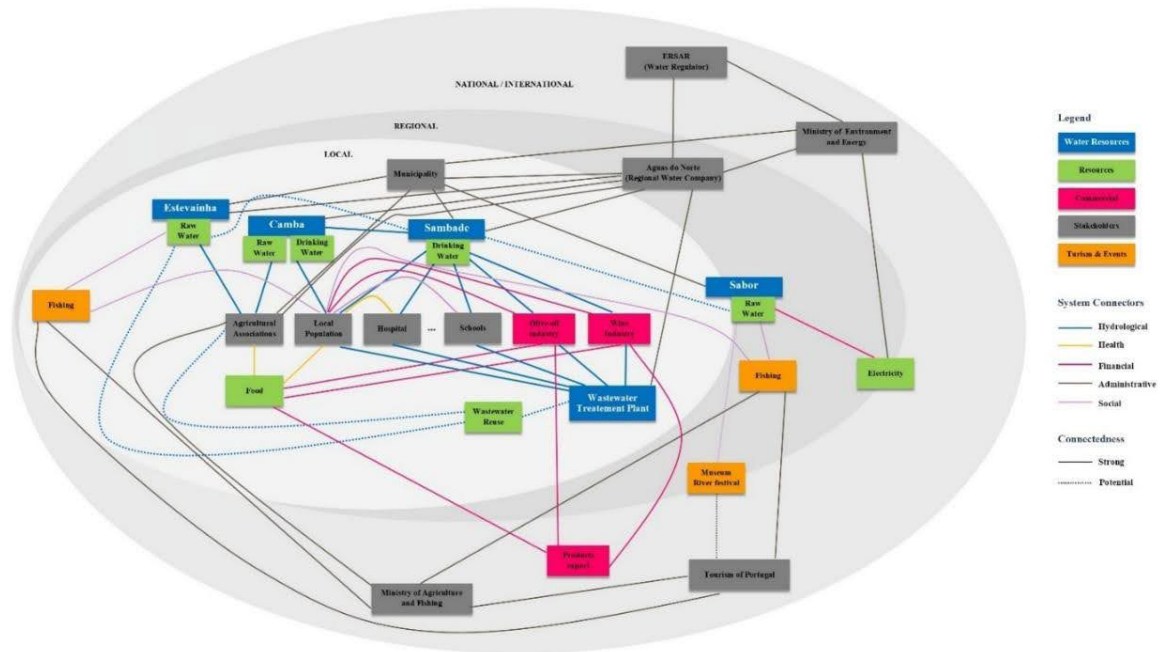
8 (economic growth) to harness water's industrial potential revealed by the CANVAS analysis. SGD 2 (zero hunger) is placed as directly related, not as the eradication of hunger itself, but in achieving food security and improved nutrition and promoting sustainable agriculture.

Resilient infrastructure, sustainable industry and innovation directly strengthen water systems and help mitigate climate impacts. These investments deliver fast results in drinking water and wastewater efficiency. They also drive SGD 8 (economic growth), SGD 10 (reduce inequality), and SGD 1 (tackle poverty) - both in Portugal and globally. In Portugal, they support the vital connection between countryside and coastline. While other SDGs may not influence SGD 4 (education), quality education powers progress across many goals. It fosters responsible water use, supports healthy ecosystems and enables sustainable cities and communities. Prioritizing water education now will deliver long-term resilience.

Rethinking the Water System

From a technical point of view, part of the resilience of the water drinking systems in this municipality comes from the diversity of water sources. The Sabor River can have a huge impact on other subsystems, such as reinforcing raw water for other systems in times of drought. Also, the wastewater reuse, considering its adaptability for different uses, represents a challenge but also a solution. Implementing these solutions balances water distribution between drinking supply and agricultural or irrigation demands.

Education is both a lesson from the past and a value that will shape the future. Building water awareness among local people is essential, fostering the ability to address many different concerns related to water, and strengthening the connection between people and this vital resource. Currently, domestic water consumption in Alfândega da Fé is around 400 liters per



^ Fig. 5 CANVAS design of Alfândega da Fé study case (Source: Joao Camelo, 2024).



^ Fig. 6 SDGs and their relevance to the Alfândega da Fé study case (Source: Joao Camelo, 2024).

person per day, well above the European average and higher than in other regions of Portugal (according to EUROSTAT 2007 [European Union 2007], Portugal's average is 161 liters per person per day, while Lithuania, for example, reports just 97 liters).

This situation in the region is due to irresponsible consumption by the population; examples include outdated high-flow toilets, showerheads and appliances; running taps and wasteful daily habits; excessive outdoor irrigation and watering of public and private green spaces, often amplified by seasonal tourism; and high distribution losses from ageing networks that inflate apparent per-capita use. This highlights the urgency of promoting “responsible consumption” as a key target, (SDG 12). Tourism can also play a role by using water bodies for recreational purposes, encouraging people to build stronger relationships with water in this area.

Looking ahead, meeting the challenges of water management will require cooperation among all stakeholders, water education and efforts to conserve both the quality and quantity of water resources - working together to secure a sustainable and equitable future for all.

Gamification for Water Utilities

Who doesn't appreciate a good game?

The initiative proposed in the course focuses on community education and involvement through gamification. Gamification uses strategies and game mechanics to foster deeper engagement between organizations or brands (and their products or services) and both internal and external audiences (Elsayed 2021). Games are among the oldest forms of social interaction and communication. While the typical function is entertainment, serious games have been developed to aid learning. Through gamification, stakeholders in the water supply chain can better understand each other's roles and responsibilities. This experience ultimately can support strategic decision-making, for example, related to asset maintenance and setting replacement priorities.

For water utilities, games offer many possibilities:

- Behavioral nudging – utilities use game-like elements such as points, badges and leaderboards to encourage users to adopt water-saving habits.
- Smart meter integration – real-time data

from smart meters allows users to track their consumption and compete with neighbors or household members.

- Rewards and incentives – users earn discounts, donations to community projects or loyalty points for meeting water-saving goals.
- Social engagement – sharing achievements on social media can boost motivation and spread awareness.

Action Plan

The demand for water, often associated with irresponsible use, has been increasing drastically. When water services no longer have the capacity to meet demand, there is often no capacity for expansion and investment. In addition to water management entities working to make production more efficient, encouraging responsible water consumption can play a fundamental role, adding sustainability benefits of water conservation.

Generally, city residents do not have easy access to water and are unaware of how water is distributed to residences. Public awareness regarding water conservation is expected to increase with television advertisements, freeway signs and pamphlets included with monthly utility water bills. These media still fall short of giving residents a clear picture of their water usage and the water cycle. There need to be better ways to bring information to the public and to encourage actions based on facts that are quickly and easily adopted. Technology can help. Increasingly, we live in a cellular wireless information age today. The impact on society is only beginning.

Led by the municipality and Águas do Norte, this project proposes an interactive digital plat-

form that makes local water use a collaborative challenge. Designed for residents, it combines personalized consumption feedback with real-time data and social features to spark behavioral change.

The aim of the platform is to change behavior related to water in general and includes:

- Smart comparisons – users monitor their water footprint and benchmark it against friends, family or neighbors.
- Eco competition – rankings highlight “Most Responsible Consumers,” encouraging neighborhood-level campaigns and inter-community contests.
- Points and rewards – every liter saved earns points, unlocking individual perks and collective benefits for the broader community.
- Real-time alerts – the system detects anomalies like leaks or excessive use, prompting timely action.

This platform doesn't just measure water – it inspires stewardship, pride and playful accountability.

In Alfândega da Fé, where home gardens, vegetable plots and personal water tanks are part of daily life. This initiative is designed to draw on community practices to advance a circular water approach. Residents earn points by repurposing treated wastewater for irrigation - turning everyday actions into sustainability wins. Indirectly, the engagement of the different institutions involved in this project (the municipality, Águas do Norte and agricultural associations) will strengthen relationships among them and reduce conflicts regarding future decisions.

Awareness campaigns can address a wide variety of topics, including how to reduce water

Scene	Visual / Action	Purpose	Notes
Campaign Launch Poster	A banner in town square "Play for Water + Save Water, Celebrate Heritage!"	Introduce initiative and spark interest	Icons of water, badges, and Alfândega da Fé landmarks
App Home Screen	Gamified interface featuring goals, community goal tracker	User-friendly entry point	Includes local heritage motifs and water facts
Weekly Missions Panel	Example: "Shorten your shower by 2 mins"	Trigger behavior change	Tips drawn from traditional water-saving practices
Mission: Reuse & Repurpose	"Collect rainwater for garden" or "Reuse laundry water for cleaning"	Promote decentralized reuse	Tips based on traditional practices and modern tech
Community Progress Dashboard	"Maria saved 1,200L this week!"	Foster collective impact	Show progress toward tree-planting or civic rewards
Local Stories Feature	Short video or quote from a resident: "My grandma reused laundry water"	Build emotional connection	Authentic narratives to drive retention
Local Innovation Spotlight	Feature a local farmer using treated wastewater for irrigation	Inspire systemic change	Connects users to real circular economy champions
Share & Challenge Screen	"Share your badge!" + "Challenge 3 friends to play"	Viral loop and user acquisition	Social media integration with regional flair
Circular Trivia Pop-up	"Did you know Alfândega da Fé's cisterns were early circular systems?"	Link heritage to circular economy	Delivered between missions or as mini games

^ Table 1. Storyboard sketch for the Water information/challenge platform (Source: Joao Camelo, 2024).

consumption, basic aspects of the water cycle, application operation; they can be geared to the community in general or more specifically for use in schools. Games for children are also an option. Raising awareness about water among members of future generations is very important. Although the results are residual in the short term, it will bring benefits in the long term. The author proposes launching the challenge on social media, local news outlets, digital platforms and community associations to maximize reach and resonance. The next table shows a storyboard sketch with some examples of this water challenge platform.

Conclusion

Gamification offers a novel and influential tool for engaging communities at the intersection of the water-culture-heritage nexus. By transforming abstract concepts such as responsible water use and reclaimed wastewater use into interactive and locally grounded experiences, gamification fosters deeper public participation and awareness.

In fact, fostering responsible water use remains a steep behavioral challenge. Everyday habits – e.g., leaving taps running and overwa-

tering gardens - are deeply ingrained and hard to break. The invisible nature of water waste and the lack of immediate consequences dull individual motivation, while social norms rarely praise conservation efforts. Without compelling incentives, tailored outreach and visible feedback on savings, meaningful shifts in household and community practices continue to lag.

In the same way, despite environmental and economic benefits, the adoption of reclaimed wastewater remains a profound behavioral challenge for communities. Deep-seated perceptions of cleanliness, cultural taboos and psychological discomfort often lead to resistance, regardless of scientific assurances of safety. The "yuck factor," amplified by limited public awareness and trust in treatment processes, continues to hinder widespread acceptance.

Playful digital strategies can reinforce cultural memory, build resilience in rural water systems and align with broader sustainability goals, particularly in regions facing environmental strain. The example of Alfândega da Fé suggests the scalable potential for integrating gamified models into participatory governance and heritage-based water planning.

Acknowledgment

This contribution was peer-reviewed. It was edited by members of the editorial team of the UNESCO Chair Water, Ports and Historic Cities: Carola Hein and Matteo D'Agostino.

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