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RESEARCH ARTICLE

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Key Points:

- Climate services are the result of the combination of scientific and practice-based knowledge
- This paper describes a method for the co-creation of climate services using a business focus approach
- The approach is applied to co-design & co-develop a climate service for the adaptation of the Valencia water supply system to climate change

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Structuring Climate Service Co-Creation Using a Business Model Approach

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Abstract Climate services are tools or products that aim to support climate-informed decision making for the adaptation to climate change. The market for climate services is dominated by public institutions, despite the efforts made by the European Commission to increase private enterprise in the market. The business model perspective has been proposed as a framework for enabling market growth through the development of appropriate business models for the provision of climate services. However, there is a lack of structured knowledge on how to approach climate service design and development from a business model standpoint. In this contribution, we first analyze the role of stakeholders in the design and development of climate services and identify opportunities for engaging users in the creation process. Afterward, we explain our approach to climate service design and development using a business model perspective. To illustrate the proposed approach, we describe the co-creation of a climate service to support the adaptation to climate change of the urban water supply system in Valencia, Spain, and discuss the main findings and lessons learned from applying this approach.

Plain Language Summary Climate services are customized products that support climate change adaptation. The uptake of climate services by users from the private sphere has been minimal during the last decade. Many reasons have been provided for this, but the main issue is the lack of communication between final users and developers during the design process. In this contribution, a business model perspective has been applied for the creation of climate services in order to bridge the gap between users and developers.

1. Introduction

Climate change impacts are global, multi-sectoral and diverse depending on the region and the scale of interest. In the global landscape, climate services have assumed the role of supporting tools and services for climate-informed decision making, taking into account not only climate information. Climate services are customized products such as projections, forecasts, information, trends, economic analysis, assessments, counseling, evaluation of solutions and any other service that may be of use for the society at large (EC, 2015). Climate services were described as crucial products for sustainable development already in the 2009 World Climate Conference. Years later, the European Commission expressed in their Roadmap for Climate Services the objective of building Europe's resilience to climate change by developing a strong global market for climate services (EC, 2015). After years of research and support at European and global scale, doubts regarding the strength of the climate service market have already arisen, and many researchers have discussed the perceived weaknesses and challenges faced by the market (Bessembinder et al., 2019; Brasseur & Gallardo, 2016; Tart et al., 2019). The public sector has been the driving force of the development and the main user of climate services, while the impact on the private sector has remained minor (Tart et al., 2019). A further analysis of the current state of climate services providers in the European Union shows that the sector is still dominated by public institutions such as universities, research institutions and public climate service centers (Cortekar et al., 2019) and that, despite the support of public funding at the European and national scales, private actors are still mainly concerned about the financial structure of climate adaptation and climate services (Larosa & Mysiak, 2020).

Given the limited uptake by the private sector, a "business model design" approach has been proposed as a method for enabling market growth through the development of appropriate business models for the provision of climate services (EC, 2015). The term business model is broadly used to represent core aspects of a business, including purpose, activities, customers, organizational structures, and operational processes, as well as to describe how an organization creates, delivers, and captures value (Shafer et al., 2005). The commercial success of a business model depends on its ability to sustain itself in time while delivering a useful service to a set of customers or users. A business model approach could be useful to take a more user centered and marketable approach to the design of climate services. Previous research indicate that the market for climate services remains on its infancy and many authors have proposed potential reasons for why this is the case (Brasseur & Gallardo, 2016; Damm et al., 2020; Hoa et al., 2018):

1. Insufficient awareness by societal actor of their vulnerability to climate change.
2. Other issues rather than climate change receive higher priority.
3. Lack of relevant services provided from the scientific community.
4. Lack of perceived value by users.
5. Lack of trust from the users.
6. Inappropriate format in which the service is provided.
7. Inadequate business models adopted by climate services providers.

In his famous speech from 2015, Mark Carney, governor of the Bank of England, referred to climate change as the "tragedy of the horizon," as its impact will be felt beyond the traditional horizons of most decision-makers, including those of business and policy. "Once climate change becomes a defining issue for financial stability, it may already be too late" (Carney, 2015). To avoid this, we need to ensure that the users can perceive the value of the provided climate services. In order to do this, we must improve our knowledge of the current needs of the potential climate service users and to identify the resources and actions required to provide valuable services to these users. A business focus approach to climate service development puts users in the center of the development process and understands that making users part of the process increases the acceptability and usefulness of the resulting service (Larosa & Mysiak, 2020).

Webber and Donner (2017) indicated that climate services should be driven by users (adaptation and disaster managers) instead of scientists or science-funding agencies that make assumptions regarding useful data and the climate impacts that are of most concern to managers. Co-design is increasingly recognised as a method to match adaptation needs, user's skills and climate-services-providers capabilities. Business models have been on the core of two Horizon 2020 projects about climate services: MARCO3 and EU-MACS (Hoa et al., 2018). The research presented in this paper has been developed within INNOVA, an ERA4CS project that aims to bridge the gap between climate service providers and targeted users integrating business model practices to the co-design of climate services.

This paper describes a framework for the co-creation of climate services using a business-focus approach aligned with the needs of the climate service market and users at the local scale (bottom-up approach). We test the implementation of this process in Valencia, Spain, co-creating a climate service jointly with a water treatment and supply company. The barriers for climate change adaptation in water management organizations, include the ones previously listed and issues such as cognitive barriers (e.g., on risk perception), the lack of relevant information at the appropriate scale, inadequate human-financial resources, the lack of confidence, interest or leadership, the focus in the short term, or the lack of clear and consistent policies (Azhoni et al., 2018). For these reasons, water management companies are the perfect candidate to test and validate new methods to co-develop climate services. We are proposing that the business approach for climate service development is useful in two ways: First, it serves as a roadmap for the market-driven or user-based creation of climate services. A business-focus approach is inherently aligned with the emerging concepts of co-design and user-focused climate services. Second, the proposed approach bridges the gap between the scientific and practice-based development of climate services. The creation of climate services sustained by a business approach is essential to engage the private sector into the process.

The paper is structured as follows. Section 2 starts by reflecting on the role of end-users in the creation of climate services and categorizes the potential climate service users based on their knowledge of climate data and their position in the adaptation cycle. Section 3 describes the proposed framework for creating climate services using business model thinking. Section 4 showcases the described procedure for the Valencia case study: the co-creation of a climate service for the urban water sector. Finally, Section 5 presents the main conclusions of the research.

2. Engaging Stakeholders for Climate Service Creation

A climate service is the transformation and use of climate data and knowledge for helping decision-makers (Vaughan & Dessai, 2014). According to the EU Roadmap, the customized products known as climate services can be projections, forecasts, trends, economic analysis, assessments, counseling on best practices, development and evaluation of solutions and any other service in relation to climate that may be used for the society at large (Street et al., 2015). Climate services should be user-centric, supported by active research, based on the use of detailed data and information about the future (including predictions) and, usually, involving participation of government, business, organized civil society, and academia (Brasseur & Gallardo, 2016). Climate services must integrate climate and non-climatic information to be able to adequately answer the stakeholder's needs and demands (Vincent et al., 2018). End-user participation is essential during the production of climate services.

The creation of climate services can be divided in two distinct phases: the design and the development phases. Although "designing" and "developing" are two verbs commonly used as synonyms in the climate service literature, we would like to underline some differences that may be useful to characterize the role of end-users during the whole process. The co-design phase is when users and developers agree about the features and purpose of the service. After an understanding is reached, the development team will materialize the service or product that was envisioned, thus beginning the development phase. The participation of end-users in the development process is not always required, but they often cooperate by -for instance-providing data or feedback. Although conceptually the design and development phases are different entities, in practice it is common to loop between both. For instance, if problems arise during the development, it may be necessary to return to the design phase to come up with an agreed solution.

The success of a climate service requires that stakeholders are meaningfully engaged from the beginning in the joint design and evaluation of the product (Bremer et al., 2019). Therefore, identifying the potential users of climate services is a fundamental step in the process. There is not a single and correct way to categorize climate service users. Some studies have described and grouped users based on their needs and economic sector (Tart et al., 2019). According to these analyses, agriculture and forestry, environmental agencies, water and energy utilities, and research and development organizations are the main economic sectors using climate services. Most users, however, do not operate within a single sector, and utilities is the top sector for State-owned companies, while energy and agriculture are the main sectors for private enterprises (Tart et al., 2019).

The users of climate service can also be characterized according to how they use climate information (Skelton et al., 2019). Methods of classifications based on how users interact with climate data are better for identifying systemic barriers for the uptake of climate services. The lack of interest of users in climate services often results from lack of awareness of the existing relevant data, or for lacking knowledge about the specific threat that climate change creates for their activities (EC, 2015).

In order to identify promising users interested in the co-creation of customized climate services, we propose characterizing users based on their knowledge of climate data and their awareness about the potential impact of climate change on their respective field of interest. This method serves two purposes: first, it helps to assess the readiness of users to participate in the co-design and co-development of the climate service. Second, it will provide insights to climate service developers regarding the potential actions required for promoting the engagement of users with insufficient level of readiness or awareness. Figure 1 depicts the process in which potential users of climate services may become aware of the need for climate services. The entry points where climate service developers can provide external support to certain users are identified.

During the process of coming to an awareness of the climate change-related problem, we have distinguished three stages that stakeholders go through. Each step has primary information that can be classified according to the spatial and temporal resolution, quality, quantity and level of detail. In all cases, the legitimacy,

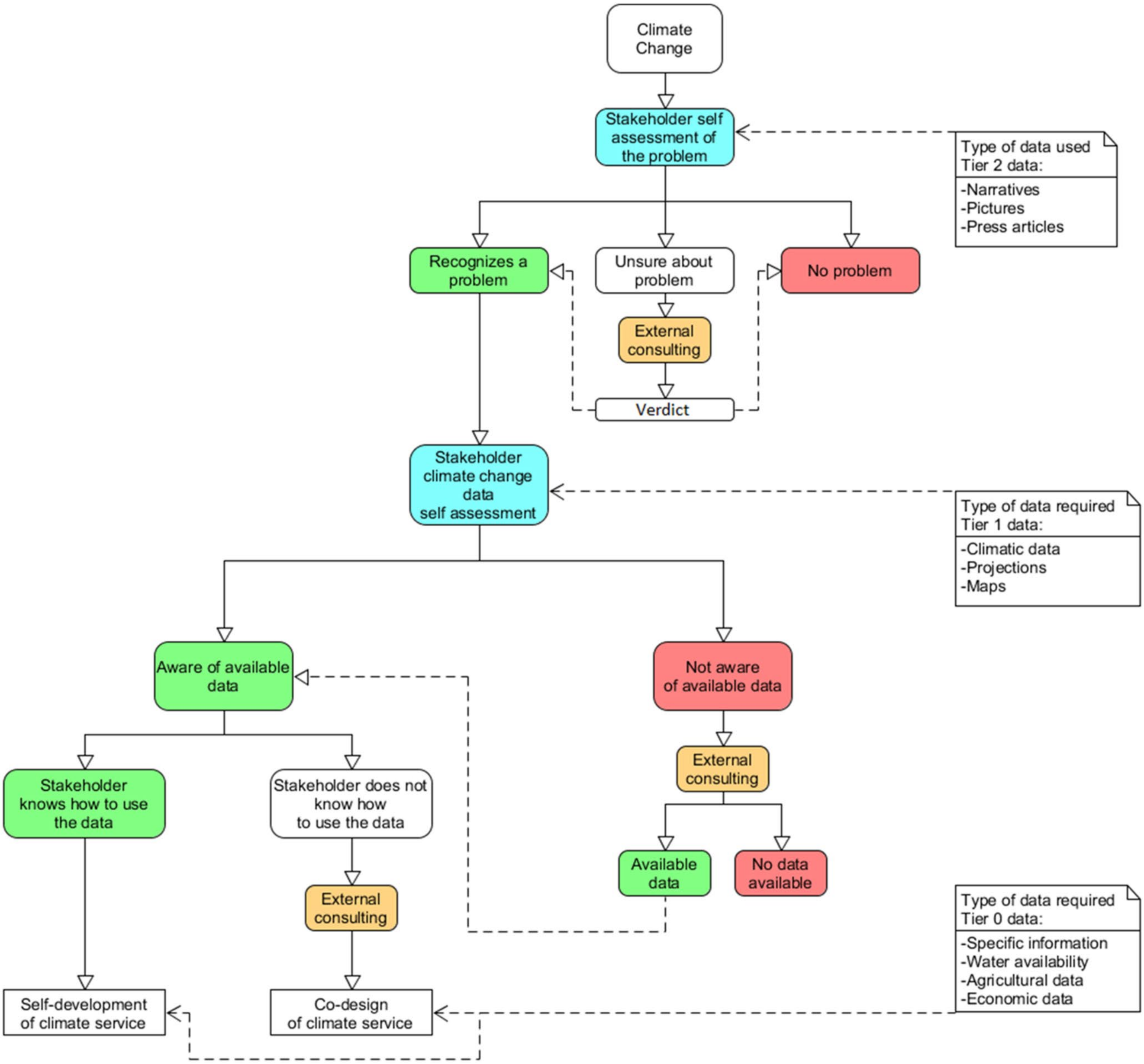

Figure 1. Stakeholder pathway from problem awareness to climate service demand.

credibility and usability of data is essential for the user to remain interested and confident. Tier two information is general and easy to understand data about climate change impacts and threats. This data is usually heavily processed and it is presented in the shape of articles, pictures, and infographics. Tier 1 data is semi-processed data such as climate maps and climate projections of certain variables such as temperature and precipitation for a specific region and time scale. Tier 0 data is raw data on climate, economy, agriculture, water and detailed information about any sector interested in climate services provision. During the climate service co-development process, tier 0 information is very often partially provided by the end-user of the climate service, to ensure that the climate service is useful for their decision-making process.

Understanding this process may help climate service developers and providers to comprehend the decision context of the user facilitating the communication between all parts and promoting the interest in the co-creation of climate services. Users with preliminary knowledge are users who would like to know more about climate change in general and its potential impacts on themselves. These users would benefit more

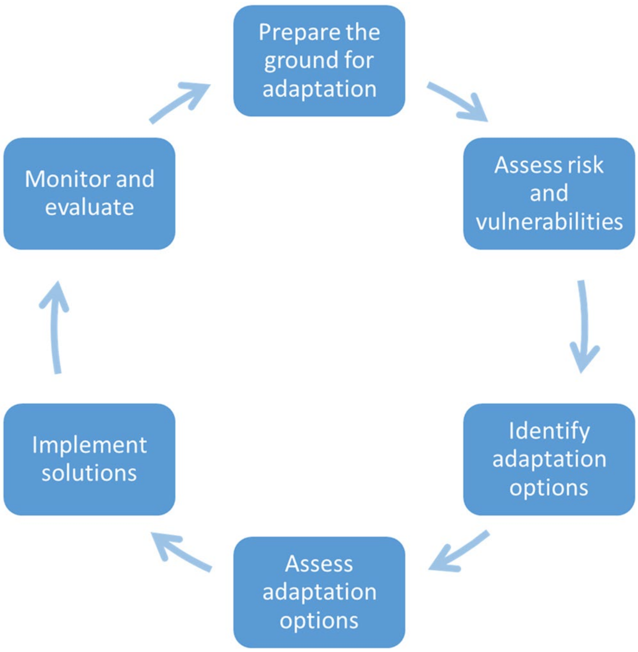

Figure 2. Climate change adaptation cycle (Redrawn from Climate-Adapt EEA).

from tier 2 data such as narratives, pictures and press articles to access to easy to digest information for recognizing and identifying their potential problems and interest on the issue. Users who have a deeper knowledge and awareness of climate change are likely to be in search of tier 1 data to support their decision-making processes to progress toward climate adaptation. Having recognized the problem, they aim at tackling it. These users could start getting familiar with the climate change data and projections. As familiarity of users with data increases, they can start requesting more detailed information based on their specific requirements (tier 0 data). At this point, if all data is available, users with complete understanding, knowledge and skill would be able to design and develop the climate service that they need. Of course, this degree of proficiency and skill is not found very often, hence the need for climate service developers to assist into the co-design and co-development of the service.

The process followed by users in Figure 1 can be linked to the famous climate change adaptation cycle (Figure 2).

The climate change adaptation cycle represents the different steps in which stakeholders progress in their path toward climate change adaptation. Starting from preparing the ground for adaptation and finishing at the monitoring and evaluation of the already implemented adaptation strategies. Depending on the phase of the process there are also different information needs. In Figure 1, we suggested the type of information that would be useful in each step of the process. Relating this evaluation to Figure 2, we can also see how the data required is more specific and detailed as users advance in the adaptation cycle. For example, the data used to assess the risk generated by climate change is often easier to obtain and process than the information required to evaluate the best adaptation solutions. The latter requires further information and processing, such as developing models to calculate the impact of climate change under each management alternative and scenario. In general, users will need more detailed and refined information as they increase their awareness and knowledge of the problem. For climate service developers, the required information is not limited to ordinary data collection on easily quantifiable variables, it entails analyzing the decision context of the users and detailed information provided by the users, as well as having into account their needs and expectations.

The application of this knowledge may benefit climate service developers and providers that are trying to engage users into the process. From the point of view of climate service providers, the co-creation process begins from the identification of the impacts that climate change is going to have at the area and scale of interest. Finding stakeholders affected by those impacts is the next step of the process. Identifying the affected stakeholders is essential for developing climate services, as the resulting product or service has to respond to the needs and demands of the end users. As mentioned before, the involvement of users during the co-design of the service is required. Ideally, the result of the co-design process will be a detailed description of the objective and features of the climate service. This will be called the "value proposition" of the climate service in our proposed framework. User participation during the development process is also possible but not always required. During the development users can provide fundamental data, essential feedback or even their own knowledge and resources such as models and facilities. Drafting a preliminary list of potential user helps developers to narrow down the ideas for potential climate services. It also allows climate service providers to obtain and process useful data and information for engaging users and get their attention.

The orange boxes in Figure 1 indicate the different points where a climate service provider could assist the user into the solution of their specific problems. The service offered by the providers must be different in each phase of the process. In the first phase—that takes place from the starting point to the point where the stakeholder recognizes a climate-related problem—the service may take the form of a climate change risk assessment. The risk assessment will be classified as a climate service if the user interacts with the providers in a meaningful way to specify their uncertainty realm and their specific needs. Otherwise, at this initial stage the service will more often be a preliminary consultation that a provider may offer to potential candidates for climate service co-design. In the second phase, the climate service developer may help to identify the useful information for the user, both for improving the first risk and impact assessment and to start identifying relevant information required for the development of adaptation strategies. In the third and final phase, the climate service developer and the user will work together to co-create the tailored service to solve the specific problem identified during the process. A single climate service developer might support the user during the whole process, from problem recognition to solution development. However, some users may require the assistance of a climate service developer just for the designing phase (third phase) or for the data availability phase (second phase). Again, these phases are related to the different steps described in the adaptation cycle (Figure 2). Progressing in the adaptation cycle means that more socio-economic and technical information will be required for developing climate services. The most simple climate services are usually located in the assessing risk and vulnerabilities phase, and they use mostly climate information. As we advance in the adaptation cycle, more information is required—often provided by the users involved in the co-development process—and the resulting climate service will be more customized, transdisciplinary and specific to the needs expressed by the users.

3. Development of Climate Services Using Business Model Thinking

3.1. Process Overview and Objectives

The term "business model," which originated in entrepreneurship and e-commerce, is nowadays used for all business strategy research, often including public sector discussion (Ranerup et al., 2016). The most essential definition of business model states that it is the description of how an organization creates, delivers and captures value (Shafer et al., 2005). This definition immediately raises questions such as who is creating value, for whom, how the value is created and how it is delivered and perceived. Within the project INNOVA (INNOVA D3.1, 2018), we have defined the following process for creating climate services by using business model concepts (Figure 3).

The process uses concepts taken from the business model world to describe the design and development of climate services. The business model terms are contained in orange boxes. This facilitates the transition from the description of climate service development to business model description, helping climate service developers to think about how their climate service relates to end users and market needs. Each one of the processes represented in Figure 3 can be broken down into smaller steps for describing in more detail the dynamics involved. The process presented in Figure 3 describes a loop, meaning that after the climate service is delivered to the user, the user can express if there is a need for more or different services, effectively restarting the co-design process. The objective of this guideline is to narrow the conceptual gap between climate service and business model creation, facilitating business model thinking and the transition from conceptual design to climate service and business model development, as illustrated in Figure 4.

The fact that climate service development is a co-design implies that the collaboration between developers and end-users is required during the whole development process. As a result, stakeholders interested in participating in the co-design can be part of the user segment. Characterizing the users by using the classification described in the previous section will help to better identify the needs, expectations and data required for the co-development of the climate service. Climate data is essential for developing climate services, as the best available climate information is the initial resource of every service. However, limiting the use of information exclusively to climate information may result in narrow and risk-oriented climate services that may lack the customization required from the final users. The need for additional non-climate information may be revealed in the co-design phase or during the iterative co-design and co-development process. In this regard, the final user of the service often is an indispensable data provider for the developer, as it may have access to specific data (economic, agricultural, environmental...) corresponding to the specific economic or professional activity that they perform. Climate services are user-oriented services and it is more likely that additional user-specific and non-climate information is required to co-develop them as the level of customization is increased. The integration of the users' knowledge into the co-development process will result in the combination of know-hows that regularly will come from different branches of sciences, resulting in truly transdisciplinary outcomes.

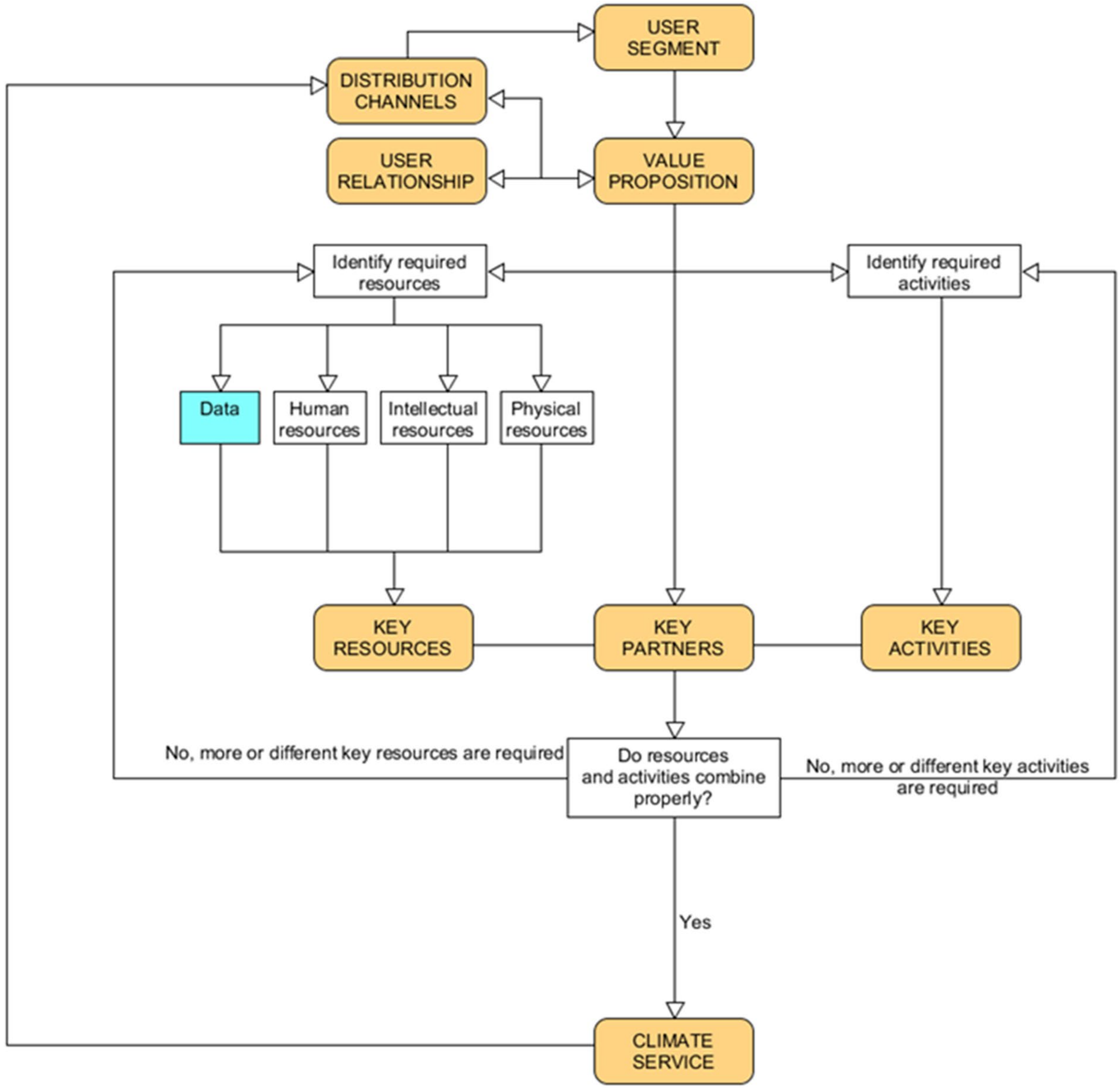

Figure 3. Process for creating a climate service using business model concepts.

The traditional notion of business models requires the definition of the cost-revenue structure, as seen in Figure 4. However, the fact that the public sector has been the driving force in the development and use of climate services (Tart et al., 2019) is an essential issue when addressing the economic side of climate services. For many stakeholders, climate change defies the traditional cost-benefit analysis (CBA) that just expresses cost and benefits in monetary units because the deep uncertainty and the scale of the expected impacts obstruct pure economic evaluation (Scovronick et al., 2019). Additional obstacles that can be added to the ones listed in the introduction for private involvement and use of climate services derive from two facts: (a) Climate change impacts are often widespread and mainly affect resources that are frequently considered common goods. (b) Climate change impacts do not occur abruptly but develop progressively in time (Swart et al., 2013). The first point drives some stakeholders to inaction and apathy, as climate change may seem too broad or abstract to tackle and acting upon it can easily per perceived as the responsibility of others. The second point is one of the main motives behind the tragedy of the horizon as described in the introduction and causes some stakeholders to delay their response to climate change until it may be too late. Despite all of these obstacles and constraints, significant opportunities have been identified in different

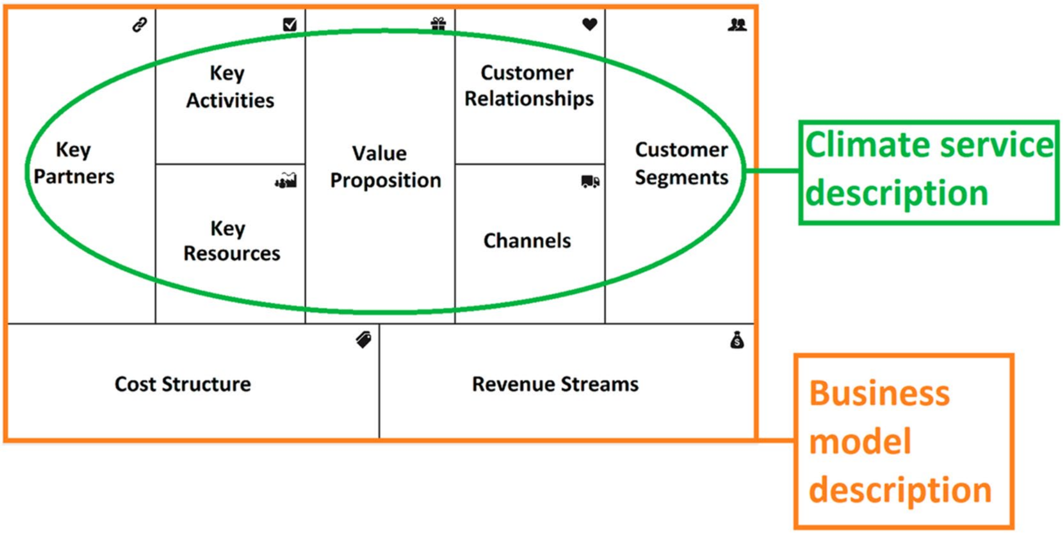

Figure 4. Relationship between climate service and business model description based on the business model canvas (Osterwalder & Pigneur, 2010).

sectors like water resources and risk, energy and agriculture (Cavelier et al., 2017). Furthermore, new CBA methods that are suitable for Climate Adaptation analyses and capable of integrating additional factors not expressed in monetary units have been developed and are gaining traction (Bresch & Aznar-Siguan, 2021; Souvignet et al., 2016).

3.2. Process Description

The process of developing the climate service can be described in 3 steps that contain the concepts borrowed from the business model literature (Figure 5).

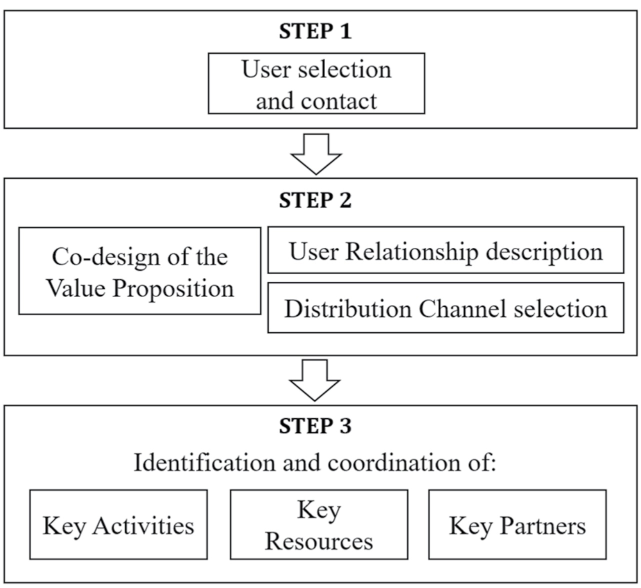

Figure 5. Steps required for the creation of climate services using business model concepts.

The Step 1 requires identifying and verifying the composition of the *user segment*. This process can happen top-down or bottom-up. Conceptualized as a top-down process, the climate service provider identifies which users are the ones in need of a service. As a bottom-up process, users, based on their experience and knowledge may contact a climate service provider to address their needs. Due to stakeholder's general lack of awareness of climate services as a product, it is most likely that a top-down approach is required at this stage. If that is the case, the processes described in Section 2 and Figures 1 and 2 will help climate service providers to understand the context of the potential users, facilitating the identification of the most promising stakeholders and enabling better communication between all parts. The user segment may be formed by a group of different users that can be segmented based on their different needs and attributes to ensure the appropriate development of a service that meets the specific needs of each group (Hedman & Kalling, 2003). The business model literature describes a diversity of users, differentiating between mass users, niche users, multi-sided users or segmented users inside a business field (Osterwalder & Pigneur, 2010).

Step 2 is the stage in which the co-design happens. In this step, the aim is to co-design with the user the goal of the climate service, and its main features, including the format and the kind of relationship that will be established between user and provider during and after the creation of the product or service. The concepts from this step are known in business language as *value proposition*, *user relationship* and *distribution channel*. The value proposition is the collection of products and services a climate service developer or provider offers to meet the needs of its users (Richardson, 2008). In the climate service context it defines the objective, added value and competitive advantage that the proposed climate service will provide to the user. If the user asks for a service that already exists, the value proposition of the service should include a competitive advantage over other similar products available for the user (Zhang et al., 2019). The competitive advantage provided by the climate service may be an additional value for the price, a deeper customization of the product compared to the existing offer in the market or any other feature that signifies a special value for the user. This step includes reaching an agreement on the preferred user relationship. The user relationship is the type of relationship that developer and user are going to create (Osterwalder & Pigneur, 2010). Some examples of user relationship are personal assistance, self-service, automated services or on-demand service. User relationship can change and evolve in time according to the needs and capacities of the targeted user and providers. The distribution channel refers to the methods used to deliver the climate service to the end user. Effective channels will be agreed with the users and will be designed depending on the user's needs (Osterwalder & Pigneur, 2010). The distribution through these channels must be as efficient and cost-effective as possible for the end-users. A climate service provider can communicate with its clients through different channels. Examples of channels are climate fact sheets, counseling or a web-product. User relationships and channels are intrinsically related, as the channel of communication can limit or influence the type of relationship that the end-user is going to maintain with the service developer. In some cases, user relationships can even be outsourced to partners specialized in communication and dissemination.

The Step 3 is to identify the *key activities* required for the development and delivery of the climate service or product. These activities include ways to achieve and maintain the developer-user communication, or users' relationship, through the previously specified channels. Processing and managing climate and other relevant data is almost guaranteed to be a fundamental activity for most climate services. Climate data is one of the critical resources that should be identified and collected during the process. *Key resources* are all the assets needed to sustain and support the climate service development. These resources can be human, financial, physical, and intellectual (Osterwalder & Pigneur, 2010). Although climate projections and climate information are essential resource for developing climate services, they are often not enough to provide an useful service to the end-users. *Key partners* are the external associates required to create and deliver the climate service, or to establish and optimize operations and communication (Chesbrough & Schwartz, 2007). In many cases, developers need to find key partners that will support the development or delivery of the climate service with key resources or key activities. Data supply, technical support or communication are some of the activities that are often outsourced to third parties. Public organization may be accounted as key partners of the climate service when the service depends on their funding. From our experience, users involved in the co-design of climate services end up participating in the co-development process as key partners. Their involvement is very often needed for the success of the final service, as they can provide essential data and valuable feedback required to customize the service to their own needs.

After the third step is finished, the climate service will be completed and prepared to be delivered to the user. As mentioned before when describing the design and development phases, steps have not to be taken as tasks to be finished, but as a part of a creation process. This means that at any step of the process, the climate service developer may need to engage again with the user to modify the value proposition, change or add new key partners, add additional resources not previously considered, etc. Once the climate service has been delivered, the relationship between user and developer does not necessarily end. The climate service may require several iterations to be useful for the user, or it may require the support of the developer over time. The after-delivery support to the user will be described when defining the user relationship (Step 2). Guaranteeing support to the end-user after the delivery of the climate service increases trust and promotes better cooperation between providers and users during the co-creation process.

Figure 6. Area where EMIVASA is currently operating.

4. Application: Climate Service for the Drinking Water Supply of the City of Valencia (Spain)

4.1. Case Study and User Description

Valencia is a coastal city located on the east coast of Spain, in a semi-arid region that suffers from long and frequent droughts due to its Mediterranean climate. With around 1,600,000 habitants in the city and its metropolitan area, Valencia is the third-largest city in Spain (INE, 2019). Extreme weather events typical of the Valencian region, such as droughts and floods have a very well-known negative effect on both water quantity and quality (Hrdinka et al., 2012). Water scarcity is the main issue for the agricultural sector—responsible for 80% of the water consumption in the region—while issues derived from water quality affect mainly the urban water supply sector. EMIVASA is the company responsible for purifying and providing water to the habitants living in the city of Valencia and the surrounding cities (Figure 6).

EMIVASA is a public-private partnership. Global Omnium owns 80% of EMIVASA, and is a private company that provides services to more than 300 municipalities in Spain and has projects in Africa, Asia and Latin America. The company was founded in 1890, and operates in the water sector as a whole, purifying, supplying and treating water, while leading and promoting R&D projects to ensure the future development and synergies with other business and territories. The remaining 20% of EMIVASA is owned by the Municipality of Valencia.

The metropolitan area of Valencia receives water from the Jucar and Turia Rivers. The qualitative and quantitative status of both rivers are critical factors to consider for EMIVASA. Around 75% of the water supplied to Valencia and its metropolitan area comes from the Jucar River. The water transfer from the Jucar to the Turia River is carried out through a 60 km channel that starts at the Tous reservoir and finishes at the Manises water purification plant, where the Jucar and Turia water is mixed (Figure 7). The current Tous reservoir was built in 1996, it is the downstream reservoir of the Jucar River basin and it is used for flood control, hydroelectric production, irrigation and urban water supply.

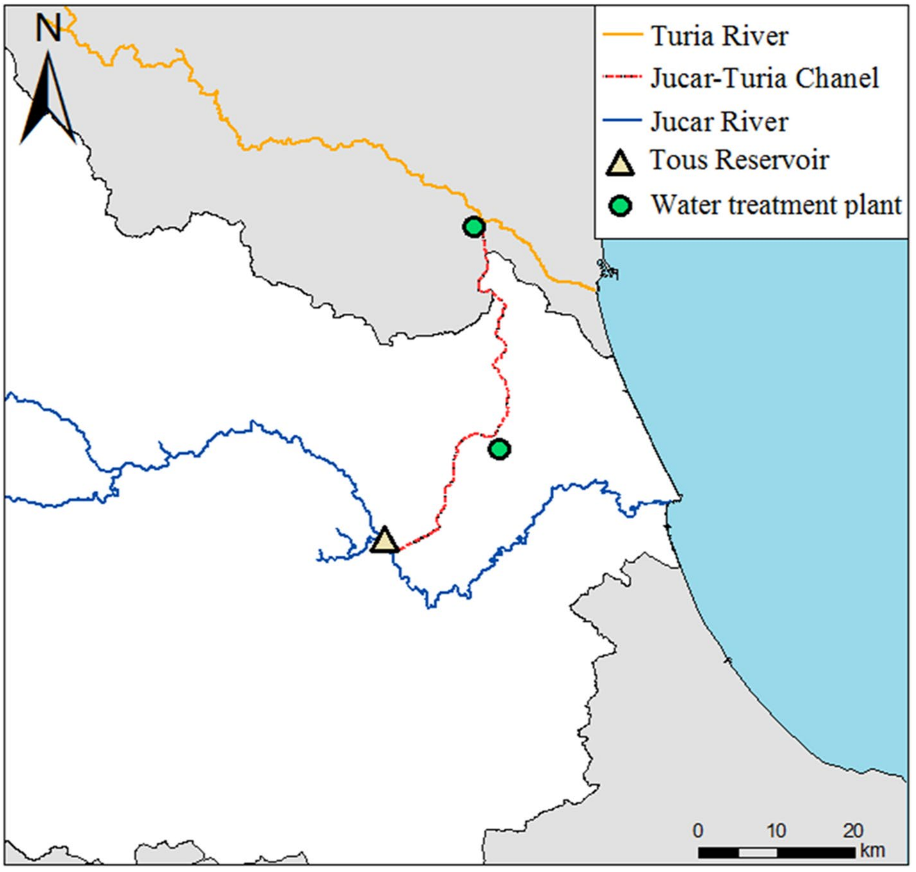

Figure 7. Water management infrastructures involved in the raw water management and treatment for Valencia City and its metropolitan area.

4.2. Climate Service Co-Creation With the Water Utility Company of Valencia

The climate service creation started by identifying the stakeholders in the region that are more vulnerable to climate change impacts. The partnership with the main user, EMIVASA, was built based on previous experiences between both partiers. The co-design of the objectives and features of the climate service (value proposition) was carried out with EMIVASA. During this meetings both parties identified other users potentially interested in the climate service. EMIVASA and the development team also reached agreements upon the communication and distribution channels. Following the process described in S3.2, step 1 recognized the following main and secondary users:

STEP 1
User segment:

- **EMIVASA (main user): Formed by Global Omnium, company responsible for purifying the water for the city of Valencia and its metropolitan area, and the Valencia Municipality.**
- **EMSHI Metropolitan Area Authority for Water Supply: interested in the results.**
- **Water Authority of the basin: interested in the results.**

STEP 2
Value proposition: Assessing the effect that climate change will have on the future raw (untreated) water available in the Valencia region in terms of both quality and quantity. Assist EMIVASA into finding the best strategies to treat and manage this resource and calculate the cost of the adaptation strategies.
User relationship:
- **Periodic meetings and email communications (early stages)**
- **Reports and presentations submitting (mid stages)**
- **Periodic visits to the water treatment plant (late stages)**
- **On-demand consulting (after project completion)**

Distribution channels:
- **Reports with the predicted state of the system in terms of water quantity and water quality for current and future climate change scenarios**
- **Counseling on the best treatments strategies for the future water**
- **Final report to EMIVASA and the water authorities including cost**

The challenge that climate change presents for the water utility system in the region is caused by the impact that the combined effect of increasing water scarcity and higher temperatures may have on the raw water quality.

The elements belonging to the Step 2 of the process are the following:

The value proposition of the co-designed service was to analyze the effect that climate change will have on the future raw water available in the Valencia region, in terms of quality and quantity. The first co-design meetings were used to clarify how the climate service could be of most use for EMIVASA. This included aligning the climate service to the company's decision-making process in terms of time and spatial scales. Subsequent meetings tackled issues such as identifying the main water quality parameters of interest for the company (physical, chemical, and biological). Contact with the company remained active during the different phases of the co-development of the climate service. Some of the following meetings were held at the water treatment plant of the company, and involved the technical staff from the plant to discuss the provisional results obtained.

The Water Authority of the Júcar River Basin, "Confederación Hidrográfica del Júcar" (CHJ) was also engaged during the co-development of the climate service. This public entity is attached to the national government of Spain as an autonomous body under the Ministry for Ecological Transition and Demographic Challenge. The bilateral meetings with representatives from this institution were held during May 2019 in the main office of the entity, located in Valencia. The operating officer and several engineers involved in the management of the channel responsible for providing water to the city of Valencia and its surroundings assisted the meetings. The contact with the water treatment company afterward has continued for data and knowledge exchange through email. Finally, due to the scope of the climate change impact on the region, agricultural associations were contacted and several meetings were held between 2018 and 2019 with representatives of the irrigation communities of the farmlands surrounding the city of Valencia. The purpose of these meetings was to show them the predicted water resources availability obtained by our models under the different climate change scenarios, in order to explore the possibility of co-creating an ad-hoc climate service. However, this line of work was not further advanced due to time constraints and the increasing complexity of the climate service already under development.

Step 3 of the process started by identifying the required resources for the development of the service. Key activities and partners were also identified.

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STEP 3

Key resources:

- **Global and regional climate projections (selected scenarios: RCP4.**5 and 8.5 for the 2020–2040 and 2040–2070 periods). Obtained from the Copernicus open repository and EURO-CORDEX (Copernicus Climate Change Service, 2017; Jacob et al., 2014)
- **Historical data of natural inflows on the region's different sub-basins from 1970 to 2013 (MAPAMA, 2018)**
- **Historical data of the reservoir storage, water demands and main users of the system**
- **Data of environmental flows for the Jucar and Cabriel Rivers.**
- **Scientific publications and previous research on the operating rules of the system during the 2003–2013 period**
- **Historical data on the water quality parameters (nutrients, phytoplankton and physical parameters)**
- **Data on the water infrastructures that affect the user segment operation**
- **Human resources: 2 professors, 2 postdocs, 1 pre-doc student and additional support of EMIVASA employees during the late stage of the project**
- **Material resources: 4 computers, licenses for modeling software (Vensim Pro, GAMS, Aquatool/GESCAL)**
- **Physical resources for the construction of a testing scaled-down model of the plant by Aguas de Valencia**
- **Data on the cost of the different water treatments for EMIVASA**
- **Information about potential innovations for the water treatment**

Key activities:

- **Data gathering and processing**
- **Downscaling and bias-correction for climate projections.** Comparison with the reference period for the region and selection of regional/global combination
- **Development of hydrological model of the Jucar River basin at the sub-basin scale**
- **Scientific literature revision for the creation of both the water resource management model and the water quality model**
- **Development of a basin-scale water resource management simulation model to assess future water availability in the region**
- **Periodical meetings with the final user to select the water quality parameters of interest and to obtain additional data of water quality**
- **Periodical meetings with the final user to report on advancements and receive validation and feedback**
- **Development of a water quality model of the Tous reservoir**
- **Internal exchange between the water management development team and the water quality modeling team to coordinate the development and ensure inputs/outputs compatibility**
- **Results processing.** Models results were processed and statistical analysis was developed to assess the impact of every qualitative and quantitative scenario for the future water resource
- **Design and construction of a scaled-down model of the water treatment plant (done by EMIVASA)**
- **Operation of the testing plant under the scenarios provided by the models (done by EMIVASA)**

Key partners:

- **EMIVASA: as the final user of the climate service, their cooperation for the co-design of the service is capital for the success of the project.** They also provided data on water quality for the Tous reservoir and the Jucar-Turia Channel
- *Confederación Hidrográfica del Júcar*: **as the water authority of the basin, they are the main data providers for hydrological information.** Including some data of water

quality for Tous.

- *Comunidad General de Usuarios del Canal Jucar-Turia*: **this irrigation community provided information about the Jucar-Turia channel configuration and its operation**
- **Valencian municipality: they provided data of water quality for the Tous reservoir and the Jucar-Turia Channel**
- **Coordinated Regional Climate Downscaling Experiment EURO-CORDEX (Jacob et al.**, 2014) and Copernicus Climate Change Service (2017): to obtain the regional and global raw climate projections data
- **AEMET (Spanish National Meteorological and Climate Agency, 2019) for the data on precipitation and temperature in the region**

Historical data of natural inflows in the region's different sub-basins was obtained from the online repository of the Spanish Ministry of Agriculture, Fisheries, Food and Environment (MAPAMA, 2018). It was used to calibrate the water management model, in combination with past data on the reservoir storage, water demands, environmental flows and main users of the Jucar system (Confederación Hidrográfica del Júcar, 2019). Historical data about the water quality parameters of the Tous reservoir (Confederación Hidrográfica del Júcar, 2019) was collected and processed to create the water quality models. Key partners were contacted to access not freely available data of infrastructures such as the Tous reservoir and the Jucar-Turia channel. The output of the water management model running the selected climate change scenarios was introduced to the water quality model to estimate the effect of climate change both in terms of water quality and quantity. The initial results of the models were processed and presented to the end-user to validate them and to receive feedback on different variables and scenarios of interest.

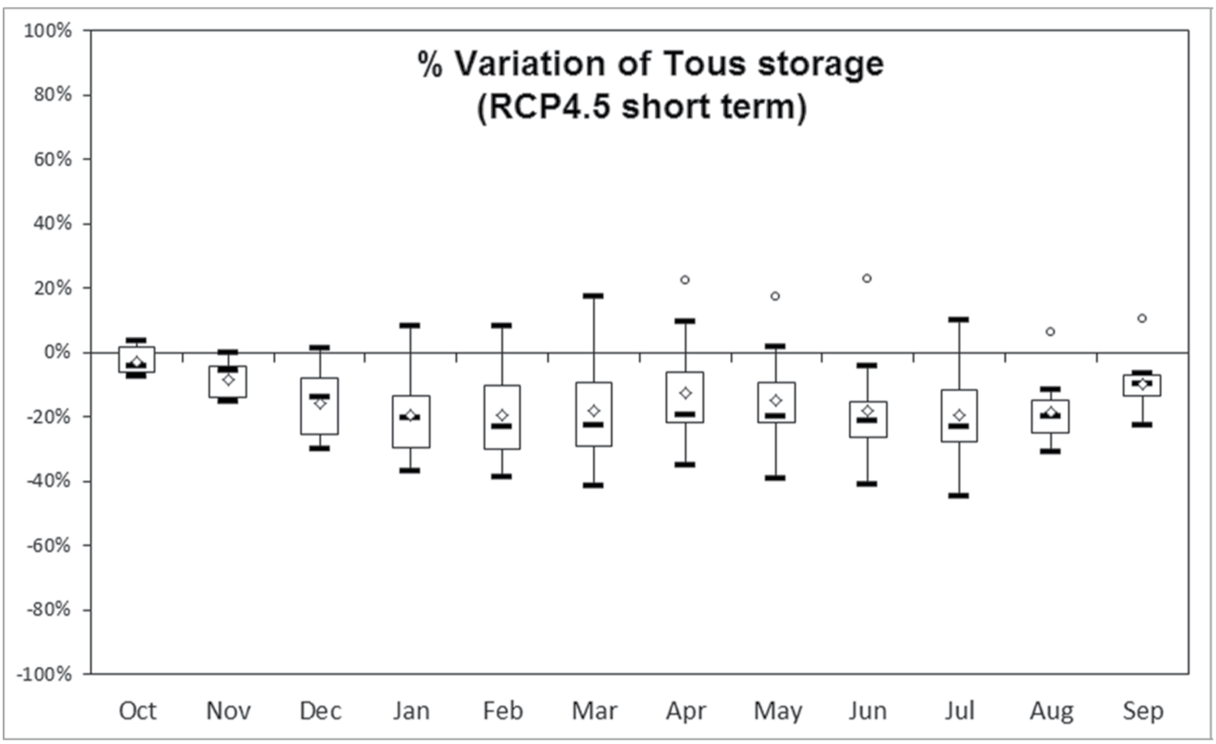

Figure 8. Average monthly variation of Tous water storage for the RCP4.5 short-term scenario compared to the reference period.

Table 1
Main Parameters and Summary of Results Obtained by the Climate Service

			Results	
Parameter	Water body	Units	2020–2040	2040–2070
Water storage	Jucar basin	Mm^3	−22%	−41%
Water storage	Tous	Mm^3	−11%	−23%
Water temperature	Tous	°C	+1°C	+1.5C
Chlorophyll *A*	Tous	µg/l	x4 peak concentration	x10 peak concentration
Oxygen dissolved	Tous	mg/l	+15% anoxia events	+25% anoxia events
Organic nitrogen	Tous	mg/l	x10 concentration on bloom events	x12 concentration on bloom events
Ammonium	Tous	mg/l	Not significant	Not significant
Nitrates	Tous	mg/l	Not significant	Not significant
Total phosphorus	Tous	mg/l	Not significant	Not significant
MIB	Tous	µg/l	+40% events	+60% events
			+45% concentration	+55% concentration
GEOSMIN	Tous	µg/l	+20%	+30%

Note. MIB, Methylisoborneol.

4.3. Summary of Results Obtained by the Co-Designed Climate Service

The co-designed climate service developed for the water utility company of Valencia obtained numerous results during the 3-year process of its creation. The first valuable results were the ones that described the effect of climate change on the water availability for EMIVASA and the system as a whole. The results for the different climate scenarios were processed and presented in figures and graphics (Figure 8).

The water management model developed was able to show not only the water storage in the different reservoirs of the system, including Tous, but also the monthly inflows and outflows of the three reservoirs of the system and the water shortages that each typology of water user suffered during the different RCP scenarios. The predicted reduction in water availability does not compromise the water supply to Valencia and its metropolitan area in terms of water quantity. However, it puts in jeopardy the water supply to other stakeholders of the Jucar River system, particularly agricultural users. Furthermore, analyzing the effect that the forecasted available water resources and the new climate conditions may have on the quality of the raw water storage in Tous required a previous assessment of the water resources availability in the whole basin.

The second set of results of the climate service analyzed the impact that climate change will have in the quality of water. The analysis focused on the parameters of most interest for EMIVASA. The complete list of parameters and results that have been obtained is collected in Table 1. Results were obtained for the RCP4.5 and 8.5 scenarios in a monthly time step. For the water quality parameters, results were obtained separately for the hypolimnion and the epilimnion of the Tous reservoir. All simulations used the same reference period 1970–2000 as comparison to show the variation that each climate projection introduces. The chain of models developed to achieve these results include:

1. System dynamics model to simulate the management of the basin and fed by the climate projection data achieved for the main water inflows of the basin (Rubio-Martin et al., 2020);
2. A water quality model of Tous reservoir developed using the SIMGES module from Aquatool (Andreu et al., 1996) and able to simulate the interaction of physical, organic and chemical components present in water.
3. A fuzzy logic model of the Tous reservoir to estimate the concentration of Methylisoborneol (MIB) and geosmin, the two main organisms responsible for causing unpleasant taste and odor to the water of Tous.

The short and medium-term results presented in Table 1 are average results obtained for the RCP4.5 and 8.5 climate scenarios. The detailed climate service results provided to EMIVASA, however, do differentiate between different RCP scenarios, climate projections, monthly averages and seasonal variation.

In terms of water quality, the concentrations of ammonium, nitrates and, total phosphorus do not increase significantly due to the fast assimilation of these nutrients by the more abundant phytoplankton. The phytoplankton, measured by the Chlorophyll a concentration, benefits from the increasing water temperatures and nitrogen concentration. The blooms of Chlorophyll a during the warmer months (spring and summer) will require from EMIVASA to adapt the current treatment facilities and methodologies. The trophic state of the Tous reservoir will change from the optimal oligotrophic state to mesotrophic. MIB concentration increasing by 50% in some scenarios would not be manageable by the existing water treatment facilities, and would require the adaptation of the water treatment plant. The same issue arises from the increasing geosmin concentrations. The optimization of the water treatment processes for the removal of MIB and geosmin is an on-going line of research by EMIVASA that the co-designed climate service has further justified. Currently, the results obtained by the co-created climate service are being used to assess the cost of adapting the existing water treatment processes to the new climate scenarios. To do so, the testing plant is being used to assess how the present technologies handle the predicted raw water. Additionally, operational and technological changes are being analyzed to select the most efficient and cost-effective solutions. The collaboration between EMIVASA and the climate service providers is continuing in the search of the best alternatives for the adaptation of the water treatment plant.

5. Conclusions

This article highlights the value of involving users in the co-design of climate services to fully comprehend their system understanding, previous assumptions and specific demands for climate data and information. Additionally, users' knowledge has been integrated into the process supporting a truly transdisciplinary outcome. In this article, we propose to use a business model perspective to support the co-design of climate services, and we explain how the business-focus approach has been applied to develop a climate service for the water utility company of the city of Valencia, Spain. The resulting climate service is a customized product that has answered the specific needs and requirements of the water utility company. The integration of the user knowledge during the co-design phase was essential to find the appropriate spatial and time scales. Engaging the user in the co-design process also allowed to discover the most critical water infrastructure for the modeling analysis. During the co-development, the end-user provided essential data, feedback and validation. Additionally, they built and started to operate a testing water treatment plant to assess the impact of the new raw water into their system. The successful application of the approach to the described case study facilitates replication and learning by other actors interested in climate service development. In the water utility sector, we pave the way for recreating the service in other areas with similar conditions, replicating the co-design process and learning from the insights provided.

The way we have engaged stakeholders in the co-design has provided multiple advantages. First, it has supported constructive and targeted discussions relevant to the identification of needs for climate services design tailored specifically to the user. Second, it has allowed the integration of local knowledge in the process supporting the integration of a variety of data. Third, co-designing the services this way, we avoided user rejection on the produced service. Finally, the process itself has promoted awareness and collective learning of those participating in the co-design.

The development of climate services that generate knowledge for the adaptation is essential in many sectors that need to carefully plan in advance their adaptation pathway. In the case of the water utility industry, future water quality problems may require infrastructure changes and additional investments in research to find the best solutions for treating and delivering tap water safely. In this context, climate services allow to contemplate future scenarios in advance, smoothing the decision-making process for adaptation, and the potential success of any adaptation strategies or actions (Bowyer et al., 2014).

The business model approach here introduced has not addressed in detail the economic side of business models. As mentioned in section 3.1 traditional CBA is hardly applicable to climate change and the topic of who has the economic responsibility for climate change adaptation is an issue that would deserve its own analysis. Particularly when talking about private-sector companies that supply critical services or infrastructures for public benefits, such as water supply companies. Many authors (Bruijne & van Eeten, 2007; Zürn et al., 2005) agree that the ultimate responsibility is on the state, because the state is responsible for public security. However, private businesses that provide public services are subject to public scrutiny regarding climate change adaptation, as they hold a secondary responsibility as operators. Previous authors have considered that climate services that serve a public good are anticipated to be funded in large part by the taxpayer (Brasseur & Gallardo, 2016). These are some of the reasons why the financial aspect of business models is not as significant for climate service development as it is for traditional private plans. However, we must seek to explore the use of our business focus approach for the co-creation of climate services in the private sector with a greater focus on the cost and revenue streams. To do so, new CBA methods able to capture externalities and the public value of climate adaptation may be required.

The application of the INNOVA climate service development approach to the Valencia water supply case shows how public and private collaboration can be a powerful instrument for climate change adaptation. The co-creation of customized and useful climate services require the coordination of climate service providers and users. As shown in the example, a business model approach can help to bridge the gap between scientific and practice-based knowledge, supporting climate service development and climate change adaptation.

Data Availability Statement

The data supporting this research includes global and regional climate projections obtained from EURO-CORDEX and Copernicus (Copernicus Climate Change Service, 2017; Jacob et al., 2014), inflows for the modelled sub-basins (MAPAMA, 2018), water transfers, users, demands, reservoirs information and water quality parameters from CHJ (Confederación Hidrográfica del Júcar, 2019), and air temperature and precipitation data from AEMET (Spanish National Meteorological and Climate Agency, 2019).

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