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Perspective

Conditions for a market uptake of climate services for adaptation in France

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ABSTRACT

This perspective paper reports the results of a collaborative survey of French research institutes concerned with environmental issues, which examined the potential for a market uptake of climate services for adaptation in France. The study is based on a review of existing reports on the market of climate services, and on interviews of 68 climate service providers and users in public and private organizations. Although the study does not allow to provide quantified estimations regarding the present and future size of the market, its results offer new perspectives with implications extending far beyond the sole case of France: first, while the market is still in its infancy, significant opportunities exist in sectors such as flooding risks, and, to a slightly lesser extent, hydro and nuclear energy and viticulture. In addition, the study identifies critical conditions for the uptake in climate services: (1) a coordinated delivery of data, information, expertise and training by public research institutes concerned with climate change and its impacts; (2) the inclusion of adaptation in the regulation and in public and private tenders. Finally, (3) uncertainties in climate projections appear as a major barrier to the uptake of climate services. However, ambitious greenhouse gas emission reduction as planned by the COP-21 Paris Agreement contribute to reducing this uncertainties by allowing users to select a subset of climate change projections, avoiding those for which adaptation is most problematic.

1. Introduction

The fact that climate is changing due to anthropogenic greenhouse gas emissions has now become a consensus shared by a scientific community extending far beyond the sole climate researchers (e.g., Carlton et al., 2015; Cook et al., 2016). Some economic impacts have been observed already, for example in the sector of agriculture (Cramer et al., 2014), and some future impacts are now recognized unavoidable, even if an ambitious mitigation target is met. For example, it is well established that sea-level will continue to rise and increase risks of coastal flooding over the coming decades (e.g., Hallegatte et al., 2013), and that the ocean and coastal ecosystems and services will be severely affected by ocean warming and acidification (Gattuso et al., 2015). With 7bn inhabitants on the Earth, it appears essential to address these challenges seriously and, therefore, to engage ambitious adaptation strategies.

Adaptation to climate change refers to actions either aiming at coping with already ongoing climate change impacts, or focused on the anticipation of future environmental conditions. It not only requires technical infrastructures such as observation systems, climate models and portal, but also a significant amount of economic and human resources. In some sectors such as agriculture, the market has already developed an adaptive capacity to the adverse impacts of climate variability (Porter et al., 2014). However, this capacity remains often reactive and can often not be isolated from an adaptation to other drivers of change (Berrang-Ford et al., 2011). In addition, this adaptive capacity does not guarantee that adaptation to the specific issue of climate change will take place. As a consequence, the present market of climate services for adaptation cannot be considered mature enough to meet the societal needs for adaptation.

To finance this adaptation, a realignment of current investment fluxes is needed. The case of the developing countries reveals the magnitude of the "adaptation gap", defined as the difference between the needs for investment in adaptation and the actual

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financing of these activities. In developing countries alone, the IPCC has evaluated that the needs for investment of adaptation should be as large as 60–90 billions Euros by 2030 (Chambwera et al., 2014), and might even be underestimated by a factor of 2 or 3 (UNEP, 2016). These figures show that the emergence of a market of adaptation is needed over the coming decade. However, we do not know what form the market for climate services will take. Development aid is clearly a necessary component in the case of the developing countries, which are the most vulnerable to climate change. Conversely, in France and other developed country, the emphasis is put on *creating the conditions* for a market of adaptation to emerge.

"Climate services for adaptation" are defined as all public and private services supporting adaptation to climate change (Hewitt et al., 2012; Brasseur and Gallardo, 2016). While climate services can be provided by both private and public sectors (Tompkins and Eakin, 2012; Bierbaum et al., 2013), environmental research organizations (which are often public) are expected to play a key role in this context: they should provide reliable data, methods and information in support to climate services. They should also support the setting up of new monitoring and modeling infrastructures, the transfers from research to innovation, and contribute to the training of the required human resources. To fulfill these assignments, public organizations need to understand their respective positioning as well as the economic environment in which climate services should emerge.

In 2014, the consortium of French organizations concerned with environmental research (AllEnvi) has mandated its Economic Intelligence department on these issues. This perspective paper reports the major outcome of this study, by examining the conditions under which climate change services could take off in France.

2. The French Common Strategic Analysis (FCSA) on climate services: Outlines

The economic system of climate services can be divided into several components (Fig. 1). First, "Data providers" deliver the fundamental observations and modeling results allowing the evaluation of past, present, and future changes. These datasets can be used directly by public authorities to raise awareness on climate change impacts and to favor adaptation. Between *beneficiaries* and *data-providers*, the products delivered by *in-sector providers* can be sorted in three categories:

(1) organizations designing added value products such as portals and tools providing impact assessment results (e.g., Lémond et al., 2011; Kjellström et al., 2016);
(2) design of adaptation strategies and support for decision making on adaptation (e.g., Ranger et al., 2013);
(3) education and professional training, which is expected to provide the human capacity to adapt to climate change and perform the transition to an economy more respectful for the environment (e.g., Gornish et al., 2013; Brasseur and Gallardo, 2016).

The FCSA first analyzed the two components of the ecosystems of climate services: service providers and users (Fig. 1). Then, it examined under which conditions the market of climate services could emerge in France. The sources of information are public reports and scientific articles, as well as two sets of interviews: (1) within 16 institutes that are members of AllEnvi in order to analyze the current offer; (2) within the semi-public and private sector in order to analyze the potential of a market uptake (39 interviews in 11 different European countries plus the USA). Finally, a more detailed analysis is performed for a selection of 4 sectors and 8 subsectors: Energy (including hydro, nuclear and renewable energies), management of the risks induced by flooding, agriculture: (viticulture and forestry) and transport (road and aerial transport).

The energy and transport sectors were selected because of their high level of connectivity to other economic sectors in France and the European Union. Any reduction of their productivity would propagate through the European economy. In addition, the risks due to water have the potential to have major impacts in the economy (Hallegatte, 2008; Hinkel et al., 2014). Finally, the viticulture sector is selected based on cultural and economic considerations. The sector of water resources was not directly analyzed despite its recognized importance for Europe (Kovats et al., 2014). However, it is indirectly considered through the analysis of agriculture and energy. This analysis is however not exhaustive and other sectors will be impacted as well (Arent et al., 2014). For example, the sector of tourism needs to adapt to reduced snow cover and increasing rates of sandy beaches erosion, however not necessarily

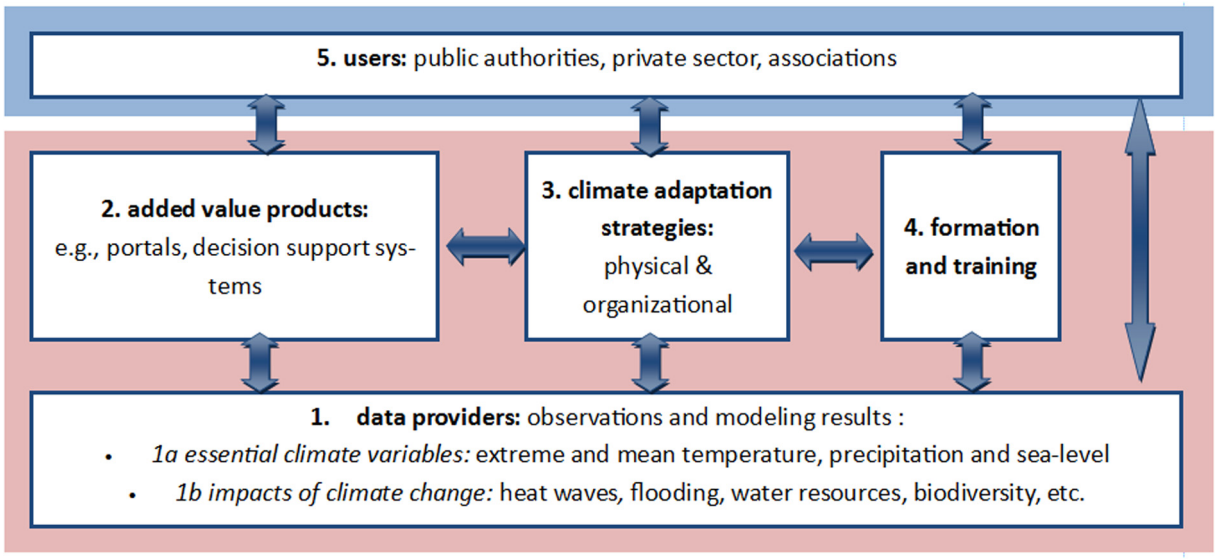

Fig. 1. Climate services providers and users and their interactions: simplified scheme after JPI-Climate (Monfray and Bley, 2016).

with as much systemic impacts as the transport and energy sectors in France and Europe.

The results of the study were further discussed and refined during a workshop held in Paris in January 2016 (Cavelier, 2016).

3. Results: The potential for a climate service uptake in France

3.1. The French climate services providers: Analysis of the current offer and challenges

The survey showed that most of the current providers of climate services are research institutes and universities. 16 organizations participating to the French research alliance for the Environment declared activities in the field of climate services, which represents a large majority of public organizations concerned with Environmental research in France (Table 1). These organizations have large differences in size (from 80 to 12,000 employees, mean and median of 2500 and 1600 respectively) and nature (e.g., meteorological office, research center, network of universities, research institute on engineering or energy, geological survey).

The services delivered by these organizations cover the following challenging aspects: observations, modeling, portals, impact studies, activities in support to adaptation. Overall, Table 1 shows that most organizations have well established added-value services such as territorial vulnerability maps and scenarios. Only two organizations presently declare having a strong expertise on adaptation already, and nine organizations spontaneously declared that they are currently moving toward more applied activities, such as impacts studies or support to adaptation (Meteo-France, IPSL, Ifremer, CIRAD, IFSTTAR, CEREMA, INRA, IRSTEA and IGN; see Table 1). Conversely, only two institutes announce putting a stronger emphasis on developing their upstream observing and modeling capacity (IRSTEA and CIRED; see Table 1). However, the interviews indicate that the field of adaptation appears relatively disconnected from climate information in key fields such as engineering design, although interactions between the two communi-

Table 1
Description of the 16 French public organizations currently providing climate services which have been surveyed during this study. Note that the information provided in this table results from a 4 step approach, consisting in (1) interview of key experts within the organization; (2) bibliometric analysis of the scientific production of each organization in the area of climate services (3) review by the climate group of the Allenvi research Alliance, (4) request to the management of each organization to comment on the results. It is therefore mostly a self-assessment of their status in 2015, including some heterogeneity in the details provided by the respondents. Note that two organizations may address the same economic sector in different ways (e.g., estuarine zones adaptation may be considered from a biodiversity or human risks perspective), and that the organizations have reported collaborations and complementarities (thematical, sectorial, geographical and positioning in the research to application chain).

Organisation and their role	Priority economic sectors	Services currently supplied		
		Climate observations, models and knowledge	Impact studies, portals and advanced products	Adaptation studies
Météo-France: meteorological office and research institute on climate and meteorology (www.meteo.fr)	Multi-sectorial approach	Strong expertise	Strong and developing expertise	In development
Institut Pierre Simon Laplace (IPSL): research institute on climate and environment (www.ipsl.fr)	Multi-sectorial approach	Strong expertise	Strong and developing expertise	In development
Ifremer: institute performing research and innovation on ocean, coastal zones and the related activities (www.ifremer.fr)	Fisheries, marine and water ecosystemic services and infrastructures	Strong expertise	Strong and developing expertise	In development
IRD: French Research Institute for the Development with a strong focus on international projects, especially in intertropical zones and the Mediterranean (www.ird.fr)	Agriculture, forestry, water and health.	Strong expertise	Strong expertise	Strong expertise
CNRS: National Center for Scientific Research (www.cnrs.fr)	Multi-sectorial approach.	Strong expertise	Strong expertise	Expertise
CIRAD: French Research Institute for International Cooperation on Agronomy and for Sustainable Development (www.cirad.fr)	Agriculture, forestry, water and health.	–	Strong expertise	Rapidly developing expertise
INERIS: National Institute on Industrial Environment and Risks (www.ineris.fr)	Multi-sectorial approach.	–	Strong expertise	–
IFSTTAR: French Institute on Transport, networks and land planning sciences and technologies (www.ifsttar.fr)	Water, transport and infrastructure.	–	Strong expertise	Rapidly developing
CEREMA: Center for Studies and Expertise on Risks, Environment, Mobility and urban and country Planning (www.cerema.fr)	Transport and infrastructure.	–	Strong expertise	Rapidly developing expertise
INRA: French National Institute for Agricultural Research (www.inra.fr)	Forestry, agriculture, viticulture, water and marine sectors and ecosystemic services.	–	Strong expertise	Rapidly developing expertise
IRSTEA: National Research Institute of Science and Technologies for Environment and Agriculture (www.irstea.fr)	Forestry, agriculture, water sectors, tourism and infrastructures.	In development	Strong expertise	Rapidly developing expertise
CEA: French Alternative Energy and Atomic Energy Commission (institute performing research, development and innovation) (www.cea.fr)	Energy, insurance and finance.	Strong expertise	Strong expertise	Expertise
BRGM: French Geological Survey (www.brgm.fr)	Water resources and coastal risks and their sectorial implications.	–	Strong expertise	Expertise
CIRED: International Research Center on Environment and Development (www2.center-cired.fr)	Multi-sectorial approach.	–	Rapidly developing	Strong expertise
CPU: Conference of University Presidents, gathering the director of university and high education organizations (www.cpu.fr)	Multi-sectorial approach.	–	Strong expertise	–
IGN: National Institute for Geographical and Forestry Information (www.ign.fr)	Forestry, agriculture, water sectors and infrastructures.	–	Strong and rapidly developing expertise	In development

ties are recognized essential to evaluate the efficiency of adaptation measures (Hallegatte, 2009; McNie, 2012).

The scale and territories addressed by each institute varies from global to regional scale, with focus areas mostly focused in metropolitan France, and growing efforts to also provide climate services in the overseas territories, whereas delivering services at international scale is a priority for only a few organizations. While a portal involving the two French producers of climate projections is in place (DRIAS, Lémond et al., 2011), the need for elaborated products focused on users' needs and regional to local scales is highlighted by most organizations working in the field of impacts and adaptation. Interestingly, most organizations faced difficulties to quantify their number of employees currently working on climate services. 8 organization were unable to provide figures, while the sum, median and mean of full time jobs in the field of climate services in the remaining institutes was estimated to 100, 8 and 17 respectively. This difficulty in providing figures could be either due to climate services being embedded in too many different activities, or to difficulties of the public organizations to assign resources to move from research to operations in the field of climate change (Brooks, 2013). Besides the public sector, the survey reminded that several small and medium companies are attempting to elaborate an offer on climate change adaptation for several years, building on their current meteorological services. It also reminded that the issue of adaptation to climate change is addressed internally by large companies of the energy and transportation sector. Respondents justify this autonomous development by the fact that specific types of data are needed for each type of sector, whereas the existing portals and services delivered by public organizations remain too generic (as noticed previously by Brasseur and Gallardo, 2016). However, as in many other countries, neither climate services nor the supporting infrastructures are presently considered to have reached maturity, such progresses relying on current European programs such as Copernicus, JPI Climate, KIC Climate, etc.; e.g., Street, 2016; Monfray and Bley, 2016).

3.2. Current and potential users of climate services in France

Today, most of the current final users of climate services remain public and governmental organizations. These final users can be supported by the private sector to implement their policies. However, the survey highlighted that private actors and the industry are usually not using the climate services supplied by the French climate services providers, except in the case of a few "early adopters" such as some insurance companies. Respondent in the private sector expressed the need for climate services supporting them in the process of saving costs and reducing risks in the long term. In practice, some users have created their own capacities (see Section 3.1) and most potential users have first of all expressed an interest in free of charge services. This indicates that businesses have not yet identified how climate services can help them to gain in productivity or avoid losses, and that more interactions between users and providers are needed. Nevertheless, this survey enables to gather some key requests from potential users, which can be useful to stimulate such interactions:

- providing access to understandable and reliable information,
- better defining the vision on the use and benefits of climate services, in particular by publicizing some emblematic successes
- improving the salience of the climate services (Cash et al., 2002), by providing access to information relevant for each specific sector,
- further integrating the challenges of adaptation in the regulatory frameworks, so that considering climate change can become a competitive challenge in the private sector.

These four key requests are consistent with other needs collected through empirical research in other countries (e.g., Bierbaum et al., 2013; Allen et al., 2017; Golding et al., 2017). The last point is reported as well in previous research (e.g., Cheong et al., 2013), but remains perhaps more prominent in the case of France. These user requests are detailed and further discussed in the remaining of this subsection.

Users partly attribute the current slow uptake of climate services to the lack of visibility of the current offer of climate services and their potential benefits. Along with previous studies (Allen et al., 2017), our survey suggests that mediators of knowledge will be needed to meet this communication challenge and make connections among the different scientific and technological professional communities involved in climate services and specific sectorial activities.

Users requested to share information on exemplary case studies. This approach was successfully implemented in other countries (Bierbaum et al. 2013). Such success stories exist in France as well, as some of them were gathered and published to prepare for the COP21 and COP22 summits (e.g., though the Allenvi network of French Research Institutes Concerned with Environment). However, our survey suggests that users would welcome further efforts to share and publicize exemplary climate services for adaptation.

The survey highlighted a need for tailoring climate services to specific users or economic sectors (Cash et al., 2002). Indeed, users consider that a climate service dedicated to viticulture or coastal risks should not only provide the relevant climate variables and impacts, but also identify where the climate information can help them in their decisions, in order to ultimately build the relevant workflows improving the production of grapes or coastal risk prevention and adaptation. This is illustrated by a comment of an expert in a private company in the sector of viticulture: 'Needs are in the integration of more wine-oriented information'. In addition to the European research programs listed in Section 3.1, other initiatives are emerging at national scale to address this need. For example, the C-Life Innovation project aims at stimulating co-innovation in the area of climate adaptation and mitigation, and involving both services providers and major companies in telecommunication networks and energy.

Some respondents mention the role of new regulatory frameworks in stimulating the emergence of climate services. This request may be partly driven by the recent implementation of adaptation in France. Indeed, from 2011 to 2015, the French National Adaptation Plan was accompanied by specific measures leading to integrate climate change adaptation and mitigation in land use planning and risk regulation (ONERC, 2011; Bériot and Jouzel, 2011). Two examples are: (1) the regional climate, air and energy plans, which include a regional vulnerability assessment intended to support the regional to local land use planning; (2) the coastal risks prevention plans, which consider a standard uniform sea-level rise scenario of 0.6 m by 2100 to avoid further urbanization in the most exposed areas to coastal hazards. In the first case, users face difficulties in applying the regulation and writing call for tenders, because no guidelines are provided to identify the needs to be fulfilled in priority and the methods to be applied to assess vulnerability to climate change. Conversely, methodological documents were made available by the state to evaluate present and future coastal flooding risks, so that the difficulties are essentially related to the availability of data and the choice of appropriate modeling frameworks, which coastal managers are used to deal with. In 2015, the French adaptation plan was evaluated (Caude et al., 2015), and has now engaged in a process of renewal, which offers an opportunity to further mainstream climate change adaptation and mitigation in the current regulatory framework and economic environment.

3.3. Lessons learnt from the 8 sector case studies

The review of the 8 sector case studies has identified that climate services have the highest potential to emerge in the sector of flooding risks (Table 2). However, even in this case, the interviewees considered that the offer of climate services is currently not provided at the relevant spatial scale. For example, the sea-level change reports at national scale are useful for justifying mitigation of climate change, but at the same time, the needs for local information regarding future flooding risks are hardly met due to the lack of data and funding to site specific studies.

Other sectors with a potential to emerge include the energy and agriculture. Surprisingly, the survey indicates little concerns in the transport sector on the topic of adaptation. However, many transport infrastructures (railways, roads, cycling paths…) have been revealed vulnerable to flooding events such as the spring 2016 event in the center of France. Interestingly, such events have been shown related to climate change (Van Oldenborgh et al., 2016).

The 8 sectorial case studies further support the previous statements of Section 3.1. In addition, it allowed identifying additional opportunities and constraints (Table 3), reminding again the difficulties related to timescales and uncertainties of climate products. Uncertainties are reported especially difficult to manage in the flooding risk, agriculture, viticulture and energy sectors, and when they are hardly quantified: for example, an expert in a research institute on agriculture reported that "the impact of climate change on insects remains still ill-known". While some approaches exist to deal with hardly quantified uncertainties in a consistent way across climate models, impact studies and user's workflows (e.g., Haasnoot et al., 2013), our survey highlights the need for new case studies specifically addressing this issue. Finally, the recognition that uncertainties are prominent in many areas of climate change impacts weakens, to some extent, the confidence in some statements in Table 2: for example, the low impacts of climate change to the nuclear industry is conditional to moderate changes in river water flow and sea-level rise. However, for such critical infrastructures, relying only on the likely range of climate change projections may not be sufficient to meet the required security standards (e.g., Hinkel et al., 2015).

4. Discussion and conclusion: Critical conditions for the uptake in climate services

The FCSA has allowed identify current opportunities and barriers (Table 3) in the current climate services development in France.

Table 3
summary of opportunities and constraints in the ecosystem of climate services in France identified in this study.

Opportunities	Constraints
Strong scientific basis in support to the potential development of climate services	Difficulty in integrating the available climate information in the existing practices and workflows
Economic benefits are recognized by the private sector, mainly in the domain of saving costs	Different timeframes for climate impacts and for planning investment and return on investment cycles
Observed benefits of integrating climate change requirements in call for tenders and the regulations	Difficulties in translating climate change impacts in economic terms within both organizations and individuals
The challenge is increasingly being recognized important by businesses, citizens and governments (Paris agreement)	Difficulties in understanding current climate information and their uncertainties

It has shown that while the market is still in its infancy, significant opportunities exist, in particular in the sectors of water resources and risks, and, to a lesser extent, hydro and nuclear energy and viticulture. The study faced difficulties in collecting reliable quantitative data on the current and future development of climate services. However, its qualitative conclusions are useful in France and for many other countries that are currently investing in the development of climate services. Following the FCSA, the following recommendations are proposed for the future development of climate services in France:

- **To coordinate the work on climate services across the various organizations concerned by climate change adaptation**, in order to deliver consistent and complementary services, such as data, information, expertise, education and training. In this field, two models are proposed in the literature: (1) a unique organization responsible for operating climate services; (2) a network of organization collaborating on the topic of climate services. Brasseur and Gallardo (2016) argue that the first choice is a condition for the success of climate service. Indeed, the cases of Germany and Canada, which both have established climate service centers like Gerics or Ouranos, suggest that the emergence of climate services is favored by the existence of a single organization where all the necessary expertise on climate services is gathered. Conversely, in France, climate services are presently delivered by a complex and diverse network of providers, mainly in the field of environmental research (Table 1),

Table 2
synthesis of the sectorial analysis in France according to the interviews and the complementary analysis: a qualitative ranking (5 classes from very low to very high) has been assigned to each criterion.

Economic sector	Economic sub-sector	Expected impacts of climate change	Present days use of climate services	Ability of the sector to provide its own climate services	Interest for free climate services	Interest for chargeable climate services	Perspectives of expansion	Synthesis: current perspectives of climate services development	Synthesis: perspectives of climate services development over the coming decades
Agriculture	Viticulture	High	Low	High	Medium	Low	Medium	Low	Medium
	Forestry	High	Low	High	Low	Very low	Low	Low	Low
Energy	Hydro-energy	Low	High	Low	Medium	Low	High	Low	Medium
	Nuclear energy	Low	High	Low	Medium	Low	High	Low	Medium
	Renewable energy	Medium	Medium	Low	Low	Low	Low	Low	Low
Risks	Flooding risks	High	High	Medium	High	Medium	High	Medium	High
Transport	Air transport	Low	Low	High	Low	Very low	Very low	Low	Low
	Road transport	Low	Low	High	Low	Very low	Very low	Low	Low

and the interactions between users and providers occurs within expert groups operating at different scales, from regional to national. In such a context, a high degree of cooperation is required, so that this first recommendation appears especially important to consider.

- **Making existing climate services more relevant for users:** at present, research is the essential mission of most existing climate services providers in France. Indeed, as highlighted by many authors (Hewitt et al., 2012; Vaughan et al., 2016), observations and multidisciplinary research is needed to support the development of climate services. For example, research in the area of uncertainties characterization, propagation and communication appears as a priority, being one of the barriers to the uptake of climate services in our survey (Table 3) as well as in other studies (e.g., Otto et al., 2016). At the same time, however, users are already requesting operational products that could help them to adapt. Demonstrators of climate services applied to specific sectors or territories are needed to bridge this gap between research and applications.
- **Developing common climate services portals**, building on the existing ones, so that potential users are supported in their efforts to integrate climate data in their practices. Here, research in the field of geographic information management is needed to ensure that the different types of databases (climate, soils, impacts...) can communicate and be used in distributed systems of systems.
- **Continuing the integration of adaptation in the regulation and in public and private tenders** so that private actors can take ownership of the challenge of climate adaptation, and translate their investments in this field by an improved offer and competitiveness when responding to such tenders.
- **Certification of climate services,** so that the translation form research to operation keeps the high level of quality required to manipulate climate data and information.
- **Support education and training:** whatever the economic sector and organization considered, the interviews revealed a need for expertise in the area of adaptation, combining a detailed understanding of climate change and of the economic sector considered. University and master student education are essential to create the community of professionals who will supply and offer climate services on adaptation over the coming decade. This challenge is one of the priorities of most organizations of Table 1 involved in education, as well as of other actors such as the KIC-Climate. At the same time, there is a need to provide fundamental knowledge on climate change adaptation and mitigation to professionals, especially lawyers, investors, financial officers and managers currently shaping the economic, normative and regulatory environment. Hence, our study recommends coordinating the professional training across the public organizations involved in environmental research, so that contract officers in regional or state organizations in charge of contracting adaptation projects have the requested expertise to define priorities and needs. This dual approach toward education and training appears essential given the urgency to conduct an energy transition compatible with the Paris Agreement targets.
- **Provide a clear roadmap toward mitigation:** despite the Paris Agreement, the current commitments of the various countries presently do not guaranty that the greenhouse gas concentrations in the atmosphere will be sufficiently reduced to meet the 2 °C objective. However, adapting to a 2 °C world is very different from adapting to a 4 or 6° world, and additional benefits are expected if global warming can be maintained below the 1.5 °C threshold (Lissner and Fischer, 2016). We suggest that climate change services for adaptation will emerge more rapidly if public and private beneficiaries know better to what they should adapt. This implies that the new dynamics created by the Paris agreement progressively moves toward real reductions of greenhouse gas emissions and concrete perspectives to achieve negative greenhouse gas emissions over the mid-21st century.

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