



**HAL**  
open science

# Towards the development of climate adaptation knowledge-action systems in the European Union: An institutional approach to climate service analysis

Anastasia Panenko, Emmanuelle George, Céline Lutoff

## ► To cite this version:

Anastasia Panenko, Emmanuelle George, Céline Lutoff. Towards the development of climate adaptation knowledge-action systems in the European Union: An institutional approach to climate service analysis. *Climate services*, 2021, 24, pp.100265. 10.1016/j.cliser.2021.100265 . hal-03432368

**HAL Id: hal-03432368**

**<https://hal.science/hal-03432368v1>**

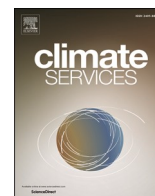
Submitted on 3 Aug 2023

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial - NoDerivatives 4.0 International License



## Perspective

# Towards the development of climate adaptation knowledge-action systems in the European Union: An institutional approach to climate service analysis



Anastasia Panenko<sup>a,\*</sup>, Emmanuelle George<sup>b</sup>, Céline Lutoff<sup>c</sup>

<sup>a</sup> Univ. Grenoble Alpes, PACTE, INRAE, LESSEM, 38000 Grenoble, France

<sup>b</sup> Univ. Grenoble Alpes, INRAE, LESSEM, 38000 Grenoble, France

<sup>c</sup> Univ. Grenoble Alpes, PACTE, 38000 Grenoble, France

## ARTICLE INFO

## Keywords

Climate services  
Adaptation  
Adaptation services  
Adaptation governance

## ABSTRACT

Six years have passed since the European Commission published its Roadmap for Climate Services (2015). Nowadays, this domain is characterized by a complex constellation of different products, services, and actors. Indeed, the definitions of climate services adopted by the WMO and the European Union are very vague, leading to possible mismatches between users' expectations and producers' offers in terms of services. Consequently, several authors and institutions have adopted different terminologies. For example, Weichselgartner and Arheimer (2019) argue for "climate adaptation products, climate adaptation services and climate adaptation knowledge-action systems". Therefore, this article will pursue two goals: first, we will apply new terminologies to climate services across the European Union; secondly, we will investigate the possible correlation between the degree of decentralisation, the policymaking traditions (statist or corporatist), and the emergence of climate adaptation knowledge-action systems in selected countries (EU 27). From our analysis we conclude that climate change adaptation knowledge action systems were most developed in corporatist and/or decentralized countries such as Austria, Denmark, Germany, Ireland, Netherlands, and Spain. At the same time, statist and centralized countries show different degrees of integration of climate products and services in their adaptation governance: some developed adaptation services (France), for others no product or service was found (Greece). We believe that better use of terminology (e.g., product vs service) is an important step for the development of climate services and a sign of increasing maturity in the field.

## Introduction

The impacts of climate change are increasingly visible over the whole planet: from increasing/decreasing precipitations or their intensity to rising sea levels and melting glaciers. Although in certain cases these effects are less evident on local scales, the overall trend of global warming is impacting every society on Earth. As pointed out by the [European Environment Agency \(2019\)](#), in the last decade the European land temperature has increased by 1.7–1.9 °C compared to the pre-industrial era, leading to various impacts across Member States (the global average is 0.9–1 °C). According to the Green Paper on Adaptation, several areas in the EU will be affected by climate change ([European Commission, 2007](#)). For example, Mediterranean and mountainous regions recorded a higher temperature rise and/or subsequent decrease in

annual precipitations and river flows, a decrease in glacier volumes and permafrost areas, and a risk of biodiversity loss and species extinction ([EEA, 2016](#)). In addition, many economic sectors which strongly depend on climatic conditions, such as agriculture, fisheries, or tourism are affected. To face these challenges, the European Union has been formulating mitigation and adaptation measures while encouraging Member States to act.

Until recently, adaptation to climate change was perceived as something that could undermine mitigation efforts. As [Biesbroek et al. \(2010\)](#) pointed out, adaptation appeared on policy agendas as the impacts of climate change were increasingly observed across different scales. Adaptation was defined by Adger et al. as a "continuous stream of activities, actions, decisions and attitudes that inform decisions about all aspects of life, and that reflect existing social norms and processes"

\* Corresponding author.

E-mail address: [anastasia.panenko@umrpacte.fr](mailto:anastasia.panenko@umrpacte.fr) (A. Panenko).

<https://doi.org/10.1016/j.cliser.2021.100265>

Received 23 March 2021; Received in revised form 21 July 2021; Accepted 12 November 2021

Available online 16 November 2021

2405-8807/© 2021 The Authors.

Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license

(<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

(2005:78). It is in this perspective that climate services appear as an emerging topic in the area of climate change adaptation. Nonetheless, these tools can be largely deployed for both mitigation and adaptation in different sectors of our economies - from agriculture to insurance, energy, or tourism (as illustrated in Table 1). Moreover, Swart and Raes (2007) argued that both strategies should be considered as complementary.

Climate Services - based on historical data and climate modelling - offer estimates/predictions on future weather conditions on different scales and for different weather variables. The WMO defines them as “a decision aid derived from climate information that assists individuals and organizations in society to make improved ex-ante decision-making” (2013:7), while the EU considers them as a process “transforming climate-related data and other information into customized products such as projections, trends, economic analyses, advice on best practices, the development and evaluation of solutions, and any other climate-related services liable to benefit that may be of use for society” (2015:10). In practice, there is no common blueprint for climate services, as they vary from the provision of mapping tools to capacity building activities such as workshops. Moreover, they can be provided by NGOs, research entities or consultancy companies, focused on specific sectors and spatial scales, and provided free of charge or not. This complex constellation of different products, services and actors makes any comparison or evaluation quite challenging. Such broad definitions<sup>1</sup>, coupled with a growing literature on the limits and lack of connection with end-users, has pushed several authors to formulate their own distinctive types of climate services. For example, Goosen et al. (2014) and the German Climate Preparedness Portal KLiVO<sup>2</sup> put forward the concept of *adaptation services* to highlight the importance of decision-support practices associated with climate information use. Weichselgartner and Arheimer (2019) proposed three different types of climate services: climate adaptation products, climate adaptation

**Table 1**  
Where are climate services used?

Sector/Industry	Applications
Water	Pricing and allocation, storage and conservation decisions. Eg.: <a href="#">SMHI Aqua</a>
Agriculture	Crop management; irrigation decisions; product marketing; herd management; input use (fertilizers). e.g., <a href="#">Climate Change Impact on Cotton (CCIC)</a>
Disasters	Preparedness; early warning systems. e.g., <a href="#">National Flood information portal (Ireland)</a>
Health	Endemic transmissions; disease surveillance. e.g., <a href="#">Climatic suitability for the presence and seasonal activity of the Aedes albopictus mosquito for Europe derived from climate projections</a>
Energy	Planning the purchase of gas and electricity; managing responses in emergency situations; grid/distribution management; optimization of reservoir/hydropower operations. e.g., <a href="#">Project Ukko: seasonal wind predictions for the energy sector</a>
Infrastructure	Site location, facility design; emergency preparedness; in all domains of urban planning, e.g., <a href="#">Urban climate service centre</a>
Transport	Fuel purchasing; snow preparation/removal; accident reduction. e.g., <a href="#">Met Office Rail Weather and Climate Services</a>
Finance	Insurance and derivatives. e.g., <a href="#">Axa insurance</a>
Tourism	Forecasts for aviation and transportation; revenue forecasting, seasonal occupancy forecasts. e.g., <a href="#">Prosnow: prediction system for snowmaking in Alpine resorts</a>
Fisheries/ Forestry	Harvest management; resource management. e.g., <a href="#">European Forest Fire Information System</a>

Source: compiled from USAID (2013), John A. Dutton (2002) Daniel J. Scott et al (2011), Jorg Cortekar et al (2016), Catherine Vaughan et al (2016) and WMO.

**Table 2**  
Different types of climate services.

Type	Definition
Climate Change Adaptation Products (CCAP)	“data, tools to support decision-making for adaptation, including efforts to identify information needs”.
Climate Change Adaptation Services (CCAS)	“activities, consultations and other forms of interaction that enable decision-makers to make better use of CCAP. <b>CCAS are not only products, but also the mechanisms for interaction and knowledge exchange between producers, users and providers</b> ”.
Climate change adaptation systems (CCAKAS)	“networks of individuals, organisations, coordinating bodies, and institutional and communication structures that cooperatively design, produce, provide and use CCAP and CCAS”.

Source: Weichselgartner and Arheimer (2019).

services and climate adaptation knowledge-action systems (Table 2). This article is an attempt to apply these new typologies of climate services to several climate service producers across the EU. The aim of this article is to shed light on conditions for the development of climate adaptation services and systems.

The first section of this article will provide a literature review on climate services and introduce new terminologies. Secondly, we will discuss multi-level and polycentric governance, as it is particularly interesting to investigate how climate services have evolved in different institutional settings of selected EU Member States<sup>3</sup>. Multi-level governance is defined by Carina H. Keskitalo as “a decision-making process steered by multiple actors across multiple geographic levels and sectors” (Carina H. Keskitalo ed., 2010:4), whereas polycentricity refers to a complex form of governance with multiple centres of decision-making nested in multiple overlapping jurisdictional levels (Ostrom, 2009; Carlisle and Gruby, 2019). Therefore, in the second part of this study we will ask: 1) whether country specific institutional features, such as the degree of decentralisation, have influenced the implementation of adaptation strategies on sub-national levels; and 2) whether policy-making traditions have influenced the establishment of adaptation knowledge-action systems. We assume that the institutional context can determine the degree of integration of climate services in adaptation governance structures. To discuss this correlation, we will focus on EU countries and provide a panorama of climate services according to the three types formulated by Weichselgartner and Arheimer (2019).

## Climate services as part of adaptation governance

### Brief overview of the emergence of climate services

The emergence of climate services is linked to the development of international cooperation in the areas of the weather and climate, and marked by the creation of international organizations. This process started at the beginning of the 19th century with the founding of the WMO in 1950, in view to sharing climate-related information across borders (Vaughan and Dessai, 2014). As climate science and cooperation progressed, new institutions for international cooperation were established: more specifically, the IPCC, UNFCCC and, finally, the GFCS (in 1988, 1992 and 2009 respectively)<sup>4</sup>. In 2015 the European Commission published its “Roadmap for Climate Services” to guide the development of the sector and reinforce Europe’s resilience to climate change. In the official EU discourse, the development of climate services is aimed at

<sup>3</sup> Austria, Belgium, Bulgaria, Croatia, Czech Republic, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden.

<sup>4</sup> IPCC - Intergovernmental Panel on Climate Change; UNFCCC - United Nations Framework Convention on Climate Change; GFCS - Global Framework on Climate Services.

<sup>1</sup> Definitions proposed by WMO and European Commission

<sup>2</sup> <https://www.klivportal.de/EN/>

enabling market growth (European Commission, 2015; R. Street, 2016). The EU takes the perspective of services, as stated from the outset in the foreword: “Climate services have the potential of becoming a supportive and flourishing market, where public and private operators provide a range of services and products that can better inform decision makers at all levels, from public administrations to business operators, when taking decisions for which the implications of a changing climate are an issue”. Climate Services, through the delivery and application of improved forecasting capabilities, can enable evidence-based decision-making in several sectors and across different scales (please see Table 1 for more examples). For example, climate services developed by the Ukko project offer seasonal wind prediction for the energy sector. The Clara project has been developing services for energy (solar and hydropower), disaster risk reduction, water management and agriculture. Climate services, such as the EuroHEAT project, can foster the protection of human health from the vagaries of climate variability and change such as heatwaves. Prosnow offers real-time optimization of snow management for mountain ski resorts through weather and seasonal forecasting and snow cover modeling. According to John A. Dutton (2002), USAID (2013) and the European Commission (2015), climate services can contribute to adaptation and mitigation efforts in several sectors, as illustrated in Table 1.

However, R. Street<sup>5</sup> (2016)<sup>5</sup> underlined that the “potential market is largely untapped” (2016:3). According to him, demand is relatively fragmented and the available services are primarily supply driven. Indeed, as demonstrated by Sarewitz and Pielke (2007), these services will follow the logic of supply and demand and thus could suffer from a mismatch between what is being produced and what is being demanded. The use of information will depend on its relevance, the consistency between research and policy agendas, institutional constraints, etc. (Sarewitz and Pielke, 2007). Merely producing knowledge on a specific topic does not indicate whether this information is being used; also, “more information does not mean better decisions” (Sarewitz and Pielke, 2007). According to them, “the potential for science to contribute to societal goals depends critically on factors well beyond science” and that “better science portfolios would be achieved if they reflected an understanding of supply, demand and the complex dynamic relationship between them” (2007:6). Dilling and Lemos (2011) argued for better iterability and “purposeful and strategic interaction between climate knowledge producers and users so as to increase knowledge usability” (2001:681). When defining iterability, Sarkki et al (2015) stressed the need to “go beyond simple repetition” in order to “foster constructive relationships and knowledge itself” (2015:507). Policymaking is a dynamic process that requires feedback and adjustments. Thus, there is a need for a constant twofold connection and the exchange of feedback between all the stakeholders involved in the creation of climate services and their use. In other words, there is a need for the “next generation of climate services”, nested within the interfaces of science-to-service-to-practice, capable of improving connections between users and producers (Jacobs and Street, 2020), and delivering salient, credible, and legitimate information.

Scholars of science-policy interaction have built several frameworks to assess the efficiency of research in informing policy and decision making. These frameworks have also been applied to climate services (Reinecke, 2015). For example, the CRELE framework aims at assessing the Credibility, RElevance (or salience), and LEgitimacy of information (Sarkki et al., 2015; Reinecke, 2015). Credibility refers to whether the knowledge and its production are perceived as valid and adequate (trust in science and scientists). The information will be relevant if it answers the needs of society (when the demand for science matches its supply, as in Sarewitz and Pielke, 2007 and in McNie, 2007). Legitimacy is the fairness of knowledge and policy production – whether unbiased or not

(Sarkki et al., 2015; McNie, 2007; Cash et al., 2003; Reinecke, 2015). Later, Dunn and Laing (2017) pointed out that most CRELE studies focused on the scientific side of the science-policy interface, without evaluating these concepts with decision-makers (often absent from study groups). Following their study with decision makers in Australia, Dunn and Laing (2017) built a different framework – ACTA, or the Applicability, Completeness, Timing and Accessibility of information. They concluded that these criteria better summarize the most important aspects of scientific research when it comes to influencing decision-making“ (Dunn and Laing, 2017). Schuck-Zöller S. et al. (2016) from GERICS<sup>6,7</sup> have developed a specific framework for assessing climate services and co-produced services<sup>7</sup>. It studies criteria for products / services such as availability, visibility, quality, relevance; and results such as use, satisfaction, dissemination, user learning effects and their evaluation. However, so far, most of the literature on climate services had focused on a given product developed for a particular sector, with specific actors. In addition, these case studies described a wide variety of climate services at different scales (spatial, administrative, and temporal), with different interactions between stakeholders. Indeed, the term “climate service” itself has a very broad definition, which can lead to misconceptions: climate data, customized products, services, the development of solutions. Hence, the need to refine the terminology used.

#### *Different types of climate services*

Adaptation tools and actions are not isolated from the context and must take into account (or be part of) demographic, cultural and economic changes (Adger et al., 2005). At the same time, decision making for adaptation requires an integrated cross-sectoral approach, capable of capturing the complexity of decision processes, greatly affected by environmental and social contexts (Celliers et al., 2021). Despite several advances in climate science, local institutions still lack robust knowledge on impacts on their territories. This is not due to lack of information on climate change and its impacts per se; often this information is not directly exploitable at regional/local levels where most adaptation activities occur (Ford et al., 2011; Räsänen et al., 2017). Krauss and von Storch (2012) pointed out that “there are significant disturbances in communication between climate change science and the public” (2012:213). The authors argue that the increasing amount of information on the climate does not include the experiences and perceptions of people. According to them, the linear model of the science-society relationship is still dominant in climate science. Cognitive institutional or individual gaps in science and decision-making represent an obstacle for successful adaptation. For example, Porter and Dessai (2017) concluded that often climate scientists do not have the capacity to listen and respond to users’ needs; Celliers et al. (2021) highlighted the presence of individual-level barriers, such as lack of understanding of climate change and adaptation solutions. Furthermore, the usability of climate services can be negatively influenced by a set of constraints linked to the context or intrinsic features of climate information. Constraints can be rooted in **formal and informal institutional obstacles** related to regulations, or to the mismatch between climate change and electoral cycles (Dilling and Lemos, 2011; Celliers et al., 2021). Several labels are used to portray this lack of connections between scientists and policy-makers, such as the science-policy gap (Choi et al., 2016), or the

<sup>6</sup> GERICS is scientific organizational entity of Helmholtz-Zentrum Geesthacht – Zentrum für Material- und Küstenforschung GmbH

<sup>7</sup> Schuck-Zöller S et al. (2016), *Towards a framework for the evaluation of climate service and knowledge transfer products within climate and coastal research*, [Online poster], Available from <https://www.gerics.de/methods/evaluation/index.php.en>, [https://www.researchgate.net/publication/328956686\\_Towards\\_a\\_framework\\_for\\_the\\_evaluation\\_of\\_climate\\_service\\_and\\_knowledge\\_transfer\\_products\\_within\\_climate\\_and\\_coastal\\_research](https://www.researchgate.net/publication/328956686_Towards_a_framework_for_the_evaluation_of_climate_service_and_knowledge_transfer_products_within_climate_and_coastal_research)

<sup>5</sup> R. Street is part of the *ad hoc* Expert Group which elaborated the EU’s « Roadmap for climate services » in 2015.

valley of death (Buontempo et al., 2014). On the other hand, multiple strategies exist to establish these connections and narrow the science-policy divide. Many case-studies have highlighted the importance of knowledge brokers and boundary organisations as means of improving both CRELE and iterability (Kirchhoff et al., 2015). The role of cross-scale interactions for multi-interest problems is discussed in Cash et al. (2003), where the authors highlighted the need for the co-production of knowledge through boundary organizations or the use of adaptive co-management. According to them, since boundary organizations act as bridges between different scales, they can encourage the co-production of credible, relevant, and legitimate knowledge. Likewise, Goosen et al. (2014) proposed a definition of climate **adaptation service (CAS)**: “an information service supporting the assessment of vulnerability in a **wider perspective** and including the design and appraisal of adaptation strategies in a **multi-stakeholder setting**” (2014:1035). Moreover, the German Climate Preparedness Portal KLIVO, defines adaptation services as “guidelines, web tools and maps, and the provision of specialist training, while climate change adaptation services offer assistance in choosing, planning, and implementing appropriate measures and evaluating their effectiveness”. From this perspective, the terminology suggested by Weichselgartner and Arheimer (2019) is particularly interesting for describing different forms of institutionalisation of climate services.

What distinguishes CCAS (and CAS) from CCAP are the notions of “multi-stakeholder setting”, “interacting”, “knowledge exchange mechanism” and “assistance”. Therefore, it is safe to assume that to be considered an adaptation service, a given CCAP needs to provide more than just data and tools, but be built with end-users to allow them to appropriate, monitor and evaluate them (e.g., iterability). Therefore, we imply that CCAS will have several of the features of boundary organizations described in Cash et al. (2003): 1) accountability on both sides of the boundary; 2) the use of co-produced maps, reports; 3) cross-boundary participation; 4) conveying, translation, mediation, coordination, and synergetic expertise. Interestingly, the concept of CCAKAS can be interpreted from the perspective of polycentric governance systems. According to Ostrom (2009), polycentric governance systems are composed of overlapping decision-making units and include specific arrangements/special-purpose units that work across multiple jurisdictional levels to ensure sufficient coordination. Polycentricity is associated with better links to local knowledge, improved information transmission, and enhanced adaptive-management capacity (Marshall, 2009). According to Weichselgartner and Arheimer (2019), the value of climate services for decision-making increases from CCAP to CCAS. This plus-value of CCAS is nested in behavioural theory which assumes that “while individuals do not possess perfect information, they are capable of learning more accurate information as they interact in a particular setting” (Ostrom, 2009:11). Moreover, this added-value of CCAS is directly linked to boundary spanning arrangements and activities.

From another perspective, the development of CCAKAS is associated with the notion of multi-level governance. According to the European Commission, “one of the greatest challenges for cost-effective adaptation measures is to achieve **coordination and coherence at the various levels of planning and management**” (COM (2013):5) 216 final). From this perspective, CCAKAS will be characterised by joint efforts to coordinate adaptation policy, actions and actors through vertical and horizontal mainstreaming. Tracing the development of CCAKAS in European Member States represents a useful exercise from many perspectives: more than providing a state-of-the-art on climate services in the Union, this article also aims at identifying potential institutional levers and barriers for their implementation.

**Table 3**  
Definitions of multi-level governance.

Definition	Authors
The <b>polycentric structure</b> spans from global to national and sub-national levels, relying on both <b>formal and informal networks and policy channels</b> , where state and non-state actors are involved in formulating and implementing climate policies and actions.	Di Gregorio et al. (2019:64)
The multi-level system of governance combines sufficiently decentralized adaptive governance for local initiatives to grow, but also <b>fostering networks and the diffusion of best practices and enhancing collective action across scales</b> .	Underdal (2010)
Multi-level governance tends to refer to systems of governance where there is a <b>dispersion of authority upwards, downwards and sideways between levels of government</b> – local, regional, national and supra-national – as well as across spheres and sectors, including states, markets and civil society.	Daniell and Kay (2017)

#### *Multi-level governance of adaptation to climate change*

There are several ways to define multi-level governance (Table 3)<sup>8</sup>. For this study, the definition by Di Gregorio et al. (2019) is the most appropriate, as it represents a perfect match with the notions of CCAKAS networking and coordination (Table 2).

Furthermore, Corfee-Morlot et al. (2009), underlined 2 dimensions of multi-level governance: 1) a vertical dimension or a “two-way relationship between local and national action on climate change”, where the local scale functions within legal and institutional frameworks implemented at higher scales (useful for understanding adaptation across scales); 2) a horizontal dimension, or “a relationship based on formal and informal networks and coalitions, where actors operate across organisational boundaries” (as in polycentric governance systems). Therefore, we can consider that the passage from CCAS to CCAKAS will consist in establishing coordination bodies and mechanisms across scales between different CCAS and other relevant stakeholders (Plummer and Baird, 2013; Fennell et al., 2008). CCAKAS have the highest value for decision makers because network governance fosters social capital among actors and offers solutions for problems such as climate change (Borzel, 1998; Koppenjan and Klijn, 2004). What is more, as Imperial (1999) pointed out, polycentric governance systems can achieve a balance between centralized and fully decentralized governance.

From a vertical perspective, the EU’s Green and White Papers for adaptation recognize the importance of different territorial levels and the interplay between them (COM (2009) 147/4; COM (2013):5) 216 final). Indeed, for each level the EU assigns its own role as illustrated in the Table 4.

In the light of the above, we expect European and national institutions to ensure vertical integration, and national and sub-national knowledge brokers and networks to promote the horizontal dimension. For example, the EU’s Climate-ADAPT platform aims at facilitating the collection, sharing and use of information; at encouraging the effective uptake of the relevant knowledge by decision-makers; and at contributing to a greater level of coordination between sectors and institutional levels (EEA, 2016). However, approaches to vertical and horizontal integration will differ between countries and reflect their intrinsic features, such as degrees of decentralisation or policy-making traditions. We assume that the development of CCAKAS will be impacted by these characteristics, an aspect discussed in the next section.

<sup>8</sup> See Paul Stephenson (2013) for a literature review on multi-level governance

**Table 4**  
Multi-level governance of the adaptation and distribution of roles according to the EU.

Scale	Role
EU level	Coordinating role for impacts that transcend national boundaries (e.g., river basins), or for sectors that are integrated through the single market and common legislation (e.g., agriculture, fisheries, etc.); providing funding for disadvantaged States and regions (Life + program, Cohesion Funds, etc.); coordinating research and innovation (Horizon 2020).
National level	Developing adaptation strategies and improving disaster crisis management.
Regional level	Including adaptation in spatial planning to raise the awareness of citizens and decision-makers (e.g., development of specific technical guidance or “good practices” and exchange of information).
Local level	Since a large number of climate-related decisions are taken on local levels, local authorities have an important role to play (SEC (2007) 849). In addition, the Green Paper highlighted that the local level “is where detailed knowledge on natural and human conditions is available” (2007:11).

Source: European Commission, COM (2009) 147/4; COM (2013:5) 216 final.

### Research methodology

Our research question can be formulated as follows:

#### Can a given country’s degree of decentralisation and/or policy-making process influence the development of so-called “climate change adaptation systems”?

To answer this question several steps were taken. There are multiple ways to classify European Member States: they can be centralized or decentralised, statist or corporatist, federal or unitary (Carina H. Keskitalo, 2010). We will focus on the distribution of resources and responsibilities, thus on the governmental system and the level of decentralisation in each country. To this end, we will use Ljiphart’s (2012) federal-unitary axis which includes the level of decentralisation as follows:

- **Federal and decentralized:** Austria, Belgium, Germany.
- **Semi-Federal:** Netherlands, Spain.
- **Unitary and decentralized:** Sweden, Finland, Denmark, Italy (to a certain extent).
- **Unitary and centralized:** Bulgaria, Croatia, Czech Republic, Cyprus, France, Greece, Estonia, Hungary, Ireland, Latvia, Lithuania, Luxembourg, Malta, Romania, Poland, Portugal, Slovenia, Slovakia.

Firstly, to shed light on how governmental systems have influenced the development of adaptation policies on sub-national levels, we analysed the timing of implementation of European and national adaptation strategies and plans. We were interested in identifying early birds, and in highlighting the importance of European funding mechanisms for the development of adaptation strategies in Central and Eastern European countries. Secondly, a systematic review of sub-national adaptation strategies was conducted to assess the correlation between the degree of decentralisation and the timing of implementation of sub-national adaptation policy. We will employ the term “sub-national” and we will not make distinction between NUTS 1, NUTS 2 and NUTS 3 levels (Nomenclature of territorial units for statistics)<sup>9</sup>. Selected countries have different national administrative units and different legal obligations applies to them: in federal states such as Germany or Belgium, adaptation strategies and plans concern the NUTS1; In France or Netherlands it is the NUTS2 (Région and Province respectively); in

Sweden it is the NUTS3 (län or county). To build our database, we used the EUR-Lex portal as a source for the EU’s adaptation strategies and communications, while information on national adaptation strategies and plans was obtained from the Europe-ADAPT platform. Missing or outdated data were completed by using information available on national adaptation portals and by extended research on the web. This data was organized and compiled in a table found in Appendix A.

However, from the angle of polycentric governance, the statist/corporatist dichotomy (or policy making process) also appears relevant. Corporatist traditions are characterized by the collective policy-making process and collaborative bargaining of the main societal actors (S. Oshitani, 2006). On the contrary, statist countries grant societal actors little access to, or influence in, policy building. Given the definition of multi-level governance by Di Gregorio et al. (2019), we can expect corporatist countries to be one step ahead in developing CCAKAS. Although it is not always possible to define a clear contrast, as some countries like Italy have features of both categories, we classify EU Member States as in Schmidt (2006) in Magone (2014) and in Roza et al. (2019):

- **Statist:** Bulgaria, Croatia, Cyprus, Czech Republic, France, Greece, Estonia, Hungary, Latvia, Lithuania, Poland, Slovenia, Slovakia, Romania.
- **Corporatist:** Austria, Belgium, Germany, Finland, Denmark, Italy, Ireland, Luxembourg, Malta, Netherlands, Sweden, Portugal.

The last step consisted of the analysis of national forms of climate services. In order to classify national climate services, we followed the definitions formulated by Weichselgartner and Arheimer (2019) and used inputs from multi-level governance theories. We did not consider private providers as we are interested in the public and non-profit sector only. In line with Samuelson (1954), we consider that spontaneous market initiatives would not provide an optimal level of collective consumption goods. According to Stern, “market forces alone are unlikely to lead to efficient adaptation because of a certain degree of uncertainty in climate projections and a lack of financial resources” (Stern, 2014). This does not undermine the value of numerous for-profit climate products that have emerged in recent years<sup>10</sup>, but at this stage we consider climate change adaptation as a matter of collective action. The data collected was organized as in Table 6 and Appendix 1, and discussed in section 3.

#### Climate change adaptation knowledge-action systems in the EU

Prior to discussing adaptation knowledge-action systems in selected countries, this section will provide an overview of adaptation strategies on both the EU and national levels. Most EU countries have legislation aimed at protecting citizens from the current and future negative effects of climate change (European Convention of Human Rights, the European Charter of Human Rights, the EU treaty, national constitutions, and ordinary legislation). There are several perspectives on why a government should engage in adaptation actions - not only for *safety* reasons, but also from the economic viewpoint. Indeed, “from the perspective of economic theories, the provision of collective goods is one of the most important reasons for the government to take the lead in climate adaptation” (flood risk prevention is a collective good par excellence, (SEC (2007) 849:2). Moreover, failure to implement policy responses will trigger reactive action, which is more expensive compared to active or proactive adaptation (EEA, 2007). According to the EEA (Report No. 12/2012), the costs of not adapting to climate change were estimated to range from EUR 100 billion a year in 2020 to EUR 250 billion a year in 2050 for the EU.

<sup>9</sup> <https://ec.europa.eu/eurostat/web/nuts/national-structures>

<sup>10</sup> A database of climate services providers can be consulted here: <https://www.climate-knowledge-hub.org/>

## Adaptation strategies in the EU

To date, four main documents are used to guide adaptation action in EU. As one can see from the table below, all of them highlight the importance of knowledge provision for better decision-making. Indeed, climate services are part of “knowledge adaptation as a tool for better resilience” (EU COM (2013) 216).

As illustrated in Fig. 1, there are significant differences between the Member States in terms of timing of the implementation of adaptation strategies and plans (NAP and NAS)<sup>11</sup>. If we compare the timing of NAP and NAS to the European Adaptation Strategy of 2013 (EUAS)<sup>12</sup>, we can distinguish 3 groups of countries:

- early birds, or those who formulated NAP and NAS before 2011,
- just in time, or those who formulated NAP and NAS between 2012 and 2013,
- post-EUAS, those who formulated NAP and NAS after 2014.

There are several explanations for early birds. For example, Finland was the first European country to publish a National Adaptation Strategy in 2005. Considered to be a pioneer in environmental policy, the Finnish government adopted the National Climate and Energy Strategy in 2001 (focus on energy issues and mitigation). Moreover, Finland’s promotion of climate research programs started in 1990, with, for example, the Finnish Research Program on Climate Change. Focusing events<sup>13</sup> such as extreme weather can act as a nudge for reactive adaptation policy-making. According to McConnell (2003), the answer to focusing events will depend on the nature of the crisis - sudden, creeping, or chronic. An example of a sudden focusing event is the European heatwave of 2003, which led to 15,000 deaths in France alone (Hémon and Jouglu, 2004). In fact, according to the first French adaptation strategy, the heatwave enabled a shift in the perception of climate and adaptation activities (ONERC, 2007, p. 17). Likewise, the Netherlands, as a low-lying country, launched a coastal management program after a disastrous flood in 1953 that claimed 1836 lives and destroyed 42,000 homes. With time, the constant “battle against water”, coupled with growing concern over rising sea levels due to climate change has led the Dutch authorities to adopt ‘a new water vision’ and formulate the first Dutch National Adaptation Strategy (Dutch Minister for the Environment, NAS 2016).

As pointed out by several authors (Adger et al., 2005; Amundsen et al., 2010), and by the European Commission itself (COM (2013):5) 216), the impacts of climate change will not respect boundaries, and as a consequence will require multi-scale coordination. Cross-boundary actions represent sine qua non mechanisms for building up coherent adaptation practices across European States. Indeed, the presence of an integrated single market, governed by common policies entitles the EU to play a crucial role in this domain. Several Central and Eastern European countries have formulated their NAS as part of European and international programs. For example: Romania took part in the World Bank Initiative<sup>14</sup>; the Croatian NAS/NAP was partially funded by the

Purchaser Central Finance and Contracting Agency for European Union Programs and Projects (SAFU); the Estonian NAP was funded by an EEA grant and driven by the Stockholm Environmental Institute (Tallinn); Bulgaria and Poland made use of the EU’s Cohesion Funds; Cyprus’ combined NAP/NAS was formulated within the CYPADAPT project, which was co-financed by the EU through the LIFE + program. Moreover, several joint adaptation projects between EU states have emerged. The Cohesion Fund co-finances many cross-border and interregional projects such as the EU macro-regional strategies in the Danube area, the Baltic Sea and the Alps (Eg.: [Interreg Alpine Space](#)). The existence of knowledge gaps was identified in the EU’s very first adaptation-related documents (Table 5). Consequently, research on climate services has been conducted within multiple research programs. For example, the EU has been investing in developing applications in the framework of the Global Earth Observation System of Systems (GEOSS), in the Copernicus Climate Change Service (C3S), in the European Climate Adaptation platform (Climate-ADAPT), and in the European Research Area for Climate Services (ERA4CS). The C3S has released an interactive tool with climate variables and indices - the European Climate Data Explorer (ECDE). The ERA4CS, among others, has mapped climate service providers - [Climate Knowledge Hub](#).

## Adaptation policies at sub-national levels

Fig. 2 depicts the timing of the implementation of sub-national strategies/plans compared to national plans (for more details, please see Appendix A). While the aim of the NASs is to introduce adaptation issues in policy agendas, the NAPs contain specific means to achieve the objectives of the NASs. Therefore, it is interesting to assess whether sub-national adaptation policies emerged before specific guidelines from national governments. Out of EU’s 27 countries, 13 have seen their sub-national levels produce adaptations plans and strategies: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Italy, Netherlands, Portugal, Slovakia, Spain, and Sweden (Fig. 2). The horizontal N-axis depicts the year of emergence of sub-national strategies and plans. It was normalised around the publication of NAPs. This enables cross-country comparison in terms of sub-national capacities to engage in adaptation actions. More specifically, the plot illustrates whether regional strategies and plans emerged prior (on the left of axis N), or after the national plan (on the right of axis N).

Although it is not possible to establish a single rule that would explain differences between these countries, we can nonetheless draw initial conclusions. As was expected, federal and corporatist states show similar patterns. In Sweden, Austria, Denmark, or Finland sub-national authorities have elaborated adaptation strategies years before national plans were published. In Belgium climate policy is subject to intergovernmental negotiation, but the regions have significant decision-making powers (Jørgensen et al., 2015). In Germany, the landers are “fully responsible for the implementation of their environmental, climate and energy policies and can put in place a variety of crucial measures including the setting of ambitious targets, the removal of planning barriers, instituting strong heating laws and facilitating ambitious research and education” (Jørgensen et al., 2015:241). France, Italy, and Portugal - unitary and centralized countries - have seen their regions adapt after the national strategy was published. However, these countries represent different degrees of centralization and sub-national fiscal autonomy, as major administrative reforms have been implemented during the last three decades. For example, in France a reform of 2015 (Law no. 2015-991) reorganized the administrative system and reduced the number of regions from 22 to 14. This law, while increasing regional responsibilities in spatial planning, made it mandatory to include climate adaptation in strategic documents such as the regional plan for land use planning, sustainable development and equality (SRADDET, or schéma régional d’aménagement, de développement durable et d’égalité des territoires). In addition, French regions obtained the authority to manage European funds only in 2014. In Italy, regional

<sup>11</sup> National Adaptation Strategies (NASs) usually address overarching issues that allow them to position adaptation on the policy agenda. National Adaptation Plans (NAPs) usually aim to implement NASs and organize activities for achieving their objectives, typically through sectoral implementation (EEA, 19/2019)

<sup>12</sup> Compared to Green and White Papers which provide frameworks, EUAS is set out in actions, which is more interesting for comparisons with NAP and NAS.

<sup>13</sup> Focusing events are defined as “sudden, relatively rare, can be reasonably defined as harmful or revealing the possibility of future harms, inflict harms or suggest potential harms that are or could be concentrated in a definable geographical area or community of interest, and that are known to policy-makers and the public virtually simultaneously” (Birkland (1998) seen in DeLeo et al. 2021).

<sup>14</sup> <https://www.worldbank.org/en/country/romania/brief/romania-climate-change-and-low-carbon-green-growth-program>

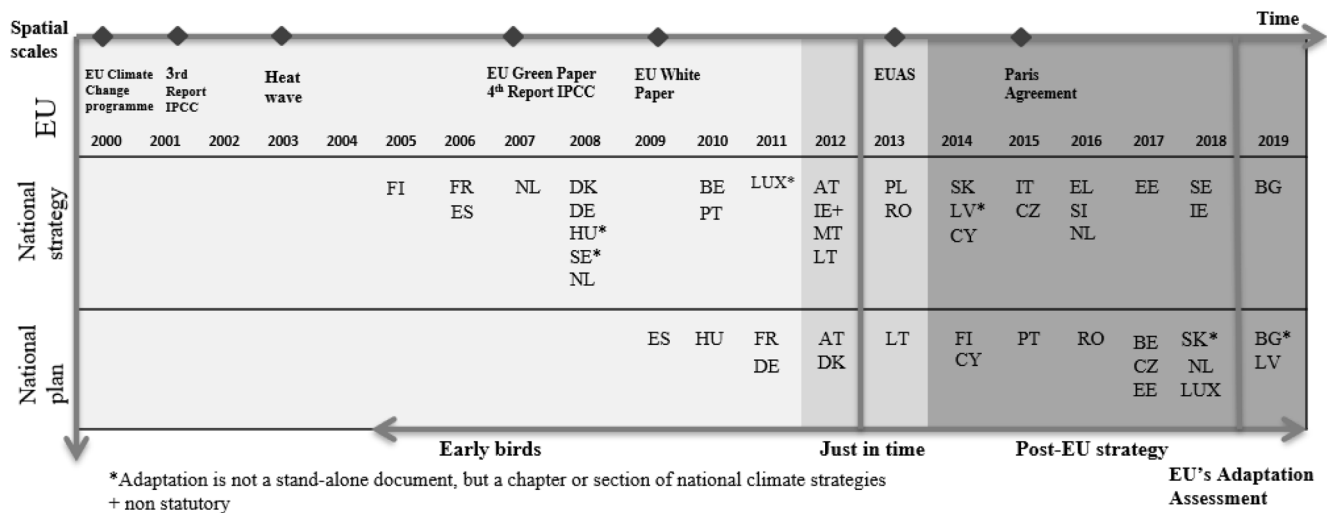


Fig. 1. State of art of Adaptation in EU and its member states. Source: The European Climate Adaptation Platform Climate-ADAPT.

Table 5  
Adaptation in the EU, a summary of communications and plans.

Document	Core ideas and aims
Green Paper (2007)	The need to support practitioners through guidance on existing scientific knowledge and adaptation measures; promote European-wide networks for the exchange and consolidation of knowledge, experience and adaptation; facilitate the transmission of knowledge from the research community to practitioners (SEC(2007)849). Modern Information and Communication Technologies (ICT) are shown to be a key instrument to support the above-mentioned processes COM (2007) 354.
White Paper (2009)	Built on consultations carried out in 2007, the white paper sets out a framework to reduce the EU’s vulnerability through: 1) building a solid knowledge base on the impact and consequences of climate change for the EU; 2) integrating adaptation into key EU policy areas; 3) employing a combination of policy instruments (market-based instruments, guidelines, public-private partnerships) to ensure the effective delivery of adaptation; and 4) stepping up international cooperation on adaptation (COM (2009) 147/4).
Adaptation Strategy (2013)	This document structures the EU’s action-plan around 3 main objectives: 1) encouraging Member States to implement adaptation strategies (funding LIFE and Covenant of Mayors); 2) promoting better informed decision-making (bridging the knowledge gap and further develop Climate-ADAPT); 3) promoting adaptation in vulnerable sectors (climate-proofing of the Common Agricultural Policy, the Cohesion Policy, and the Common Fisheries Policy, Infrastructure) (EU COM (2013) 216).
Adaptation Strategy (2021)	Stresses the “need to act NOW” and to accelerate adaptation; highlights the costs of climate change and “an increasing demand to translate the wealth of climate information available into customised, user-friendly tools” to support policy development at all levels and in all sectors (COM (2021) 82, p4).

Source: European Commission, <https://eur-lex.europa.eu>

statutory autonomy and legislative competences were enhanced by a constitutional reform in 2001. However, the central government exercises exclusive legislative power in environmental and ecosystem protection. Nonetheless, the region of Lombardy adopted an adaptation plan in 2012 and an adaptation strategy in 2015. It is noteworthy that Lombardy is the most populated region and second in terms of GDP per capita (ISTAT, 2019). Besides Lombardy, the only region to have adopted an adaptation plan was Sardinia (an island region) in 2019. Similarly, in Portugal, 2 autonomous island regions adopted their plans before or at the same time as the national one (2011 Azores, 2015

Madeira). In fact, Portugal’s Constitution of 1974 makes provision for the two autonomous regions, while referendum to extend this to mainland was defeated in 1998.

Overall, we can conclude that adaptation policies have blossomed everywhere across the European Union (Fig. 1). Moreover, as illustrated in Fig. 2, countries characterized by a higher level of decentralisation have seen their sub-national levels implement adaptation plans and strategies before national guidelines (eg.: Belgium, Austria, Germany, or Sweden). Centralized states, such as France or Portugal, followed different patterns – sub-national adaptation strategies were developed after the national guidelines, except for autonomous regions (Azores and Madeira in Portugal). Unfortunately, it was not always possible to have a complete assessment of sub-national strategies in Central and Eastern European Countries due to the lack of available information and language barriers. The capacity of sub-national scales to engage in proactive adaptation could foster the development of CCAKAS, which will be discussed in the next section.

#### Climate change adaptation knowledge action systems in European Member States

As outlined in Dilling and Lemos (2011), formal and informal institutional barriers will have an impact on the use of climate services. Institutions operate within inflexible rules which slow down the implementation of new mechanisms (e.g., the impacts to climate change are addressed within existing decision processes). Socio-political barriers to adaptation actions include, among others, the complexity of local politics and the role of networks (Celliers et al., 2021). Furthermore, policymakers tend to prefer tested solutions instead of taking risks by using new tools and methods. Therefore, the institutional context and political support are among the most important pillars for successful adaptation and climate service use. The integration of climate issues in policy and practice can take the form of intra- and inter-organizational mainstreaming, or the promotion of collaboration and networking with other departments and stakeholders to generate shared understanding and knowledge (Berkhout et al. 2015). Nowadays, the numerous and diverse climate institutions have shifted adaptation governance from monocentric structures, such as the Kyoto protocol and the Paris Agreement, towards more polycentric systems, where subnational governments and actors have expanded their commitments and roles (Abbott, 2017). Nonetheless, although in general polycentric governance theory, organizations can emerge and coordinate their actions spontaneously, in climate governance such organizations are created thanks to facilitation by the state and other actors. Polycentric climate



Table 6

EU: from CCAP to CCAKAS.

Country	CCAP: Data, tools, maps produced by CCAS or by national meteorological services <sup>1</sup>	CCAS: Boundary organisations involved in CCAP production, or selected adaptation services offered by CCAS	CCAAS: Adaptation knowledge-action networks. Presence of coordination mechanisms built by at least 2 different entities/networks (institutional, research, professional)
<b>Austria</b>	Fact sheets, Data portal, Literature Database by CCCA and ZAMG	KLAR! k.i.d.Z.21-Austria	CCCA – Climate Research Network Austria; The Disaster Competence Network Austria
<b>Belgium</b>	Adapt2Climate	N/A	N/A
<b>Bulgaria</b>	N/A	N/A	N/A
<b>Croatia</b>	DHMZ, Prilagodba-klimi (portal)	N/A	N/A
<b>Czech Republic</b>	CHMI	N/A	N/A
<b>Cyprus</b>	Department of Meteorology Ministry of Agriculture, Rural Development and Environment (but no tools or maps were found)	N/A	
<b>Estonia</b>	Riigi Ilmateenistus	N/A	N/A
<b>Denmark</b>	KlimaAtlas (DMI)	Klimatilpasning (collaboration between Danish Regions, Danish Road Directorate, Local Government Denmark, DMI and several ministries and organisations)	
<b>Finland</b>	Climate-Proof City	Finland Climate Guide	N/A
<b>France</b>	DRIAS; TerriSTORY	AcclimaTerra ; Grec-Sud ; Ouranos AuRA ; RECO ; Creseb	ONERC (work in progress)
<b>Germany</b>	KomPass	GERICS	KliVo Portal; KlimAdapt and DKD networks
<b>Greece</b>	Hellenic National Meteorological Service (HNMS, but no maps or tools were found)	N/A	N/A (A beta release of the national online adaptation hub is planned for the end of 2021)
<b>Hungary</b>	NAGIS	N/A	N/A
<b>Ireland</b>	Met Eireann; Adaptation Tool Box (Climate Ireland)	Climate Ireland	
<b>Italy</b>	ISPRA	CMCC	N/A
<b>Latvia</b>	Klimatariks, LEGMC	N/A	N/A
<b>Luxembourg</b>	MeteoLux (but no maps or tools were found)	N/A	N/A
<b>Lithuania</b>	LHT, klimatokaita.lt	N/A	N/A
<b>Malta</b>	The Climate Research Group (CRG), part of the Department of Geosciences at the University of Malta (but no tools or maps were found)	N/A	
<b>Netherlands</b>	Climate Atlaas (CAS); Climate-Proof City Toolbox (Kennisportaal)	Climate Adaptation Services (CAS);	KennisportaalThe Delta Plan on Spatial Adaptation and Delta Programme Steering Groups.
<b>Poland</b>	Klimada	N/A	N/A
<b>Portugal</b>	Portal Do Clima (IPMA)	N/A	N/A
<b>Romania</b>	Meteo Romania	N/A	N/A
<b>Slovakia</b>	SHMU	N/A	N/A
<b>Slovenia</b>	Meteo.si	N/A	N/A
<b>Spain</b>	AEMET	BC3	AdapteCCA
<b>Sweden</b>	Climate scenarios for the sea by SMHI	SMHI (Adaptation center)	KlimatanpassningGovernmental agency network for climate change adaptation

Source: The European Climate Adaptation Platform Climate-ADAPT.

<sup>1</sup>Note that most national meteorological services state that they offer climate services. However, when information on a *specific* tool is not available (e.g., map or knowledge portal), we do not consider them as CCAP, but include them in the table in *bold*.

governance will rely on extensive orchestration between intergovernmental (IPCC, The UNFCCC<sup>15</sup>), state (for national laws and policies), subnational actors (individually or through transnational associations, such as the *Covenant of Mayors*), and private initiatives (*Abbott, 2017*). Therefore, climate adaptation knowledge action systems must rely on networks between relevant stakeholders - institutional, research and professionals. *Weichselgartner and Arheimer (2019)* highlighted that climate services will gain value for decision-makers as they evolve from products into services, and from services into knowledge-action systems. This process is characterized by the transformation of *useful* knowledge into knowledge *used* for decision making (*Celliers et al., 2021*). *Table 5* represents a list of identified initiatives that match the typologies of climate services discussed previously.

*Fig. 3* shows a graphical illustration of *Table 5*. Based on this table, we can roughly distinguish 4 categories of countries:

- Countries without CCAP: Bulgaria, Cyprus, Czech Republic, Greece, Estonia, Malta, Luxembourg, Slovakia, Romania;

- Countries with CCAP: Croatia, Czech Republic, Hungary, Latvia, Lithuania, Poland, Portugal, Slovenia, Romania;
- Countries with CCAS: Belgium, Finland, France, Italy;
- Countries with CCAKAS: Austria, Denmark, Germany, Ireland, Netherlands, Spain, Sweden;

As expected, several decentralised and/or corporatist countries have developed CCAKAS. Since corporatist countries are characterized by the collaborative bargaining of the main societal actors, their policy-networks are well established and have co-operative membership, ensuring the government strong infrastructural power (*S. Oshitani, 2006*). Moreover, According to *Oshitani (2006)*, “corporatism has the institutional capacity to pursue the public good of environmental protection strategically and in a concerted manner” (2006:45). Countries such as Austria, Denmark, Germany, Ireland, the Netherlands, Norway, Spain, and Sweden were able to incorporate climate products and adaptation services into CCAKAS. This was probably facilitated by the presence of existing mechanisms and by the accumulated experience of coordination between different administrative levels. For example, in both Austria and Germany there is strong emphasis on networking between government, societal actors and research. Moreover, this **networking is institutionalized** with the establishment of

<sup>15</sup> The United Nations Framework Convention on Climate Change

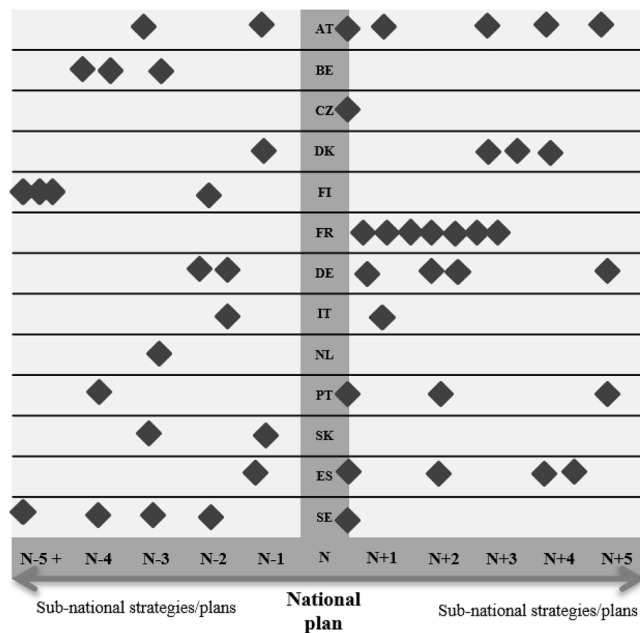


Fig. 2. Timing sub-national strategies and plans in EU countries.

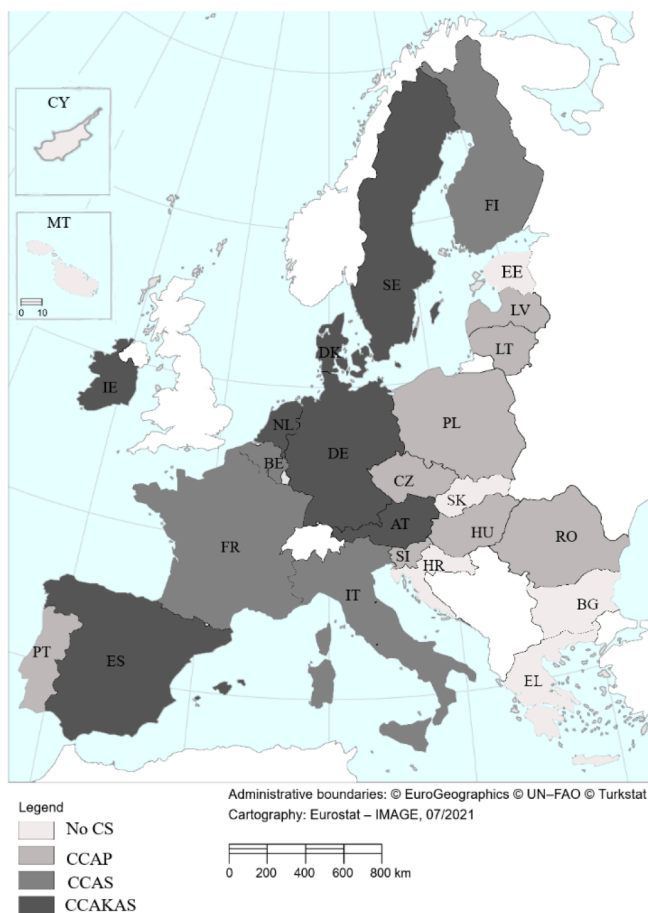


Fig. 3. Climate Change Adaptation Knowledge Action Systems in EU.

coordinating mechanisms.

In Austria, “The Climate Change Centre Austria (CCCA) is a research network supported by Austria’s most important research institutions. It promotes climate research and climate impact research and fosters collaboration in and among those fields. It also provides society and policymakers with scientifically sound information and advice on climate-relevant topics”<sup>16</sup>. What is more, the CCCA has developed partnerships with Green Tech Valley in Styria, the European Forum Alpbach (an interdisciplinary platform for science, politics, business and culture) and Disaster Competence Network Austria (a scientific collaboration platform between universities, research institutes and their stakeholders)<sup>17</sup>.

In Germany, “The two administrative offices, DKD and KlimAdapt, are in each case supported by a network which forms the interface between the providers and users of climate services. This network provides support and advice to the administrative offices regarding climate-related information and adaptation services. They hold discussions on existing services, on the interests of users, on gaps in research activities and on the further development of the services offered”<sup>18</sup>. These two networks group several Federal Agencies such as the Federal Environment Agency and the Federal Ministry for Economic Affairs and Energy, cities such as Munich and Hannover, the German Association of Local Utilities, Deutsche Bahn AG, the German Insurance Association (GDV), WWF Germany, etc.<sup>19</sup>

The AdapteCCa portal in Spain is an initiative of the Spanish Climate Change Office and the Biodiversity Foundation, aimed at information exchange and communication between various actors across different scales: *The AdapteCCa platform for the exchange of information on impacts, vulnerability and adaptation to climate change, facilitates the coordination and transfer of information, knowledge and experiences in this field between the different Spanish administrations and the scientific community, planners and managers, both public and private, and other agents, thereby forming a multi-directional communication channel with each other*<sup>20</sup>.

On the contrary, statist countries grant societal actors little access to or influence in policy formulation. As pointed out by Schmidt (2006), policy networks will have little societal consultation, and will be characterized by “unstable, competitive membership with little participation through lobbying” (2006:677). Indeed, statist countries such as France and to some extent Italy, did not integrate climate products and services in knowledge-action systems. Although regional CCAS are emerging in France (e.g., AcclimaTerra and Ouranos AuRA), there is no strong coordination between national and sub-national levels regarding adaptation. French regional CCAS cooperate and organise events on regional and national scales (e.g., 3rd National Adaptation Conference). Nonetheless, the vertical dimension of multi-level governance is not fully operational: the national adaptation portal is still work in progress. In Italy, the CMCC (The Euro-Mediterranean Center on Climate Change) has networking activities and involves stakeholders on different scales, but a knowledge portal/knowledge exchange mechanism is still missing. When it comes to Greece or Central and Eastern European Countries, we cannot assume that their statist traditions alone represent a barrier to the development of CCAKAS. Zbigniew W. Kundzewicz et al. (2017) pointed out that Central and Eastern European Countries have no national climate services. The availability of resources - technical, human, financial - is as important as the institutional context itself. The Greek National Adaptation Hub is under construction within the LIFE-IP AdaptInGR programme. The CCAP developed in some Central and Eastern European Countries rely on LIFE + programmes and Cohesion Fund grants. For example, the Polish Klimada knowledge portal is financed by the European Cohesion Fund and is expected to be completed by 2021.

<sup>16</sup> www.ccca.ac.at

<sup>17</sup> Ibidem

<sup>18</sup> www.klivoportal.de

<sup>19</sup> Ibidem

<sup>20</sup> www.adaptecca.es

## Conclusions

This article described a study on the possible correlation between the policymaking traditions of selected countries, their degree of decentralization and the respective integration of climate services in their climate change adaptation governance. We argued that corporatist policy-making traditions - characterized by the collaborative bargaining of multiple societal stakeholders and the presence of strong networks - facilitates the development of climate change adaptation knowledge-action systems. In other words, climate services must become an integral part of inter- and intra-organisational mainstreaming in the context of the multi-level governance of climate change adaptation.

Indeed, CCAKAS were mostly developed in corporatist and/or decentralized countries such as Austria, Denmark, Germany, Ireland, Netherlands, and Spain. To ensure coherent spatial planning and resource management across scales regarding adaptation, these countries have: 1) created coordination structures at the national level, such as knowledge portals (built in collaboration with multiple stakeholders) or adaptation networks; 2) and pursued the integration of climate information in policy and practice through science-policy interfaces and boundary organisations such as BC3, CAS and Climate Ireland. The statist countries in our sample showed different degrees of integration of climate products and services in their adaptation governance. As underlined in the literature (see section 2.4), policy networks are unstable in statist countries, leading to barriers for the inter- and intra-organisational mainstreaming of adaptation. France has developed CCAP via regional CCAS initiatives such as Ouranos AuRA, Grec-Sud, Acclimaterra, and RECO, but top-down coordination is still work in progress. From our analysis we can conclude that countries with strong coordination traditions and policy networks are those where the most CCAKAS have emerged. When it comes to Greece and Central and Eastern European Countries, we cannot assume that their statist traditions alone represent a barrier to the development of CCAKAS. The availability of resources - technical, human, financial - is as important as

the institutional context itself.

Several countries were difficult to classify because of a lack of information in English, or because climate service providers fell between two categories. Finland, for example, has a national climate adaptation and mitigation portal, but this entity does not have networking activities, nor a forum for knowledge exchange. The next step would be to complete a case study for each country to provide an in-depth analysis of their adaptation governance systems.

Finally, one of the objectives of this study was to put in practice the definitions by [Weichselgartner and Arheimer \(2019\)](#) and provide a state of the art on climate services in the EU. We believe that better use of terminology (e.g., product vs service) is an important step for the development of climate services and a sign of increasing maturity in the field.

## CRedit authorship contribution statement

**Anastasia Panenko:** Conceptualization, Writing – original draft, Formal analysis, Writing – review & editing. **Emmanuelle George:** Supervision, Writing – review & editing. **Céline Lutoff:** Supervision, Writing – review & editing.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgements

This work was supported by the French National Research Agency through the “Investissements d’avenir” program (ANR-15-IDEX-02) within the CDP-Trajectories project.

## Appendix A.: EU, national and subnational adaptation plans and strategies

Country	NAS	NAP	Sub-national strategies and plans
Austria	2012 ( <a href="#">upd 2017</a> )		2009 <a href="#">Wien</a> and 2011 <a href="#">Niederösterreich</a> , 2012 <a href="#">Tyrol</a> , <a href="#">Oberösterreich</a> , 2013; <a href="#">Steiermark</a> , 2015; <a href="#">Vorarlberg</a> , 2016; <a href="#">Salzburg</a> , 2017.
Belgium	<a href="#">2010</a>	<a href="#">2017</a>	2014 <a href="#">Wallonne</a> ; 2013 <a href="#">Bruxelles-Capitale</a> (further developed in 2016); 2013 <a href="#">Flemish Region</a> .
Bulgaria	<a href="#">2019</a>	N/A	N/A
Croatia	<a href="#">2017 draft</a>	N/A	N/A
Czech Republic	<a href="#">2015</a>	<a href="#">2017</a>	2017 <a href="#">Prague territorial self-governing unit</a> (Urban region)
Cyprus	2014 ( <a href="#">upd 2017</a> )		Combined NAS/NAP elaborated in 2014, updated and formally adopted in May 2017
Denmark	<a href="#">2008</a>	<a href="#">2012</a>	2015 <a href="#">South Denmark</a> , 2016 <a href="#">North Jutland</a> , 2015 <a href="#">Region Zealand</a> and the 2011 <a href="#">Capital Region</a> .
Estonia	<a href="#">2017</a>	<a href="#">2017</a>	Combined NAP/NAS.
Finland	<a href="#">2005</a>	<a href="#">2014</a>	<a href="#">Regional Councils</a> of Itä-Uudenmaan liitto, 2007; Lapin liitto, 2005; Pirkanmaanliitto, 2007; Pohjanmaan liitto, 2006; Pohjois-Karjalan liitto, 2005; Uudenmaanliitto, 2006. <a href="#">Helsinki Metropolirtan Area 2012</a> .
France	<a href="#">2006</a>	<a href="#">2011</a> (upd 2017)	2012 <a href="#">IDF</a> , Grand Est ( <a href="#">upd 2018</a> ), 2012 <a href="#">Franche-Comté</a> , 2013 <a href="#">Nouvelle Aquitaine</a> , <a href="#">upd 2021</a> ), 2013 <a href="#">PACA</a> , 2014 <a href="#">Auvergne Rhône-Alpes</a>
Germany	<a href="#">2008</a>	<a href="#">2011</a> Upd <a href="#">2015</a>	2009 Bavaria <a href="#">upd 2016</a> , 2008 <a href="#">Brandenburg</a> , 2009 <a href="#">Mecklenburg Western Pomerania and Schleswig-Holstein</a> , 2012 Lower Saxony, 2013 <a href="#">Hambourg</a> , 2015 <a href="#">Baden-Württemberg</a> , 2012 <a href="#">Hessen</a> <a href="#">upd 2017</a> .
Greece	<a href="#">2016</a>	N/A	2016 LIFE-IP AdaptInGR - Boosting the implementation of adaptation policy across Greece. The 13 Regional Authorities are now preparing their Regional Adaptation Action Plans (RAAPs).
Hungary	<a href="#">2008*</a> <a href="#">Upd 2018</a>		Combined NAP/NAS. National Adaptation Plan part of Climate Change Action Strategies
Ireland	2012+	<a href="#">2018</a>	A non-statutory National Climate Change Adaptation Framework (NCCAF) was adopted in December 2012. Ireland's first statutory National Adaptation Framework (NAF) was published in 2018. In January 2018 the Government established four Climate Action Regional Offices (CAROs). Under the National Adaptation Framework and Climate Action Plan 2019, each local authority developed its own adaptation strategy,
Italy	<a href="#">2015</a>	<a href="#">2017 draft</a>	2015 <a href="#">Lombardy</a> ; 2019 <a href="#">Sardinia</a>
Latvia	<a href="#">2019</a>		Combined NAP/NAS. Subnational level has no defined role in climate adaptation. Nonetheless, the Salacgriva urban region adopted a plan in 2011 (a declaration).
Luxembourg	2011	<a href="#">2018</a>	Not a standalone document, a section of the 2011 “Paquet Climat”. There is no self-governing sub-national level in Luxembourg.
Lithuania	<a href="#">2012</a>	<a href="#">2013</a>	Municipalities, together with relevant national-level ministries, are responsible for the implementation of the Strategy for National Climate Change Management Policy.
Malta	<a href="#">2012</a>	N/A	Adaptation planning at local level is not foreseen in the NAS, but 24 local councils signed the Covenant of Mayors.
Netherlands		<a href="#">2018</a>	

(continued on next page)

(continued)

Country	NAS	NAP	Sub-national strategies and plans
	2007 ( <a href="#">upd</a> <a href="#">2016</a> )		The Delta Programme was initiated in 2010 and covered a large part of climate adaptation. Dutch provinces had to elaborate strategies by 2015 (law 2009): 10/12 have published key vulnerability assessments; <a href="#">9/12 have published</a> policy documents on adaptation.
Poland	<a href="#">2013</a>	N/A	N/A
Portugal	2010	<a href="#">2015 Upd</a> <a href="#">2019</a> <a href="#">2016</a>	2011 <a href="#">Azores</a> upd, 2015 <a href="#">Madeira</a> , 2017 Alentejo, 2020 de adaptação às alterações climáticas do <a href="#">Algarve</a> (Plano Intermunicipal).
Romania	<a href="#">2013</a>	<a href="#">2016</a>	Region Centre implemented a project aiming to develop a set of good practices in adaptation to climate change, "Greenways for Sustainable Development" in February 2015 – April 2016.
Slovakia	<a href="#">2014 Upd</a> <a href="#">2018</a>	2018	2015 <a href="#">Horná Ondava</a> , 2017 <a href="#">Bratislava Self-Governing Region</a> (Urban region).
Slovenia	<a href="#">2016</a>		N/A
Spain	<a href="#">2006 Upd</a> 2014		Combined NAP/NAS. 2008 <a href="#">Basque country</a> (upd 2015), 2009 <a href="#">Aragon</a> , 2009 <a href="#">Castilla y Leon</a> , 2010 <a href="#">Andalusia</a> , 2011 <a href="#">Navarra</a> 2011 <a href="#">Castilla-La Mancha</a> , 2013 <a href="#">Catalunya</a> , 2013 <a href="#">Balears</a> , 2013 <a href="#">Comunidad Valenciana</a> , 2014 <a href="#">Extremadura</a> , 2014 <a href="#">Madrid</a> , 2016 <a href="#">Galicia</a> , Principality of Asturias, Cantabria, Murcia, La Rioja (work in progress). 2011 Södermanland 2012 Kalmar; 2014: Blekinge, Östergötland, Gävleborg, Halland, Skåne, Stockholm; 2015 Jönköping; 2016 Kronoberg; 2018 Gotland, Västernorrland. ( <a href="#">list of countries</a> )
Sweden	<a href="#">2018</a>	x	

## References

- Abbott, Kenneth. 2017. Orchestration: Strategic Ordering in Polycentric Climate Governance. <https://doi.org/10.13140/RG.2.2.10435.60962>.
- Adger, W.N., Arnell, N.W., Tompkins, E.L., 2005. Successful adaptation to climate change across scales. *Glob. Environ. Change Adapt. Clim. Change: Perspect. Across Scales* 15 (2), 77–86. <https://doi.org/10.1016/j.gloenvcha.2004.12.005>.
- Amundsen, H., Berglund, F., Westskog, H., 2010. Overcoming Barriers to Climate Change Adaptation—A Question of Multilevel Governance? *Environ. Plan. C Gov. Policy* 28 (2), 276–289. <https://doi.org/10.1068/c0941>.
- Buontempo, C., Hewitt, C.D., Doblas-Reyes, F.J., Dessai, S., 2014. « Climate Service Development, Delivery and Use in Europe at Monthly to Inter-Annual Timescales ». *Climate. Risk Manage.* 6 (janvier), 1–5. <https://doi.org/10.1016/j.crm.2014.10.002>.
- Berkhout, F., Bouwer, L.M., Bayer, J., Bouzid, M., Cabeza, M., Hanger, S., Hof, A., Hunter, P., Meller, L., Patt, A., Pfluger, B., Rayner, T., Reichardt, K., van Teeffelen, A., 2015. European policy responses to climate change: progress on mainstreaming emissions reduction and adaptation. *Reg. Environ. Change* 15 (6), 949–959. <https://doi.org/10.1007/s10113-015-0801-6>.
- Biesbroek, G.R., Swart, R.J., Carter, T.R., Cowan, C., Henrichs, T., Mela, H., Morecroft, M.D., Rey, D., 2010. Europe adapts to climate change: Comparing National Adaptation Strategies. *Glob. Environ. Change, Governance, Complex. Resilience* 20 (3), 440–450. <https://doi.org/10.1016/j.gloenvcha.2010.03.005>.
- Borzil, T.A., 1998. Organizing Babylon - On the Different Conceptions of Policy Networks. *Public Adm.* 76 (2), 253–273. <https://doi.org/10.1111/padm.1998.76.issue-210.1111/1467-9299.00100>.
- Carlisle, K., Gruby, R.L., 2019. Polycentric Systems of Governance: A Theoretical Model for the Commons. *Policy Stud. J.* 47 (4), 927–952. <https://doi.org/10.1111/psj.v47.410.1111/psj.12212>.
- Cash, D.W., Clark, W.C., Alcock, F., Dickson, N.M., Eckley, N., Guston, D.H., Jäger, J., Mitchell, R.B., 2003. Knowledge systems for sustainable development. *Proc. Natl. Acad. Sci.* 100 (14), 8086–8091. <https://doi.org/10.1073/pnas.1231332100>.
- Celliers, L., Costa, M.M., Williams, D.S., Rosendo, S., 2021. The 'Last Mile' for Climate Data Supporting Local Adaptation. *Global Sustain.* 4 <https://doi.org/10.1017/sus.2021.12>.
- Choi, B.C.K., Li, L., Yaogui, L.u., Zhang, L.R., Zhu, Y., Pak, A.W.P., Chen, Y., Little, J., 2016. Bridging the gap between science and policy: an international survey of scientists and policy makers in China and Canada. *Implementation Sci.* 11 (février), 16. <https://doi.org/10.1186/s13012-016-0377-7>.
- Corfee-Morlot, J., Kamal-Chaoui, L., Donovan, M.G., Cochran, I., Robert, A., Teasdale, P. J., n.d., 2009. Cities, Climate Change and Multilevel Governance. OECD 125.
- Daniell, Katherine A., Kay, Adrian, 2017. In: Multi-level Governance: Conceptual challenges and case studies from Australia. ANU Press, pp. 3–32. <https://doi.org/10.22459/MG.11.2017.01>.
- Di Gregorio, M., Fattorelli, L., Paavola, J., Locatelli, B., Pramova, E., Nurrochmat, D.R., May, P.H., Brockhaus, M., Sari, I.M., Kusumadewi, S.D., 2019. Multi-level governance and power in climate change policy networks. *Glob. Environ. Change* 54, 64–77. <https://doi.org/10.1016/j.gloenvcha.2018.10.003>.
- Dilling, Lisa, Lemos, Maria Carmen, 2011. Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy. *Glob. Environ. Change, Special Issue Politics Policy Carbon Capture Storage* 21 (2), 680–689. <https://doi.org/10.1016/j.gloenvcha.2010.11.006>.
- DeLeo, Rob A., Taylor, Kristin, Crow, Deserae A., Birkland, Thomas A., 2021. « During Disaster: Refining the Concept of Focusing Events to Better Explain Long-Duration Crises. *Int. Rev. Public Policy* 3 (1). <https://doi.org/10.4000/irpp10.4000/irpp.160510.4000/irpp.1868>.
- Dunn, G., Laing, M., 2017. Policy-makers perspectives on credibility, relevance, and legitimacy (CRELE). *Environ. Sci. Policy* 76, 146–152. <https://doi.org/10.1016/j.envsci.2017.07.005>.
- Dutton, John A., 2002. Opportunities and priorities in a new era for weather and climate services. *Bull. Am. Meteorol. Soc.* 83 (9), 1303–1312. <https://doi.org/10.1175/1520-0477-83.9.1303>.
- European Commission, 2007. Green Paper - Adapting to climate change in Europe – options for EU action, Brussels.
- European Commission, 2009. White Paper - Adapting to climate change: Towards a European framework for action, Brussels.
- European Commission, 2013. An EU Strategy on adaptation to climate change, Brussels.
- European Commission, 2015. A European research and innovation roadmap for climate services, Luxembourg.
- European Commission, 2021. Forging a climate-resilient Europe -the new EU Strategy on Adaptation to Climate Change, Brussels.
- European, Environment Agency, 2007. Climate Change: The Cost of Inaction and the Cost of Adaptation, Luxembourg.
- European Environment Agency, 2012. Climate change impacts and vulnerability in Europe, Luxembourg.
- European Environment Agency, 2016. Climate change impacts and vulnerability in Europe. Luxembourg.
- European Environment Agency, 2019. The European environment — state and outlook 2020: knowledge for transition to a sustainable Europe, Luxembourg.
- Fennell, David, Plummer, Ryan, Marschke, Melissa, 2008. Is adaptive co-management ethical? *J. Environ. Manage.* 88 (1), 62–75. <https://doi.org/10.1016/j.jenvman.2007.01.020>.
- Ford, James D., Berrang-Ford, Lea, Paterson, Jaclyn, 2011. A systematic review of observed climate change adaptation in developed nations. *Clim. Change* 106 (2), 327–336. <https://doi.org/10.1007/s10077-011-0045-5>.
- Goosen, H., de Groot-Reichwein, M.A.M., Masselink, L., Koekoek, A., Swart, R., Bessemlinder, J., Witte, J.M.P., Stuyt, L., Blom-Zandstra, G., Immerzeel, W., 2014. Climate Adaptation Services for the Netherlands: an operational approach to support spatial adaptation planning. *Reg. Environ. Change* 14, 1035–1048. <https://doi.org/10.1007/s10113-013-0513-8>.
- Hémon, Denis, et Eric Jouglà, 2004 . « Surmortalité liée à la canicule d'août 2003: suivi de la mortalité (21 août - 31 décembre 2003), causes médicales des décès (1 - 20 août 2003) », Institut national de la santé et de la recherche médicale (INSERM). 2004, 76 p.
- ISTAT. 2019. « Conti economici territoriali - anni 2017-2019 ».
- Imperial, Mark T., 1999. Institutional Analysis and Ecosystem-Based Management: The Institutional Analysis and Development Framework. *Environ. Manage.* 24, 449–465. <https://doi.org/10.1007/s002679900246>. In press.
- Jacobs, Katharine L., Street, Roger Brian, 2020. The next Generation of Climate Services. *Clim. Serv.* 20 (décembre), 100199 <https://doi.org/10.1016/j.cliser.2020.100199>.
- Koppenjan, J., Klijn, Erik-Hans, 2004. Managing Uncertainties in Networks : Public Private Controversies. Routledge. <https://doi.org/10.4324/9780203643457>.
- Jørgensen, Kirsten, Jogesh, Anu, Mishra, Arabinda, 2015. Multi-level climate governance and the role of the subnational level. *J. Integr. Environ. Sci.* 12 (4), 235–245. <https://doi.org/10.1080/1943815X.2015.1096797>.
- E. Carina H. Keskitalo, (Ed.), 2010. Developing Adaptation Policy and Practice in Europe: Multi-level Governance of Climate Change. Springer Netherlands. <https://doi.org/10.1007/978-90-481-9325-7>.
- Krauss, W., von Storch, H., 2012. Post-Normal Practices Between Regional Climate Services and Local Knowledge. *Nat. Cult.* 7, 213–230. <https://doi.org/10.3167/nc.2012.070206>.
- Kirchhoff, C.J., Lemos, M.C., Kalafatis, S., 2015. Narrowing the gap between climate science and adaptation action: The role of boundary chains. *Clim. Risk Manage.* 9, 1–5. <https://doi.org/10.1016/j.crm.2015.06.002>.
- Kundzewicz, Z.W., Førland, E.J., Piniowski, M., 2017. Challenges for developing national climate services Poland and Norway. *Clim. Serv.* 8, 17–25. <https://doi.org/10.1016/j.cliser.2017.10.004>.
- Lijphart, A., 2012. *Patterns of Democracy: Government Forms and Performance in Thirty- Six Countries*. Yale University Press.
- Magone, José M., 2014. *Routledge Handbook of European Politics*. Routledge. ISBN 9780815373889.
- Marshall G., 2009. Polycentricity, reciprocity, and farmer adoption of conservation practices under community-based governance, *Ecological Economics*, 2009, vol. 68, issue 5, 1507–1520, [https://econpapers.repec.org/article/eeeeecole/v3a68\\_3ay3a2009\\_3ai3a5\\_3ap3a1507-1520.htm](https://econpapers.repec.org/article/eeeeecole/v3a68_3ay3a2009_3ai3a5_3ap3a1507-1520.htm).

- McConnell, A., 2003. Overview: Crisis Management, Influences, Responses and Evaluation. *Parliam. Aff.* 56 (3), 363–409. <https://doi.org/10.1093/parlij/gsg096>.
- McNie, Elizabeth C., 2007. Reconciling the supply of scientific information with user demands: an analysis of the problem and review of the literature. *Environ. Sci. Policy, Reconciling Supply Demand Sci. Focus Carbon Cycle Res.* 10 (1), 17–38. <https://doi.org/10.1016/j.envsci.2006.10.004>.
- Minister for the Environment, 2016. « National Climate Adaptation Strategy 2016 (NAS) ». Consulted on 20/07/2021 <https://klimaadaptatienederland.nl/en/policy-programmes/nas/>.
- ONERC, 2007. Stratégie nationale d'adaptation au changement climatique. La Documentation française, Paris.
- Oshitani, S., 2006. Global warming policy in Japan and Britain: Interactions between institutions and issue characteristics. Manchester University Press.
- Ostrom, E., 2009. A Polycentric Approach for Coping with Climate Change (Background Paper to the 2010 World Development Report). World Bank.
- Plummer, R., Baird, J., 2013. Adaptive Co-Management for Climate Change Adaptation: Considerations for the Barents Region. *Sustainability* 5, 629–642. <https://doi.org/10.3390/su5020629>.
- Porter, J.J., Dessai, S., 2017. Mini-me: Why do climate scientists' misunderstand users and their needs? *Environ. Sci. Policy* 77, 9–14. <https://doi.org/10.1016/j.envsci.2017.07.004>.
- Räsänen, A., Jurgilevich, A., Haanpää, S., Heikkinen, M., Groundstroem, F., Juhola, S., 2017. The need for non-climate services – Empirical evidence from Finnish municipalities. *Clim. Risk Manag.* 16, 29–42. <https://doi.org/10.1016/j.crm.2017.03.004>.
- Roza, Lonneke, Bethmann, Steffen, Meijs, Lucas, 2019. et Georg von Schnurbein. Corporate and Civil Society Perspectives. Springer Nature, Handbook on Corporate Foundations.
- Reinecke, S., 2015. Knowledge brokerage designs and practices in four european climate services: A role model for biodiversity policies? *Environ. Sci. Policy* 54, 513–521. <https://doi.org/10.1016/j.envsci.2015.08.007>.
- Samuelson, P.A., 1954. The Pure Theory of Public Expenditure. *Rev. Econ. Stat.* 36, 387–389. <https://doi.org/10.2307/1925895>.
- Sarewitz, Daniel, Pielke, Roger A., 2007. The neglected heart of science policy: reconciling supply of and demand for science. *Environ. Sci. Policy* 10 (1), 5–16. <https://doi.org/10.1016/j.envsci.2006.10.001>.
- Sarkki, S., Tinch, R., Niemelä, J., Heink, U., Waylen, K., Timaeus, J., Young, J., Watt, A., Neßhöver, C., van den Hove, S., 2015. Adding 'iterativity' to the credibility, relevance, legitimacy: A novel scheme to highlight dynamic aspects of science-policy interfaces. *Environ. Sci. Policy* 54, 505–512. <https://doi.org/10.1016/j.envsci.2015.02.016>.
- Schmidt, Vivien A., 2006. Procedural democracy in the EU: the Europeanization of national and sectoral policy-making processes. *J. Eur. Public Policy* 13 (5), 670–691. <https://doi.org/10.1080/13501760600808444>.
- Stern, Nicholas, 2014. The Economics of Climate Change. Cambridge University Press. <https://doi.org/10.1017/CBO9780511817434>.
- Street, R.B., 2016. Towards a leading role on climate services in Europe: A research and innovation roadmap. *Clim. Serv.* 1, 2–5. <https://doi.org/10.1016/j.cliser.2015.12.001>.
- Swart, Rob, Raes, Frank, 2007. Making integration of adaptation and mitigation work: mainstreaming into sustainable development policies? *Clim. Policy* 7 (4), 288–303. <https://doi.org/10.1080/14693062.2007.9685657>.
- Underdal, Arild, 2010. Complexity and challenges of long-term environmental governance. *Glob. Environ. Change, Governance, Complexity Resilience* 20 (3), 386–393. <https://doi.org/10.1016/j.gloenvcha.2010.02.005>.
- USAID, 2013. The Value of Climate Services Across Economic and Public Sectors: A Review of Relevant Literature.
- Vaughan, Catherine, Dessai, Suraje, 2014. Climate services for society: origins, institutional arrangements, and design elements for an evaluation framework. *WIREs Clim. Change* 5 (5), 587–603. <https://doi.org/10.1002/wcc.290>.
- Weichselgartner, Juergen, Arheimer, Berit, 2019. Evolving Climate Services into Knowledge-Action Systems. *Weather, Climate, and Society* 385–399. <https://doi.org/10.1175/WCAS-D-18-0087.1>. In press.