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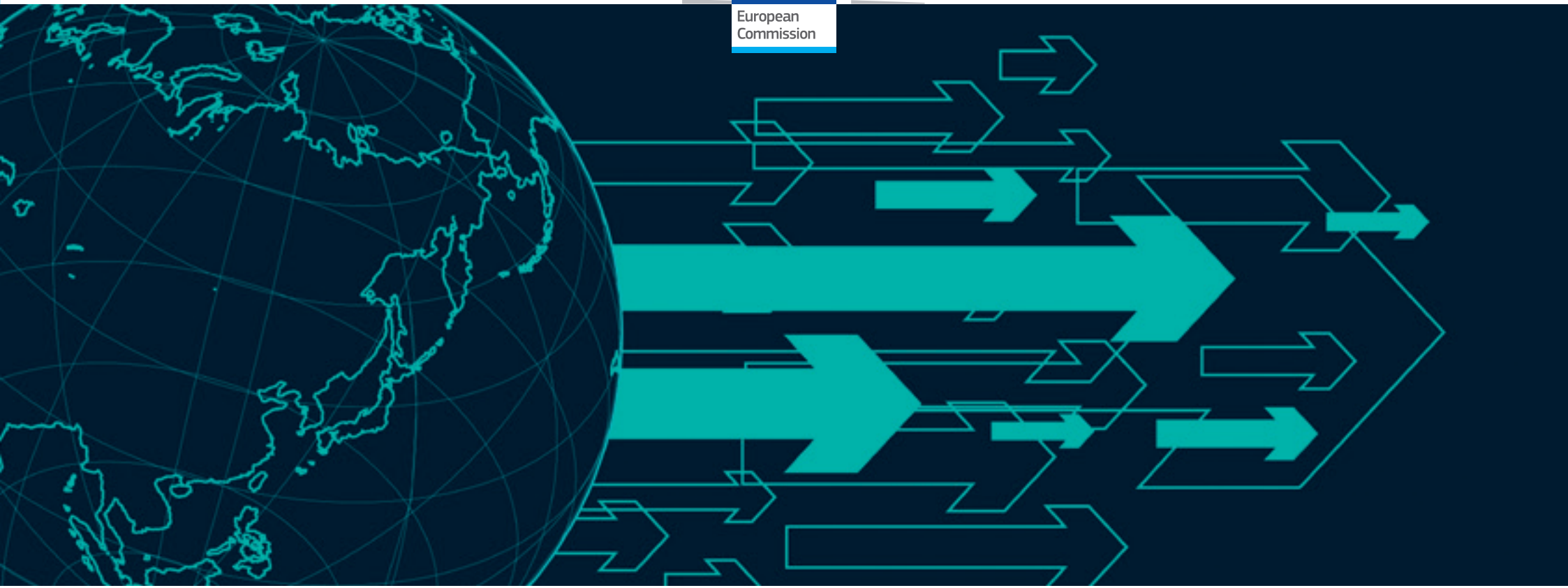

A European research and innovation

Roadmap

for Climate Services

Research and Innovation

EUROPEAN COMMISSION

Directorate-General for Research and Innovation
Directorate I — Climate Action and Resource Efficiency
Unit I.4 — Climate Action and Earth Observation

Contact: Andrea TILCHE
E-mail: RTD-CLIMATE-SERVICES@ec.europa.eu
RTD-PUBLICATIONS@ec.europa.eu

European Commission
B-1049 Brussels

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2015

Directorate-General for Research and Innovation

Expert group

Roger Street, Rapporteur
Director of the UK Climate Impacts Programme (UKCIP), University of Oxford and member of the Joint Programming Initiative on Climate

Martin Parry,
Centre for Environmental Policy, Imperial College London and Department of Geography, University of Birmingham

Jesse Scott,
Member of the Gas, Coal, and Power Markets team, International Energy Agency, Paris

Daniela Jacob,
Acting Director of the Climate Service Centre 2.0, an independent establishment at the Helmholtz Zentrum Geesthacht, Hamburg

Tania Runge,
Senior Policy Advisor, Copa Cogeca secretariat
Environmental issues: water management, biodiversity (European Farmers, European Agri Cooperatives)
Chair of the Stakeholder Advisory Board of FACCE JPI

Supporting group

Mark Doherty, European Space Agency (ESA), Member of the Horizon 2020 Advisory Group SC5
Jean Noel Thepaut, Head of the Data Division of the Research Department of the European Centre for Medium Range Weather Forecasts (ECMWF), Reading, UK
Ralph Toumi, Imperial College, London; European Institute of Innovation and Technology (EIT) Climate KIC
Alfonso Gutierrez Teira, European Commission, DG Climate Action, Adaptation
Anna Maria Johansson, European Commission, DG Research and Innovation, Research infrastructure
Frank Raes, European Commission, Joint Research Centre (JRC), Head of Unit Climate Risk Management
Peter Breger, Bernard Pinty, Hugo Zunker, European Commission, DG Internal Market, Industry, Entrepreneurship and small to medium sized enterprises (SMEs), Copernicus: Services

Management team

European Commission
Directorate-General (DG) for Research and Innovation
Directorate Climate Action and Resource Efficiency
Unit Climate Action and Earth Observation

Andrea Tilche, Head of Unit
Anastasios Kentarchos, Deputy Head of Unit
Alessia Pietrosanti, Drafting coordination
Michael Berger, Claus Brüning, Marco Gemmer, Peter Horvath, Rossella Riggio, Climate services team members
Edita Kuzmova, Expert group assistant

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Foreword

One of the biggest and most important challenges of our time is to avoid the dangerous consequences of climate change. This is why Climate Action is one of the Societal Challenges that the European Union is addressing through Horizon 2020, its Research and Innovation Framework Programme for the period 2014-2020. The goal is to invest at least 35 % of Horizon 2020's budget in climate-related research.

Responding to the climate change challenge implies taking rapid and effective steps to reduce greenhouse gas emissions, in particular through new low-carbon energy and transport technologies, while at the same time adapting to the unavoidable changes that are already happening. This requires climate-informed decision-making at all levels, in order to minimise risks and costs, and to seize opportunities.

President Jean-Claude Juncker has clearly said: *'I want the European Union to lead the fight against global warming'*. Europe is already leading in climate science and technology. Our ambition now is to also be the lead in channelling this science and technology to develop solutions to climate change and to stimulate sustainable economic growth. This Roadmap is a positive step in that direction.

I am very grateful to the expert group who worked hard to produce this Roadmap for Climate Services and to all the other experts and stakeholders who responded to consultations or participated in hearings. They contributed to making this result possible.

As this roadmap reads, *"Climate services have the potential to become the intelligence behind the transition to a climate-resilient and low-carbon society".* This statement alone highlights how important this document is. But this report is also an excellent example of how, through Horizon 2020, the European Commission is treating research and innovation as a critical factor for economic growth and job creation and for developing the new markets of solutions to societal challenges.

According to the roadmap, *"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".* The proposed choices of investment in research and innovation that the document presents are designed to promote this vision.

This report will be a source of inspiration and reference for research and innovation policy and investments in the field of climate in the years to come, and will provide an essential contribution to achieving the EU objectives of an Energy Union with a forward-looking climate policy.

Robert-Jan Smits
Director-General
European Commission,
Directorate-General for Research and Innovation

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Table 1. Roadmap synthesis

Main activities	*Specific actions*
Challenge 1: Enabling market growth	
1.1: *Assessing the nature of climate services market.*	(a) Assessing the climate services market (demand and supply).
	(b) Translating users' needs into services and access required.
	(c) Exploring the public and private domains of the market.
1.2: *Growing the climate services market.*	(a) Developing foresight into perspective market growth: identifying untapped potentials, and measures to promote market growth.
	(b) Establishing the means of enhancing the awareness of, and promoting, climate services.
	(c) Developing appropriate business models for the provision of climate services.
1.3: *Demonstrating the added value.*	(a) Identifying mature markets and front-runners.
	(b) Demonstrating the impacts and full value of climate services as standalone services and/or integrated into broader decision-support systems.
Challenge 2: Building the market framework	
2.1: *Communities and infrastructures to support and grow the climate services market.*	(a) Developing a viable climate services community that engages users, providers, purveyors and researchers.
	(b) Building and widening capacity for climate services development, provision and use.
	(c) Computing, data and information technology (IT) infrastructure required to develop, deliver and support access/use of climate services.
2.2: *Standards, quality assurance and control, access and legal aspects.*	(a) Demonstrating credibility and assuring quality of climate services.
	(b) Implications of limited, and open and free access to data and information for services supply and demand.
	(c) Liability in providing climate services and market implications.
	(d) Intellectual property (IP) implications of co-design, co-development and co-delivery.
2.3: *International cooperation.*	(a) Engaging the European climate service community internationally.
	(b) Supporting the growth of climate service capacities (demand and supply) within least developed countries (LDCs), with a focus on Africa.
Challenge 3: Enhancing the quality and relevance of climate services	
3.1: *Information frameworks in support of climate services.*	(a) Integration of physical and socioeconomic data and information.
	(b) Developing standards and protocols for data in support of vulnerability and risk assessments, and decision-support systems.
	(c) Establishing confidence in, and the role of uncertainty, in climate services and decision-support systems.
3.2: *Strengthening the scientific basis and relevance of climate services.*	(a) Improving modelling and prediction capacity relevant to improve climate services.
	(b) Developing tools and supportive resources needed by users - local, national and transnational.
	(c) Identifying and evaluating the implications of scientific development on climate processes in terms of improving climate services.
3.3: *Climate information and end-users' needs*: *innovations and products.*	(a) Making better use of available climate information and knowledge
	(b) Making innovations in service products and presentation.

Executive summary

In June 2014 the European Commission (EC), established an expert group with the task of proposing a research and innovation roadmap for climate services that could be used for the definition of future actions promoted by the EC — mainly through Horizon 2020 ([1]), but also the European Earth Observation Programme: Copernicus ([2]), and the European Institute of Innovation and Technology (EIT) climate-knowledge and innovation communities (Climate-KIC) ([3]) — as well as by other transnational, national and regional programmes. The expert group analysed the evolution of climate services in Europe and worldwide, assessed the output of European Union (EU) funded projects in the field and other relevant documents, carried out — with the help of EC services — a dedicated stakeholder consultation and held several discussion sessions that led to the elaboration of the present report.

It is recognised that climate services, although still a relatively new and specialised sector, 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 have the potential to become the intelligence behind the transition to a climate-resilient and low-carbon society. They can enable informed decisions where the goal is to increase resilience and adaptation capacity by addressing existing or emerging risks, and enhance the capabilities of seizing the opportunities of the transition to a low-carbon economy.

In Europe the growth of the Copernicus Climate Change service (C3S) and of national climate service centres offer the conditions for realising such potential. Through the provision (in a free and open access mode) of a consistent layer of data, data products, and model outputs, they can support the development of a market, in which public and private climate services operators develop a variety of customised high added-value services with and for users.

Facilitating the development of such a market requires sustained research and innovation funding to address the main three challenge areas identified:

- enabling market growth,
- building the market framework,
- enhancing the quality and relevance of climate services.

A coherent set of nine main activities and 25 specific actions under these challenges is proposed and form the roadmap itself. It is introduced in a narrative mode (Chapter 3), and presented more analytically as a table of actions (Chapter 4, **Table 3**; a synthesis is presented in **Table 1**).

Key aspects of the roadmap are: the stakeholder engagement in practical and realistic demonstration of the benefits that climate services can generate; a series of actions targeted at building engaged communities of users and providers/purveyors; a sustained flow of new trans-disciplinary science to the operational dimension and supportive feedback; and supporting open access to data and data products.

Several documents have been published in relation to knowledge gaps towards improving the capabilities of predicting the evolution of climate and better estimating future possible impacts. This roadmap acknowledges them. However, it does not enter into the technical details of other research agendas, but puts these scientific developments in the context of the co-design and co-development process that is needed to enhance the quality and relevance of climate services and to grow their market.

The ambition of this roadmap is not to set a definitive research and innovation agenda, but to offer a framework for discussion to the relevant actors and stakeholders, and to find shared solutions and pathways facilitating the development of a market for climate services that provides benefits to society.

([1]) Horizon 2020 is the EU Framework Programme for Research and Innovation 2014–2020 (http://ec.europa.eu/programmes/horizon2020)
([2]) www.copernicus.eu
([3]) www.climate-kic.org

1. Vision: enabling European leadership on climate services

1.1. Rationale for a European flagship initiative

The recent Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report ([4]) has shown very clearly that collective, urgent action is needed to keep the planet's climate within tolerable levels of warming. It also estimated that annual economic losses for a temperature increase beyond 2°C are between 0.2 % to 2 % of income by affecting human health, impacting food production, disrupting water supplies and damaging property/infrastructure, and that these costs will rise with warming. On the other hand, proactive action for keeping the world within the 2 °C warming boundaries is estimated to cost much less, between 0.04 % and 0.14 % of gross domestic product (GDP) per year during this century, not even taking into account the huge co-benefits of action.

At EU level, ambitious targets have been set on greenhouse gas (GHG) emissions reduction, renewable energy and energy efficiency ([5]), and efforts are accelerating to implement the climate adaptation strategy ([6]). The recent United States (US) - China joint announcement on climate change provided a clear sign that major emitters are beginning to engage with the decarbonisation process. In parallel, the business community is increasingly calling for ways to incorporate climate risks into long-term capital investment decisions and operations.

As a result, there is increasing demand for customised climate-related tools, products and information (climate services) that will enable climate-smart, strategic decisions at various levels for a range of end-users (businesses, the public sector, and individuals), enabling a more systemic approach to risk management. There is great potential for the creation of a new service sector, specialising in the provision of customised climate information services to various stakeholders and customers. Public policy can stimulate the creation of a community of climate services application developers and users that matches supply and demand for climate information and prediction, by providing a framework that enables economic value to be derived from the wealth of climate data and models and from the ongoing climate research.

Reliable and actionable climate services, integrated with socioeconomic assessments, will scale-up the cost-effectiveness of climate change mitigation and adaptation solutions. The growth of the climate services market will make the EU a world leader in this sector and contribute directly or indirectly to economic growth and job creation. Even more importantly, it will increase the quality and effectiveness of decision-making (e.g. on mitigation policies, resilient infrastructures, novel business opportunities, future investments) and thus positively impact on the competiveness of the European economy ([7]).

Although the knowledge of the global climate system and its dynamic interaction with human activity is expanding, many gaps still exist not only in the underlying science, but especially in tailoring the available and newly produced information to the users' needs and bridging demand and supply. Public investment in research and innovation is therefore needed in order to seize the full opportunity for the development of a European market for climate services.

In defining its vision for the future, the Climate Action and Resource Efficiency Directorate of DG Research and Innovation (European Commission) has identified a small number of 'flagship initiatives' on key areas of public interest in which to invest with priority during Horizon 2020. The area of climate services is one of those.

The objective is to build Europe's resilience to climate change by strengthening significantly the global market for climate services.

An EU agenda for climate services will further add value to the investment already made in Copernicus — which is going to launch an operational 'Climate Change service' (C3S) at European level ([8]) — and provide incentives for developing specific applications in the framework of the Global Earth Observation System of Systems (GEOSS) ([9]) developed through the Group on Earth Observation (GEO) ([10]), and further promote the European Climate Adaptation Platform (Climate-ADAPT) ([11]). It will also contribute to and benefit from the World Meteorological Organisation Organisation's Global Framework for Climate Services (WMO-GFCS) ([12]). Furthermore, it will support the development of national climate services and nurture a new business sector. A number of EU Member States are in fact establishing national climate service centres, whose value will be enhanced by a shared European approach.

([4]) www.ipcc.ch/report/ar5

([5]) European Council 23 and 24 October 2014 (SN79/14): Conclusions on 2030 Climate & Energy Policy Framework

([6]) *An EU Strategy on adaptation to climate change*, COM(2013)216 final of 16 April 2013

([7]) On the role of R&I as a driver for growth, see the EC Communication *Research and innovation as sources of renewed growth*, COM(2014) 339 final of 10 June 2014

([8]) cf. Box 4

([9]) www.earthobservations.org/geoss.php

([10]) www.earthobservations.org

([11]) cf. Box 5

([12]) cf. Box 2

Box 1. Definition of climate services

Being relatively new, various definitions and interpretations exist for the concept of climate services.

For the scope of this document, we attribute to the term a broad meaning, which covers *the transformation of climate-related data — together with other relevant information — into customised products such as projections, forecasts, information, trends, economic analysis, assessments (including technology assessment), counselling on best practices, development and evaluation of solutions and any other service in relation to climate that may be of use for the society at large.*
As such, these services include data, information and knowledge that ***support adaptation, mitigation and disaster risk management*** (DRM).

1.2. Objectives and timeframe of the roadmap

The roadmap builds on the rationale and motivation mentioned above, and proposes a strategy for action. More specifically, the roadmap is intended to do the following.

- Contribute to set an EU research and innovation agenda for climate services, ensuring a coherent and focused framework for action, able to leverage and add value to existing initiatives at EU and national level, as well as to offer a support framework to the regional/local initiatives.
- Propose actions to identify both the enabling conditions and the barriers for the development of a market for climate services, as well as actions that will allow overcoming those barriers and enabling actors to take advantage of the opportunities.
- Define the main activities required at different timeframes (short, medium and long-term) in supporting the growth of a European market for climate services, taking into account both demand-side and supply-side perspectives.
- Identify opportunities for international cooperation and transfer of services beyond Europe.

1.3. Process and methodology

In developing its strategy, the European Commission has engaged with the research community and a wide range of stakeholders from the public and private sector — representing users, suppliers, purveyors and intermediaries — in a forward looking discussion on the development of a market for climate services.

This process started with the workshop 'Towards a European market for climate services' (Brussels, 18 March 2014), which produced some actionable conclusions ([13]), that were operationalised by the Commission services.

These conclusions were as well taken into account by the Advisory Group of the Horizon 2020 Societal Challenge 'Climate action, environment, resource efficiency and raw materials' (SC5), which produced a report — containing a section on climate services — that was used for launching a stakeholder consultation in May-June 2014 ([14]).

Following upon one of the key March 2014 workshop conclusions and taking stock of the elaboration of the SC5 Advisory Group, an *ad hoc* independent expert group was set up, with the mandate to develop a long-term research and innovation roadmap for climate services.

The expert group has worked closely with a larger supporting group, which included representatives from relevant Commission services and relevant European initiatives in the field — such as Copernicus and the Climate-KIC of the EIT. A management team of DG Research and Innovation within the Directorate 'Climate action and resource efficiency' has steered the process, acted as meeting facilitator and has supported the stakeholder consultation and the roadmap drafting.

The expert group held several meetings and teleconferences, carried out dedicated consultations and hearings with selected stakeholders and analysed the available literature, in particular the documents delivered by various EU-funded projects, by the Joint Programming Initiative (JPI) on Climate (JPI-Climate), and by several European climate service centres. The roadmap drafting was facilitated by the expert group rapporteur.

([13]) cf. Reference documents and web resources

([14]) cf. Annexes. Complete report available at: http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetailDoc&id=14223&no=1

2. The climate services landscape: the basis for action

2.1. The global context, actors and initiatives

The European and international landscape of climate services has been the subject of a document prepared for the 18 March 2014 EC workshop ([15]) and of other reviews, like those carried out by the relevant EU-funded projects ([16]) and by JPI-Climate ([17]). They constitute a relevant information source which has been used by the expert group for preparing this roadmap.

The main message coming from the above-mentioned reviews is that the growth of climate services centres, mainly in the public sphere, is mostly linked to the national meteorological services, which generally represent national centres of competence on climate science. Moreover, the Global Framework for Climate Services (GFCS) ([18]) is an initiative of the World Meteorological Organisation (WMO), a global institution that federates all national meteorological services.

Although there are substantial similarities between models and methods used in meteorology and those used in climate modelling, the provision of climate services implies the capability of using other data sources and the mastering of competences which are not always available in meteorological services. Moreover, without a single interpretation of what climate services are, the national climate services centres which grew in Europe and worldwide in the recent years

([15]) cf. Reference documents and web resources
([16]) The list of relevant EU funded projects can be found under: Reference documents and web resources
([17]) www.jpi-climate.eu
([18]) cf. Box 2, www.gfcs-climate.org

Box 2. The Global Framework for Climate Services (GFCS)

The World Meteorological Organisation (WMO) launched the process for developing the Global Framework for Climate Services (GFCS) at the World Climate Conference 3 (WCC-3) in September 2009. The vision was to turn scientific information from climate monitoring, research and modelling into operationally available information and services that would help society to better cope with climate variability and change. The GFCS seeks to enable 'better management of the risks of climate variability and change and adaptation to climate change, through the development and incorporation of science-based climate information and prediction into planning, policy and practice on the global, regional and national scale'.

The initial four priority areas of the GFCS are: (1) agriculture and food security, (2) disaster risk reduction, (3) health, and (4) water. The regional focus is on Africa. The GFCS now consists of five components: (1) observations and monitoring, (2) research, modelling, and prediction, (3) Climate Services Information System (CSIS), (4) User Interface Platform (UIP) and (5) Capacity Development (CD), which cuts across all the other four components.

Box 3. European national climate services centres: various models and products

Different types of climate services have been developed in recent years: on the one hand, large companies have developed dedicated departments for the incorporation of climate services and the promotion of climate-smart products in-house, e.g. the re-insurance industry. On the other hand, different models of climate services with public or private funding have been established, providing external services and products. The latter include, among others, physical data and data products like maps and charts, synthesis reports, guidance documents and consultancies for business strategies.

Type of climate services providers/ purveyors	Strengths	Weaknesses	Cultural background
Extension of meteorological services.	Strong infrastructure.	Main focus on physical data, limited socio-economic aspects.	Meteorology/hydrology.
Public climate services centres (not from meteorological services).	Fit for purpose.	Limited business orientations.	Multidisciplinary.
Services offered by a university or a group of universities.	Often include physical and socio-economic competences, research oriented.	Little user knowledge.	Multidisciplinary, academic.
Private business development.	Business orientation, user knowledge.	Dependence on external climate information.	Multidisciplinary, business.
Incorporation of climate information management in business consulting services.	Very good knowledge of users' needs, integration with other consulting needs, cost-orientation.	Limited climate knowledge.	Economic, business, marketing.

follow different models and have different strength and weaknesses ([19]).

Within the European landscape, a new key initiative — the Copernicus Climate Change service (C3S) ([20]) — has been launched in 2014 after several years of preparation through the Global Monitoring for Environment and Security (GMES) programme of the European Commission. A delegation agreement for the operationalisation of the C3S has been recently signed between the EC and the European Centre for Medium-range Weather Forecasts (ECMWF), an international organisation based in Reading, UK. The C3S should enter soon in a pre-operational phase, and progressively by 2020 should be capable of delivering on a free and open access basis 33 Essential Climate Variables (ECVs) and a number of indices and information for supporting services for 8-10 economic/societal sectors.

A business area is slowly growing, in the field of provision of customised high added-value services to a range of private and public users. This business area is still small, also due to the fact that the awareness of climate change impacts has started to influence business and people's decisions only recently, and that only recently climate intelligence has started to become a requirement — for instance in the preparation of dossiers for banking the funding of infrastructures. However, the market potential looks to be large, but still untapped.

Companies providing climate services are still of small size, frequently established by groups of climate scientists as consulting businesses. However, large business consultancies are also starting to incorporate climate change impact analyses in their business consulting operations, and large companies are starting to acquire climate competences for their in-house operations — and this goes beyond the well-known cases of risk assessment departments of re-insurance companies.

Climate information can also be organised and provided through *ad hoc* web-based tools and platforms, such as the Climate-ADAPT platform ([21]) managed by European Environment Agency (EEA).

Climate science is still highly functional to the development of climate services, in particular by improving the predictive capacities across time and spatial scales, and through the co-design of service products to be established with relevant stakeholders. This is already reflected in Horizon 2020, in the strategic research agenda of JPI-Climate, in national research programmes, internationally in the World Climate Research Programme (WCRP) Grand Challenges, as well in the actions carried out by Climate-KIC of the EIT which is bridging science and innovation with entrepreneurship and creation of new business.

In this context, the present roadmap has the ambition to provide a framework of actions with the objective of promoting the growth of a European market of climate services.

([21]) cf. Box 5

Box 4. The Copernicus Climate Change service (C3S) ([1])

The service will combine observations of the climate system with the latest science to develop authoritative, quality-assured information about the past, current and future states of the climate in Europe and worldwide. The service will benefit from a network of observations, both from in situ and satellite sensors, and modelling capabilities. Moreover, it will provide key indicators on climate change drivers (such as carbon dioxide) and impacts (such as reducing glaciers).

The service will deliver substantial economic value to Europe by: (1) informing policy development to protect European citizens from climate-related hazards such as high-impact weather events, (2) improving planning of mitigations and adaptation practices for key human and societal activities, (3) promoting the development of new services by providing datasets and tools following and free and open data policy.

The portfolio of service products will include consistent estimates of multiple ECVs, global and regional reanalyses (covering a comprehensive Earth-system domain: atmosphere, ocean, land, carbon), products based on observations alone (gridded; homogenised station series; reprocessed climate data records), a near-real-time climate monitoring facility, multi-model seasonal forecasts and climate projections and scenarios at global and regional scales.

This wealth of climate information will be the basis for generating a wide variety of climate indicators aimed at supporting adaptation and mitigation policies in Europe in a number of sectors including (but not restricted to) energy, water management, agriculture and forestry, insurance, health, tourism, infrastructure, disaster risk reduction, coastal areas.

The service will be fully operational by 2018, and will be continually and independently evaluated and improved, to ensure that C3S represents the latest developments in climate science and that innovative service elements are introduced reflecting current research. Appropriate channels and interfaces with research and innovation activities in Europe will be established to ensure an efficient transfer from research to operational climate service related activities.

([1]) www.copernicus.eu/pages-principales/services/climate-change

The vision is that the growth of Copernicus and of national climate services centres should make available — on a free and open access basis — a wealth of data, data products, model results and indices. Their availability should steer the growth of business operators capable of providing customised and specialised high added-value services to a growing landscape of users.

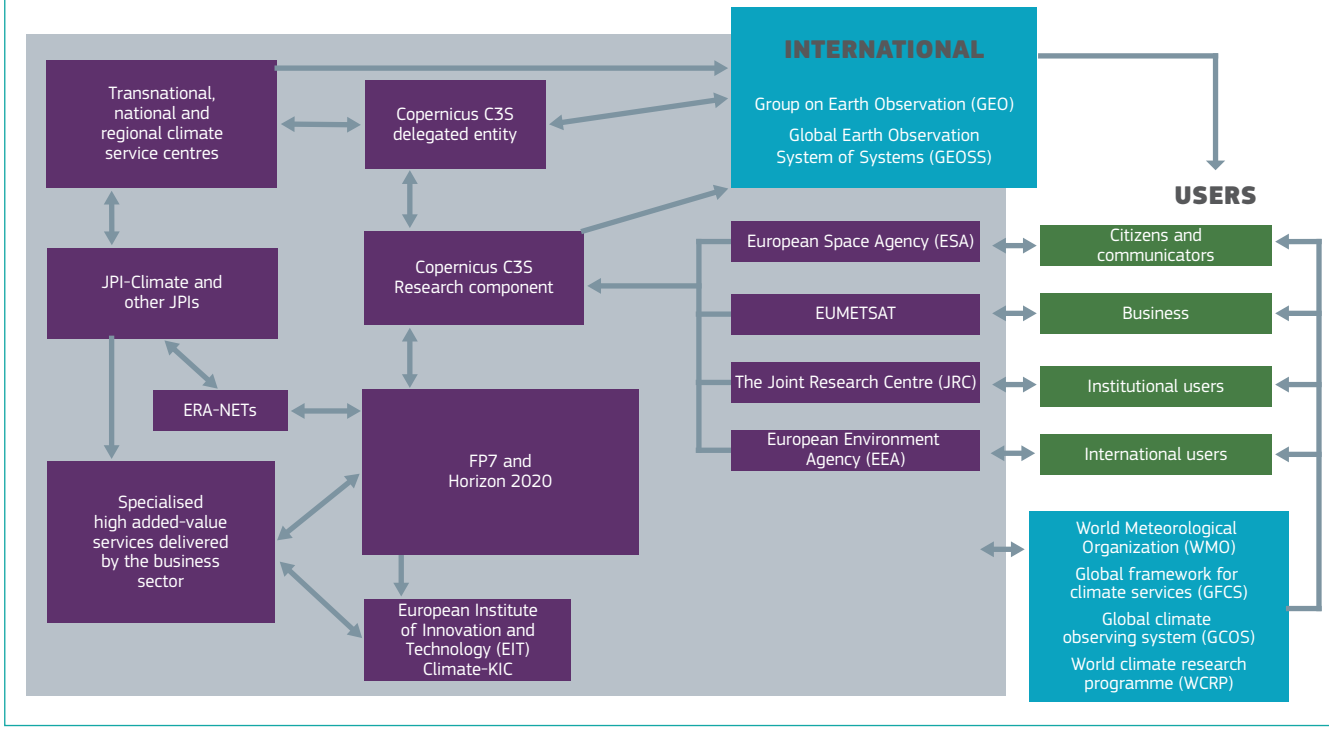
The growth of this market — that will be promoted by the implementation of this roadmap — will create new demand and demand of higher service quality, thus generating in turn new demand for research and innovation. The feedback from the operational services to research will add strategic dynamics to market development.

Research and innovation supporting climate services is therefore important, as the capacity for providing relevant, credible and accessible climate services at the required spatial and temporal resolutions that can inform decisions remains limited.

A conceptual scheme representing the relationships among various actors and initiatives is reported in **Figure 1.** As reflected in this scheme, there is space and reasons for the required research and innovation actions at various levels:

- actions under the EU Framework Programmes for Research and Innovation (FP7 and Horizon 2020),
- actions under Copernicus,
- actions promoted and funded by Joint Programming Initiatives (JPI-Climate; JPI-Water; agriculture, food security and climate change (FACCE-JPI), etc.),
- actions promoted by JPIs and co-funded by the European Commission,
- actions carried out at EU Member State and at regional levels outside JPIs,
- international cooperation actions with partners beyond the EU,
- actions funded by other European bodies (e.g. European Space Agency (ESA)),
- actions funded by other entities and the private sector (e.g. the EIT Climate-KIC).

Figure 1. Scheme of relationships within the European climate services landscape



Box 5. The European Climate Adaptation Platform (Climate-ADAPT) ([1])

Climate-ADAPT is an interactive web-based tool on adaptation to climate change. It is hosted and managed by the EEA. Climate-ADAPT aims to support Europe in adapting to climate change by helping users to access and share best practices and information on: (1) expected climate change in Europe, (2) current and future vulnerability of regions and sectors, (3) national and transnational adaptation strategies, (4) adaptation case studies and potential adaptation options, (5) tools that support adaptation planning.

In 2014, the platform was enriched by an online visualisation tool for observations and projections for a set of climate change parameters and indicators based on European state-of-the-art climate models. As a climate knowledge intelligent portal, it can be considered as a sort of climate service platform.

([1]) http://climate-adapt.eea.europa.eu

2.2. Stakeholder consultation and analysis

The development of the roadmap relied on the analysis and consultation of the relevant stakeholders, which aimed at: identifying their needs, constraints and capabilities; understanding their potential role in developing a climate services market, and surveying their interest and availability to engage in the process. This work, already started with the Workshop 'Towards a European Market for Climate Services', continued with a public online stakeholders consultation based on the Horizon 2020 SC5 Advisory Group report ([22]) and was further developed through a focused user-oriented survey (September 2014), especially designed to support the expert group work. It benefited as well from the available literature, and in particular from the relevant FP7 projects on climate services which carried out related stakeholder consultations ([23]). The expert group members themselves were also selected in their capacity to represent and reach out to different stakeholder communities.

2.2.1. Public online consultation on Horizon 2020 priorities, including climate services

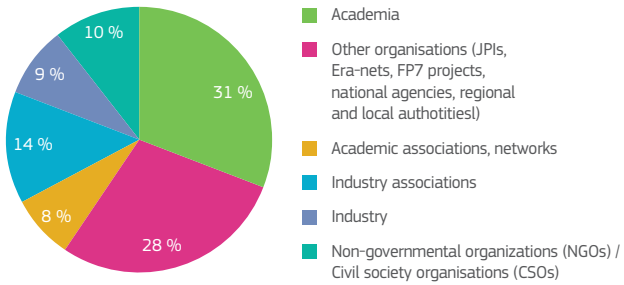
The online stakeholder consultation was a general public consultation on potential priorities for EU research and innovation funding in the field of climate action, environment, resource efficiency and raw materials (Societal Challenge 5) in the Horizon 2020 work programme 2016-2017. The consultation was open from 14 May 2014 to 23 June 2014 and publicly accessible on the Horizon 2020 website. Some relevant stakeholders were directly contacted through e-mail and invited to contribute, such as industrial organisations, including European Technology Platforms (ETPs), financial organisations, foundations, non-governmental organisations (NGOs) and regional stakeholders. A total of 139 contributions were received, 24 from individual respondents and 115 from organisations. Most individual respondents were affiliated with academic institutions. The type of organisations that participated in the public consultation was dominated by academic institutions and associations.

Climate change and services were not the only topic covered by the consultation, but were often mentioned in the stakeholders' contributions. Over 25 % of contributions were broadly relevant to the topic, and around 20 % very relevant to the topic.

According to respondents, one key issue in this field consisted of '*improving climate information/projections at regional level and the capacity to provide 'regional perspectives' of changes, risks and impacts at timescales (seasonal to inter-annual to decadal) that were relevant for decisions to businesses, industry and local authorities.*

Climate change services were understood in a broad sense, including climate change-related forecasts and risk/vulnerability assessments (not forgetting risks that are currently less understood, such as those related to water stewardship, forest commodities or supply chain resilience). It was also noted that *research on high-resolution regional modelling* was essential in order to improve our capacity to assess impacts and risks.

Figure 2. Breakdown of organisational contributors by nature of the organisation



To develop a climate change services market, a need emerged to '*strengthen the provider-user interface*, whereas currently there is only limited consideration of the products needed by the users. It is also necessary to create appropriate 'communities of practices' and emphasise the co-design of climate services products. Overall, appropriate involvement of stakeholders was highlighted as a key element to identify users' needs, develop users' capacity and improve the exploitation of existing capabilities.

The predominant vision in the public consultation focused on development of a *public-private climate services market, based on free and open basic services*. Building on this, small to medium-sized enterprises (SMEs) and other businesses would provide fee-based highly customised climate services for specific needs/customers.

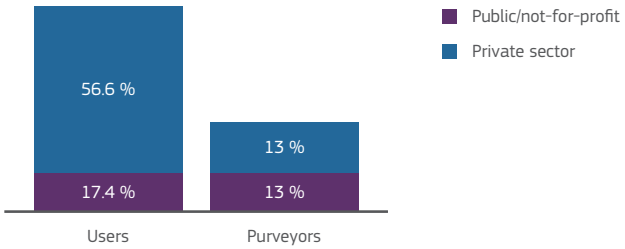
Stakeholders recommended maintaining and expanding observation and monitoring systems. New observation systems that take advantage of new technologies and trends; targeting global (e.g. nutrient cycles, carbon budgets, land-use, water) and also local information/parameters is key to fostering the establishment of a market for climate services. Both space and in-situ measurements should be considered.

2.2.2. Focused user-oriented survey on climate services

Building on the existing literature, and on the results of the public consultation on the 2016-17 Horizon 2020 programming cycle, a focused survey has been developed to further support the expert group work. The survey expressly addressed the actual or potential end users, and different kind of intermediary organisations between information providers and users (the so called *purveyors*). Those stakeholders groups were chosen either because they were underrepresented in the first consultation and in the available literature, or were not easily reachable through the existing climate services networks, which mainly include data providers, research centres and academia. The objective was to understand stakeholders' attitudes, needs,

([22]) cf. Reference documents and web resources
([23]) cf. Reference documents and web resources

Figure 3. Breakdown of respondents in climate services users/purveyors



constraints and capabilities regarding the use and provision of climate services.

An *ad hoc* open questionnaire ([24]) has been designed and used to conduct interviews as well as hearings for a qualitative survey of the selected group. A sample of 23 stakeholders was identified and surveyed in September 2014. In depth 1-hour interviews were held with 18 stakeholders, while five stakeholders had 1-hour hearings with the expert group and supporting group members. The people interviewed covered key positions within their organisations, either (potential) climate services purveyors or users. Purveyors were surveyed also in their role of users of data providers' services.

For the user groups, the sample was determined in order to cover the main categories described in **Table 2**.

The sectors covered included agriculture and forestry, energy networks, logistics, retailing, the chemical industry, insurance, banks and investment groups, city planning, national adaptation policy. For the private sector, multinational companies, SMEs and business associations were represented in the sample.

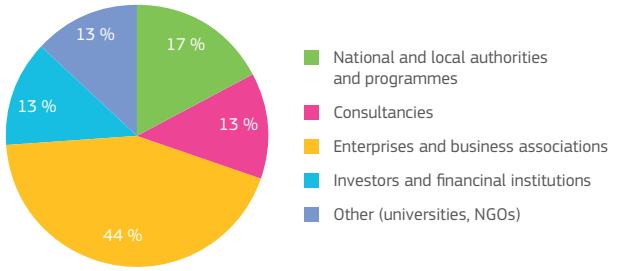
A summary of the key outcomes is presented below along three main themes.

a. Perception of climate change and relative importance in decision-making

All stakeholders confirm that they consider climate change to have an impact on their organisation/activities. With few exceptions, climate change is hardly dealt with in a strategic way, but rather sparsely, on demand, if related to legal requirements or specific business operation and investment. *Overall, climate/weather information is considered in the sampled organisations, but plays a minor role in decision-making*, which is mainly driven by policies, regulations, and market considerations, such as commodities prices, labour conditions and competition.

([24]) cf. Reference documents and web resources

Figure 4. Breakdown of respondents by type of organisation



Short-term weather forecasts and the impact of extreme events are in most cases considered very relevant for decision-making. Long-term climate change is either considered less relevant (with the main exception of sectors linked to mitigation policies and bound to GHG reductions) or, even if considered relevant, it proves difficult to integrate it into the decision-making/investment cycle. This asynchrony between the planning and investment time (or better, the time of return on investments) and the timeframe for climate change impact is among the main constraints to the strategic use of climate services (see dedicated point (b)).

b. The demand for climate services (drivers and barriers)

Three main drivers or reasons encouraging the use of climate information have been identified, mostly in the private sector.

- *Economic benefits* (mainly costs saving), e.g. adopting resources-efficient processes and technologies, identifying the appropriate suppliers, selecting the right

Table 2. User categorisation table

Type/nature of decision	Example of user groups	Character of the service
Relatively complex decisions in relation to a single or a well-identified set of short-to-medium-term climate indicators.	Agriculture, wind energy, solar energy.	Highly focused and customised, technical, related to business processes.
Relatively complex decisions in relation to a single or a well-identified set of long-term climate indicators.	Infrastructure development (dams, railways, energy networks etc.); forestry.	Medium focus/customisation.
Decisions requiring the integration of multiple sets of complex information.	City planners, companies relying on sensitive or complex/long value chains.	Highly integrated, trans-disciplinary.
Decisions having strong impacts on properties and assets.	Flood protection managers, insurance, banks, investors.	Relevant element of costing.
Policy development.	Policymakers, business organisations, trade unions, citizens.	Mainly in relation to adaptation and mitigation strategies and economic evaluation.

species/varieties/breeds in agriculture and forestry, optimising the logistics and mitigating its possible disruptions.

- *Positioning the organisation towards relevant publics*, e.g. corporate social responsibility (CSR), branding or green labelling, and customer satisfaction.

- *Policy push*, referring to meeting current legal requirements or anticipating possible future legal requirements ('fear of legislation'), e.g. regulation, standards, green procurement, and voluntary schemes.

Among the constraints in using climate services, three emerged as critical.

- *Difficulty in integrating the available climate information with the organisation's logics*, management practices and with the other socioeconomic factors influencing decision-making (this covers but goes beyond the mere compatibility of data and information).

- *Different timeframes for climate change impact and for planning, investment and return on investment cycles*. While the timeframe for climate change impact goes from decades to centuries, the planning cycle is usually 20 years, and the timeframe for return on investments is often 3-5 years. This does not necessarily apply to the infrastructure sectors and other long-term assets, and is likely to change in the near future, when the lifecycle of new facilities will start spanning beyond 2050, when the impacts of climate change are expected to become more evident and important.
  This constraint is particularly relevant for the majority of SMEs, which in the current European economic scenario have to struggle for their short-term sustainability. In addition, the short turnover time for decision-makers (both chief executive officers (CEOs) and governments) reinforces this asynchrony between climate and decision-making cycles.

- *Translating in economic/monetary terms the implications of climate change for a given organisation* proves challenging. This equally applies to presenting a proposal to a board of directors, a bank or a national ministry of finance.

As climate change is not among the main criteria informing decisions, *(potential) end-users are often reluctant to adopt new planning methods and models, assessing the climate component per se*. Where climate adaptation and/or mitigation are addressed is rather integrated into existing approaches/processes, e.g. environmental impact and/or risk assessment, CSR — though the relative importance attributed to the various components can vary significantly. The very term 'climate services' is not commonly used in their working context, even when the organisations are actual users or purveyors of climate services. In the context of DRM and adaptation, 'adaptation services' is more common, while in the context of mitigation and energy, a different wording is used, referring to carbon and energy market consultancy.

Product development is demand-driven, e.g. in the insurance sector, *and it is hardly possible to push the use of climate services without a proper marketing or capacity building at the level of final users*. From the purveyors' point of view, better assessing and presenting the indirect impacts of climate change and the multiple benefits of climate-wise solutions can overcome some of the identified barriers, and better market the services to clients.

In summary, *a certain demand for climate services already exists but is not very obvious and rather related to existing processes*. This varies greatly between SMEs and big multinationals, between public and private sectors, and within sectors. The business community does conduct risk assessments, and climate services could play an important role there, but mostly embedded in existing processes. If provided fit-for-purpose, climate services are more attractive if they save costs or provide opportunities that can be monetarily assessed. Businesses would pay for the entire consultancy process and not for a climate service per se.

c. Attributes and modes of delivery of required services

Although the need for higher resolution of information which is better at addressing uncertainties, and enhanced data compatibility are mentioned, these are hardly the main concern in evaluating climate services. Key attributes of required services emerged to be as follows.

- *Reliability*. This applies to both providers and services. Reputable, trustworthy sources are sought by users, whereas the definition of what a reliable provider is varies significantly. However reputation, size of organisation, public character, independence, and closeness to the raw data generation process are recurring elements in the definition. Reliability of services/information is often assessed by direct experience (comparison with in-house information, historical data, past performances, etc.).

- *Fit-for-purpose*. This is linked to the need for users to be guided in the scattered market of available resources, have information translated into their own language and logics, and integrated into their priorities, business culture, working practice and tools. Related to this is the demand for climate information that can be treated in economic/monetary term and thus play a role in planning and investment decisions.

- *Usability*. Rather than better science, most interviewees advocated practical, solution-oriented instruments, such as sectorial guidance and best practices, success and business cases, user-friendly tools and learning materials. As an interviewee said 'sophistication of models is already beyond sophistication of users'.

A bulk of core, publicly funded data are expected to be accessible free of charge, but most stakeholders would be willing to pay for customised, integrated services, provided that they bring demonstrable benefits. Indeed businesses do

already pay for climate services if this translates into cost savings.

In case of those businesses which develop sustainability and/or adaptation policies, the gradual internalisation of climate services can be observed. While at first they may buy advice on the market when they first launch relevant activities, over time they may hire experienced staff to carry out such activities in-house (e.g. carbon-related assessments).

Stakeholders belong to communities and establish relations of trust. Strong linkages are observed between the world of consultancy and enterprise on one hand, and between academia and the public sector on the other. Relationships exist also between consultancies and the public sector (e.g. land use planning), but the linkage is weaker between academia and businesses. Enterprises act in networks and pose climate-related questions within their community of peers. *Existing communities appear to be the appropriate entry point for the end-users of climate services.*

2.2.3. Priorities identified through the stakeholder analysis

The analysis of the relevant literature, Horizon 2020 public consultation and the focused survey has led to identify the following priorities, which have been reflected in the roadmap.

- *Stronger focus on the demand-side and on the provider-user interface* is needed for a proper market development, whereas climate services so far have been mainly supply-driven. This ranges from assessing users' needs and constraints, to engaging users, purveyors and providers in climate services co-design and co-development, building their capacity and demonstrating the climate services added value through users-driven demonstration activities.

- *Multidisciplinary approach and innovation*. Cooperation among providers, purveyors and users, as well as among physical scientists, social scientists, economists, behavioural experts, practitioners, software and interface designers is needed for prioritising research efforts, co-design and delivery innovative fit-for-purpose services.

- *Integrating climate information with multiple data sources and with user organisation logics*, practices, existing processes and tools, and the other socioeconomic criteria determining decision-making.

- *Improving regional modelling capabilities, and the capacity to provide regional and sectoral assessments of changes, risks and impacts at timescales (seasonal to inter-annual to decadal) relevant for decisions to businesses, industry and local authorities.*

- *Building capacities and 'communities of practice'*. Strengthening existing capabilities and building the appropriate expertise at user, purveyor and supplier levels will support the products and market development. Purveyors, in their capacity to link providers and users, and multipliers, such as networks, business organisations, existing platform and communities, front-runners and market/opinion leaders are key targets.

- *Quality control, certification and standards* have to be addressed to reinforce the relationships of trust between offer and demand, which is crucial for a healthy market.

3. Guiding action: the key challenges

Significantly strengthening the market for climate services towards supporting the building of Europe's resilience to climate change and its capacity to design a low-carbon future will require targeted research and innovation investments. These investments are required to provide the evidence, knowledge and innovations that would identify opportunities, and explore and deliver the means for fuelling the growth of this market. The nature of these investments was reflected in the conclusions of the Workshop 'Towards a European Market of Climate Services' (18 March, 2014) ([25]) which specifically identified that growing the market would require the following.

- A focus on both the demand and the supply of the climate services market.
- Co-design and co-production of services engaging users, providers/purveyors and researchers.
- Integrating climate data, information and knowledge with multiple data sources and competencies that are needed to inform decisions.
- Improving modelling capabilities needed to inform decisions and decision-making processes.
- Appropriate data and high performance computing infrastructures.
- Standards, quality assurance and a validation system to guide the development and delivery of climate services.

Considering these requirements in the context of developing an enabling European research and innovation roadmap has led to the identification of three fundamental challenges captured under the following titles: *enabling market growth*, *building the market framework*, and *enhancing the quality and relevance of climate services*.

([25]) cf. Reference documents and web resources

Addressing these challenges is seen as both central and critical to growing and sustaining a viable climate services market within Europe. Together, the research and innovation investments that address these challenges can support the development, delivery and use of high added-value and targeted services, thereby growing the market for European climate services that can support policymakers at various levels, decision-makers in the public and private sectors, NGOs, civil society organisations (CSOs), and citizens.

It is particularly noted that these challenges all begin with understanding what is needed (e.g. the decision-making processes and required decisions, and in terms of the required climate services), and bridging these with today's capabilities and tomorrow's possibilities for meeting those needs (e.g. the science, infrastructure and institutional arrangements). Rather than science driven, they reflect the need for a research and innovation roadmap that is user-driven and science informed.

3.1. Enabling market growth

The enabling market growth challenge focuses on understanding the current nature and scope of the demand and supply sides of the climate services market, and identifying where there is potential for growth. It also includes exploring the means of growing the climate services market through demonstrating and promoting the value of climate services and through the use of appropriate business models for developing and delivering relevant and credible climate services.

A strong and vibrant climate services market comprised of public and private domains, based on enabling and addressing users' demands for services and stimulating the development and delivery of quality relevant services is fundamental to supporting the building of Europe's resilience to climate change through climate services.

Addressing this challenge requires market research focused on identifying and understanding the nature and scope of demand and supply of the climate services market and their potential for growth across Europe.

As this is a relatively new and evolving market, investments are needed to develop and test (e.g. through pilot studies) frameworks and mechanisms for monitoring and evaluating both demand and supply, which are capable of reflecting the changing nature and scope of the market. Sustaining this capacity to monitor and evaluate the market is critical and needs to be entrenched within the European climate service community.

Assessments, validated through pilot studies involving users, providers and purveyors, are required to translate users' needs into relevant, credible and accessible climate services. The results of these assessments will need to be confirmed at the European, national and sub-national levels using demonstration projects and case studies at these different levels across Europe.

An aspect of the climate services market that requires better understanding is the implication of the coexistence of both private and public domains within that market, also considering that also the private sector may be the owner of data and data products. This includes the implication for demand and supply, and the nature of relationships between services operating within these two domains that can support the strengthening of the overall market. Working with stakeholders (e.g. through JPI-Climate and Copernicus), these implications should lead to recommendations tested

and validated through pilot and demonstration projects reflecting the different situations across Europe.

Growing the climate services market will require investments to assess and identify means of realising the untapped market potential and to identify means of enhancing awareness of, and promoting, climate services. Delivering on these aspects of the challenge will require engagement of users and providers/purveyors within the European climate service community through foresight research and innovation projects, workshops, and communications and outreach activities, including via JPI-Climate and Copernicus. There is also a need for activities developed working with the climate service community that are directed at enhancing the awareness of climate services and for promoting their use in different sectors and at the local to transnational levels across Europe. These should build on success stories and examples of good practice operating at different levels and within different domains.

A critical aspect of growing the climate services market is demonstrating in a meaningful way the added value of climate services and their use in terms of implications for decision-making processes and the resulting decisions. Delivering such a valuation capability will require frameworks and guidance that clearly reflect the value from the users' perspectives in different sectors and at different levels. It will also need to include consideration of climate services operating as a stand-alone service and as part of a sector-based support service, as well as consideration of the means and criteria by which providers/purveyors value their services. Fundamental to delivery this capacity is the engagement of the climate service community, including in testing through pilot studies and validating and communicating this capacity through demonstration projects at different levels and across public and private domains.

A building block for growing the climate services market is the identification of mature and potential front-runner sectors within which to undertake demonstration projects that would showcase and bring forward the added value of climate services. To this end, a call for ideas ([26]) was launched in December 2014 by the European Commission; its results will be known shortly after the publication of this report.

In the context of enabling a growing market, there is also a need for assessments of the nature of business models that can support the provision of climate services operating within a complex and evolving market. Early signs in the market show that climate services may also be mainstreamed within the traditional business consulting organisations, resulting in an integration of climate information within the more general business consulting products. Moreover, as climate intelligence becomes more relevant for organisations' decision-making processes, climate services may become an in-house resource, as is already the case today for some leading re-insurance companies.

3.2. Building the market framework

The building the market framework challenge focuses on those investments needed to engage the climate service community (users, providers/purveyors and researchers) and to put in place the infrastructures and mechanisms that will support that engagement towards growing a viable climate services market. This includes capacity building, means of assuring the quality of services and providing an enabling environment that allows users and providers/purveyors to effectively contribute to growing the market across Europe and internationally.

Central to strengthening the market for climate services is a sustained and supportive European climate service community within which users, providers and purveyors, and researchers are engaged to support a viable and growing climate services market across Europe. To support the establishment of such a community and sustain the required engagement, there is a need to identify and test the potential nature of that community through pilot studies, including perspective roles and relationships within it and with other relevant communities, as well as supportive structures and mechanisms.

The existence and continued development across Europe of a climate service community with the skills and capacities required to deliver and use climate services are critical to growing the market. Targeted training and capacity building strategies and programmes, including for those countries, areas and sectors where climate services and their use are less mature, should be developed, tested and evaluated through pilot and demonstration actions. The engagement of the climate services community in the design, development, delivery and evaluation of these training and capacity building programmes is essential to sustaining their effectiveness and to facilitating their reach.

A key element of a viable European climate services market rests in the delivering — by Copernicus and by national climate services centres — of a broad and consistent layer of publicly available (free and open access) data, data products, model results, indices and other climate-relevant information that other climate service purveyors (public or private) can use for co-developing a variety of customised high added-value services and service products with and for targeted users.

The nature of climate services, including their use and the development and exploitation of the underlying science, requires effective computing and IT infrastructures. Defining and delivering these infrastructures will need to recognise the diverse capacities that they are to support, and the requirement to support co-design, co-development, co-delivery and co-evaluation of climate services. Assessments of the 'big data' challenges associated with

([26]) https://ec.europa.eu/eusurvey/runner/CALLforIDEAS-SC5

climate services and of potential solutions are also needed, including addressing the implications for computing and IT infrastructures and the required skills and capacity building. The engagement of the climate service community in these assessment and pilot studies to test potential solutions is critical, including moving towards sustaining the capacity to assess challenges and potential solutions in the longer-term. The role of Copernicus, of the national climate services centres and of ESA (as far as satellite data management for ECVs and Earth observation data provision is concerned) and of GEO/GEOSS will be fundamental.

Part of the framework needed to support growing climate services relates to building trust among users, provider/purveyors and researchers, and providing a supportive environment that promotes and enables the development, delivery and use of climate services. One aspect of building trust requires being able to evaluate and demonstrate credibility and assure the quality of climate services and of those providing such services. Delivering these will include working with the climate service community to develop appropriate and meaningful standards and quality assurance and control mechanisms that are based on a needs assessment and testing of options. These standards and schemes will also require supportive governance and other structures and measures (e.g. training and capacity building, demonstration projects, and case studies) to promote and sustain their use and continued development.

The extent to which evidence, data and information are accessible can have implications for the climate services market and its growth. Assessments are needed of the implications for users and providers/purveyors of limited and differentiated/inequitable access, including identifying barriers and enablers to open and free access. The intention is to explore these implications from the perspectives of users and of those operating at different levels and in different domains (public and private) and to develop recommendations for addressing these. It is also intended that the assessments will identify supportive structures and mechanisms, including testing and demonstrating the value of open and free access in terms of supporting decision-making and growing the market.

> Providing commercial climate services may imply the need of elaborating tailored information on the basis of climate projections. In order to provide statistically credible data, the soundest scientific approach is using ensembles of model runs. However, still some of the model runs are only available for research purposes, and not for commercial use, or are granted free and open access after an embargo period. This may constitute a major barrier to the use of state-of-the-art climate information in the provision of climate services. A fully free and open access to model products — or a short embargo period — would generate relevant added value.

Addressing the legal issues associated with developing and using climate services can provide a supportive environment. These include assessing the nature and scope of liabilities associated with the development, provision and use of climate services, as well as the intellectual property (IP) implications, particularly in the context of co-design, co-development and co-delivery of climate services. Means of addressing these implications, along with supportive mechanisms and structures should be developed, tested and demonstrated under different circumstances working with the climate service community.

International cooperation is an important building block of strengthening the climate services market as it can contribute to the growth of climate services through sharing of research results and innovations, and collaboration on the development and delivery of climate services, particularly where decisions and service development are linked internationally. This requires prioritisation of actions, and should focus on delivering added value.

There is particular interest within Europe in supporting sustainable growth of climate services (demand and supply) within LDCs, with a particular focus on those within Africa. Efforts in this area — such as supportive training and capacity building programmes — will need to build on existing initiatives (e.g. GMES for Africa), take advantage of what Copernicus is able to deliver and the broader capacity of European climate service communities.

3.3. Enhancing the quality and relevance of climate services

> The enhancing the quality and relevance of climate services challenge seeks to engage users, providers, purveyors and researchers to identify and provide through co-design, co-development and co-evaluation the improvements and innovations in climate services that are needed to better inform decision-making processes and the resulting decisions.

Research agendas in relation to the science for climate services have already been delivered, such as the report of the European Climate Observations, Modelling and Services (ECOMS) ([27]) of March 2013 ([28]) – particularly in relation to seasonal to decadal forecasting — the Strategic Research Agenda of JPI-Climate in relation to climate services ([29]), and within the WCRP Grand Challenges ([30]). The programmes for the Copernicus C3S already consider a supporting and long-lasting reanalysis activity. Other documents, such as those of the Infrastructure for the European Network for Earth System Modelling (IS-ENES2) project ([31]) dealing with high performance computing, address issues in relation to data infrastructure. The present roadmap does not address the level of detail of the above-mentioned documents, but puts these scientific developments in the context of the co-design

([27]) ECOMS represents the cluster of all EU-funded projects in the field.
([28]) Report available at: http://www.euporias.eu/system/files/D2.1_Final.pdf
([29]) www.jpi-climate.eu/jpi-themes/research-agenda
([30]) www.wcrp-climate.org/grand-challenges
([31]) https://verc.enes.org/ISENES2

and co-development processes that are needed to engage stakeholders within the climate service community and grow the climate services market.

The starting point for these developments is in fact based on assessing users' needs and capabilities and then relating these to the existing science (data, modelling and decision-support resources), and the needs and priorities for further development in that science. This also includes investments in research and innovation needed to translate these improvements into relevant, usable, trustworthy and credible climate services (including their presentation and accessibility). Critical to addressing this challenge are the means to link and demonstrate the added value of proposed and realised improvements in science from the intended users' perspectives.

Integration and framing of data and information to support decision-making is fundamental to enhancing the quality and relevance of climate services. Effective decision-making must draw on a variety of physical data, socioeconomic, and other non-physical data and information. Their integration and framing to support decision-making processes, including impacts, vulnerability and risk assessments, are critical to improving the quality and robustness of decisions. To this end, assessments are needed to identify data and information sources of interest (including data and information from in-situ and remote sources, from business and industrial sources, and qualitative information and traditional knowledge) where integration will deliver demonstrable benefits to users. Initially focusing on those sectors or decisions where early benefits could be realised, these assessments should lead to the development of coherent sets of data and information and identification of the means of integrating them into decision-making processes. Working with users and providers/purveyors is also required, in order to interpret the results of these assessments in terms of the design and development of salient and legitimate climate services. As the aim is to inform further integration and development of associated climate services, these assessments should also lead to the development of tested and validated standards and protocols supported by demonstration projects and case studies that support learning.

> In order to maximise the impact and the effectiveness of the proposed activities, their implementation plans should foresee specific interfaces with operational services, such as the Copernicus programme. This will allow taking into account the operational products development and the research and innovation needs identified through the practice of operational services and through the users' feedback.

An essential aspect of framing data and information is related to the inclusion and presentation of the associated uncertainties. There is wide space for research and practice for increasing the effectiveness of the use of uncertain information under different decision framings. New supportive methods and guidance will be developed, tested and then further explored in different sectors and decision-making processes through demonstration projects and case studies.

A critical element of enhancing the quality and relevance of climate services is strengthening the scientific basis of the modelling and predictive aspects behind those services. As such, realising these improvements begins with identifying and prioritising where decision-making processes and decisions could experience meaningful and demonstrable benefits from improvements in models (e.g. higher spatial and temporal resolutions and improved representation of processes) and decision-support resources. This should lead to recommendations on priorities, particularly identifying those that could potentially lead to early demonstrable benefits.

Demonstration actions in front-runner sectors have been already proposed in Chapter 3.1. The co-evaluation of the resulting services should not only support the further development and improvement of the targeted climate services, but also lead to identifying where additional improvements in models and decision-support resources are needed.

The development of climate services in less mature sectors and decision areas also requires a trans-disciplinary approach of co-design, co-development and co-evaluation, with the objective of identifying where and how the use of climate intelligence in decision-making processes can provide real added value from the users' perspectives.

> In the context of growing the climate services market, improvements in data and information, modelling and decision-support resources should be those required to realise meaningful and demonstrable benefits for the intended users and their decision-making processes and decisions. The resulting processes and procedures should be tested and refined through pilot studies that involve the engagement of the intended users, and incorporated into the above-described demonstrations and case studies.

Enhancing the quality and relevance of climate services will require the development and introduction of service and product innovations — such as data visualisation, processing interfaces, web tools, applications (apps), etc. —, in the form of sets of standard tools, products and protocols, along with knowledge sharing protocols. Testing and validation of these innovations should lead to demonstration projects and case studies that should promote and enable their use, and support the development and promotion of further innovation.

4. A European research and innovation Roadmap for Climate Services

The roadmap defines a coherent set of activities, the nine *Main activities*, to be deployed to address the three key challenge identified and explained in the previous chapter. Each main activity comprises a number of *Specific actions,* for a total of 25 specific actions. Each specific action is described along four dimensions: expected outcomes, instruments, potential actors and time horizon.

Expected outcomes refer to the content and intended results of a given specific action.

Instruments refer to the type of activities which are appropriate in order to implement the proposed specific actions. In general, these are *research and innovation activities* in a broad sense, aiming to establish new knowledge and/or to explore the feasibility of a new or improved technology, product, process, service or solution. They can include basic and applied research, technology development and integration, small-scale testing and validation.

Studies are smaller size projects, which do not include a substantial validation component, whereas *pilot studies* include testing and validation of new concepts, methods, and recommendations. Studies, pilot activities, workshops and expert groups can be combined under larger research and innovation projects.

In the case of activities aimed at producing new or improved products, processes or services, entailing test, demonstration, large-scale validation and market replication, the term *Demonstration Projects* is used.

In some cases, proposed instruments go beyond traditional research and innovation projects, e.g. *market research, training and capacity building, communication and outreach activities*. However, such instruments can also be included under research and innovation projects, but on a smaller scale. In case of projects not aimed at creating new knowledge, but at facilitating networking, coordination, dissemination, policy dialogues and mutual learning, the term *Coordination and support action* is used.

Potential actors refer to established organisations, programmes, platforms, and partnerships, which can support or facilitate the implementation of the specific actions identified in the roadmap. When the European Commission is one such actor, only the relevant programmes or initiatives are mentioned (e.g. Horizon 2020, Copernicus, or GEO etc.). In the case of Horizon 2020, the centre of gravity is in the societal challenges (SC) component, in particular SC5 Environment, Climate Action, Resources Efficiency and Raw Materials. Where other Horizon 2020 components are also relevant this is specified in the table. The list of potential actors is limited to EU and international actors, but does not exclude the participation of regional, national and local actors. Where JPI-Climate, JPI-Water or FACCE-JPI are identified, it is also understood that national level actors can play an important role.

Time horizon indicates the timing for the implementation of the different specific actions. The roadmap focuses on those to be implemented in the 6-year timeframe 2015-20, but considers that some actions will span and/or will need support beyond 2020. In the table, short term (ST) refers to 2015-17, medium term (MT) refers to 2018-20, and long term (LT) refers to beyond 2020.

4.1. The roadmap

Table 3.

Specific actions	Expected outcomes	Instruments	Potential actors	Time horizon
Challenge 1: Enabling market growth				
Main activity 1.1: Assessing the nature of the climate services market				
(a) Assessing the climate services market (demand and supply).	• Comprehensive mapping of current and potential users; analysis of their needs and capabilities, assessment of the climate services currently used (in view of purpose and scope). • Assessment of decision-making processes and the potential for, and interest in including climate services. • Assessment of European climate service providers, including operational services such as Copernicus Climate Change service (C3S) and national climate service centres and purveyors; scope of services provided; capabilities and plans; and their respective markets, including the potential for provision of international climate services. This assessment should include an exploration of the roles and relationships among providers and purveyors operating at different levels (e.g. local, national and international), including market access. • Framework/mechanisms to monitor and evaluate the development of the climate services market, including market observatory — potentially as part of the activities/responsibilities within a European climate service community — tested and validated through pilot studies. • Support the definition of the required demonstration projects with case studies (e.g. identify mature markets and front-runners).	Study Market Research Pilot studies	Horizon 2020 JPI-Climate EIT-Climate KIC	ST-MT
(b) Translating users' needs into services and accesses required.	• Translate users' needs into services and accesses required, to inform identification of services and innovation gaps and responses (services co-design). • Qualitative assessments of (i) barriers and (ii) enabling conditions associated with the uptake of climate services, and the exploration of means to address these. • Assessment, supported by pilot and case studies, of the extent to which consideration of climate change is regarded as part of legal and regulatory requirements, and reflected in standards. • Assessment, supported by pilot and case studies, of the extent to which the real needs for climate services are being met and could be better met at the European, national and sub-national levels, respectively.	Workshops Studies Pilot studies/part of demonstration projects	Horizon 2020 JPI-Climate	ST-MT
(c) Exploring the public and private domains of the market.	• Assess the actual and potential role of public and private provision of climate services, including assessment of the services that users are willing to pay for and those they expect to have access to as a public good. • Analyse the potential implications (opportunities and challenges) of the co-existences and linkages of services operating in or across those domains, from the perspective of users (access/quality) and of providers/purveyors (competition, intellectual property rights (IPR)), assessed through pilot and case studies. • Develop recommendations and a framework defining the respective roles (and supporting the coexistence) of both public and private domains, validated through pilot and demonstration activities.	Studies Pilot studies/part of demonstration projects	Horizon 2020 JPI-Climate Copernicus	ST-MT

Specific actions	Expected outcomes	Instruments	Potential actors	Time horizon
Main activity 1.2: Growing the climate services market				
(a) Developing foresight into perspective market growth: identifying untapped potential, and measures to promote market growth.	• Assessment of gaps between users' needs/perceived market potential and services supplied, including recommendations to address those. • A diagnosis about existing bottlenecks and barriers (economic, technical, sociological) for the uptake of climate services, and means to overcome them. • Assessment of the implications of competition and synergies among different provision modes (public/private, EU/national/local level), in view of growing the market and enhancing users' access to appropriate quality services. • Assessment of policy environments and supportive frameworks/guidance (e.g. policy, regulations, standards, and voluntary schemes) in supporting the growth of the climate services market; validated through pilot studies with supportive case studies.	Research and innovation project	Horizon2020 JPIs	ST-MT
(b) Establishing the means of enhancing the awareness of, and promoting climate services.	• Success stories and best practices co-developed by providers and users, and communicated. • Increased awareness across various economic sectors and within local and national government of the benefits of making use of climate services.	Workshops Communication and outreach	Horizon 2020 JPI-Climate FACCE-JPI JPI-Water National programmes	ST-MT
(c) Developing appropriate business models for the provision of climate services.	• Systematic assessment of business models on which climate service providers and purveyors can draw and evaluate their governance, structures and operations (including consideration of relationships between public/private and EU/national/local provision modes). • Case studies supporting the different models and mechanisms for sharing lessons learnt and challenges. • Mainstreaming climate services into the business models of consultancies and other already established purveyors.	Studies/part of demonstration projects Capacity building	Horizon 2020 Copernicus EIT-KIC	ST-MT
Main activity 1.3: Demonstrating the added value				
(a) Identifying mature markets and front-runners	• Identify and assess mature sectors and supportive contexts for the demonstration of the added value of climate services for decisions support.	Call for ideas	Horizon 2020	ST
(b) Demonstrating the impacts and full value of climate services as standalone services and/or integrated into broader decision-support systems.	• Develop frameworks/guidance for the evaluation (expressed in terms of impacts and value from the users' perspectives and the value to the market) of climate services and their use; tested and validated through pilot and demonstration actions with supportive case studies. • Exploration studies supported by demonstration projects that illustrate the value added by including climate services in planning and decision-making (adaptation, mitigation and Disaster Risk Management). • Identification of the basis and criteria used by providers/purveyors to value climate services and their impacts • Assessment of the relationships between climate services and decision-support knowledge exchange services within different sectors. • Demonstration of the value (from the users' perspectives) of a standalone climate service and the value of those services being integrated within sector-based services, including through the use of case studies.	Studies Demonstration projects	Horizon 2020 JPI-Climate FACCE-JPI JPI-Water EIT-KIC	ST-MT

Specific actions	Expected outcomes	Instruments	Potential actors	Time horizon
Challenge 2: Building the market framework				
Main activity 2.1: Communities and infrastructures to support and grow the climate services market				
(a) Developing a viable climate services community that engages users, providers, purveyors and researchers.	• Assessment of current and potential role of a climate service community in developing a market for climate services, including: perceived roles, benefits, scope, barriers and expectations; users', providers', purveyors' and researchers' relative interest and capacity to engage in such a community. • Pilot studies assessing options for structure, mechanisms, governance and funding, including means for facilitating engagement of the climate service community in co-design, co-development, co-evaluation and co-dissemination. • Assessment of the nature and scope of potential membership and the benefits of engagement, including in terms of growing the climate services market, and building and widening European capabilities. • Assessment of means to liaise and collaborate with other relevant communities and platforms at international, EU and national levels, including mainstreaming climate services. • Effective and sustainable climate services community established, supporting the continuous implementation of the relevant specific actions (e.g. market observatory, capacity building, innovation, promotion and awareness raising).	Pilot studies Coordination and support action	Horizon 2020 JPI-Climate FACCE-JPI JPI-Water European Climate Services Partnership	ST- LT
(b) Building and widening capacity for climate services development, provision and use.	• Assessment of skills and capacities required, especially for those working at the supply-demand interface, and those supporting the process-chain of climate services in the context of co-design, co-delivery and co-evaluation. • Assessment of skills and capacities required to extract and use climate services; to engage in their co-design, co-development and co-evaluation; and to support the integration of climate services into different decision-making processes. • Assessment of the varied skills and capacity needs across Europe, including within those countries where the climate service sector and use of climate services are less well developed. • Training and capacity building strategy and programmes co-developed and tested through pilot and demonstration actions. Programmes include secondment/exchanges actions, establishing university and professional curricula, twinning activities (e.g. users with researchers/providers/purveyors, among providers/purveyors, and among users with different capacities to use climate services and engage in their development, as well as among countries, to support the ones where climate services are less developed) and training of trainers. • Evaluation, further development and implementation of the capacity building programme working with the climate service community.	Workshops Studies Pilot activities/ part of demonstration projects Training and capacity building programmes	Horizon 2020 (*including Marie Skłodowska-Curie actions, and Spreading Excellence and Widening Participation*) EIT-Climate KIC National programmes EU Structural Funds	ST MT-LT
(c) Computing, data and IT infrastructure required to develop, deliver and support access/use of climate services.	• Assessment and testing of options for computing and IT infrastructure required across the climate services community to support development (co-design and co-development) and access/use of climate services at the national and European levels. • Options and recommendations to address 'big data' challenges, including: sharing and linking international data centres; identifying the implications in terms of computing and IT infrastructures and the required skills and capacities to deliver the proposed options. • Mechanisms to support engagement of the climate service community in the assessment of options. • Joint and complementary strategies for long-term cooperation between data centres and climate services established.	Study and pilot activities Research Infrastructures actions	Copernicus Horizon2020 *(including Research Infrastructure)* European Strategy Forum on Research Infrastructures (ESFRI)	ST and MT-LT

Specific actions	Expected outcomes	Instruments	Potential actors	Time horizon
Main activity 2.2: Standards, quality assurance and control, access and legal aspects				
(a) Demonstrating credibility and assuring quality of climate services.	• Needs assessment for evaluating, assuring and demonstrating quality/credibility in terms of implications for demand and growing the market. • Assessment and testing of criteria and protocols for quality assurance (QA)/quality control (QC) evaluation and standards and their effectiveness in order to demonstrate the quality of climate services. • Recommendations for standardisation and quality assurance, and governance of such a scheme, recognising the skills and capabilities needed and the key role of users in these processes. • Pilot studies and demonstration projects with supportive case studies at various levels (local to European) and delivery domains (public and private).	Study Pilot studies/part of demonstration projects	Horizon2020 Copernicus JPI-Climate	ST-MT
(b) Implications of limited, and open and free access to data and information for services supply and demand.	• Assessment of the implications of differentiated/inequitable services from the perspective of users and providers/purveyors operating at different levels and in different domains. • Assessment of barriers and enablers supporting open and free access to data, data products and information, and the implications for provision of, and demand for, climate services. • Recommendations to address implications, including governance and mechanisms supported by a series of activities to test their validity and to demonstrate the value of open and free access (supporting decision-making and growing the market).	Expert groups Workshops Pilot studies/part of demonstration projects	Horizon 2020 Copernicus JPI-Climate GEO/GEOSS	ST-MT
(c) Liability in providing climate services and market implications.	• Assessment of the nature and scope of liabilities associated with the development, provision and use of services provided. • Explore, working with the climate service community, options for addressing these liabilities, including consideration of the ethical implications if and where liabilities act as a barrier to the provision and use of services.	Expert groups Workshops Studies	Horizon2020 Copernicus JPI-Climate	MT
(d) IP implications of co-design, co-development and co-delivery	• IP implications associated with co-design, co-development and co-delivery of climate services along the service development and delivery chain. • Recommendations for addressing these implications, supported by a series of activities to test their validity (pilot studies) and supported with a series of demonstration and case studies within different sectors and at different levels that are co-developed with providers, purveyors and users.	Expert groups Workshops Pilot studies/part of demonstration projects	Horizon 2020 JPI Climate	ST-MT
Main activity 2.3: International cooperation				
(a) Engaging the European climate service community internationally.	• Building an analytical framework to assess existing relationships among European and international climate services providers/purveyors and initiatives. • Definition of priorities for joint activities of mutual interest and mechanisms for delivery of these priorities, including recommendations for supporting engagement, such as a possible network. • Pilot studies exploring enabling mechanisms, and transferability of lessons learnt towards enhancing the quality and impacts of the joint activities.	Studies Workshops Pilot studies	Horizon2020 JPIs/Belmont Forum WMO/GFCS Climate Services Partnership	ST-MT and LT
(b) Supporting the growth of climate service capacities (demand and supply) within LDCs, with focus on Africa.	• Assessment of existing climate service capacity, demand and supply within LDCs. • Identification of training and capacity building needed and the potential of European programmes of meeting those demands. • Develop and implement targeted capacity building programmes through appropriate means and mechanisms (e.g. joint projects and pilot activities including secondments/exchanges). • Sustainable programme to continue to support needs.	Studies Workshops Training and capacity building programmes	Horizon 2020 EC–DG International Cooperation and Development, Copernicus WMO/GFCS, National development cooperation agencies	ST-MT

Specific actions	Expected outcomes	Instruments	Potential actors	Time horizon
Challenge 3: Enhancing the quality and relevance of climate services				
Main activity 3.1: information frameworks in support of climate services				
(a) Integration of physical and socioeconomic data and information.	• Assessment of the need for, and availability of, physical, socioeconomic, land-use and other non-physical data and information in the context of supporting adaptation, mitigation and DRM decisions and decision-making processes. • Based on these assessments, integration of the required physical, socioeconomic and other non-physical parameters and information to establish coherent series for the development and delivery of climate services. • Interpretation of the results of these assessments in terms of what they mean for design, development and delivery of salient and legitimate climate services. • Standards and protocols to support the required integration of climate service relevant information; test and validate these, along with case studies to support learning.	Research and innovation projects	Horizon 2020 Copernicus JPI-Climate	ST-MT
(b) Developing standards and protocols for data in support of vulnerability and risk assessments, and decision-support systems.	• Standards and protocols for facilitating incorporation of global and regional observations of physical and non-physical data and information into impacts, vulnerability and risk assessments and related decision-support systems. • Interpretation of what and how these standards and protocols could be used to support the development and delivery of climate services that meet users' needs. • Testing, refining and validating the standards and protocols and their functionality using pilot studies across different sectors and different decision-making framings (co-designed, co-produced and co-evaluated with end users). • Explore options and develop recommendations to facilitate implementation of these standards and protocols, and to support innovations in the development of relevant and credible climate services, and related training activities.	Research and innovation projects	Horizon 2020 GEO Copernicus JPI-Climate	ST - MT
(c) Establishing confidence in, and the role of uncertainty in climate services and decision-support systems.	• Assessment of the roles of uncertainties within decision-making (adaptation, mitigation and DRM), and means of increasing the effectiveness of uncertain information under different decision framings. • Develop methods and guidance for interpreting and integrating uncertainties from different sources (e.g. those associated with climate, socioeconomic and impacts) as a basis for better informing decision-making processes and decisions. • Assess existing and develop appropriate methods and processes of including and presenting uncertainties that enhance the effectiveness and robustness of decision-making processes and the resulting decisions. • Test and validate methods and processes (developed working with users and providers/purveyors) across a number of sectors with case studies to support learning, training and capacity building.	Research and Innovation projects	Horizon 2020 JPI-Climate	ST

Specific actions	Expected outcomes	Instruments	Potential actors	Time horizon
Main activity 3.2: Strengthening the scientific basis and relevance of climate services				
(a) Improving modelling and prediction capacity relevant to improving climate services	• Identify and prioritise improvements in models, models skills and assessment support tools, on the basis of their potential to deliver output which is more relevant to decision-making, including those able to deliver early demonstrable benefits (based on analysis of users' needs and gap analysis of existing climate, impacts and socioeconomic models). • Based on the above, document processes and mechanisms (e.g. criteria, frameworks and protocols) that could be used to undertake future assessments of required improvements, including recommendations as to how these assessments could be undertaken within the climate services community. • Develop the required models and decision-support resources. This includes: spatial and temporal scales (e.g. regional modelling, downscaling and connecting across scales) and higher resolution models consistent with the needs of local and regional decision-makers; treatment and analysis of magnitude and frequency of extremes, including the potential for abrupt changes in systems of relevance to decision-makers; development of consistent reanalyses in support of improved climate predictions; approaches that can best take advantage of imminent advancements in computer architecture. • Identify, working with climate service providers/purveyors and targeted users, implications of these improvements for climate services and their use, including implications for guidance, and training and skill development. • Based on this assessment and working with users, develop the suggested climate services (with the supportive guidance) for different sectors and decision framing with an initial focus on those that are likely to lead to early benefits to users. • Interface with the operational products development, as well as adequate consideration of research and innovation needs emerging from the practice of the operational services, in terms of improving their quality and relevance.	Research and Innovation projects (part of) demonstration projects	Horizon 2020 JPI-Climate National/sectoral actors Copernicus	ST-MT-LT
(b) Developing tools and supportive resources needed by users - local, national and transnational.	• In collaboration with intended users, identify and prioritise required improvements in assessment and decision-support models, methods, tools and other resources needed by users in different sectors to integrate climate services into decision-making processes, including those required to foster consideration of cross-sector interactions. • Evaluation of constraints associated with these resources in terms of implications for service developments and delivery and their uses in decision-making. • In collaboration with users, and considering the experience from operational services, identify and define standards and protocols to support improvements of these decision-support resources, and principles and framework(s) for enabling co-design, co-development and co-evaluation of supportive climate services with refinement and validation. • Based on identified priorities, co-design and co-develop these supportive climate services as demonstration and case (learning) studies. Develop learning and training capacities to broaden the uptake and application of these climate services.	Demonstration projects	Horizon 2020 JPI-Climate National/sectoral actors	ST-MT
(c) Identifying and evaluating the implications of scientific development on climate processes in terms of improving climate services.	• Identify processes and procedures to assess how improved observations, modelling and decision-support resources may lead to improved climate services (e.g. enhanced relevance and credibility), and associated decision-making processes. • Develop, working with users and providers/purveyors (e.g. through the climate service community), means for meaningfully demonstrating and communicating these implications. • Using these processes and procedures, identify the implications of improved observations, modelling and decision-support resources realised through the above main activities. • Demonstrate and communicate the implications of improvements on climate services and associated decision-making processes and decisions.	Pilot studies/ part of demonstration projects Outreach	Horizon 2020 JPI-Climate	ST-MT

Specific actions	Expected outcomes	Instruments	Potential actors	Time horizon
Main activity 3.3: Climate information and end-user needs: innovations and products				
(a) Making better use of available climate information and knowledge.	• Exploration, working with researchers, users and providers/purveyors, of the potential use of existing climate data and information to support adaptation, mitigation and DRM decision. • Improvements in, and provision of credible and relevant climate services based on that existing climate data and information, considering a broad range of sectors (industrial and social) and different decision-making circumstances (local to national and transnational). • Support learning, training and capacity building actions to sustain and broaden climate service applications.	Research and innovation projects Pilot activities/ (part of) demonstration projects	Horizon 2020 JPI-Climate	ST-MT
(b) Making innovations in service products and presentation.	• Identify and prioritise based on assessment of users' and providers'/purveyors' needs and capabilities new processes, methods and tools (including uncertainty information) that can support innovations in climate services and their provision (e.g. analysing and presenting services and processing interfaces), and consideration of where innovations could lead to demonstrable benefits. • Based on this assessment and on an assessment of existing capabilities and planned developments, develop standard tools, products and prototypes, including knowledge sharing protocols. Those to be developed should include relevant and easy-to-use public access online visualisation/graphic tools and other resources, as well as apps for citizens' use. • Explore and test the feasibility and relevance of those developed, leading to demonstration projects and new products, and case studies to support learning and to provide a framework that would support the development and promotion of other innovations, such as citizens' observatories.	Research and innovation projects Pilot activities/ (part of) demonstration projects	Horizon 2020 JPI-Climate Copernicus GEO/GEOSS	ST-MT

4.2. Roadmap time horizon

Table 4.

Specific actions	Time horizon		
	ST: 2015-2017	MT: 2017-2020	LT: 2020 - →
Challenge 1: Enabling market growth			
Main activity 1.1: Assessing the nature of the climate services market			
(a) Assessing the climate services market (demand and supply)	Study Market research	Pilot studies	→
(b) Translating users' needs into services and access required.	Workshops Studies	Pilots and demonstrations	
(c) Exploring the public and private domains of the market.	Studies	Pilots and demonstrations	
Main activity 1.2: Growing the climate services market			
(a) Developing foresight into perspective market growth: identifying untapped potential, and measures to promote market growth.	Research and innovation	Research and innovation	
(b) Establishing means of enhancing the awareness of, and promoting, climate services.	Workshops	Communication and outreach	
(c) Developing appropriate business models for the provision of climate services.	Studies and demonstrations	Demonstrations and capacity building	
Main activity 1.3: Demonstrating the added value			
(a) Identifying mature markets and front-runners.	Call for ideas		
(b) Demonstrating the impacts and full value of climate services as standalone services and/ or integrated into broader decision-support systems.	Studies Demonstration projects	Demonstrations projects	
Challenge 2: Building the market framework			
Main activity 2.1: Communities and infrastructures to support and grow the climate services market			
(a) Developing a viable climate service community that engages users, providers, purveyors and researchers.	Study Pilot studies	Pilot studies Coordination and support	Coordination and support
(b) Building and widening capacity for climate services development, provision and use.	Workshops, studies and pilots	Pilot activities and demonstrations	Training and capacity building
(c) Computing, data and IT infrastructure required to develop, deliver and support access/use of climate services.	Study and pilot activities	Study and pilot activities	Research Infrastructures actions
Main activity 2.2: Standards, quality assurance and control, access and legal aspects			
(a) Demonstrating credibility and assuring the quality of climate services.	Study and pilot studies	Pilots and demonstrations	→
(b) Implications of limited, and open and free access to data and information for services supply and demand.	Expert groups, workshops	Pilot studies and demonstrations	
(c) Liability in providing climate services and market implications.		Expert groups, workshops and studies	→
(d) IP implications of co-design, co-development and co-delivery.	Expert groups, workshops	Pilot and demonstrations	

Specific actions	Time horizon		
	ST: 2015-2017	MT: 2017-2020	LT: 2020 - →
Main activity 2.3: International cooperation			
(a) Engaging the European climate service community internationally	Studies Workshops	Pilot studies	→
(b) Supporting the growth of climate service capacities (demand and supply) within LDCs, with focus on Africa	Studies Workshops	Training and capacity building	→
Challenge 3: Enhancing the quality and relevance of climate services			
Main activity 3.1: Information frameworks in support of climate services			
(a) Integration of physical and socioeconomic data and information.	Research and innovation	Research and innovation	
(b) Developing standards and protocols for data in support of vulnerability and risk assessments, and decision-support systems.	Research and innovation	Research and innovation	
(c) Establishing confidence in and the role of uncertainty in climate services and decision-support systems.	Research and innovation		
Main activity 3.2: Strengthening the scientific basis and relevance of climate services			
(a) Improving modelling and prediction capacity relevant to improve climate services.	Research and innovation, and demonstrations	Research and innovation, and demonstrations	→
(b) Developing tools and supportive resources needed by users - local, national and transnational.	Demonstration projects	Demonstration projects	→
(c) Identifying and evaluating the implications of scientific development on climate processes in terms of improving climate services.	Pilot studies and demonstrations	Pilot studies and demonstrations, Outreach	→
Main activity 3.3: Climate information and end-users' needs: innovations and products			
(a) Making better use of available climate information and knowledge.	Research and innovation, pilot and demonstrations	Research and innovation, pilot and demonstrations	
(b) Making innovations in service products and presentation.	Research and innovation	Pilots and demonstrations	

→ Signifies that there is a need for action/capability to be continued beyond 2020

5. Recommendations for the roadmap implementation

These recommendations cover the aspects considered crucial for an effective roadmap Implementation. They are not listed in order of priority.

- *Promote and support the growth of the climate services market* (demand and supply) across Europe based on an understanding of the evolving needs and capacities of users, providers and purveyors, and the potential for its growth in the context of continuing to provide benefits to society.

- *Engage stakeholders*. Enabling the growth of a market for climate services calls for a stronger focus on the demand side and on the providers-users interface, and for the engagement of stakeholders in the roadmap implementation. Building on market research and foresight studies, the *services co-designed and co-developed* by providers/purveyors and users will ensure that research and innovation in support of climate services is user-driven and science informed.

- *Demonstrate the benefits.* To build the market case for climate service, their added value for decision-making and the resulting decisions will need to be showcased through pilot and demonstration actions in key economic sectors, starting with more mature aspects of the market and where early demonstrable wins are more likely.

- *Build capacities and communities*. Climate services is a relatively new market, calling for increased expertise and awareness of users, providers and purveyors to be built or strengthened, as well as in countries and regions where climate services are less developed. A viable climate services *community* is the appropriate platform for engaging stakeholders, promoting awareness and mutual learning, and facilitating cooperation, both between the actors and in the international context. A viable climate service community will not only contribute to enhancing the quality of the available climate services, but will build trust and provide an effective forum to address the legal and ethical issues related to *quality assurance* and *access.*

- *Ensure the quality and relevance of climate services through targeted advancements* in transdisciplinary science and in the integration of observations and socioeconomic data, and development of decision-relevant prediction tools and methods that also consider the associated infrastructure needs and capacity/skill requirements.

- *Promote and support a trans-disciplinary approach*, to trigger the innovation and the out-of-the-box thinking required to develop fit-for-purpose cutting-edge climate services and solutions.

- *Ensure that scientific advancements and emerging needs in terms of climate information and services continuously feed each other*, with the aim of delivering demonstrable benefits for society.

- *Develop synergies between the key players on the supply side (Copernicus and the national climate services centres) and 'second-tier' operators.* The former should ensure the provision of a broad and consistent layer of public, free and open access data, data products, model results, indices and climate information; the latter should use such products for providing customised high added-value services and service products to users, thus developing a healthy market dynamics.

Reference documents and web resources

Climate Service Center 2.0, www.climate-service-center.de/053206/index_0053206.html.en
- Report 15 - Mapping of Climate Service Providers. Theoretical Foundation and Empirical Results: A German Case Study, www.climate-service-center.de/imperia/md/content/csc/csc_report15.pdf

Climate Services Partnership, www.climate-services.org

Climate-ADAPT, The European Climate Adaptation Platform, http://climate-adapt.eea.europa.eu/

CMCC, Centro euro-Mediterraneo Cambiamenti Climatici, Mapping of Climate Service Providers in Italy: summary Report February 2014, www.cmcc.it/wp-content/uploads/2014/03/rp0213-serc-02-2014.pdf

Copernicus, the European Earth System Monitoring Programme, www.copernicus.eu
- Copernicus Climate Change Service, www.copernicus.eu/pages-principales/services/climate-change
- Copernicus Climate Change Projects, www.copernicus.eu/pages-principales/projects/other-fp7-projects/climate-change

EC, Communication 'An EU Strategy on adaptation to climate change', COM(2013)216 final of 16 April 2013, http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52013DC0216

EC, Communication 'Research and innovation as sources of renewed growth' COM(2014) 339 final of 10 June 2014, http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52014DC0339

EC flagship initiative on Climate Services, http://bit.ly/EUClimServ

EC, WS 18/03/14 background document - Research and innovation activities in the field of climate services in the Work Programme 2014-15 of Horizon 2020, http://bit.ly/EUClimServ

EC, WS 18/03/14 background document - The European Landscape on Climate Services - A short note with focus on Climate Service initiatives promoted by or with the support of the European Commission, http://bit.ly/EUClimServ

EIT Climate-KIC, European Institute of Innovation & Technology - Climate Knowledge and Innovation Community, www.climate-kic.org

ESACCI, European Space Agency Climate Change Initiative, www.esa.int/Our_Activities/Observing_the_Earth/Space_for_our_climate/ESA_s_Climate_Change_Initiative_CCI

European Council, Conclusions on 2030 Climate and Energy Policy Framework (SN79/14), European Council of 23 and 24 October 2014, www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/145356.pdf

FACCE JPI, The Joint Research Programming Initiative on Agriculture, Food Security and Climate Change, www.faccejpi.com
- FACCE JPI, Strategic Research Agenda, www.faccejpi.com/Strategic-Research-Agenda

FP7 project CIRCLE 2 (Climate Impacts Research and Coordination for a Larger Europe), www.circle-era.eu/np4/home.html

FP7 project CLIM-RUN (Climate Local Information in the Mediterranean region Responding to User Needs), www.climrun.eu
- First stakeholder workshop synthesis report, www.climrun.eu/news_data/262/d4.3.pdf
- Second stakeholder workshop synthesis report, www.climrun.eu/news_data/125/d4.2synthesisreportworkshop.pdf

FP7 project ECLISE (Enabling CLimate Information Services for Europe), www.eclise-project.eu
- Report on a web-document presenting the different initiatives towards Climate Services in the world, www.eclise-project.eu/content/mm_files/do_830/D7.1_ECLISE.pdf
- Report on initial user requirements for climate services of the ECLISE cases, www.eclise-project.eu/content/mm_files/do_824/D1.1_Eclise_User_Needs_Report.pdf
- Report on user guide on uncertainties, www.eclise-project.eu/content/mm_files/do_824/D%201.2-User%20guide%20on%20uncertainties.pdf
- Report on user evaluation document, www.eclise-project.eu/content/mm_files/do_824/D1.3%20ECLISE-User%20evaluation%20and%20best%20practices.pdf

FP7 project ERA-CLIM2 (European Reanalysis of the Global Climate System), www.era-clim.eu

FP7 Project EUPORIAS (European Provision of Regional Impacts Assessments on Seasonal and Decadal Timescales), www.euporias.eu
- Report of recommended priorities for Horizon 2020, www.euporias.eu/system/files/D2.1_Final.pdf
- Report on findings on S2D users' needs from workshop with meteorological organisations, www.euporias.eu/system/files/D12.2_Final.pdf

- Outlook of sector specific vulnerabilities for Europe S2D horizon, www.euporias.eu/sites/default/files/deliverables/D11.1_Final.pdf
- Report on survey of end-user needs for improved uncertainty and confidence level information, www.euporias.eu/sites/default/files/deliverables/D33.1_Final.pdf
- Report from the workshop "Reconciling scientific capability with current and potential user needs at the seasonal to inter-annual timescale in Europe", www.euporias.eu/sites/default/files/deliverables/D12.4_Final.pdf

FP7 project GEOCARBON (Operational Global Carbon Observing System), www.geocarbon.net

FP7 project GEOWOW (GEOSS interoperability for Weather, Ocean and Water), www.geowow.eu

FP7 Project IS-ENES2 (Infrastructure for the European Network of Earth System Modelling), https://verc.enes.org/ISENES2

FP7 project NACLIM (North Atlantic Climate: Predictability of the climate in the North Atlantic/European sector related to North Atlantic/Arctic sea surface temperature and sea ice variability and change), www.naclim.eu

FP7 Project SPECS (Seasonal-to-decadal climate Prediction for the improvement of European Climate Services), www.specs-fp7.eu

FP7 projects cluster ECOMS, (The European Climate Observations, Modelling and Services initiative), www.eu-ecoms.eu

GEO, Group on Earth Observations, www.earthobservations.org

GEOSS, The Global Earth Observation System of Systems, www.earthobservations.org/geoss.php

GFCS, Global Framework for Climate Services, www.gfcs-climate.org

GMES for Africa, www.eumetsat.int/website/home/AboutUs/InternationalCooperation/Africa/GMESAfrica/index.html

Horizon 2020 Societal Challenge 5: 'Climate Action, Environment, Resource Efficiency and Raw Materials', Advisory Group Report 2014, http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetailDoc&id=14223&no=1

Horizon 2020, the EU Framework Programme for Research and Innovation 2014-2020, http://ec.europa.eu/programmes/horizon2020

Horizon 2020, Environment and Climate Action, http://ec.europa.eu/programmes/horizon2020/en/area/environment-climate-action

IPCC, The Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA (2014) www.ipcc.ch/report/ar5

JPI-Climate, The Joint Programming Initiative on Climate, www.jpi-climate.eu/home
- JPI-Climate, Strategic Research Agenda, www.jpi-climate.eu/jpi-themes/research-agenda

Water JPI, The Joint Research Programming Initiative 'Water challenges for a changing world', www.waterjpi.eu
- Water JPI Strategic Research Agenda, www.waterjpi.eu/images/SRIA/WATER%20JPI%20%20SRIA%201.0_2014.pdf

WCRP, World Climate Research Programme, www.wcrp-climate.org
- WCRP, Grand Challenges, www.wcrp-climate.org/grand-challenges

Composition of the expert group on climate services

© Nicole Keller

Daniela Jacob

Acting Director of the Climate Service Center 2.0

Climate Service Center 2.0 is an independent establishment at the Helmholtz-Zentrum Geesthacht.

Daniela Jacob studied meteorology in Darmstadt and completed her dissertation in Hamburg. Since 1993 she has been a researcher at the Max Planck Institute for Meteorology in Hamburg, where she developed the regional climate model REMO. In June 2010, she was appointed as one of the lead authors of the 5th Assessment Report on Climate Change of the Intergovernmental panel on climate change (IPCC). Daniela Jacob was leading the "Climate System" department of the Climate Service Center since 2010, and she has taken over as Acting Director of the Climate Service Center 2.0 as of June 1st. The Center is the main contact for all climate-change related questions and for information on adaptation strategies. It is intended as an information and consulting platform for decision makers within the spheres of politics, economics and administration.

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Martin Parry

Centre for Environmental Policy, Imperial College London and Department of Geography, University of Birmingham

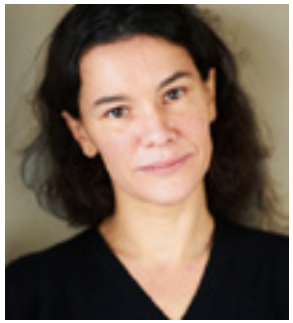
Professor Parry is Visiting Professor at The Centre for Environmental Policy, Imperial College London, and in the Department of Geography, University of Birmingham.

Until September 2008 he was Co-Chair of Working Group II (Impacts, Adaptation and Vulnerability), of the Intergovernmental Panel on Climate Change (IPCC) based at the Hadley Centre for Climate Prediction and Research, U.K. Meteorological Office. Previously he was Director of the Jackson Environment Institute (JEI), and Professor of Environmental Science at the University of East Anglia (1999-2002); Director of the JEI and Professor of Environmental Management at University College London (1994-99), Foundation Director of the Environmental Change Institute and Professor of Geography at the University of Oxford (1991-94), and Professor of Geography at the University of Birmingham (1989-91).

Tania Runge

Senior Policy Advisor, Copa-Cogeca (European Farmers, European Agri-Cooperatives), Chair of the Stakeholder Advisory Board of FACCE JPI

Tania Runge has been working since October 2007 as senior policy advisor at Copa-Cogeca in Brussels. Copa-Cogeca is the European umbrella organisation representing farmers and agri-cooperatives. Copa represents over 11 million farmers whilst Cogeca represents the interest of some 38,000 agricultural cooperatives. Jointly they have 70 member organisations from EU Member States. Her responsibilities include environmental topics with a particular focus on biodiversity, water management and environmental sustainability. In September 2012 she was nominated chair of the Stakeholder Advisory Board of JPI FACCE, the Joint Programming Initiative tackling agriculture, food security and climate change. Since April 2014 she is coordinating the Action Group WIRE (Water & Irrigated agriculture Resilient Europe) under the EIP on water. Tania Runge worked as scientist at the German Federal Agricultural Research Centre (Thünen-Institute) from 2004 to 2007. She is an agricultural economist (M.Sc.) and did her PhD in landscape planning analysing the economic and ecologic impacts when adapting farming practices to reach environmental targets using a modelling approach.



Jesse Scott

Member of the Gas, Coal, and Power Markets team, International Energy Agency, Paris

Since January 2015 Jesse Scott is a member of the Gas, Coal, and Power Markets team at the International Energy Agency in Paris. She was Head of the Environment & Sustainable Development Policy Unit at EURELECTRIC during 2012-14, responsible for EU electricity sector positions and advocacy on European and international climate targets and policies. In 2011 she worked for DemosEUROPA as the Programme Director for Energy and Climate on the Polish EU Presidency and was a member of the Polish Ministry Advisory Group for the EU Presidency. From 2008 till 2011 she was head of the EU Office of Third generation Environmentalism (E3G). Jesse holds a B.A. and M.Phil. from Cambridge University.

Roger Street, rapporteur

Director of the UK Climate Impacts Programme (UKCIP), University of Oxford and Member of the Joint Programming Initiative on Climate

Roger Street has an MSc in Physics from the University of Toronto and came to UKCIP in January 2006 after working over 32 years with the Canadian federal government. Much of his work has focused on climate, and climate impacts, vulnerability and adaptation, including the provision of information to inform climate decision-making processes. Roger has also contributed to the Intergovernmental Panel on Climate Change beginning with its first assessment report, led the Canada Country Study, was involved in the first US National Assessment on climate change impacts, and supports the UK Climate Change Risk Assessment process. As UKCIP Director, Roger leads the Programme's technical and scientific work aimed at guiding impacts, risk and adaptation studies, developing and delivering new supportive resources and tools, and supporting the design and development of climate services and the use of web-based platforms that support adaptation.

Annexes

Summary and Conclusions of the Workshop 'Towards a market for Climate Services'

Brussels, 18 March, 2014, Covent Garden, Nowotny Auditorium

This note summarises main messages arising from the workshop, flags possible follow-up actions and invites comments and suggestions from stakeholders for further informing the Commission's action.

The European Commission, DG Research and Innovation, has organised the Workshop 'Towards a European Market of Climate Services'. The Workshop, for invitation only, put together the organisations which are today in charge of producing "climate information" with a sample of organisations representing sectors of the public administrations and of the business sphere which may become (or are already) customers/users of future climate services. A third group of 'intermediaries', mainly represented by technical or business consultancies, was as well invited. 124 participants, representing 80 different organisations plus the European Commission, took part in the Workshop.

The Workshop had the goal of feeding into the development of a Roadmap for research and innovation for Horizon 2020 and beyond, which should fuel the growth of a European market of Climate Services. The ambition was to look ahead through a visionary and forward-looking discussion, and to bridge users' needs with today's and tomorrow's possibilities of producing usable climate information. This will be translated into high-added-value and targeted services for a variety of end-users, spanning from policy makers at various level, to public administrators, to business actors in different sectors of the economy, to NGOs, civil society organisations and citizens.

These concepts were stated in the opening presentation of Kurt Vandenberghe, which brought to the attention of the Workshop some considerations, namely:

- today the main focus is on the supply side
- operational services still need and will need for long time a sustained research and innovation support
- the supply side is today mainly providing climate information
- for passing from information to services we need:
  - to co-design and co-produce the Services with the USERS
  - crossing climate intelligence with multiple data sources, competences, actors
  - appropriate data/HPC infrastructures
  - to develop standards, QA and a "validation" system

The keynote speech of Yvo de Boer provided an out-of-the-box view on climate services, focussed on how to create a demand for them in a business system which is today very much geared towards very short-term returns. With a reduced average term for CEOs of 6y (from the double of 20 years ago), only in very few cases companies look at their long-term risks and profitability. He pointed out that in the triangle between business, policy-makers and investors, we have today to address the investors who may be interested – like the pension funds – to the long-term performance of their investments and therefore impel the CEOs for having climate services included in the business intelligence.

A Panel discussion among 'climate information users' preceded a second one of 'climate information suppliers'. Bringing users' needs and demands upfront oriented the discussion more towards the 'service' dimension of climate services, which should not only provide a regular flow of data on the 'essential climate variables', but merge those data with other sources of data – most of which of socio-economic nature – and, most importantly, with various kind of modelling and assessment tools, impact and vulnerability data and adaptation or mitigation solutions, in order to be translated into useful and usable services.

The integration of climate information in the assessment of risks and opportunities of any organisation (business/administration/service) is more and more needed, but it is in the development of options for solutions that climate services may express their best market value.

Users and providers do not use yet the same language, and there is mutual ignorance about the needs, the potential and the limitations of climate services. This issue needs to be addressed through a proactive dialogue, which may be facilitated by intermediaries, typically consultancies who know well the business sectors and may be capable of bridging between users and providers.

A major effort is on-going in the Earth Observation dimension, in particular through the Copernicus programme, which will very substantially increase the availability and density of climate data, thus leading to an expected increase of accuracy in forecasts and predictions, if adequately supported by research actions and by the growth in computing infrastructures.

The three afternoon breakout sessions allowed a broad discussion on a series of questions which will help the Commission to design the Roadmap and to establish supply- and demand-side strategies. The conclusions of the three sessions have been reported by the Rapporteurs in the final session, where the Commission provided its conclusive remarks.

Some considerations can be drawn from the Workshop, which will lead to follow-up actions:

Networking: an appropriate networking tool is the Coordination Action of Societal Challenge 5 on 'Earth-system modelling and climate services' foreseen in the Horizon 2020 Work Programme of 2015. It should ensure the presence of suppliers of climate information as well as of users – representing a variety of societal and

business sector – and of intermediary organisations. The establishment of a **'Climate Services User Forum'** even before the launch of this Coordination Action would be an initiative in the direction of the structuring of the demand side. The Coordination Action should engage with existing international and European networks. In particular, the international Climate Service Partnership and its European branch, but as well other sectoral associations and platforms in relation to specific business areas.

Horizon 2020 and Copernicus: the operational 'Copernicus Climate Change Service' is going to be launched during 2014, but will produce first products only in the next years. A close partnership between Horizon 2020 (Societal Challenge 5 and the Space programme) and Copernicus is being built, in order to ensure a constant flow of research results supporting the growth of the operational service. Research activities should – among others – continue to improve the modelling capabilities through the better understanding of key processes, the improvement of model resolution – also in relation to available High Performance Computing (HPC) capabilities – and the downscaling to the regional and local level. In this context, a strong cooperation is growing with the Member States – grouped in the **Joint Programming Activity on Climate** – supported by a major ERA-scheme in 2015 that may lead in the future to the establishment of a large public-public partnership (Art. 185).

User-driven projects in Horizon 2020: the role of the actual and potential Users of climate services has to be put up-front. The Commission may launch soon a call for **Expressions of Interest** in relation to **User-driven demonstration projects** in order to identify most promising sectors for the early development of climate services on which to open calls for proposals. This may be complemented by a climate services-dedicated **SME call** in 2016 in relation to high added value customised climate services for the business sector, by a possible **Public Procurement for Innovation** action in relation to climate service needs of public administrations. Taking into account the 35% climate-related expenditure target of H2020, complementary actions will be explored in other societal challenges (e.g. agriculture, energy, transport) to promote the development of solutions contributing to climate services.

Widening European capabilities: a **'Widening'** activity may be launched with the objective of extending the research and innovation capabilities in support of climate services to a wider number of EU countries, also in combination with the use of **structural funds**. This action could be carried out in cooperation with the **EIT Climate KIC** and its **Regional Innovation and Implementation Communities**.

International cooperation: specific actions combining **research, innovation, training and capacity building** should be focused on less developed countries, with a focus on Africa – where the MESA project of the 10th EDF is already on-going, paving the way to GMES Africa. Research, innovation and capacity building on climate services has a major international cooperation component, and joint actions within the international programmes (World Climate Research Programme, Future Earth, Belmont Forum) and in the context of the development of the WMO-Global Framework for Climate Services need to be sustained.

Data, data infrastructure and research infrastructures: Copernicus – whose first Sentinel satellite will be launched in early April – will dramatically increase the amount of available data. Moreover, many other datasets of different nature should be made available – among which also unconventional data deriving from **citizens' observatories** – in order to allow transforming climate information into services. This will imply the development of an appropriate e-infrastructure, but puts tremendous pressure on the expansion of existing HPC infrastructures. The growing demand of a dedicated European infrastructure for climate modelling (predictions and projections) will be addressed in cooperation with the European Strategic Forum for Research Infrastructures (ESFRI) (who was represented in the Workshop by the chair of the Environment ESFRI working group). This activity will be carried out in strict partnership with DG CNECT and the JRC.

Standardisation, certification, quality assurance and issues in relation to liability: the development of climate services should be accompanied since the early phase by the standardisation of data and protocols, the development of a certification system and of Quality Assurance methodologies. Only this may allow to appropriately addressing potential **legal issues** in relation to the **liability of the operators** providing climate services. **Specific research activities** should be foreseen, also in cooperation with the JRC. Options around self-regulatory governance models will be also examined.

Public and private dimension of the market of climate services: in the Workshop, there was consensus among the participants that a market of climate services should contain a public together with a private dimension. **Free and open access to observational data**, in line with the GEO and the Copernicus data policies, should be ensured. However, other socio-economic data sources – like for instance market data – may not be freely available. The Copernicus services and part of those provided by national public sources will be free. This data and "first layer service" regime will **trigger the growth of a business sector** which, by adding proprietary data and intelligence, may provide customised services to a variety of specific users. The boundary between the "public good" dimension and the "private" one cannot be easily drawn up-front. It will be based on the natural evolution of technologies and of the skills and capacities of the various public and private service providers.

Follow-up of the Workshop: a small **Expert Group** of 5 experts will be established. It will work hand-in-hand with the sub-group on Climate Services of the Advisory Group of H2020 Societal Challenge 5. The Expert Group will have the task – also taking into account the variety of contributions received in the Workshop – of developing **a long-term**

Research and Innovation Roadmap for Climate Services, and to identify the **demand-side measures**, notably measures to be taken forward in other policy fields, that may facilitate the growth of a market of them. It may engage with users group, consult with institutional investors, and suggest **short-term studies (e.g. market surveys) and targeted networking activities** that the Commission may contract out to professional service providers. The Expert Group should deliver its conclusions before the end of 2014, in order to allow them to be used for the next H2020 programming cycle 2016-17. The intermediate products and the draft conclusions of the Expert Group will be made available to the Workshop participants and to the wider community. A **second Workshop** will be organised for a public discussion of the Roadmap and of the Expert Group recommendations.

Horizon 2020 SC5 Advisory Group Report 2014: extract on Climate Services

First Report of the Horizon 2020 Advisory Group (AG) for Societal Challenge 5: 'Climate Action, Environment, Resource Efficiency and Raw Materials'

[...]

Priorities in the Area of Climate Services

18. The objective here is to strengthen significantly the global market for climate services, designed to provide cutting-edge customised information services and adaptation solutions to a range of end-users in the business domain, the public decision-making domain and to individuals, making the EU a world leader in this sector. The group attributes to the term 'climate services' a broad meaning, which covers the transformation of climate-related data into customised products, their subsequent application and outreach and strong links with social sciences and humanities. Climate-related data in this context goes beyond the physical climate data, aiming to represent the Human Earth System with its various connectivities between physical, chemical, biology, social, economic systems.

19. Figure 1 represents schematically our broad view of Climate Services. Climate System Science explicitly goes beyond the physical realm as described above. The social science aspects are crucial. The links between natural and human/economic systems provide important drivers for market development from both business and decision making perspectives. This creates the "service demand" which represents a strong feedback to future model development. The key features related to the figure are the following:

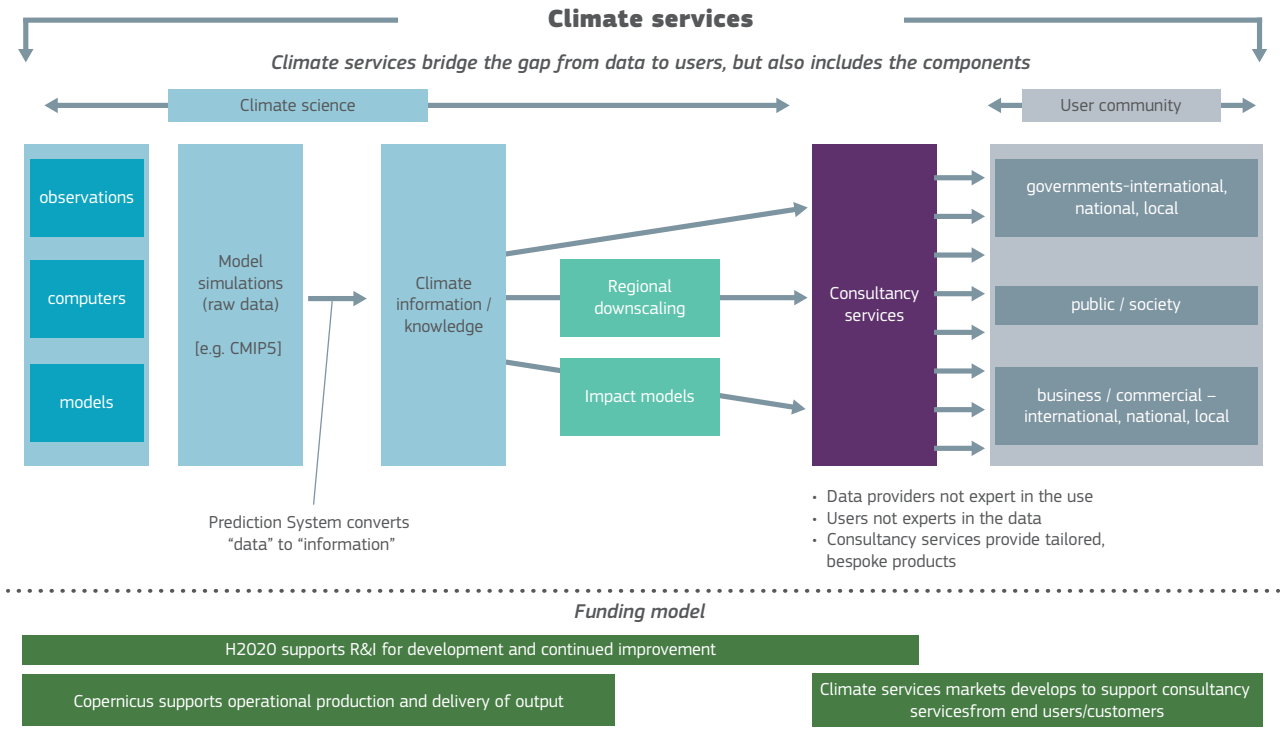
    i. "Climate system science" can, and does provide lots of raw data, and also processed information aimed at end users, but without much expert knowledge of the requirements of these users. These components already exist but require continuing investment in development and improvement.

    ii. End users have access to large databases (such as CMIP5) but lack expert knowledge in using that raw data. Users are much more than just business and local governments – national and international level policy makers (i.e. mitigation as well as adaptation) are also users.

    iii. There is a requirement, and emerging activity, to bridge this gap – shown here as "consultancy services" which might be through large data providers, but should also include many smaller services (e.g. SMEs) with local or sector-specific expertise. These consultancies will draw on information including, but not limited to, downscaled regional output and output from impacts models. There is a R&I requirement here for cross-disciplinary expertise in both the data and the user needs.

    iv. "Climate Services" is much more than just this consultancy area – it has to encompass the whole spectrum and includes the components of science

Figure 1. The Essence of Climate Services



which provide the information to start with. It is also vital to ensure that the service demand side gets a strong role. The services have to reflect societal needs both related to business activities and to public decision making. This requires effort in the initial phase of development in order to reveal user needs, to clarify legal issues and other critical market framing issues.

v. While Copernicus will support operational running of an eventual service there is a clear and central role for continued investment in R&I through H2020.

20. The plenary discussion on climate services noted that other initiatives were also engaged in the same field (notably the Copernicus programme and Joint Programming Initiatives) and coordination with them is essential if H2020 is to provide genuine value added. There is a clear distinction between continued requirement for R&I to develop and improve underpinning components and the need for operational support of data provision.

21. The subgroup identified a number of actions that should be included in any future programme. These are listed here and further elaborated in the Road Map, attached as Annex II:

    i. Observations and monitoring. Combine global *in situ* monitoring networks with satellite observations and models and other data related to climate system change.

    ii. Modelling. Climate services built on today's state-of-the-art climate system understanding will be useful for only a short-time period without a strong effort in improving and regularly updating the fundamental understanding of the climate system. Continued R&I investment in development and improvement of climate-system and socio-economic models is vital to enable Europe to stay at the forefront of climate services.

    iii. Use of infrastructure and technology. Climate services will require extensive, adequate, dedicated HPC and IT infrastructure for storage and dissemination.

    iv. Adding value. Enhance the global environmental change information and outreach capacity that considers societal behaviour and human decision-making. At present there is a dis-connect between supply and demand for climate services so that what is supplied does not match what is demanded and potential demand for services is not fully developed. The Commission will need to work with business and local government as well as education providers in this endeavour[32].

22. There will be demand for initialised near-term predictions as well as scenario-based long term predictions. R&I is required to make improvements in both, and also to combine both in a seamless manner at intermediate timescales. Climate services output will be both deterministic and probabilistic in nature, depending on the type of service considered and the question addressed. R&I is required into how to extract useful forecasts from model output, how to evaluate such output and how to communicate and use it. Regional downscaling of climate, mechanisms of climate variability and its impacts and risks of extreme events will become increasingly important to end users.

23. Uncertainty related to climate services is a major factor that needs to be specified. Framing of outputs in probabilistic terms is fundamental for development of risk-based decision making on mitigation and adaptation. European decision makers and businesses are currently lacking access to a consistent, authoritative set of high-resolution climate projections linked to impacts, and socioeconomic information for Europe. There is therefore a need to develop science to underpin a climate service prediction system for the European region. In the first instance the prediction system could be based on the current generation of models to produce a probabilistic set of high-resolution projections, covering timescales from seasons to decades. R&I is also required to develop the next generation system, at higher resolution, incorporating additional improvements in initialisation techniques, process representation and earth system components.

24. As the demand for services grows, users will want some guarantee that the private sector provider is using the latest information and is qualified to supply the relevant information. There may therefore be a need for certification of private suppliers, which the EC could help up to structure, working with private associations. At the same time the private sector is likely to develop financial instruments that are related to climate mitigation, an extension of the growing "green bonds" market. Again H2020 could help develop the criteria under which a bond may be considered as supporting low carbon investment.

25. Overall the AG felt there was potential for the EU to lead in the provision of climate services at the global level. This would require, however, strong cross-disciplinary teams as well as effective interaction with stakeholders. Some certification system to guarantee quality may be necessary. Capacity building on bridging the gap between disciplines is needed on the supply and demand side. This could be done through:

    i. Providing general knowledge to the demand side on diverse climate-related information and modelling,

([32]) To better quantify and understand the demand for climate services a market survey should be carried out on what are the areas where climate services are (and will be) needed by the business and other communities. This should stimulate the service developments for the future across the various sectors.

taking account of different time scales for different uses[33].

ii. Demonstrating the added-value for developing markets and businesses of networking, information sharing, open access, and transparency.

iii. Mapping stakeholder interests related to different planning issues and business creation and to achieve leadership by including the private sector, governments, insurance, and Public Private Partnership needs.

iv. A crucial aspect of the capacity building is to identify and target the right actors/ people on the right position, who are knowledgeable how to deal with the climate service information, including dealing with uncertainties & serve as quality multipliers to the respective sectors.

[...]

Priorities in the Integrating Social Sciences and Humanities (SSH) Across the Priority Areas

39. The societal challenge of climate action, environment, resource efficiency and raw materials implies a strong movement of adaptation in society. SSH expertise will be particularly necessary to understand what this implies and to accompany change. There are a number of ways in which SSH could play a role in the design of actions on the four priority areas. In addition there are some issues that cut across the four strategic areas and that may "fall between the cracks" if not addressed specifically.

[...]

(33) Weather services are closely related to user needs, and the feedback on the value of more accuracy is straightforward. We can learn from looking at the weather service customers, and transfer the lessons to other services.

Climate Services

43. Climate services provide information and predictions about the climatic trends but, as noted, also need to provide a comprehensible analysis of how society can and does react to major climate events.

    Expertise in the social, economic and political impact of climate change has to be a major dimension of climate services, analysing geo-political changes; migration and poverty induced by climate and sea-level change; the situation of small countries/populations that have few resources to face climate change (Pacific islands, Arctic); etc. In other words Europe should offer climate services centred on the social dimensions of climate change as well as on the physical ones. It should provide a sort of observatory of how the world is evolving, with geopolitics, migration, poverty, etc. being monitored. Getting a global understanding of what is happening will be very important.

44. The following disciplines within SSH can make the following contributions that are important

    i. *Sociology, anthropology:* Society will need to learn from new events. This learning process will have to be as efficient as possible. Examples are studies on Katrina in the US but also the 1999 storms in Europe, e.g. on how populations managed before the arrival of help from outside. Another example is a study on the way public decision makers in the Bordeaux area use satellite pictures to try to handle future rise in sea-level.

    ii. *Geography, political sciences, history:* how does climate change affect political and economic power balances in the world? How will governance issues in the "new" Arctic and Antarctic areas be handled?

    iii. *Communication sciences:* how can a massive amount of new information on climate be communicated efficiently? How can it be linked to end-users needs and constraints? What role do the media play in disseminating knowledge?

    iv. *Psychology, cognition sciences:* how is satellite information, GIS maps understood and used by non-specialists?

45. In terms of content the subgroup had noted that the demand for climate services will need to be built up through capacity building. This will, however, need to focus in particular on the role of socioeconomic data, where the following issues need to be addressed:

    i. Potential users of climate services should be included in an assessment of needs and markets, including current users of "weather information".

    ii. Attention should be paid on how the ownership of a service platform can be structured in a way where data is open source, and business creates tools and custom designed products.

    iii. A mainstreaming approach should be developed, where climate services are related to other planning issues and GIS based information. This could for example be with respect to sustainable cities, energy, transportation, water systems, and other regional planning issues.

    iv. A link to new and already existing data beyond the traditional scope of climate information could be made. Socioeconomic information and planning data are very important here, and Eurostat and other statistical offices are key partners.

    v. A protocol for consistent cross country data systems and at EU level should be set up, where cross boarder/regional data can be generated in a consistent way.

vi. An approach for handling risks and uncertainties related to climate services needs to be elaborated. This should address:

   a. How can the uncertainty be communicated
   b. Approaches for decision making given uncertainty, different decision rules
   c. Considerations of consumer and the private sector preferences given uncertainty and ambiguity.

vii. Consideration of legal issues in relation to:

   a. Uncertainties of potential damages in relation to investments and insurance. Examples of these are adaptation measures and design standards, private houses, infrastructure.

   b. Who are going to carry the losses, when climate information do not show up to be a good forecast.

   c. Private sector responsibility versus the public sector.

viii. Collection of experiences with similar data service platforms, which can be used to develop climate services (satellite information, weather services, environmental data, water systems).

[...]

Appendix: Meetings of the AG and Members of the Group

The AG has met so far on four occasions (4th October 2013, 11th December 2013, 29th -30th January 2014 and March 13th 2014).

The names of the 31 members of the AG are given below.

Name	Country
Prof. Almut ARNETH	Germany
Dr Nikolaos ARVANITIDIS	Sweden
Prof. Manuel BARANGE	UK
Dr Danilo BONATO	Italy
Dr David BRESCH	Switzerland
Ms Laura BURKE (Chair)	Ireland
Dr Suzanne DE CHEVEIGNE	France
Dr Mark DOHERTY	Ireland
Prof. Eeva FURMAN	Finland
Prof. Kirsten HALSNÆS	Denmark
Dr Corina HEBESTREIT (Vice Chair)	Belgium
Mr Chris JONES	UK
Dr Ewa KOCHANSKA	Poland
Mr Stefan KUHN	Germany
Dr Hab. Joanna KULCZYCKA	Poland
Mme Anne LAPERROUZE	France
Prof. Michal V. MAREK	Czech Republic
Prof. Anil MARKANDYA (Rapporteur)	Spain
Prof. Beatriz MORALES-NIN	Spain
Dr Antonio NAVARRA	Italy
Ms Ana NEVES	Portugal
Dr Enrique PLAYAN	Spain
Mr Lars-Otto REIERSEN	Norway
Prof. Katherine RICHARDSON	Denmark
Dr Aurela SHTIZA	Belgium
Mr Hervé SUTY	Belgium
Prof. Dr Erja TURUNEN	Finland
Dr Sybille VAN DEN HOVE	Spain
Dr Saskia VAN DEN MUIJSENBERG	Netherlands
Prof. Shearer WEST	Belgium
Prof. Dr Roko ZARNIC	Slovenia

[...]

Annex II: Road Map for Climate Services

Objective: To create a European market for climate services designed to provide cutting-edge customised information services and adaptation solutions to a range of end-users, both in the business to business domain, in the public decision-making domain and to consumers, making the EU a world leader in this sector.

Actions	Stakeholders	Expected Outcome/Impact
Combine global and regional data from in situ and remote monitoring networks, with impact data, socio-economic and land use information, and other sources of data and knowledge at local level (including traditional knowledge). This involves coordinating discussions between suppliers and users of climate data in agriculture, forestry, marine, industry, insurance etc., as well as the modelling community.	Suppliers and users of data. Research, governments, business communities. Statistical services.	Framework for facilitating data provision and access, enhanced use of multiple data streams à test models; data-assimilation into models; develop localised adaptation options; assess potential of success for mitigation options.
Continuing development of underpinning models and modelling techniques. Improved incorporation of observational data into modelling systems: applications in model evaluation and constraints.	Research community, developers and users of models and users of model output; decision makers, business	Improved realism and reliability of models. Enhanced trust in their projections
Identify the main modelling gaps and deficiencies in understanding the linkages between the climate, biogeochemical, economic, social and health system models and support work to fill these gaps. The research community will need to discuss the issues with policy and business user communities and the outcome should be a prioritisation of the modelling needs and actions to address them.	Research community; policy makers/institution, business	Prioritisation of modelling needs, emphasising the interactions and feedbacks (and action to improve on these)
Develop a prediction system to produce an authoritative set of high resolution, probabilistic projections for Europe linking climate, impacts, and socioeconomic information. Continued R&I into improved resolution, process representation and initialisation of predictions. Database on agreed global climate variables (beyond T and P...), agreed common format and required resolutions (space, time) (for seasonal to decadal to longer time frames).	Governments, research and business Engage with WMO, and WCRP/CMIP	Improved capacity to produce probabilistic predictions from model output. Availability and documentation of database of authoritative model projections in standardised, defined formats with quantified uncertainties and probabilities, at high resolution.
Use of infrastructure and technology. Numerical modelling is the main tool to deliver climate information both via analysis of observation and/or numerical forecasts and scenarios. Sufficient resources therefore should be dedicated to the development of models and analysis techniques to fully exploit research infrastructure and computing advances that will occur in the coming years to decades.	Model developers and data suppliers. Engage with ESFRI.	More efficient models, faster availability of outputs, more reliable and faster access to data etc.
Develop suitable methodologies for downscaling global ESM understanding to regional and local levels for building reliable regional circulation models, impact models, economic models, sectoral models, social and health system models, etc.	Research community; policy makers/institution, business	Testing of different methodological approaches, assess outcome vs. suitable observations and identify most suitable way forward
Knowledge creation and capacity building for decision making and climate proofing existing and future assets under uncertainty, targeting both private sector and government, including behavioural issues and response capacity.	EC, business (marketing), teaching (schools, universities), policymakers, local administrators	Engage with public and private sector, encourage better integration between natural, economic, social sciences; show opportunities for using climate services to develop e.g., mitigation/adaptation options.
Aid developing a future enlarged market for climate services, identify untapped potential, and how it can be stimulated recognizing gaps in knowledge and uncertainties	EC, business, research community	Identify service development track from where we are today to where we aim to be tomorrow; development of opportunities for various sectors
Develop the demand for climate services through the demonstration of potential capabilities on specific applications of high economic potential and societal added value – to launch a competitive bid for expressions of interest in order to identify possible sectors in which to invest with priority	Climate services users	Successful case studies may stir the diffusion of climate services to other business sectors

[...]

Expert group on climate services stakeholders' questionnaire

Stakeholders' consultation on the development of a market for climate services

Background

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change states that *'in recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans'.* Among the consequences of global warming are the changes in water availability and quality, extreme temperatures, extreme weather events – droughts, storms and floods –, biodiversity migration, sea level rise, ocean acidification, etc. Global warming is very likely to continue throughout the 21st century, though in different extent depending on mitigation efforts. Extreme weather events will keep on occurring with potentially greater impact. This will require appropriate adaptation and mitigation measures from organisations, businesses, countries and citizens. Doing so will require credible, relevant and usable climate–related information and knowledge enabling the different actor to take climate-smart decisions.

The European Commission – DG Research and Innovation – has identified the climate services as one of the 'flagship initiatives' in the area of climate and environment in which to invest with priority during Horizon 2020, the 7-years EU Research and Innovation financing programme.

The Commission is currently developing a long-term Research and Innovation Roadmap for the development of climate services. The challenge is to derive societal and economic value from the wealth of climate data and information produced by observation systems, scientists, companies and practitioners, by turning them into customised knowledge and tools enabling public and private sectors organisations to take climate-smart, strategic decisions at various levels.

The Commission is assisted on this task by an *ad-hoc* Expert Group, but inputs are needed by a wide range of stakeholders in order to clearly understand the different needs and constraints for the development of a market for climate services. Within the stakeholders, the actual or potential users are the key target group, since so far climate services have been mainly orientated by providers, while users' engagement is an essential requirement to understand and develop the market potential.

Climate services

We attribute to the term 'climate services' a broad meaning, which covers the transformation of climate-related data – together with other relevant information - into customised products such as projections, forecasts, information, trends, economic analysis, assessments (including technology assessment), counselling on best practices, development and evaluation of solutions and any other service in relation to climate that may be of use for the society at large.

Stakeholders' consultation

The Commission intends ensuring that stakeholders are involved throughout the process. A wide stakeholders' consultation has been launched by the EC on the next Horizon 2020 programming cycle and closed in June. This was a general consultation, not focused on Climate Services, and therefore a more targeted specific consultation has been prepared for a restricted stakeholders group, mainly including actual and potential climate services users.

This specific stakeholder consultation will be carried out through the questionnaire here attached. Among the respondents, a restricted number of stakeholders may be invited for a hearing with the *ad-hoc* Expert Group, while a broader group will be contacted by European Commission's staff for phone interviews. The content of the stakeholders' consultation will be treated as confidential and not circulated publicly.

Questionnaire for actual/potential climate service users

QUESTION BLOCK 1: Understanding the demand for climate services

1. **Do you think that changing climate has or will have an impact (positive or negative) on your business or organisation? Which climate events do you expect to have an impact on the functioning of your business or organisation?**

2. **Is climate change considered in your organisation? Why (is it considered or not considered)?**

If it is considered then:

- Does your organisation have a climate change mitigation or adaptation plan? If so, how is this plan used within your organisation?

- To what extent is your consideration of climate change related to reducing emissions and/or energy efficiency? To what extent do you also address the impacts/risks/ opportunities related to climate change relevant to your organisation/business operations?

- What is the relative importance of considering climate compared to other issues?

3. **Do you use or have used climate information and other services to support decisions in your organisation/ business?**

If yes then:

- For what purposes are climate information used (support policy, decisions, investments…)
- What climate information and climate-related services are you using? Why are you using these?
- What are your main sources of climate information and related services? Why are you using those sources?
- What are the main constraints you face in the integration of climate related information in your decision making process?

If not then:

- Which are the reasons/barriers that prevent you from using such services and what would need to change, so you can use climate services?

QUESTION BLOCK 2: Attributes of the required climate services

4. **In terms of supporting your requirements/needs, what are critical characteristics of climate information and related services?**
5. **Do the climate information and related services to which you have access meet those requirements? If not, what is missing?**
6. **Have you been or would you consider being engaged in the development of specific climate products or services (together with climate services providers)?**

If yes:

- What did encourage you to participate in the co-design and co-development of climate services?

If not:

- What would encourage you to participate in the co-design and co-development of climate services?

7. **Would you be willing to pay for high quality customised climate –related services that you consider useful for the operation of your organisation/business?**

If yes:

- Which are to your view the benefits and disadvantages of paying for such services? What type of information/ services should be freely available and what should be commercially available?

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The ambition of this roadmap is to offer a framework for discussion to the relevant actors and stakeholders. It paves the way to shared solutions and pathways facilitating the development of a market for climate services that provides benefits to society.

This document offers an essential contribution to achieving the EU objectives of an Energy Union with a forward looking climate policy.

Publications Office