Initial state of the market: actors, sectors, terminologies

Deliverable 4.2

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Table of Contents

1 Background and Aim 7
1.1 Aim of work package 4 and task 4.1 7
1.2 Key terminology used for assessing the CS market 8
1.3 Methodology for mapping the CS market 11
2 Screening of CS applications in EU projects 13
2.1 Introduction 13
3 Assessing the current CS market from a user perspective 17
3.1 Introduction 17
3.2 Key climate risks in Europe providing a potential for CS markets 17
3.3 Review of CS market assessments 20
3.4 Assessing the user side of the CS market 24
3.4.1 Studies of the implementation of adaptation 24
3.4.2 Adaptation in Cities: Risk assessment and adaptation planning 26
4 Assessment of the market supply side 29
4.1 Financial climate disclosures market 29
4.2 Earth observations (EO) based on CS market supply 33
4.3 Copernicus Climate Services 35
4.4 Mapping of CS supply capacities in the EU by WMO 37
4.4.1 Climate services in the European Union 38
4.4.2 Climate services by value chain components 39
4.5 The Global Framework for Climate Services (GFCS) 40
5 Case Study of the financial sector as a potential large CS user 42
6 Conclusions 46
REFERENCES 48
APPENDIX 1 51

List of tables

Table 1. Categories of Climate Services 8
Table 2. Proposition of user categories to guide user identification 9
Table 3. Economic sector codes 10
Table 4. Overview of sector focus, CS users, and CS taxonomy categories in projects identified in CORDIS database 14
Table 5. Overview of sector focus and funding for projects identified in CORDIS 16
Table 6. Summary of the literature review findings 23
Table 7. Climate hazard reported by pct. Share of CDP reporting European cities (180 cities) 27

Table 8. Status of National Framework for Climate Service (NFCS) Implementation 41
Table 9. Total MDB adaptation finance by sector in low and middle-income countries, 2021. 44
Table 10. Sector A: Agriculture, Forestry and Fishing.....0
Table 11. Sector D: Electricity, Gas, Steam and Air Conditioning Supply 1
Table 12. Sector E: Water Supply, Sewerage, Waste Management and Remediation Activities.....2
Table 13. Sector H: Transportation and Storage.....3
Table 14. Sector L: Real Estate Activities.....3
Table 15. Sector M: Professional, Scientific and Technical Activities.....4
Table 16. Sector Q: Human Health and Social Work Activities 5
Table 17. Sector R: Arts, Entertainment and Recreation.....6
Table 18. Sector S: Other Service Activities.....7
Table 19. Sectors not classified. 10

List of figures

Figure 1. Overview of major CS market elements 12
Figure 2. Key climate risks to Europe under low to medium adaptation 18
Figure 3. Welfare loss (% of GDP) from considered climate impacts at warming levels for the EU and the UK, and for macro regions. The results represent changes in welfare if warming levels would act upon current economy, compared to the current economy under present climate. 19
Figure 4. National annual damages without and with adaptation (for high RCP 8.5 emissions scenario in 2100).....20
Figure 5. Progress in national adaptation plans and status of national adaptation strategies and plans in Europe.....25
Figure 6. The urban adaptation gap to current climate risks 29
Figure 7. Overview of the adoption of financial disclosures. Data as of Sept. 8, 2023. Chart from S&P Global ESG Raw data based on responses from 13,810 companies assessed in the 2022 S&P Global Corporate Sustainability Assessment (CSA) 32
Figure 8. Screen captures of the climate service offer of private financial actors. 33
Figure 9. The EO based climate services value chain of EO considering key global and European companies involved in EO downstream activities. Private (light orange) and public (light green) actors are listed with European-based companies marked with (*).....34
Figure 10. Revenue of EO data (top) and services (bottom) sales and by application (left) and region (right) 35
Figure 11. CDS Users' distribution by dataset type by July 2022 36
Figure 12. CDS User sectorial profile by dataset categories 37
Figure 13. Climate services functional capacities across the climate services value chain 38
Figure 14. European Union Overview of generalized climate services capacities (not sector specific) Source; WMO Climate Service Checklist, 2023 39
Figure 15. Overview of the percentages of functionalities satisfied (green) and not satisfied (red) in the value chain components based on data from 24 European Union Members states; Source; WMO Climate Service Checklist, 2023 40
Figure 16. Adaptation Finance by Sector in USD billion 42
Figure 17. Number of climate finance projects in cities reported by hazard. 43
Figure 18. Physical Risks to firms in Europe stemming from climate change mainly arise from floods, wildfires, heat stress or water stress. 45

About Climateurope2

Timely delivery and effective use of climate information is fundamental for a green recovery and a resilient, climate-neutral Europe, in response to climate change and variability. **Climate services address this through the provision of climate information for use in decision-making to manage risks and realise opportunities.**

The market and need for climate information have seen impressive progress in recent years and are expected to grow in the foreseeable future. However, the communities involved in the development and provision of climate services are often unaware of each other and lack interdisciplinary and transdisciplinary knowledge. In addition, quality assurance, relevant standards, and other forms of assurance (such as guidelines, and good practices) for climate services are lagging behind. These are needed to ensure the saliency, credibility, legitimacy, and authoritativeness of climate services, and build two-way trust between supply and demand.

Climateurope2 aims to develop future equitable and quality-assured climate services to all sectors of society by

- Developing standardisation procedures for climate services
- Supporting an equitable European climate services community
- Enhancing the uptake of quality-assured climate services to support adaptation and mitigation to climate change and variability

The project **will identify the support and standardisation needs of climate services, including criteria for certification and labelling, as well as the user-driven criteria needed to support climate action**. This information will be used to propose a taxonomy of climate services, suggest community-based good practices and guidelines, and propose standards where possible. A large variety of activities to support the communities involved in European climate services will also be organised.

Acronyms

CDS Climate Data Store
CE2 Climateurope2
CORDIS Community Research and Development Information Service
CPI The Climate Policy Initiative
C3S The Copernicus Climate Change Service
CS Climate services
ECB European Central Bank
EO Earth observations
ESG Environmental, Social, and Governance
GFCS Global Framework for Climate Services
GRI Global Reporting Initiative
IPCC The Intergovernmental Panel on Climate Change
NACE Statistical Classification of Economic Activities in the European Community

NMHS National Meteorological and Hydrological Services
PI Principal Investigator
SASB Sustainability Accounting Standards Board
SFC Seasonal climate forecasts
TCDF Task Force on Climate-related Financial Disclosures
USAID United States Agency for Development Assistance
WMO World Meteorological Organization

Executive Summary

This deliverable D4.2 of the Climateurope2 (CE2) project provides an overview of the initial state of the current climate service (CS) market: actors, sectors, and terminologies. The report is the first version of a continuous inventory of existing CS across economic sectors, geographies, policy areas.

A terminology for CS categories-, users-, and use sectors is introduced and used in relation to a screening of how CS development and deployment have been addressed in EU funded projects on the basis of a screening of the EU project database CORDIS. Among 75 EU projects identified in the CORDIS screening several of the projects are targeting multiple sectors jointly, and develop data and decision-making support platforms, which can be used by a broad range of CS users. It has in the current screening of the project outputs not been possible to identify how CS has been used after end of projects.

Based on an international literature review of climate risks in Europe, it is concluded that it could be beneficial to use CS in the development of adaptation strategies, in order to reduce the damages by climate change. There is also a wide range of adaptation activities going on in Europe, where CS is used and where further improvements could be beneficial. It is however not directly documented how- and in which form CS is used in adaptation planning and implementation. Some of the areas, where we have distinguished a high level of adaptation planning and other uses of CS in Europe are: the health sector, the energy- and water sectors, and also in city adaptation planning. European cities are very busy with adaptation planning, and the further development of these plans will require the use of very sophisticated and context specific CS.

CS are supplied by both private and public providers, the latter through large open data platforms like Copernicus. The supply side of the CS market is not very transparent because a lot of the CS supply provided by the private sector are not reported openly, and a number of very large CS providers are embedding CS in more general existing customer relations, where the specific CS component cannot be distinguished. The open data platforms have a large number of users, and as far as information is available, they primarily supply data in the form of processing and reanalysis of climate data.

A current and potential large user of CS is the financial sector, where binding commitments from the European Central Bank has initiated a process, where the financial institutions are to supply climate stress tests. Conducting climate stress tests in the financial sectors will require very sophisticated use of CS including both modelling and context specific data.

Keywords

Climate service markets, climate service typology, user sectors, data providers

1 Background and Aim

1.1 Aim of work package 4 and task 4.1

Work package 4 seeks to understand the Climate Service market development. The objectives are: "Create an inventory of the current market of climate services (CS), including an analysis of its gaps and possible pathways of future developments; showcase good practices and learn from failures to increase the performance of CS and increase their impact on the ground; increase trust and transparency in CS by the joint definition of standards of guiding principles of high-quality CS based on the analysis of the current market of climate services and CS performance; and facilitate market development through market stimulating and knowledge brokerage services".

In this framing, task 4.1 was designated to make an inventory of climate services markets. This deliverable D4.2 of the Climateurope2 (CE2) project provides an overview of the initial state of the current climate service (CS) market: actors, sectors, and terminologies. The report is the first version of a continuous inventory of existing CS across economic sectors, geographies, policy areas and positions in the value chain, which will evolve and will be updated over the course of CE2. The overview of the current state of the CS market aims at providing key information about both the user- and the provider side of the CS market in order to identify areas where the standardization of CS will be important, and further to identify context specific challenges for the use of CS and thereby standardisation options. The focus of the review is Europe, but supplementary information is also provided about CS markets in the rest of the world.

The review builds upon previous assessments of the CS market (e.g. EU-MARCO and EU-MACS projects (EU-MARCO 2018a, b; EU-MACS, 2018a, b; Cortekar et al., 2020)), and other projects and initiatives supported by European Research Programmes, Climate-KIC, Copernicus C3S, JPI Climate, WMO, GFDRR, and national and sub-national programmes and communities.

In this first version we are in section 2 including a review of past and ongoing EU projects based on a screening of the CORDIS database (https://cordis.europa.eu/) of CS development and applications in relation to focal economic sectors, categories of CS , and users of CS. The review is based on definitions of key CS market terminologies and taxonomies of economic sectors, CS categories, and CS user categories, which are in accordance with the terminology used in D4.1 of Climateurope2 (https://climateurope2.eu/resources/public-deliverables).

This is followed up in section 3 by an assessment of studies of the demand side of the CS market in Europe based on an identification of sectors facing major climate risks in Europe, that could benefit from using CS as part of adaptation strategies, followed by a review of implemented adaptation strategies in Europe as an indicator of where CS today is playing a role.

The supply side of the CS market is addressed in section 4 by presenting an overview of large players supporting climate disclosures of companies followed by core activity data for large supply platforms including Copernicus and Earth observations (EO). International capacities for CS supply are finally introduced.

The report also includes in section 5 a case study of the financial sector, which due to climate finance commitments by Multilateral Development Banks and mandatory rules for reporting of climate risks to the financial sector by the European Central Bank (ECB), is a very large user of CS.

1.2 Key terminology used for assessing the CS market

The terminology for assessing the CS market is based on the CS taxonomy developed in D4.1 of Climateurope2, which as far as possible is in accordance with the CS taxonomy developed in the EU H2020 MARCO and EU MACS projects (EU-MARCO, 2018a, b; EU-MACS, 2018a).

The CS taxonomy used in this deliverable is shown in Tables 1, 2, and 3.

Table 1. Categories of Climate Services

TYPE	DESCRIPTION	NUMBER
Measurements	Instruments and technologies for measurement and calibration.	1
Operations	Collection and provision of raw data	2
Modelling	Modelling of data, both certified and non-certified	3
Data Management	Provision of calibrated data sets, data archiving, data certification and data sales	4
Processing & Re-Analysis	Provision of data analysis and retrieval services including data mining tools	5
Advisory Services	Advisory services, risk assessment and decision support tools provided to public and private sector organisations	6
Other Consulting	Consulting services not elsewhere covered	7
Publication	General publication of analysis findings	8

Source: EU-MARCO,2018, Cortekar et al., 2020

Table 2. Proposition of user categories to guide user identification

CATEGORIES	TYPES	CODE
Policymaker	Local, subnational, national, and supranational level	1
Governmental body	Environmental and conservation agencies, climate change offices, and funding agencies	2
Resource manager (public)	Local, regional, and national authorities or resource authorities (e.g., river basin management authorities), public utilities, and resource suppliers	3
Resource manager (private)	Landowner associations, professionals, mediators, and practitioners	4
Data-related stakeholder	Data provision, supplier, purveyor, developers, and manager	5
Civil society/community representatives	Citizen associations, local communities (hybrid), consumer associations, citizen representatives, social movements, and youth representatives	6
NGOs and foundations	Local, regional, and national NGOs	7
Private sector	Companies, industry representatives, and associations	8
Networks	Transnational networks, global initiatives, and umbrella organisations	9
Media	Journalists and specialised media	10
Other	Non-project-related scientists, technologists (vendors, computing centres, etc.), and experts; educators	11

Source: Baulenas et. al, 2023

We are mapping the sectors where CS are used according to sectoral NACE codes (Table 3).

Table 3. Economic sector codes

SECTOR	CODE
Agriculture, Forestry and Fishing	A
Mining and Quarrying	B
Manufacturing	C
Electricity, Gas, Steam and Air Conditioning Supply	D
Water Supply; Sewerage, Waste Management and Remediation Activities	E
Construction	F
Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles	G
Transportation and Storage	H
Accommodation and food service activities	I
Information and Communication	J
Financial and Insurance Activities	K
Real Estate Activities	L
Professional, Scientific and Technical Activities	M
Administrative and Support Service Activities	N

Public Administration and Defense; Compulsory Social Security	O
Education	P
Human Health and Social Work Activities	Q
Arts, Entertainment and Recreation	R
Other Service Activities	S
Activities of Households as Employers; Undifferentiated Goods and Services Producing Activities of Households for Own Use	T
Activities of Extraterritorial Organisations and Bodies	U

Source: NACE Rev.2, 2008[1]

There are in practice several limitations facing mapping of the CS market in relation to the CS taxonomy, the user categories, and the economic sectors. However, we have as far as possible aimed at assessing direct and indirect CS market information in relation to the taxonomy. Details about this will be provided in the subsequent methodology section.

1.3 Methodology for mapping the CS market

For this deliverable we have concentrated on the open-source public sector of CS as very limited information is available on the commercial part of the CS market in particular for the private sector. A few international market survey companies supply CS market surveys, but these are only available for a very high price implying that data from these surveys are not part of our review. We are in our assessment of the CS market overcoming this limitation by combining statistical market exchange data and indicators of adaptation activities, where CS play a key role, without being able to distinguish CS products, which directly have been part of the adaptation activities.

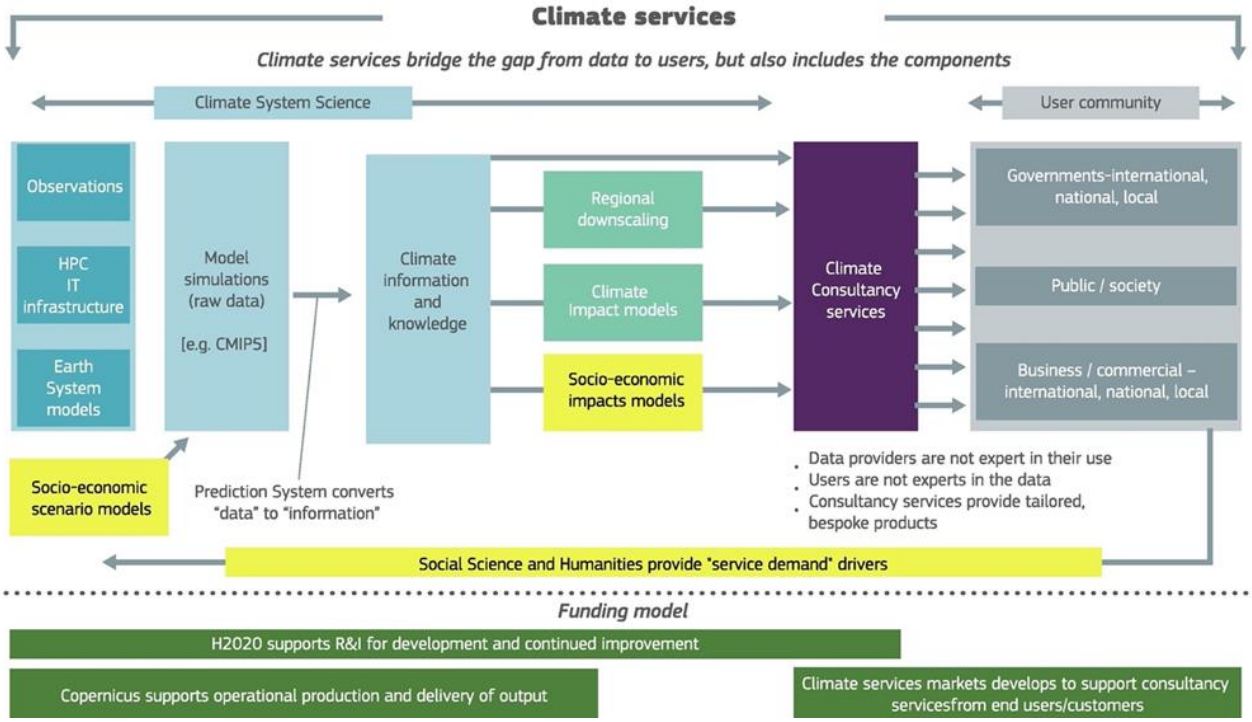
The EU H2020 project MARCO (EU-MARCO 2018a, b; Cortekar et al., 2020) included an attempt to map present and future CS markets and concluded that the currently available market information did not constitute a basis for assessing current or potential future potential CS markets. Sectoral analysis

[1] Reference: NACE Rev. 2 - Statistical classification of economic activities - Products Manuals and Guidelines - Eurostat (europa.eu)

of climate risks and planning, and adaptation planning however, could be used as indicators of present and future CS markets.

The EU-MARCO project framed the CS market assessment based on the EU roadmap for climate services (EU, 2015) and its CS roadmap definitions. Figure 1 from the EU roadmap is illustrating the major structural elements of the CS market interactions (EU, 2015).

Figure 1. Overview of major CS market elements



Source: EU, 2015.

Based on the EU roadmap figure, the CS market can be described as the exchange of information marked by the purple box in Figure 1. The supply side is covered by the left side of the purple box, and the demand side by the right side of the purple box.

The CE2 survey of the current CS market will, as in the MARCO project, focus on the purple box in Figure 1, and we will include information on publicly available CS as well as on commercial products as far as information is available. In the context of this report the term "market" as in the MARCO project will be used to describe all sorts of CS information exchange including both commercial transactions and the use of freely available data (MARCO, 2018d).

Measuring the CS market is a complicated matter because there are no formal markets for CS characterised by well-defined CS products, suppliers; purveyors and buyers, and there is no statistical data on the CS, which is actually exchanged. According to the terminology included in Section 1, CS includes both product-oriented activities like data, and modelling and advisory services, and support to decision making oriented towards a broad range of stakeholders. This implies that many intangible CS products are involved. In order to reflect the broad range of CS products in our assessment of the CS market, we are including a number of indicators of where decision making activities are expected to embody the use of CS without being directly reported.

Further complications in measuring the CS market arise from issues related to mainstreaming, where CS are integrated into normal planning and business practice without showing up as specific climate related activity. Mainstreamed CS activities are difficult to measure since these by definition are embedded in more general planning and management activities and open information about CS is then not easy to find. Mainstreamed CS activities however, seem to be expanding according to Hermansen et al., 2021. Mainstreaming of CS into existing business activities can be driven by several factors including:

- Mandatory reporting requirements e.g. the EU rules on environmental, social, and governance issues (ESG) for the financial sector.
- Voluntary commitments by companies as part of strategies and for Corporate Social Responsibility accounting.
- Mandatory planning and binding commitments for management of climate risks for local and national governments.
- Insurance companies demand customers to climate proof their insured assets.

As climate policies become more stringent and extreme events become more frequent over time, CS mainstreaming could also be more dominant as part of the CS exchange, which might make it in the future even more difficult to measure CS markets than it is today.

In conclusion, it can be said that measuring the extent of the CS market is masked by lack of statistical data, and by commercial interests implying that open information about the provision and use of CS is very limited. Our review of the current CS market will address these information deficits by supplementing the available statistical CS market information with a number of indicators, which are pointing to where different sorts of CS have been used without directly showing up in official statistics.

From the user side of the CS market, we will include indicators of measurable activities in terms of e.g. implementing adaptation plans, and from the supply side we will include information about specific CS, where information has been available on the use of the products.

2 Screening of CS applications in EU projects

2.1 Introduction

The section is providing a preliminary overview of past and ongoing EU funded projects, which have aimed at supporting the development and deployment of CS. The EU CORDIS database (https://cordis.europa.eu/) has been searched to identify such projects. The screening keywords in CORDIS have been '**Climate service' + 'Europe**'. In addition, we have supplemented the database with additional information for 9 projects which were not captured by the search but are, based on our own knowledge, relevant to include in an assessment of CS as part of the CORDIS project portfolio. It should here be recognized, that the screening of the CORDIS database is very sensitive to the screening criteria applied, and that the current screening will be updated in subsequent versions of this deliverable with more comprehensive information. In total 75 projects from the CORDIS database have been selected for our assessment, and these projects have been undergoing a more in depth assessment including sectors (based on NACE code taxonomy) CS products, CS users, and CS products planned and marketed.

The current assessment is limited in terms of being able to address issues related to how CS developed in CORDIS projects have been further developed and used after the end of the projects. No information about these key issues are included in CORDIS. As a preliminary attempt, we have contacted PIs of selected projects in order to address these issues, but more time is needed to collect more comprehensive information on the projects since in a number of cases neither project teams nor web sites exist any longer.

The codes used for the assessment of the projects are included in section 1.

General conclusions based on identified projects in this first screening in the following will be provided in relation to sectoral coverage of the projects, categories of CS provided, targeted CS users, and the funding resources allocated to these main categories of CS projects. Table 4 provides an overview of CS targeted sector, users and CS categories.

Table 4. Overview of sector focus, CS users, and CS taxonomy categories in projects identified in CORDIS database

Sectors	Number of Projects							
	Single sector focus	Sectors in depth cases	Multiple sectors	User category 1-2: Policy maker or Government user	User category 3,4 and 8: Private sector user	All the other user categories:Other Users	CS category 0 - 6: Climate data forecasting etc.	CS category 7-8: Climate advisory and other services
Agriculture, Forestry and Fishing (A)	5	4	26	2	8	4	6	2
Mining and Quarrying (B)								
Manufacturing (C)	1				1		1	
Electricity, Gas, Steam and Air Conditioning Supply (D)		6		2	5	2	6	3
Water Supply; Sewerage, Waste Management and Remediation Activities (E)	2	6		4	6	3	6	6
Construction (F)								
Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles (G)								
Transportation and Storage (H)		2						2
Accommodation and Food Service Activities (I)								
Information and Communication (J)								
Financial and Insurance Activities (K)								
Real Estate Activities (L)		3					1	3
Professional, Scientific and Technical Activities (M)	2			all users			1	2
Administrative and Support Service Activities (N)								
Public Administration and Defence; Compulsory Social Security (O)								
Education (P)								
Human Health and Social Work Activities (Q)	3	3			3	4	5	3
Arts, Entertainment and Recreation (R)	7	1		6	5	5	11	2
Other Service Activities (S)								
Activities of Households as Employers; Undifferentiated Goods and Services Producing Activities of Households for Own Use (T)								
Activities of Extraterritorial Organisations and Bodies (U)								

Note 1: Projects can be counted more than once in the table cells if they include several users' categories and/or categories of CS.
Note 2: The CS user categories in accordance with the definitions in Section 1 are: Policymaker 1; Governmental body 2; Resource manager (public) 3; Resource manager (private) 4; Data-related stakeholder 5; Civil society/community representatives 6; NGOs and other foundations 7; Private sector 8; Networks 9, Media 10; Other 11.
Note 3: The CS user categories in accordance with the definitions in Section 1 are: Measurement 1; Operation 2; Publication 2; Data management 4; Processing, Re-analysis & interpretation 6; Modelling 6; Climate advisory service 7; other consulting 8.

As it can be seen from Table 4, 26 out of the 75 projects included were addressing multiple sectors, and dominant sectors which were addressed in several projects included 'agriculture, forestry, and

fishing', 'water supply, sewerage, waste management', and remediation activities, and 'arts, entertainment, and recreation'. Projects that focused on individual sectors or in-depth case studies on a sector, as part of a project with more sectors included, were only undertaken for a few of the sectors. Sectors in this category with many projects include 'electricity, gas, steam, and air conditioning supply', 'real estate', 'human health and social work activities', and 'arts, entertainment and recreation'. In total 14 projects had policy makers and/or government bodies as a user category, and 46 other user categories (private sector, utilities, NGOs etc). The CS category measurement, operation, publication, data management, processing, re-analysis & interpretation, and 'modelling' dominated the CS projects, while the CS categories 'climate advisory services' and 'other service activities' were included in few projects.

Table 5 shows that the sectors that are part of the largest total funding allocation are 'agriculture, forestry and fishing' and 'water supply; sewerage, waste management and remediation activities', and other sectors included with relatively large funding are 'electricity, gas, steam and air conditioning supply', 'human health and social work activities', and arts, entertainment and recreation'. The specific funding for each of these sectors cannot be seen in the CORDIS database, since the individual sectors are often addressed in case studies as part of larger projects, therefore it is difficult to detect the specific funding for individual sectors. A further complication in measuring how much funding, which has been allocated to specific CS is that some projects have developed a wide range of CS without specific the resources allocated to each CS, and other projects have only developed one CS or a few. As shown in Table 5 a large fraction of funding is going to other service activities or to not classified activities in the NACE codes, and a careful examination of the individual projects therefore will be needed beyond the information included in CORDIS in order to measure how much funding, which has been allocated to specific CS and sectors.

In the following a very brief overview of the projects included in the individual sectors is given, and this is supported by detailed information project by project in Annex 1 with detailed information about funding and focus of individual projects.

Within the sector 'agriculture, forestry and fishing' there are 6 projects, which specifically address CS applications in relation to the sub-categories agriculture or forestry, and the sector is also part of three more comprehensive projects addressing several sectors. 'Processing, re-analysis & interpretation, modelling, advisory services, and other consultancy services CS are included in the projects.

The projects included in the sector 'electricity, gas, steam and the air conditioning' are in most cases integrated in larger portfolios of sectors except in the case of the S2S4E project on seasonal forecasting for energy (https://s2s4e.eu), and the SIM4Nexus project https://sim4nexus.eu/ , which are integrating the energy and the water sector. CS categories within the sector are both processing, re-analysis & interpretation, modelling and consultancy services and advice.

The sector 'water supply sewerage, waste management, and remediation activities' include a few separate sector focused projects. Like for the sector 'electricity, gas, steam and the air conditioning', the CS categories are predominantly processing, re-analysis & interpretation, modelling, advisory and consulting.

The 'transportation and storage' sector has been included in two multi sectoral projects, which are addressing urban planning issues. The 'real estate activities' sector is part of three projects and two of them are related to urban planning, these latter projects are also including the transportation sector. The CS categories included in these sectors are advisory services and other consulting.

Table 5. Overview of sector focus and funding for projects identified in CORDIS

Sector (according to NACE code)	Single sector focus Number of projects including the sector (a)	Sectors in depth in depth cases Number of projects including the sector (b)	Multiple sectors Number of projects (c)	Total funding mill EUR of a + b + c
A - Agriculture, Forestry and Fishing	9	5	4	54.5
D - Electricity, Gas, Steam and Air Conditioning Supply	6	0	6	36
E - Water Supply; Sewerage, Waste Management and Remediation Activities	8	2	6	62
H - Transportation and Storage	2	0	2	9
L - Real Estate Activities	3	0	3	14
M - Professional, Scientific and Technical Activities	2	2	0	6.2
Q - Human Health and Social Work Activities	6	3	3	32.6
R - Arts, Entertainment and Recreation	8	7	1	35.2
S - Other Service Activities	44	9	35	292.8
Not specified	9			173.8

Note 1: Rounded numbers for funding are shown including EU funding and own contribution.
Note 2: Projects can be counted more than one time in the table cells if they are including several users categories and/or categories of CS

Two projects include very specific technology-oriented measures related to 'professional, scientific and technical activities'. All users are the CS target group.

'Human health and social work activities' projects include both separate health focused projects that are developing specific CS related to warning systems and projects, where the health sector is part of a multiple sector approach. The CS involved are predominantly consultancy services and advice, and many user categories are targets.

There are many projects related to the 'entertainment and recreation' sector including projects related to the tourist sectors and to cultural values. Monitoring, and advisory services are typical CS categories. All projects in the category 'other services' contain CS that generally can be applied across many sectors and geographical areas. The CS categories modelling, measurements, data analysis, and other consulting and advisory are very frequently involved in relation to such projects.

3 Assessing the current CS market from a user perspective

3.1 Introduction

The review of the current CS market includes an assessment of the CS market based on a literature review with a number of indicators, which are pointing to, where different sorts of CS has been used without directly showing up in official statistics of CS use.

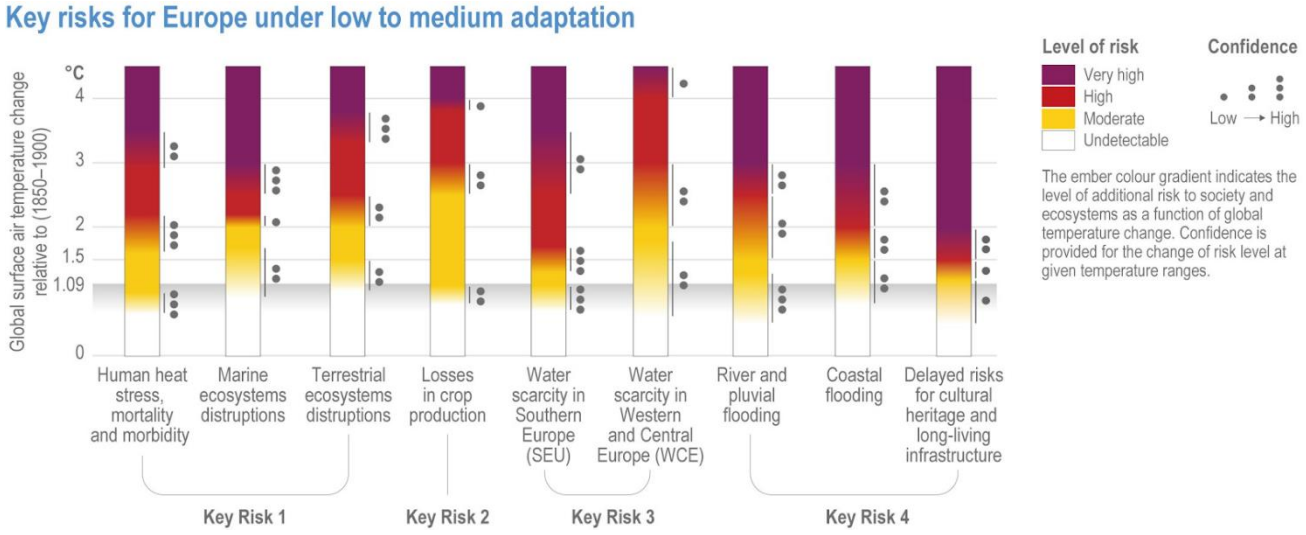
From the user side of the CS market we are including indicators of measurable activities in terms of e.g. adaptation planning and commercial requests for CS.

The section is starting with a brief overview of climate risks in Europe and sectoral and geographical coverage as an introduction to, where there could be a high benefit of using CS. This is followed by a review of the available literature on CS markets followed by a review of selected CS user sectors.

3.2 Key climate risks in Europe providing a potential for CS markets

The use of CS is driven by its potential to support adaptation and thereby reduce the risks of climate change and extreme events. A very extensive international literature has assessed the major climate risks globally and regionally, and general conclusions about these risks are included in IPCC, 2022. In the case of Europe. The following Figure 2 shows the key risks assessed by IPCC, 2022 for Europe.

Figure 2. Key climate risks to Europe under low to medium adaptation



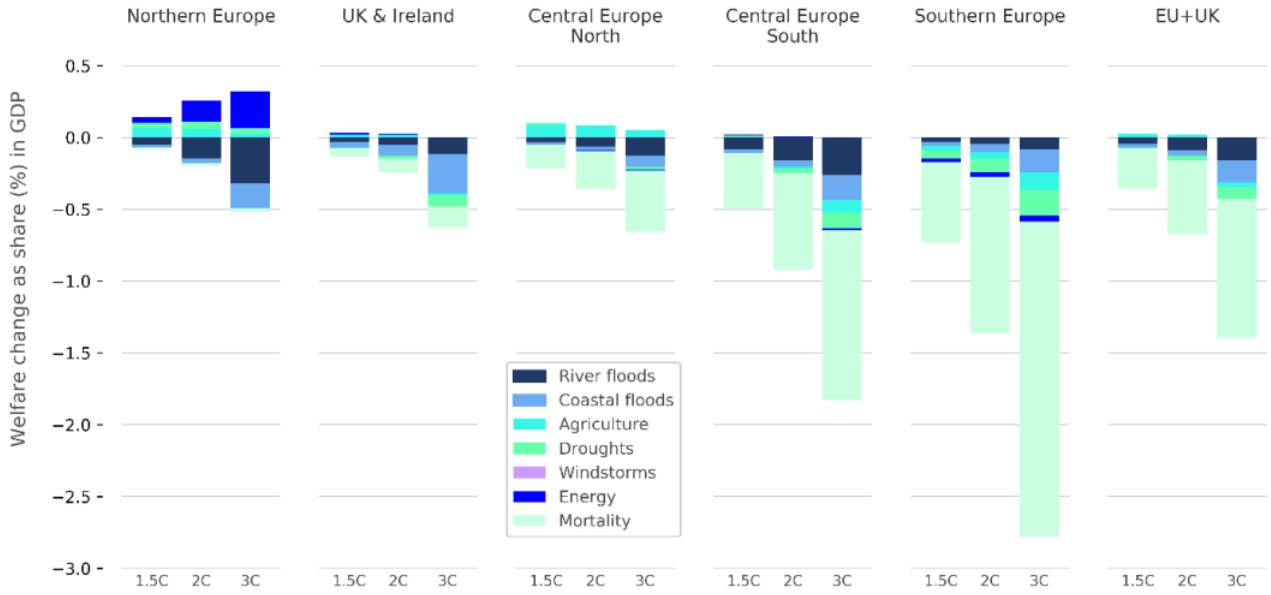
Source: IPCC, 2022 Figure 13.028

Figure 2 shows risk levels for regions and sectors in Europe corresponding to temperature change above the preindustrial level 1850 to 1900. It can be seen that the sectors and regions in Europe that will be most affected by climate change at relatively low levels of temperature change are 'human, heat stress, mortality and morbidity', 'water scarcity in southern Europe', 'coastal flooding'; and 'delayed risks for cultural heritage and long living infrastructure'. The risks are assessed to be relatively low for 'food production' at low temperature changes, and these risks are assessed could be substantially reduced by adaptation. When high risks for some sectors are arriving already with low average global temperature change, i.e. it implies that it could be beneficial very fast to develop and implement adaptation plans for these sectors and regions, and CS application could thereby be important in these areas.

Several economic modelling studies have assessed the damage costs of climate extremes to sectors, and the benefits of adaptation, and such studies can also be used as indicators of, where CS could be beneficial to apply. In the following, a few examples of damage cost studies for Europe is provided.

The EU Peseta project (Feyen et al., 2020) included projections of GDP losses to sectors based on a Computable General Equilibrium Model (CGE), where climate scenarios corresponding to 1.5°C, 2°C, and 3°C temperature change were exposed to the European economies and the UK assuming the current economic structure. The results are shown in Fig 3.

Figure 3. Welfare loss (% of GDP) from considered climate impacts at warming levels for the EU and the UK, and for macro regions. The results represent changes in welfare if warming levels would act upon current economy, compared to the current economy under present climate.



Source: Feyen et al., 2020

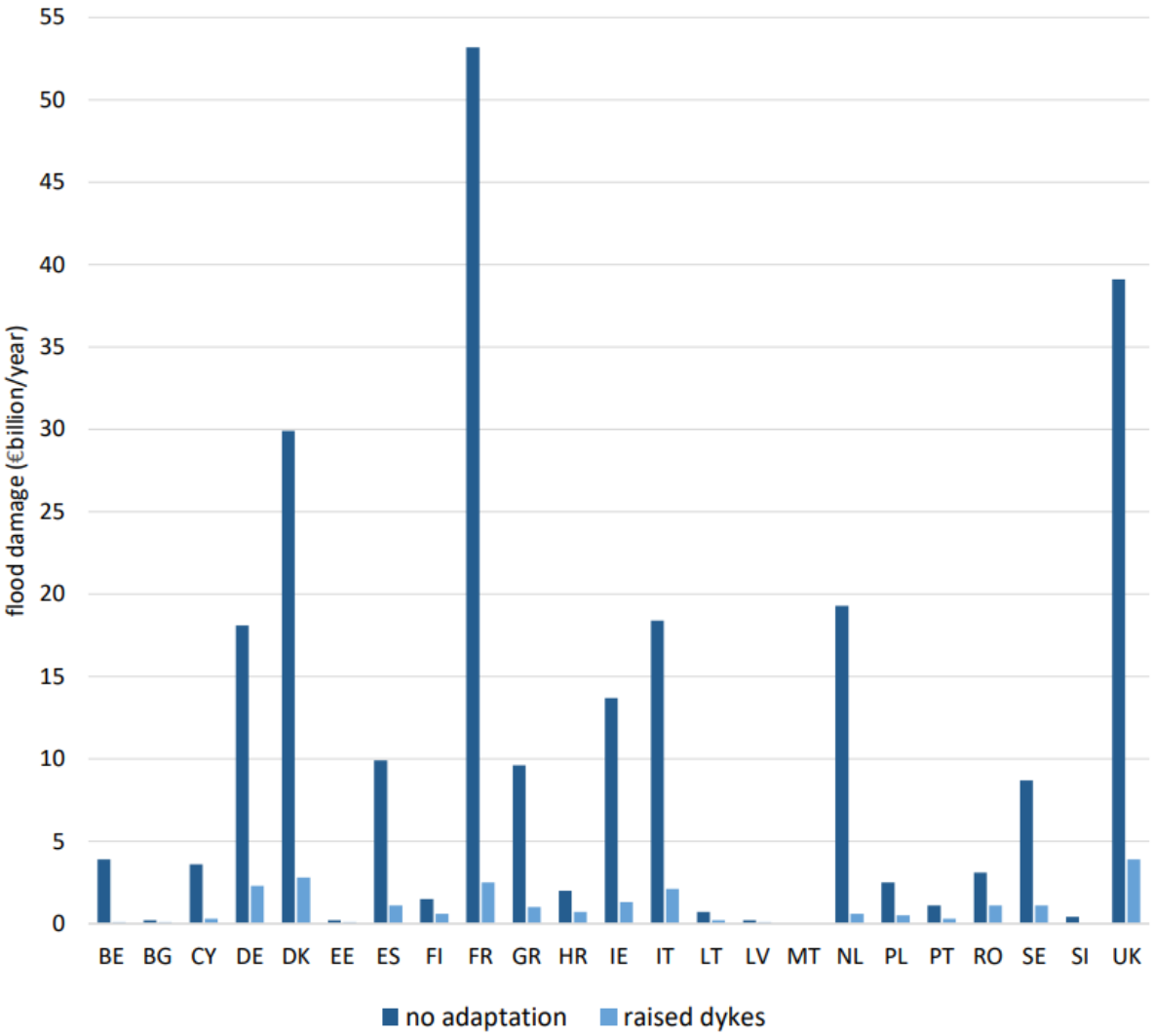
Human mortality from extreme heat dominates the aggregated economic impacts of climate events in Europe as it can be seen in Figure 3. The related welfare loss reaches 36, 65 and 122 €billion at 1.5°C, 2°C and 3°C global warming, respectively. More than 80% of the mortality related welfare loss is estimated for southern EU regions. It should be noted that the share of human mortality loss to the total economic impact depends strongly on the appreciation of the economic value of life.

In terms of people being affected by mortality from extreme heat Feyen et. al., 2020 estimated that with a 1.5°C stabilisation scenario, each year more than 100 million Europeans would be exposed to an intense heatwave (this is a heatwave that under present climate is expected to happen once every 50 years), compared to around 10 million/year now (1981-2010). With 2°C, this increases to 176 million people per year and with unmitigated climate change (3°C in 2100) to nearly 300 million/year, or more than half of the European population. The death toll of such events will depend on adaptation measures. Primarily southern Europe has a high risk within this area.

Coastal and river flooding is the second largest risk area considered by Feyen et. al., 2020 and both northern Europe, the UK and central, and southern Europe can face these risks in particular in the case of 3 degrees stabilisation scenarios.

Vousdokas et. al., 2020 assessed the damage costs of coastal flooding in Europe and the UK with and without implementing adaptation measures and concluded that there could be a very large difference between the damage costs by countries with and without adaptation as it can be seen in Figure 4.

Figure 4. National annual damages without and with adaptation (for high RCP 8.5 emissions scenario in 2100)



Source: Vousdoukas et. al., 2020

In conclusion, climate risk assessments have identified health issues related to extreme heating, coastal and river flooding, and culture and infrastructure as major risk areas in Europe, and some regions also have specific risks as e.g. with agriculture and drought in southern Europe. It is then interesting to study whether CS applications in Europe are particularly intensive in sectors with high climate risks and large potential benefits of using CS as a coping measure, and in this context to assess whether there seems to be gaps between CS markets and risk management.

3.3 Review of CS market assessments

The literature on the extent of climate service markets is very limited and studies on the current and future CS markets therefore to a large extent have relied on the assessment of risks and sectors, where

there could be benefits associated with the use of CS. In the following a brief overview is provided of studies that have assessed the markets for CS.

The EU H2020 project MARCO (2016-2018) (EU-MARCO, 2018 a,b) concluded that there was a gap between what could be economically attractive in terms of risk reduction benefits by using CS, and the actual use of CS. This implied that there could be an efficiency loss in coping with climate change impacts because economic attractive adaptation options were not identified and used. Efficiency improvements in the use of CS to support adaptation could therefore be economically attractive.

MARCO also concluded that potential users of climate adaptation services faced a very "fluffy/intangible" product, and there was very limited transparency on the market. Furthermore, the quality of services was uncertain, and the value of using CS was difficult to understand for potential users. The consequence could be a restricted and relatively small CS demand compared with what could be beneficial. A further consequence of the market obstacles could be very high transaction costs to CS providers, purveyors, and users. This would make it difficult to plan product development and to identify user needs, and the CS exchange is therefore facing significant barriers.

The MARCO project and its sister project EU MACS (2018 a,b) included quantitative estimates of the current CS market based on indicators, and it was here concluded that in particular the public sector dominated the CS use (Hoa et al., 2020). However, in recent years the share of the private sector in climate services provision reached around 30 - 35%, and according to the forecasts the CS use by the private sector was expected to grow. The most important user segments identified were: water management, energy, agriculture, spatial planning, education, business services, and forestry.

A review study by USAID (USAID, 2013) on CS markets concluded that a further penetration of climate services would depend on a clearer estimation of the economic value of using climate services in order to facilitate that potential CS users could identify more tangible values. The study included a review of 139 studies on the value of using CS with a focus on agriculture and the energy sector. It was concluded that the majority of the studies included *ex ante* predictions of potential values by using CS based on models using historical climate data, which did not reflect the full scale of adaptation needs given future climate change. The value of further extending the use of CS and thereby market potentials was assessed in the USAID study assuming optimal response behaviour without including scenarios representing actual behaviour in terms of using CS, and the market forecast in this way only represented optimal solutions in using CS rather than actual market implementation.

Soares et al., 2018 conducted 75 in-depth interviews with organisations working across eight sectors (including energy, transport, water, and agriculture) in 16 countries and found that the majority of the organisations interviewed did not currently use seasonal climate forecasts (SFC) (50 studies) despite this sort of CS could be considered to be beneficial to the users. The energy and the water sectors had the highest frequency of using SFC among the interviewed. It was concluded that a major factor behind the limited use was low reliability and skill of seasonal climate forecasts as well the lack of awareness of SFC in organisations.

Halsnæs et al., 2020 estimated the current and future CS market potential for the renewable energy sector, climate finance, and city adaptation planning based on existing scenarios and official plans. A large potential for the further development and penetration of context-specific CS were identified in relation to renewable energy sources including technologies such as solar and wind energy, which require smart management of fluctuating energy production and thereby context-specific information on resources, requiring tailor-made CS information. Similarly, investments in new renewable energy

capacity would critically depend on efficient planning and the use of CS implying a large market within this sector. International finance by the multilateral development banks (MDB) were also assessed to be a very large sector, which would need CS for climate proofing of climate change mitigation and adaptation investments. According to the guidelines for these investments both currently and in the future, the MDB climate finance is expected to increase fast from the US$51 bill. In 2021 to low and middle income countries. City adaptation plans were also considered to be main drivers for CS use currently and in the future. Cities are developing very fast both in Europe and globally, with large-value assets in the form of buildings, infrastructure, historical and cultural heritage, ecosystems, and people. However, the wide application of CS into city adaptation plans was considered to be limited compared with all the context specific CS needed for advanced adaptation planning.

Tart et al., 2020 conducted an online survey among climate service users around the world (n = 248), and interviews with both users and non-users of climate services (n = 36). The top sectors within Europe were renewable energy, agriculture, built environment, and research and development. Outside of Europe, the top four sectors were agriculture, research and development, education and training, and renewable energy, the sector "built environment" was not far behind. Researchers were included in the respondents, which partly explains the important role of the education and training sector. Overall, the type of the organisation did not seem to change the demand trends much. Utilities (energy and water), however, was the top sector for state-owned enterprises, and the built environment and renewable energy were the most important sectors among private organisations (agriculture was next).

Georgeson et al., 2017 introduced a mixed top down/bottom-up approach for estimating the CS market. Future climate service needs were addressed by comparing the state of the current commercial climate service market by regions and sectors with the average GDP per country and a climate risk index provided by Germanwatch (Kreft et al., 2015). It was concluded that there is a correlation between the scale of commercial climate service transactions and GDP per capita, but not between climate vulnerability and climate service transactions. In terms of CS forecasting this suggests that further market development will depend on both economic growth in the countries and on their capacity to use climate services in risk coping strategies. The current CS markets were also assessed using transactional data in terms of annual spendings by private and public organisations on commercial weather and climate information in more than 180 countries by industrial sector, region, and per capita. Total spending in 2014/2015 on weather and climate services reached more than $56 billion, with 54% spent on weather services and 46% in climate services. This compares to an estimate of annual public funding of national hydrological and meteorological services globally of $15 billion. Using the same transactional data methodology, global spending on adaptation to climate change in 2014/2015 was estimated to be $357 billion.

It was concluded by Georgeson et al., 2017 that the global measurement of spending on CS and adaptation demonstrates that there is a significant and vibrant economic sector for commercial weather and climate services beyond freely available publicly funded weather and climate data. In particular sectors with long term planning perspectives have played a key role in the CS market such as for example the built environment (weather, $1.442 million; climate, $2.414 million), agriculture (weather, $458,5 million; climate, $1.183 million), forestry and timber (weather, $693 million; climate, $1.088 million), exploration and extractives (weather, $1.052 million; climate, $1.675 million), and tourism (weather, $292,8 million; climate, $826 million) have a higher share of climate services. The regional spendings were the most in total in East Asia and the Pacific ($16,500 million), whereas sub-Saharan Africa spent less than $1.400 million. Based on this Georgeson et. al., 2017 concluded that the market for weather and climate services was not fully exploited at the time of the study.

A number of commercial market studies have assessed the CS markets based on information about current market transactions, as a basis for market forecasts. Due to commercial reasons, it is difficult to get extensive information from these studies, but a few conclusions is provided openly.

Environmental Business International (EBI) regularly publishes comprehensive studies on CS markets based on the environmental industry and thereby the supply side of the climate service market (EBI, 2022) Market forecasts are developed as commercial products covering sectors related to climate change mitigation and adaptation. The methodology includes regular surveys with panel companies, specific contact to industry leaders, and industry datasets. Very detailed reports are commercially available including information about CS providers, market segments, economic turnover etc., which are expected to provide key information on the current CS market.

kMatrix Kmatrix | Evidence-based Industry Data - Kmatrix is like EBI developing climate service market forecasts based on commercial transactions related to climate change risks and adaptation. The approach is parallel to market forecasting by the company for other sectors based on a review of various data sources, business accounts, and other commercial information. Climate service market forecasts based on the current market overview are established as a projection of historical growth rates for different market segments. kMatrix (Howard et al., 2020) assessed that in the EU28 Countries the complete Weather & Climate Services (W&CS) market was worth €12.9bn in the financial year 2016/17, shared between Climate Services with €7.3bn (55% of the total) and Weather Services with €6.1bn (45% of the total). Annual CS market growth rates were estimated for the period 2017/2018 to 2024/2025 to be between about 11% and 14%.

The main findings of studies addressed in this section are summarised in Table 6.

Table 6. Summary of the literature review findings

STUDIES	SECTORS USING CS	TOTAL CS SPENDING
Soares, 2018 Energy, transport, water, and agriculture	A majority out of 75 in depth interviews concluded that seasonal CS forecasts were not used. Water and the energy sector most frequently used the forecasts	
Halsnæs et al, 2020 Renewable energy climate fiancé and cities	All sectors are expected to grow fast in their use of CS	
Tart et al., 2020	CS top user sectors in Europe were renewable energy, energy, agriculture, built environment, and research and development	
Georgeson et al., 2017		56 bill. USD on weather and climate services in 2014/15 Globally Climate services amounted to 46% of the spending
Kmatrix Howard et al., 2020		spending on weather and climate services in Europe amounted to EUR 12.9 billion in 2016/17 of which climate services amounted to 55%

3.4 Assessing the user side of the CS market

As pointed out previously there is very limited evidence available on the full scale of CS markets, and there is also very limited information about the user side of the CS market. We will therefore add to the conclusions of the already presented CS market studies by presenting examples of ongoing climate change adaptation activities, where CS is an intrinsic part without being separately documented as a product. Ongoing adaptation activities can be understood as being a good indicator of where CS is used in practice, and can be used to measure CS related adaptation. The indicator is a way of verifying CS exchange as in relation to adaptation, and in this way can be used to identify CS, which are not directly visible and measurable.

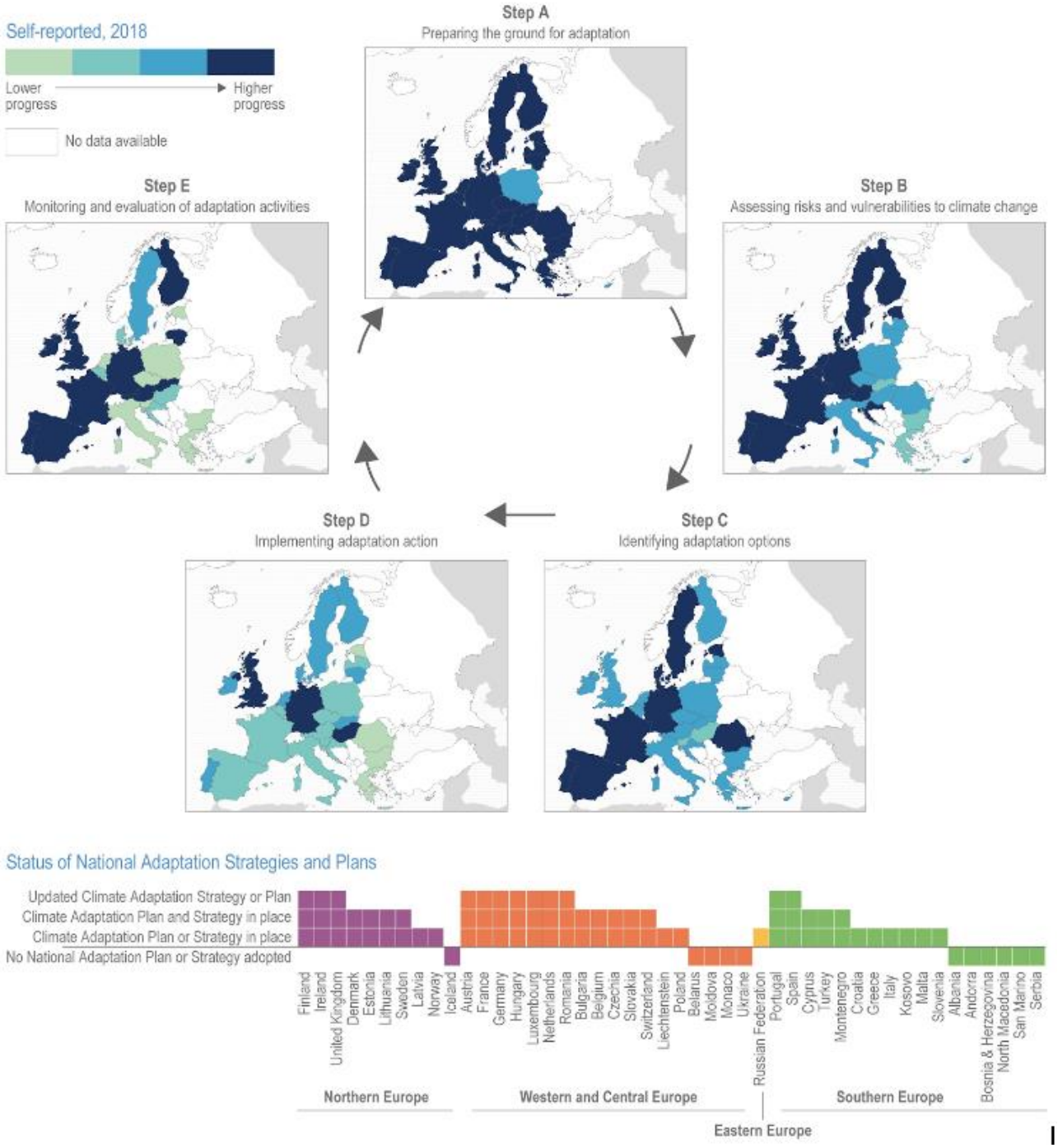
3.4.1 Studies of the implementation of adaptation

Based on a global systematic literature review IPCC, 2022 and Berrang-Ford et al., 2021 identified 1682 empirical scientific studies that report observed and implemented adaptation related responses, which can be considered as being close to an indicator of where CS have been used. Adaptation responses is reported across all global regions, with the greatest number of responses in Asia (35% of articles) and Africa (32%). Studies for Europe were relatively few. A minority of studies focused on Central and South America (6%) or on Small Island States (2%). The most extensively covered sectors were food and agriculture for all regions except for Oceania and Europe where health topics were dominant. Flood risk was a major focal area in European urban areas. In terms of hazards reflected in adaptation plans, extreme precipitation and inland flooding, precipitation variability, and drought dominated and in terms of sectors, food, fibre, and other ecosystem products were the most prevalent in the literature on adaptation implementation in Europe. The literature for Europe included adaptation options implemented by government actors, individuals, and households, and there were fewer examples of private sector actions.

Developing and implementing adaptation plans is a long process, which will involve CS in several steps of the process implying that the use of CS in adaptation planning will be an ongoing process. A status of the progress in European adaptation plans is shown in the following Figure 5 based on IPCC, 2022.

Figure 5 shows that in the first initial stages of adaptation plans including "preparing the ground for adaptation" and "assessing the risks and vulnerabilities" and "identifying adaptation options" large parts of Europe show a high progress, but moving on to stages like "implementing adaptation options" and “monitoring and evaluating” the progress is only high in a few European countries. There are large differences between the sub regions, and in terms of implementing adaptation actions Germany and the UK have the highest progress, and when taking monitoring and evaluation of adaptation activities into consideration also Western and Southern European countries are amongst the countries with highest progress. Some East European countries show slow progress in national adaptation planning. In terms of the status of adaptation plans as illustrated in the lower part of Figure 3 Northern, Central and Western Europe is more advanced in adaptation planning than Southern Europe.

Figure 5. Progress in national adaptation plans and status of national adaptation strategies and plans in Europe



Source: IPCC, 2022, Chapter 6.

The IPCC literature review also assessed the type of actors, which were using the CS, and globally it was concluded that in 82% of the papers the actors were households or individuals. In Europe however, the private sector e.g., the tourism sector was more actively involved.

Comparing the systematic literature review for Europe by IPCC, 2022 on implemented adaptation plans with the key climate risks in Europe (see Figure 2), where health and flooding were highlighted as major risk areas together with cultural heritage and infrastructure (in section 3.2), it is striking that implementation adaptation plans are not more frequently represented by studies for Europe.

3.4.2 Adaptation in Cities: Risk assessment and adaptation planning

Globally, 55% of the world's population reside in urban areas (UN, 2018). In Europe, cities are home to about 75% of the European population, comprise a major part of the European economy and house many valuable built and natural assets with historical and cultural values. Whilst cities are increasingly at risk from climate change, cities also have a unique opportunity to provide adaptation measures that mitigate the impacts of climate change across a broad section of sectors and to the population. As such, climate change adaptation in cities is a very high EU priority (EEA, 2020).

The Carbon Disclosure Project (CDP) serves as an official reporting platform for the Compact of Mayors, and administrates, collects, and analyses a global survey of city based environmental and climate change data on an annual basis and underpins the city-level adaptation measure reported by the Lancet Countdown Commission on Climate Change and Human Health (Romanello et al., 2022). In 2022, 94% of cities reporting to the Carbon Disclosure Project's global survey completed or were in the process of conducting city-level climate change risk assessments, an increase from 46% of reporting cities over the previous 5 years.

Focusing on the European region, of the 171 cities that reported on their climate change risk assessments, 98% had completed, were completing or intended to complete a climate change plan in 2022. Of the 180 European cities that reported climate hazards, key climate hazards reported were heavy precipitation and extreme heat (Table 7). Transportation and storage is the major sector affected by extreme precipitation, and human health and social work activities are the major sectors affected by extreme heat. There are some regional differences in the most important climate hazards by region, where extreme precipitation and urban flooding are major concerns in northern Europe, extreme heat and heat stress are the most important climate hazards in western, central Europe and in southern Europe with key sectors anticipated to be infrastructure and health and social services.

Moving from risk assessments to climate action plans, in 2022, 88% of European cities (n=182) self-reporting to the CDP noted that they had a formal climate action plan or strategy that addresses climate mitigation and/or climate adaptation, whilst 91% (n=186) cities had enacted some form of climate action (reporting a climate adaptation action was not dependent on having a formal climate action plan).

Whilst the cities self-reporting to the CPD demonstrate that climate change adaptation is occurring in European cities, the self-selection to report to the platform indicates a pre-existing acknowledgement that climate change adaptation is necessary. Using the Urban Audit database, Reckien et al., (2023) assessed the quality of urban adaptation plans of European cities from the period 2005 to 2020. Across a representative sample of 327 European cities 51% (161) cities have an adaptation plan, with cities in the UK (30 plans), Poland and France (22 plans each), and Germany (19 plans) having the highest number of plans. Within these four countries, legal obligations were an important driver with 32% of these plans developed in response to a national, regional, or local law that requires municipalities to develop an urban climate adaptation plan.

Table 7. Climate hazard reported by pct. Share of CDP reporting European cities (180 cities)

Region	Climate Hazard		Sector 1	%	Sector 2	%	Sector 3	%	Sector 4	%
Europe	Heavy Precipitation	24	Transportation and storage	21	Agriculture	18	Sewerage, waste management	13		
	Extreme Heat	24	Human health and social work activities	24	Water supply	18	Agriculture	15		
	Urban Flooding	10	Agriculture	13	Accommodation and food service activities	13	Sewerage, waste management	13		
Northern Europe	Heavy Precipitation	24	Construction	17	Transportation and storage	17	Agriculture	18	Sewerage, waste management	18
	Urban Flooding	15	Sewerage, waste management	16	Accommodation and food service activities	16				
	Extreme Heat	13	Agriculture	25	Human health and social work activities	17	Water Supply	17		
Western and Central Europe	Extreme Heat	38	Electricity, gas, steam and air conditioning..	40	Human health and social work activities	20	Construction	20	Transportation and storage	20
	Heat Stress	24	Human health and social work activities	20	Agriculture	20	Sewerage, waste management	20	Water Supply	20
	Heavy Precipitation	14	Public administration & defense	50	Sewerage, waste management	50				
Southern Europe	Extreme Heat	35	Human health and social work activities	31	Water Supply	25	Forestry	19		
	Heavy Precipitation	29	Agriculture	29	Transportation and storage	29	Sewerage, waste management	21		
	Fire	8	Transportation and storage	17	Construction	17	Agriculture	11	Human health and social work activities	11

Reicken, 2018 assessed the relationship between the development of adaptation plans and policy frameworks and international networks such as Covenant of Mayors. Reckien et al. (2018) found that cities with a national obligation to develop a local climate plan are 5 times more likely to have an adaptation plan. Over 50% of cities have adaptation plans in the case where climate plans are mandatory (This only concerns 4 of the EU-28 countries (Denmark, France, Slovakia and United Kingdom)). Of the total sample of 273 cities, 56.4% have an adaptation plan in 2018 (Reckien et al., 2018). 40% of the sample of 885 cities are signatories of the Covenant of Mayors, whereof 93 cities (10.5%) have an adaptation commitment. In 24 of the EU-28 countries there is no requirement for cities to prepare a local climate plan, so the development of such plans are driven by local engagement and action (Reckien et al., 2018). Of the total sample of 612 cities, 11.3% have an adaptation plan and 3.1% a joint mitigation and adaptation plan (Reckien et al., 2018).

The quality development of urban adaptation plans over time in Europe has been assessed by Reckien et al., 2023 using indicators to measure the quality of adaptation plans in 327 cities from the period 2005 to 2020. In terms of the use of CS several quality criteria directly related to the use of CS are applied including criteria 1 "the fact base", and criteria 3 "consistency, measures, monitoring and evaluation, and participation". Out of the 327 cities assessed, 167 had an adaptation plan, and the

average quality score on all plans was 34 out of a maximum of 100. This implies that there is a large potential for further development and application of CS within urban adaptation planning in Europe. The quality of adaptation plans has increased over time, but the assessment also points to a number of weaknesses in relation to the existing plans, and i.e. they include consistency between risk assessment and adaptation measures. Another limitation is that vulnerabilities of some sectors are relatively well covered, but vulnerabilities of social groups are not included. In terms of getting more detailed information about specific gaps in CS elements of the analysis, the paper included a data repository, which will be freely accessible after 30. April 2024.

Ozabal et al., 2019 has assessed the extension of worldwide coastal adaptation planning in 136 coastal port urban agglomerations covering 68 countries (cities with more than one million inhabitants were included). 226 adaptation policies were identified, but in half of the cases there is no evidence of policy implementation, and in almost 85% of the cases the plans were not driven by a thorough assessment of present or future climate risks. Major sources of information were government plans. The study points to large unexploited potentials for using CS in coastal adaptation planning, and similarly to the study of IPCC (2022) and of Berrang-Ford et al., 2021 it is concluded that some sectors like agriculture and food, coast and water, health and urban areas are the primary focus of the studies.

The review of European adaptation plans points to the conclusion that there is still a large scope for further development of adaptation plans in European cities and thereby for using CS, and this is also in line with a global mapping of adaptation gaps by regions in IPCC, 2022 as shown in Figure 6.

For Europe it is concluded that there is an adaptation gap in relation to storms and coastal flooding in particular but also to coastal flooding, heat waves and water security are not very progressed in terms of current adaptation in Europe compared with other regions.

Figure 6. The urban adaptation gap to current climate risks

Source: IPCC, 2022, Chapter 6

4 Assessment of the market supply side

The section will introduce a number of big market actors in terms of international consultancy companies that have integrated climate disclosures and thereby CS information into their general business practice, followed by statistical information data provision by CS providers related to climate modelling, forecasts, earth observation etc. including Copernicus. An overview of the capacity for providing and using CS by WMO and GFCS will finally be provided.

4.1 Financial climate disclosures market

Financial-related climate disclosures refer to the reporting of information by companies and financial institutions that is specifically related to the financial risks and opportunities associated with climate change. These disclosures are designed to provide investors, stakeholders, and regulators with a clear

understanding of how climate-related factors may impact the financial performance and stability of an organisation. The key components of financial-related climate disclosures are:

- Climate risk exposure: companies may disclose their exposure to various climate-related risks, including physical risks (e.g., extreme weather events, sea-level rise) and transition risks (e.g., policy changes, market shifts towards renewable energy). They may assess how these risks could affect their operations, supply chains, and financial performance.
- Financial Impact Assessment: companies may provide an assessment of the potential financial impact of climate-related risks and opportunities. This can include scenario analysis, stress testing, and modelling to estimate how different climate scenarios could affect revenue, costs, and asset valuations.
- Mitigation and adaptation strategies: disclosure often includes information about the strategies and actions taken by the company to mitigate climate risks and capitalise on climate-related opportunities. This may involve investments in renewable energy, energy efficiency, carbon reduction initiatives, and adaptation measures.
- Regulatory compliance: companies may report on their compliance with existing and anticipated climate-related regulations and reporting requirements, including those related to carbon emissions, emissions reductions targets, and sustainability reporting frameworks.
- Green financing: financial institutions, in particular, may disclose their involvement in green financing and investments. They may report on the allocation of funds to environmentally sustainable projects and the impact of these investments on their portfolios.
- Metrics and key Performance Indicators (KPIs): companies often provide specific climate-related metrics and KPIs, such as greenhouse gas emissions, carbon intensity, and energy consumption. These metrics help stakeholders track progress toward climate-related goals.
- Governance and oversight: disclosure may include information about the governance structures and oversight mechanisms in place to manage climate-related risks and opportunities. This can involve details about board committees, executive leadership, and risk management processes related to climate issues.
- Scenario Analysis: Some disclosures involve scenario analysis, where companies explore different climate-related scenarios (e.g., a 2-degree Celsius temperature rise) and assess their potential impacts on the company's operations, assets, and financial performance.

At least the first 3 components (climate risk exposure, financial Impact Assessment, and adaptation strategies) can be qualified as Climate Services, although the term is not yet widely used by the financial community. Financial-related climate disclosures are becoming increasingly important as investors and stakeholders seek to understand how climate change can affect the financial viability and sustainability of businesses and financial institutions. The Task Force on Climate-related Financial Disclosures (TCFD) has developed a widely recognized framework for climate-related financial disclosures, and many organisations use this framework as a guide for reporting on climate-related financial risks and opportunities.

The market for climate disclosures continues to grow and evolve rapidly. Climate disclosures refer to the reporting of information related to a company's environmental impact, particularly in terms of its contributions to climate change and efforts to mitigate those impacts. This information is typically included in sustainability reports, annual reports, and other corporate disclosures. There are several market drivers of the financial climate related disclosures:

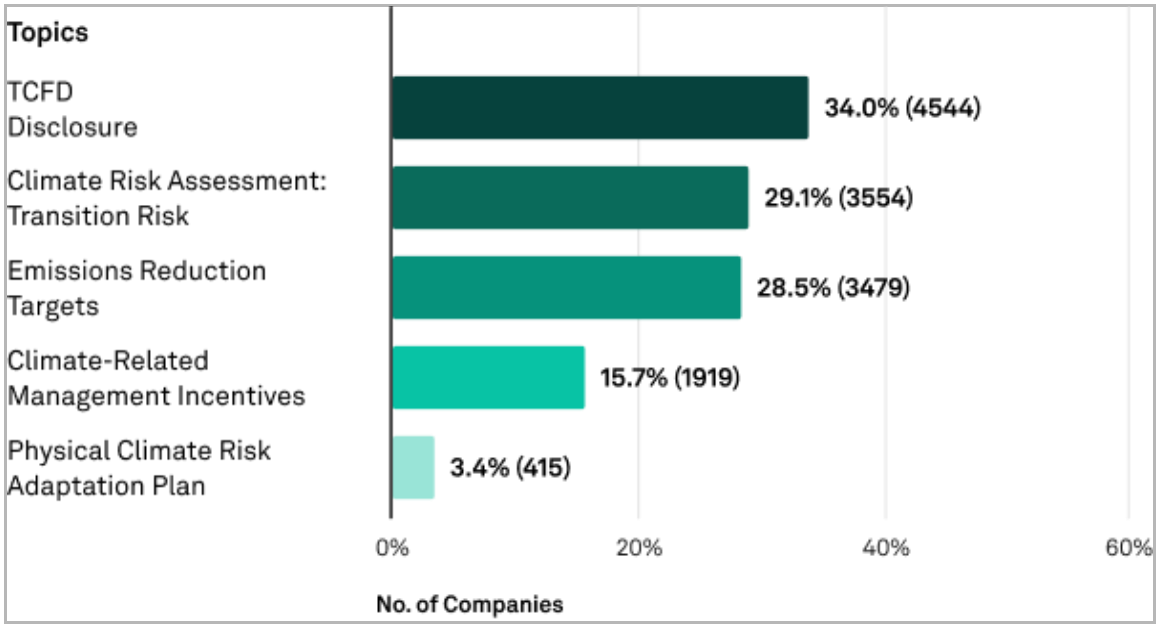
- Regulation: Many countries and regions were implementing or considering regulations that required companies to disclose their climate-related risks and initiatives. These regulations

aimed to promote transparency and help investors and stakeholders assess a company's climate-related performance.

- Investor demand: Investors were increasingly interested in understanding the climate-related risks and opportunities associated with their investments. Asset managers, pension funds, and other institutional investors were incorporating climate disclosures into their investment decisions.
- Consumer and stakeholder pressure: Consumers, employees, and other stakeholders were placing pressure on companies to be more transparent about their environmental practices and to take action to reduce their carbon footprints. This pressure was influencing companies to enhance their climate disclosures.
- Competitive advantage: Companies recognized that climate disclosures could provide a competitive advantage. Demonstrating a commitment to sustainability and responsible environmental practices could attract customers and investors who prioritise these values.
- ESG envesting: Environmental, Social, and Governance (ESG) investing was gaining momentum, and climate disclosures were a key component of ESG analysis. Companies that scored well on ESG criteria, including climate-related factors, were often seen as more attractive to investors.
- Reporting frameworks: various reporting frameworks, such as the Task Force on Climate-related Financial Disclosures (TCFD), Global Reporting Initiative (GRI), and Sustainability Accounting Standards Board (SASB), provided guidelines for companies to disclose climate-related information consistently and effectively.
- Survive and technology solutions: consulting services as well as technology solutions for collecting, analysing, and reporting climate data were advancing. Companies were increasingly using consulting services or platforms to streamline their disclosure processes.

However, it should be noted that the majority of disclosures focus on the transitional risk (cost of moving to a low carbon economy in an emissions reduction context). A recent survey by S&P of over 13,000 companies has found that over a third of them have published a climate disclosure but with only about 3,5% having a physical climate risk analysis and an adaptation plan (Figure 7). This could explain a growing demand for climate for clients that addresses transitional risk in their reports and are now moving towards disclosing physical risk, this in the context of general adoption of climate related financial disclosures.

Figure 7. Overview of the adoption of financial disclosures. Data as of Sept. 8, 2023. Chart from S&P Global ESG Raw data based on responses from 13,810 companies assessed in the 2022 S&P Global Corporate Sustainability Assessment (CSA)



Source: S&P[2]

Although there are no evaluation of the service and data included in the climate disclosure market, it is noteworthy that it has attracted sufficient interest from large corporations from rating agencies (S&P[3], Moody's and Fitch), the top end strategic consulting firms (McKinsey[4], Boston Consulting Group and Bain) as well as the large auditing/accounting companies (PwC[5], EY, KPMG and Deloitte) but also others[6], that developed new services and product lines to assist their existing clients with these new mandatory reporting obligations. This new business line is either developed internally or through acquisition of dedicated companies (eg. Acquisition of The Climate Service, by S&P in early 2022[7]) indicates the recent growth of this market and the new positioning of traditional financial firms in climate services.

Examples of CS of private companies are shown in Figure 7 and with a screenshot of a market player in Figure 8.

[2] https://web.archive.org/web/20231011083823/https://www.spglobal.com/esg/solutions/find-your-answers#climate-risk-management

[3] S&P Global (The Climate Service): spglobal.com/esg/solutions/the-climate-service

[4] Mc Kinsey mckinsey.com/capabilities/sustainability/our-insights/climate-risk-and-response-physical-hazards-and-socioeconomic-impacts

[5] PwC https://www.pwc.de/en/sustainability/climate-excellence-making-companies-fit-for-climate-change.html

[6] Roland Berger rolandberger.com/en/Insights/Global-Topics/Sustainability-Climate-Action/Solutions/
Ramboll ramboll.com/services-and-sectors/water/climate-adaptation-and-landscape

[7] press.spglobal.com/2022-01-04-S-P-Global-Acquires-The-Climate-Service,-Inc

Figure 8. Screen captures of the climate service offer of private financial actors.

4.2 Earth observations (EO) based on CS market supply

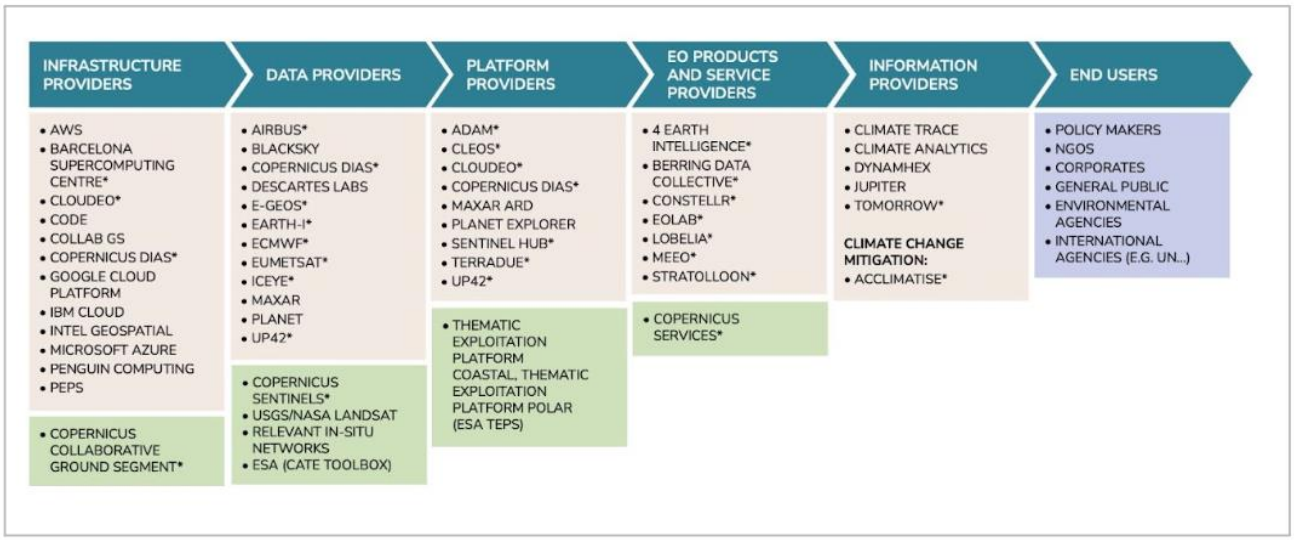
Satellite data plays a major role as a source of information for climate services. Coordinated and managed by the European Commission, Copernicus is the European Union's Earth Observation (EO) and Monitoring programme. Copernicus relies on its own set of satellites (Sentinels), as well as contributing missions (existing commercial and public satellites), and a variety of technologies and in-situ measurements systems at atmosphere, land and ocean. The generated data is turned into value-added information by the Copernicus Services for thematic monitoring (atmosphere, marine environment, land, climate change) and security and emergency management. Most data generated by Copernicus are made available on a Full, Free and Open (FFO) data policy through various services, including a set of cloud-based platforms called Data and Information Access Services (DIAS). EO data are often used together with in-situ observations in climate models. These constitute an invaluable source of climate monitoring and climate forecasting, which provide the necessary awareness of the state of our climate and its evolution.

Global climate and environment-related trends and policies are driving and generating demand for EO data and applications. Funding and innovation support for climate applications is growing globally while EO-based solutions are at the centre-stage of major climate-related initiatives in the EU. For example, the Global Environment Facility (GEF) is an independent financial organisation providing grants for projects related to environmental issues, including climate change. For three decades of operational activity, GEF has funded over $20 billion through loans related to environmental problems. Opportunities for EO data and services providers in Europe continue to emerge. This is unsurprising considering the European Union's Climate Fund will dispatch €10 billion over 2021-2030, and the European Commission's aim to mobilise at least €1 trillion of sustainable investment over this period. The Climate-Knowledge and Innovation Community (Climate-KIC) recently concluded a call for strategic partnerships aimed at building and developing investment capability to mobilise capital for climate innovation projects, while also in the process of launching a revamped accelerator programme and investor marketplace with a goal to invest €100 million (and leveraging over €1 billion) in innovation for climate actions.

Recent and future developments in EO will probably have a strong impact on generating climate applications in carbon offset markets, climate modelling, and the Earth's Digital Twin and Destination Earth initiatives. Indeed, EO solution developers are finding a source of new demand driven by the need to provide regular and accurate monitoring, reporting and verification of greenhouse gas emissions as well as a need to offset some side effects of growing economies. On the modelling side, EO provides invaluable large-scale data which, combined with in-situ measurements, results in higher accuracy in reconstructing the historical, present and future states of the Earth's climate system. Finally, the DestinE digital twin for climate change adaptations and extreme events will give users access to high-quality information, services models, trustworthy and reliable scenarios and visualisations, while also enabling them to interact with the systems and to bring their own scenarios,

thus potentially assisting the public sector in carrying out better informed decision-making processes. Although the potential of downstream services remains unclear.

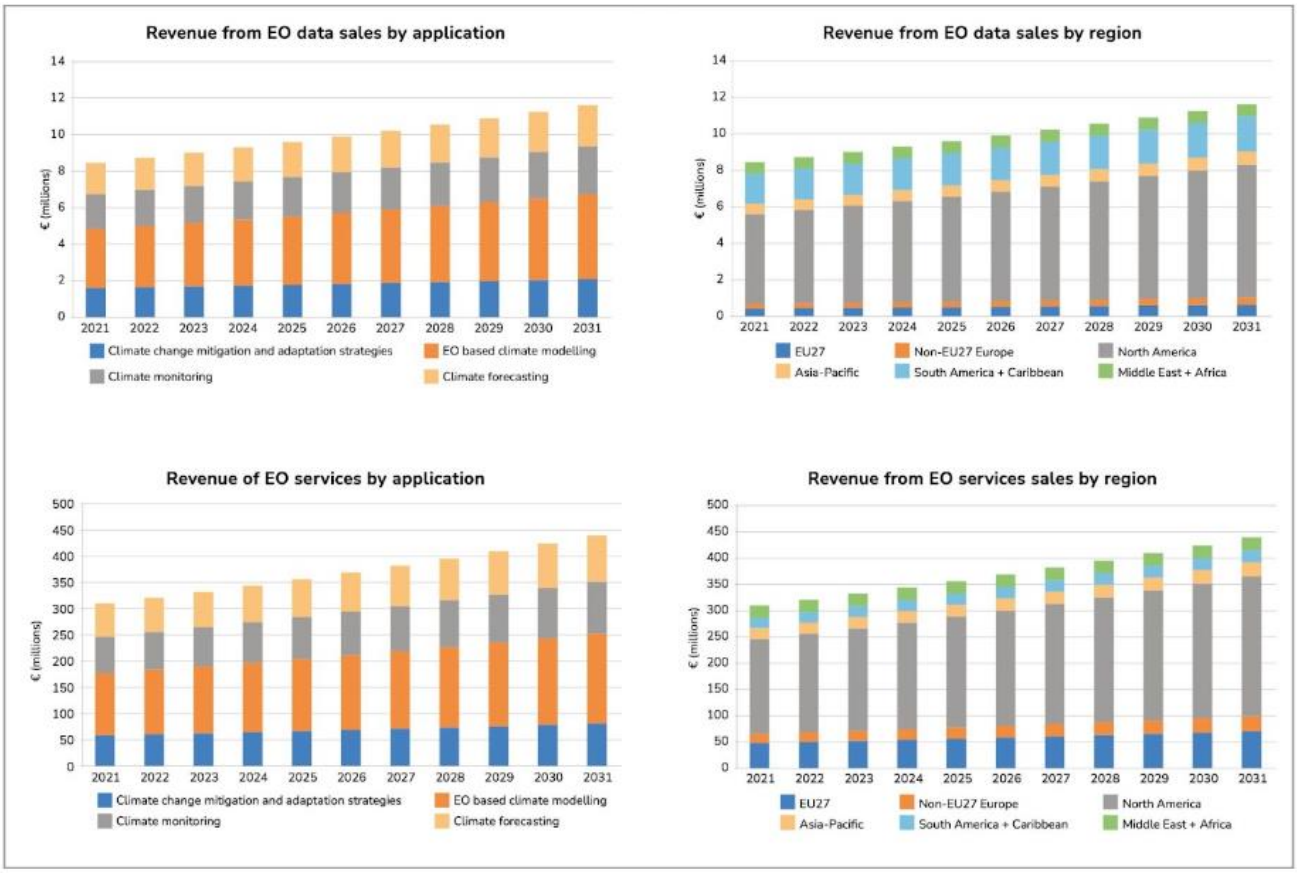
Figure 9. The EO based climate services value chain of EO considering key global and European companies involved in EO downstream activities. Private (light orange) and public (light green) actors are listed with European-based companies marked with (*)



Source: *EUSPA EO and GNSS Market Report* 2022 page 58.

The revenues from the sale of both EO data and services in the Climate services sector in 2021 amounted to €318 M€ and is projected to increase regularly in the coming decade by almost 50% to reach 451 M€ in 2031 (see Figure 10). The data market is expected to grow from about 8M€ to almost 12M€ and services from about 300M€ to over 420M€. The breakdown in terms of applications shows that EO-based climate modelling is the dominant segment for both data and services, being about twice the similar market shares of the other sectors (monitoring, climate forecasting and climate change mitigation and adaptation strategies) over the decade. North America demand is driving the market with 50% to 80% of the demand of EO based climate services. The EU, although the second market, represents less than 25%. The report concludes that the development of new skills and policies will be important in expanding the CS market. EUSPA, 2022.

Figure 10. Revenue of EO data (top) and services (bottom) sales and by application (left) and region (right)



Source: EUSPA EO and GNSS Market Report report 2022 page 62.

4.3 Copernicus Climate Services

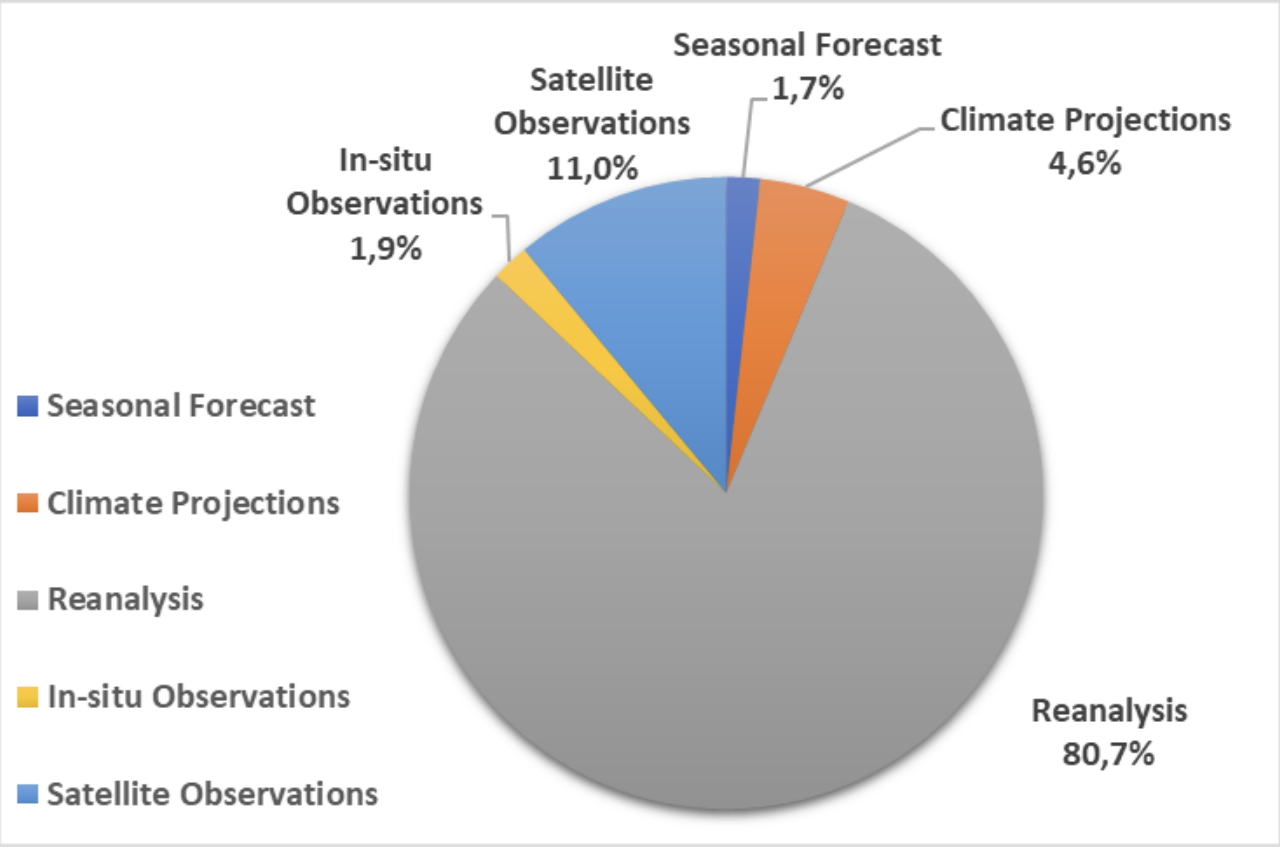
The Copernicus Climate Change Service (C3S) provides authoritative information about the past, present and future climate, as well as tools to enable climate change mitigation and adaptation strategies by policy makers and businesses. C3S is implemented by the European Centre for Medium-range Weather Forecasts on behalf of the European Commission. Its main mission is to provide free access to quality-assured, traceable data and applications. This means anyone can delve into the wealth of information provided in its Climate Data Store (CDS), which is a one-stop-shop for anyone looking for climate data. As part of the European Union's flagship Earth observation programme, C3S takes observations from satellites as well as sensors on the ground, in the oceans and in the air to provide climate data.

The CDS functions as a distributed centre of free, full, and open access quality-assured data and tools for users and developers. The CDS catalogue contains a wide variety of datasets. The CDS has surpassed 150,000 (C. Buontempo, C3S general Assembly September 2022) registered users of various profiles with different levels of expertise, such as scientists, policymakers, government, media, industry and business, who access information, invoke tools and download data with some datasets

being more popular than others. Typically, over 100TB of data are downloaded and more than 500,000 user requests are processed every day by the CDS, ensuring an optimal quality of service to meet users' needs.

Since the offer of C3S data is quite large and the analysis in terms of volumes doesn't reflect the intended use, it makes more sense to look at the user sectoral profile to infer the type of use the data is intended for. In mid-2022 there were 77 catalogue entries that could be grouped in 6 main categories: Seasonal Forecasts (6), Climate Projections (6, either global or regional); Reanalysis (21, global or regional), In situ observations (8) and Satellite Observations (36). The popularity of the dataset categories in terms of user access is given in Figure 1 below. A large majority of users were interested in Reanalysis (about 81%, mostly ERA5 catalogue entries), a well-known and thus popular dataset in the CDS. The second most used dataset type was Satellite Observation (11%), followed by Climate Projections (4.6%) followed by Seasonal Forecast and In-situ Observation with only about 2%. From a climate service point of view, one could say that more than 96% of users are interested in climate monitoring and historical analysis rather than future looking changes (either seasonal or long term).

Figure 11. CDS Users' distribution by dataset type by July 2022

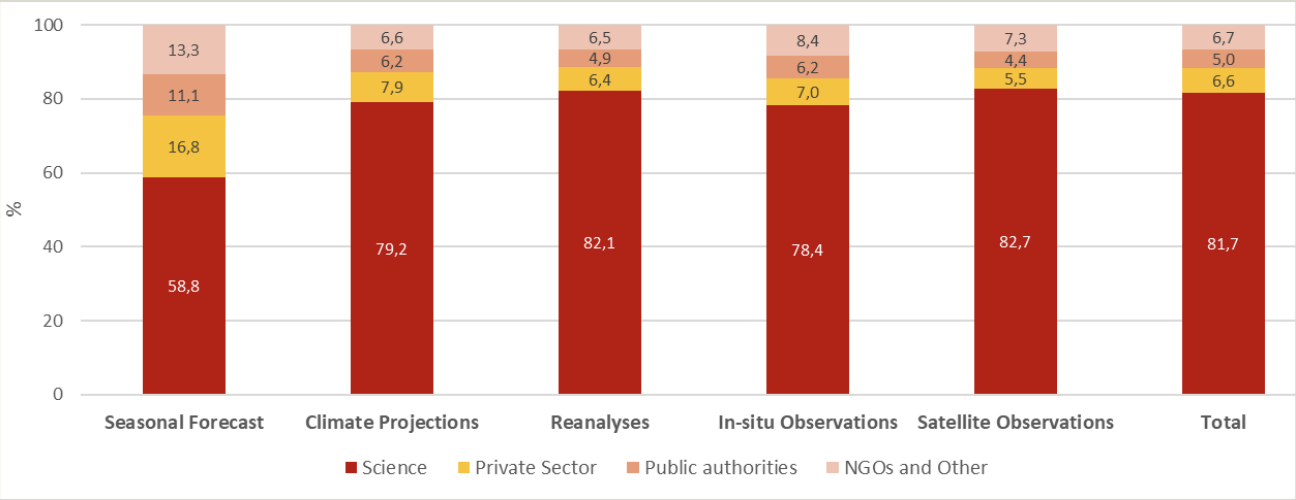


Source: ECMWF/C3S.

Concerning the user's sectorial profile type, the data presented in Figure 2 shows that about 82% come from "Science", followed by "NGOs and others" (6,7%), "Private Sector" (6,6%), and "Public authorities" (5%). When looking at the users' profiles by dataset type, both Reanalysis, In-situ and Satellite Observation have the same profile pattern than the total pool. Only Seasonal Forecast is slightly different from the others, with less science users (about 59%) and an increase of the other profiles, in particular the private sector (about 17%). Although the presence of scientists might look

overwhelming, the presence of societal actors is actually significant because of the large number of users. Indeed, around 5% to 6% for each category (NGOs, local authorities, private) means around 7,000 to 9,000 users for each. Considering that C3S users are growing rapidly (over 200,000 users in September 2023) with the same proportion, those numbers could reach around 12,000 for each of the 3 non-scientist categories which is very important. It is our opinion that one of the main challenges of C3S in the next few years is to extend its reach to those societal users. This could be facilitated by the addition of new datasets and services, such as decadal forecasts and climate change attribution service that can move from research to operation and are attracting a lot of attention.

Figure 12. CDS User sectorial profile by dataset categories

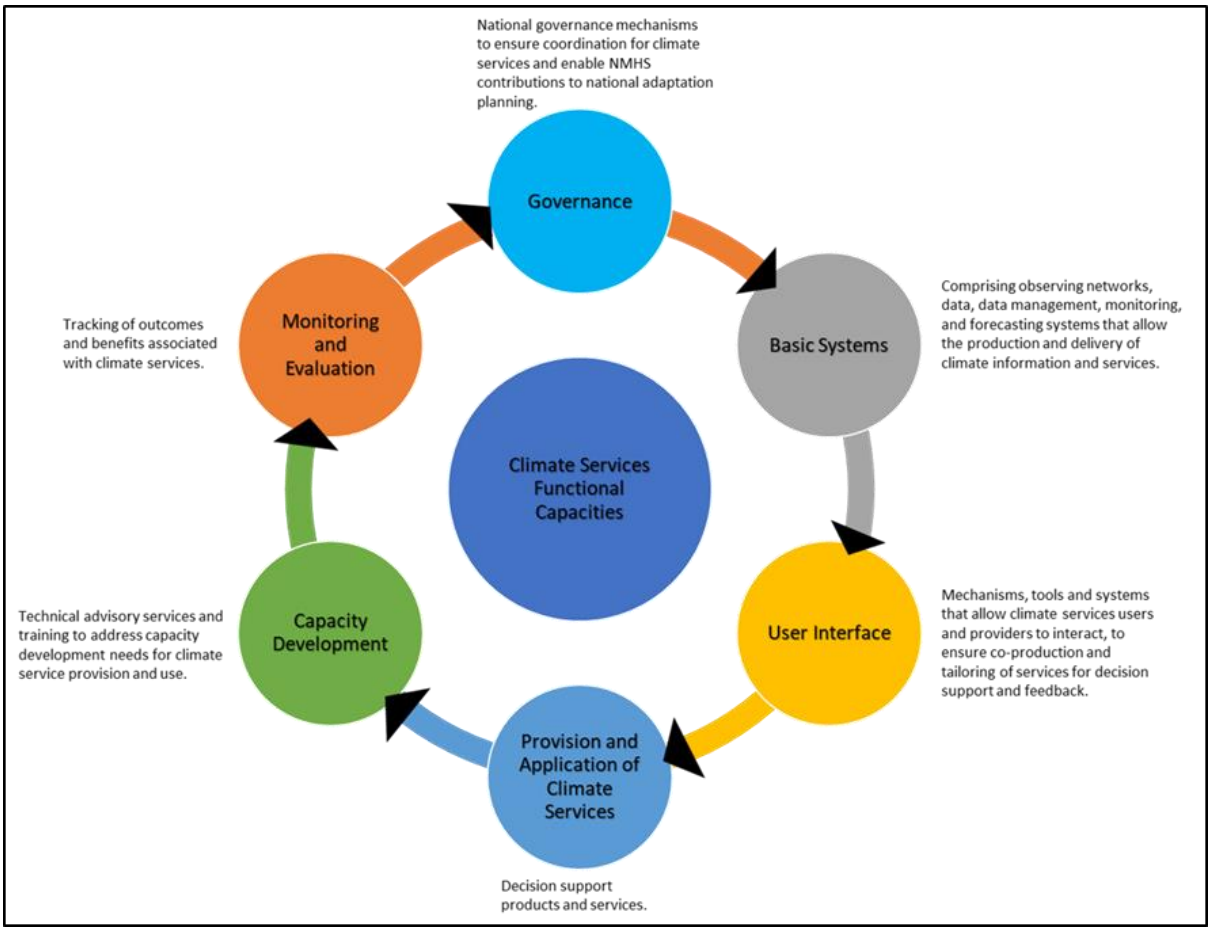


Source: ECMWF/C3S.

4.4 Mapping of CS supply capacities in the EU by WMO

WMO has developed a checklist for CS implementation for the National Meteorological and Hydrological Services (NMHS) to assess their capacity for providing CS. Functional capacities assessed by the checklist are organized into six groups (Figure 13). Additionally, the extent to which NMHS delivers services depends on its capacity to access and process observational data, manage and analyze climate data, convert the data into relevant and usable information and products, and contribute to developing a range of products supporting decision-making. Based on these criteria, the capabilities of national climate services are classified as (1) basic capacity; (2) essential capacity; (3) full capacity; and (4) advanced capacity [2]. The purpose of this classification is to help countries better understand the capabilities required to provide climate, weather, and hydrology services, and identify what is needed in their own NMHS to ensure the desired service level.

Figure 13. Climate services functional capacities across the climate services value chain

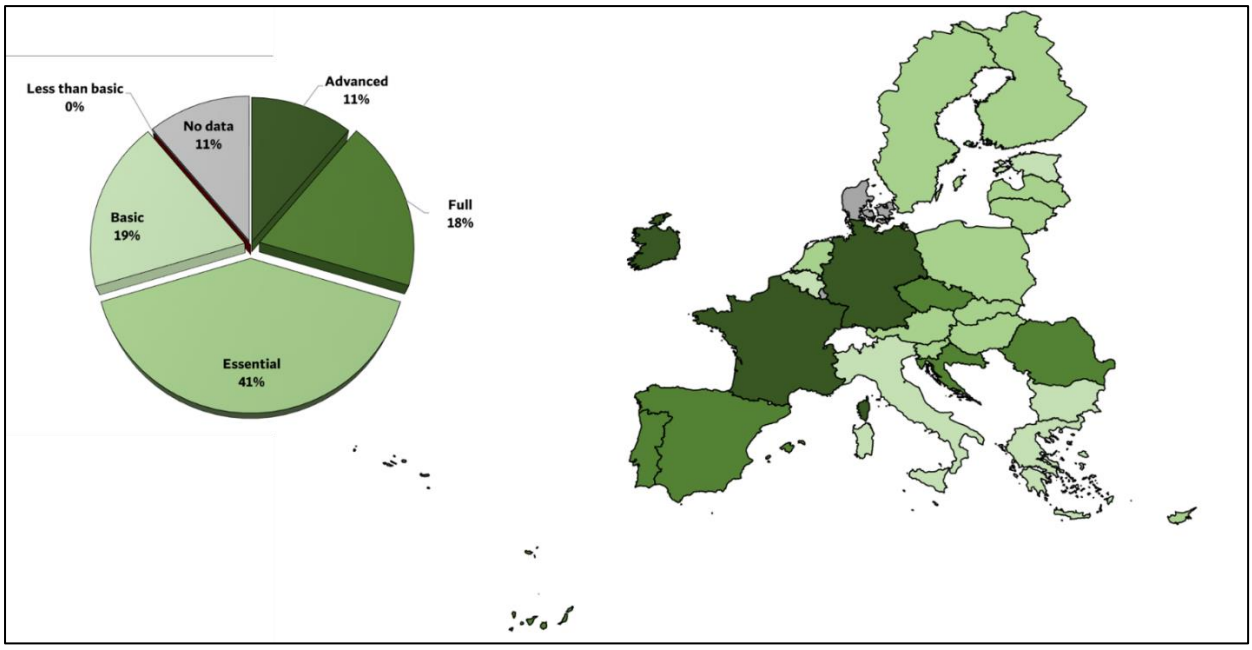


Source: Grasso et al., 2021

4.4.1 Climate services in the European Union

Climate services provide information and tools to support decision-making and adaptation to climate change impacts. The EU and its Member states have made significant efforts in developing and improving climate services capacities in recent years. Based on the available data, 41% of EU Member states provide climate services at an essential level, and only 29% provides climate services at full/advanced level (Figure 14). The results, shows that of the EU Member states have-established meteorological and climate research organizations that are averagely capable of collecting, analysing, and disseminating climate data and information to various users, including government agencies, and the public at large.

Figure 14. European Union Overview of generalized climate services capacities (not sector specific)
Source; WMO Climate Service Checklist, 2023

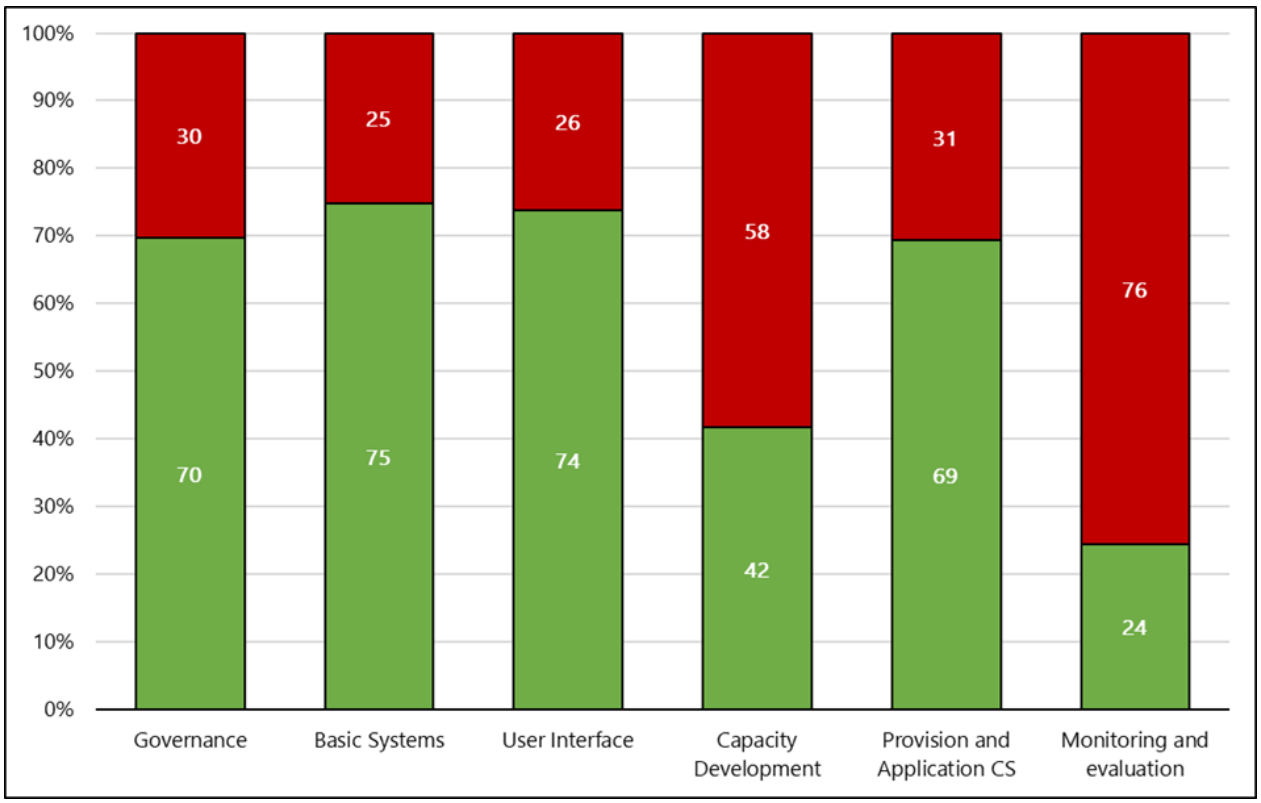


Note: 1. The percentages on the pie chart are based on the 24 EU Member States
2. The information in the figure represents 2 European Union Members states whose data has been validated by International certified auditors. Those Members are Greece, Croatia.

4.4.2 Climate services by value chain components

Despite the tremendous development of climate services in the EU, gaps still exist. Based on the available data from 24 EU Member states, governance, user interface, basic systems and provision and application of climate services are quite developed components, however capacity development and monitoring and evaluation of socio-economic benefits of climate services need more attention. There seems to be a lack in monitoring and evaluation capacities across the region, with only 24% of Members states tracking outcomes and benefits associated with climate services, according to the available data (Figure 15). This is especially a gap, as monitoring and evaluation of socio-economic benefits of climate services is essential to assess the effectiveness and impact of the already provided or existing climate services.

Figure 15. Overview of the percentages of functionalities satisfied (green) and not satisfied (red) in the value chain components based on data from 24 European Union Members states; Source; WMO Climate Service Checklist, 2023[8]



4.5 The Global Framework for Climate Services (GFCS)

The Global Framework for Climate Services (GFCS)[9] has been established in order to support application of CS, and the framework is closely related to supporting nations in being able to meet the goals of the Paris agreement. Focal areas are agriculture and food security, disaster risk reduction, energy, health and water. GFCS has developed a national framework for CS implementation, which is focusing on the establishment of national centres for CS provision GFCS, 2023. Table 8, shows different levels of NFCS implementation according to status and countries.

[8] More information can be found in: Climate services dashboard. The data is updated biannually.
[9] https://gfcs.wmo.int

Table 8. Status of National Framework for Climate Service (NFCS) Implementation[10]

COUNTRY	STEP OF IMPLEMENTATION	COUNTRY	STEP OF IMPLEMENTATION	COUNTRY	STEP OF IMPLEMENTATION	COUNTRY	STEP OF IMPLEMENTATION
Switzerland	6	Guinea	5	Congo Brazaville	4	Burundi	0
China	6	Guinea Bissau	5	Cuba	3	Chile	0
Germany	6	Liberia	5	Ethiopia	3	Djibouti	0
United Kingdom	6	Madagascar	5	Kiribati	3	Peru	0
Benin	5	Mali	5	Malawi	3	Eswatini	0
Burkina Faso	5	Moldova	5	Mauritania	3	Uganda	0
Cabo Verde	5	Niger	5	Nigeria	3	Nauru	0
Chad	5	Senegal	5	Rwanda	3	Samoa	0
Côte d'Ivoire	5	Sierra Leone	5	Colombia	2	Solomon Islands	0
Cameroon	5	Togo	5	Kenya	1	Cook Islands	0
Democratic Republic of Congo	5	Tanzania	5	Namibia	1	Tonga	0
Gambia	5	Vanuatu	5	Gabon	0	Ecuador	0
Ghana	5	South Africa	5	Argentina	0	Zimbabwe	0
				Botswana	0	Armenia	0

Note: Step 0: Planned phase
Step 1: Assess the baseline on climate services capacities
Step 2: Organize a national consultation workshop
Step 3: Develop a national strategic plan and costed action plan
Step 4: Endorse the strategic plan and a costed action plan with timelines for NFCS
Step 5: Launch the NFCS, implement the national plan and conduct rigorous M&E implementation
Step 6: Countries with NFCS providing advanced services
Source: GFCS, 2023

Predominantly non-OECD countries have implemented the NFCS framework, and in particular many African countries are on advanced level in the NFCS implementation corresponding to level 5 with Launch the NFCS, implement the national action plan and conduct rigorous M&E. UK, Germany, and Switzerland are the only OECD countries, which are implementing the NFCS framework.

GFCS is funding a number of projects with the aim to support CS deployment with a user focus, but there is no data available about the actual deployment of CS connected to the frameworks.

[10] NFCS_Status_20210708_world_table.pdf (wmo.int)

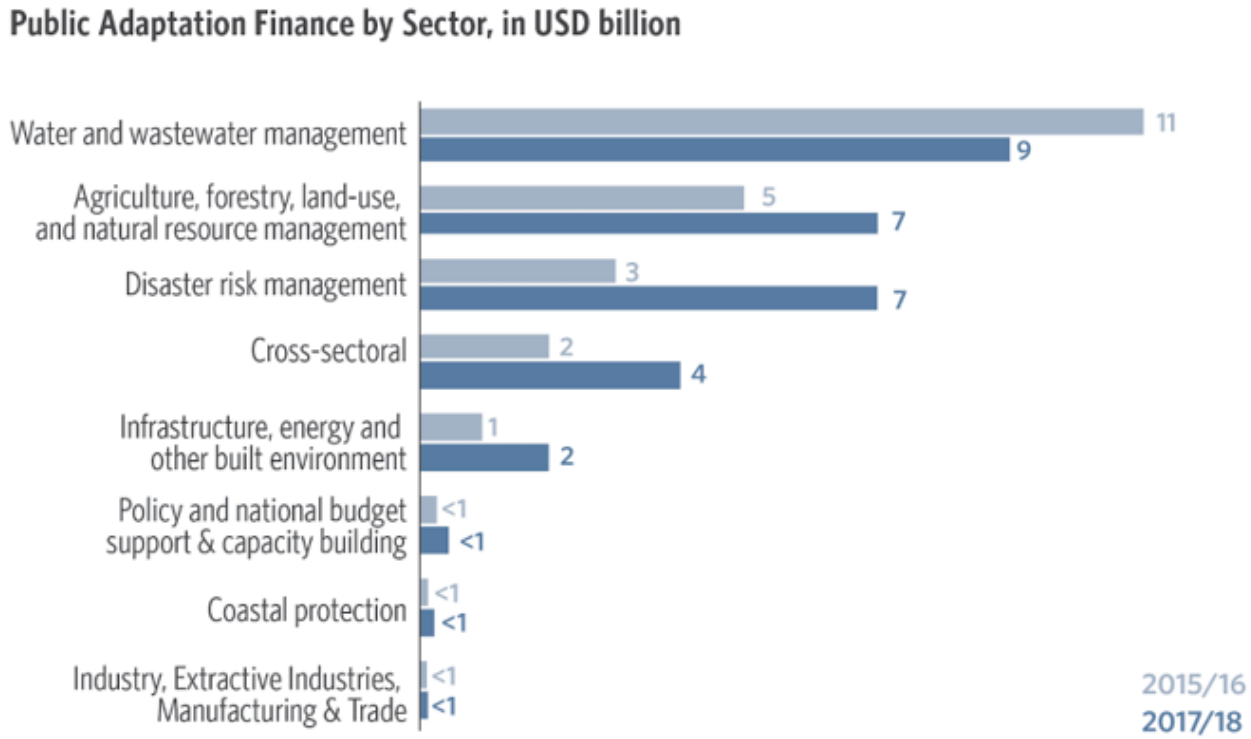
5 Case Study of the financial sector as a potential large CS user

Investments and finance with a long lifetime can be exposed to climate risks, and this sector is therefore a very important user of CS. The case study is addressing key financial systems, which already today take climate risks into consideration including the climate finance initiatives by the Multilateral Development Banks (MDBs), and the climate stress test of the European Central Bank (ECB).

The section will provide a short overview of the scale, geographical location and focal climate hazard areas, which are today addressed in climate finance. The use of specific CS is not reported in the climate finance context, but integrating climate risks and its management in finance actually requires very detailed use of high-quality CS.

The Climate Policy Initiative (CPI) has assessed global adaptation finance (Buchner et al., 2019), and adaptation finance in cities (Richmond et al., 2021) based on CPI's Global Landscape of Climate Finance, World Bank Private Participation in Infrastructure, and CDP for cities. The global adaptation investors according to CDI invested more than in on average $579 billion annually in 2017 and 2018, and this was a steep 25% investment increase from 2015 to 2016. Figure 16 based on Buchner et al., 2019 shows the public adaptation finance by sector.

Figure 16. Adaptation Finance by Sector in USD billion

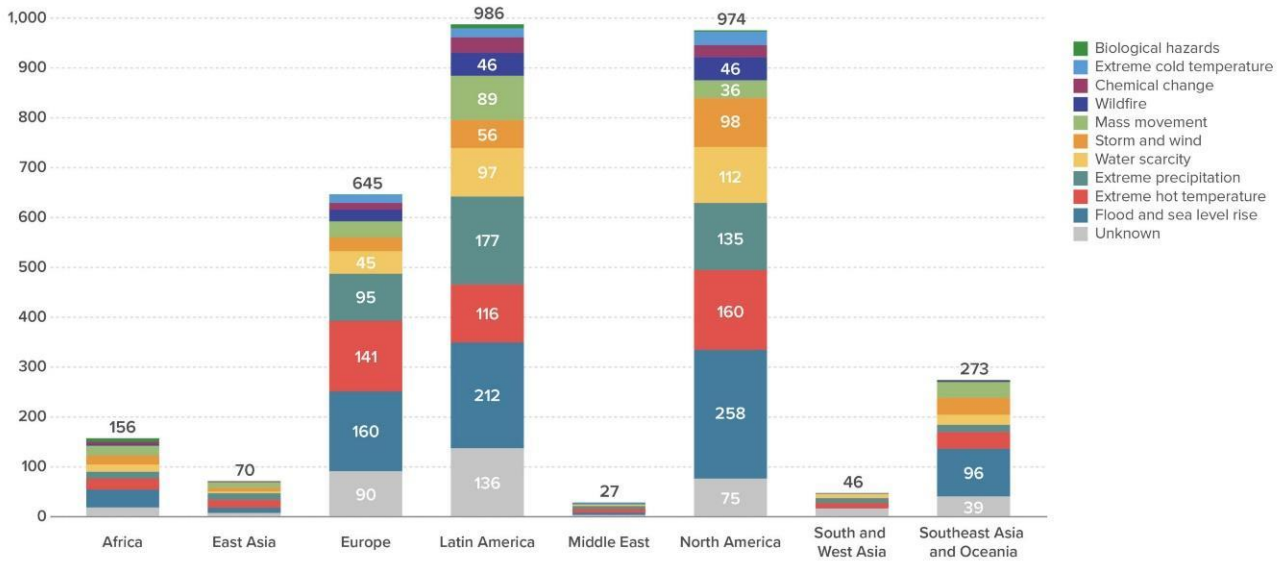


Source: Climate Policy Initiative, 2019

According to CDI, 2019 water and wastewater management was by far the largest adaptation finance sector followed by agriculture, forestry, and land use, and natural resource management. Another large sector was disaster risk management.

CDI has also provided details on the number of adaptation finance projects by regions and their relationship to climate hazards, Figure 17.

Figure 17. Number of climate finance projects in cities reported by hazard.



Source: CDI, 2021

As shown in Figure 17, in almost all regions, extreme hot temperature and flood & sea level rise were the most common climate hazards that have been addressed in adaptation investment projects. The number of projects were relatively high in Europe compared with regions with larger populations. The climate hazards addressed in most European projects were sea level rise and coastal flooding, extreme precipitation, and extreme heating.

Various international and domestic finance sources are involved in adaptation finance including both public and private investors. The finance is based on guidelines for the financial institutions on how to measure and report risk reduction by adaptation, and the guidelines give an indication of how CS related information has been used in the planning and design of projects. Despite the guidelines there exhibit a large variety in how climate information like CS have been used in climate finance, it is obvious from the available CDI numbers on adaptation finance, that climate finance and the number of projects demonstrate an extensive use of CS.

One of the very large contributors to adaptation finance is the Multilateral Development Banks[11] (MDB's), and they are thereby very large users of CS as part of their project evaluation framed by their

[11] The MDBs are the African Development Bank (AfDB), the Asian Development Bank (ADB), the Asian Infrastructure Investment Bank (AIIB), the European Bank for Reconstruction and Development (EBRD), the European Investment Bank (EIB), the Inter-American Development Bank Group (IDBG), the Islamic Development Bank (IsDB) and the World Bank Group (WBG)

common focal climate programme including both mitigation and adaptation. The climate funding programme is documented in detail in annual reports, and the information provided by these is total project funding without a specific indicator of the extent of using CS in project preparations.

In 2021 the MDBs contributed in total about $81 million climate finance of which 35% was allocated to adaptation finance. A special effort has been undertaken to increase the adaptation finance and the following common MDB criteria of tracking adaptation finance has been determined in order to facilitate an increase in adaptation finance. It is in the criteria stated that "Identification of climate change adaptation finance is the result of a three-step process and thus, for a project to be counted either fully or partially towards MDB adaptation finance, it must: a. Set out the project's context of vulnerability to climate change. b. Make an explicit statement of intent to address this vulnerability as part of the project. c. Articulate a clear and direct link between the vulnerability and the specific project activities." (MDB, 2022). These funding criteria are not directly in detail specifying CS to be involved, but funding information by the MDBs can however be understood as being a good indicator of CS required and embedded in the projects.
The total cost of adaptation finance by MDB's and by sectors in 2021 is shown in Table 9.

Table 9. Total MDB adaptation finance by sector in low and middle-income countries, 2021.

Sector	Adaptation finance in mill. USD
Coastal and riverine infrastructure	532
Crop and food production	1699
Cross-cutting sectors	3052
Energy, transport and other built environment and infrastructure	4547
Financial services	1832
Industry, manufacturing and trade	32
Information and communications technology	176
Institutional capacity support or technical assistance 2400	2400

Source: MDB ,2022, Table 12.

The MDBs were funding adaptation components of projects of in total $19,187 million in 2021 as can be seen in Table 9. The largest sector was energy, transport and other built environment and infrastructure with 26% of the funding, and other large sectors were institutional capacity support or technical assistance, and water and wastewater systems. Crop and food production only amounted to about 10% of the total adaptation funding.

The EU has adopted rules for mandatory reporting of climate risks, and the European Central Bank (ECB) is required to carry out annual stress tests on supervised entities in the context of its Supervisory Review and Evaluation Process. This implies that the financial sector has a mandatory reporting requirement to the ECB, and an evaluation of the 2100 climate stress reporting. ECB, 2022a provides a status of what has been reported (Climate-related risk and financial stability (europa.eu).

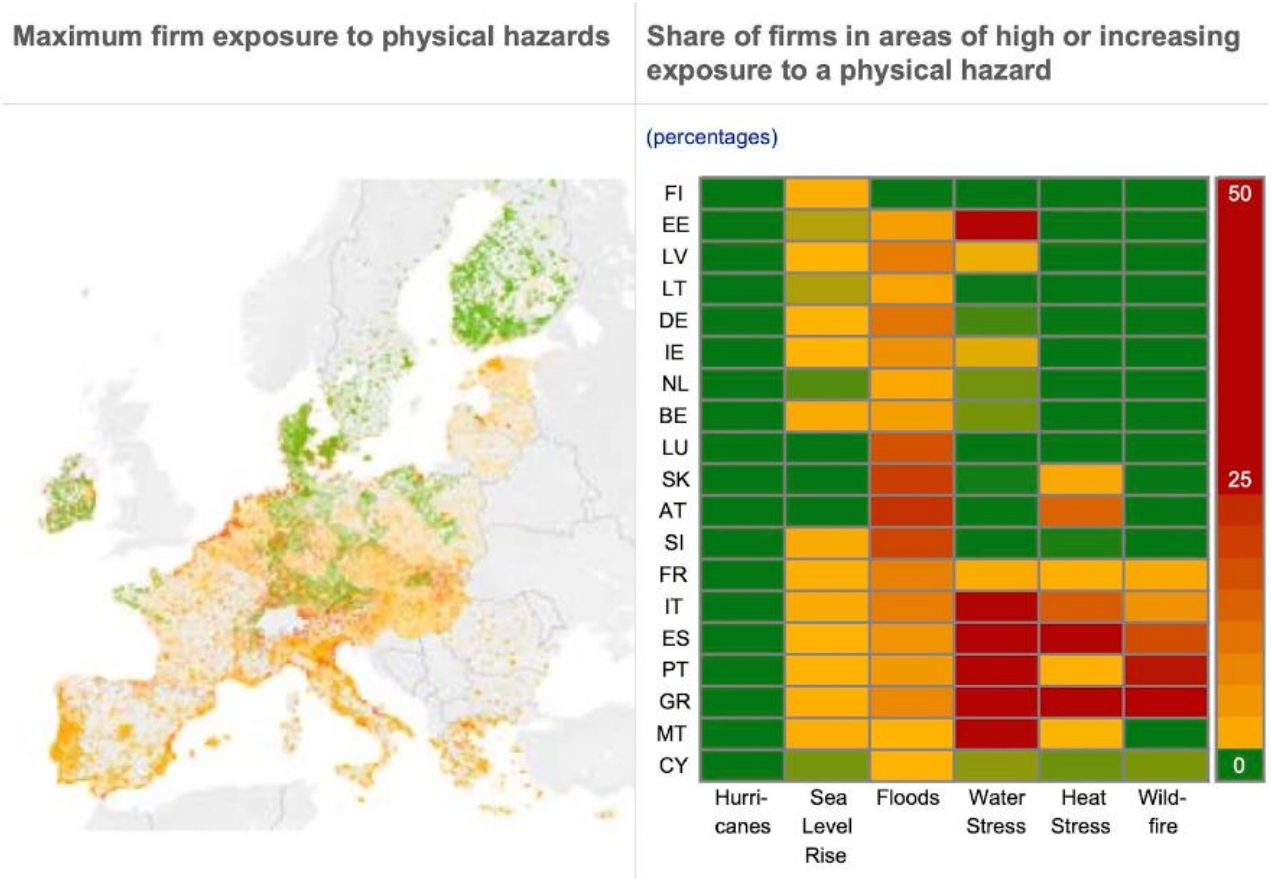
The climate stress reporting requires very detailed reporting of all sorts of climate risks to the financial sector including both climate change mitigation and adaptation and policies, which implicitly requires

a very extensive use of CS. There are several background reports to the ECB guidelines reviewing the scientific literature, and specific assessment of climate risks facing the financial sector providing the basis for ECB guidelines for how climate risks could be measured as part of the reporting ECB, 2021 (ECB guidelines for climate stress test and reporting). In this report we are only focussing on the climate risks and adaptation measures, and the ECB guidelines are here focussing on key physical risk drivers in Europe, which are considered to impose the highest risks to the financial sector namely floods, water stress and heat stress, including wildfires.

The ECB guidelines emphasise that a very comprehensive assessment of physical risks to the financial system is required. The risk assessment should address the physical hazard itself, entities exposures to these hazards, their vulnerability, and on the risk mitigation measures in place, including insurance coverage. It is stated that assessing financial system exposures to physical risk drivers requires granular information on the geo-spatial characteristics of financial institutions' exposures, combined with data on physical risk drivers. The guidelines conclude that there is a gap in the access to such information, which will limit the accuracy of the climate risk assessments.

The ECB guidelines include a mapping of the physical climate risks in Europe to firms, which is based on a survey of 1.5 million firms, which point to particular financial risks in geographical regions, Figure 18.

Figure 18. Physical Risks to firms in Europe stemming from climate change mainly arise from floods, wildfires, heat stress or water stress.



Source: ECB, 2022a. Chart 1, page 12 Climate-related risk and financial stability (europa.eu)

The financial risks to companies in Europe as shown in Figure 18 are particularly high in southern-eastern-, and western Europe, and a general threat in almost all countries are related to flooding. In southern Europe there are several major climate stress factors including flooding, water stress, heat stress, and wildfire.

The ECB (2022a and b) reviewed the actual climate stress reports submitted in 2021, which as an initial step included physical risk scenarios for flooding, drought, and heat stress. It was here concluded that within these areas the combined credit and market risk losses for the 41 banks could amount to around €70 billion. This estimate is considered as significantly understating the risks according to ECB due to limitations in the economic modelling and the preliminary state of the data and modelling underlying the banks' projections with the climate factors only captured to a rudimentary degree. It is finally concluded that only one-third of the climate exposure of the 41 banks have been covered, and there is a learning process ahead in providing good climate stress tests.

6 Conclusions

The 6th assessment report of the IPCC stated that Europe already today faces large risks from climate change. To develop the necessary adaptation responses and strategies to mitigate these risks, it is critical to have access to the most up-to-date, robust and diverse climate services. Drawing on statistical information and indicators of adaptation activities and climate disclosures, which rely on the use of CS, we find that the demand for, and supply of climate services in Europe is large.

Regarding the development and supply of CS, the EU funding through the major framework programmes FP7, H2020 and Horizon Europe have allocated extensive funding to projects to support the development of the CS market. Based on our preliminary review of the major repository of EU-funded projects, the CORDIS database, we found a large number of projects, which are providing data products and decision support platforms targeting a broad user community and multiple sectors. It is difficult to assess whether these projects have developed CS that are sustainable and widely disseminated beyond the end of the projects, without a more extensive evaluation and long-term monitoring of the use of these data and platforms.

Within the private sector, our review indicates that the commercial CS market is characterized by an increasing trend that large consultancy companies are entering the continuously growing market for climate disclosures. Climate disclosures refer to the reporting of information related to a company's environmental impact, particularly in terms of its contributions to climate change and efforts to mitigate those impacts. This information is typically included in sustainability reports, annual reporting, and other corporate disclosures. Among other elements, such reporting of company activities include elements of CS. However, there is no explicit information available about the data/information used for these reports.

Regarding user demand, data-based platforms like EO and Copernicus provide CS information to a large user community. For example, Copernicus, has already registered more than 200,000 users in September 2023. Our review focused on two specific user groups: cities and the financial sector. We found that there are many city adaptation plans under way, with key adaptation areas in the health & social and infrastructure sector. However, as complex systems, further development and sophistication of the plans will require the use of more context specific CS and detailed local studies that map onto each city broader political agenda including business development, cities for people,

green growth, lifestyle, and culture. The evolution of CS must be able to accommodate such information needs and provide information not just on climate hazards, but also information on the sectors and population groups that will be most affected.

Another emerging and potentially large user of CS is the financial sector. International climate finance and mandatory climate stress reporting to the ECB extensively require detailed context specific information. Guidelines are developed for the sector, but the CS applications are still in a very early stage.

A common conclusion across all the studies and data, which we have reviewed is, that the CS market could benefit from creating more transparency including the use of a consistent framework for the reporting of key assumptions and methodologies for CS offered and used. Part of such a framework could also be the development of a benchmarking approach, which could facilitate comparability of CS applications.

A key conclusion is that to inform potential users and suppliers of CS in a fast paced, emerging CS market, the CS market would benefit from demonstrating how specific examples of CS are developed and applied by users. Such real-life examples would help stimulate interest in, and demand for CS on the user side, and provide guidance and support to CS suppliers to understand, how the CS market could be strengthened based on user needs and what role standardization of CS could have in this.

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APPENDIX

The Annex provides a detailed overview of the projects identified in the EU project CORDIS database as outlined in section 2 section which have aimed at supporting the development and deployment of CS. We have searched the EU CORDIS database (https://cordis.europa.eu/) to identify such projects. The screening criteria in CORDIS have been '**Climate service' + 'Europe**'. In addition, we have supplemented the database with additional information for 9 projects which were not captured by the search but are, based on our own knowledge, relevant to include in an assessment of CS as part of the CORDIS project portfolio. It should here be recognized that the screening of the CORDIS database is very sensitive to the screening criteria applied, and that the current screening will be updated in subsequent versions of this deliverable with more comprehensive information. In total 75 projects from the CORDIS database have been selected for our assessment, and these projects have been undergoing a more in depth assessment of the sectors included using a taxonomy of sectoral NACE codes, CS included, CS users, and CS planned and marketed.

Table 10. Sector A: Agriculture, Forestry and Fishing

Project name	Funder	Coordinating institution	Region	Sector	CS User	Type of service	Business strategy	Funding - Total Cost
e-shape: EuroGEO Showcases: Applications Powered by Europe	EU H2020	ASSOCIATION POUR LA RECHERCHE ET LE DEVELOPPEMENT DES METHODES ET PROCESSUS INDUSTRIELS	Europe	A, D, E, Q, S	5	1	open source	15 mill
Blue-Action: Arctic Impact on Weather and Climate	EU H2020	DMI	Europe + Arctic	A, R, S	6,8,?	1,6	open source?	8 mill
CLARA: Climate forecast enabled knowledge services	EU H2020	CMCC	Europe	A, D, E, Q, S	3,4,6,8	6		3 mill
MED-GOLD: Turning climate-related information into added value for traditional MEDiterranean Grape, OLive and Durum wheat food systems	EU H2020	AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE	Europe	A	8	6	open source	5 mill
TWIGA: Transforming Weather Water data into value-added Information services for sustainable Growth in Africa	EU H2020	TECHNISCHE UNIVERSITEIT DELFT	Africa	A		1		5 mill
VISCA Vineyards´ Integrated Smart Climate Application	EU H2020	METEOSIM SL	Europe	A	8	7, 8		3 mill
LANDMARC H2020[AV1] [AV2] (Land Use Based Mitigation for Resilient Climate Pathways) (https://www.landmarc2020.eu/), ongoing project (-24), different tools and case studies	H2020	TECHNISCHE UNIVERSITEIT DELFT	Europe	A, S	all users	6, 7, 8,		7 mill
Vitigeoss H2020	H2020	FUNDACIO EURECAT		A	8	1,4		3 mill
ONEForest A Multi-Criteria Decision Support System For A Common Forest Management to Strengthen Forest Resilience, Harmonise Stakeholder Interests and Ensure Sustainable Wood Flows	H2020	TECHNISCHE HOCHSCHULE ROSENHEIM / TECHNICAL UNIVERSITY OF APPLIED SCIENCES	Europa	A	1. 2, 4,			5.5 mill

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Table 11. Sector D: Electricity, Gas, Steam and Air Conditioning Supply

Project name	Funder	Coordinating institution	Region	Sector	CS User	Type of service	Business strategy	Funding - Total Cost
S2S4E: Sub-seasonal to Seasonal climate forecasting for Energy	EU H2020	BSC	Europe	D, S	8	6	open source	4 mill
e-shape: EuroGEO Showcases: Applications Powered by Europe	EU H2020	ASSOCIATION POUR LA RECHERCHE ET LE DEVELOPPEMENT DES METHODES ET PROCESSUS INDUSTRIELS	Europe	A, D, E, Q, S	5	1	open source	15 mill
CLARA: Climate forecast enabled knowledge services	EU H2020	CMCC	Europe	A, D, E, Q, S	3,4,6,8	6		3 mill
SECLI-FIRM: The Added Value of Seasonal Climate Forecasts for Integrated Risk Management Decisions	EU H2020	UEA	Europe , South America	D, E, S		6		4 mill
Climate-fit.City: Pan-European Urban Climate Services	EU H2020	VLAAMSE INSTELLING VOOR TECHNOLOGISCH ONDERZOEK N.V.	Europe	D, E, H, L, S		7	open source	3 mill
SIM4NEXUS Sustainable Integrated Management FOR the NEXUS of water-land-food-energy-climate for a resource-efficient Europe	EU H2020	STICHTING WAGENINGEN RESEARCH	Europe	D,E	1, 2, 3	7, 8		7 mill

Table 12. Sector E: Water Supply, Sewerage, Waste Management and Remediation Activities

Project name	Funder	Coordinating institution	Region	Sector	CS User	Type of service	Business strategy	Funding - Total Cost
e-shape: EuroGEO Showcases: Applications Powered by Europe	EU H2020	ASSOCIATION POUR LA RECHERCHE ET LE DEVELOPPEMENT DES METHODES ET PROCESSUS INDUSTRIELS	Europe	A, D, E, Q, S	5	1	open source	15 mill
CLARA: Climate forecast enabled knowledge services	EU H2020	CMCC	Europe	A, D, E, Q, S	3,4,6,8	6		3 mill
SECLI-FIRM: The Added Value of Seasonal Climate Forecasts for Integrated Risk Management Decisions	EU H2020	UEA	Europe , South America	D, E, S		6		4 mill
Climate-fit.City: Pan-European Urban Climate Services	EU H2020	VLAAMSE INSTELLING VOOR TECHNOLOGISCH ONDERZOEK N.V.	Europe	D, E, H, L, S		7	open source	3 mill
RESCCUE: RESilience to cope with Climate Change in Urban arEas - a multisectorial approach focusing on water	EU H2020	Aquatec SUEZ Advanced Solutions	Europe	E, S		1,6		8 mill
SIM4NEXUS Sustainable Integrated Management FOR the NEXUS of water-land-food-energy-climate for a resource-efficient Europe	EU H2020	STICHTING WAGENINGEN RESEARCH	Europe	D,E	1, 2, 3	7, 8		7 mill
GROW The GROW observatory	EU H2020	UNIVERSITY OF DUNDEE	Europe	E	6, 8	1, 7		5 mill
Accelerating Water Smartness in Coastal Europe	H2020	WW RHEINISCH-WESTFALISCHES INSTITUT FUR WASSER BERATUNGS- UND ENTWICKLUNGSGESELLSCHAFT MBH	Europe	E	1, 2, 4,	7,8		17 mill

Table 13. Sector H: Transportation and Storage

Project name	Funder	Coordinating institution	Region	Sector	CS User	Type of service	Business strategy	Funding - Total Cost
Climate-fit.City: Pan-European Urban Climate Services	EU H2020	VLAAMSE INSTELLING VOOR TE	Europe	D, E, H, L, S (Urban Planning)		7	open source	3 mill
CLARITY: Integrated Climate Adaptation Service Tools for Improving Resilience Measure Efficiency	EU H2020	AIT AUSTRIAN INSTITUTE OF TE	Europe	H, L, S (Urban planning)		7		6 mill

Table 14. Sector L: Real Estate Activities

Project name	Funder	Coordinating institution	Region	Sector	CS User	Type of service	Business strategy	Funding - Total Cost
Sec	EU H2020	VLAAMSE INSTELLING VOOR TECHNOLOGISCH ONDERZOEK N.V.	Europe	D, E, H, L, S (Urban Planning)		7	open source	3 mill
CLARITY: Integrated Climate Adaptation Service Tools for Improving Resilience Measure Efficiency	EU H2020	AIT AUSTRIAN INSTITUTE OF TECHNOLOGY GMBH	Europe	H, L, S (Urban planning)		7		6 mill
CityCLIM: Next Generation City Climate Services Using Advanced Weather Models and Emerging Data Sources	EU H2020	OHB SYSTEM AG	Europe	Q, L? (Urban Planning)		6, 7	Private for-profit entities	5 mill

Table 15. Sector M: Professional, Scientific and Technical Activities

Project name	Funder	Coordinating institution	Region	Sector	CS User	Type of service	Business strategy	Funding - Total Cost
RESTORe4CS RESTORation of wEtlands for Carbon pathways, Climate Change mitigation and adaptation, ecosystem services, and biodiversity, Co-benefits	Climate, Energy and Climate	UNIVERSIDADE DE AVEIRO	Europe	M	All users	6, 7		6 mill
TOMOSLATE New uses for X-ray Tomography in natural building stones: characterization, pathologies and restoration of historical and recent roofing slates	Specific programme "People" implementing the Seventh Framework Programme of the European Community for research, technological development and demonstration activities (2007 to 2013)	University of Gent	Europe	M	All users	8		235 k

Table 16. Sector Q: Human Health and Social Work Activities

Project name	Funder	Coordinating institution	Region	Sector	CS User	Type of service	Business strategy	Funding - Total Cost
ACCLIM: Acclimatization scenarios and early warning system of temperature-related mortality in Europe	EU, Marie Skłodowska-Curie Actions	Barcelona Institute for Global Health (ISGlobal), Barcelona, Catalonia, Spain	Europe	Q	-	no climate service	-	158 k
e-shape: EuroGEO Showcases: Applications Powered by Europe	EU H2020	ASSOCIATION POUR LA RECHERCHE ET LE DEVELOPPEMENT DES METHODES ET PROCESSUS INDUSTRIELS	Europe	A, D, E, Q, S	5	1	open source	15 mill
CLARA: Climate forecast enabled knowledge services	EU H2020	CMCC	Europe	A, D, E, Q, S	3,4,6,8	6		3 mill
CityCLIM: Next Generation City Climate Services Using Advanced Weather Models and Emerging Data Sources	EU H2020	OHB SYSTEM AG	Europe	Q, L?		6,7	Private for-profit entities	5 mill
Acclimatization scenarios and early warning system of temperature-related mortality in Europe | ACCLIM | Project | Fact sheet | H2020 | CORDIS | European Commission (europa.eu)	Marie Skolodowska	FUNDACION PRIVADA INSTITUTO DE SALUD GLOBAL BARCELONA	Europe	Q	All users	6		158 k
Infectious Disease decision-support tools and Alert systems to build climate Resilience to emerging health Threats	H2020	Umeå university	Europa	Q	all users	7, 8,		9.2 mill

Table 17. Sector R: Arts, Entertainment and Recreation

Project name	Funder	Coordinating institution	Region	Sector	CS User	Type of service	Business strategy	Funding - Total Cost
STORM: Safeguarding Cultural Heritage through Technical and Organisational Resources Management	EU H2020	ENGINEERING - INGEGNERIA INFORMATICA SPA	Europe	R	7	1,6,7	Private for-profit entities	7 mill
Blue-Action: Arctic Impact on Weather and Climate	EU H2020	DMI	Europe + Arctic	A, R, S	6,8,?	1,6	open source?	8 mill
IPERION CH Integrated platform for the European research infrastructure on cultural heritage	Excellent science - Research infrastructure	CONSIGLIO NAZIONALE DELLE RICERCHE	Europe	R	1, 2, 8, 9	no climate service	not specified	8 mill
CLINT CLImate INTelligence: Extreme events detection, attribution and adaptation design using machine learning	EU H 2020	POLITECNICO DI MILANO	Europe	R	1, 2, 8	4, 5, 6		6 mill
PROSNOW Provision of a prediction system allowing for management and optimization of snow in Alpine ski resorts		METEO-FRANCE	Europe	R	7,8	8	commercial	3 mill
REGOTHICVAULTDESIGN Design Principles in Late-Gothic Vault Construction - A New Approach Based on Surveys, Reverse Geometric Engineering and a Reinterpretation of the Sources	FP7-IDEAS-ERC			R	1,3,	No climate service		1 mill
Fragsus Fragility and sustainability in restricted island environments: adaptation, cultural change and collapse in prehistory	FP7-IDEAS-ERC			R	all users	No climate service		2 mill
SmARTS Smart technology for analysis and monitoring of Cultural Heritage materials	H2020-EU.1.3.,H2020-EU.1.3.2.			R	1,2,8	No climate service		170 k

Table 18. Sector S: Other Service Activities

Project name	Funder	Coordinating institution	Region	Sector	CS User	Type of service	Business strategy	Funding - Total Cost
ECOPOTENTIAL: Improving Future Ecosystem Benefits Through Earth Observations	EU H2020	CONSIGLIO NAZIONALE DELLE RICERCHE, Italy	Europe + few worldwide	S	7	1	open source	16 mill
IMPREX: IMproving PRedictions and management of hydrological EXtremes	EU H2020	KNMI	Europe	S		6	open source	8 mill
Climateurope: European Climate Observations, Modelling and Services	EU H2020	UK Metoffice	Europe	S	1	8	open source	3 mill
S2S4E: Sub-seasonal to Seasonal climate forecasting for Energy	EU H2020	BSC	Europe	D, S	8	6	open source	4 mill
ACTRIS-2: Aerosols, Clouds, and Trace gases Research InfraStructure	EU H2020	CNR	Europe	S	5	1,5	open source	10 mill
e-shape: EuroGEO Showcases: Applications Powered by Europe	EU H2020	ASSOCIATION POUR LA RECHERCHE ET LE DEVELOPPEMENT DES METHODES ET PROCESSUS INDUSTRIELS	Europe	A, D, E, Q, S	5	1	open source	15 mill
Blue-Action: Arctic Impact on Weather and Climate	EU H2020	DMI	Europe + Arctic	A, R, S	6,8,?	1,6	open source?	8 mill
CLARA: Climate forecast enabled knowledge services	EU H2020	CMCC	Europe	A, D, E, Q, S	3,4,6,8	6		3 mill
H2020_Insurance: Oasis Innovation Hub for Catastrophe and Climate Extremes Risk Assessment	EU H2020	PIK	Europe + global	S		6	open source	5 mill
Climateurope2: Supporting and standardizing climate services in Europe and beyond	EU Horizon Europe	BSC	Europe	S	1	no climate service	open source	8 mill
SECLI-FIRM: The Added Value of Seasonal Climate Forecasts for Integrated Risk Management Decisions	EU H2020	UEA	Europe , South America	D, E, S		6		4 mill
Climate-fit.City: Pan-European Urban Climate Services	EU H2020	VLAAMSE INSTELLING VOOR TECHNOLOGISCH ONDERZOEK N.V.	Europe	D, E, H, L, S		7	open source	3 mill
MARCO: MArket Research for a Climate Services Observatory	EU H2020	CLIMATE-KIC	Europe	S	1	no climate service	open source	1 mill
AtlantOS: Optimizing and Enhancing the Integrated Atlantic Ocean Observing System	EU H2020	GEOMAR	Europe	S	5	1	open source	20 mill

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CLARITY: Integrated Climate Adaptation Service Tools for Improving Resilience Measure Efficiency	EU H2020	AIT AUSTRIAN INSTITUTE OF TECHNOLOGY GMBH	Europe	H, L, S		7		6 mill
SPECS: Secure Provisioning of Cloud Services based on SLA management	EU FP7	CENTRO REGIONALE INFORMATION E COMMUNICATION TECHNOLOGY SCARL	-	S	-	no climate service		11 mill
RESCCUE: RESilience to cope with Climate Change in Urban arEas - a multisectorial approach focusing on water	EU H2020	Aquatec SUEZ Advanced Solutions	Europe	E, S		1,6		8 mill
REACHOUT: Resilience in Europe Through Activating City Hubs Reaching out to Users with Triple-A Climate Adaptation Tools	EU H2020	Deltares	Europe	S		1,5,6,7	open source	5 mill
HELIX High-End cLimate Impacts and eXtremes	Specific Programme "Cooperation": Environment	University of Exeter	Europe	S	1, 2, 3, 4, 6	3, 4, 6	open source	11 mill
ECLISE - Enabling CLimate Information Services for Europe	Specific Programme "Cooperation": Environment	KNMI Netherlands	Europe	S	1, 2, 3, 4	1, 2, 3, 4	open source	4 mill
RISES-AM Responses to coastal climate change: innovatine strategies for high End Scenarios Adaptation and Mitigation	Specific Programme "Cooperation": Environment	Universitat Politecnica de Catalunya	Europe	S	1,2,3,4	4,5,7	open source	5 mill
KADI Knowledge and climate services from an African observation and data research infrastructure	Research infrastructures	NTEGRATED CARBON OBSERVATION SYSTEM EUROPEAN RESEARCH INFRASTRUCTURECONSORTIUM	Africa	S	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	2, 4, 5	not specified	1 mill
EU MACS European market for climate services	EU2020	ILMATIETEEN LAITOS	Europe	S	1,2,3, 4, 8	6.7,8		1 mill
NEXTGEOSS Next Generation GEOSS for Innovation Business	EU H2020	DEIMOS ENGENHARIA SA	Europe	S	all users	1,4		10 mill
CoCliCo Coastal climate core services	H2020	BUREAU DE RECHERCHES GEOLOGIQUES ET MINIERES	Europe	S	All users	Costal climate data platform		6 mill
FIDUCEO Fidelity and Uncertainty in Climate data records from Earth Observations	INDUSTRIAL LEADERSHIP - Leadership in enabling and industrial technologies – Space	The University of Reading	Global	S	All users	4,5		5 mill
HERACLES HEritage Resilience Against CLimate Events on Site	EU H2020	CONSIGLIO NAZIONALE DELLE RICERCHE	Europe	S	All users	4,5,6		6 mill
Ground Truth 2.0 - Environmental knowledge discovery of human sensed data	H2020-EU.3.5.5.,H2020-EU.3.5.	STICHTING IHE DELFT INSTITUTE FOR WATER EDUCATION	Europe, Africa	S	6	1	Commercial	5 mill
LANDSENSE A Citizen Observatory and Innovation Marketplace for Land Use and Land Cover Monitoring	H2020-EU.3.5.5.,H2020-EU.3.5.	INTERNATIONALES INSTITUT FUER ANGEWANDTE SYSTEMANALYSE	Europe	S	6	1	Commercial	5 mill

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XAIDA EXTREME EVENTS: ARTIFICIAL INTELLIGENCE FOR DETECTION AND ATTRIBUTION	H2020-EU.3.5.,H2020-EU.3.5.1.	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS		S	1,2,	4, 5, 6,		6 mill
IMPETUS4CHANGE (I4C): IMPROVING NEAR-TERM CLIMATE PREDICTIONS FOR SOCIETAL TRANSFORMATION	HORIZON.2.5,HORIZON.2.5.1	NORCE NORWEGIAN RESEARCH CENTRE AS		S	1,2,	6, 7, 8,		9 mill
COORDINATINGforLIFE Coordinating for life. Success and failure of Western European societies in coping with rural hazards and disasters, 1300-1800	FP7-IDEAS-ERC	UNIVERSITEIT UTRECHT		S	1,2,	6,8,		2 mill
ESM2025 Earth system models for the future	H2020-EU.3.5.,H2020-EU.3.5.1.	METEO-FRANCE		S	all users	1,2,3,4,5,6		11 mill
PLACARD PLAtform for Climate Adaptation and Risk reDuction	H2020-EU.3.5.,H2020-EU.3.7.	FCIENCIAS.ID - ASSOCIACAO PARA A INVESTIGACAO E DESENVOLVIMENTO DE CIENCIAS		S	all users	7,8,		3 mill
FOCI Non-CO2 Forcers and their Climate, Weather, Air Quality and Health Impacts	HORIZON.2.5,HORIZON.2.5.1	UNIVERZITA KARLOVA		S	6,8,	7,8,		6 mill
PROVIDE Paris Agreement Overshooting – Reversibility, Climate Impacts and Adaptation Needs	H2020-EU.3.5.,H2020-EU.3.5.1.	HUMBOLDT-UNIVERSITAET ZU BERLIN		S	6,8,	6,7,8,		6 mill
ESCAPE Energy-efficient SCalable Algorithms for weather Prediction at Exascale	H2020-EU.1.2.,H2020-EU.1.2.2.			S	all users	No climate service		4 mill
TRANS-SAHARA Trans-SAHARA: State Formation, Migration and Trade in the Central Sahara (1000 BC - AD 1500)	FP7-IDEAS-ERC			S	all users	No climate service		2 mill
LANDMARC H2020[AV1] [AV2] (Land Use Based Mitigation for Resilient Climate Pathways) (https://www.landmarc2020.eu/), ongoing project (-24), different tools and case studies	H2020	TECHNISCHE UNIVERSITEIT DELFT	Europe	A, S	all users	6, 7, 8,		7 mill
EnhANcing emergencY management and response to extreme WeatHER and climate Events	H2020	UNIVERSITAT POLITECNICA DE CATALUNYA	Europa	S	all users	4,5,6,		14.8 mill
ECFAS European Coastal Flood Awareness System	INDUSTRIAL LEADERSHIP - Leadership in enabling and industrial technologies – Space	ISTITUTO UNIVERSITARIO DI STUDI SUPERIORI (I.U.S.S.) DI PAVIA	Europe	S	all users	5,6,		1.5 mill
RECEIPT Project, H2020 https://climatestorylines.eu	H2020	STICHTING DELTARES	Europe	S	all users	6		7 mill
PROTECT (Procuring innovative climate services	H2020	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	Global	S	all users	1,6,		10 mill
Impact2C (https://www.atlas.impact2c.eu/en/	Specific Programme "Cooperation": Environment (including Climate Change)	HELMHOLTZ-ZENTRUM HEREON GMBH	Global	S	all users	6,7,8,		6.5 mill

Table 19. Sectors not classified.

Project name	Funder	Coordinating institution	Region	Sector	CS User	Type of service	Business strategy	Funding - Total Cost
EUPORIAS: EUropean Provision Of Regional Impact Assessment on a Seasonal-to-decadal timescale	EU FP7	UKMO	Europe	div.		6	open source	13 mill
EUCP: European Climate Prediction system	EU H2020	UKMO	Europe	div.		6	open source	13 mill
ERA4CS European Research Area for Climate Services	EU H2020	AGENCE NATIONALE DE LA RECHERCHE		-		No climate service		65 mill
ERA-Planet The European network for observing our changing planet	EU H2020	CONSIGLIO NAZIONALE DELLE RICERCHE		-		4		37 mill
ERA-NET Plus on Cultural Heritage and Global Change Research	Programme Cooperation Environment including climate change	MINISTERO DELLA CULTURA Italy	Europe			No climate service		9 mill
ACCLIM	Spreading excellence and widening participation	FACULTY OF PHYSICS OF THE UNIVERSITY OF BELGRADE				No climate service		158 k
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	Specific Programme "Cooperation": Environment	Hamburg University	North Atlantic/Europe			No climate service		11 mill
SINCERE Strengthening INternational Cooperation on climatE change REsearch	EU H2020	Service Public Fédéral de Programmation Politique Scientifique (Belspo)	Europe			No climate service		2 mill
RESPONSE (Integrated solutions for positive energy and resilient cities	H2020	EIFER EUROPAISCHES INSTITUT FUR ENERGIEFORSCHUNG EDF KIT EWIV			CS related to energy system planning			23.6 mill