HACID - Deliverable

Requirements from climate services

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[1] The following codes are admitted:
- R: Document, report (excluding the periodic and final reports)
- DEM: Demonstrator, pilot, prototype, plan designs
- DEC: Websites, patents filing, press & media actions, videos, etc.
- DATA: Data sets, microdata, etc.
- DMP: Data management plan
- ETHICS: Deliverables related to ethics issues.
- SECURITY: Deliverables related to security issues
- OTHER: Software, technical diagram, algorithms, models, etc.

[2] The following codes are admitted:
- PU – Public, fully open, e.g. web (Deliverables flagged as public will be automatically published in CORDIS project's page)
- SEN – Sensitive, limited under the conditions of the Grant Agreement
- Classified R-UE/EU-R – EU RESTRICTED under the Commission Decision No2015/444
- Classified C-UE/EU-C – EU CONFIDENTIAL under the Commission Decision No2015/444
- Classified S-UE/EU-S – EU SECRET under the Commission Decision No2015/444

Document History

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4	30/05/2023	Final review	Aleks Berditchevskaia	NESTA

Glossary/Terminology

Terminology	Definition
Data provision (climate service)	The provision of climate data to external organisations who need curated datasets to, for example, inform adaptation plans. Sometimes organisations may also need climate data to combine with other datasets and answer specific questions (e.g., rainfall dataset combined with drainage dataset).
Briefing document (climate service)	The provision of briefing documents, such as policy notes, factsheets, case studies and guidance, to external organisations. These documents can have different purposes such as stimulating conversations about climate

	change, informing the design of assets (e.g., ships, trains) or managing infrastructures and services (e.g, public health services). The documents are tailored to the user needs and aim at communicating climate data in a simple and succinct form.
Training (climate service)	The provision of training to external organisations who want to learn how they can account for climate hazards in their business (e.g., sustainability officer). The training is especially relevant for those relatively new to climate change and adaptation management.
Emission scenarios	Emission scenarios are plausible future development pathways of human greenhouse gas and aerosol emissions.

Acronyms	Definition
HACID-DSS	Hybrid Human Artificial Collective Intelligence in Open-Ended Domains - Decision Support System. This acronym is used to denote a technology solution that combines knowledge graph technology, AI and collective intelligence of experts for decision support to professionals facing complex open-ended problems, promoting engagement, fairness and trust.
CI	Collective intelligence - a research field that brings together people, technology and data to enhance the problem-solving skills of organisations and communities.
DKG	Domain Knowledge Graph - a knowledge graph that defines and encodes knowledge about a given domain. Knowledge graphs and structured knowledge bases represent and store data and information differently from traditional databases. They make it easier to discover new patterns and relationships between data – helping to overcome information silos.
CKG	Case Knowledge Graph - it extends and integrates domain knowledge from a DKG with specific knowledge about a case, i.e., a specific question or scenario to be addressed by experts and decision makers in the reference domain.
UX	User Experience - the overall experience of a

	person using a product such as a website or a computer application.
UI	User Interface - point of contact between humans and computers. For example, screens, sounds, overall style, and responsiveness are all elements of UI.

We also use the following acronyms to refer to partners: MetO = Met Office, CNR = ISTC-CNR; MPG = Max Planck Gesellschaft, Institute for Human Development; HDx = Human Diagnosis Project.

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1. Introduction

In this section, we provide an introduction to the purpose and content of this report and a short explanation of the HACID-DSS project and the main concepts associated with the project.

1.1. Overview of the deliverable

The HACID project aims to develop new tools that can support decision-makers working on open-ended problems[3] in domains such as climate services. It will help better inform climate adaptation strategies by bringing together multiple sources of climate data, models and information.

This report was produced by Nesta to outline key findings from user research with the Met Office (MetO) and prototype requirements for deploying a system that aims at combining existing knowledge with expert contributions to aid decision-making in climate services. This system will be referred to as the 'Hybrid Human Artificial Collective Intelligence in Open-Ended Domains - Decision Support System' (HACID-DSS).

This report details how findings will feed into a new deployment of the HACID-DSS that allows multiple climate science experts to formulate better decisions around climate change adaptation. The report is published alongside three design outputs, which, in combination, make up the full deliverable:

1) A service blueprint that details the user interactions with the HACID-DSS,
2) A prototype that details the functionality and user experience of the future HACID-DSS, and
3) A preliminary roadmap with indicative developmental milestones and evaluation checkpoints for the prototype.

1.1. Introduction to the HACID project

The HACID project aims at bringing together multiple sources of climate data, models and information to inform better climate adaptation strategies. The project will create new tools for knowledge integration and decision-making using a new approach that combines knowledge graphs, artificial intelligence and hybrid collective intelligence.

Collective intelligence is the enhanced capacity created when groups solve problems, exceeding the capabilities of single individuals.[4] In the 21st century collective intelligence has been greatly enhanced by digital technologies and, increasingly, machine intelligence.[5] The

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[3] They are typically ill-defined problems that do not have an obvious single correct answer or a limited set of alternatives, and require discussion and collaboration to solve.

[4] Krause, J. et al. Swarm intelligence in animals and humans. Trends in ecology & evolution, 25(1):28–34, 2010.

[5] Berditchevskaia, A., Baeck, P.(2020). The Future of Minds and Machines.London: Nesta.

HACID project uses the collective intelligence method of crowdsourcing to collect experts' solutions for open-ended questions. The HACID-DSS then leverages advanced processing to provide a single solution aggregated from a combination of the experts' suggestions.

1.2. The HACID-DSS

The HACID-DSS uses a knowledge graph for the underlying information architecture. A knowledge graph is a graph of data intended to accumulate and convey knowledge of the real world, whose nodes represent entities of interest and whose edges represent relations between these entities.[6] Within the DSS, we define two distinct knowledge graphs: the *Domain Knowledge Graph (DKG)* and the *Case Knowledge Graph (CKG)*.

A DKG encodes knowledge about a given domain, for example, climate services. Knowledge that contributes to a DKG can be derived from a variety of sources, ranging from domain experts to scientific and grey literature. Such knowledge is stored, organised, managed and made available in the form of a structured knowledge base, so that it can be queried, searched, explored and, if needed, extended and integrated with new knowledge. The DKG is designed and built to include the relevant knowledge representation elements (schema and supporting data) needed for answering specific questions or addressing scenarios within that domain (i.e., it is able to represent specific *cases*).

When domain experts and decision-makers are addressing a specific case, they provide information that contributes to the definition of a CKG, i.e., the knowledge graph that defines and encodes knowledge about the specific case to be addressed. The CKG extends, refines and specialises the DKG with case-specific knowledge. A CKG typically instantiates schemas defined in the DKG with case-specific data, which in turn may refer to domain entities in the DKG.

Domain experts are requested to propose a range of potential solutions to the case under consideration. As they are defining their solutions, they draw on their existing knowledge and their interaction with the CKG. These solutions are then processed and analysed by the AI-based HACID-DSS, which aggregates and enriches the available solutions into a comprehensive collective solution, supported by evidence from the CKG. Experts' and machine-generated knowledge are thus combined within a *hybrid collective intelligence* process. The resulting collective solution is then evaluated, taking into account different evaluation criteria and dimensions.

2. Methodology

In this section, we provide an overview of the methodology used during the research and development phase of the project. We introduce the approach and design process, highlighting 3 main steps: discover, define and develop. For each phase, we describe our goals, the design activities and the processes that helped us achieve them. We present the results in subsequent sections.

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[6] Hogan, A., Blomqvist, E., Cochez, M., d'Amato, C., Melo, G.D., Gutierrez, C., Kirrane, S., Gayo, J.E.L., Navigli, R., Neumaier, S. and Ngomo, A.C.N., 2021. Knowledge graphs. ACM Computing Surveys (CSUR), 54(4), pp.1-37.
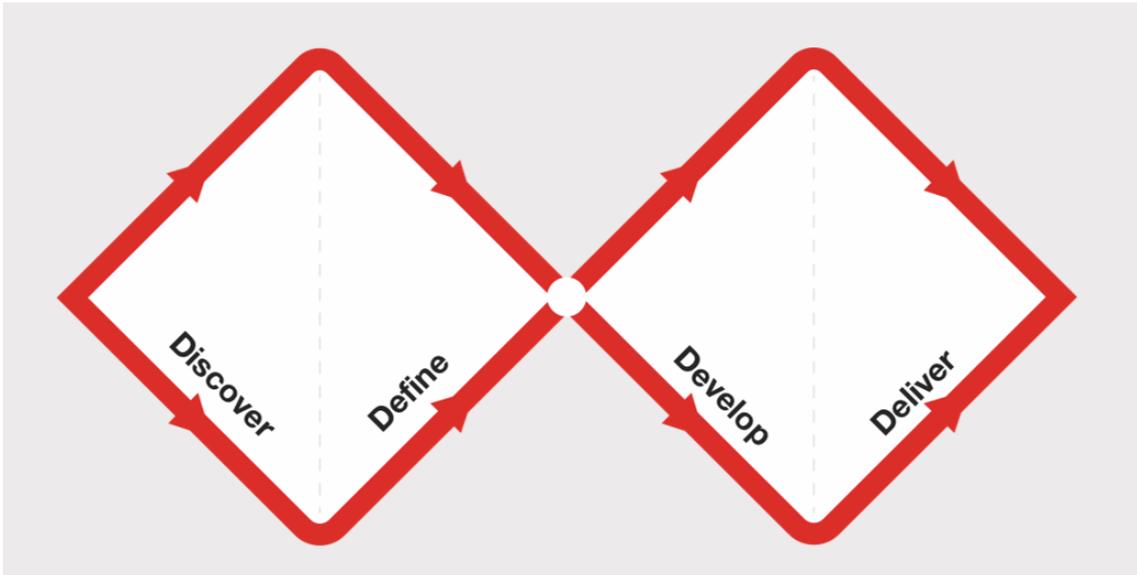
Figure 1 - Double Diamond design process visualisation - Design Council 2023 'The Double Diamond by the design Council'. The Double Diamond. Retrieved May 05, 2023 (https://www.designcouncil.org.uk/our-resources/the-double-diamond.)

2.1. Overview: discover, define, develop

The HACID project follows a <u>participatory AI</u>[7] approach to explore the benefits of involving domain experts in the design of new decision-making tools to improve their performance and utility, as well as helping professionals to build trust and understanding of AI.

Participatory AI *refers to the range of practices and methods that involve a wider range of stakeholders than just technology developers in the creation of an AI system, model, tool or application. As a field, it sits within the broader category of participatory design of technology.*

Engaging wider stakeholders in the design process can also help identify potential unintended consequences of new technology and opportunities to address these.

We undertook user research through a range of qualitative research techniques (interviews, surveys, and workshops) with climate services and climate change experts to capture their information needs and challenges, strategic policy decisions, and constraints (organisational, legal, financial, operational, etc.) in the context of data-driven decision-making for climate adaptation.

The NESTA team collaborated closely with consortium partners throughout the research and design process using a series of internal workshops and co-design sessions. This participatory approach helped us develop a final design concept that is both meaningful for domain specialists and technically feasible.

The report focuses on the initial scoping and development of the HACID-DSS prototype. It refers to three methodological phases of the design process: Discover, Define and Develop (The fourth phase 'deliver' will take place in the next phase of the project and it is not

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[7] Berditchevskaia, A., Peach K., Maliaraki E. Participatory AI for humanitarian innovation. Nesta. 2021

included in this deliverable). These phases are aligned with the [double-diamond](#) design process. The 'double-diamond' is a visual representation of the design and innovation process that was created by the Design Council. It demonstrates that design involves multiple phases of exploration, refinement and iteration.

We briefly describe the approach taken for each of these stages below and present results in subsequent sections.

Discover: The first phase of the process focuses on understanding domain context, including core characteristics and friction points of climate services provision. This step involves speaking to and spending time with people who are affected by the issues. We undertook user research through a range of qualitative research techniques (interviews, surveys, and workshops) with climate services and climate change experts to capture their information needs and challenges, strategic policy decisions, and constraints (organisational, legal, financial, operational, etc.) in the context of data-driven decision-making for climate adaptation.

Define: This phase focuses on synthesising the insights gathered from Discovery to define a design opportunity. We identified the main insights from the user research and grouped them into themes relating to user challenges. During a series of workshops with the MetO and CNR, we articulated what the different challenges referred to, and whether they could be addressed through the HACID-DSS prototype. We evaluated and prioritised the different themes using the criteria of feasibility, innovation and user value to identify a core design opportunity.[8]

Develop: This phase explored different ways to apply the HACID-DSS approach to the core challenge selected in Define. The NESTA team collaborated closely with consortium partners throughout this phase using internal workshops and co-design sessions. This helped us develop a final design concept that would both be relevant for domain specialists and technically feasible.

2.2. Discover phase

2.2.1 Initial scoping

The initial phase of research focused on understanding the context and limits of the design scope. During this phase, we set out to 1) better understand the field of climate science including key processes and stakeholders; 2) better understand the technical capabilities and constraints of the HACID-DSS technology; 3) create a shared understanding of the HACID-DSS between the partners. The three core activities that supported this phase included:

1) **A rapid review of relevant literature, artefacts and resources**: We consulted recent academic articles and grey literature using keywords "climate services" and "knowledge graphs" ([Bibliography](#)). The MetO also provided user scenarios that described past climate services provided to external organisations for decision-making in climate adaptation.

2) **Interviews and demos with project partners:** To better understand the field of climate science in the context of data-driven decision-making for climate adaptation,

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[8] A design opportunity is a challenge, identified during research, that could be addressed through the design process. The term 'design opportunity' frames a challenge in a positive way. It first became popular in the fields of 'design thinking' and 'innovation'.

NESTA conducted interviews with the MetO. To better understand the HACID-DSS technology as well as its potential and limitations, NESTA conducted interviews with CNR, who provided explanations and demos.

3) **Co-created system map**: To create a shared understanding between the partners of what the HACID-DSS system could technically achieve, we collated our findings to create a simple system map that illustrated how the HACID-DSS could work in future. This artefact helped the consortium to define the design scope and gain a better understanding of the actors, actions and components involved in the system.

2.2.2 User Research

NESTA conducted user research with 21 people across 4 organisations. The full list of participants in this process and the activities they contributed to can be found in the Appendix.

The main objectives for the user research phase were to 1) discover opportunities for the HACID-DSS to support external organisations who use climate data to make climate adaptation decisions; 2) discover opportunities for the HACID-DSS system to be integrated into current climate services processes. There were 3 key activities:

1) **Semi-structured interviews with external organisations** who already use climate services, to help identify user needs, challenges and friction points for using climate data to make climate adaptation decisions (see table below).
2) **A survey with MetO internal staff** who deliver climate services, to gather examples and help understand past climate delivery processes and challenges involved (see table below).
3) **A system-mapping workshop with MetO internal staff** who deliver climate services, to inform understanding of the current state of climate service delivery, the high-level steps involved in these processes and uncover key challenges faced by climate scientists (see table below).

Research with Internal MetO staff: System Mapping Workshop & Survey

As part of the user research, we facilitated a workshop with MetO internal teams. The participants came from a variety of backgrounds and teams (see Appendix for domain expertise and roles of participants). Although the current processes of climate service provision are heterogeneous and do not follow a standard across the organisation, all climate services follow the same three high-level steps: 1) planning, 2) development/creation of content and 3) delivery. The 3 most common types of climate services are briefing documents, training and data provision (please refer to the terminology section of this document for definitions).

The workshop was delivered online and composed of two parts, an individual survey and a group activity. In the survey, participants contributed real examples (past projects) of one of the three types of climate services focusing on the main steps in the process and the challenges.
During the workshop, participants were grouped into one of the three climate services based on their previous experience. In groups of 4-6, they mapped out a high-level step-by-step process using the collaborative visualisation platform, Mural.

Following the workshop, the high-level processes for each of the climate services were developed into user journeys and shared with participants for feedback. (please see current state: service delivery in the Appendix)

Stakeholder group	Method	User Research question	Participants
External organisations _who already make use of climate services_	Semi-structured interviews (1 hr)	- What does the process of making a request look like? - What are the key moments/decision points? - What are the needs and friction points for each stakeholder? - What are the motivators and drivers of the process and the partnerships?	3
External organisations _who could make use of climate services_	Semi-structured interviews (1 hr)	- Which climate/weather-related phenomena and events are of primary concern to external organisations? - Which decisions they make or processes they follow, would benefit from climate information? - Who in the external organisations participates in the decision-making process?	2
Internal MetO staff _involved in the delivery of climate services_	System mapping workshop (2 hrs)	- What are the current processes to deliver climate services? - What are the high-level steps involved? - What are the key moments/ decision points? - What are the needs and friction points of staff? - What are the touch points that they interact with during the process? (request, software, data)	12
	Survey	- What are some real examples of delivering climate services? - What are the key moments/ decision points? - What are the needs and friction points of staff? - What are the touch points that they interact with during the process? (request, software, data)	6

Please choose which climate service you would like to provide an example for:
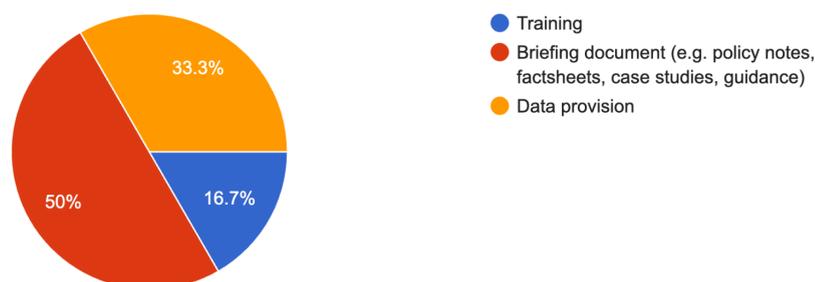6 responses

- Training
- Briefing document (e.g. policy notes, factsheets, case studies, guidance)
- Data provision

Figure 2 - *Survey result: 50% of participants provided examples for briefing documents; 33.3% Data provision and 16.7% Training*
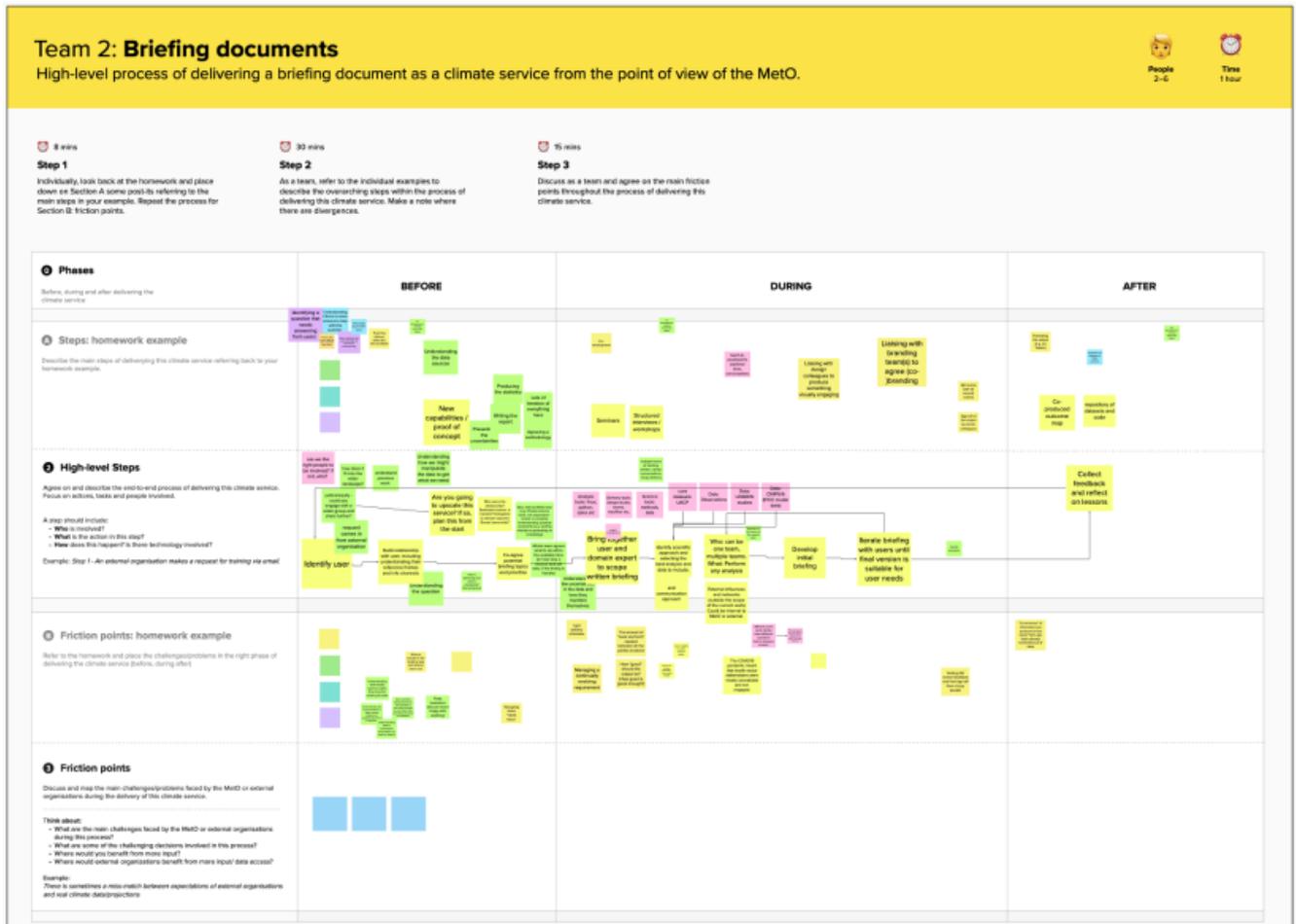
Figure 3 - *Mural Activity: participants mapped the high-level process of delivering each climate service. The figure is an example from the 'briefing documents' team.*

2.3. Define phase

2.3.1 Analysis and identification of design opportunities

The user research was analysed using <u>thematic analysis</u> — a process for identifying the main themes in data from user studies and grouping them into themes. During this process, NESTA identified the main insights in the research and grouped them into themes. The themes referring to challenges and research questions were selected for further analysis. Following this process, the main themes identified were articulated and communicated to the larger team as design opportunities. In this case, we were interested in identifying relevant challenges that could be addressed by the HACID-DSS.

2.3.2 Evaluation and selection of design opportunities

The aim of this phase was to choose one or two design opportunities to address through the HACID-DSS. This process had several steps: 1) NESTA presented an analysis of key findings and emerging design opportunities to the MetO and CNR. 2) Partners contributed to an online workshop to discuss the design opportunities. CNR, MetO and NESTA voted on the most relevant opportunities for the HACID-DSS using criteria of feasibility, user value and

innovation. 3) Following the workshop, NESTA documented the discussions and the imagined applications of HACID-DSS for each of the relevant design opportunities. This was used to make recommendations on which had the most potential and were feasible for building the HACID prototype.

The partners agreed to prioritise three design opportunities. These were then illustrated as blueprints[9] (similar to a user journey) to help the partners visualise how the HACID system could tackle each design opportunity.

NESTA presented the blueprints to partners during an in-person workshop in Berlin (March 2023). The consortium partners selected one design opportunity to focus on for the development of the HACID-DSS based on criteria of feasibility, user value and innovation.
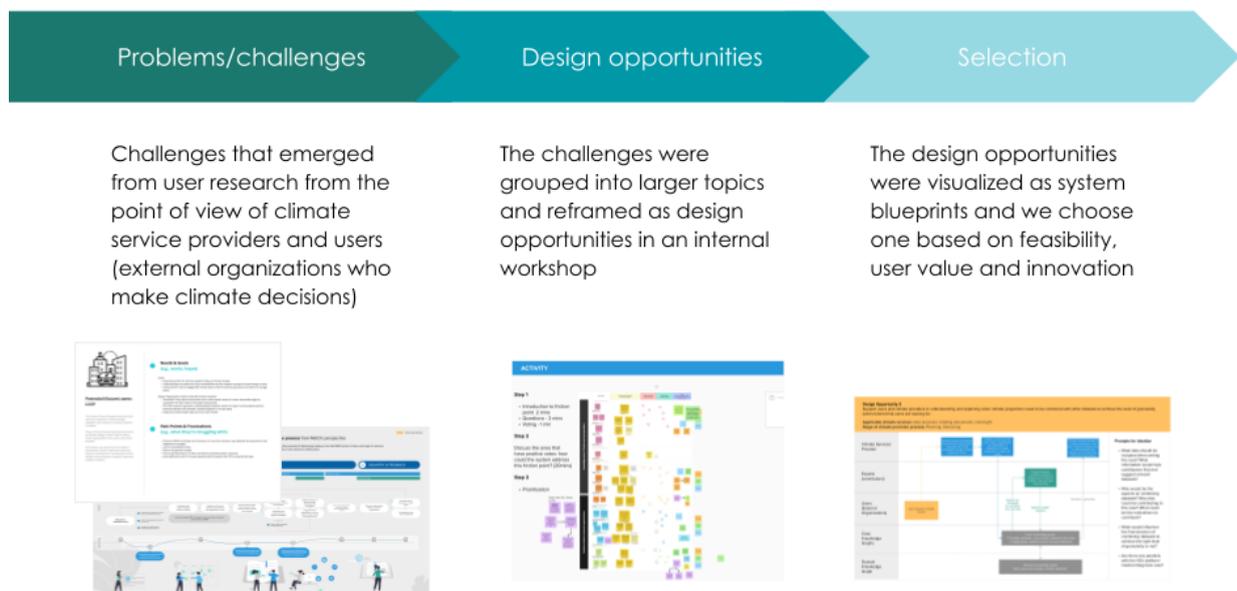
Figure 4 - *Summary of the process of going from user research to design opportunities*

2.4. Develop phase

2.4.1 Ideation

All partners contributed ideas on different ways the design opportunity could be realised during the in-person consortium meeting in Berlin. The ideas were collected through a collaborative workshop (see Figure 5) and further developed by the NESTA team.

2.4.2 Co-design

After initial ideation, NESTA worked closely with the MetO and CNR to further refine the concept. NESTA produced prototypes that were iterated based on 1) technical feedback on the system's capabilities and limitations and 2) domain-specific feedback on the user value and climate science community behaviours and needs.

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[9] A service blueprint is a visual representation of the customer experience and the operational processes involved in delivering a service.

Figure 5 - *Blueprint of design opportunity with ideas contributed by partners during the March Berlin Consortium meeting.*
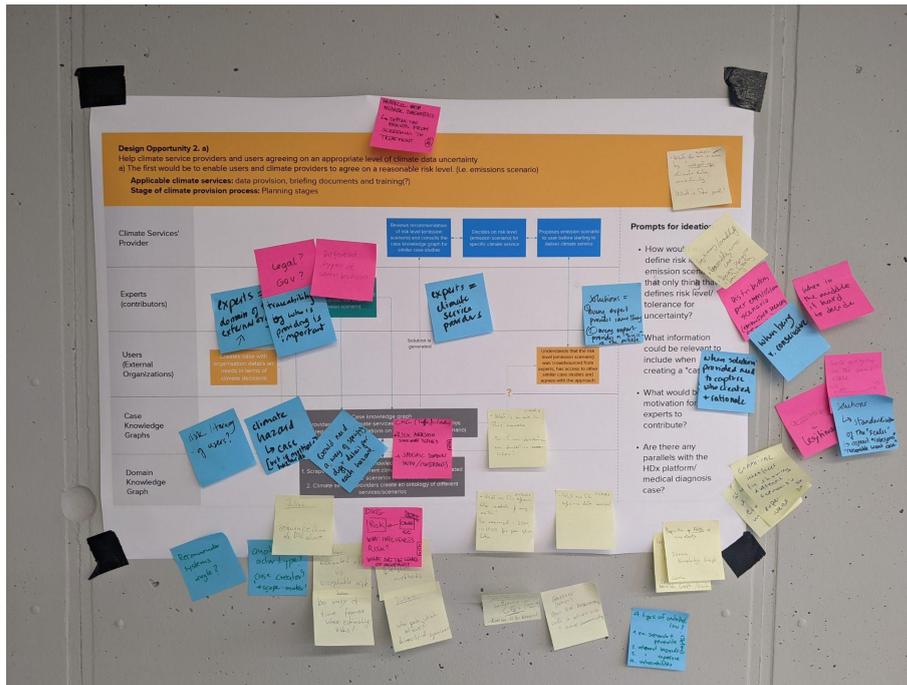
3. Results

In this section, we provide a synthesis of the key findings from the activities detailed in the Methodology section. We start by summarising the results from User interviews with external organisations and the Discovery workshop with climate scientists (DISCOVER). Then we detail the four Design opportunities that were identified from these findings and the prioritisation process that led to the selection of the final concept for the HACID-DSS prototype (DEFINE). In the final part of this section, we give an overview of the HACID-DSS describing the role of different users and provide a scenario for current and future use.

3.1. Discover: Key Findings from User Research

NESTA conducted user research with 21 people in 4 organisations. The full list of participants in this process and the activities they contributed to can be found in the [Appendix.](#)

The main objectives for the user research phase were to 1) discover opportunities for the HACID-DSS to support external organisations who use climate data to make climate adaptation decisions; 2) discover opportunities for the HACID-DSS to be integrated into the current climate services processes. In this section, we describe the results from the following research activities:

- **Interviews with external organisations** who request climate services, helped inform user needs, challenges and friction points when using climate data to make climate adaptation decisions. Sample size: 5 participants. This helped to identify:

<ol type="a" start="1">
Motivators and drivers
Needs and goals
Challenges

- **A workshop and a survey with MetO internal staff (climate service provider)** who delivers climate services, helped inform the current state of climate service delivery, the high-level steps involved in these processes and uncover challenges. Sample size: 12 participants in the workshop and 6 participants in the survey. This helped to identify:
<ol type="a" start="4">
Process of delivering climate services
Challenges
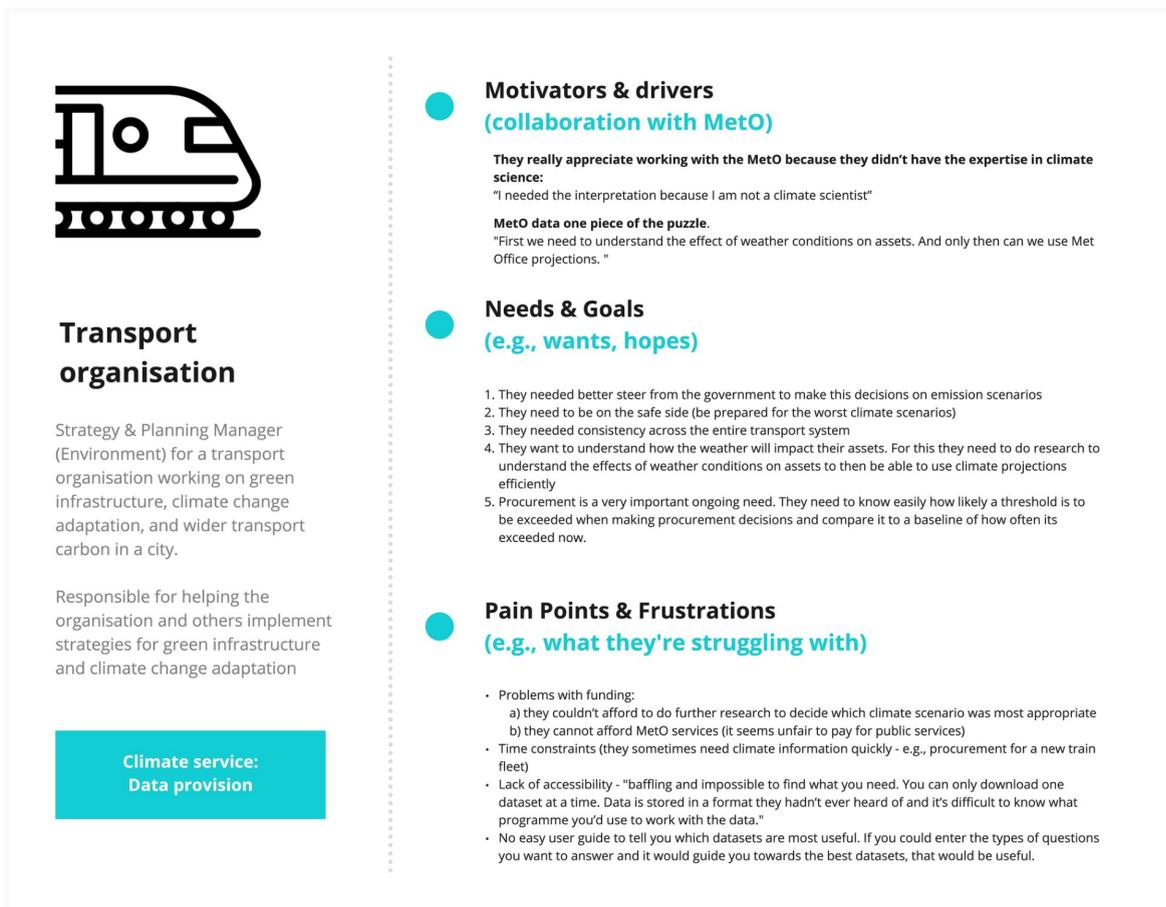
Figure 6 - Visual summary of one of the interviews with an external organisation (transport organisation)

3.1.1 External Organisations: Motivators and Drivers

Organisations have strong motivators and drivers for collaborating with the MetO:

1. Expertise in Climate Science: Organisations appreciate working with the MetO because they lack the specialised knowledge in climate science, relying on the agency's expertise for interpretation and understanding of climate-related data and projections.
2. Effective Communication: Some organisations place importance on creative practices as a means of connecting with people. However, they also prioritise scientific

validation, recognizing the value of collaborating with climate scientists from the MetO to ensure accuracy and credibility in their communications.

3. Limitations: Advanced organisations working on adaptation plans recognize that the MetO data is one piece of the puzzle. They acknowledge they need research on the impact of weather conditions on their assets in order to utilise the MetO's projections effectively.

Overall, organisations recognize the value of partnering with the MetO to leverage their climate science expertise, integrate it with their own understanding, and effectively communicate climate-related information to stakeholders.

3.1.2 External Organisations: Needs and Goals

The overall goals of an organisation seeking for climate services can be summarised as follows::
- Prepare for extreme weather events today and climate change impacts in the future.
- Understand vulnerabilities and expected impacts of climate change.
- Engage partners to inform business operations and asset management using climate data.
- Provide spatially and granularly detailed data for identifying threshold exceedance areas and supporting decision-making.
- Ensure simplicity and user-friendliness in accessing climate data for all stakeholders.

The users expressed several needs regarding climate change adaptation and decision-making:

1. Need for Government Guidance: Users required better guidance from the government to make informed decisions on emission scenarios and address climate change effectively.
2. Preparedness for Worst-Case Scenarios: Users emphasised the importance of being on the safe side and prepared for the worst climate scenarios, understanding the potential risks and impacts they may face.
3. Consistency across Organisations/partnerships: Users sought consistency of emission scenarios across their organisations/partnerships to ensure smooth operations and reliable services in the face of changing climate conditions.
4. Understanding Weather Impact on Assets: Users aimed to understand how weather conditions would impact their assets (e.g., how will high-temperatures impact train's cooling systems?), requiring research on the effects of weather and the ability to efficiently utilise climate projections.
5. Procurement Decision Support: Users highlighted the ongoing need for procurement decision-making, requiring easy access to information on the likelihood of threshold exceedance and comparisons to baseline conditions.
6. Detailed and User-Friendly Climate Data: Users sought more detailed climate data as their adaptation planning progressed, specifically with a simple user interface for accessing locally-specific information.

3.1.3 External Organisations: Challenges

External organisations face several challenges when using climate data and making decisions for climate adaptation. These are discussed below.

Constraints when using climate data:

1. Funding Constraints: Limited resources hinder organisations from conducting further research to determine appropriate climate scenarios, and they may struggle to afford services provided by organisations like the MetO. In this case, paying for a public service is perceived as unfair.
2. Time Constraints: External organisations often require climate information quickly, particularly for time-sensitive decisions (for example, procurement for new train fleets).
3. Lack of In-House Expertise: Some partners face limitations in utilising climate data due to a lack of in-house expertise, highlighting the need for external support.
4. Pressure from Regulatory Authorities: Regulatory pressure drives councils to produce detailed risk assessments and adaptation strategies.

Type of Climate Data:

5. Integration of Local Impact Data: Linking National-level predictions with locally-specific impact data poses a significant challenge, often realised at a late stage of the decision-making process.
6. Granularity and Threshold Information: Lack of granular data and difficulty in obtaining information on when and where thresholds will be surpassed present additional challenges for decision-making.

Data accessibility:

7. Lack of Data Accessibility: Accessibility to climate data is challenging, with difficulties in finding the needed data, limitations on downloading multiple datasets at once, unfamiliar data formats, and uncertainty about which programs to use for data analysis.
8. Absence of User-Friendly Guidance: There is a need for an easy-to-use user guide that recommends the most useful datasets based on the specific questions organisations want to answer, facilitating efficient data utilisation.
9. Need for Data Interpretation: Limited expertise among stakeholders necessitates intermediaries who can interpret climate data, making it essential to find ways to make data accessible at scale.
10. Unnecessary Commissioning of Consultancies: Organisations sometimes end up commissioning consultancies for basic climate information that should already be available to them, resulting in unnecessary costs.

Using climate data to collaborate:

11. Inconsistent Use of Climate Data: Establishing a shared understanding and consistent use of climate or emissions scenarios and adaptation plans among stakeholders is a challenge, with the value lying in helping stakeholders navigate uncertainty, interpret climate projections, and foster collaboration.

3.1.4 Climate service provider: The Process of Delivering Climate Services

The process of developing a climate service typically involves three high-level phases: planning, creation of content, and final delivery, each of which is briefly described below. Although most climate services broadly follow these three phases, the process is not always

linear. The amount of time and the opportunity for iteration or feedback between the phases depends on a given project's constraints and resources.

Planning Phase

During this phase, climate service providers determine the objectives and requirements of the climate service. This includes identifying the target users, understanding their specific needs and requirements, and defining the scope of the service.

Creation of Content Phase

The development phase of the climate service involves identifying, analysing, and interpreting existing weather/climate data and models to generate meaningful information and insights. Various models, tools, and techniques may be employed to interpret the data and produce relevant outputs that are able to address user needs at the appropriate level of granularity.

Delivery Phase

The final phase focuses on making the climate service accessible and understandable to the end users. This involves packaging the information and insights into user-friendly formats such as reports, visualisations, or interactive tools. Delivery may also involve incorporating additional features to help with interpretability, for example providing uncertainty estimates to give users insight into the data reliability. Efforts are made to communicate the properties of the data, associated uncertainties, and guidance on its appropriate usage. Ongoing conversation with external organisations throughout this final phase helps to refine and finalise the climate service.

3.1.5 Climate service provider: Challenges

Research with internal MetO employees on the high-level process of delivering climate services (data provision, briefing documents and training) revealed several challenges in current practice:

Planning phase:
1. Customization of Services: The challenge lies in meeting broad and changing user requirements, which require customization to ensure each climate service is useful.
2. Limited User Research: Input from end users of the information/data is sometimes lacking. Communication and research are primarily limited to individuals within the external organisation involved in climate service development.
3. Integration of Knowledge and Expertise: Aligning the expertise of different teams involved in climate service delivery poses a challenge. There is sometimes a gap between teams helping clients articulate their needs in the 'planning phase' and those providing technical advice during the 'creation of content and delivery phases

Creation of content phase:
4. Difficulty in Achieving Certainty: Climate scientists struggle to achieve a level of certainty that they are comfortable with, emphasising the inherent uncertainty in climate data.

5. Working with Time Constraints and Imperfect Data: Some team members may prefer receiving imperfect climate data from climate scientists along with explanations of uncertainty characteristics to avoid delays in the process.
6. Evolving Information and Models: Keeping climate service outputs updated and relevant is challenging due to the constant evolution of information, data, and models supporting them.
7. Numerical Representation of Uncertainty: Users express a preference for incorporating uncertainty estimates numerically into climate services, as indicated by surveys and interviews across Europe.[10]

Delivery phase:
8. Effort in Communicating Data Properties: Explaining data properties, associated uncertainty, and appropriate usage to external organisations requires significant effort.
9. Standard Supporting Processes: There is a need for standardised processes and practices to support the development and documentation of climate services, particularly in ongoing conversations with external organisations.

3.2. Define: Identified design opportunities

Thematic analysis of key findings from the user research, wider literature review and other activities during the Discover phase (see Figure 7) generated four concrete design opportunities for the HACID-DSS system:
1) Understanding user needs for climate services
2) Addressing the non-static/uncertain nature of climate information
3) Matching granularity of climate data to granularity of users' decisions
4) Helping users navigate and discover climate information

We briefly describe each of these below drawing out the underlying findings from the Discover phase.

Four design opportunities for the HACID-DSS system
  a. *Understanding user needs for climate services*
  The user requirements for climate services are broad ranging and can change throughout the process of developing the climate service. This means that the development of the climate service needs to be iterative, responsive and highly customised each time. Climate services providers spend a lot of time and effort understanding and adapting to user needs.
  b. *Addressing the non-static/uncertain nature of climate information*
  Climate projections are uncertain by nature: models evolve quickly, and errors can be discovered at any point. There is currently no standard on how to answer climate questions or what future scenarios (i.e., emission scenarios) to consider in each case. This is challenging for climate scientists, and they can spend a long time analysing different approaches that seem appropriate for the case and minimise uncertainty. However, the tolerance for risk of users varies (e.g., climate awareness

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[10] Soares B., Suraje S., (2017). Sectoral use of climate information in Europe: A synoptic overview. Climate Services.

campaign versus national transport system). It is important for climate scientists to understand the level of uncertainty that is reasonable for the specific user and their specific climate decisions. Similarly, it is important for the user to understand the uncertainty properties of the data and how they can use it in their climate decisions.
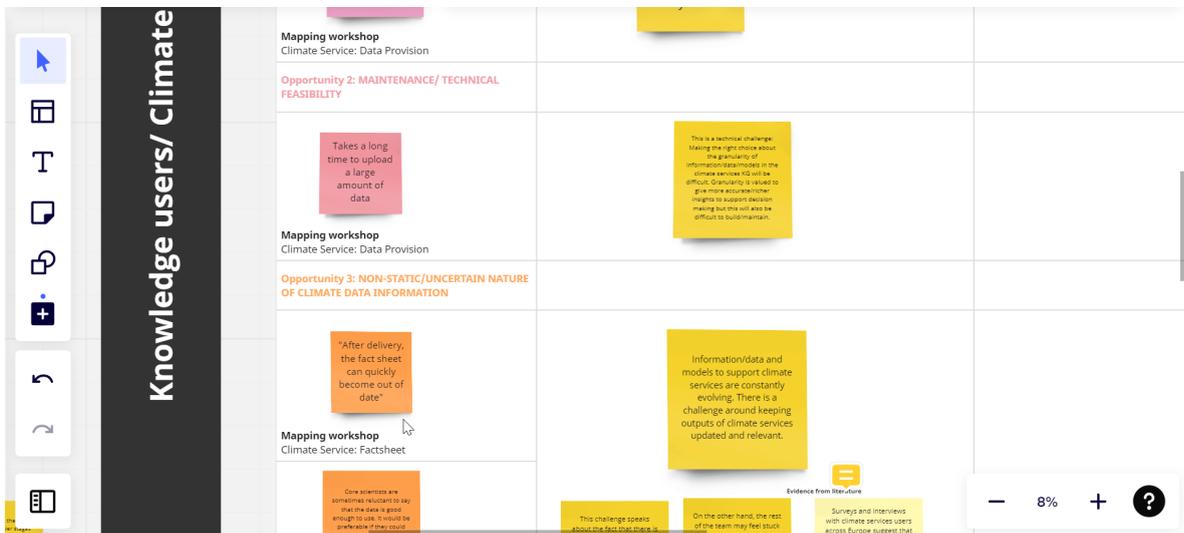

Figure 7 - Miro board showing part of the thematic analysis to identify key themes across all findings from the Discover phase.

c. *Matching granularity of climate data to granularity of users' decisions*

Users often need more granular data (i.e. south of London v.s north of London) to make informed decisions for their areas of interest. However, climate projections are limited in terms of granularity by data availability, computational power and the inherent uncertainty associated with predicting the future. Climate projections often need to be combined with other datasets to achieve the level of granularity (both temporal and geographical) that users are looking for to inform the types of strategic decisions being taken by their organisation.

d. *Helping users navigate and discover climate information*

There currently aren't easy ways for users to see all available climate datasets or models to be able to interpret and use them in-house. Despite the abundance of existing climate resources, it can be difficult for non-experts to navigate this information overload or select the ones most relevant for their needs. For example, a railway infrastructure manager may be trying to understand how flooding will impact railroads in a certain area. Instead of making a request to the MetO to answer this question, they would like to be able to search and understand whether there are existing datasets or models to answer this question. They would also like to have the datasets be accompanied by information on how to interpret the data and use it. Users complain that they currently end up paying climate service providers for information that is already available but not easily discoverable.
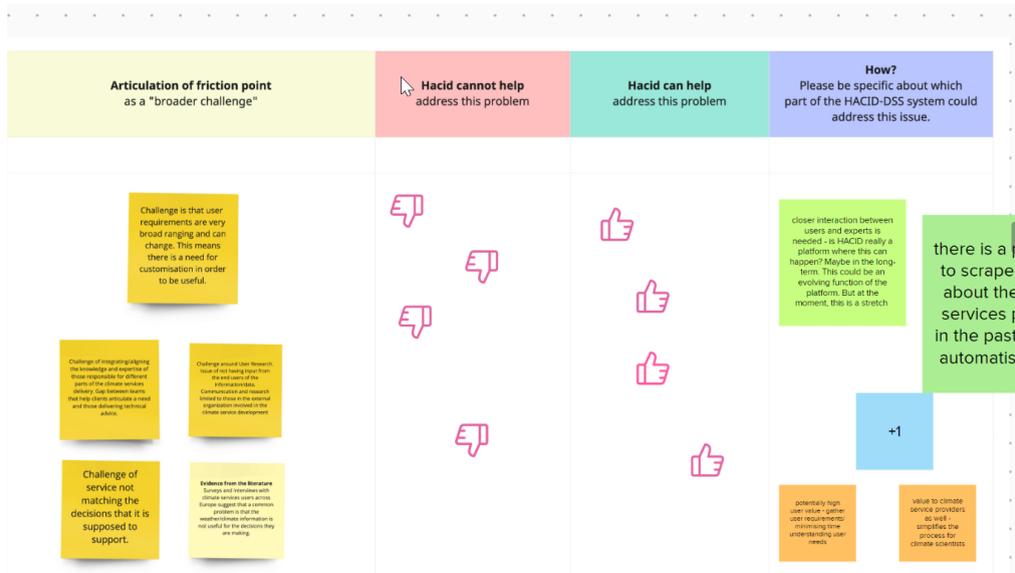
Figure 8 - Collaborative workspace used during the workshop to prioritise and refine design opportunities. (see methodology section: define, for full description of methodology)

3.2.1 Prioritised design opportunity

The consortium selected design opportunity *'b. Addressing the non-static/uncertain nature of climate information',* as described above, based on feasibility, user value and innovation. Please refer to the methodology section for more detail on the selection process.

The prioritised design opportunity was further refined as:

> *'Supporting climate scientists - decisions on appropriate information sources, methodologies and future scenarios by crowdsourcing solutions from other experts.'*

This opportunity addresses an important decision during the climate services development process: deciding on an adequate level of uncertainty and appropriate datasets/methodologies. It is a good fit for the HACID-DSS technology because it has the potential to:

- a) Enable climate scientists to provide better evidenced, more accurate and trusted solutions to users in an efficient way by crowdsourcing input from other climate experts.
- b) Create consensus and contribute to the creation of standardised processes in the domain of climate science.
- c) Increase the visibility of climate science practices and enable peer learning.
- d) Increase intelligibility and explainability of the process of selecting datasets and methodologies as the knowledge graph can make visible the provenance of climate information.

3.3. Develop: Final Design for HACID-DSS prototype in climate services

During the development phase, NESTA led ideation sessions to receive input from the partners and co-create the final design described in this section and the design outputs listed in the following section. For more information on this process, please refer to the [Methodology Section: Develop.](#) This section describes the concept design for the HACID-DSS prototype and provides the necessary context required to interpret the design outputs in the next section. It details:

- Users: the envisioned users of the system, describing who would interact with the system and what would be their role;
- Scenario: the scenario of use, describing an imagined scenario of how the HACID-DSS would be used, in what context and for what purpose;
- Future vision: a long-term vision that describes what the HACID-DSS prototype could enable in future.

3.3.1 Users

There are different users of the HACID-DSS platform in this concept:

Primary users:
- **Climate Service Providers:** Teams in organisations that provide climate services (i.e., MetO; climate agencies; consultancies)
  - Role: In the HACID-DSS, climate providers would create 'cases' - they would interface with the external organisations to understand and document their profile, the user needs and details about the specific climate service request. These cases are then uploaded to the system.
- **Lead Climate Scientist (climate service provider):** Climate scientist working on providing a climate service and answering the external organisation's climate questions
  - Role: In the HACID-DSS prototype, climate scientists receive new cases and add 'climate questions' for contributions. Climate questions are specific questions that would benefit from input given a certain case. For example, if a transport organisation asks for support drafting an adaptation plan, the climate scientists might break this down into smaller data analysis of flooding and heat-shock events rather than tackling 'climate change' as a whole. A climate scientist can use the HACID-DSS prototype to add a specific climate question for contributions around 'the best information sources for flooding events in the area of greater London 2030-2045' for example.
  - **Experts pool:** International community of experts in climate science. Experts can come from academia, consultancies agencies, MetO etc.
    - Role: The experts' pool will provide contributions to climate questions.

Any primary users of HACID-DSS with climate science knowledge are able to both post cases and contribute to other cases.

Indirect users - don't interact with the system directly but may be exposed to visualisations or outputs:
- **External organisations:** Organisations that need the information to make decisions about climate adaptation (i.e., council; transports company)
  - Role: External organisations may be given access to the HACID-DSS prototype via the climate service provider. The climate service provider may use the tool and the interactive dashboard to show the external organisation initial results or to expose the collaborative solution and explain the process of selecting information sources and methodologies for their specific request.

3.3.2 Scenario

The following illustrative scenario describes how the HACID-DSS prototype would work in practice. It is intended to inform the next stages of design and development but is subject to change as the project progresses and we iterate on the prototype.

The scenario imagines the MetO as the climate service provider and a local council in the UK as the external organisation (please refer to section 'a.Users' above). The scenario should be read alongside the service blueprint, which provides a visualisation of the steps it describes and the user interactions. The scenario contains the ID numbers (e.g., 1.1) that correspond to the wireframes of the user interactions' prototype.

Scenario: The Met Office was approached by a local council to support them in creating a climate adaptation plan.

The Met Office's 'planning team' worked closely with the local council to understand their needs and the types of climate questions that they needed to answer. After they had a clear understanding, the MetO planning team created a case in the HACID-DSS system with all the information gathered about the organisation and their needs (refer to prototype ID numbers 1.1. and 1.1.1).

The climate scientists received this case, explored it and decided what were the climate questions that would benefit from crowdsourcing solutions (refer to prototype ID numbers 1.2 and 1.2.1). Then the climate scientist added the climate questions to the case and published it for contributions (refer to prototype ID number 1.3).

The pool of experts received a notification about the new case. An expert decided to open the HACID-DSS platform and learn more about the case (refer to prototype ID number 2.1 and 2.1.1). They decided to contribute. Their contribution included a dataset, a couple of variables and what they considered were appropriate future scenarios (refer to prototype ID number 2.2). They also provided a methodology for how they would use this dataset and an overall rationale for their approach (refer to prototype ID number 2.3).

The climate scientist received a notification that the case was closed and a 'collective solution' was created. She opened the HACID-DSS platform and explored the 'collective solution'. She uses the summary to see what future scenarios and information sources are most recommended (refer to prototype ID number 3.1).

She then explores further using the dashboard to look at contributions with a specific dataset that the climate scientists never used (refer to prototype ID number 3.2). This is a

new approach and she is interested in learning more. Finally, she decided to use this new dataset combined with the most recommended information sourced. She feels confident about this approach and shares the interim results with the local council for feedback. The council was impressed to see that their request had input from over 30 experts and was pleased with the approach. The climate scientist is prompted to rate the 'collective solution' (refer to [prototype](#) ID number 4). She is very happy with the results and rates it highly, especially in terms of diversity and innovative approaches. Finally, the climate scientist produces the final output and uses the HACID-DSS automated summary to include it in the official documentation. The local council uses this to produce their climate adaptation plan.

3.3.3 Future vision

The focus of the current HACID-DSS prototype design is to provide support to climate scientists who need to make decisions about climate adaptation questions.

However, in the future, as the climate science community continues to contribute and solve numerous cases within the system, External Organisations may have the opportunity to directly ask questions and receive valuable suggestions. These suggestions can cover a range of topics, including:

Future Scenarios: The system could provide insights on which future climate scenarios are most appropriate for addressing their specific climate-related questions. This guidance will address some of the concerns identified in the user research around the lack of guidance, consistency and funding to support the selection of future scenarios (please refer to the user research results for more details)

Relevant information sources: The system could offer recommendations on information sources that contain climate information related to their specific inquiries. This will help them navigate, access and utilise the most appropriate and reliable climate data for their needs, which was a challenge mentioned by all participants during the user research.

Similar Past Cases/Organisations: The system could allow External Organisations to explore and analyse similar past cases or cases created by similar organisations. By drawing upon the knowledge and experiences of previous instances, they could gain valuable insights and lessons learned that are relevant to their own climate-related challenges.

Co-creation of risk management plans: External organisation could take parte to the collaborative solution process providing/seeking experts to complement the climate scientists with domain-specific information (e.g., urban planning experts to provide knowledge on how to best address different hazard levels).

By leveraging the collective knowledge and expertise within the HACID-DSS, in future, External Organisations could improve their access and understanding of climate data, and be empowered to make informed adaptation decisions.

4. Design outputs

In this section, we present the three design outputs containing the prototype requirements for developing the HACID-DSS prototype:
    a) a service blueprint that details the user interactions with the HACID-DSS system,

b) a prototype that details the functionality and user experience of the future HACID-DSS, and

c) a preliminary roadmap with the indicative developmental milestones and evaluation checkpoints for the prototype.

4.1. Service Blueprint for HACID-DSS

Service Blueprint	How to use it	Document
A service blueprint is a diagram that displays the entire process of service delivery, by listing all the activities that happen at each stage, performed by different actors. The HACID-DSS service blueprint provides an overview of the components and steps necessary to deliver the HACID-DSS prototype.	The service blueprint should be used as an overview of the HACID-DSS prototype and a map of the different interactions within the system. The service blueprint also contains numbered steps that correspond to product requirements in the prototype and roadmap (see design outputs below). The service blueprint can also be read alongside the scenario in the previous section for added detail and context.	Link to live document Please find a pdf version attached to this report.

4.2. Key User Interactions (prototype)

User Interactions (prototype)	How to use it	Document
The prototype provides a visual representation of the web platform's layout, structure, and functionality. We created a Figma prototype of the HACID-DSS platform with wireframes that visualise the main user interactions and user flows.	The prototype should be used to clarify user interface elements; identify technical requirements; support user experience tests/validation and provide a starting point for iterative development. The prototype can also be read alongside the scenario in the previous section for added detail and context	Link to prototype Please find a images of the prototype attached to this report.

4.3. Preliminary Roadmap

Preliminary Roadmap	How to use it	Document
The roadmap includes indicative	The roadmap should be	Link to live document

steps and milestones for delivering the HACID-DSS prototype. Beyond technical development, the roadmap has an overview of other expected phases of development such as user testing. Roadmap/timeline: This is a tentative timeline linked to the interactions with the different phases, tasks and milestones to build the HACID-DSS prototype for climate services, and is useful to guide integration activities and testing to be performed within WP7..	used for project management. It is a living document and all milestones, timelines and activities are subject to change. It is intended as a tool for the consortium alignment during the next phase of development.	Please find a pdf version attached to this report.

5. Appendix

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Interview Guide

This interview guide is an overview of interview questions for external organisations.

The objectives of the interview are:
- Understand the process of collaborating with the MetO (from request to delivery)
- Explore important decision points
- Identify their needs and the needs of the organisations that they support
- Understand the motivators and drivers for the ongoing collaboration

The interview lasts approximately 1 hour, and there are four sections to the interview:

- Background and role
- Current Experience
- Needs and aspirations
- Value of collaborating with MetO

Introduction, background and role
- Firstly, can you tell me about your role in the organisation?
- What are your main tasks and/or responsibilities?

Current Experience
- Could you please walk me through the process of making a request to the MetO (and/or starting a new project/collaboration?) If you have a concrete example that would be useful.

- What happens after? How do you collaborate?
- What is your role vs. the MetO role in the project?

- What are some of the decision points (e.g., how do you decide what emissions scenario or data to include for projections?)

- What would help you with decision making?

- What were some of the important roles and stakeholders involved in the process?

- How do you support other organisations adapting to climate change?
- Could you give us examples of the types of adaptation that you help organisations with?

Interview participants

- Senior Policy and Projects Officer - Climate Change, at Climate Adaptation partnership
- Deputy Director at Climate Adaptation partnership
- Climate Resilience Manager at a Climate Adaptation Partnership
- Programme Manager at a Climate Adaptation Partnership
- Strategy & Planning Manager (Environment) at a transport organisation
- Climate Scientists and experts in climate change from the MetO (x4)

Survey questions

Please find the explanation of the methodology here.

    a. Survey brief for respondents:

During the workshop, we will be mapping the high-level processes for delivering 3 different climate services:

Training, Briefing document and Data provision. We are interested in learning about the different steps involved in delivering climate services from the point of view of the MetO. To help you prepare we would like you to spend 15-20 mins preparing using the prompts below. Please base your answers on one specific example of a climate service. You can refer to your answers during the workshop activities.

This exercise is meant to be useful for you as a starting point and to spark ideas! There are no wrong answers. Please feel free to share opinions and personal perspectives.

b. Survey Questions:

Q1: Please choose which climate service you would like to provide an example for:

- Training
- Briefing document (e.g. policy notes, factsheets, case studies, guidance)
- Data provision

Q2: What was the climate hazard in this **specific example**?

Q3: Who requested/ who was the recipient of this climate service? (external organisation)

Q4: What was the request/ need that the climate service addressed?

Q5: Please capture the main steps of the **end-to-end process** of delivering this climate service (specific example) from the point of view of the MetO. Capture the internal as well as external interactions.

Q6:What are the main challenges / friction points during the process?

Discovery workshop instructions

Please find the explanation of the methodology here and the findings/results from the workshop here.

Activity:
In teams, participants build on the homework activity to map the high-level process of delivering their chosen climate service & discuss friction points.

Objectives:
Understand the current climate services processes and identify friction points.

Steps:
end-to-end process of delivering this climate service. Focusing on actions, tasks and people involved.

Friction points:
main challenges or problems faced by the MetO or external organisations during the

delivery of this climate service.

Step 1:
Individually, look back at the homework and place down some post-its referring to the main steps in your example and the friction points that you identified in your homework.

Step 2:
As a team, refer to the individual examples to describe the overarching steps within the process of delivering this climate service. Make a note where there are divergences.

A step should include:

- **Who** is involved?
- **What** is the action in this step?
- **How** does this happen? Is there technology involved?

Step 3:
Discuss as a team and agree on the main friction points throughout the process of delivering this climate service.

Think about:
- What are the main challenges faced by the MetO or external organisations during this process?
- What are some of the challenging decisions involved in this process?
- Where would you benefit from more input?
- Where would external organisations benefit from more input/ data access?

Workshop participants

1. Manager of Urban Climate Services team within UK Applied Science
2. Principal fellow across applied and climate science and head of climate services
3. Manager Industry Science & Consultancy team
4. Manager of the Science for Impacts, Resilience and Adaptations (SIRA) team
5. Fellow of Weather & Climate Extremes
6. Product manager and owner of Climate Services Pathfinder.
7. Manager Knowledge Integration Team
8. Senior scientist working on climate change with UK health data.
9. Manager of the Climate Security team - International Applied Science and Services area
10. Member of Defence Applications team within UK Applied Science
11. Manager of the UK Climate Resilience team
12. Strategic head of the UK Applied Science area

Current state journeys

The current state service blueprint captures the current process of delivering a climate service. The current service blueprint is used as a strategic design document to understand the organisation's current processes and to articulate potential points of improvement and design opportunities for the HACID DSS.

Internal processes documented as part of the current service blueprint mapping exercise:

1. High-level process of delivering the climate service - Data provision:

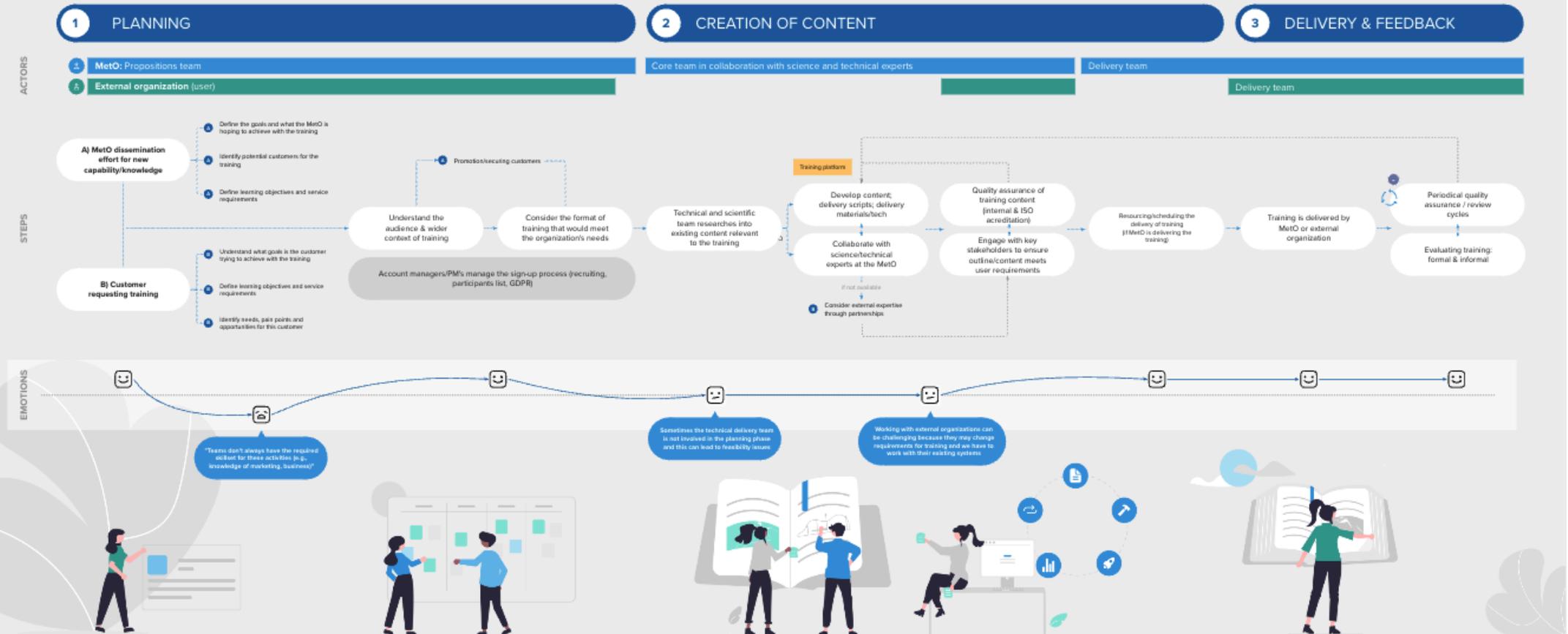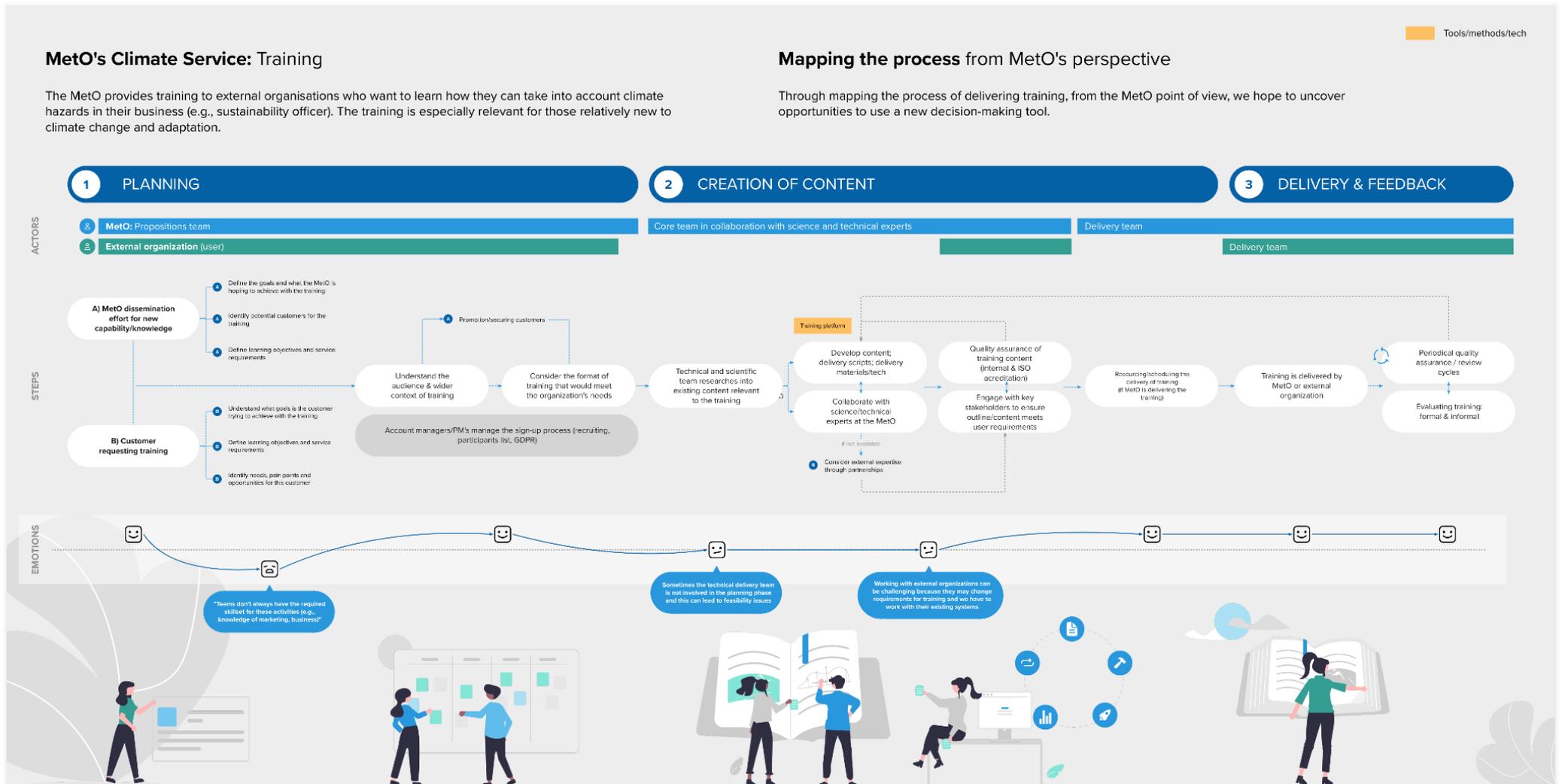## 2. High-level process of delivering the climate service - Training:

MetO's Climate Service: Training

The MetO provides training to external organisations who want to learn how they can take into account climate hazards in their business (e.g., sustainability officer). The training is especially relevant for those relatively new to climate change and adaptation.

Mapping the process from MetO's perspective

Through mapping the process of delivering training, from the MetO point of view, we hope to uncover opportunities to use a new decision-making tool.

Tools/methods/tech

1 PLANNING

2 CREATION OF CONTENT

3 DELIVERY & FEEDBACK

ACTORS

MetO: Propositions team

Core team in collaboration with science and technical experts

Delivery team

External organization (user)

Delivery team

STEPS

A) MetO dissemination effort for new capability/knowledge

- Define the goals and what the MetO is hoping to achieve with the training
- Identify potential customers for the training
- Define learning objectives and service requirements

Promotion/securing customers

B) Customer requesting training

- Understand what goals is the customer trying to achieve with the training
- Define learning objectives and service requirements
- Identify needs, pain points and opportunities for this customer

Understand the audience & wider context of training

Consider the format of training that would meet the organization's needs

Account managers/PM's manage the sign-up process (recruiting, participants list, GDPR)

Technical and scientific team researches into existing content relevant to the training

Training platform

Develop content; delivery scripts; delivery materials/tech

Collaborate with science/technical experts at the MetO

if not available

Consider external expertise through partnerships

Quality assurance of training content (internal & ISO accreditation)

Engage with key stakeholders to ensure outline/content meets user requirements

Resourcing/scheduling the delivery of training (if MetO is delivering the training)

Training is delivered by MetO or external organization

Periodical quality assurance / review cycles

Evaluating training: formal & informal

EMOTIONS

"Teams don't always have the required skillset for these activities (e.g., knowledge of marketing, business)"

Sometimes the technical delivery team is not involved in the planning phase and this can lead to feasibility issues

Working with external organizations can be challenging because they may change requirements for training and we have to work with their existing systems

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3. High-level process of delivering the climate service - Briefing documents:

MetO's Climate Service: Briefing documents

The MetO provides briefing documents, such as policy notes, factsheets, case studies and guidance, to external organisations. These documents can have different purposes such as stimulating conversations about climate change, informing the design of assets (e.g., ships, trains) or managing public health services. The documents are tailored to the user needs and aim at communicating climate data in a simple and succinct form.

Mapping the process from MetO's perspective

Through mapping the process of delivering a briefing document from the MetO point of view, we hope to uncover opportunities to use a decision-making tool.