ICARIA
Improving climate resilience of critical assets

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# D4.1 Trial design



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## D4.1 Trial design

Detailed description of the trial and mini-trial design for each of the three case studies and summary explaining the overall expectations, similarities and differences between them.


**Summary**

Deliverable 4.1. presents the trial design for the trials performed in each ICARIA case study region. The ICARIA approach for validating the innovative potential of the ICARIA solutions, is based on the Trial Guidance Methodology, developed in the DRIVER+ project and has been adapted to project's purposes. The outcomes for each step of the trial planning will be discussed in detail along with the outline of dissemination of the trial results through mini-trials and demos in the upcoming tasks.


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# List of Acronyms and Abbreviations

| Acronyms Table | |
|---|---|
| AMB | Barcelona Metropolitan Area |
| CoP | Community of Practice |
| CS | Case Study |
| DSS | Decision Support System |
| KPI | Key Performance Indicator |
| RAF | Resilience Assessment Framework |
| RAT | Resilience Assessment Tool |
| TGM | Trial Guidance Methodology |
| WP | Work Package |
| SAR | South Aegean Region |
| SLZ | Salzburg Region |

# Executive summary

This document presents the ICARIA approach for testing and validating the project results through trials to be conducted in the three ICARIA case study regions (Barcelona Metropolitan Area, South Aegean Region and Salzburg Region). The Trials themselves are designed according to the Trial Guidance Methodology, which ensures the assessment of the innovative potential of the ICARIA solutions:

- Risk assessment framework
- Hazard and risk assessment models
- Resilience assessment framework
- Resilience assessment tool
- Portfolio of adaptation solutions
- Decision support system

Combined in the decision support system, the applications provide a comprehensive tool for decision makers, allowing not only to assess the risk of climate change induced hazards and their impact on certain critical assets, but how to increase the region's resilience through adequate climate adaptation measures and even cost-effective adaptation strategies.

To ensure the stakeholder's needs are met and identified gaps bridged, the tools will be validated in computer-based field trials. Since trials are usually performed in the context of crisis and disaster management (e.g. earthquake, floods etc.), certain adaptations of the underlying methodology have been made to accommodate ICARIAs purposes. Regardless, the resulting trial designs present a first idea of each trial. Though the trial context (location, gaps etc.) are already set, some aspects of the design may change throughout the following tasks, since the trial will take place in a later phase of the project and some tools have yet to be fully developed or validated.

However, the six steps to designing a trial have been undertaken, to form a baseline for the upcoming trial planning phase, including:

1. **Objectives** of each trial have been defined, consisting of overarching objectives relevant for all trials as well as case study region specific ones.
2. **Research questions** for different aspects:
    - Science and technology
    - User experience
    - User acceptance and sustainability
    - Socio-economic impacts and ethics
3. The feedback will be gathered by pre-defined **data collection plans** which will enhance the information and benefit that can be extracted from the collected data.
4. **Evaluation approaches and metrics** for the gathered data have been discussed and will determine the interpretation and evaluation of the data collected in the trials.
5. A first formulation of the **trial scenario** has been designed.

6. The first step to **select** the aspects of the **solutions** that have to be trialled has been done.

Finally, deliverable D4.1. will outline the upcoming second part of the Trial Guidance Methodology – the trial execution phase and trial evaluation. Moreover, it will discuss how the solutions and results can be disseminated and the project impact maximised along the way through mini-trials and demos.

# 1 Introduction

## 1.1 Project ICARIA

The number of climate-related disasters has been progressively increasing in the last two decades and this trend could be drastically exacerbated in the medium- and long-term horizons according to climate change projections. It is estimated that, between 2000 and 2019, 7,348 natural hazard-related disasters have occurred worldwide, causing 2.97 trillion USD losses, and affecting 4 billion people. These numbers represent a sharp increase of recorded disaster events by comparison with the previous twenty years. Much of this increase is due to a significant rise in the number of climate-related disasters (heatwaves, droughts, flooding, etc.), including compound events, whose frequency is dramatically increasing because of the effects of climate change and the related global warming. For the future, by mid-century, the world stands to lose around 10% of total economic value from climate change if temperature increase stays on the current trajectory, and both the Paris Agreement and 2050 net-zero emissions targets are not met.

In this framework, Project ICARIA has the overall objective to promote the definition and the use of a comprehensive asset level modelling framework to achieve a better understanding about climate related impacts produced by complex, compound and cascading disasters and the possible risk reduction provided by suitable, sustainable and cost-effective adaptation solutions.

This project will be especially devoted to critical assets and infrastructures that are susceptible to climate change, in a sense that its local effects can result in significant increases in cost of potential losses for unplanned failures, as well as maintenance – unless an effort is undertaken in making these assets more resilient. ICARIA aims to understand how future climate might affect life-cycle costs of these assets in the coming decades and to ensure that, where possible, investments in terms of adaptation measures are made up front to face these changes.

To achieve this aim, ICARIA has identified 7 Strategic Sub Objectives (SSO) in its Grand Agreement, each one related to one or several work packages. They have been classified according to different categories: scientific, corresponding to research activities for advances beyond the state of the art (SSO1, SSO2, SSO3, SSO4, SSO5); technological, suggesting and/or developing novel solutions, integrating state-of-the art and digital advances (SSO6); societal, contributing to improved dialogue, awareness, cooperation and community engagement as highlighted by the European Climate Pact (SSO7); and related to dissemination and exploitation, aimed at sharing ICARIA results to a broader audience and number of regions and communities to maximise project impact (SSO7).

- SSO1.- Achievement of a comprehensive methodology to assess climate related risk produced by complex, cascading and compound disasters
- SSO2.- Obtaining tailored scenarios for the case studies regions
- SSO3.- Quantify uncertainty and manage data gaps through model input requirements and innovative methods

- SSO4.- Increase the knowledge on climate related disasters (including interactions between compound events and cascading effects) by developing and implementing advanced modelling for multi-hazard assessment
- SSO5.- Better assessment of holistic resilience and climate-related impacts for current and future scenarios
- SSO6.- Better decision taking for cost-efficient adaptation solutions by developing a DSS to compare adaptation solutions
- SSO7.- Ensure the use and impact of the ICARIA outputs

The ICARIA project focuses on three case study regions (Figure 1) with profound geographical, environmental, and socio-economical differences which will necessarily be taken into account for the holistic modelling framework development in a multi-hazard risk/impact assessment perspective.

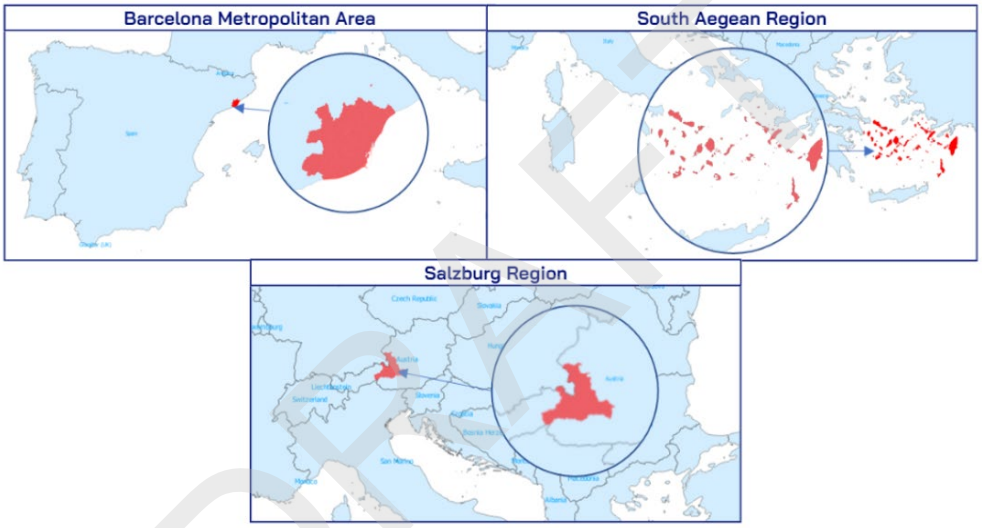


**Figure 1: ICARIA trial regions at a glance.**

The Barcelona Metropolitan Area (AMB) and the Archipelago of South Aegean Region are located in the coastal area of the Mediterranean Sea and are facing increasingly climate extremes (e.g., storm surges, pluvial floods, heatwaves, drought and forest fire) with huge impacts in socio-economic and environmental terms. The third one, the Salzburg Region, is located in Austria and is particularly sensitive to the effects of climate change (e.g. glacier melt and heatwaves) that directly impact the prevailing energy production assets (extremely critical infrastructures) and other important sectors. Seven additional follower regions will be considered for replication beyond the project.

Across different climate-related hazard categories and their multiple interrelations (e.g. complex, compound and cascading disasters), case studies will be used to test the risk/impact modelling methodology and technical solutions primarily through Trials. Secondarily, the development and execution of Trials will be used to implement Mini-trials and will be planned for "demonstrators".

## 1.2 Objectives of the deliverable

Work package 4 encompasses the trials in which the ICARIA solutions will be tested and further improved even beyond the project. More specific, WP4 entails the following main objectives:

- Design and detailed **structure for the trials** performed in each case study region. (*T4.1. Trial design*)
- **Adapting methods and tools** resulted from WP1-WP3 for three case study- specific hazard and resilience assessments and model validations based on historical data. *(T4.2. Trial implementation and assessment)*
- Model **future climate future change scenarios** in the three case studies and define adaptation measures that could reduce the impact of future extreme events. *(T4.2. Trial implementation and assessment)*
- Validation and assessment of the **solution's transferability** by performing mini-trials and demos. (*T4.3. Replications and demos*)
- Design the ICARIA **sustainability and exploitation** plan. (*T4.4. Sustainability and exploitation*)

Task 4.1. focuses on the very first objective, designing the overall structure of the trial performed in each case study region. Starting with the selection of the solutions tested based on results of the CoP meetings, over identifying how and what must be assessed to gain specific and stakeholder-oriented answers, to eventually designing mini-trials for assessing the transferability of the ICARIA tools beyond the ICARIA case study regions and, subsequently, beyond the ICARIA project itself.

The overall design of the trials aims to assess whether case study region-specific knowledge gaps have been successfully bridged. For this, results of WP1-WP3 will be analysed and suitable KPIs defined, while keeping close contact to the stakeholders, ensuring their expectations are met.

## 1.3 Document Structure

This document first introduces project ICARIA itself followed up by the WP4 – trial design's purposes and the deliverables main objectives (section 1), before diving into the main part – the ICARIA trial designs.

To ensure an overall understanding of the general importance of trials (section 2) and how they are designed to especially fit the needs of the ICARIA case study regions, trials and the applied methodology that sets the approach followed throughout the document will be explained

thoroughly. Subsequently, the trial regions (subsection 3.1) and the solutions to be tested (section 4) will be described, before starting in on the various trial aspects (section 5). Finally, upcoming dissemination and evaluation approaches through mini-trials and demos (section 6) will be outlined.

# 2. Trial Guidance Methodology and CoPs

The ICARIA testing and validation process is an extension of the Trial Guidance Methodology (Fonio et al., 2023), which has been initially developed and successfully tested by the DRIVER+ project[1] - DRiving InnoVation in crisis management for European Resilience, 2014-2020 (FR7 programme, Grant agreement ID: 607798, 2014-2020;).

**Trial Guidance Methodology (TGM)** is a structured methodology for assessing the innovation potential of socio-technological solutions for specific **stakeholders** or stakeholder organisations (Fonio et al., 2023). TGM provides a structured approach for assessing the innovative potential of novel solutions to address specific societal or organisational needs (gaps). The TGM handbook (Fonio *et al.*, 2020) provides step-by-step **guidelines for designing the trials, a list of roles and responsibilities, tools, and methods to perform a trial through a clear, pragmatic and systematic approach, evaluate the outcomes and identify lessons learned**. TGM rules and methods are strict enough to ensure appropriate replicability of the results while being flexible enough to ensure wide applicability of the methodology.

Thanks to its generic nature, TGM has already been successfully applied in multiple H2020 and HE projects (Fonio *et al.,* 2023) and entered a standardisation process through the publication of the CEN Workshop Agreement CWA 17514 (CEN-CENELEC Management Centre, 2020[2]). Despite being designed for use in a crisis management context, its successful application in the RESILOC[3] - Resilient Europe and Societies by Innovating Local Communities (H2020, Grant agreement ID: 833671, 2019-2022) project indicates that TGM is applicable in a wider context of societal resilience, with minor adaptations. Most importantly from the ICARIA perspective, TGM helps to objectively assess the project results, by insisting on an up-front definition of the gaps, objectives and research questions the trial will address as well as on the up-front definition of data that will be collected during the trial and the ways this data will be interpreted in trial assessment.

Moreover, TGM foresees **active involvement of key stakeholders in trial preparation, execution and assessment of the trial results**. In ICARIA, this link between the core trial team and relevant stakeholders is established through **Communities of Practice (CoPs)** and, more specifically, through CoP events that are defined in Section 4 of the project deliverable D5.4 "Stakeholder Engagement Plan" (Turchi et al., 2023a). In the context of TGM, following definitions apply.

TGM describes the three main phases of the trial i.e., (**planning, execution,** and **evaluation**), and provides detailed description of the activities, methods, support tools and practical examples for designing, executing and evaluating the trials. Each of the phases is further split into separate steps, as shown in Table 1.

[1] https://www.driver-project.eu/driver-project/

[2] https://www.cencenelec.eu/news-and-events/news/2021/publications/2021-06-21-cen-clc-annual-reports-2020/

[3] https://cordis.europa.eu/project/id/833671

**Table 1: DRIVER+ Trial guidance methodology – all steps**

| DRIVER+ Trial Guidance Methodology | | |
|---|---|---|
| **Step Zero** | Gaps | Identification of current problems and needs the stakeholders are facing. |
| | Trial context | Comprehensive description of the gap-specific aspects and factors. |
| **Preparation** | Trial Objective | Defining the specific goals and desired achievements. (SMART) |
| | Research Question | Formulating a research question on what is wanted to find out in the context of these trials specifically. |
| | Data Collection Plan | Detailed plan on what data must be gathered in order to answer the research question, including the methods required on how the data will be acquired. |
| | Evaluation approaches & metrics | Analysis and evaluation of the gathered data, previously defined in the data collection plan. |
| | Scenario formulation | Developing a simulated real-life situation in which the addressed gap occurs, depending on the gap and trial-specific underlying conditions. |
| | Solution selection | Selecting a reasonable and manageable number of solutions and aspects that has to be tested. |
| **Execution** | Trial integration meeting | Discussion with the trial participants on how the solutions will be integrated in the tester's operations. |
| | Dry Run 1 | First test run of the trial. |
| | Dry Run 2 | Second test run (full test). |
| | Trial Run | Execution of the planned trial. |
| **Evaluation** | Data Quality Check | Identification of possible deviations of the data |
| | Data analysis | Analysation and evaluation of the gathered data. |
| | Data synthesis | Discussing the data with the CoPs to gain further insights and conclusions. |
| | Disseminate results | Formulating lessons learned and possible adaptations for the mini-trials and demos. |



In the context of ICARIA, this deliverable marks the end of the preparation phase and the start beginning of the trial execution phase. It therefore primarily focuses on the first two steps **Step Zero** and **Preparation**, paving the way for the execution and evaluation in the following tasks (T4.2 Trial implementation and assessment).

On top of TGM, the ICARIA methodology foresees re-use of the trial results and findings in "**mini trials**" and "**demos**" at the project end (Figure 2).

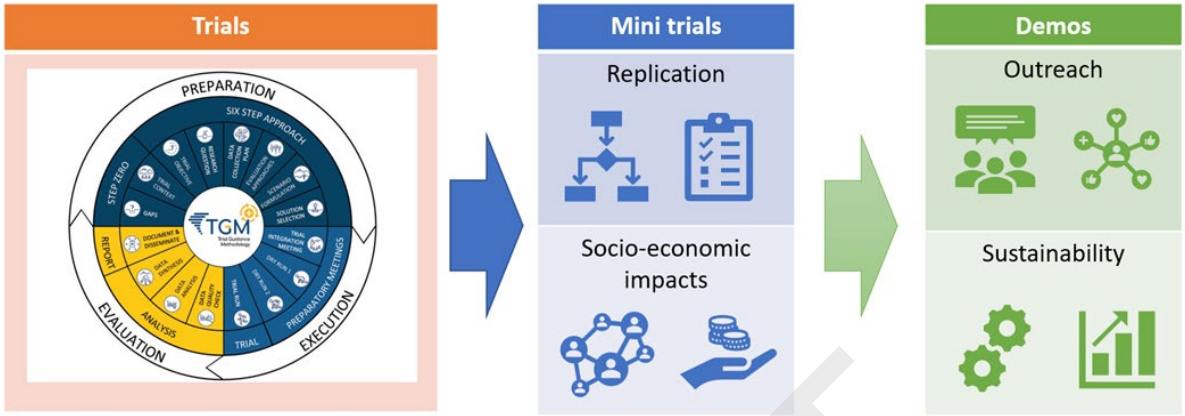


**Figure 2: Overarching ICARIA methodology for assessing the solutions developed in the project.**

In simple terms:

- **Trial** is an assessment of the performance, qualities, or suitability of solutions for current and emerging needs in such a way that relevant stakeholders can execute it following a pragmatic and systematic approach.
- **Solution** is a combination of one or more processes and/or tools with related procedures that can potentially contribute towards resolving the operational gaps of the relevant stakeholders.
- **"Capability gap" (Gap)** is a difference between a current capability and the capability necessary for an adequate performance of different tasks.
- **Mini trials** are specific to ICARIA and do not exist in TGM, but largely follow the same methodology. As the name indicates, mini-trials feature their own objectives, research questions, data collection plans, evaluation approaches and metrics. With the innovative potential of ICARIA solutions already assessed through trials, the mini trials will mainly be used to assess the **transferability and socio-economic impact** potential of the trialled solutions and scenarios to the areas where the availability of the data is not guaranteed as the same level as it is for the trials[4].
- **Demos** are a tool to advertise the project results to the wider public and assess their interest in the exploitation of the project results, mainly in the trial regions. They could be organised as a "second coming of the mini-trials for a wider public", or as a presentation of the key findings of ICARIA trials and mini-trials (e.g., we might decide to show a recording made at previous events and discuss it with demo participants). More

[4] The project will invest considerable resources to assure the availability of the data and calibrate the models for the trials, but mini-trials will have to make do with what is available or can be easily derived from already available data.

detailed planning for demo event(s) will be made later in the project and depend on the lessons learnt in trials and mini-trials.

- **Community of Practice (CoP)** is a group of people who all contribute and participate in a process of collective learning when dealing with a shared concern or passion. (Wenger-Trayner et al., 2015).

Key elements of the TGM and their relation to ICARIA CoPs were already introduced in D5.4 "Stakeholder Engagement Plan" (Turchi et al., 2023a), which details illustrates the composition, organisation, and activities of ICARIA CoPs. To avoid the need for extensive cross-referencing, parts of this deliverable are replicated in relevant sections of this deliverable as necessary.

# 3 Trial planning: gaps and context

According to TGM, the trial preparation starts with the so-called **"step zero"**, where two key pieces of information have to be considered: the overarching trial goals, and the circumstances and boundaries for the trial organisation, such as the composition of the trial team, and the context in which the trials will be executed. Trial goals are defined through **Trial Gaps,** whereas the circumstances and boundaries are defined through **Trial Context**.

Trial context covers various practical aspects of the trial preparation, such as assigning the **roles** of **Trial Owner**, **Technical Coordinator, Evaluation Coordinator** and **Practitioner Coordinator** to individuals or organisations, and agreeing on the main **conditions and parameters** of the trial such as location and timing of the trial, and initial ideas on the trial scenario, participants, tools, and procedures to be evaluated.

These elements, as well as the solutions to be trialled are to a large extent already pre-defined by ICARIA Grant Agreement, but they needed to be critically examined and further refined in the first phase of the project. Results of this refinement are presented hereafter.

## 3.1. Trial Regions

ICARIA project is built around three case studies, each represented by one trial region (Figure 1). Two of these regions, the Barcelona Metropolitan Area and the Archipelago of South Aegean Region are located in the coastal area of the Mediterranean Sea and are facing increasingly extreme weather events (i.e., storm surges, pluvial floods, heatwaves, drought and forest fire) with critical socio-economic and environmental impacts. The third one, the Salzburg Region is in Austria and highly affected by climate change with effects (i.e., glacier melt and heatwaves) that directly impact the prevailing energy production assets (extremely critical infrastructures) and other important sectors.

### 3.1.1. Barcelona metropolitan area (AMB)

The Barcelona Metropolitan Area, comprising 36 municipalities, is the largest conurbation in Catalonia (Spain) with a population of over 3.2 million. As the largest metropolitan agglomeration in the Western Mediterranean, it plays a significant role in developing and implementing climate change solutions. According to the Climate and Energy Plan 2030, throughout the 21$^{st}$ Century, the climate will continue to change, and the **major threats** will include higher temperatures, lower annual average rainfall and more extreme weather events such as storm surges and heavy rains, increasing their impacts (e.g., he at islands, heatwaves, floods) on human beings, housing, infrastructures, services, and environment. Therefore, the Plan outlines a comprehensive strategy until 2030, focusing on adaptation to enhance resilience at local and regional scale. Key hazards, critical assets and expected tangible impacts to be assessed through the Spanish trial are summarised hereafter:

**Table 2: AMB trial - hazards, assets and impacts.**

| Barcelona Metropolitan Area | | | | | | |
|---|---|---|---|---|---|---|
| **Hazards** | Flood compound events | | | Storm surges | | |
| **Critical assets** | Properties | Natural areas | Transport | Water | Waste | Electricity |
| **Tangible impacts** | Flood damage | | | | | |

### 3.1.2. South Aegean Region (SAR)

The South Aegean Region, an archipelago region at the South-eastern edge of Greece, administratively includes the island clusters of the Cyclades and the Dodecanese with a population of approximately 309 thousand inhabitants, or ~3% of the total Greek population. In the last 30 years, climate change had a more pronounced effect in this region compared to continental Greece and Europe at large. The major hazards included sea level rise, higher temperatures (resulting in heatwaves), fires, and more extreme weather events such as heavy rains, resulting in heatwaves, floods and on human beings, housing, infrastructures, services, environment, and local economy. Considering the geographical location of the region, which hinders the adequate supply and of the inhabitant's primary needs, such as availability of drink water, food, electricity and healthcare. This condition is further aggravated during the tourist season, with the increase in the overall population during the summer season. Key hazards, critical assets and expected tangible impacts to be assessed through Greek trial are summarised hereafter:

**Table 3: SAR trial – hazards, assets and impacts.**

| South Aegean Region | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Hazards** | Heat waves | | Forest fires | | Droughts | | |
| **Critical assets** | Properties | Natural areas | Transport | Tourism | Water | Waste | Electricity |
| **Tangible impacts** | Flood damage | | | | | | |



### 3.1.3. Salzburg region (SLZ)

The Salzburg Region, situated in the Eastern Alps, has more than 550 thousand inhabitants. Since 1880, a significant increase (approx. 2°C) in the average air temperature has been recorded in Austria, and the mountainous regions are already suffering from the effects of global warming such as rapid melting of glaciers, thawing of permafrost, increasing number of hot days, or changes in rain patterns towards extreme values, increasing their impacts mainly on human beings, housing, infrastructures, services, environment, and local economy. The Salzburg Region region represents one of the major tourist areas of Austria and plays an important role in energy production as it incorporates various hydro power plants. Therefore, changes in precipitation patterns make more vulnerable both hydro power plants themselves and related connecting roads and infrastructure to direct and indirect effects of climate change. Considering the ongoing increase in electricity consumption (up to 66% in 2050 compared to 2017, according to Austria's National Energy and Climate Plan) and also the importance of renewable energy (already 77% due to hydro power plants) even more enhanced in the Austrian climate and energy strategy "#mission2030", any repercussions on the energy production system could drastically compromise the future energy stability of the entire region. Key hazards, critical assets and expected tangible impacts to be assessed through Austrian trial are summarised hereafter:

**Table 4: SLZ trial - hazards, assets and impacts.**

| Salzburg Region | | | | |
|---|---|---|---|---|
| **Hazards** | Flood compound events | | Droughts | |
| **Critical assets** | Properties | Transport | Tourism | Electricity |
| **Tangible impacts** | Flood damage | | Energy demand | |

## 3.2 Trial Team

Key TGM roles and their naming conventions in TGM and ICARIA context are summarised in Table 5.

**Table 5: TGM definitions of relevant trial roles and their adaptation to ICARIA Trial purposes**

| TGM Role | ICARIA naming convention | Organisations | Objective |
|---|---|---|---|
| **Trial Owner** | Problem Owner | VERBUND (At), SAR (Gr), AMB (Es) | Ensures that the needs of the infrastructure provider & problems owner are adequately represented. |
| **Technical Coordinator** | Technical Coordinator | AIT (At), DMKT (Gr), AQUA (Es) | Ensures that the solutions developed by ICARIA are well understood and adequately positioned in the Trial. Coordinates the technical integration, training and trial execution. In project ICARIA, The Technical Coordinator will also be responsible for scenario definition, hosting and directing of the trial, including the related event management; despite these tasks are often developed by the trial owner. |
| **Evaluation Coordinator** | Evaluation Coordinator | AIT (At), DMKT (Gr), AQUA (Es), PLINIVS (It) | Ensures that the evaluation of the trials is adequately designed in the trial preparation phase and that the necessary data is correctly collected during the trials and interpreted afterwards. |

| TGM Role | ICARIA naming convention | Organisations | Objective |
|---|---|---|---|
| **Practitioner Coordinator** | Case Study Facilitator | AIT (At), DMKT (Gr), SAR (Gr), AQUA (Es) | Manages the relationship between the core trial Team and the CoP members. Ensures adequate participation of the CoP members in trial preparation (co-design) and execution phase of the trials. |
| **CM Practitioners** | Community of Practices | Three regional CoPs | Represent the needs of regional stakeholders beyond those of the three problem owner organisations. CoP members thus need to be involved in trial design as well as in the trial execution phase. Typically, CoP members are provided opportunities to assess solutions and the trial organisation, and their feedback is collected through interviews or questionnaires as a part of the trial execution. |
| **Core Team** | Core Team | VERBUND (At), SAR (Gr), AMB (Es), AIT (At), DMKT (Gr), AQUA (Es), PLINIVS (It) | The core team includes Trial Owner (Problem Owner), Technical Coordinator, Evaluation Coordinator and Practitioner Coordinator (Case Study Facilitator). |
| **Extended team** | Core Team & CoP members | VERBUND (At), SAR (Gr), AMB (Es), AIT (At), DMKT (Gr), AQUA (Es), PLINIVS (It) & CoP members (Section 3.2) | It is important to keep in mind that CoP members are an essential part of the trial team and are involved in all phases of the Trial design and execution, even though their participation is far less intense than that of the core team. This is reflected in the design of the CoP Events in Section 4. |

Considering the requirements on CoP members and the organisational capabilities of the partners, most of the trial-related work will be shared by the problem owners (VERBUND (At), SAR (Gr), AMB (Es)) and a designated regional technical partner:

- VERBUND and AIT in Austria
- SAR and DMKT in Greece
- AMB and AQUA in Spain

Moreover, The event organisation will be delegated to regional technical partners, with Trial Owner/Problem Owner merely overseeing the organisation.

## 3.3 Trial Gaps

The overarching goal of every trial is to identify and evaluate one or more innovative socio-technological solutions that can bridge gaps the stakeholders face in relation to adaptation to extreme weather events occurring in their region. The first step in trial preparation is thus to identify gaps that will be addressed in a trial.

Trial gaps are, in principle, specific to stakeholder organisations, individual roles and responsibilities within the organisation and the climatic and socioeconomic characteristics of the region. In ICARIA, the initial identification of gaps has already been performed at the project preparation phase. Initial gap definitions, which were already stated in the Grant Agreement, were reassessed during D4.1 preparation, in a dialogue between the Trial Owners (problem owners) and the CoP members (stakeholders, practitioners), resulting merely in addition of G4 generic gap of interest to all three trial regions:

**Table 6: ICARIA Trial Gaps and their relevance for each case study region.**

| Gap No. | Gap | SLZ | SAR | AMB |
|---|---|---|---|---|
| G1 | Lack of adequate assets-level models for impacts of climate hazards and adaptation options | + | + | + |
| G2 | Lack of adequate decision support for holistic multi-hazard/multi-assets resilience assessments and planning | + | + | + |
| G3 | Lack of guidance and decision support for optimising the interactions between climate change, climate adaptation and society | + | + | + |
| G4 | Lack of knowledge about multi-hazard events | + | + | + |
| G5 | Planning of resilient renewable electricity production in the alpine region | + | - | - |
| G6 | Planning of sustainable and resilient infrastructure in tourist regions with extreme seasonal population fluctuations | - | + | - |
| G7 | Anticipating the impacts of future compound extreme weather events in major metropolitan areas in SE Europe | - | - | + |



## 3.4 Trial context

In ICARIA, much of the trial context is pre-defined by project objectives, which is to addresses the need for **asset-level impact modelling, planning and decision support. Trial locations** in

Austria, Greece and Spain (section 3.1) were also pre-defined by the project's Grant Agreement, and the **trial teams** easily formed (section 3.2). However, concrete ideas for trial organisation, expectations on the types of information the trials should provide, as well as the timing and duration of the "trial run" events still had to be agreed upon as a part of the work leading to this deliverable.

At the start of T4.1 work, the trial teams confirmed that TGM is indeed a valid approach for validating the outcomes of ICARIA and agreed to organise the trial run events and mini trials as **computer assisted desktop exercises and to validate the project's outputs (mainly) through questionnaires that will be answered by the CoP members participating in the trials.**

In terms of **trial run event duration**, the trial teams decided that the TMG recommendation to hold the trials as two-day events is incompatible with the ICARIA's intent to organise the trials and mini trials as two of the six CoP workshops, and agreed to **organise all the CoP events (and thus also the trials and mini-trials) as 1-day events.** This decision is already recorded in section four of D5.4 (Turchi et al., 2023a), along with the tentative dates for the two events:

- workshop four **"trial execution" at M28 (April 2025)**, and
- workshop five **"mini trials and socio-economic impacts" at M31 (July 2025)**

In the course of D4.1 preparation, they subsequently agreed that **each trial will validate the overall ICARIA methodology, and all four of the solutions that are developed by the project** (section 4), in the region-specific trial context. As a part of region-specific trial preparation, region-specific data and modelling will needs to be conducted, plausibility of the results assessed (e.g. against some real-world events) by the scientific team, and the results of this assessment validated against the neds and expectations of the CoP members at the trial run event.

Based on these two decisions, the trial teams realised that there isn't enough time to teach the stakeholders how to use the tools and measure such aspects as the "quality of the training materials" or assess the usability of the tools by measuring the ability of the stakeholders to use them after a short training session at the trials. This is considered a minor issue, as most of the CoP members aren't supposed to use the ICARIA tools on their own.

Moreover, all three trial teams agreed that **no scientific/statistical assessment of the quality of the data and model predictions can be performed during the trial run event**. However, this type of assessment must be performed by the scientific team during the trial preparation, e.g. by comparing the results against the known data from the past. Results of such assessment will be included as auxiliary information for the final trial assessment and presented to the CoP members on trial run events, to validate if the quality of the data/model outputs meets their needs and expectations.

Consequently, the "trial context" was defined as follows:

- Trial run events (and mini-trials) will be organised as **computer assisted desktop** exercises.
- Trials (and mini trials) will be put into a context of **1-2 types of compound events that are relevant to the trial region**.
    - Ideally, both the real events that the stakeholders are familiar with, and synthetic future events according to CC projections will be addressed.
    - Necessary region-specific data/modelling will be performed during the "trial execution" phase (section 6.1), quality of the results assessed by the scientific team, and these findings also validated by the CoP members at the trial run events.
    - Mini-trials will, among other, test the transferability of the ICARIA results to new regions, under the conditions of limited data availability and limited time and resources that can be allocated to resolving the data gap and adjusting the hazard and impact models.
- Event **duration will be 1 day** (both for the trials and for the mini trials)
- Each trial will **assess the ICARIA methodology and the four tools** developed by the project (section 4)
    - Methodology and the tools will be presented by dedicated team members and validated by CoP members.
    - No attempt will be made to train the stakeholders in using the tools on their own during the trial run events.
- **Feedback on specific questions** of interest to the project and regions will be collected using some form of a questionnaire.
    - Questionnaire results will be filled in and submitted digitally, not orally or on a paper.
    - Our main interest is in validation of the project by CoP members, but he questionnaires should also be filled by ICARIA team members to ground the results and measure the difference between expectations and perception of the project team and of the CoP members.
    - Auxiliary information may be collected to complement the questionnaires, e.g. in the form of group discussions or interviews - to be decided nearer to trial run events.

# 4 ICARIA solutions

The solutions that need to be assessed through trials have also already been to some extent pre-determined by ICARIA GA and further specified and at least partially developed in the first project year. These are:

- **ICARIA Risk Assessment Framework**
- **Resilience Assessment Framework (ICARIA RAF)**
- **Resilience Assessment Tool (ICARIA RAT)**
- **ICARIA Portfolio of Solutions**
- **ICARIA Decision Support System (ICARIA DSS)**

Detailed specifications of ICARIA RAF and RAT tools are available in deliverable D3.2- Holistic resilience methods (Brito et al., 2024). ICARIA's Portfolio of solutions is described in deliverable D3.3- Portfolio of adaptation solutions (Hidalga et al., 2024), and the preliminary features of Decision Support System in D3.6 -WP3 Lab test results (de la Cruz Coronas et al., 2024).

While the ICARIA RAF (section 4.2) and ICARIA RAT (section 4.3) share various similarities, they differ in their main focus. The Resilience Assessment Framework provides a holistic assessment of regions and services, while the Resilience Assessment Tool completes the overall Resilience Assessment service with its focus on critical infrastructure. Both tools are stand-alone apps embedded in the ICARIA Shell (Figure 3), complemented with the ICARIA Portfolio of Solutions (section 4.4), shaping the ICARIA Decision Support System (section 4.5) (Brito et al., 2024).


**Figure 3: ICARIA Shell which provides access to the ICARIA RAT and the ICARIA RAF.**

## 4.1. ICARIA Risk assessment framework

The ICARIA Holistic Modelling Framework is a comprehensive approach designed to assess risks and impacts of climate-related hazards, focusing on compound events and cascading effects. The framework, outlined in Deliverable 1.1 (Turchi et al., 2023b), provides a structured methodology for conducting a multi-hazard risk/impact assessment across various climate-related hazard categories such as heat waves, forest fires, droughts, floods, storm surges, and wind storms.

Its structured methodology ensures consistency in assessing risks and impacts across different hazard categories, enabling a comprehensive understanding of complex interactions and potential cascading effects. By providing a systematic approach to evaluating climate-related hazards, the ICARIA Holistic Modelling Framework aims to support decision-making processes and enhance preparedness for climate change impacts.

In terms of implementation, the framework is structured in seven main steps:

1. Identification of a time-space window for the compound events and cascading effects scenario assessment, and definition of risk/impact metrics.
2. Identification of the triggering hazards affecting the case study regions.
3. Quantification of damage, in time and space, caused by different interactive causal chains represented in a time-history of events, with assigned intensity and probability, on specific exposed assets in relation to their vulnerability.

4. Consideration of the coping, adaptive and transformative side of resilience, which further influence the system's response to combined events.

5. Correlation between suitable, sustainable, and cost-effective resilience strategies/measures and potential risk reduction benefits (social, environmental and economic).

6. Optimization of the exploitation of satellite/remote sensing data and methods in order to address possible gaps and/or uncertainties.

7. Post-processing of modelling results through the cost-based and multi-criteria analysis as key-aspects of ICARIA DSS.

As for the analysis of multi-hazard events, the framework emphasises the need to understand how different hazards can interact both individually and in combination, leading to diverse impacts on the risk receptors of interest. By assessing the spatial and temporal propagation of hazards and their interactions, the framework allows to capture the severity of these events on various scales. It also highlights the role of socio-technological and economic drivers in influencing the outcomes of compound events. For this reason, an accurate understanding and modelling of the interaction established between individual hazards during multi-hazard events is an essential point of project ICARIA.

The figure below (Figure 4) is a graphic representation of project ICARIA. It illustrates the concept of "elementary bricks" as units of analysis within the framework representing Time, Space, Hazards, Exposure, Vulnerability, Dynamic Vulnerability, Coping Capacity, Adaptive Capacity, Transformative Capacity, Damage, and Human behaviour. Time and Space serve as the reference frame for the other elementary bricks. Hazard, Exposure and Vulnerability represent input data in peacetime, while Dynamic Vulnerability evolves gradually as a result of the occurrence of the event assessed. Coping, Adaptive, and Transformative Capacities are essential for identifying actions that can enhance resilience in the face of combined events. Damage on risk receptors is the output data of the risk/impact/resilience scenario assessment. Human behaviour is highlighted as a factor that can significantly influence the other "elementary bricks".

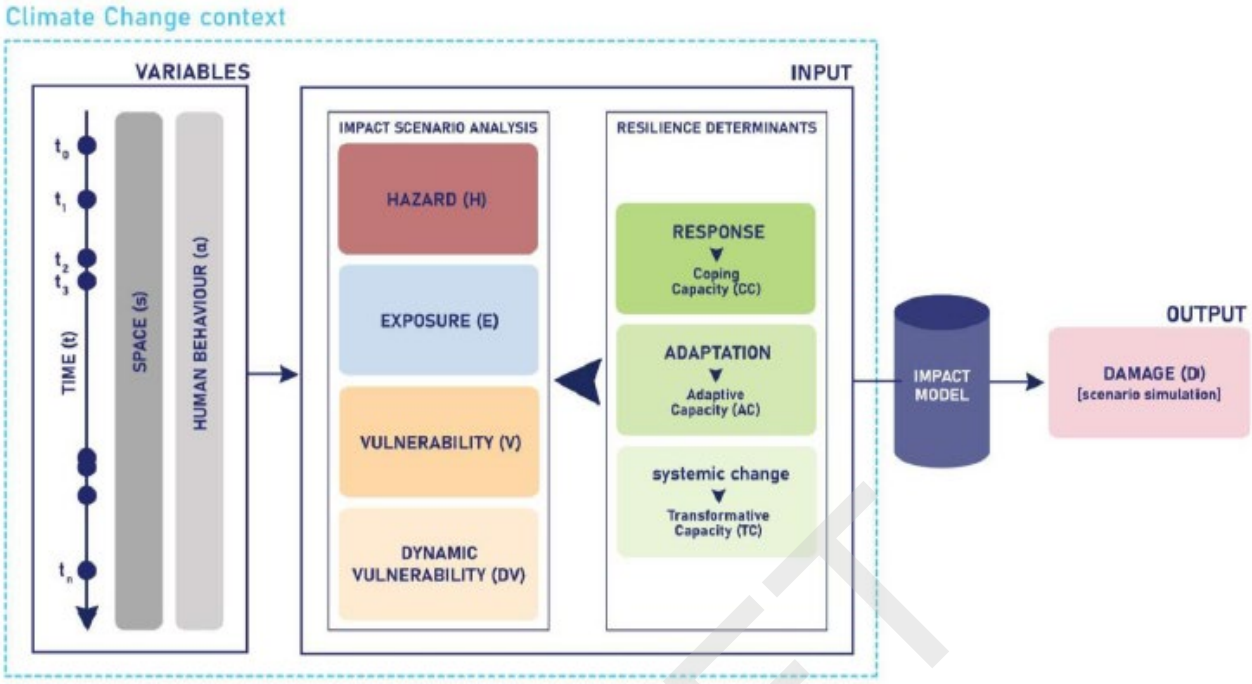


**Figure 4: The ICARIA holistic multi-hazard risk and impact assessment framework (Turchi et al., 2023b).**



The presented framework is the basic guideline for all the risk assessment related activities that are done in project ICARIA. However, the framework itself is not one of the developments that will be assessed in the Trials. The main reason for this is that such Trials will be focused directly on the key technological outcomes of the project, meaning tangible tools that stakeholders will be able to use after the end of the project. Furthermore, the Trial will be conducted in the context of the project CoPs, groups of stakeholders related to resilience policy making and operation of critical infrastructures threatened by extreme weather events. After the initial working session with them, it was concluded that their main interest lies in the need to have access to reliable and structured tools to perform risk assessment of natural hazards, evaluation of current reliance of regions and infrastructure and to have decision making support tools to define plans to improve climate resilience both at regional and singular asset level.

## 4.2 Resilience Assessment Framework (RAF)

Urban and regional climate resilience, consequently reducing negative impact of climate disasters, is essential when it comes to improving preparedness and reducing damage to cities and their inhabitants (Cardoso et al., 2020). In supporting decision makers in their enormous task of identifying vulnerable areas and distributing their limited resources, resilience assessment tools are key (Sharifi et al., 2016).

Based on the already available assessment tool RESCCUE RAF[5], the existing framework has been further developed and extended to meet ICARIA purposes (e.g. update of cities and services, adapted and newly developed metrics, include forest fires in the RESSCUE RAF, etc.). The resulting ICARIA RAF allows decision makers a comprehensive assessment of given services and infrastructure for a specific hazard (or compound hazards) in a certain given timeframe.

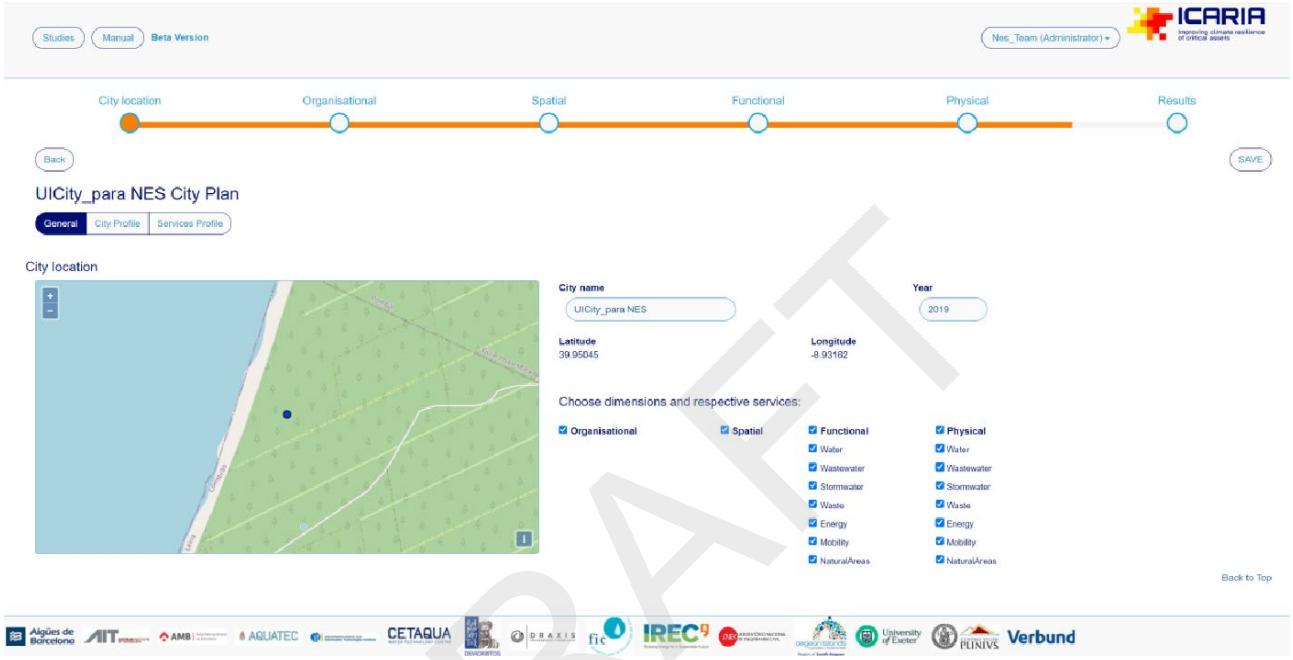


**Figure 5: Front Page of the ICARIA RAF App.**

For a comprehensive and customised assessment, the user can select the relevant attributes in the ICARIA RAF (Figure 5). The individual and user-bound studies (assessment of the region and its services, for a given period and for a specific hazard or compound hazards) support a visual comparison of different assessment moments for a specific region and allows monitoring the resilience progress in a given time frame. Furthermore, the tool supports the visualisation of the impact of the metrics affected by the resilience actions on the expected level of resilience development. It also provides an initial identification of resilience strengths, gaps and improvements opportunities. The final result can be summarised in a predefined report which highlights the most important findings and conclusions.

### 4.2.1 RAF implementation plan

In D3.2. – Holistic resilience methods (Brito et al., 2024) detailed instructions on how to set up and navigate through both the ICARIA RAF and ICARIA RAT have been provided and will be

[5] https://toolkit.resccue.eu/wp-content/uploads/2021/01/D6.4.pdf

validated in the case studies. The main steps are as follow and can be investigated in the corresponding Deliverable if needed.

**Table 7: step by step instruction for implementing the ICARIA RAF.**

| ICARIA RAF implementation | |
|---|---|
| **Step 1** | Defining the scope of assessment (i.e. hazards, services etc.). |
| **Step 2** | Defining the purpose of the assessment. |
| **Step 3** | Identifying and involving stakeholders, assigning responsibilities.<br>Establishing overall coordination. |
| **Step 4** | Defining the context of application (time period, level of analysis, level of relevance). |
| **Step 5** | Identifying data requirements and selection of analytical tools for supporting the application. |
| **Step 6** | Establishing a program for the application of the RAF by each member of the team, with assigned responsibilities and timeline. |
| **Step 7** | Performance of the preliminary assessment and evaluation of the results in the RAF App. |
| **Step 8** | Teams feedback for preparing the final version of the assessment. (Feedback loops) |

In addition to the steps listed in Table 7, D3.2 (Brito et al., 2024) provides various use cases and their realisation with the ICARIA RAF, such as:

a. Perform an overall resilience assessment of a region, for a preliminary evaluation.
b. Compare the evolution of resilience between 2019 and 2024.
c. Compare resilience to different hazards.
d. Compare how resilience changes when actions are taken.
e. Overall resilience of critical infrastructure (CI)

## 4.3 Resilience Assessment Tool (RAT)

Similar to the ICARIA RAF, the Resilience Assessment Tool (RAT) is also based on previous projects outcomes (UN-Circle RAT[6]). With the UN-Circle RAT as a starting point, potential gaps (e.g., assets, hazards, geographical scale etc.) between the available tool and the ICARIA scope have been analysed. Thus, for the projects purposes the ICARIA RAT has been extended

[6] https://www.lmaleidykla.lt/ojs/index.php/energetika/article/view/3725

accordingly (e.g., include compound hazards in EU-Circle RAT) and now includes the following hazards: flooding (rain induced, fluvial, and coastal), drought, heat wave, cold wave, windstorm, and forest fire. Furthermore, it considers both urban and regional scales, addresses people, buildings, the urbanised and natural areas, and various urban services and assets.

The resulting **Overall Resilience Index** is composed of the *indicator level* (e.g. a numerical value on a scale 1-10) that can be further aggregated in different categories on the *category level* (using a weighted averaging approach), which can again be further accumulated at the capacity level (five capacity levels: Anticipatory, Absorptive, Coping, Restorative, Adaptive). This resilience categorization allows the combination of relative rating categories and narrative qualitative description (IAEA, 2015). In addition to the Overall Resilience Index, the ICARIA RAF provides an assessment of each resilience capacity – the **Capacity Indices**. The overall purpose of the app is the detailed assessment of the resilience of critical assets, based on the users' input data, providing a final resilience indicator and various possible visualizations of the achieved results (Brito et al., 2024).

### 4.3.1 RAT implementation plan

In D3.2. – Holistic resilience methods (Brito et al., 2024) detailed instructions on how to set up and navigate through both the ICARIA RAF and ICARIA RAT have been provided and will be validated in the case studies. The main steps are as follow and can be investigated in the corresponding Deliverable, if needed.

**Table 8: step by step instruction for implementing the ICARIA RAT.**

| ICARIA RAT implementation | |
|---|---|
| **Step 1** | Identify the Resilience Assessment Team. |
| **Step 2** | Contextualise the Resilience Assessment. |
| **Step 3** | Determine the existing operational resilience and climate adaptation local legislative and operational environment. |
| **Step 4 (Opt.)** | Frame stakeholder collaborative environment. |
| **Step 5** | Data collection from diverse sources. |
| **Step 6** | Prepare different tools (ICARIA RAT and potentially other tools). |
| **Step 7** | Conduct a multi-hazard assessment |
| **Step 8** | Identify CI assets and characterize them |
| **Step 9** | Conduct Risk and Resilience Assessment. |
| **Step 10** | *Assessment of risk and resilience* quantifiable results |

| ICARIA RAT implementation | |
|---|---|
| **Step 11** | *Re-evaluate CI asset resilience* based on proposed interventions / adaptive measures. |
| **Step 12** | Report *Results and Recommendations*. |

## 4.4 Portfolio of Adaptation Solutions

With a specific adaptation objective in mind, decision makers (Adaptation Strategy Design Team) can design and evaluate their region of interest-shaped Adaptation Strategy, by combining various cost-effective adaptation measures.

To realise effective matching of the required adaptation objectives and the provided key purpose of the solution, a characterization of measures has been implemented (Table 9). For each measure information regarding technical specification, implementation requirements and potential impacts are analysed leading to a characterisation scheme which allows a user-beneficial prioritisation of suitable measures (Hidalga et al., 2024).

**Table 9: Characterisation of measures included in the ICARIA Portfolio of Solutions (Hidalga et al., 2024)**

| Measure categorization and characterisation | | |
|---|---|---|
| **Key benefits** | Citizen engagement | Key benefit of implementing the adaptation solution. |
| | Climate hazards reduction | |
| | Exposure to climate hazards reduction | |
| | Governance improvements | |
| | Efficiency gains (public or private service) | |
| | Nature positive | |
| | Resource saving | |
| | Vulnerability to climate change | |
| **Area Type** | Urban areas | Area where the adaptation measure is designed to be applied. |
| | Rural areas | |
| | Natural areas | |

| Measure categorization and characterisation | | |
|---|---|---|
| **Spatial scale** | Building | Spatial magnitude of the measures' intended range. |
| | Street | |
| | Neighbourhood | |
| | City | |
| | River Basin | |
| | Metropolitan Area | |
| | Region | |
| **Measure type** | Governance and institutional | Key Type Measures (KTM) for convenient progress reporting for the National Adaptation Plans. (Leitner et al., 2021) |
| | Economic and finance | |
| | Physical and Technological | |
| | Nature Based Solution and Ecosystem-based Approaches | |
| | Knowledge and Behavioural change | |
| **Co-benefits** | Environmental (e.g., improved air quality, water quality) | Additional positive impacts and benefits when implementing the adaptation measure (in addition to the key benefit). |
| | Social (e.g., Noise abatement, social cohesion and inclusion) | |
| | Economic (e.g., cost savings, Job creation etc.) | |
| **Costs** | Low implementation and low maintenance costs | Enables comparison of measures in terms of expenditure considering implementation as well as maintenance. |
| | Low implementation and average maintenance | |
| | Average implementation and low maintenance costs | |
| | Average implementation and average maintenance costs | |
| | Average implementation and high maintenance costs | |
| | High implementation and low maintenance costs | |
| | High implementation and average maintenance costs | |
| | High implementation and high maintenance costs | |

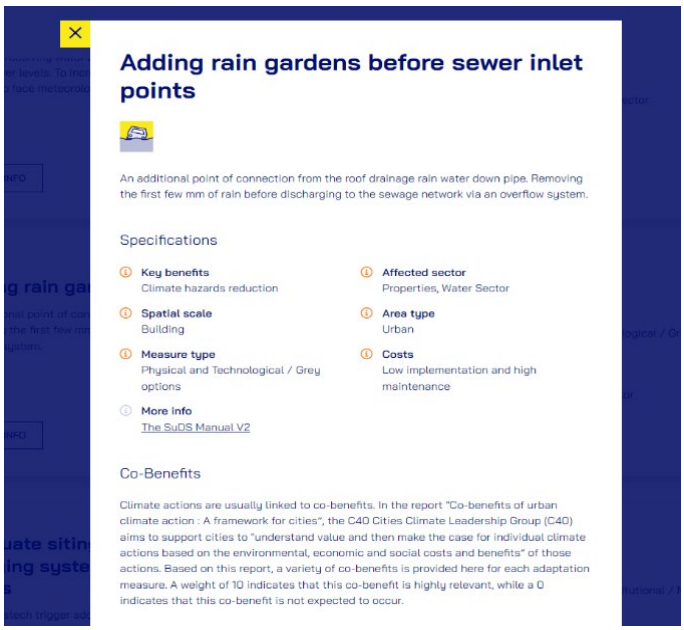


**Figure 6: Specific Measure Pane for each solution.**

The ICARIA Portfolio of adaptation solution platform itself consists of a user-friendly front-end that displays the currently 228 publicly available adaptation measures and their corresponding information and details (Figure 6).

The platform supports user-friendly filtering of adaptation measures by various categories, such as Climate Hazard, Key Benefits, Measure Types etc.

When deciding to add a new adaptation solution to the platform, the user will be guided through the process by the platform itself, explaining different characterisation measures and criteria to evaluate potential co-benefits along the way (Hidalga et al., 2024).

## 4.5 Decision Support System

Results from both the ICARIA Resilience Assessment Framework and Tool (ICARIA RAF & ICARIA RAT) and from the ICARIA portfolio of adaptation solutions will feed into the ICARIA Decision Support System (DSS). The input provided by the other solutions allow decision-makers to visualise impacts from single and compound hazards as well as their corresponding most cost-effective adaptation scenarios. Furthermore, the tool provides various resilience and risk assessment scenarios. Decision makers are, hence, enabled to compare different scenarios for their region to identify the most fitting and promising adaptation solutions based on their adequacy (including Cost-Benefit Analyses). RAF and RAT are expert tools, but a simplified view of the results can (and should) be shared with the public to increase transparency.

Although the tool itself has yet to be developed (starting in the upcoming months), the main components are already known, due to validation of the DSS workflow with the case studies:

**Table 10: Main components of the ICARIA Decision support system according to D3.6. (de la Cruz Coronas et al., 2024).**

| DSS component | Details |
|---|---|
| **Landing page** | • User authentication and authorisation<br>• Introduction to the DSS |
| **General pages** | • About page<br>• Account management<br>• User feedback and guide |
| **Project manager** | • Data upload (Hazard maps, exposure and vulnerability data etc.)<br>• Creation and management of projects<br>• Building or scenarios |
| **Map viewer** | • Preload (static) project data<br>  ○ Hazard maps<br>  ○ Climate projections<br>  ○ Weather observations<br>  ○ Other spatial representations<br>• User data uploaded via the project manager (data on hazard maps, vulnerability and exposure information)<br>• Essential GIS functionality<br>  ○ Single and multiple data layers and side-by-side comparison<br>  ○ Descriptive information (data legends etc.)<br>  ○ Download (data and other results)<br>  ○ Temporal range of data |
| **Risk/impact assessment** | • Quantification of risk score<br>• Quantification of damage |
| **Adaptation measures** | • Integration of measures (ICARIA portfolio of solutions)<br>• Cost-Benefit Analysis and Multicriteria Analysis for identifying most appropriate solution |
| **Holistic resilience assessment** | • Integration of ICARIA RAT and RAF applications (metrics on the resilience of the region/critical infrastructure) |

Since the DSS is due to be developed in the following months the components and aspects may change due to newly gained insights and feedback.

# 5 Trial planning: six steps approach

As explained in section 2, *Trial Guidance Methodology and CoPs*, the Trial planning phase consists of two steps: "step zero" and the "trial preparation". Furthermore, the trial preparation is a process in which six different aspects of the trial are iteratively designed: **objectives, research questions, data collection, evaluation approaches and metrics, trial scenario and the selection of the solutions**.

## 5.1. Objectives

Trial objectives indicate the overarching goals and aspirations of the trial team. They are intimately related to trial gaps and must be formulated in a SMART way. SMART stands for Specific, Measurable, Achievable, Reasonable and Time-bound. Trial objectives are typically defined in a brainstorming session, by asking the participants to answer the following questions:

1. **SPECIFIC**: What are the main "problems" that you wish and would like to resolve through this trial?
   - These "problems" must relate to trial gaps, otherwise, the team will have to go back to step zero and redefine the trial gaps and context.
2. **MEASURABLE**: What measurable effects should be achieved to resolve these problems?
   - Do you need to be faster? More accurate? To be able to perform some tasks you cannot do at all today?
3. **ACHIEVABLE**: is it possible to achieve this within the trial context?
   - In subsequent iterations, this question will change to "is this possible to achieve within the planned scenario and with solutions that will be trialled?
4. **REASONABLE**: is it possible to achieve this with resources available for the trial?
   - In this context, it is important to ask if the organisations involved in a trial would ever be able to implement the trialled solutions - be it for legal, organisational or budgetary reasons.
5. **TIMELY**: can this objective be reached within the time available for the trial?
   - For example, ICARIA is a three-years project and even if it would have stated the interest and the budget to implement any recommendations for climate change adaptation within the trial, it wouldn't have enough time to monitor the effects of implemented measures.

Each trial had to define at least one SMART overarching objective as a "trial slogan". This overarching objective can be accompanied by a small number of secondary objectives. All three trial teams agreed on a following overarching objective (slogan) for the trials:

**Trial Slogan (Overarching Objective):**

**Assess the capability of the ICARIA tools and models to improve the understanding of the climate resilience and climate change preparedness among local risk owners (authorities and critical asset operators) by simulating the impact of extreme multi-hazard events on critical infrastructure and helping the stakeholders to decide which adaptation options to implement.**

Specific objectives are presented in Table 11.

**Table 11: ICARIA Trial specific objectives.**

| Obj. No. | Objective |
|---|---|
| O1 | Validate the **plausibility of ICARIA data and modelling results (hazards, impacts/damage estimates, impacts of adaptations)**. |
| O2 | Validate the **appropriateness (relevance, effectiveness, side effects, societal justice) of the adaptation measures** suggestions provided by ICARIA solutions. |
| O3 | Validate the **capability of proposed adaptation measures to reduce impacts**. |
| O4 | Validate the capability of the ICARIA tools and models to **simulate impact associated with the long-term changes in weather patterns (caused by climate change) on critical infrastructure assets.** |
| O4 | Assess to what extent/how ICARIA models/data/tools can help Regional Authorities and other stakeholders to **assess the CC vulnerability/resilience (strengths and weaknesses) of their critical infrastructure assets.** |
| O5 | Assess to what extend/how ICARIA models/data/tools can help the Regional Authorities and other stakeholders to **assess and improve the CC adaptation plans for their critical infrastructure assets** |

Notes:

- Scientific assessment of the quality of data/model outputs is primarily a task for the scientific team. CoP members will primarily validate if the results meet their needs and expectations, but may also be able to validate the plausibility of some outputs, based on their experience with previous real-world events.

- For the **Austrian trial**, the trial slogan and objectives have to be understood in the context of renewable energy production in the alpine region.
- For the **Greek trial**, the context is the critical infrastructure on the islands with high seasonal fluctuations of the population due to tourism.
- Finally, for **the Spanish trial**, the context is the critical infrastructure in a major metropolitan area in the south of Europe.

## 5.2 Research Questions

Research questions are specific questions of interest to the trial team. They need to be formulated as questions so that they can be answered in a simple way (yes/no, good/bad/evil, 0-5 likert scale, etc). Research questions connect different aspects of the trial: they address specific trial gaps, need to be answerable in an objective way within the trial, and need to be understood and approved by all trial stakeholders. Good research questions are formulated in a simple and easy-to-understand way and have a clear relation to trial gaps and objectives.

ICARIA trial teams have decided to group their research questions for trials and mini trials into following RQ dimensions:

- **(Sci) Science and technology** (e.g., "how good are the model predictions?", "how well does the DSS work?"),
- **(UX) User experience** (e.g., "How much training do potential users need to use the solutions?"),
- **(Acc) User acceptance and sustainability** (e.g., "Do potential users want to use this type of solution in their work?", "how well do the solutions support their decision-making process?"),
- **(Soc) Socio-economic impacts and ethics** (e.g., "what socio-economic impacts do CoP members anticipate from trialled solutions?", "how do proposed adaptations contribute to just transition?")

Summary of the research questions is presented in Table 12.

**Table 12: ICARIA research questions for the trials**

| RQ No. | Research Question | RQ dimension | Comment |
|---|---|---|---|
| **RQ-Sci1** | How plausible are ICARIA data/modelling results? | Sci | This question relates both to numeric comparison of the hazard and impact model results with the known data (from past events) by ICARIA scientific team and to professional opinions of the regional stakeholders.<br><br>All questions related to the model and data outputs must first be answered by the scientific team. At the trial run, the stakeholders should primarily be asked to validate the results of scientific assessments against the needs and expectations of the stakeholders, e.g. with a Likert scale ranging from 0= "completely misleading/useless" to 5= "beyond needs/expectations". In addition, they should also be asked to assess the plausibility of the data/model outputs based on their experiences with real world events. For this reason it's also important that the trial scenario resembles some of the past events that the CoP members are familiar with.<br>Please also note that this question is in reality a whole set of questions (one for each relevant hazard, risk/impact estimate etc. |

| RQ No. | Research Question | RQ dimension | Comment |
|---|---|---|---|
| **RQ-Sci2** | How easy/difficult/expensive would it be to apply the ICARIA solutions in new regions? | Sci | This question should be assessed separately for each relevant input (e.g. hazard/impact model) by ICARIA sci/tech experts, presented in tabular form, and then an overall summary written in form of a short text explaining the key challenges, opportunities and best guesses for the efforts needed to transfer specific features of interest for the Regional Authorities and other stakeholders.<br><br>Transferability is validated through mini trials. |
| **RQ-Sci3** | Which data/modelling aspects of ICARIA solutions need to be further developed/improved? | Sci | This question needs to be answered separately by the scientists and developers that understand how the systems work and by the users that understand the actual requirements on the data and hazard and impact models. The result is a list of suggestions for future research and development, ideally weighted by the level of RA/SH interest. |
| **RQ-Sci4** | To what extend does the functionality of the ICARIA tools go beyond the state of the art/ what is currently used in the region? | Sci | For evaluating the added value of the tools in relation to already available and in use tools, stakeholder and scientist should provide insight by giving via free text response.<br>Each tool/aspect has to be assessed separately. |
| **RQ-Ex1** | How easy or difficult is it to use the solutions? | Ex | Likert scale 0-5 for each of the assessed solutions, based on RE/SH responses. 0 means that the application appears to be very difficult to use, 5 that the solution can be easily used without any training. It is important to profile the responders, in order to differentiate between the difficulty in using the solution and the difficulty in understanding the problem space. |
| **RQ-Ex2** | How easy or difficult is it to understand the results/recommendations offered by the solutions? | Ex | Likert scale 0-5 for each of the assessed solutions, based on RE/SH responses. 0 means that the results are completely incomprehensible, 5 that the results are very easy to understand, to the point where no training is required. Similar question can also be asked for the methodology. Again, responders profiling is essential for interpretation of the result. |
| **RQ-Ex3** | What needs to be done to improve the user experience / usability of the solutions? | Ex | Free text suggestions, ranked by number of similar requests and responder's profile. |
| **RQ-Acc1** | How useful is ICARIA methodology for the Regional Authorities and other stakeholders? | Acc | Answer to this question can be compiled from responses to questions of the "how useful is the ICARIA methodology for assessing and improving the CC resilience of critical infrastructure assets? (0-5 Likert scale)", and "how well aligned is ICARIA methodology with the needs of your organisation? (0.5 Likert scale) questions. |

| RQ No. | Research Question | RQ dimension | Comment |
|---|---|---|---|
| **RQ-Acc2** | How useful are ICARIA solutions for the Regional Authorities and other stakeholders? | Acc | Answer to this question can be compiled from responses to questions of the "how useful would each of the presented solutions be in your work? (0-5 Likert scale)" or from answers to more fine-grained questions on specific features of the solutions. |
| **RQ-Acc3** | Do potential users want to use this type of solutions in their work? | Acc | Answer to this question can be compiled from responses to questions of the "how likely are you to recommend purchasing this type of solution within next five years? (0-5 Likert scale)". In some cases it may be also appropriate to ask the stakeholders if someone other than them should purchase this type of solution to provide them with specific service. |
| **RQ-Acc4** | Which improvements / additional features would make the ICARIA methodology and/or solution(s) significantly more attractive for potential users? | Acc | Free text response, ranked by number of similar requests and responder's profile. |
| **RQ-Soc1** | How much socioeconomic impact (including gender and ethics issues) do trial participants anticipate from ICARIA methodology and solutions? | Soc | Likert scale -2 to +2, with -2 meaning strong negative impact, 0 meaning no impact and +2 meaning strong positive impact. |
| **RQ-Soc2** | What kind of socioeconomic impacts (including gender and ethics issues) do trial participants anticipate from use of ICARIA methodology and solutions? | Soc | Free text, ranked by number of similar answers. |

## 5.3 Data collection plan

Well-formulated trial questions must be answerable in an unambiguous way by collecting specific data during the trial and assessing it afterwards. What data needs to be collected and how, depends on the trial objectives and research questions, but also on the characteristics of solutions and the overall trial context. Typically, some data may be collected automatically or using technical tools and sensors (e.g., "time needed to perform a task"), whereas other data may be collected through initial brain-storming, round table discussions, retrospective sessions, surveys, or interviews.

### 5.3.1. ICARIA Questionnaires

In ICARIA trials, the trial teams have agreed to collect most of the data from trial participants (CoP members), using dedicated questionnaires that are filled in individually by each of the event participants and digitally submitted per e-mail or using some dedicated questionnaire tool. This has some advantages, as it minimises the effect of peer pressure on responders. Moreover, the survey could even be used by CoP members that couldn't make it to the trial run event, especially if a recording of presentations is provided.

However, such questionnaires also have disadvantages. Most notably, the trial participants might misunderstand the questions, forget to fill in or submit the questionnaire after the event, or give up answering when they realise that this takes more time than they anticipated. This is especially challenging for "free text" type of questions, which require more effort to answer.

**When designing the questionnaires, the trial teams will have to estimate the attention span they can expect from CoP members and double check the clarity of the questions and the time needed to fill in the questionnaire with independent testers**.

Most of the questions will relate to "research questions" (Table 12), but questionnaires will also contain the profiling questions (e.g. organisation/role/education/professional background, possibly also nationality/gender/age) and possibly some questions on event organisation.

**Profiling questions must be handled with care, as they typically include information on age, gender, and professional background of the participants, which might raise privacy concerns in the sense of the European General Data Protection Directive (GDPR).**

Questions can also be added to the questionnaires to help us **understand the sentiment and cultural bias of the trial participants / CoP members**. For example, the questionnaire could include a few questions related to event organisation:

- How satisfied are you with overall event organisation?
- How satisfied are you with event location?
- What could be improved?

The contrast of the answers provided by the ICARIA team self-assessment and the responses gathered from the CoP members can be used as a measure for cultural biases.

**Finally, it is important to allow the users to explicitly answer the questions with 'cannot assess'.**
This will allow us to differentiate between the following two cases: (1) CoP members didn't answer some of the questions because they were overwhelmed by the length of the questionnaires, and (2) Trials didn't provide the CoP members with information needed to answer the questions.

### 5.3.2 Auxiliary data collection methods

Some shortcomings of the questionnaires can be mitigated by complimenting them with other types of information gathering from CoP members / trial participants:

- **Dedicated interviews with the key event participants** can help assure that their feedback is captured, and all the questions are well understood. Such videos could also be conducted as video interviews and potentially used in project communication (beware: if any of the event participants aren't ream or CoP members, they will have to sign event-specific informed consent form to satisfy the GDPR requirements)

- **Iterative group exercises** during the event (e.g. mentimeter-type[7] mini-polls, world cafe, or final group discussions to establish the group consensus on questions of specific interest to the project team and/or the regions) should be integrated in trial run and mini trial events to complement the questionnaires, especially for collection and prioritisation of the "free text" feedback, such as the ones needed to resolve RQ-UX2, RQ-acc4 and RQ-soc2.

- **Dedicated observers** can be used e.g. to capture the sentiment and informal comments of participants.

Finally, the **trial teams may also consider a possibility for measuring the shifts in knowledge, sentiment, and expectations of the CoP members, e.g. by designing an auxiliary (shorter!) questionnaire that is answered by CoP members several times during the project execution (e.g. ask them about event organisation at the end of each event).**

### 5.3.3 Scientific data collection

In addition to information collection from the CoP members / trial participants, some information will also need to be collected from the ICARIA scientific team prior to the trial run. Most notably, the scientific analysis of the quality of the data/model outputs must be performed well before the trial run event, and the lessons learnt summarised and presented to the CoP members with a request to assess the plausibility of the results (based on their expert knowledge), as well as to validate if results are good enough to be used in regional planning/decision making.

**Concrete methods for collection of scientific data still need to be defined in cooperation of the trial teams and scientific experts**. They will depend on the type of data that's being analysed and needs to be defined by scientific experts and aligned with the scientific best practices that are relevant to specific data/models being analysed. For example, it is important to design the data collection in a way that will assure the optimal coverage of the relevant data space (geographic, temporal, different scenarios) and to assure that the data used in validation hasn't been previously used for calibrating the model.

[7] https://www.mentimeter.com/

## 5.4 Evaluation approaches and metrics

Collecting the data without a clear understanding of the ways this data will be processed and used to answer them would be an exercise in futility. A clear up-front definition of the evaluation approaches and metrics by which measured data and indicators based on this data will be used to assess the trial results and resolve the research questions and objectives is the main difference between merely "playing with the solutions to see if we like them" and objectively assessing them in a trial.

Our experience from previous trials shows that defining the evaluation approaches and metrics is the single most difficult task for the trial teams. As a result, we have decided to approach it in two steps: first by providing the generic rules on how to interpret the results in this document and then by double-checking how these rules are implemented through dry run events.

### 5.4.1 Interpreting the free text responses

**"free text" responses can be** collected through questionnaires, interviews or group exercises. It is difficult to analyse this type of response analytically, but this type of responses can help us to understand what trial participants really want or need and why some of the trial aspects got exceptionally high or low ratings.

As already mentioned in section 5.3, this type of data collection is also costly and needs to be used sparingly (especially in questionnaires) to avoid the risk of overwhelming the trial participants/ CoP members. One way to achieve this would be to only ask such additional questions after analysing the trial run event, e.g. in the scope of mini trials.

### 5.4.2 Interpreting the numerical values from the questionnaires

Most of the data collected in trials will be in the form of 0 to 5 or -2 to +2 Likert scale, since such data is both easier to collect and easier to interpret than free text.

Obvious way to interpret such data is by **calculating the mean and the average values of the results and interpreting them against some relatively arbitrary "level of satisfaction" scale**. E.g., we could declare that the values below 3 are bad, 3 is fine, 4 is great and anything above 4.5 is beyond expectations. While this approach is reasonable, there are also issues with it, which prevent us from using it in ICARIA. Most notably:

- We lack "baseline" that could be used to calibrate the expectations and the effort required to establish such a baseline may be beyond the project scope.
- The correspondence between the 0-5 note and the actual level of satisfaction can be very different depending on the local culture. Whereas some cultures encourage overly positive feedback, others consider this a bad form and tend to assign lower notes for the same level of achievement and satisfaction.

Luckily, we do not really need to know the baseline to extract the useful information from the data.

**Baseline approximation**

With just three trials, it's difficult to establish a solid baseline, but we can use the following methods to approximate it:

- Ask team members to answer the questionnaire. While the project team will bring in its own bias, this bias is expected to be the same or all three trials. A significant difference between "team mean" and "CoP mean" at three locations can be thus used o approximate the cultural bias.
- Ask both the team members and CoP members to answer some control questions. For example, the questionnaires could contain some questions about event location, food, and organisation. ICARIA team is experienced enough to organise the events reasonably well (and realise if anything went wrong). Consequently, the averages to these answers can be used to calibrate the expectations for the rest of the questionnaire.

**Data analysis 101**

A bit of elementary statistical analysis will help to understand the answers. As a guideline:

1. **Start by calculating the mean and median values** for each of the questions, for a single trial
    - **Significant difference between mean and median value may be a sign that the sample is too small,**
    - **Alternatively, such difference may be a result of participant-profile related bias.**
2. G**roup the answers in quantiles (e.g. quartiles or deciles)** and try to figure why some of the questions are in upper or lower quantile.
    - **In interpretation of the answers with numeric values, it is important concentrate at questions that have been rated best or worst by the CoP members. Particularly positive answers could potentially be used in the project communication and help shaping the sustainability plans, whereas the particularly negative answers could either indicate which areas need further development, or general challenges in acceptance of the project results.**
    - **In case the reason for particularly good or bad notes is unclear, additional analysis of the answers or additional questions (e.g. in mini trials) may be necessary.**
3. If a profile-specific bias is suspected, assessment should be repeated for the subgroup of participants.

- **"Profiling questions" should always be included in the questionnaire to allow this type of analysis.**

4. At a later stage, cross-region and cross-even analysis should also be made to figure out if here are significant differences in the voting patterns of stakeholders from different regions.
    - **"Profiling questions" should always be included in the questionnaire to allow this type of analysis.**

### 5.4.3 Scientific data analysis

As already mentioned in section 5.3, some information will also need to be collected from the ICARIA scientific team prior to the trial run, scientific analysis of the quality of the data/model outputs performed well before the trial run event, and the lessons learnt summarised and **presented to the CoP members with a request to assess the plausibility of the results (based on their expert knowledge), as well as to validate if results are good enough to be used in regional planning/decision making.**

Concrete methods for analysis of scientific data will depend on the type of data that's being analysed. Ideally, the model results should be compared to data collected during some previous extreme weather and the average, as well as extreme deviations noted (e.g. 1% average error, with >10% error occurring in 2 % of the cells of the type X due to <specific features of the model> / <specific features of the underlying input data>). However, this may not always be possible, especially for estimating the impacts of adaptation options.

**Concrete methods for analysis of scientific data still need to be defined in cooperation of the trial teams and scientific experts.**

## 5.5 Trial Scenario formulation

Once the question of "what needs to be measured, why, and how" has been answered, the trial team must design specific activities and situations in a trial where such data can be collected. A detailed description of such situations, with definitions of all involved roles, their activities and the information exchanged is called a "trial scenario".

A rough trial scenario is already part of the trial context definition (subsection 3.4) and subsequently refined to accommodate the definitions of trial objectives, research questions and data collection plan. As explained in subsection 3.4, both the trials and the mini-trials will be organised as 1-day computer-assisted desktop exercises, and each trial will assess the overall ICARIA methodology, as well as the tools that are being developed by the project (section 4). Moreover:

- ICARIA methodology and tools will be presented to the stakeholders by dedicated team members and no attempt will be made to train the stakeholders in using them on their own during the trial run events.
    - Trial team will have to figure out how to activate the CoP members, e.g. by including the scenario alternatives and letting the CoP members decide which way to go.
- Trials will be put into a context of **compound events that are relevant to the trial region**. Ideally, both the real events that the stakeholders are familiar with, and synthetic future events according to CC projections should be addressed.
- Feedback on specific questions of interest to the project and regions will be collected through a questionnaire.
    - Questionnaires will reflect the research Questions (subsection 5.2)
    - Questionnaire results will be filled in and submitted digitally.
    - Methods for auxiliary data collection (if any) will be discussed in the context of developing the detailed trial scripts.

Finally, all three trial teams agreed that **no scientific/statistical assessment of the quality of the data and model predictions can be performed during the trial run event**. This type of assessment must be performed by the scientific team during the trial preparation, e.g. by comparing the results against the known data from the past. Results of such assessment will be presented to the CoP members, mainly to validate if the quality of the data/model outputs is sufficient for their needs. In addition, some CoP members might be able to notice implausible patterns in this data.

Overall trial run planning is the same for all three trial locations and summarised in Table 13.

**Table 13: ICARIA Trial run event organisation.**

| Slot | Duration | Activities | Comment |
|---|---|---|---|
| **1** | ½ h | Welcome and introduction:<br>- Welcome by regional problem owner<br>- Tour de table<br>- Reminder on project and event goals and agenda<br>- Remind all participants of their roles and clarify expectations | It is a good practice to let someone "higher up" in the organisation hierarchy endorse the project by opening the event. This could also be some regional politician.<br><br>Moreover, we also need to explain the event planning and expectations, instruct the CoP participants, and ensure that everyone is informed about the data collection, storage, and interpretation. Signed "Informed consent" form is a prerequisite for participants that are neither team members nor CoP members (ideally this should be collected before the event). |
| **2** | 1 h | Presenting the overall methodology of the project and collecting the first feedback. E.g.: | As indicated in section 4.3, trial teams are urged to integrate some discussion and interactive data collection in the trial run, rather than relying only on questionnaires for data collection (all presentation slots). |

| Slot | Duration | Activities | Comment |
|---|---|---|---|
| | | 1. General presentation of the climate resilience assessment process (hazards, exposed assets and their vulnerability, risk/impact vs adaptation/resilience effects and side effects/co-benefits)<br>2. Specificities of the ICARIA approach (short introduction of the applied tools).<br>3. Main observed challenges in regional implementation of the methodology and approaches/solutions to resolve them<br>4. Validation of methods and results (presenting scientific and technological validation of the data and models and interactive session for stakeholder validation, to assess with the participants the relevance of ICARIA findings against their experience and expectations) | Presentation should not take up more than half of the available time slots – the rest should be used for interaction, discussion, and group exercises (all presentation slots).<br><br>Presentation of the "scientific and technological validation" can be either added in this time slot or spread over the solution-specific slots to avoid overwhelming the audience. The main goal of this slot is to collaboratively validate solutions with respect to stakeholders needs and expectations.<br><br>Ideally, slots 2, 4, 5, 7, and 8 should all follow a common storyline that's shortly introduced here. Later presentations should refer to what's already been presented in previous ones where appropriate. |
| **3** | ½ h | break | Coffee, networking, continuing discussion in a less formal setting. |
| **4** | 1h | Interactive presentation of the RAF solution and collecting the relevant feedback, e.g.:<br><br>1. Perform an overall resilience assessment of a region, for a preliminary evaluation.<br>3. Compare resilience to different hazards.<br>4. Compare how resilience changes when actions are taken.<br>5. Overall resilience of critical infrastructure (CI) | Short introduction (what is RAF, what is it good for), followed by a live demonstration of the way the tool can be used to assess and improve regional resilience in a step-by-step fashion. Pre-recorded video presentations of this life demonstration should also be prepared, to minimise the risk of failure.<br><br>Presentation needs to be anchored in a predefined trial region specific hazard/impact/adaptation scenario (valid for all time slots). Ideally, the public should be occasionally asked to decide which action to perform next, to make the presentation more interactive (valid for all presentation slots). (See implementation plan – subsection 4.1) |
| **5** | 1h | Interactive presentation of the RAT solution, and collecting the relevant feedback. | Similar format to slot 4, just with a different tool (same for slots 7 and 8).<br><br>Due to similarities of the two solutions, initial introduction could be made for both solutions, followed by interactive presentation and discussion / data collection for each of the solutions.<br><br>A rough idea and guideline for the presentations content is the RAT implementation plan and possible scenarios – subsection 4.3) |

| Slot | Duration | Activities | Comment |
|---|---|---|---|
| **6** | 1h | Lunch break | The breaks can be moved around as necessary.<br><br>Lunch break is longer and therefore should be also used to take some group photos. Ideally, the participants should have a short walk outside the building during this break. |
| **7** | 1h | Interactive presentation of the ICARIA portfolio of adaptation solutions and collecting the relevant feedback. | This presentation should not only demonstrate how end users can work with the tool to select and prioritise adaptation measures, but also mention the ICARIA/MAIA experiment on AI-assisted production of new entries, as this may be relevant for the usability and long-term sustainability of the platform. |
| **8** | 1h | Interactive presentation of the DSS solution and collecting the relevant feedback. | • Introduction to the DSS and its main functionalities (project manager, map viewer, integrated portfolio of solutions / RAF and RAT apps)<br>• Demonstration of an impact assessment workflow with data provided by case study facilitators<br><br>The presentation will consider the regional decision-making process (who, what, how, when, why?) that the DSS is supposed to support. |
| **9** | ½ h | break | |
| **10** | 1 h | Debriefing. | • Thank everyone for participating and remind them that they need to fill in the questionnaire so that we can perform the final assessment and write down the lessons.<br><br>• Summarise the event and discuss what went well and less well. Collect feedback related to event organisation and ideas for improvements (e.g. using mentimeter[8])<br>• Explain what to expect from the mini-trial. |

**Detailed scripts for each of the time slots need to be prepared and tested by the core trial team on "dry run" meetings and the timings adjusted depending on the needs / complexity of the topics.**

[8] https://www.mentimeter.com/

While sharing the same solutions and trial run event planning, three ICARIA trials will differ mainly in the choice of hazards, assets and impacts that will be assessed in each of the trials. An overview of these scenario elements for each of the trials and mini trials is shown in Figure 7. Ideally, the trials should not just address these elements in an abstract setting but reflect on some real-world event(s) that the CoP members are well aware of. This will maximise both their interest in the trial and the usability of their feedback for the project team.

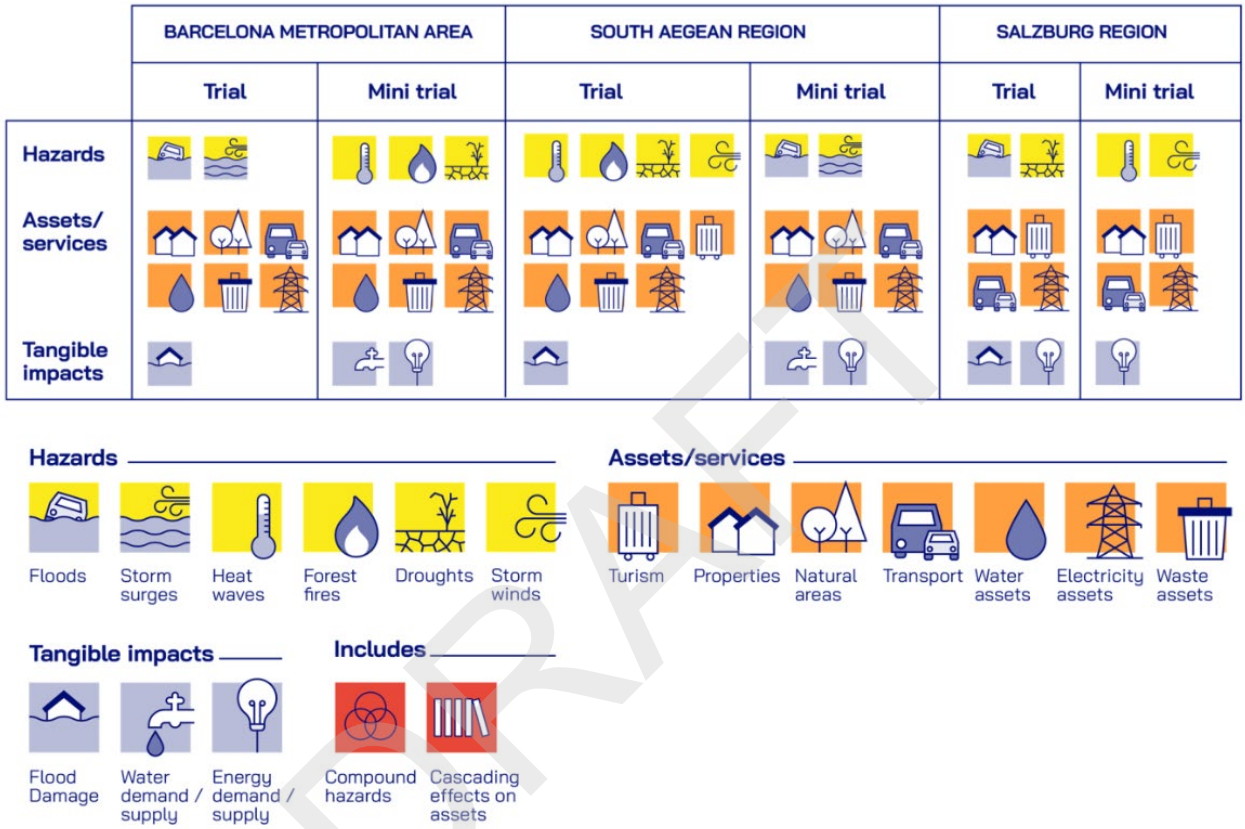


**Figure 7: Initial hazards, assets and tangible impacts to be addressed in each of ICARIA trials and mini-trials.**

Moreover, ICARIA project has the overall objective of "*promoting the definition and the use of a comprehensive asset-level modelling framework to achieve a better understanding of climate-related impacts produced by* ***complex, compound and cascading disasters*** *and the possible risk reduction provided by suitable, sustainable, and cost-effective adaptation solutions*".

Consequently, the trials will have to address the hazards and impacts in the context of complex events in addition to / rather than handling each hazard separately. Possible compound events that the project team can model, and the interest of each region in these events, is summarised in Table 14. Final decision which of the multi-hazard/combined hazard events to embed in which of the trials will be made nearer to the trial run.

**Table 14: ICARIA multi-hazard and combined hazards potentially addressed in the trial regions.**

| Compound Hazard | Description | Region | | |
|---|---|---|---|---|
| | | AMB | SLZ | SAR |
| **Pluvial flood & Storm surge** | The rise of sea level due to storm surges can result in upstream oversaturation of the drainage system, especially in case the drainage system is already strained with additional water masses due to heavy rain. Subsequently, increasing the likelihood and severity of flooding. (de la Cruz Coronas, 2023; Evans, 2024) | x | | x |
| **Fluvial flood & Extreme wind** | Extreme winds and storms can lead to an increased potential occurrence of flooding in various scenarios regarding the alteration of river flows (de la Cruz Coronas, 2023; Evans, 2024):<br>• Weakening river outflows and causing fluvial flood<br>• Storms can support or increase development of tree swamps which subsequently lead to an increase of inflow to the streams, while simultaneously decreasing the slopes stability due to the loss of soil cohesion | | x | |
| **Drought & Forest fire** | Meteorological droughts can lead to a severe increase in occurrence potential as well as severity of forest fire due to the more flammable attributes of the dried-out environment (de la Cruz Coronas, 2023). | x | | x |
| **Drought & Heat wave** | The occurrence-overlap of precipitation and heat waves results in a possible decrease of surface runoff that again can lead to or increase of severity of hydrological droughts (Hao et al., 2022) | x | x | x |
| **Heatwave & Forest fire** | ICARIA focuses on the increased severity and likelihood of forest fires due to vegetation's higher susceptibility to ignition ( de la Cruz Coronas, 2023). | x | | x |
| **Extreme wind & Forest fire** | A wildfires' spreading and intensity can be severely accelerated by extreme wind causing even more area burned and subsequently leading to more severe crown fires (Zong et al., 2023; Richardson et al., 2022). | x | | x |
| **Heat wave, Drought & Forest fire** | This scenario considers the co-occurrence of Heat wave & Forest fire and Drought & Forest fire. The increased likelihood and intensity that leads to severe potential damages and impacts of forest fire is increased by two different hazards and describes a "worst case scenario" (de la Cruz Coronas, 2023). | x | | x |

## 5.6 Solution selection

In TGM logic, the solutions already exist in some form and can be chosen for use in a trial once the previous steps have all been defined. In research project reality, this is often not the case and solutions are developed in the same project where they will be trialled and in-parallel with the trial preparation and execution,. In this context, "solution selection" must be interpreted as cross-checking of the solution specifications against the trial needs (gaps, objectives, research questions), figuring and potentially choosing which of the project solutions, or which features of solutions, to test in each of the trials rather than choosing which of the solutions to trial out of a larger solution pool. This is also the case in ICARIA. At the project start, the trial teams discussed the possibility of testing only part of the ICARIA solutions in each of the trials, but this was abandoned since all solutions are of interest to all the trials, just in a different resilience context (different hazards, different assets).

In ICARIA context, "solution selection" therefore can be understood as checking which solution features need to be tested and validated in the trials and cross-checking this against the trial objectives and research questions, The result of this work is summarised in the tables below (ICARIA RAF: Table 15, ICARIA RAT: Table 16, ICARIA portfolio of solutions: Table 17, ICARIA decision support system: Table 18). These tables are already aligned with the research questions in subsection 5.2, and a starting point for designing the solution-specific detailed trial scripts.

**Table 15: ICARIA Resilience assessment framework - key information for the trial**

| **Fact sheet: ICARIA RAF** | | | |
|---|---|---|---|
| **General** | Solution | ICARIA Resilience assessment framework | |
| | Objective | Facilitate a structured holistic resilience assessment of climate residence at regional scale against a wide variety of climate hazards and applicable to specific groups of risk receptors | |
| | Gap addressed | Need of a holistic region-scale tool to support decision making for adaptation plans and policies | |
| | Stakeholder /audience | • Experts on climate resilience assessment and developers of adaptation plans<br>• Regional authorities willing to assess the current resilience situation of their region | |
| **Trial information** | To be tested | S1-T1 | Interest of stakeholders with a tool with such characteristics |
| | | S1-T2 | Applicability of the tool to a case-study region |
| | To be validated | S1-V1 | The adequacy of the resilience assessment metrics and the structure of the tool for the needs of the regions. |
| | | S1-V2 | If the tool really helps stakeholders to identify their own resilience gaps |
| | | S1-V3 | To which extent stakeholders have the information required by the RAF to perform a full assessment |

The ICARIA Resilience assessment framework addresses the following gaps: G4, G5, G6, G7 (3.3).

**Table 16: ICARIA Resilience assessment tool - key information for the trial.**

| Fact sheet: ICARIA RAT | | | |
|---|---|---|---|
| **General** | Solution | ICARIA Resilience assessment tool | |
| | Objective | Provide a structured tool to assess the climate resilience of any critical infrastructure against any climatic hazard of interest | |
| | Gap addressed | Need for a versatile infrastructure-centred tool to assess climate residence at single asset level | |
| | Stakeholder /audience | • Owners, responsible or operators of critical infrastructure | |
| **Trial information** | To be tested | S2-T1 | Interest of stakeholders with a tool with such characteristics |
| | | S2-T2 | Applicability of the tool to specific infrastructures or group of infrastructures in a region |
| | To be validated | S2-V1 | The adequacy of the resilience assessment metrics and the structure of the tool for the needs of the regions. |
| | | S2-V2 | If the tool really helps stakeholders to identify their own resilience gaps |
| | | S2-V3 | To which extent stakeholders have the information required by the RAT to perform a full assessment |

The ICARIA Resilience assessment tool addresses the following Gaps: G1, G2 (3.3).

**Table 17: ICARIA Portfolio of adaptation solutions - key information for the trial.**

| Fact sheet: ICARIA Portfolio of adaptation solutions | | | |
|---|---|---|---|
| **General** | Solution | ICARIA Portfolio of adaptation solutions | |
| | Objective | Provide a comprehensive and structured platform for adaptation measures to define adaptation strategies adapted to specific risk receptors considering a multi-criteria analysis perspective. | |
| | Gap addressed | Need to integrate similar work done in previous EU research projects under the same framework. | |
| | Stakeholder /audience | • Experts on climate resilience assessment and developers of adaptation plans<br>• Regional authorities willing to assess the current resilience situation of their region<br>• Owners, responsible or operators of critical infrastructure | |
| **Trial information** | To be tested | S3-T1 | Interest of stakeholders with a tool with such characteristics |
| | | S3-T2 | If the classification of measures, their description and identification of associated co-benefits is actually useful for its users to develop adaptation strategies |
| | To be validated | S3-V1 | General usability of the tool from stakeholder's point of view |

The ICARIA Portfolio of adaptation solutions addresses the following gaps: G3, G7 (3.3).

**Table 18: ICARIA Decision support system - key information for the trial.**

| Fact sheet: ICARIA Decision support system | | | |
|---|---|---|---|
| **General** | Solution | ICARIA Decision support system | |
| | Objective | Provide a versatile tool, applicable to any hazard and risk receptor, to allow non-expert stakeholders to develop a full risk assessment analysis (with the support of experts in the topic) and develop adaptation strategies. | |
| | Gap addressed | Need for a comprehensive decision support system encompassing all the steps in a climate risk assessment process. | |
| | Stakeholder /audience | • Experts on climate risk and resilience assessment<br>• Regional authorities willing to assess the current resilience situation of their region<br>• Owners, responsible or operators of critical infrastructure<br>• General audience | |
| **Trial information** | To be tested | S4-T1 | Interest of stakeholders with a tool with such characteristics |
| | | S4-T2 | Match between the risk assessment approach considered in the tool and the data availability within the regions |
| | To be validated | S4-V1 | General usability of the tool from stakeholders' point of view |
| | | S4-V2 | Capacity of the DSS to assess impacts and define adaptation measures both for regional and asset level studies. |

The ICARIA Decision support system addresses the following gaps: G2, G3, G5, G6, G7 (3.3).

# 6 Conclusions and the way forwards

This deliverable is a result of initial trial planning exercise and provides the trial specifications according to the TGM methodology:

- **What operational capability gaps are addressed by the trials?**
- **What are the concrete objectives of the trials?**
- **Which specific research questions need to be resolved by the trials?**
- **What data needs to be collected during the trials (data collection plan)?**
- **How will this data be interpreted (evaluation approaches and metrics)?**
- **How will the trial runs be organised (trial context, trial scenarios)?**
- **Which solutions will be trialled?**

Overall, the TGM approach has proven to be helpful for the trial design in ICARIA, with following adaptations:

- **"Solution selection" had to be reinterpreted, as the solutions were pre-selected by the project plan.**
- **Detailed solution-specific scripts still need to be developed, mainly because the solutions are still being developed and the script needs to be aligned to actually implemented features, not to requirements or specifications.**
- **Mini-trials and demos aren't part of original Trial Guidance Methodology.**

This deliverable marks the end of the task T4.1 and the start of the task T4.2, where the trial will be executed and evaluated. Further trial-related activities in T4.2 (trial execution) and T4.3 (mini trials and demos) are summarized below.

## 6.1 Trial Execution

Similarly, to the six-step approach, the trial execution is also defined as an iterative process where all aspects of the trial are gradually assembled and tested in several preparatory meetings, before executing the final "trial event": initial trial integration meetings, two "dry runs", and the final "trial run".

**Trial integration meeting** is a kind of "trial execution kick-off" where all the people who will be involved in the trial come together and align their understandings and expectations. In addition to the trial core team and the CoP members, the scientist and developers that weren't previously involved in trial preparation are for the first time join the trial team at the integration meeting. Typically, the solution owners are asked to demonstrate their solutions (or solution prototypes) to the trial team at this meeting, while the trial owner and the core team present the trial plan to

both the solution owners and the practitioners that will participate in trial execution as testers or observers.

**Two dry runs** are used to test the technical setup of the trial and rehearse specific parts of the trial scenario.

In ICARIA, the **tool development, modelling of the future climate change scenarios and modelling of the impacts and impact-mitigation scenarios** will proceed in-parallel with the trial execution. Consequently, these three meetings will also be used to align the detailed solution-specific "scripts" that will be executed at the trial run with the progress in scientific and technological developments.

Finally, the grand finale is the trial itself, also known as the **trial run** - a final event where all the people involved in the trial come together for the second time, execute the complete trial scenario, and collect the data necessary for trial assessment. With the trial run being scheduled for m28 (April 2025), the **integration meeting needs to be scheduled in September/October 2024, and the two dry runs in November/December 2024 and February/March 2025 respectively**.

## 6.2 Trial evaluation

After the trial, the core trial team will have to analyse the data collected during the trial, answer the research questions, indicate to which extent the objectives were met and formulate the lessons learnt. This phase is governed by the rules and recommendations set up in subsection 5.4 of this document. It starts with a data quality check and continues with data analysis and data synthesis.

In terms of the data quality check, the team will first need to assess the completeness and statistical significance of the data, followed by data consistency. Some questions to ask at this stage include:

1. How many trial participants answered the questionnaires?
2. How many of them indicated that they are unable to answer some questions or didn't answer some of the questions at all?
3. How consistent are the answers to each of the questions? Do all participants roughly agree on their assessments or are there significant discrepancies?

## 6.3 Mini-trials and demos

According to TGM, the final step of the trial evolution is "dissemination of the results". One of the unintended effects of this design decision is that the final trial event often mixes the elements of trialling and dissemination and is sometimes difficult to differentiate from demonstrators. In short, the TGM tends to put too much pressure on the trial team to ensure that the trial "works",

because any negative findings will be perceived as a failure of the project by numerous guests who do not understand the difference between a trial and a demonstrator.

In ICARIA, a more structured approach is added to bridge the gap between trialling the solutions (step one - trial itself), trying to figure out to what extent these solutions can have socio-economic impacts (step 2 - mini-trials) and maximising the project impacts through the dissemination of the trial results (step three - demo).

**Mini-trials** are specific to ICARIA and do not exist in TGM, but largely follow the same methodology. As the name indicates, mini-trials feature their own objectives, research questions, data collection plans, evaluation approaches and metrics. However, the mini-trials are sufficiently similar to trials that the **trial planning can be considered a starting point for planning the mini-trials**.

With technology already being tested in trials, the mini-trials will concentrate on assessing the socio-economic impact potential of the trialled solutions and scenarios. Moreover, the mini-trials will test different strategies for mending the data gaps, as the scenarios previously tested in one trial location are transferred to new locations.

The main objectives of the mini-trials will thus be "to **assess transferability**" and "to **assess socio-economic impacts**", with related mini-trial research questions assessing the following:

1. the existence and severity of the data gaps,
2. methods for mending the discovered data gaps, and
3. the anticipated socio-economic impacts of ICARIA solutions for these regions.

Task 4.3 of the project will be specifically devoted to this matter.

Mini trials are scheduled for **M31 (July 2025), which leaves ~3 months of time for fine-tuning them based on the outcomes of the trial runs.** This will also allow us to ask the CoP members additional questions about the trials in case we couldn't satisfactorily interpret some of their answers to trial questionnaires at the trial evaluation stage.

Finally, the **demos** are designed as a tool to advertise the project results to the wider public and assess the interest in the exploitation of the project results in the follower regions. They could be organised as a "second coming of the mini trials", or as a presentation of the key findings of ICARIA trials and mini trials (e.g., we might decide to show a recording made at previous events and discuss it with demo participants). Detailed planning for demo event(s) will be made later in the project and incorporate the lessons learnt in trials and mini trials.

# 7 References

[1] Brito, R., Cardoso, M.A., Sfetsos, A., Mendes, A., Matos, R., Oliveira, A. (2024). Holistic Resilience Methods. ICARIA project Deliverable 3.2

[2] Cardoso, Maria & Telhado, Maria & Almeida, Maria & Brito, Rita & Pereira, Cristina & Barreiro, João & Morais, Marco. (2020). Following a Step by Step Development of a Resilience Action Plan. Sustainability. 12. 9017. 10.3390/su12219017.

[3] de la Cruz Coronas, (2023). Holistic modelling framework for multi-hazard events. ICARIA project Deliverable 2.1

[4] de la Cruz Coronas, A., Molina, P., Zarikos, I., Bügelmayer-Blaschek, M., Lavasa, A. (2024). WP3 testing results. ICARIA project Deliverable 3.6

[5] Evans, B. (2024). Multi-hazard scenario building methods. ICARIA project Deliverable 2.2

[6] Fonio, C., Widera, A. (Ed.) Trial Guidance Methodology Handbook. DRIVER+ (Driving Innovation in Crisis Management for European Resilience), Brussels, 2020.

[7] Fonio, C., Widera, A., & Zwęgliński, T. (Eds.). (2023). *Innovation in Crisis Management*. London, UK: Routledge.

[8] Hao, Z., Hao, F., Xia, Y., Feng, S., Sun, C., Zhang, X., ... & Meng, Y. (2022). Compound droughts and hot extremes: Characteristics, drivers, changes, and impacts. Earth-Science Reviews, 235, 104241.

[9] Hidalga, M.G., Rodriguez, A.C. (2024). Portfolio of adaptation solutions. ICARIA project Deliverable 3.3

[10] IAEA (2015). Risk informed approach for nuclear security measures for nuclear and other radioactive material out of regulatory control, Implementing Guide, NSS No. 24-G, IAEA Vienna.

[11] IPCC, 2019: Annex I: Glossary [Weyer, N.M. (ed.)]. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In Press

[12] Leitner, M., Dworak , T., Johnson , K., Capela Lourenço , T., Lexer , W., Vanneuville , W., Tamasova , A., & Prutsch , A. (2021). Using Key Type Measures to report climate adaptation action in the EEA member countries.

[13] MYRIAD. (2022). Deliverable 1.2 - Handbook of Multihazard, Multi-Risk Definitions and Concepts. Project MYRIAD, grant agreement number 10100327.

[14] Richardson, D., Black, A. S., Irving, D., Matear, R. J., Monselesan, D. P., Risbey, J. S., ... & Tozer, C. R. (2022). Global increase in wildfire potential from compound fire weather and drought. NPJ climate and atmospheric science, 5(1), 23.

[15] Sharifi, A. (2016). A critical review of selected tools for assessing community resilience. Ecological Indicators. 69 (2016), 629-647. 10.1016/j.ecolind.2016.05.023.

[16] Turchi, A., Tedeschi, A., Bügelmayer, M., Sfetsos T., de la Cruz Coronas, A., Havlik. D. (2023a) Stakeholder engagement plan. ICARIA project Deliverable 5.4 https://www.icaria-project.eu/?sdm_process_download=1&download_id=1833

[17] Turchi, A., Tedeschi, A., Leone, M.F., De Gregorio, D., Zuccaro, G., de la Cruz Coronas, A., Bügelmayer-Blaschek, M., Zarikos, I. (2023b). Holistic modelling framework. ICARIA project Deliverable 1.1

[18] Wenger-Trayner, E. and Wenger-Trayner, B. (2015) *An introduction to communities of practice: a brief overview of the concept and its uses*. Available from authors at https://www.wenger-trayner.com/introduction-to-communities-of-practice.

[19] Zong, X., Yin, Y., Yin, M., Hou, W., Deng, H., & Cui, T. (2023). Occurrence and hotspots of multivariate and temporally compounding events in China from 1961 to 2020. NPJ Climate and Atmospheric Science, 6(1), 168.

# Annex 1: Data Management Statement

**Table A1.1.** Data used in preparation of ICARIA Deliverable 4.1

| Dataset name | Format | Size | Owner and re-use conditions | Potential Utility within and outside ICARIA | Unique ID |
|---|---|---|---|---|---|
| **Trial Guidance Methodology** | PDF | 11.938 KB | DRIVER+ consortium / Open Source / https://www.driver-project.eu/wp-content/uploads/2020/02/TGM-handbook-FINAL.pdf | Guidelines and Methodology on Trial planning, execution and validation | FP7, No607798, 2014-2020 |

**Table A1.2.** Data produced in preparation of ICARIA Deliverable 4.1

| Dataset name | Format | Size | Owner and re-use conditions | Potential Utility within and outside ICARIA | Unique ID |
|---|---|---|---|---|---|
| **Initial Trial Design** | D4.1. | 5.82 MB | ICARIA Consortium | Design for validating tools and solutions in the context of climate change. | |

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