D4.1 Technology Support Plan

WP4 - Technology Support

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Table of Contents

List of Figures

CLARITY Project Overview

Urban areas and traffic infrastructures that are linking such areas are highly vulnerable to climate change. Smart use of existing climate intelligence can increase urban resilience and generate benefits for businesses and society at large. Based on the results of FP7 climate change, future internet and crisis preparedness projects (SUDPLAN, ENVIROFI, CRISMA) with an average TRL of 4-5 and following an agile and user-centred design process, end-users, purveyors and providers of climate intelligence will co-create an integrated Climate Services Information System (CSIS) to integrate resilience into urban infrastructure.

As a result, CLARITY will provide an operational eco-system of cloud-based climate services to calculate and present the expected effects of CC-induced and -amplified hazards at the level of risk, vulnerability and impact functions. CLARITY will offer what-if decision support functions to investigate the effects of adaptation measures and risk reduction options in the specific project context and allow the comparison of alternative strategies. Four Demonstration Cases will showcase CLARITY climate services in different climatic, regional, infrastructure and hazard contexts in Italy, Sweden, Austria and Spain; focusing on the planning and implementation of urban infrastructure development projects.

CLARITY will provide the practical means to include the effects of CC hazards and possible adaptation and risk management strategies into planning and implementation of such projects, focusing on increasing CC resilience. Decision makers involved in these projects will be empowered to perform climate proof and adaptive planning of adaptation and risk reduction options.

Abbreviations and Glossary

A common glossary of terms for all CLARITY deliverables, as well as a list of abbreviations, can be found in the public document "CLARITY Glossary" available at http://cat.clarityCLARITY-h2020.eu/glossary/main.

Abbreviation/Acronym	Definition
ADM	Architecture Development Method
AJAX	Asynchronous JavaScript and XML
BB	Building Block
C3S	Copernicus Climate Change Services
CC	Climate Change
CCA	Climate Change Adaptation
CERN	Conseil Européen pour la Recherche Nucléaire
CKAN	Comprehensive Kerbal Archive Network
CLARITY	Integrated Climate Adaptation Service Tools for Improving Resilience Measure
Climate-ADAPT	European Climate Adaptation Platform
COSMO-CLM	COnsortium for Small-scale MOdelling - Climate Local Model
CRISMA	Modelling crisis management for improved action and preparedness
CS	Climate Service
CSIS	CLARITY Climate Services Information System
CSS	Cascading Style Sheets
CSV	Comma Separated Values
CSW	Catalogue Service for the Web
CTA	Constructive Technology Assessment
DC	Demonstration Case
DC	Dublin Core
DEM	Digital Elevation Model
DM	Decision Maker
DMP	Data Management Plan
DOI	Digital Object Identifier
DOM	Document Object Model
DRR	Disaster Risk Reduction
DWD	Deutscher Wetterdienst
EC	European Commission

ECA&D	European Climate Assessment & Dataset
ECMWF	European Centre of Medium-Range Weather Forecasts
ECW	Enhanced Compression Wavelet
EEA	European Environment Agency
EGI	European Grid Infrastructure
ERDDAP	Environmental Research Division's Data Access Program
EU-GL	Non-paper Guidelines for Project Managers: Making vulnerable investments climate resilient (Document)
EU-MACS	European Market for Climate Services
GDAL	Geospatial Data Abstraction Library
GeoJSON	geographical JavaScript Object Notation
GEOSS	Global Earth Observation System of Systems
GeoTIFF	Geographic Tagged Image File Format
GML	Geography Markup Language
GPS	Global Positioning System
GPX	GPS Exchange Format
HTML5	Hypertext Markup Language, version 5
HTTP	Hypertext Transfer Protocol
ICMS	Integrated Crisis Management Middleware
ICT	Information and Communication Technologies
IPCC	Intergovernmental Panel on Climate Change
JSON	JavaScript Object Notation
MCDA	Multi-Criteria Decision Analysis
MUKLIMO_3	Mikroskaliges Urbanes Klimamodell 3D
NetCDF	Network Common Data Format
NGO	Non-Governmental Organization
OAI-PMH	Open Archive Initiative – Protocol Metadata Harvesting
OGC	Open Geospatial Consortium
OGR	OpenGIS Simple Features Reference Implementation
OpenAIRE	Open Access Infrastructure for Research in Europe
OpenDAP	Open-source Project for a Network Data Access Protocol
PDF	Portable Document Format
PHP	PHP Hypertext Preprocessor
RDBMS	Relational Database Management System

REST	Representational State Transfer
RIA	Rich Internet Application
SMS	Scenario Management System
SOS	Sensor Observation Service
SPA	Single Page Application
SPS	Sensor Planning Service
SQL	Structured Query Language
SUDPLAN	Sustainable Urban Development Planner for Climate Change Adaptation
SWICCA	Service for Water Indicators in Climate Change Adaptation
TC	Test Case
TOGAF	The Open Group Architecture Framework
TRL	Technology Readiness Level
UN	United Nations
uncertML	Uncertainty Markup Language
UrbanSIS	Climate Information for European Cities
US	User Story
WFS	Web Feature Service
WMS	Web Map Service
WMTS	Web Map Tile Service
WP	Work Package

Executive Summary

This report is the first deliverable of WP4 "Technology Support" of the CLARITY project, funded by the EU's Horizon 2020 Programme under Grant Agreement number 730355. WP4 intends to provide the technological backbone of the CLARITY Climate Service Information System (CSIS) by tailoring the technological background foreseen in the CLARITY work package descriptions to project needs. For this, WP4 will integrate and adapt all required and existing (background) tools and services that are necessary for realisation of the CLARITY reference scenarios (Demonstration Cases) and implementation of the EU-GL [1] into the CLARITY Climate Services.

The aim of this deliverable is to provide an initial plan for the WP4 work per task, taking into account the input from D1.1 "Initial Workshops and the CLARITY Development Environment" [2]:

- T4.2 "Catalogue of elements at risk and adaptation options" provides a catalogue that will serve as repository of element at risk types and adaptation options and a dedicated Catalogue of Data Sources and Simulation Models that makes climate-related information accessible and discoverable.
- T4.3 "Scenario Management" will offer the Scenario Management tool which supports and enforces first and foremost the standardised workflows of the EU-GL [1] for each of the distinct planning steps, a Data Dashboard that provides an overview of all the different datasets that are used, produced, ordered, collected, requested, exchanged etc. by an end user and a Data Package Export and Import Tool for exporting any data that is directly available in the CSIS.
- T4.4 "Scenario Transferability" provides a Map Component for clear and easy visualization of different maps and layers as well as the Scenario Transferability Component that offers general matchmaking functionality by means of graphical user interfaces (e.g. map visualisations) for side-by-side comparison of alternate (adaptation) scenarios.
- T4.5 Scenario Analysis, Decision Support and Report Generation provides software that will support the analysis and comparison of scenario candidates (options) regarding performance indicators that can be defined by the end user.

Detailed information for each of the WP4 tasks is provided as a separate section in this document. Annex 1 also provides an overview of the tools that are inherited from previous projects and explains the initial plan for using and/or extending these inputs in CLARITY.

1   Introduction

The introduction chapter defines the purpose and scope of the current version of the Technology Support Plan and briefly explains the structure of the document.

1.1   Purpose of this document

The main goal of this document is to provide an initial Technology Support Plan for the high-level CSIS Architecture and the overall CLARITY Product Vision that have been identified during the three initial stakeholder workshops organised by WP1 "Co-Creation". This initial plan encompasses on the one hand a critical assessment of the background technologies inherited from former Research & Development projects regarding their principal suitability for the implementation of the envisaged innovative products and services and on the other hand an assessment of market-ready open source technologies and software components that can fill the gaps of essential background technologies not considered in the initial CLARITY work plan or supplement initially foreseen background that does not offer a sufficient level of technological readiness or fitness for purpose.

1.2   Intended audience

The target readers of this document are mainly technical partners in charge of the Climate Service integration and development in WP1 "Co-Creation" and WP4 "Technology Support", the stakeholders of the four CLARITY Demonstration Cases in WP2 "Demonstration & Validation" that represent the Climate Service Customer perspective and the purveyors and climate data providers that represent the Climate Service Supplier perspective in the overall co-creation process.

1.3   Structure of the document

The structure of the document and the relationships between the different chapters is as follows:

Chapter 1 (this chapter) introduces the document and explains the overall purpose of this document and its relation to other work packages and deliverables.

Chapter 2 gives a brief overview on the concepts of the CLARITY CSIS Architecture, describes the approach that was followed to provide technology support for CLARITY Climate Services and summarises the overall results of this deliverable.

Chapters 3, 4, 5, 6 and 7 provide a synthetic overview on the level of technology support to be provided in relation to CLARITY tasks and the respective Building Blocks identified on basis of user and exploitation requirements.

Chapter 8 provides the conclusions and a summary on follow-up activities in other work packages.

Annex 1 gives a brief overview on the tools and technologies that are inherited from previous projects and explains the initial plan for using and/or extending these inputs.

2   CSIS Architecture, approach and results

To make this report a self-contained document, the architectural foundations of the CSIS defining the scope of CLARITY Climate Services and the role of Building Blocks in the co-creation process as well as the approach that was followed to identify Building Blocks and their requested functionality are briefly explained.

2.1   CSIS Architecture

This chapter intends to provide a brief summary on the basic properties and general concepts of the CLARITY CSIS Architecture that are essential for the understanding of the assumptions, conclusions, and suggestions provided in this document. The architecture is described in detail in CLARITY deliverable D4.2 "CLARITY CSIS Architecture" [3]. The architecture document intends to establish a shared understanding among all CLARITY stakeholders about the overall goals of the CSIS Architecture and the essential design decisions and architectural principles to realise these goals. It is therefore in general recommended to read the architecture document as it explains also relationship between CSIS Architecture and the CLARITY Demonstration Cases as well as CLARITY's approach towards data harmonisation and interoperability.

2.1.1   The CSIS in a nutshell

The overall role of the CSIS is "to bridge the gap from supply driven (Upstream) Climate Services to demand driven (Downstream) Climate Services by offering (partially) free basic and generic ICT Climate Services and to help end users to identify and discover their need for fit-for-purpose commercial Expert Climate Services" [3]. Thereby, it leverages the integration of new and available ICT Climate Services into a co-creation environment that allows Climate Service Customers and Climate Service Suppliers to create fit-for-purpose and tailored Climate Services under the umbrella of a scientifically sound conceptual methodology (EU-GL) for Climate Change Adaptation Assessment.
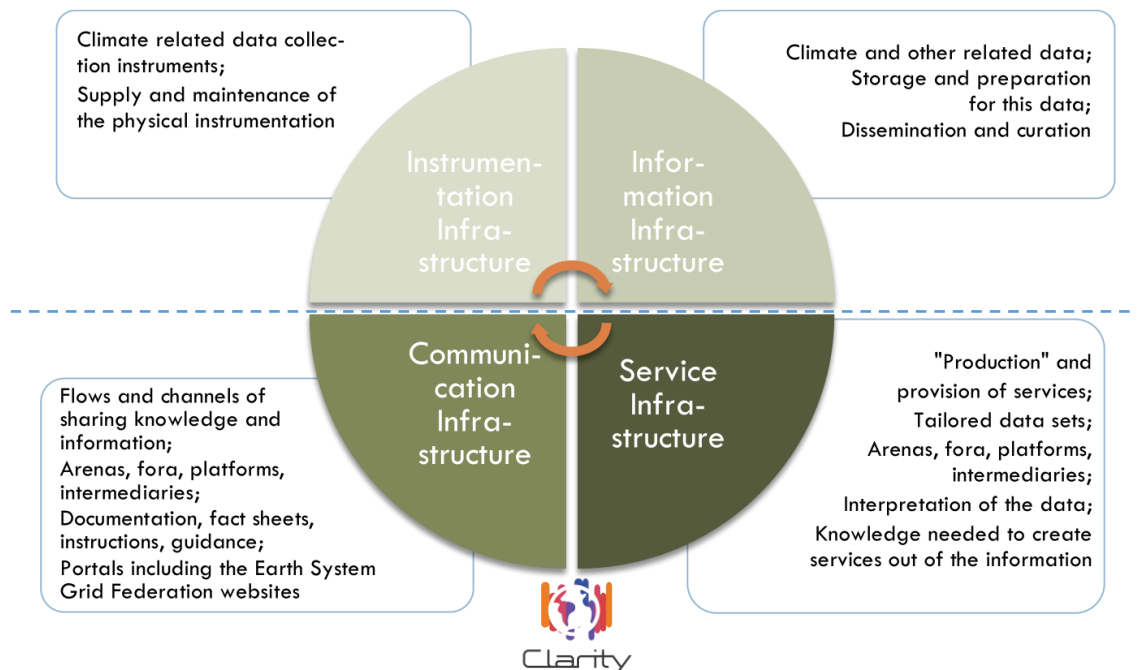
Figure 1: Climate Service Infrastructure Dimensions applied to CLARITY [4]

When put in context of CLARITY's "sister project" EU-MACS [4], the CSIS fits best into the Communication Infrastructure and Service Infrastructure dimensions of Climate Services as shown Figure 1.

Though, the aim of the CLARITY CSIS is not to establish an entirely universal and all-encompassing Climate Service infrastructure. As EU-MACS deliverable D1.3 "Analysis of existing data infrastructures for climate services" [4] pointed out "Since the degree of data organisation in climate services and neighbouring areas are far from being fully established, an enormous effort is required before it is entirely fit for purpose by specific users" and "…it might be hard to develop a universal yet single solution covering all infrastructure dimensions that serves the user community effectively. Striving for this single solution may in fact lead to an overly complex structure making the interface at the end even less user-friendly." Nonetheless, CLARITY's Exploitation Requirements demand at the same time a "user-friendly, intuitive and context-aware discovery and communication infrastructure for Climate Services" as well as "commercial fit-for-purpose tailored Climate Services targeting specific sectors and user groups" [3]. To meet this challenge of apparently conflicting requirements, the CSIS puts the co-creation ("T1.3 Climate Services Co-creation") and Marketplace (T5.4 "Climate Service Marketplace") aspects upfront and builds upon two types of Climate Services: generic **ICT Climate Services** and tailored **Expert Climate Services**.

ICT Climate Services

ICT Climate Services are **(partially) free, simple, ready to use, online ICT tools (software)**. Thereby, most complexity is hidden from the end-user to provide an easy-to-use product, for which no or just minimal knowledge of climate change science or technical skills is needed. Such basic services should not depend on costly site-specific modelling, high performance computing or expensive local high-resolution climate data. Instead, they can compromise temporal and spatial resolution as suggested in EU-MACS D1.3 [4] and rely on freely available data and model outputs. Initially, they will only cover the first step in developing an overall adaptation strategy on the basis of commercial and tailored Expert Climate Services (consultancy, advisory, modelling and development), hence performing a pre-feasibility analysis as anticipated by the EU-GL methodology (high-level application of EU-GL Modules). This will be extended by paid features (freemium model) such as usage of high-resolution climate data in the later stage of development. However, the ICT Climate Services are not meant as complete replacement for a detailed climate risk assessment and adaptation study according to the EU-GL methodology.

Expert Climate Services

An Expert Climate Service is an **individual and professional consulting and advisory service[1]** that can be provided as joint venture activity of operational, technical and industry specialists. It can be considered a tailored and fit-for purpose "micro" Climate Service that is co-created according to individual user needs and thus a commercial service that users are willing to pay for. Consequently, it may involve highly customised activities such as sector- , project- and site-specific analysis, custom data and model integration, site-specific numerical modelling and so on. If disseminated via the CSIS, such Expert Climate Services must be provided according to specific rules and guidelines that are set out for the one part in the CLARITY Modelling Methodology and for the other part in technical specifications that allow integration with the CSIS.

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[1] In other words, the CLARITY CSIS will only provide support for requesting such service from an expert and uploading the results. Support software like local models that is needed to perform such service does not need to be (technically) integrated in CSIS nor accessible through it.

	Generic	Customised
Focused	**Maps & Apps:** • Generic climate services • Freely or cheaply available … • … to all users	**Expert Analysis:** • Scientific, professional, commercial, monodisciplinary climate services • Tailored to specific decisions and decision-makers
Integrated	**Sharing Practices:** • Mutual services on … • … adapting and mitigating climate change in specific environments • Available to all users	**Climate-inclusive Consulting:** • Professional, commercial and … • … transdisciplinary climate services • Tailored to specific decisions and decision-makers

Figure 2: CTA Scenario Core Characteristics applied to CLARITY [5]

The EU-MACS Constructive Technology Assessment (CTA) workshops identified in D1.4 "A multi-layer exploration on innovations for climate services markets" [5] four scenarios for implementing climate services into institutional/organizational context in different socio-technical formats (Figure 2). Thereby, the customisation dimension distinguishes between tailored or generic services and the integration dimension between specialized services or services integrated in a broader package like Disaster Risk Reduction (DRR).

CLARITY's concept of generic and focused ICT and integrated and customised Expert Climate Services fits perfectly into these scenario definitions: ICT Climate Services correspond to EU-MAC's "**Maps & Apps**" and Expert Climate Services to "**Climate-inclusive Consulting**" service implementation scenarios.

2.1.2   The CSIS Architecture in a nutshell

The CSIS Architecture is separated into an Explicit and Emergent Architecture with an additional Transition Layer in between (Figure 3).
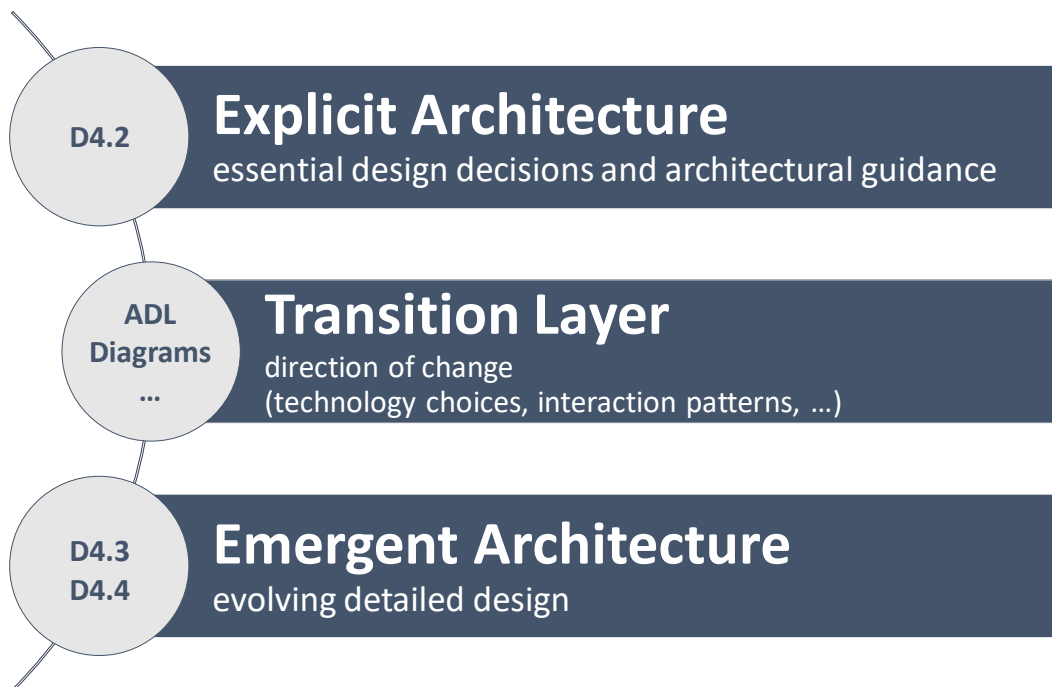
Figure 3: Transition between Explicit and Emergent Architecture [3]

The Explicit Architecture defines those architecturally significant design decisions that bear the most impact and cost of change and thus have been made early before the actual product implementation. Thereby it establishes the concepts the mission and the realisation of the CSIS. The mission of the CLARITY CSIS represents the goals, architectural qualities and -constraints, which have been derived from the project objectives, the elicitation and evaluation of Exploitation Requirements (D5.1 "Exploitation Requirements and Innovation Design" [27]) and during stakeholder workshops (D1.1 "Initial Workshops and the CLARITY Development Environment" [24]). The concepts relate to the conceptual specification of CLARITY products and services (Innovation Design) and the general principles that are used to design and implement the CSIS. This Conceptual Innovation Design consists of high-level specifications of conceptual product and service types as well as the related integration and dissemination platforms. The realisation on the other hand explains how the architectural concepts and principles introduced are applied to realise the goals formulated in the mission of Explicit Architecture. In particular, it presents the Building Blocks of the CSIS that interact in a layered and component based architecture and thus is covered by the Technology Support Plan.

The Emergent Architecture serves the purpose of documenting communicating the evolving and non-critical (less architectural significant) detailed design and the related artefacts like technology choices, Mock-Ups, Test Cases, source code and others. The Technology Support Plan, by providing recommendations and preliminary choices for technologies and software components, represents thereby an important part of the Emergent Architecture.

The absence of detailed product specifications, which is inherent to the agile development approach followed by CLARITY, requires some degree of flexibility in the planning process and may involve some contingencies. Although the realisation of the CSIS belongs to the Explicit Architecture, some details can therefore not be decided upfront and are deferred to the Transition Layer. The main role of Transition Layer is to keep the shared understudying of all stakeholders expressed in the Explicit Architecture aligned with the rather technical and near-to-development viewpoint of the Emergent Architecture. It anticipating expected changes (knowing the "direction of change" [17]) while preserving the invariant "essence of the system" [17].

2.2 Approach

The main input for developing the initial Technology Support Plan comes from results of the project-internal discussions in the first six project months and the resulting common "Product Vision" and "User Stories" of the four CLARITY Demonstration Cases that were developed in this period and documented in D1.1 "Initial Workshops and the CLARITY Development Environment" [2]. Since D1.1 merely represents a snapshot in the project development, not a final list of product requirements or specifications, the Technology Support Plan must be continuously improved and adapted to meet new demands arising not only from stakeholder requirements but also from business and market conditions. WP1 "Co-Creation" and WP4 "Technology Supports" pursue therefore a common and concerted methodological approach that is explained in the following.

The common CLARITY "Product Vision" that is presented in D1.1 and that is the basis for the architecture outlined in chapter 2.3 of this document and specified in detail in D4.2 "CLARITY CSIS Architecture" [3] addresses the core business processes and functionalities of the CLARITY Climate Services Information System (CSIS). These business processes relate to the general implementation of the methodology of the "Non-paper Guidelines for Project Managers: Making vulnerable investments climate resilient" [1] (EU-GL) that has been refined and improved according to the IPCC-AR5 framework [6] in the D3.1 "Science Support Plan" [7].

> In the context of the CSIS Architecture, the general support of the EU-GL methodology is realised by the CSIS itself and a set **ICT Climate Services** which are generic in their nature and can be considered according to EU-MAC's "**maps & apps** climate service scenario" [3] as **products** offered by CLARITY.

The CLARITY "User Stories", presented in D1.1 "Initial workshops and the CLARITY development environment" [2] and further refined and completed in D1.2, "Database of Initial CLARITY CSIS User Stories and Test Cases" [8], represent for their largest part the key user requirements that are specific to the implementation of the four CLARITY Demonstration Cases in WP2 "Demonstration & Validation". They demand for site-specific (Expert) Climate Services in different climatic, regional, infrastructure and hazard contexts, focusing on the planning and implementation of urban infrastructure development projects. Demonstration Cases are realised as a combination of tailored Expert Climate Service which in turn base on the CSIS as the central co-creation environment and on supporting generic ICT Climate Services provided through the CSIS. Interestingly, supporting ICT Climate Services will also encompass external Climate (Data) Services (e.g. common and sectoral Copernicus Climate Change Services) offered or advertised though the CSIS.

> In the context of the CSIS Architecture, the assessment of highly customised and site-specific adaptation scenarios following the EU-GL methodology is realised by **Expert Climate Services** which are tailored in their nature and can be considered according to EU-MAC's "**climate inclusive consulting** climate service scenario" [3] as **services** offered by CLARITY.

The ability to provide tailored climate advice by means of Expert Climate Services relies, at least in part, also on the availability of fit-for-purpose ICT Climate Services. Accordingly, science- as well as technology support have to be provided mainly for the implementation of CLARITY ICT Climate Services.
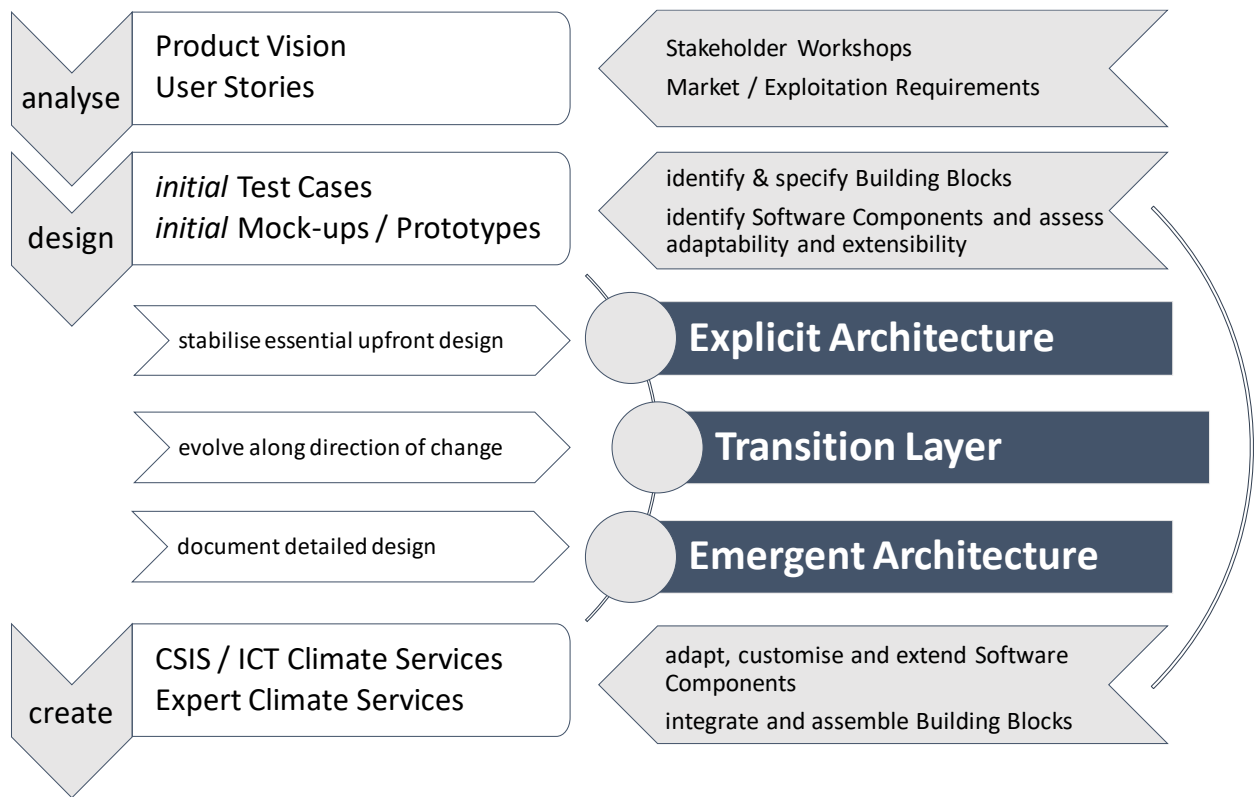
Figure 4: CLARITY product development phases and related activities [3]

As shown in Figure 4, the concerted methodological approach for providing technological (IT) support for the (co-)creation of Expert and ICT Climate Services takes place in the design and create phases of the overall product development. The current focus is on the design phase. The approach builds upon the key concepts of Business Processes Models, User Stories, Test Cases, Prototypes and Mock-Ups, Exploitation Requirements, Datasets, Building Blocks and (background) Software Components. Not shown in Figure 4 are the different feedback loops that drive the agile process regarding prototyping and development based on continuously updated user and business requirements.

User Stories and Test Cases have been introduced in T1.2 "Climate Service Requirements" while Building Blocks and Software Components are a central concept of T4.1 "CLARITY CSIS Architecture". Business Processes, Test Cases and Prototypes are in turn used in T1.3 "Climate Services Co-creation" to leverage the actual co-development of products and services.

Each of the concepts is represented as distinct item in the CLARITY coordination platform (http://cat.clarityCLARITY-h2020.eu/). Figure 5 provides a complete overview on the concepts, their input / output relationships and their relation to the respective work packages.

The key concepts are briefly explained in the following:

- **Business Processes Models**
  Business Processes Models were used to elicit core business processes of the CSIS related to co-creation, dissemination and exploitation of tailored Expert Climate Services with help of generic ICT Climate Services in the scope of the EU-GL methodology. Their most notable influence on the Explicit Architecture was to clarify the role of ICT- and Expert Climate Services regarding their value proposition in a general ecosystem of Climate Services.

- **User Stories**
  The CLARITY "User Stories", introduced in D1.1 "Initial Workshops and the CLARITY Development Environment" [2] and further refined and completed in D1.2 "Database of Initial CLARITY CSIS User Stories and Test Cases" [8], represent informal descriptions of the key (user) requirements on (mainly Expert) Climate Services expressed from the viewpoint from users that intend to perform site-specific climate change adaptation assessments.

- **Test Cases**
  Test Cases are the counterpart to the Business Processes Models and User Stories. They specify possibilities for implementing the business processes or resolving the User Stories and linking the business and user requirements with the data, models and components (Building Blocks) that shall actually be produced or used in the project.

- **Prototypes and Mock-ups**
  Prototypes and Mock-Ups are a powerful agile instrument for collecting early feedback from end users by offering a visual preview of the envisaged products and services. Moreover, Mock-Ups can serve as a blueprint for user interface design and help agile software teams to recognize further functional requirements (functionality to be provided by Building Blocks) as well as non-functional requirements (quality attributes of the overall system) that haven't been considered in User Stories and Test Cases.

- **Exploitation Requirements**
  An Exploitation Requirement is a requirement that must be met to allow for a successful exploitation of the project's results. A technology-focused assessment of Exploitation Requirements has led to a set of functional and technical requirements on Building Blocks that must be considered during product design and implementation.

- **Building Blocks**
  A Building Block is a generic, composable, adaptable as well as domain- and location-independent unit of functionality (component) that meets the identified business and user requirements by implementing a set of related functional requirements. Products and services are a composition of interacting Building Blocks.

- **Software Component**
  A Software Component is a concrete IT service, tool, system or model that is suitable for the realisation of a Building Block. It can be adapted, customised or configured to provide the functionality defined by a Building Block.

- **Dataset**
  A Dataset description provides information on used and produced data according to the requirements of the CLARITY Data Management Plan [9].
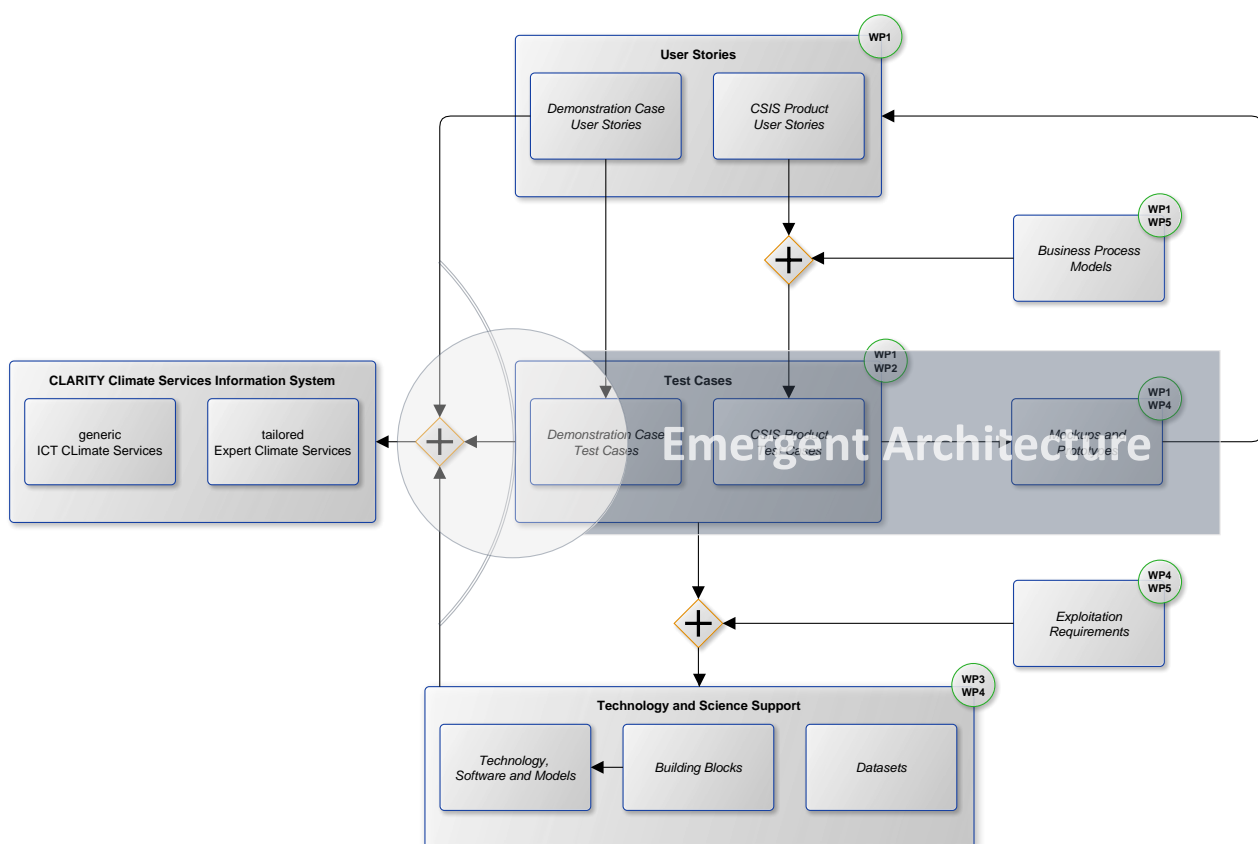
Figure 5: Relationships between Key Concepts and Work Packages [3]

In summary, WP4 "Technology Support" is responsible for the identification and provision of technical capabilities and functionalities by means Building Blocks that can be used for the development of Climate Services (with help of Test Cases) on basis of user and business requirements (documented in User Stories and Business Process Models).

2.3 Results

Following the approach laid out in the previous section (2.2), the level of technology support needed to co-develop the core CSIS infrastructure and ICT- and Expert Climate Services is being collected and discussed in the CLARITY coordination platform by means of Building Blocks and Technology and Software Descriptions.

This information, once stabilised and validated during development and by end users, can be made public as annex to WP4's Technology Support Reports (D4.3 and D4.4).

In the present Technology Support Plan, the intermediate results of this ongoing process are presented in a brief but nevertheless concise manner. The presentation format (Figure 6) used in this report is centred on the identified Building Blocks and allows therefore to quickly gain an overview on the relationship between currently requested functionality and (background) technology and software that can be used to provide or implement this functionality.
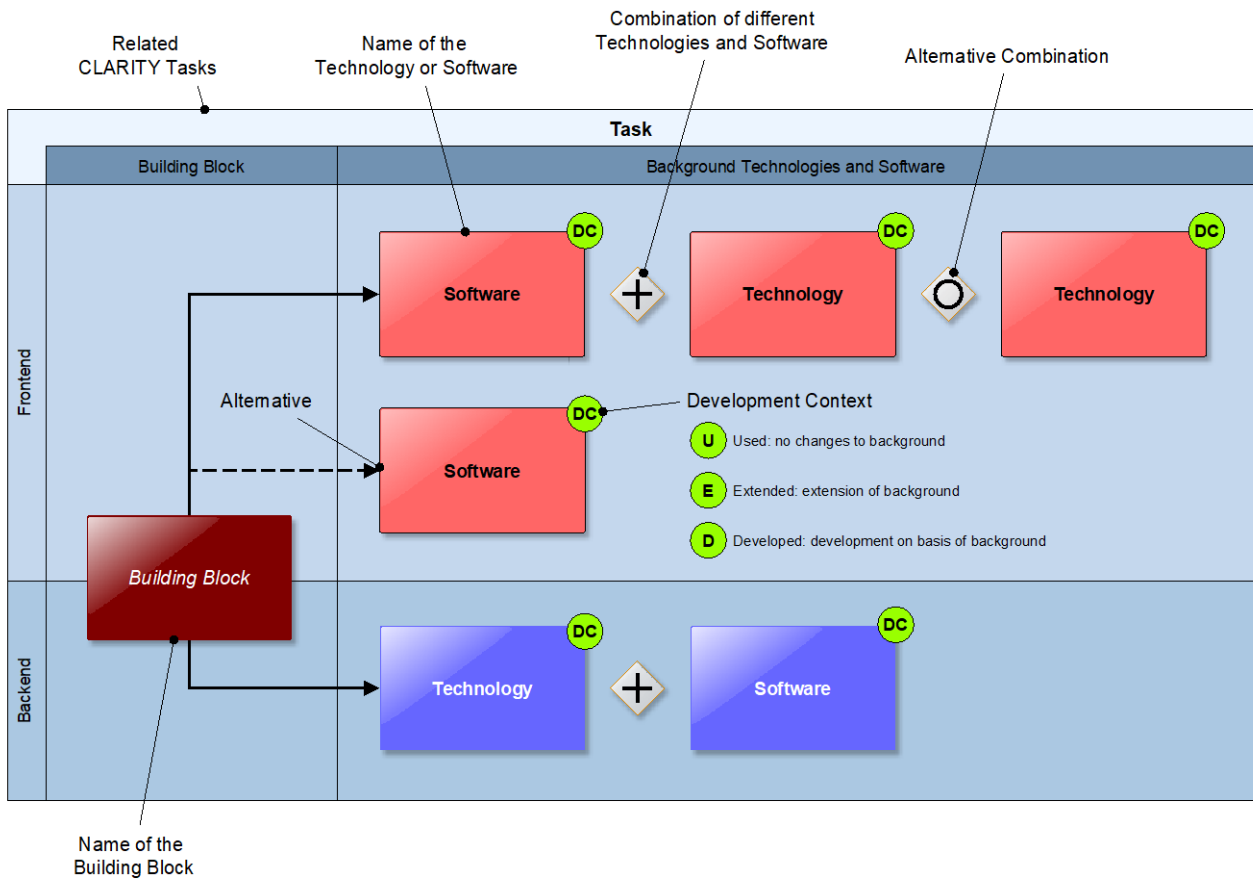
Figure 6: Technology Support Plan Overview Diagram

Figure 7 gives on overview on all Building Blocks that currently participate in the CSIS Architecture with respect to their thematic cluster (task). For each of those Building Blocks, a summary of the individual Technology Support Plans according to the presentation format explained in Figure 6 is provided in the subsequent chapters of this document.
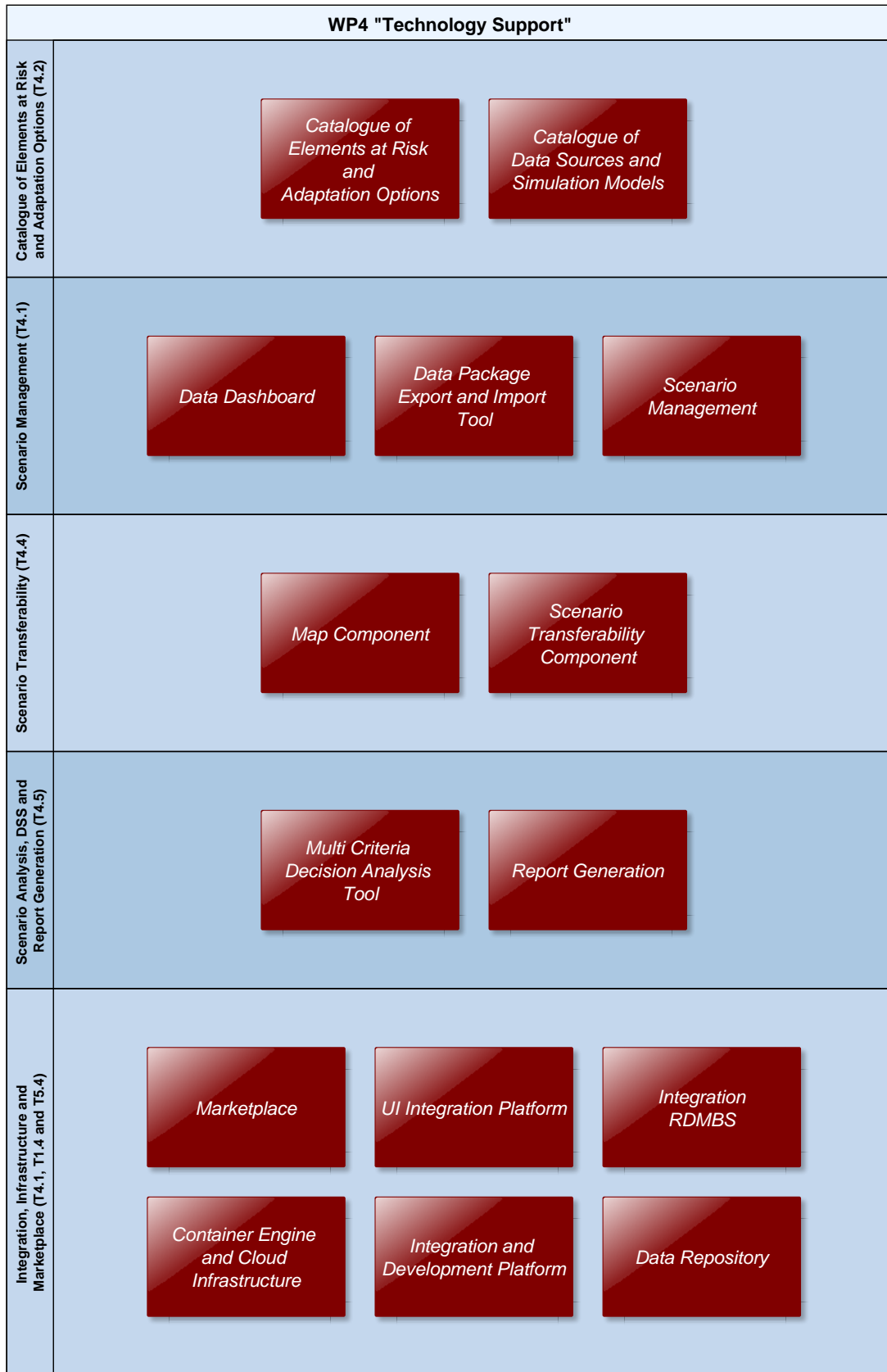
Figure 7: CSIS Architecture Building Blocks

During technology and software selection, the following main criteria to guarantee the long-term sustainability, extensibility and maturity of the CSIS and the CLARITY ICT Climate Services have been taken into account:

- fitness for purpose of the background software or technology in relation to baseline and requested functionality
- Technology Readiness Level (TRL) of the background technology or software, it's stability and dissemination level (number of products or end users)
- availability of the background technology or software under an open (source) license
- possibility to customise the background technology or software and adapt it to CLARITY needs (open source, configuration options, etc.)
- availability of high quality documentation, guidelines and case studies
- an active community of users and developers and/or the possibility to obtain professional support
- technical expertise in the CLARITY consortium to use, configure and adapt background technology or software

In this regard, Building Blocks are assigned to five thematic clusters (Figure 7) and equivalent CLARITY tasks to allow work package leaders to monitor responsibilities and planned effort and task leaders to coordinate development activities. The Technology Support Plan at Building Block level in conjunction with the respective User Stories and Test Cases serves thereby as the "Product Backlog", which is in its simplest definition "a list of all things that needs to be done within the agile product development cycle" [10].

While the section on technology support explains to a certain degree also the general interactions between the different Building Blocks, no dedicated interaction diagrams are provided. This is an architectural aspect and will thus be reported in the first revision of the Emergent Architecture in D4.3 "Technology Support V1".

3 Catalogue of elements at risk and adaptation options (T4.2)

Figure 8 provides an overview of the Building Blocks that are covered byT4.2.
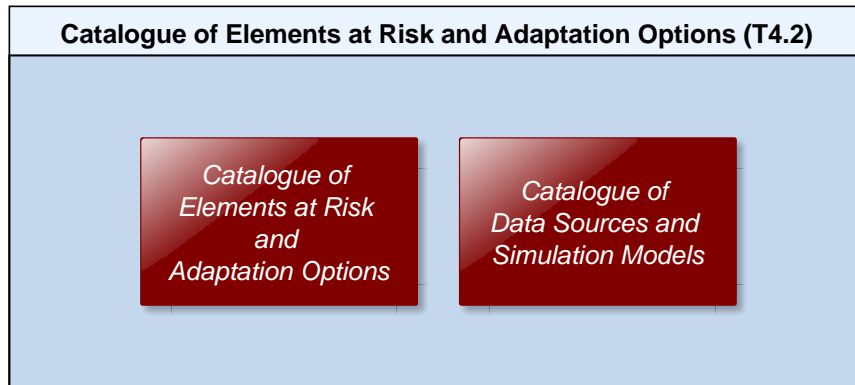
Figure 8: T4.2 Building Blocks

According to the CLARITY Work plan, Catalogue of Elements at Risk and Adaptation Options will serve as repository of element at risk types and adaptation options. It will allow users to link the vulnerability of elements at risk to key hazards and indicate[2] the applicability, impact, implementation price and time needed for implementation of different adaptation options for different element at risk/hazard combinations. Furthermore, there is also need for a related Catalogue of Data Sources and Simulation Models as requested in T2.2 "Demonstrator-specific data collection" and CLARITY's Data Management Plan [9].

3.1 Catalogue of Elements at Risk and Adaptation Options

The Catalogue of Elements at Risk and Adaptation Options is strongly linked to the EU-GL modules/steps "Characterise Hazard", "Evaluate Exposure", "Vulnerability Analysis", "Assess Risks and Impact" and "Identify Adaptation Options" (see Figure 20) as the actions to be carried out in these steps (except for "Characterise Hazard") are based on the respective elements at risk types or inventories of elements at risk.

The currently identified elements at risk per demonstration area vary. A more detailed look at the elements at risk per demonstration case is required which will be conducted as one of the next actions. As of now, the Catalogue of Elements at Risk and Adaptation Options is expected to support three distinct scenarios:

1) **Basic pre-feasibility study**: At this point, only very rough hazard maps are available. Consequently, there is no point in knowing the exact locations of the elements at risk in a project, or even their detailed characteristics. All we need at this level is to indicate which main element at risk types there are in the project (e.g. people, buildings, critical infrastructure, etc.) and roughly estimate the

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[2] At this level, we can only offer rough estimates – enough to understand what to expect, but not enough to calculate the real cost of the adaptation options.

vulnerability of these basic element types to the main hazards that are expected to occur in the project area.

2) **Advanced pre-feasibility study[3]**: At this point, we already have precise hazard maps and therefore need the actual positions of the elements at risk (element at risk inventories) to come up with a better estimate of the involved risks. Wherever possible, the elements at risk used in the project should be associated with more detailed sub-types. As a result, the service will be able to provide improved estimates of the vulnerabilities and of the adaptation options (e.g. their cost and the effect(s) they have on vulnerabilities of elements to different hazards or on their exposure).

3) The **Expert Services support**: there is a limit to the quality of the information that can be offered by the advanced pre-feasibility study. To reach beyond this limit, the experts must be consulted, e.g. to re-calculate the hazards for specific adaptation and climate scenarios[4]. Experts can also be consulted to improve and extend the catalogue of elements at risk and adaptation options with the project-specific entries, or to perform a fully-fledged impact study offline and upload the results to CSIS.

One of the functionalities which are required for the advanced pre-feasibility study and for the expert services support is the import of the site-specific data. Users should be able to upload elements at risk inventories (e.g. inventory of buildings) to a Data Repository (7.4) and/or may purchase already existing datasets in the Marketplace (7.6). Experts should be able to upload the results of their work, e.g. detailed information on elements at risk and adaptation options or project-specific hazards maps[5]. One of the challenges will be to identify a generic workflow which nevertheless is specific enough to cater to all user needs. E.g. to best enable users to add/edit/link vulnerability classes to the single elements at risk from a complete element at risk inventory which they upload, two options have been identified:

a) Enforce a specific data structure (e.g. predefined categories, like vulnerability classes etc.) and format which users must use to upload elements at risk inventories.

b) Let users upload their data first, and then link the respective columns/fields to the categories (e.g. predefined vulnerability classes) which being used/understood by CSIS.

The functionalities requested by the CSIS- and DC User Stories and Test Cases are described in the next chapter. Current works focus on the understanding of the relationships between elements at risk types/inventories, their vulnerability classes and vulnerability functions, how to best store them and their relationships and how to then calculate exposure, vulnerability, risk and impact.

3.1.1　Requested functionality

Baseline requirements elicitation and the assessment of presently available Test Cases have yielded the following functional requirements for this Building Block:

Baseline functionality

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[3] "Advanced" pre-feasibility and "expert services" could be used iteratively.

[4] Some hazards will change depending on the overall project design and adaptation measures. For example, the urban microclimate can be modified through urban greening, the use of high-reflectivity materials, and by increasing openness to allow cooling winds.

[5] Some of this will be supported by other Building Blocks.

- The Catalogue of Adaptation Options should offer the users rich and validated sets of known elements at risk types, their vulnerabilities to various hazards and adaptation options.
- User should be able to define his/her own element at risk, along with the estimates of the vulnerabilities to different hazards and adequate adaptation options. This needs to be saved in the catalogue too, with "reliability of the data" set to low so that the data set is either not shown to other users at all or shown as "low confidence" dataset.
- Users must be able to also upload an inventory of elements at risk, to add or modify elements and to visualize them on a map.
- Experts should be able to assess, modify and validate all aspects of the project as a part of the expert workflow. For example, they should be able to validate and/or improve the vulnerabilities of the elements at risk for various hazards. Data that is validated by experts will be marked as "high confidence" in the database and the provenance information stored along with the data.
- For adaptation scenarios, users should be able to modify the exposure of elements at risk.

Functionality requested by CSIS Test Cases

- from TC-CSIS-0050 Infrastructure Project Management: This Building Block should provide static information on the 4 thematic project options as defined by EU-GL, which are - On-site assets and process types (Element at Risk Types) - Transport links types - project Inputs types - project outputs types and for each of these themes vulnerability functions that provide a concrete vulnerability indicator based on hazard / exposure input.
- from TC-CSIS-0900 Data Package Export/Download/Forward To: This Building Block should allow to add elements at risk and adaptation options selected for the current project under assessment to a Data Package that can be downloaded by the end user.

Functionality requested by DC Test Cases

- from TC DC1: The Scenario Management Building Block must provide an user interface that will allow the end user to request the creation of alternate adaptation scenarios for scenario comparison in the expert workflow. This request needs to include the type of hazard/impact scenarios object of the simulation and the type of adaptation options to take into account. The supported adaptation options for a specific type of scenario are provided by the Catalogue of Adaptation Options
- from TC DC1: The Catalogue of Adaptation Options user interface needs to guide the user in the selection of adaptation options to be displayed and compared with the "no adaptation" results (could be a drop-down menu with different adaptation options, e.g. green roofs on 50% of existing buildings, 50% increase vegetative cover on streets, etc. last entry should allow on-demand adaptation measures if the desired one is not available in the list).
- from TC DC1: The Catalogue of Adaptation Options must provide a user interface to allow the user to request the simulation of a specific adaptation measure that is not yet listed in the Catalogue of Adaptation Options. We are assuming here that simulation scenarios run offline upon request of end users and are retrieved through the Scenario Management Building Block.
- from TC DC4 040: The user can incorporate new Catalogues of Elements at Risk. Also add or modify elements on an existing one and associate them with an atlas of elements at risk.
- from TC DC4 050: The user needs to add or modify elements at risk in the Catalogue of Elements at Risk.
- from TC DC4 070: The user must be able to update and incorporate new Catalogues of Adaptation Options. The catalogue must contain adaptation measures and good practices.
- from TC RA: The Catalogue of Elements at Risk should offer the possibility to edit an elements at risk feature layer (WFS) in a GUI (e.g. Map Building Block connected to Catalogue of Elements at

Risk). This would relate to adaptation scenario and modifying the exposure of elements at risk, respectively.

- from TC DC4 050: The Catalogue of Elements at Risk will contain the elements at risk available and that can be updated and modified. It must offer an OGC WFS-T interface for interactive editing of elements at risk with help of OGC compliant GUI clients like GeoExt (OpenLayers and ExtJS).
- from TC-AIT-01: The Catalogue of Elements at Risk and Adaptation Options provides the necessary data on the vulnerability of the elements at risk. If no data is available, the user should be able to define his/her own element at risk, along with the estimates of the vulnerabilities to different hazards. This needs to be saved in the catalogue too, with "reliability of the data" set to low so that the data set is either not shown to other users at all or shown as "low confidence" dataset.

3.1.2   Exploitation Requirements assessment

The assessment of the Exploitation Requirements [11] identified the following concrete technical and functional implications on this Building Block:

- from "Establish trust in Climate Services and their providers": Data Provenance Information including information about the quality of the data, uncertainty, etc. as well as the process (model) which created them must be attached to each dataset. Such Provenance information must be considered in the information model of each element of the overall climate adaptation study workflow. This includes for example also the information model of elements at risk, adaptation options, etc. Therefore, the original information source of the contents Catalogue of Elements at Risk and Adaptation Options, other CSIS catalogues, and data stores must be disclosed transparently.
- from "Follow a multi-sectoral approach that crosses the boundary of climate sciences": In order to follow such a multi-sectoral approach, the Catalogue of Elements at Risk and Adaptation Options should provide both a wide range of elements at risk types which are related to many different sectors (e.g. road infrastructure, buildings, social, etc.), as well as a wide range of adaptation options. It might be that not all sectors are fully dealt with at the beginning; therefore, a community-driven mechanism by which the gaps are being filled is suggested. This challenge could be dealt with if the catalogue enables users to provide their own elements at risk types and suggest their own adaptation options, which then might be assessed by experts. Thereby, such user provided content must follow the same quality and transparency standards as being used for essential climate data.

3.1.3   Technology support

Figure 16 gives an overview on the technological possibilities and the related backend software component that has been selected for the Technology Support Plan.
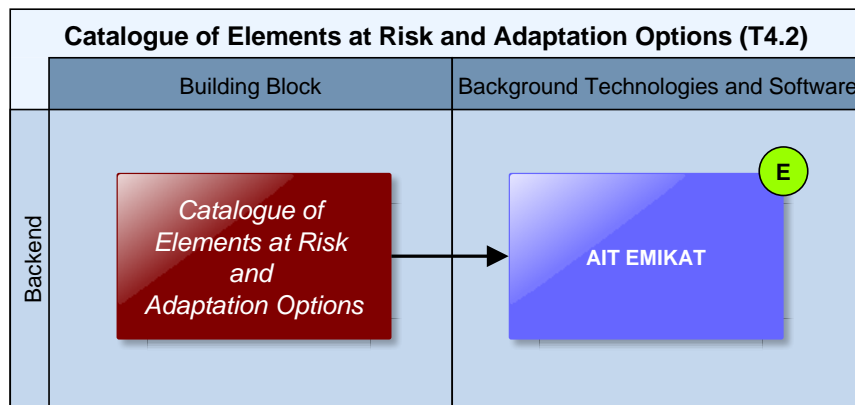
Figure 9: Catalogue of Elements at Risk and Adaptation Options Technology Support

In CLARITY, the **AIT EMIKAT** will be used for the implementation of the Catalogue of Elements at Risk and Adaptation Options which will be conducted in Task 4.2, as it is also able to provide the requested functionalities as well as the functionalities which are required by the different characteristics of the elements at risk.

> **EMIKAT** is a client/server application for collecting heterogeneous datasets for a specific project to then manage this data and perform model calculations in a scenario context. Datasets are typically defined in a spatial context including position and a geometric description. For data which is changing over time, EMIKAT manages the historical development in a documented way. EMIKAT has been developed by CLARITY partner AIT.

The system is capable of handling geo-data (e.g. points, lines, grids, political areas, etc.) which could be especially relevant for the handling of the elements at risk (e.g. points for building locations, lines for roads/transport networks, grids for population densities, etc. The background exists and is usable with minor adaptations.

EMIKAT also manages calculation models for the data in a consistent way. All results can be displayed as graphical results or shapes. Exports/communication can be via WFS or WMS service results (OGC compatible GeoServer data store), REST interface, Shape Files, Excel tables or CSV. The EMIKAT system is fully generic and capable of handling many types of data and models with spatial or temporal properties. This was demonstrated also in the CRISMA project, by using EMIKAT as a software base (http://crisma-cat.ait.ac.at/model/Population%20exposure%20model) for the population exposure model calculations and visualisation.

Besides it´s use for the Catalogue of Elements at Risk and Adaptation Options EMIKAT could provide models and data which might be relevant for or offered as an Expert Climate Service: In other projects, EMIKAT is often being used to calculate the state of air quality and the amount of air pollutants / Green-House-Gas-Emissions at certain locations at a given moment of time / period for different adaptation scenarios and then visualize the different results on a map and within an automatically generated report.

For a more detailed description of EMIKAT, please see Annex 1 and the EMIKAT project website
www.emikat.atwww.emikat.at.

3.2 Catalogue of Data Sources and Simulation Models

The Catalogue of Data Sources and Simulation Models is a meta-data catalogue that makes climate-related information accessible by providing functionalities to streamline publishing, sharing, finding and using data and models. Especially catalogue features like linking data to organisations, software (models) or underlying input data (provenance / lineage) may help to establish trust and confidence in (climate) data and thus to fulfil related Exploitation Requirements. The catalogue can be used for data discovery and meta-data storage by different Climate Services and Building Blocks, respectively. It must be integrated with the Marketplace (7.6) so that data or services offered by Climate Service Suppliers can also be discovered in the catalogue. Moreover, T2.2 "Demonstrator-specific data collection" intends to maintain a catalogue of CLARITY data and metadata that is continuously updated throughout the project in case new data will become available. Thus, it can also be used for the formal documentation (meta-data, linked data, lineage, etc.) of Open Data collected and produced by the project and thus to Data Management activities in T7.3 "Data Management".

3.2.1 Requested functionality

Baseline requirements elicitation and the assessment of presently available Test Cases have yielded the following functional requirements for this Building Block:

Baseline functionality

- REST web service and RIA frontend
- usable as source for meta-data harvesting (e.g. datasets could be made accessible through the GEOSS platform following the GEOSS and INSPIRE Data Sharing Principles)
- acts as OGC CSW or OAI-PMH (Open Archive Initiative – Protocol Metadata Harvesting) endpoint.
- integration with Marketplace (e.g. meta data in catalogue, actual data available for sale in Marketplace)
- support public / private (meta-)data and organisations
- stores machine-readable metadata for spatial extent, temporal extent, resolution, hazards, etc. (including information on uncertainty) to support automated queries to find the right dataset for the right purpose, e.g. input datasets for local hazard models
- support integration with other compatible metadata catalogues in order to enable cascading searches.

Functionality requested by CSIS Test Cases

- from TC-CSIS-0900: Retrieve metadata records from each dataset that was used in the study (and that is registered in CSIS Data Repository / Catalogue) in order to be included in the Data Package.
- from TC-CSIS-0031: New (external) data sources that will be added/modified/deleted from the Catalogue of Data Sources and Simulation Models must be managed by this Building Block.

Functionality requested by DC Test Cases

- from TC DC1: When the user is asked by the Scenario Management Building Block to provide the input data needed by the respective (hazard) model, the Catalogue of Data Sources and Simulation Models could be searched and, if suitable data is available for the project area and the respective model, it could be offered to the user.
- from TC DC1: When the user specifies individual requirements for a hazard map (hazard type, minimal resolution, ...) the Catalogue of Data Sources and Simulation Models could be searched.

- from TC DC4 010: The Catalogue of Data Sources and Simulation Models is used to get the models and data available in CSIS that could be used in the assessment. The catalogue must offer metadata both for models and datasets and provide the possibility to relate model I/O to datasets.
- from TC DC4 050: The Catalogue of Data Sources and Simulation Models must offer metadata on element at risk inventories / repositories / atlases that can be used by the Catalogue of Elements at Risk or an external or internal data repository that store the actual element at risk instances.
- from TC DC4 080: The Catalogue of Data Sources and Simulation Models must provide a list of hazards based on the geographical area selected for a study/scenario.

3.2.2 Exploitation Requirements assessment

The assessment of the Exploitation Requirements [11] identified the following concrete technical and functional implications on this Building Block:

- from "Establish trust in Climate Services and their providers": Quality assurance and uncertainty of the underlying data and models must be communicated properly throughout the whole planning process. This relates mainly to Scenario Management and a potential Catalogue of Data and Models that must include appropriate meta-information on quality and uncertainties. The data collection and harmonisation activities must take this into account also.
- from "Establish trust in Climate Services and their providers": Quality assurance must be easily recognizable in the Climate Service Catalogue / Marketplace. Thereby, Climate Service quality could be defined as ability to deliver scientifically sound predictive information that support decision-making under uncertainty.
- from "Establish trust in Climate Services and their providers": Reputation, neutrality and trustworthiness of a Climate Service provider must be somehow reflected in the Climate Service Provider Profile in the Marketplace. This could include (moderated and verified) feedback from Climate Service users (customer ratings) and links to scientific publications, talks, etc. Moreover, Climate Service Provider Profiles should also be linked to Case Studies that are available in the CSIS (e.g. CLARITY demonstrators) as it for example done in Australia Governmental Marketplace (https://marketplace.service.gov.au/search/sellers/).
- from "Establish trust in Climate Services and their providers": Data Provenance Information including information about the quality of the data, uncertainty, etc. as well as the process (model) which created them must be attached to each dataset. Such Provenance information must be considered in the information model of each element of the overall climate adaptation study workflow. This includes for example also the information model of elements at risk, adaptation options, etc. Therefore, the original information source of the contents of the Catalogue of Elements at Risk and Adaptation Options, other CSIS catalogues, and data stores must be disclosed transparently.
- from "Establish trust in Climate Services and their providers": a (lightweight) Catalogue of Models and Data Sources (e.g. based on CKAN) is needed in the CSIS in order to be able to link to this Provenance Information. The information model for such a catalogue could be based on CKANs standard meta-information model.

3.2.3 Technology support

Figure 10 gives an overview on the technological possibilities and the related open-source backend and frontend software components that have been selected for the Technology Support Plan.
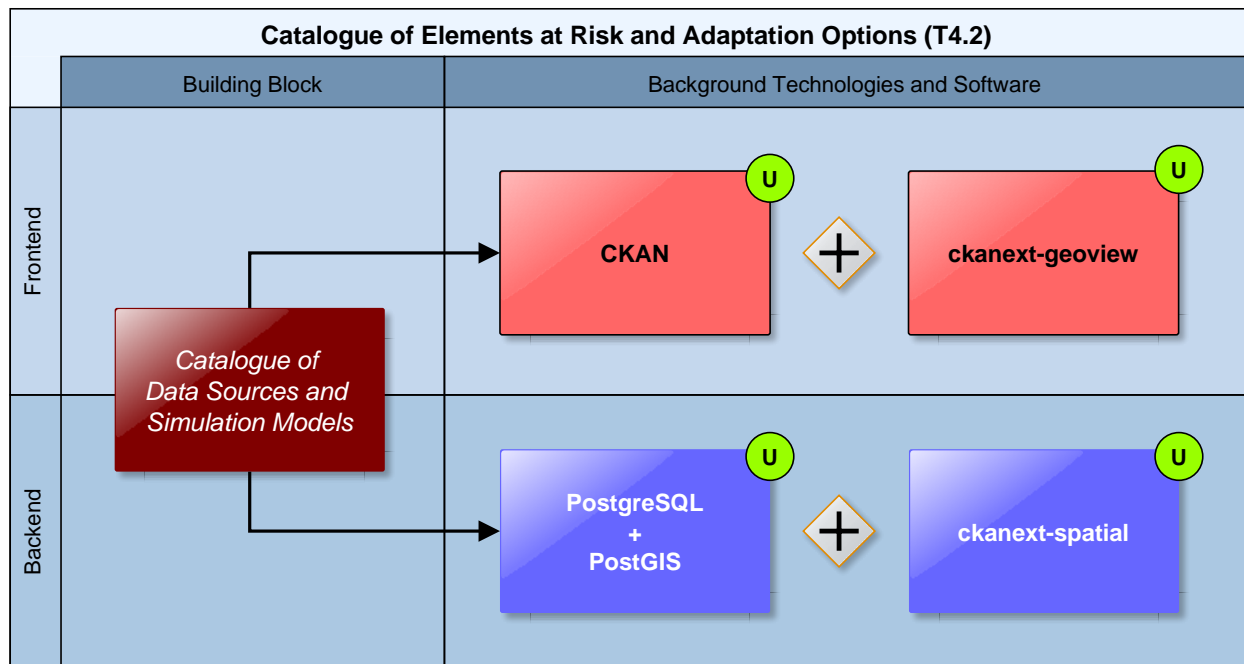
Figure 10: Catalogue of Data Sources and Simulation Models Technology Support

CKAN is a powerful data management system and the ideal background software for the implementation of the Catalogue of Data Sources and Simulation Models. It is open source software and thus free and highly flexible.

> **CKAN** is a tool for making open data websites. It helps you manage and publish collections of data. It is used by national and local governments, research institutions, and other organizations who collect a lot of data. Once your data is published, users can use its faceted search features to browse and find the data they need, and preview it using maps, graphs and tables - whether they are developers, journalists, researchers, NGOs or citizens.

http://docs.ckan.org/en/latest/user-guide.html

CKAN provides built-in tools to streamline publishing, sharing, finding and using data and can be extended with plugins like **ckanext-spatial** and **ckanext-geoview** which support spatial metadata and thus allows to perform spatial queries and to display the dataset extent on a map. Such spatial metadata could also be used in the Map Component (5.1) to show availability of relevant datasets (e.g. hazard maps) in the project area.
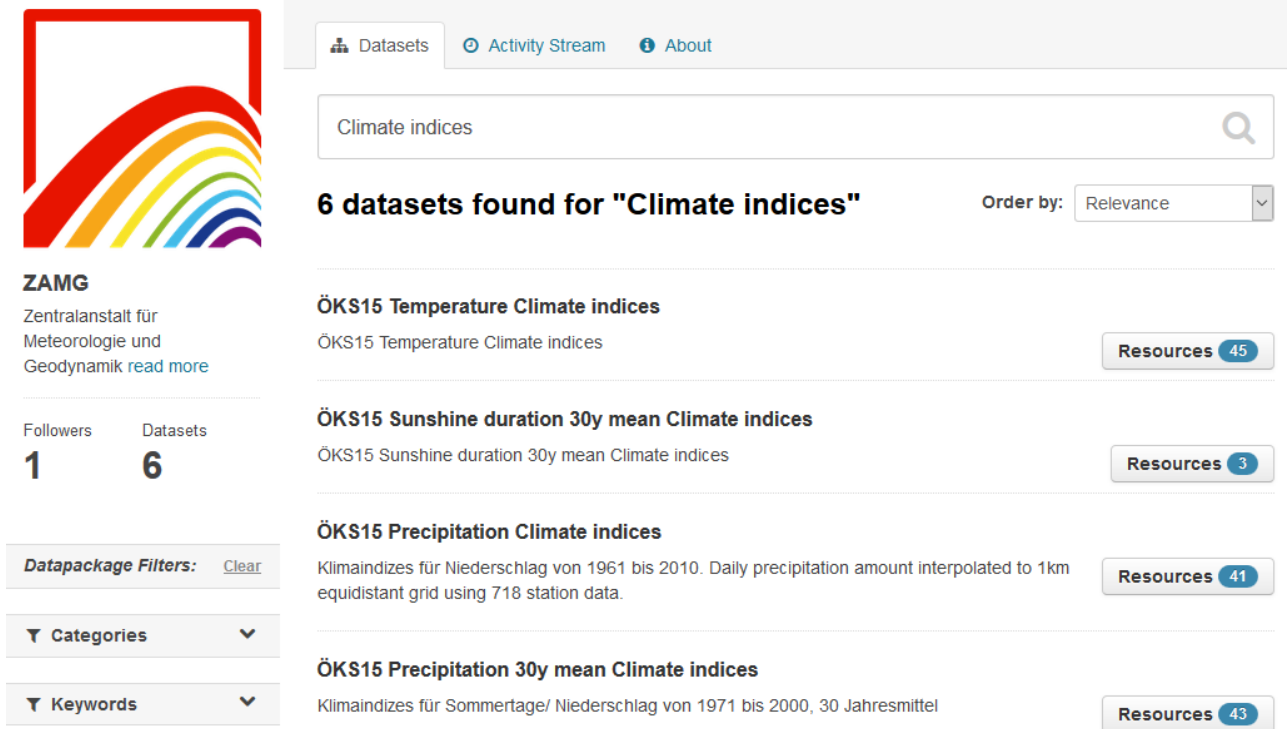
> **ckanext-geoview** is a CKAN extension that contains view plugins to display geospatial files and services in CKAN. It contains an OpenLayers based viewer originally developed by Philippe Duchesne and other view plugins like Leaflet.js that used to be part of ckanext-spatial.

https://github.com/ckan/ckanext-geoview

> The **ckanext-spatial CKAN** extension contains plugins that add geospatial capabilities to CKAN, including aspatial field on the default CKAN dataset schema (uses PostGIS as the backend), harvesters to import geospatial metadata into CKAN from other sources in ISO 19139 format and others and commands to support the CSW standard using pyCSW.

https://github.com/ckan/ckanext-spatial

Moreover, there are official Docker images (https://hub.docker.com/r/ckan/) for CKAN available, so it can be directly deployed in CLARITY's Container Engine and Cloud Infrastructure (7.1). As storage backend, **PostgreSQL** can be used, thus it is compatible to the Integration RDBMS (7.3). CKAN is for example used by the Climate Change Centre AUSTRIA (http://data.ccca.ac.at) which published Open Data created by CLARITY partner ZAMG on their Open Data portal (Figure 11).

Figure 11: Climate Change Centre AUSTRIA powered by CKAN

Another usage scenario of CKAN in CLARITY is the formal documentation (meta-data, linked data, lineage, etc.) of Open Data used and produced by the project as required by CLARITY's Data Management Plan [9]. Such a public Open Data catalogue may replace the information on datasets that is currently maintained in CLARITY's coordination platform (https://cat.clarityCLARITY-h2020.eu/). Especially CKAN features like linking data to organisations, software (models) or underlying input data (provenance / lineage) may help to establish trust and confidence in (climate) data and thus to fulfil related Exploitation Requirements. There is also the possibility for integrating CLARITY's CKAN catalogue with external catalogues and external/internal repositories (harvesting), e.g. the **GEOSS** catalogue. Thereby, also metadata on Open Data available from institutional or external repositories and used in CLARITY (e.g. climate intelligence data, model input data) can be included in CLARITY's metadata catalogue.

Optionally, Open Data (e.g. model output data) generated by CLARITY can be deposited in an institutional or external repository (Figure 12). The respective metadata could then be fed into CLARITY's Metadata Catalogue and **OpenAIRE**, either manually by Data Managers or automatically if the respective technical infrastructure (e.g. **OAI-PMH** Endpoint) is provided by the repository.

> **OpenAIRE** aims to support the implementation of Open Access in Europe. It provides the means to promote and realize the widespread adoption of the Open Access Policy, as set out by the ERC Scientific Council Guidelines for Open Access and the Open Access pilot launched by the European Commission.

https://www.openaire.eu/

Zenodo's OAI-PMH Endpoint could be used by the CLARITY metadata catalogue to harvest (https://ckan.org/portfolio/federate) metadata records of the set *user_CLARITY* (CLARITY community). These records could then in turn be harvested by the GEOSS Registry System (http://geossregistries.info/) from CLARITY's CKAN catalogue.

> **Zenodo** is an EC-co-funded, multidisciplinary repository, for publications and data. A DOI is automatically assigned to all Zenodo files, which can be uploaded in any file format. Zenodo allows researchers to deposit both publications and research data, while providing means to link them. Data is stored in the CERN cloud infrastructure. Zenodo is compliant with the open data requirements of Horizon 2020, the EU Research and Innovation funding programme and OpenAIRE.

https://zenodo.org/

Figure 12 shows an interesting possibility for a technical approach towards Data Management in CLARITY that aims at integrating CLARITY's CKAN catalogue with OpenAIRE, Zenodo and external Open Data registries.
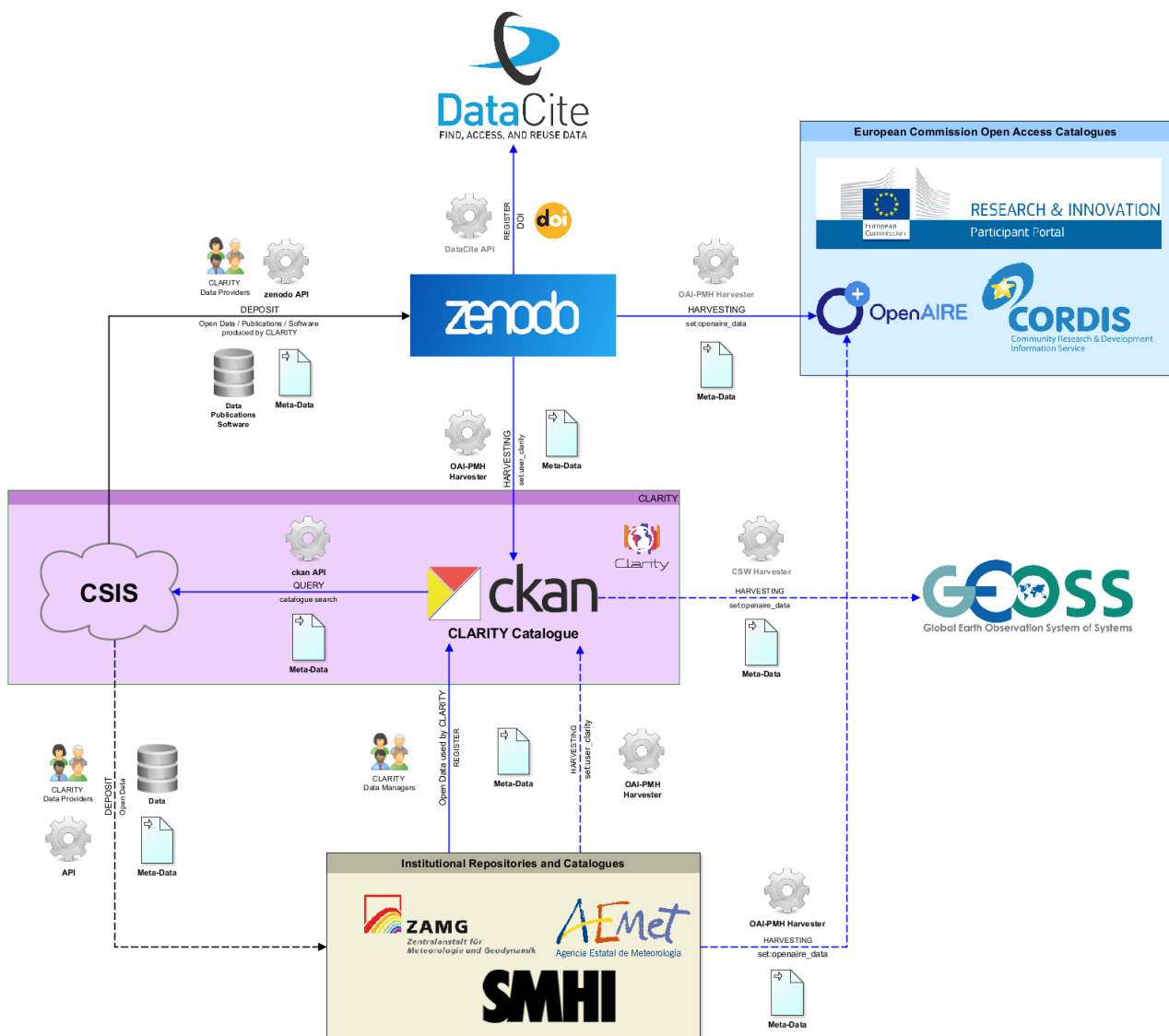
Figure 12: A possible approach towards technical Data Management

Open results deposited in Zenodo are automatically assigned a Digital Object Identifier (**DOI**) and will be indexed at **DataCite** (https://www.datacite.org/), thus receiving more exposure. Zenodo offers an OAI-PMH Endpoint with supported metadata schema *oai_dc* (**Dublin Core**). This endpoint is used by OpenAIRE to harvest metadata records belonging to the set *openaire_data* and to get these records into **CORDIS** (https://cordis.europa.eu/) and the **Participants Portal** (http://ec.europa.eu/research/participants). Therefore appropriate metadata including the metadata field *grants* (see section 2.1.5 of the CLARITY Data Management Plan [9]) must be provided along the open result deposited in Zenodo (Figure 13).
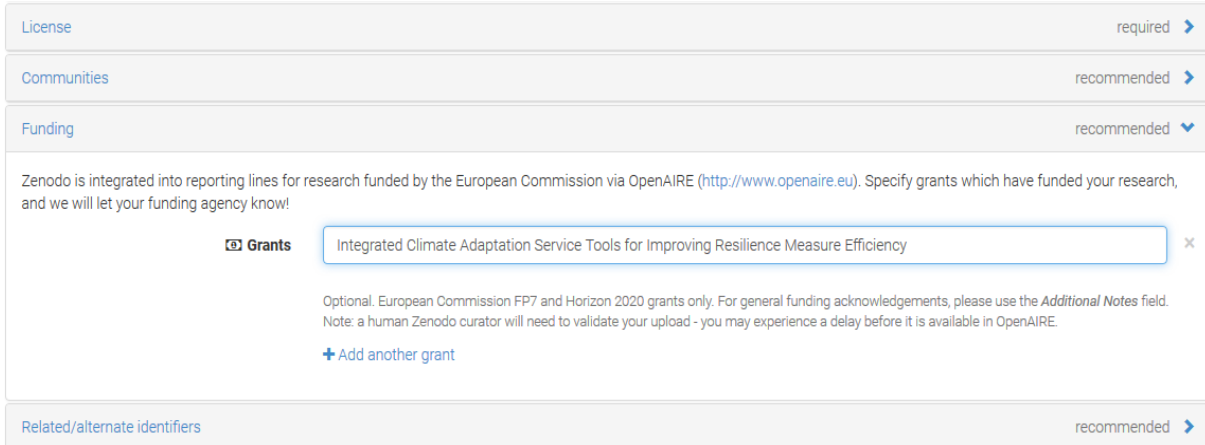
Figure 13: Assigning Grants (CLARITY) with Open Data in Zenodo

Moreover, this OAI-PMH Endpoint could be used by the CLARITY's Metadata Catalogue (CKAN) to harvest (https://ckan.org/portfolio/federate/) metadata records of the set *user_CLARITY* (CLARITY community, Figure 14).
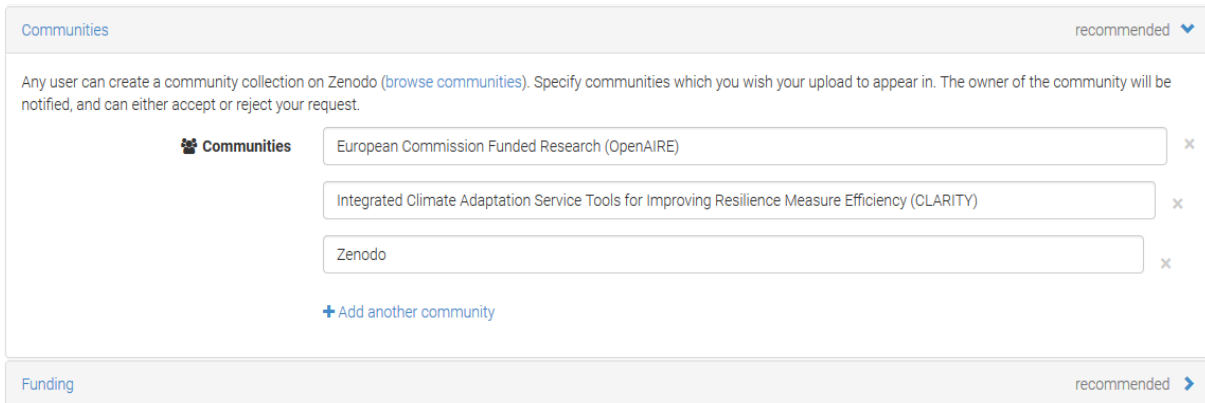
Figure 14: Assigning Communities (CLARITY) with Open Data in Zenodo

4   Scenario Management (T4.3)

Figure 15 provides an overview of the Building Blocks that are covered byT4.3.

Figure 15: T4.3 Building Blocks

Scenario Management in CLARITY is twofold and refers to

a) an expert-system for the management, execution and evaluation of alternate adaptation scenarios resulting from site- and use-case-specific impact scenario analysis; and

b) the overall Climate Service Customer and Climate Service Supplier interaction scenario for collaboratively performing a Climate Adaptation Study following the distinct steps of the EU-GL methodology.

While the second aspect demands for simple, user-friendly and generic products, the first aspect requires not only custom integration of heterogeneous models and data but is in general conducted by domain experts. Likewise a clear separation into generic ICT and tailored Expert Climate Services in the Scenario Management Building Block (4.3) as explained in the CSIS Architecture (see 2.1) can be made. Moreover, CLARITY's standards based and data-driven approach that is both valid for the generic and tailored aspects of scenario management is supported by two additional Build Blocks: the Data Dashboard (4.1) and the Data Package Export and Import Tool (4.2).

4.1   Data Dashboard

The Data Dashboard Building Block provides an overview of all the different datasets that are used, produced, ordered, collected, requested, exchanged etc. by an end user (e.g. project planner or climate resilience manager) during an assessment (planning session). Thereby, it reports also on the usage of datasets obtained or available from supply-driven Downstream Climate (Data) Services. Datasets are organised (e.g. in a folder-like structure) according to their relation to the modules of the EU-GL (e.g. hazard maps, impact scenario results, elements of risk inventory). From the dashboard, the user has access to different dataset-type-specific tools that are realised as separate ICT Climate Services integrated into the CSIS. These tools correspond to Building Blocks or external tools and provide for example map visualisation (5.1), data analysis and comparison (5), Data Package download (4.2) and Marketplace functionality (7.6).

4.1.1　Requested functionality

Baseline requirements elicitation and the assessment of presently available Test Cases have yielded the following functional requirements for this Building Block:

Baseline functionality

- provides an overview of all the different datasets that are used, produced, ordered, collected, requested, exchanged, etc. by an end user in the user's project workspace
- integrates with different (also external) (meta)data catalogues
- can show the origin (provenance) of each dataset
- integrates different tools (ICT Climate Services) that can be used to visualise the data or to perform operations on the datasets
- supports the CLARITY Data Package Standard (cf. section 4.2.3) for easy import and export of datasets with help of the Data Package Export Tools
- provides "deep links" to external Climate (Data) Services (e.g. SWICCA), so that the end user can explore, process, view, export the dataset in the original system
- Allows, via a UI, to upload new datasets (or remove them) or find them using the metadata catalogue

Functionality requested by DC Test Cases

- from TC-CSIS-0900: The Data Dashboard shows the origin (from expert study, from public data catalogue, from external climate data service), the status (ordered, available, self-provided, …) and the purpose (input for Hazard, Exposure, Vulnerability, input and output of Risk Assessment and Impact / Adaptation Scenario Analysis,) and related metadata (expert opinion, inspire metadata, provenance metadata, uncertML, etc.).
- from TC RA: The Data Dashboard is a Building Block that provides an easy overview of the results for the user.

4.1.2　Exploitation Requirements assessment

The assessment of the Exploitation Requirements [11] identified the following concrete technical and functional implications on this Building Block:

- from "Demonstrate and communicate the (co-)benefits of Climate Services": Expert Climate Services by external stakeholders should be easily integrated with generic ICT Services of the CSIS through a "data-driven" architecture.
- from "Demonstrate and communicate the (co-)benefits of Climate Services": There is a strong need for an (meta-) information model for case studies (CLARITY Demonstration Cases) that is linked with the information models for Climate Services (Marketplace offer) and their providers (Service Portfolio) and through indirection also with climate data and models, tools (provenance). This allows also for demonstrating the benefits of Upstream Climate Services (e.g. Copernicus C3S) by means of Case Studies (e.g. CLARITY Demonstration Cases).

4.1.3　Technology support

Figure 16 gives an overview on the technological possibilities and the related open-source frontend and backend software components that have been selected for the Technology Support Plan.
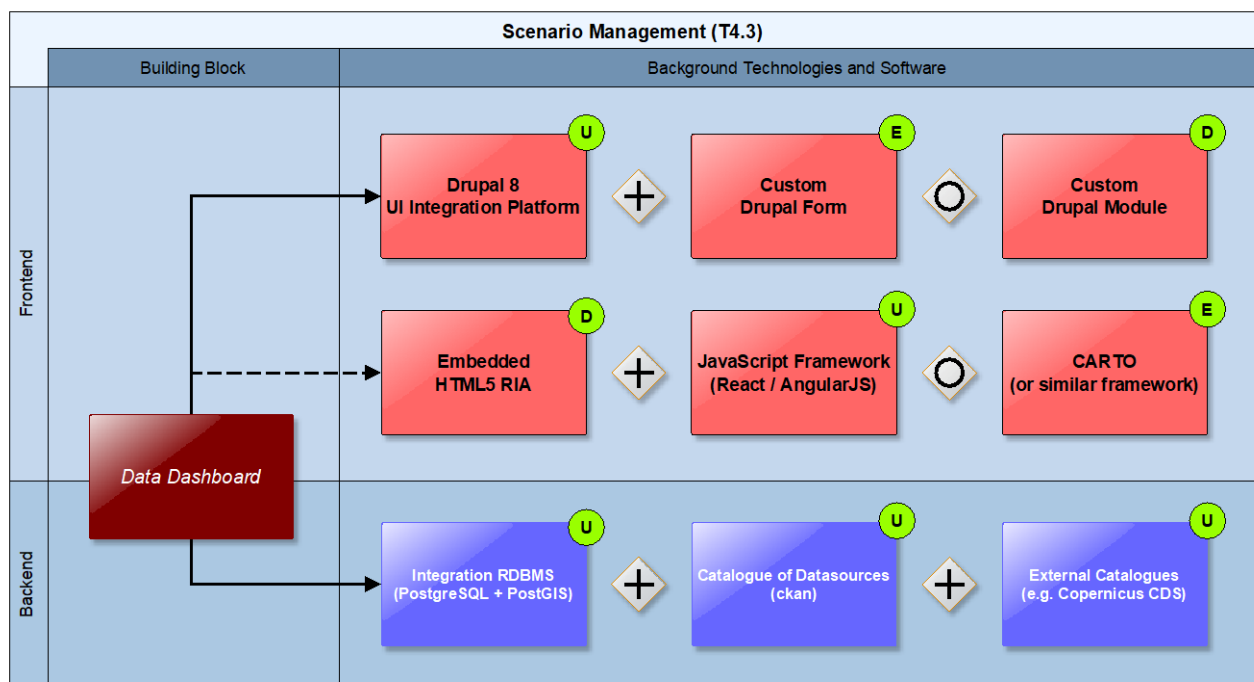
Figure 16: Data Dashboard Technology Support

Technically, the Data Dashboard is a user interface component that is embedded into the Scenario Management component (4.3) and thus the User Interface Integration Platform (7.5), respectively. According to this and in relation to the integration concept described in section 7.5.2, there are two possibilities for providing technology support for the frontend part (Figure 16) of this Building Block:

1) As independent HTML5/AJAX **RIA** that is loosely embedded as HTML5 **iframe** and communicates with the backend of the UI Integration Platform (Drupal) via a REST API exposed by the Integration RDMBS (**cids Integration base** and **PostgreSQL / PostGIS**, respectively); or

2) as dedicated **Drupal Form or Module (PHP)** that is tightly coupled to the UI Integration Platform.

A **Rich Internet Applications (RIA)** is a web application, which uses data that can be processed both by the server and the client. Furthermore, the data exchange takes place in an asynchronous way so that the client stays responsive while continuously recalculating or updating parts of the user interface. On the client, RIAs provide a similar look-and-feel as desktop applications and the word "rich" means particularly the difference to the earlier generation of web applications. [21]

http://uwe.pst.ifi.lmu.de/publications/maewa_rias_report.pdf

The general advantages and disadvantages of both approaches are described in detail in section 7.5.2. Concerning the Data Dashboard Building Block, the **RIA**-based approach offers more flexibility regarding the actual user interface design and the presentation and organisation of the different datasets.

AJAX is an acronym for Asynchronous **JavaScript** and **XML**, which already contains two technologies and a technique for loading information. AJAX is not a single new technology, but a combination of standard technologies including **HTML**, **CSS**, **JavaScript**, **XML** and **DOM** which together with the XMLHttpRequest object achieve web application richness. AJAX applications work unconditionally in browsers without the need to install any plug-ins. [21]

http://uwe.pst.ifi.lmu.de/publications/maewa_rias_report.pdf

Also integration with the internal Catalogue of Elements at Risk and Adaptation Options (3.1) and the Catalogue of Data Sources (3.2), external Catalogues like GEOSS (http://www.geoportal.org/), (Climate) Data Services like the C3S Climate Data Store (https://climate.copernicus.eu/climate-data-store) or the climate data factory (https://theclimatedatafactory.com/) that offer a public **RESTful API** is easier to accomplish due to the inherent support for REST and **AJAX** in RIAs.

> A **Drupal module** is a collection of files containing some functionality and is written in PHP. Because the module code executes within the context of the site, it can use all the functions and access all variables and structures of Drupal core. In fact, a module is no different from a regular PHP file that can be independently created and tested and then used to drive multiple functionalities. This approach allows Drupal core to call at specific places certain functions defined in modules and enhance the functionality of core.

https://www.drupal.org/docs/user_guide/en/understanding-modules.html

Although the rich functionality offered to a **Drupal Module** by the powerful **Drupal API** (https://www.drupal.org/docs/8/api) is not available when following the RIA-based approach, AJAX applications can benefit from a tremendous amount of ready-to-use solutions (packages, modules, libraries) developed by the world-wide open-source community and made available through popular registries like npm (https://www.npmjs.com/) or Yarn (https://yarnpkg.com/).

> For an interactive, data-driven website such as one built with **Drupal**, collecting and processing user submitted data will be exceptionally important. Most of this data can be captured using a web based form, i.e. An HTML structure with text fields and widgets for selecting different options. Getting a form on to a webpage is easy, getting the user's responses is easy too, getting them securely is much, much harder. Drupal provides a standard, easy to use, easy to extend and secure way of adding forms to your Drupal website: **Form API** or FAPI for short.

https://www.drupal.org/docs/8/api/form-api/

Still, there is the need for "bootstrapping" an **Angular** or **React** RIA by assembling, integrating, configuring and possibly also adapting the most suitable open-source source libraries.

> **Angular** is a platform that makes it easy to build applications with the web. Angular combines declarative templates, dependency injection, end to end tooling, and integrated best practices to solve development challenges. Angular empowers developers to build applications that live on the web, mobile, or the desktop

https://angular.io/docs

> **React** is a JavaScript library for building user interfaces. Declarative views make your code more predictable, simpler to understand, and easier to debug. Since component logic is written in JavaScript instead of templates, you can easily pass rich data through your app and keep state out of the DOM. React is flexible and can be used in a variety of projects. React can also render on the server using Node and power mobile apps using React Native.

https://github.com/facebook/react/
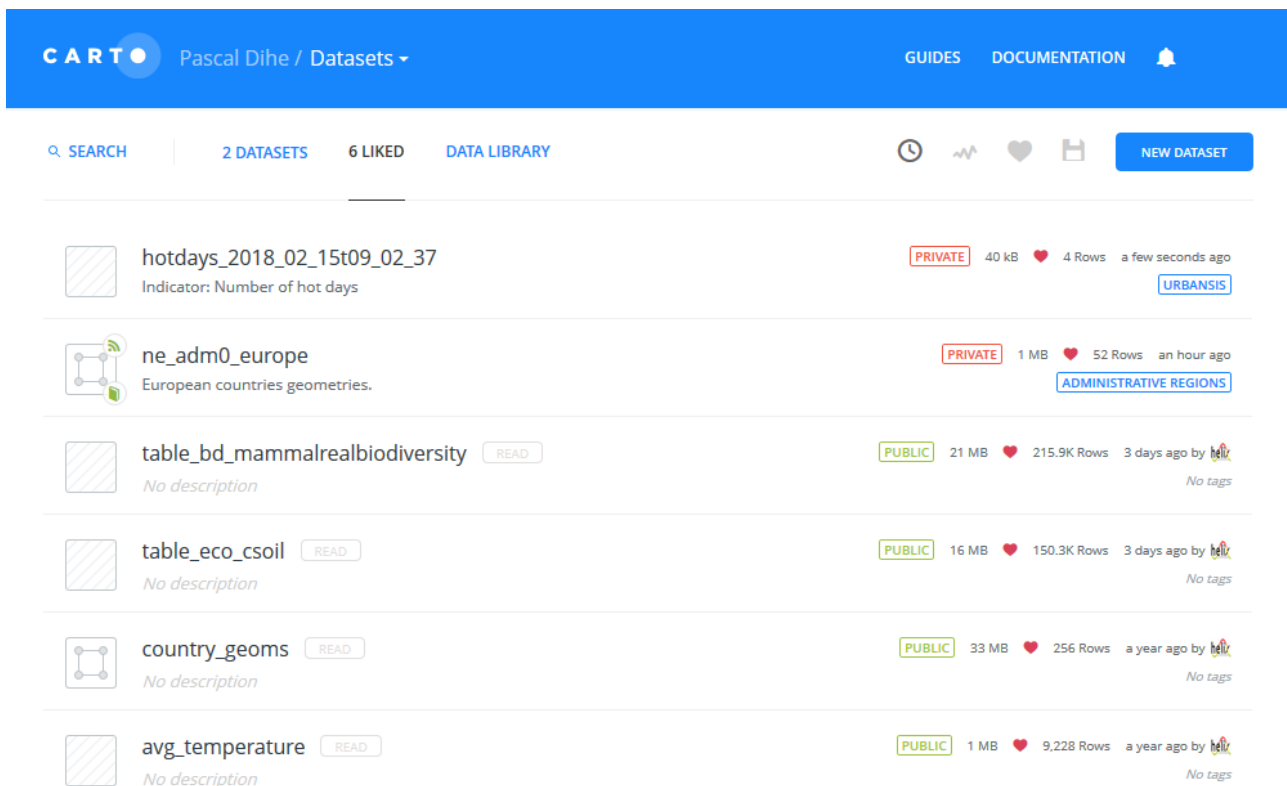
To speed up this process, it would be beneficial to base the development of the Data Dashboard on an existing RIA that offers already much of the functionally of such a dashboard. A possibly open source solution that could be used for such a purpose is **CartoDB**.

Figure 17 shows an example of the CartoDB Dataset dashboard that has been configured with public data linked from the HELIX FP7 project's Helix Scope CartoDB application (https://helixscope-app.herokuapp.com/) and data imported from UrbanSIS (http://urbansis.climate.copernicus.eu/), among others. As this dataset dashboard represents only a fraction of functionality offered, the CartoDB software suite could also be interesting for the Data Repository (7.4) and the Map Component Building Block (5.1).

> **CartoDB** is an open source tool that allows for the storage and visualization of geospatial data on the web. It was built to make it easier for people to tell their stories by providing them with flexible and intuitive ways to create maps and design geospatial applications. With CartoDB, you can upload your geospatial data (Shapefiles, GeoJSON, etc) using a web form and then make it public or private. After it is uploaded, you can visualize it in a table or on a map, search it using SQL, and apply map styles using CartoCSS.

https://cartodb.readthedocs.io/en/latest/intro.html

The main disadvantage of the CartoDB-based approach is, that out-of-the box CartoDB supports only a limited set of geospatial data formats like Shapefile, Keyhole Markup Language (KML), GeoJSON, CSV, Spreadsheets (Excel or OpenDocument), GPS Exchange Format (GPX) and their own CARTO data format. Therefore and among others, to be able to fulfil the requirements of CLARITY Building Blocks (like support for the NetCDF files), CartoDB cannot be used "as is", most likely many changes to the huge and complex open source codebase of CartoDB (https://github.com/CartoDB/cartodb) would be necessary. In consequence, the first prototype of the Data Dashboard will be devolved as Drupal Form and Drupal Module, respectively. Since Drupal Forms that use the Drupal Form API can also trigger AJAX responses, integration with other RESTful web services (external data catalogues and repositories) is possible, too. Therefore, the backend of the Data Dashboard is the same for either fronted approach.

Figure 17: CARTO Data Dashboard (Example)

4.2   Data Package Export and Import Tool

The Data Package Export and Import Building Block is a tool that can used at any stage of the adaptation planning process to export (download) any data that is directly available in the CSIS (e.g. stored in a Data Repository, see section 7.4) in standardised format, the CLARITY Data Package.

Information produced by CLARITY Climate Services must be provided in a common Data Package that accompanies the text-based report (document with text, graphs, maps, etc.) that is (semi-)automatically generated by the Report Generation Tool (6.2) at the end of the adaptation planning process. This Data Package should contain all data used to generate the contents of such a report so it can be (re)used later on in further stages. For example, a climate expert hired to further carry out local assessment of the climate impact should import the information from CLARITY Data Package and use it for his/her own analyses. Later on, he/she must generate a similar package that then can be imported in CLARITY CSIS.

Technically, a standardised Data Package can be realised as "distributed data object", so that not all data must reside in the same location (database, server). Here arises also the need for "Smart Links" (Scenario Transferability, see section 5.2) that can combine, relate and describe different information entities (in this particular case the distinct elements of Data Package). Furthermore, a serialisation feature for Data Packages is needed that allows to put all contents of package into a concrete (zip) file that can be shared, e.g. with other experts. The output of Climate Services must be delivered as such a Standardised Data Package to ensure technical interoperability to the CSIS and thus the Climate Services Ecosystem. Consequently, a Data Package can either reside on the CSIS as Virtual Data Package (distributed among several physical data stores) if the provider of the Expert Climate Service uses the CLARITY CSIS to provide its service, or as concrete file (Serialized Data Package) if the provider works offline.

4.2.1   Requested functionality

Baseline requirements elicitation and the assessment of presently available Test Cases have yielded the following functional requirements for this Building Block:

Baseline functionality

- CLARITY Data Package specification: The specification describes which standards are accepted/used to encode the information as well as metadata to be included.
- software (with a defined and exposed API) that allows writing and reading data from CLARITY Data Package

Functionality requested by CSIS Test Cases

- from TC-CSIS-0900: The tool should offer a GUI like a data dashboard (as separate Building Block or as part of the Data Package Building Block) that shows the origin (from expert study, from public data catalogue, from external climate data service), the status (ordered, available, self-provided, ...) and purpose (input for H, E, V, RA Impact Scenario Analysis, output of RA or impact/ adaptation scenario analysis) and allows to select the data for inclusion the data and related metadata (expert opinion, inspire metadata, provenance metadata, uncertML, ... etc.) package export ("download zip file").

4.2.2   Exploitation Requirements assessment

The assessment of the Exploitation Requirements [11] identified the following concrete technical and functional implications on this Building Block:

- from "Demonstrate and communicate the (co-)benefits of Climate Services": Expert Climate Services by external stakeholders should be easily integrated with generic ICT Services of the CSIS

through a "data-driven" architecture. Thereby, data standards are important. This relates to the definition of standardised "Data Packages" which include the results of a complete climate adaptation study in standardised format.

- from "Consider the role of new regulatory frameworks in stimulating the emergence of Climate Services": All datasets included in the Data Package that are provided together with the accompanying report document must enclose the corresponding metadata records so that external parties are aware of who, when, how (including information about the uncertainty) and for what purpose the data was produced.

- from "Use, define and promote open standards for data and services": A standardised Data Package "provides a simple contract for data interoperability that supports frictionless delivery, installation and management of data." (http://frictionlessdata.io/data-packages/). It is a general container format for climate risk adaptation studies that is based on the CLARITY Modelling Methodology, best practices, data standards and state-of-the art ICT technologies. As starting point, a simple directory layout that follows the CLARITY Modelling Methodology (adapted EU-GL modules) and defines the format and details of contained (model I/O) data as it is done for example by CMIP5 - Data Description (https://cmip.llnl.gov/cmip5/output_req.html). Then, the Data Package Standard will evolve during the course of the project (agile approach).

4.2.3 Technology support

Figure 18 gives an overview on the technological possibilities and the related open-source frontend and backend software components that have been selected for the Technology Support Plan.
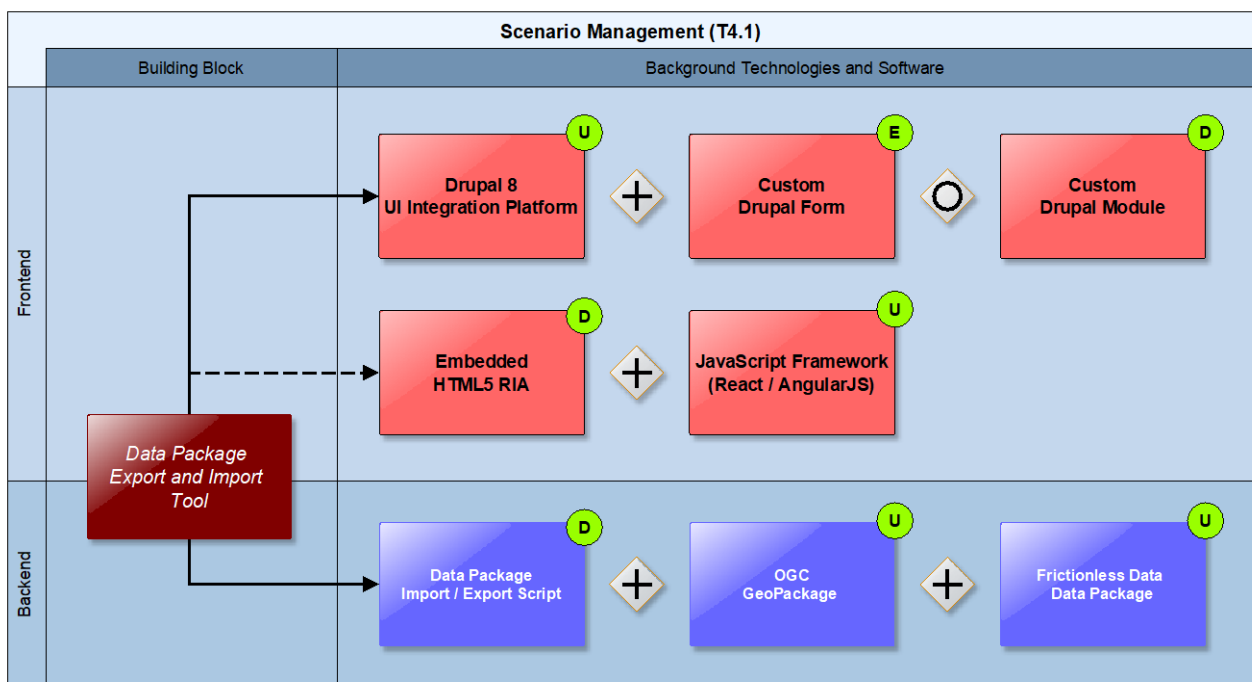
Figure 18: Data Package Export and Import Tool Technology Support

Regarding the fronted part of the Data Package Export and Import Tool, the same options as for the Data Dashboard Technology Support Plan (4.1.3) apply. The user interface could be similar to the Google Takeout Tool (https://takeout.google.com/settings/takeout) that is shown in Figure 19.

Figure 19: Google Takeout Data Export Tool (Example)

Similar to the Takeout Tool, which collects the information from different Google Services, the Data Package Tool must collect and possibly covert the user's data stored in the Integration RDBMS (7.3) and the Data Repository (7.4). This task corresponds to the serialisation feature mentioned previously and is accomplished by a server-side script that is invoked by the Data Package frontend via a **RESTful API**. The interoperability standards for serialising the CLARITY Data Package are based on **OGC's GeoPackage** and **Frictionless Data's Data Package** standards.

As described in OGC Network™ (http://www.ogcnetwork.net/), a GeoPackage [12] is a universal open file format for geo-data provided by Open Geospatial Consortium (OGC).

A **GeoPackage** is an open, standards-based, platform-independent, portable, self-describing, compact format for transferring geospatial information. It is a platform-independent SQLite database file that contains the GeoPackage data and metadata tables.

http://www.geopackage.org/spec/

It is standards-based, application and platform independent and self-describing to increase the cross-platform interoperability of geospatial applications and web services. It is designed to facilitate widespread adoption and use of a single and simple file format by open-source software applications. Since it is built on top of **SQLite**, it can be accessed through SQL standard, giving all performance of a spatial database along with the convenience of a single file-based data set that can be easily shared.

SQLite is an in-process library that implements a self-contained, serverless, zero-configuration, transactional SQL database engine. The code for SQLite is in the public domain and is thus free for use for any purpose, commercial or private. SQLite is the most widely deployed database in the world with more applications than we can count, including several high-profile projects.

https://www.sqlite.org/about.html

An OGC Data Package is able to store:

- vector features
- tile matrix sets of imagery and raster maps at various scales
- attributes (non-spatial data)
- extensions

It could be useful to manage vector data to avoid ESRI **Shapefile** limitations and can be manipulated by OpenGIS Simple Features Reference Implementation (**OGR**) and Geospatial Data Abstraction (**GDAL**) libraries. Its major downside is that the underlying SQLite database is a complex binary format that is not suitable for streaming. It either must be written to the local file system or accessed through an intermediary service like **GeoServer**, one of the Data Repository technologies (see 7.4.3) selected for CLARITY.

A complementary approach is to use Data Packages, as described by **Frictionless Data**, is a simple container format for arbitrary data files.

> **Data Package** is a simple container format used to describe and package a collection of data. The format provides a simple contract for data interoperability that supports frictionless delivery, installation and management of data. Data Packages can be used to package any kind of data. At the same time, for specific common data types such as tabular data it has support for providing important additional descriptive metadata -- for example, describing the columns and data types in a CSV.

https://frictionlessdata.io/data-packages/

It could be useful to include metadata and point to local or remote files including also OGC Data Package files as well as raster images, NetCDF files and Indicator Data resulting from (impact and adaptation) scenario analysis (see 4.1.3).

It currently offers two complexity levels:

Data Package specification, a simple format for packaging data for sharing between tools and people.

- Readme file
- Data Package, a JSON file used as general metadata and resource index
- Data files, for alphanumeric data this model uses CSV files.

Tabular Data Package, a format to package tabular data that builds on Data Package but additionally it uses:

- Table Schema, a specification to define a schema for tabular data. This means a JSON file describing data fields, description and data types.
- CSV Dialect Description Format, a JSON file where to specify and define a dialect for CSV data.

This simple format can be extended by additional CLARITY JSON metadata files that are recognized by the different Building Blocks and ICT Climate Service developed by CLARITY.

4.3   Scenario Management

The Scenario Management Building Block supports and enforces first and foremost the standardised workflows of the EU-GL [1] for each of the distinct planning steps and provides respective user interfaces that guide the user through the process of co-creating a Climate Adaptation Study. Basically, the end user is presented with the list of recommended and required steps for performing a complete Climate Adaptation Study for the respective (infrastructure) project under assessment and is asked to provide the information

that is needed to complete the current step and advance to the next step. If the user is by itself not able to give the needed information (e.g. detailed local hazard maps for hazard characterisation), the user can either perform a limited pre-assessment (pre-feasibility study) or obtain the required information from a suitable Expert Climate Service (e.g. generate tailored hazard maps by running local climate models) that is available from the CLARITY Marketplace (7.6).

For each of the distinct EU-GL modules or steps (Figure 20) the CSIS offers generic data-driven ICT Climate Services and Building Blocks, respectively, which are directly integrated into the Scenario Management Building Block. Additionally, there is the possibility for Climate Server Providers to develop sectoral or even site-specific ICT Climate Services that can be integrated into the Scenario Management Building Block on-demand for specific infrastructure project types, sectors or Climate Service Customers. This applies for example specifically to the non-generic aspect of Scenario Management, which is explained in the following.
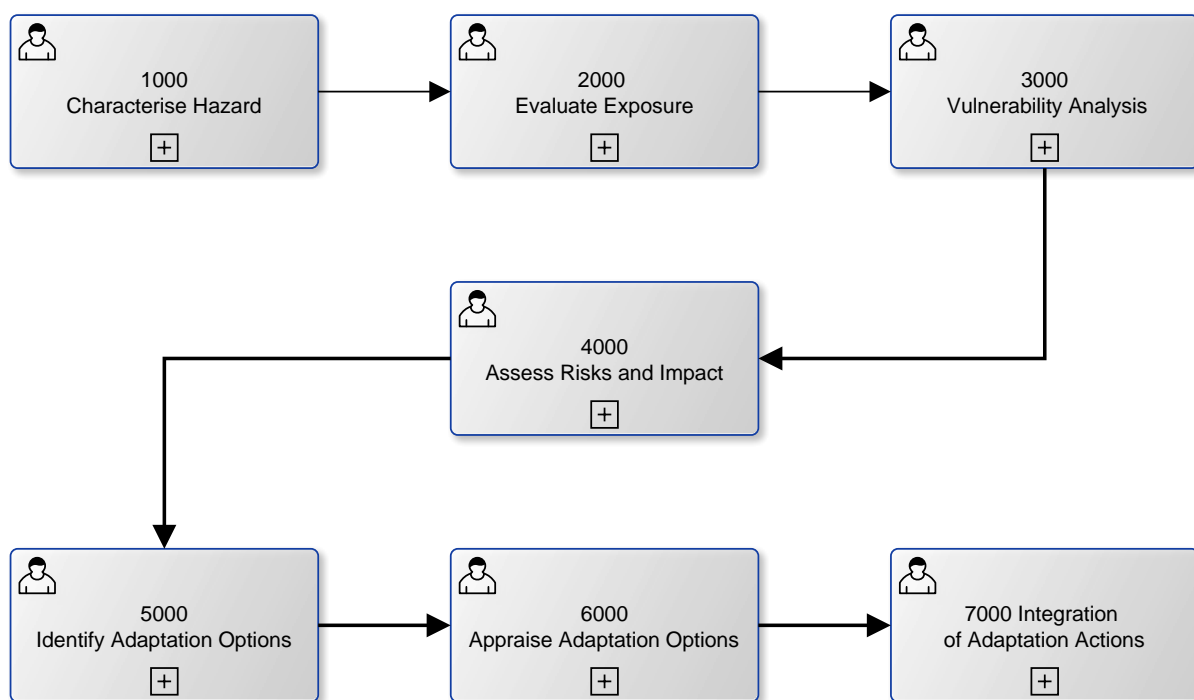
Figure 20: Modules of the EU-GL as part of the overall CLARITY CSIS workflow

The second aspect of Scenario Management, the site- and use-case-specific impact scenario analysis, covers mainly the modules related to the assessment of risks and impact and the identification of adaptation options (resulting from varying impact scenarios) and is currently foreseen to be provided as tailored Expert Climate Service rather than as generic ICT Climate Services. Nevertheless, also possibilities to support Climate Service Providers in actually performing impact scenarios are discussed in section 4.1.3. Independently of that, the results of such impact scenarios, if available in a standardised format supported by CLARITY, can of course be used in further modules and the respective Building Blocks like the Map Component (5.1), the Scenario Transferability Component (5.2) and the Multi Criteria Decision Support Analysis Tool (6.1).

4.3.1　Requested functionality

Baseline requirements elicitation and the assessment of presently available Test Cases have yielded the following functional requirements for this Building Block:

Baseline functionality

The CLARITY Description of the Actions (Annex 1 to the Grant Agreement) describes the Scenario Management Building Block as a software that "allows end-users to easily produce and manage new scenarios by editing the parameters of the pre-defined core scenarios as defined in WP1". If applied to the an "EU-GL scenario" the baseline functionality can be summarised as to

- manage projects and planning sessions (assessments)
- step-by-step guide through all steps of the EU-GL modules
- offer generic tools and (freely available) data for each step to be able to perform a pre-assessment
- offer possibilities for tailored data and services (advice, consulting, etc.) if the generic functionality is not sufficient and a detailed assessment is required

Functionality related to the EU-GL Workflow requested by CSIS Test Cases and User Stories:

- from US-CSIS-100: The Scenario Management Component supports and enforce the standardized workflows for each of the supported planning processes
- from TC-CSIS-0052: The Scenario Management Component is responsible for the management of user projects and "planning sessions" (adaptation assessments). The Building Blocks provides the respective user interfaces and communicates with the Integration RDMBS BB to obtain the list of project types (or templates) needed for initial creation of a new project as well as the user specific workspace information that consist of concrete project instances and planning sessions.
- from TC-CSIS-0000: The Scenario Management Component and the project management user interfaces, respectively, are either embedded (e.g. as iframe) in the UI Integration Platform (Drupal System) or directly as part of the UI Integration Platform (e.g. Drupal Module).
- from TC-CSIS-0000: the Scenario Management Building Block should provide APIs and user interfaces to facilitate the management of the planning scenarios.

Functionality related to the EU-GL Workflow requested by DC Test Cases and User Stories:

- from TC-AIT-01: The Scenario Management Component must produce the overall user interface and lead the user from one step to another.
- from TC DC1: The Scenario Management Building Block must provide a user interface (model input data dashboard widget) for the user with the list of required input data needed for the parametrisation / calibrating of a specific (hazard) model that is executed "offline" by an expert. The user must have the possibility to upload the data or to choose existing data from his personal workspace (data dashboard) or from the CLARITY Catalogue of Data Sources and Models or Marketplace.
- from TC DC2 P1: The Scenario Management Building Block must provide a form or questionnaire that allows the user to specify relevant information about his problem (project), such as geographic location, elements and risks, etc.
- from TC DC4 010: The Scenario Management component should generate a formal and standardised order specification for local climate information (hazard) needed by the end user to perform the climate adaptation study. The order specification must take the temporal horizons, the resolution, the spatial extent, the needed climate (hazard) variables, the data format (NetCDF, Shape, ...) requested by the user, etc. into account. The Scenario Management puts the standardised order in the Marketplace and notifies the user, if a CS Providers have accepted the order and have made an offer.
- from TC DC4 080: The Scenario Management component supports the user in selecting the hazards to be considered in his/her study and for each of them selects the impact scenarios to be considered.

Functionality related to simulation scenarios requested by DC Test Cases and User Stories:

- from TC DC1: We are assuming here that simulation scenarios run off-line upon request of end users and are retrieved through the Scenario Management Building Block. Alternatively, the Scenario Management Building Block should allow to run simulations through web services.
- from TC DC1: The Scenario Management Building Block must provide an user interface that will allow the user to request the creation of alternate (adaptation) scenarios for scenario comparison in the expert work flow (adaptation / no-adaptation option). This request needs to include the type of hazard/impact scenarios object of the simulation and the type of adaptation options to take into account. The supported adaptation options for a specific type of scenario are provided by the Catalogue of adaptation options.
- from TC DC1: Scenario Management Building Block must offer a GUI that enables the end user to provide a complete specification of different (adaptation) scenarios that should be performed (off-line) by an expert.

4.3.2 Exploitation Requirements assessment

The assessment of the Exploitation Requirements [11] identified the following concrete technical and functional implications on this Building Block:

Implications related to the EU-GL Workflow:

- from "Co-design Climate Services engaging a community of users, providers, purveyors and researchers": Be based on a well-defined and well-documented process (CLARITY Modelling Methodology) so that both users and providers of Climate Services are aware of the steps of the process as well as the required input and the required output.
- from "Establish trust in Climate Services and their providers": Users must be able to record the decisions that lead to the implementation of climate change adaptation measures and to trace them back to the underlying data and models. This relates mainly to Scenario Management.
- from "Co-design Climate Services engaging a community of users, providers, purveyors and researchers": Be based on a well-defined and well-documented process (CLARITY Modelling Methodology) so that both users and providers of Climate Services are aware of the steps of the process as well as the required input and the required output.
- from "Follow a multi-sectoral approach that crosses the boundary of climate sciences": As different user perspectives (depending on the sectors in which they work in) will lead to different solutions being assessed by the use of CSIS, the Scenario Management is required to be flexible enough to cope with this variety of possible solutions. This is heterogeneity challenge can only be addressed by enforcing standardised processes (CLARITY Modelling Methodology) and data formats (Data Packages).
- from "Provide a user-friendly, intuitive and context-aware discovery and communication infrastructure for Climate Service": At each step ("module" in EU-GL terminology) the Scenario Management Building Block that actually implements the basic or expert workflow, must present information on additional suitable context-dependent and fit-for-purpose local and sectoral data or providers that are able to generate such data. This also includes of course also potential Expert Climate Services and their providers, respectively. When linked to the Marketplace such a discovery approach that recommends relevant content opens new exploitation possibilities.
- from "Provide a user-friendly, intuitive and context-aware discovery and communication infrastructure for Climate Service": The different steps proposed by EU-GL should be presented to the user in a "story" manner, allowing him/her to go back and forth, assessing in a visual manner (i.e, maps, graphs, tables) the consequences of the decisions he/she makes in each step.

- from "Use, define and promote open standards for data and services": The CLARITY Modelling Methodology that is developed in WP3 based on EU-GL combining the concepts of IPCC AR5 and the risk assessment community must manifest in technical specifications and concrete technical solutions (e.g. Scenario Management and CSIS) that are to be provided and co-developed in WP4 and WP1.

Implications related to simulation scenarios:

- from "Provide a user-friendly, intuitive and context-aware discovery and communication infrastructure for Climate Service": ICT Climate Services that allow direct user interaction should be developed according concepts for usability and for human -computer interaction with help of state-of-the- art technologies for user interface design. This demands for modern and lightweight web applications rather than heavyweight and complex desktop applications.

4.3.3 Technology support

Figure 21 gives an overview on the technological possibilities and the related open-source frontend and backend software components that have been selected for the Technology Support Plan.
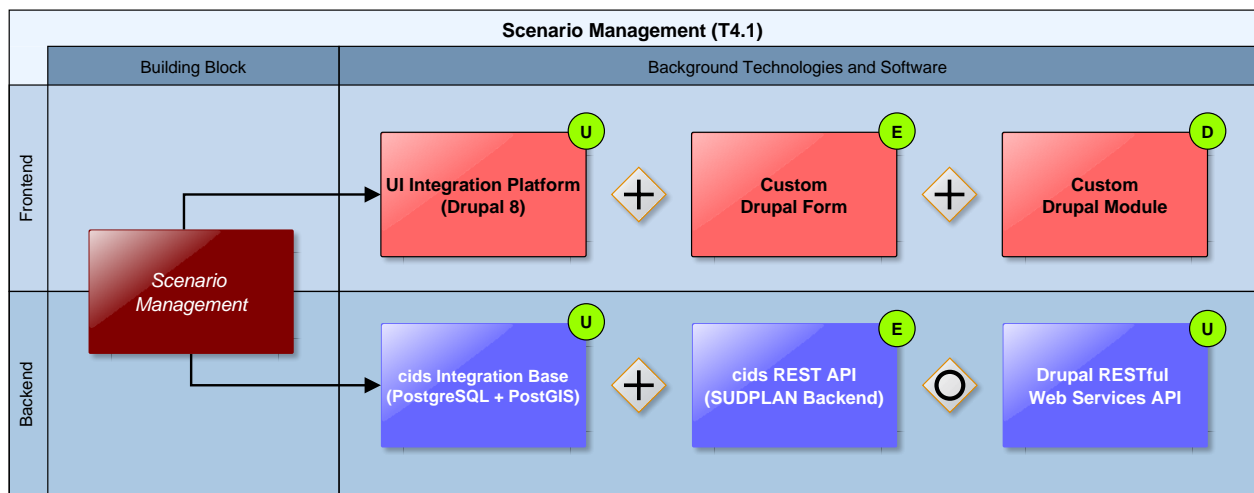
Figure 21: Scenario Management Technology Support
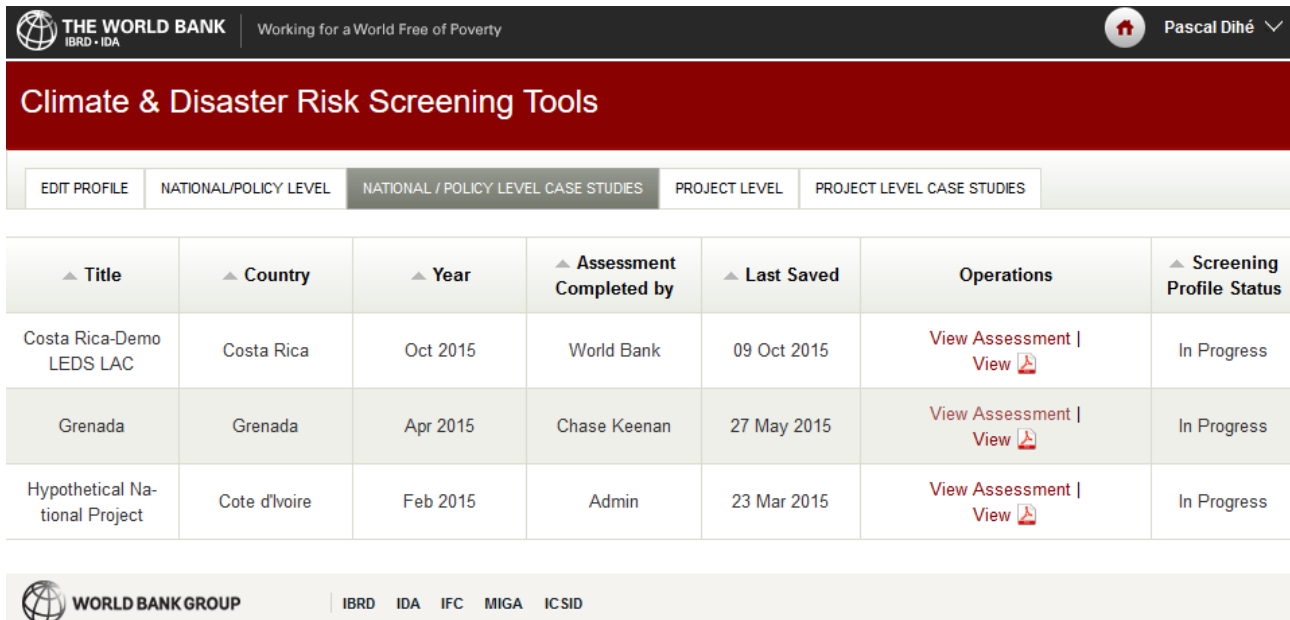
The Technology Support Plan depicted in Figure 21 refers to the Scenario Management Building Block in its role as the overall workflow tool that guides the user through the different steps of the EU-GL methodology (see Figure 20). Accordingly, it is tightly coupled with the overall UI Integration Platform (7.5) and needs to integrate and interact with nearly all other Building Blocks of the CSIS. Therefore, the fronted part of this Building Block will be realised as **Drupal Forms** and custom **Drupal Modules**, respectively as explained in the overall user interface integration concept (7.5.2).

Interestingly, the same approach has been followed for the development of the **World Bank's Climate and Disaster Risk Screening Tools**: They use same technology (**Drupal** and custom **Modules**) as planned to be used for the Scenario Management Building Block.

> The **Climate and Disaster Risk Screening Tools** developed by the World Bank, provide a systematic, consistent, and transparent way of considering short- and long-term climate and disaster risks in project and national/sector planning processes. The tools do not provide a detailed risk analysis, nor do they suggest specific options for increasing the project's resilience. They are intended to help determine the need for further studies, consultation, and/or dialogue in the course of program or project design.

https://climatescreeningtools.worldbank.org/about-the-tools

Although the scope of the World Bank tools is limited to pre-feasibility analysis ("self-assessment"), which covers only a small part of the overall EU-GL methodology and thus also the CLARITY Scenario Management Building Block, the general process of screening and assessing a project for climate risk is the same in the main. Thereby, it serves not only for confirming the technical feasibly of the Technology Support Plan for Scenario Management in CLARITY, it is also basis for discussion with potential end users. Figure 21 shows a screen shot of World Bank tools' project assessment and case studies dashboard and thus an example how the CLARITY Scenario Management could look like.

Figure 22: World Bank Climate and Disaster Risk Screening Tools

Regarding the backend of the Scenario Management, the **cids Integration Base**, which serves also as backend of the SUDPLAN Scenario Man agent System (Annex 1) can be used. Since the Integration Base builds upon the same technology as the Integration RDBMS (7.3) is also a compatible Drupal backend database.

> The **cids Integration Base** is a distributed meta database which consists of a generic meta data model placed in a relational Data Base Management System (RDBMS). It is the basis for a concrete information system and is able to describe arbitrary objects (real-world objects, services, models, geographical features, other information systems, etc.), their attributes (e.g. geographical location) and relationships by means of so-called meta classes and objects.

https://www.cismet.de/cidsReadme.html

Moreover, an additional **RESTful web services API** must be provided to allow also Building Blocks that are not implemented as Drupal Component (Module, Form, …) to communicate securely and transparently

with the backend database. For this purpose, either the new RESTful Web Services API offered by **Drupal 8**, or an extension of the **cids RESTful API** can be used. A choice for one approach depends on technical and functional requirements of the respective Building Blocks.

> The **RESTful Web Services API** is part of the core functionality in **Drupal 8**. It builds on top of Drupal 8's Serialization module to provide a customizable, extensible RESTful API of data managed by Drupal. Out of the box, it allows you to interact with any content entity (nodes, users, comments …) or config entity (vocabularies, user roles…) as well as watchdog database log entries.

https://www.drupal.org/docs/8/api/restful-web-services-api/

While the first part of the Technology Support Plan for the Scenario Management Building Block focused on functionalities for end users (Climate Service Customers), the second part discusses possibilities for supporting also Climate Service Suppliers in the provision of Expert Climate Services related to impact scenario analysis. In the original work plan, the **SUPDLAN Scenario Management System** (Annex 1) is foreseen to cover this task.

> The **SUDPLAN Scenario Management System** is the platform on which any SUDPLAN Application (or SUDPLAN System) is built. The SMS and can be seen as an integration platform that is able to facilitate climate change induced urban development planning in any city in Europe.

http://sudplan.eu/results

However, it must be admitted, that the whole field of simulation model and data integration in the context of impact scenario analysis poses several non-trivial yet only partially resolved problems. Currently, ICT is still far from being able providing a fully automated solution that can solve the integration challenge and to offer a generic scenario management system that is able to conduct arbitrary simulations at the click of a button.

Therefore, a common approach that has also been followed in the SUDPLAN (http://www.sudplan.eu/) and CRISMA (http://www.crismaproject.eu/) projects is to provide a toolkit or framework for the actual development of such an expert system for simulation management. Such a toolkit offers a set of composable and generic **Building Blocks**, which can be integrated and assembled together with local and heterogeneous data and models into complex applications. In principle, the same approach is also applied in CLARITY when ICT and Expert Climate Services are co-developed with help of Building Blocks provided by WP4 "Technology Support" (see section 1.2). Most toolkit approaches rely upon interoperability standards for data exchange and model integration, most notably the standards of the Open Geospatial Consortium (OGC) as used also in the SUDPLAN Scenario Management System's "**Model as Service Integration**" Building Bock (Annex 1). Again, this is very similar to CLARITY's data driven approach that expects generic ICT Climate Services to rely on standardised data formats.

> The **Model as Service Integration** components provide the means to control model implementations and access model results via standardised web services. Technically a new climate-, hazard- or impact models is wrapped as OGC SPS (Sensor Planning Service) so that it can be exposed as web service and executed remotely. The output of the model can be provided via OGC (Web Map Service) or SOS (Sensor Observation Service). While these components provide a standardised access interface for model execution and data retrieval, wrapping a particular model requires nevertheless a certain amount of development and data transformation effort.

http://sudplan.eu/results

In reality, local data is not always available in the standardised format expected by the tools offered by a simulation management system toolkit. Moreover, syntactical and semantic description (meta-data) of the data is often not available in a formal description that can be used for (semi-) automatic integration. Admittedly, there is no generic solution for data and model integration and thus no scenario management system without additional development and integration activities. Simulation Management for climate, impact or adaptation scenarios that require calibration and execution of local climate, hazard, and impact models involves therefore for each distinct project under assessment a certain amount of tailoring and customisation. Technology support can be provided, as for example in form of a Framework like the SUDPLAN SMS, to support this process on the Climate Service Provider side, but in the end it always boils down to custom integration and development. CLARITY's data-driven approach here is to formalise this process and to select and specify the interoperability standards at the level of the CSIS so that Climate Service Provider are encouraged to deliver the results of their impact scenario analyses in respective format. To this end, no "one size fits all" technical solution can be provided for the management, execution and evaluation of impact scenarios but a set of tools, methodologies, standards and best practices that support Climate Service Suppliers in the provision of tailored Expert Climate Services.

5   Scenario Transferability (T4.4)

Figure 15 provides an overview of the Building Blocks that are covered by T4.4.
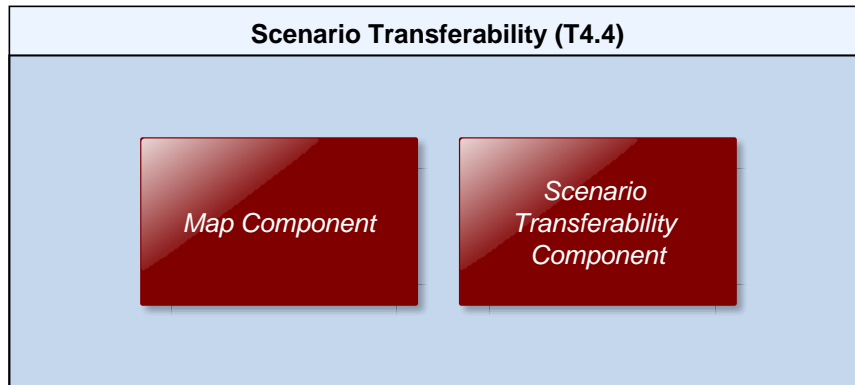
Figure 23: T4.4 Building Blocks

The Scenario Transferability task is covering the possibility of the CSIS to provide the user with the functionality to compare climate conditions, hazards and possibly project types with other such criteria at a point of interest he or she can choose on a map. In this way guiding the user to hazard information and/or solutions already found elsewhere in Europe.

5.1   Map Component

The Map Component is understood as a reusable, flexible and highly configurable Building Block meant to be used throughout CSIS. It is envisioned as an embeddable component that can be easily adapted to different parts of the common CSIS UI. The core functionalities of this component must be a clear and easy visualization of different maps and layers. It is also a key feature of the map component to allow for a degree of interactivity meant to enable users to better define locations, elements at risk, hazards, scenario results, etc.

5.1.1   Requested functionality

Baseline requirements elicitation and the assessment of presently available Test Cases have yielded the following functional requirements for this Building Block:

Baseline functionality

- Basic map functionality such as zoon in, zoom out, pan, click on a point (and get info related to it if available), draw polygon/bbox, etc.
- Visualize different types of hazard maps in relation to climate change projections for an area of interest
- Advanced layer management: the user must be able to add individual (hazards) maps as layers (e.g. from existing (local) WMS), and to provide a set predefined climate change projection layers (e.g. from C3S.)
- Support for Map Layer Timeline, e.g. visualize temperature change between 2020-2050 in an area of interest. This can be achieved using the TIME attribute in WMS GetMap requests.)
- Generate geo-referenced information to exchange with planning services (data might be obtained as of SHP, NetCDF, geoTIF, etc. export) with help of external services (GeoServer).

- Show map layers from both internal and external WMS Services (CLARITY cloud file storage / GeoServer / or public Open Data inventories.)
- Spatial data import: the user must be able to upload (hazards) maps in a standardised format, add them to a private data repository and the workspace, and show them as a layer.
- Predefined layers: provide a set predefined climate change projection layers (e.g. from C3S.)
- Tabular visualisation of GML Feature's attributes obtained from an OGC WFS.
- Editing of GML Feature's attributes via OGC WFS-T.

Functionality requested by CSIS Test Cases

- from US-CSIS-100: For the pre-feasibility study, where the user selects some random location, the system should be able to extract the information from the map at the selected location. So, the map component must be able to account for these interactions too. This information must also be available within the system (not offline, by some expert), so it can be used for the automatic evaluation: pre feasibility risk analysis and reporting. For the expert study, the expert must be able to upload/download the maps to analyse them offline, this will depend on the US/TC.
- from TC-CSIS-0053: The map component is used to specify, view and change the geospatial project location. It will also display some standard background layers (topographic, aerial, etc.)

Functionality requested by DC Test Cases

- from US-DC1-150: The results of CLARITY simulations and climate services could be visualized as Georeferenced maps.
- from US-DC1-110: Visualize heat wave, landslide and pluvial flood hazard maps in relation to climate change projections for the area of the Metropolitan City of Naples.
- from TC DC1: Display results of impact scenario (no adaptation) on a map (note that map visualization must always include a legend based on the layers included).
- from TC DC1: Map widget should allow the comparison among "non adaptation" and "adaptation" scenarios (e.g. two maps juxtaposed on the same screen), see also Scenario Transferability Component.
- from TC DC1: The Map View must provide an user interface that will allow the user to visualize the location of the current project under assessment (e.g. city) and to specific the spatial extent (area under assessment) that should be considered by a local model (e.g. urban climate model) when producing a specific hazard map (e.g. heat waves) for that particular area.
- from TC DC1: Displays hazards maps resulting from local models (e.g. urban climate models) run "offline" by experts.
- from TC DC4: Displays the hazards using a map. It must allow the user to configure how to represent them.
- from TC DC4: The user selects a specific geographical area. The user needs to modify the geographical location of a selected element at risk.
- from TC DC4: Needed to upload / store / compute / maps at a regional or local scale to allow to evaluate the climate risks.
- from TC DC4: The user defines the geographical area covered by the study and loads the elements of the area
- from TC RA: Position the elements at risk on a map, to show the hazard map layers and to show a colour-coded map with the results of the HxExV calculation (alternative to showing it in a table.).
- from TC RA: Select and show an entire inventory of elements at risk (e.g. buildings layer) on the map.

5.1.2   Technology support

Figure 24 gives an overview on the technological possibilities and the related open-source frontend and backend software components that have been selected for the Technology Support Plan.
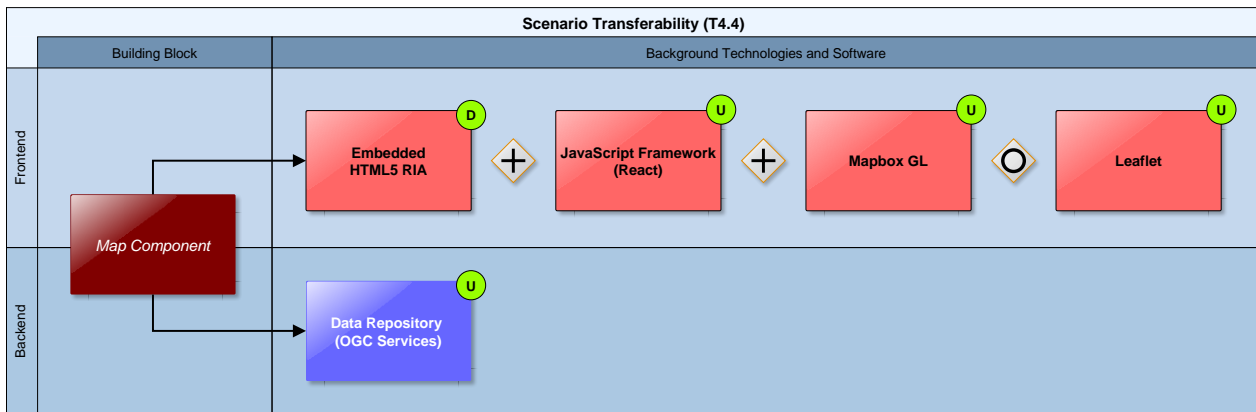
Figure 24: Map Component Technology Support

The high interactivity and flexibility expected from this component requires an approach based on responsive and highly adaptable technologies. This approach can be achieved using client-side rendering along with libraries and tools that have already proved their usability and popularity, meaning that a big and active community is supporting their development and use. To ensure this high interactivity approach of this web application a good approach would be to use **React**, React allows rich site interactions, fast website rendering after the initial load, and a good selection of JavaScript libraries. It is also designed to build encapsulated components that can be composed to make complex UIs. In consequence, the Map Component is developed as independent **HTML5/AJAX RIA** that is loosely embedded as **HTML5 iframe** in the UI Integration Platform (**Drupal 8**, see 7.5) and relies as backend on Data Repository (7.4) and various OGC Services, respectively.

In terms of an open-source solution for the map itself, a proposed solution will be the use of **Mapbox GL** and **Leaflet** depending on the necessities of each map or layer. Mapbox provides a number of tools to build maps into a website or application. It is an open source JavaScript library that can be used to display maps, add interactivity, and customize the map experience. There are also a number of plugins for extending the map's functionality with drawing tools and interfaces to Mapbox web services APIs like the Mapbox Geocoding API or Mapbox Directions API.

> **Mapbox GL** is a suite of open-source libraries for embedding highly customizable and responsive client-side maps in Web, mobile, and desktop applications. Maps render at a super high framerate. You can use custom styles designed in Mapbox Studio. You can also manipulate every aspect of the style's appearance on the fly, because Mapbox GL renders vector tiles. The abbreviation "GL" comes from OpenGL, the industry-standard Open Graphics Library.

https://www.mapbox.com/help/define-mapbox-gl/

While Leaflet is meant to be as lightweight as possible, and focuses on a core set of features, an easy way to extend its functionality is to use third-party plugins developed by an active community.

> **Leaflet** is the leading open-source JavaScript library for mobile-friendly interactive maps. Weighing just about 38 KB of JS, it has all the mapping features most developers ever need. Leaflet is designed with simplicity, performance and usability in mind. It works efficiently across all major desktop and mobile platforms, can be extended with lots of plugins, has a beautiful, easy to use and well-documented API and a simple, readable source code that is a joy to contribute to.

http://leafletjs.com/

Figure 25 shows an example from CRISMA project where Leaflet has been used for the visualisation of different maps, including geophysical hazard maps.
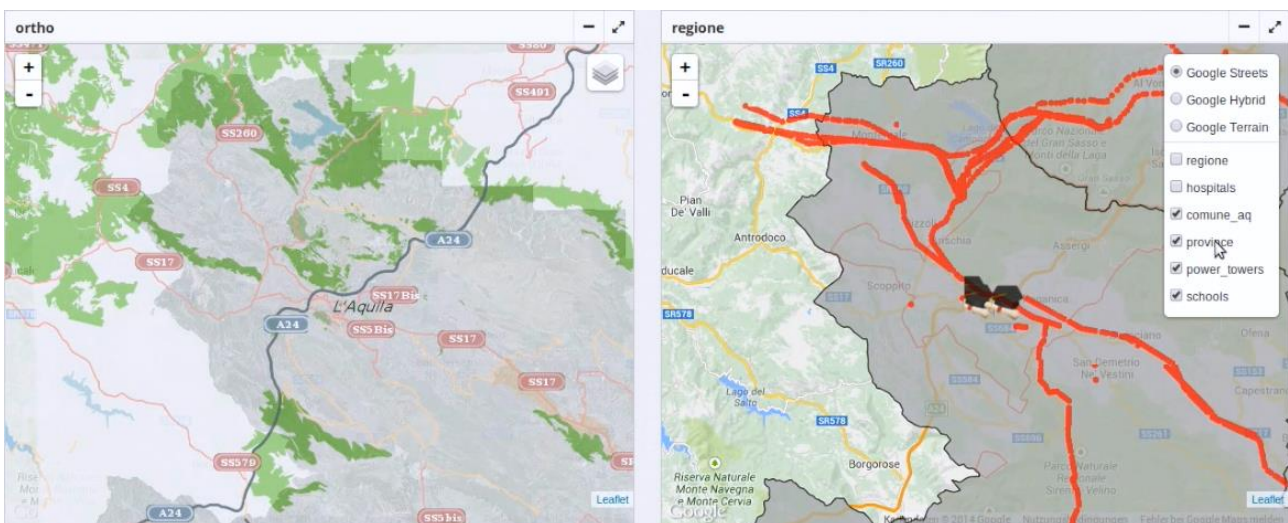
Figure 25: Leaflet Example

5.2 Scenario Transferability Component

There are two main usage scenarios for the Scenario Transferability Component: Providing general matchmaking functionality by means of "Smart Links" (REST API) and side-by-side (visual) comparison of alternate (adaptation) scenarios (graphical user interface):

Matchmaking

In the first usage scenario, the Scenario Transferability Component is used for discovery and matchmaking of related entities like scenarios, projects, elements at risk, adaptation options, etc. For example, applied to the Catalogue of Elements at Risk and Adaptation Options (3.1), infrastructure projects being assessed by end users can be matched to other projects that share the same elements at risk (covering a variety of sectors). The same could be true for adaptation options or adaptation Scenarios. Moreover, end users could discover other projects with the same proposed or already implemented adaptation options, in order to investigate further and learn from the experiences already made.

The Scenario Transferability Component should also be used to match the offer of Expert Climate Services that are described in Marketplace (7.6) as part of a Climate Service Provider's Service Portfolio against the demand of the users, e.g. when performing a Climate Adaptation Study. Moreover, the Transferability Component should also provide links to partner portals like Climate-ADAPT (http://climate-adapt.eea.europa.eu/http://climate-adapt.eea.europa.eu/) or Upstream Climate Services like SWICCA (http://swicca.climate.copernicus.eu/).http://swicca.climate.copernicus.eu/). Thereby, contextual information (e.g. spatial location, climate hazard, sector, etc.)...) should also be used (e.g. by means of HTTP

GET parameters or deep links) to direct the user to relevant information (e.g. guidance documents) and data (provenance).

Scenario Analysis and Comparison

In the second usage scenario, the Scenario Transferability Component is used for (visual) scenario analysis and comparison. Thereby, it allows the side-by-side comparison not only of different climate scenarios (Climate Twins Concepts), but also the comparison of alternate adaptation scenarios resulting from Impact Scenario Analysis as described in EU-GL Module 4 "Assess Risks and Impact" and in chapter 3.3 "Risk Assessment and Impact Scenario Analysis" of D3.1 [7]. To support a generic comparison of arbitrary impact scenarios, the Scenario Transferability Component relies on standardised data formats for aggregated scenario data (indicators) in JSON/CSV format and spatial data (maps) in OGC format. The Component supports decision making by visualising the key performance indicators (e.g. operation duration, number of evacuated citizens, number of deaths, value of lost property, value of lost productivity, price of mitigation actions, etc.) as tables, diagrams or maps.

5.2.1   Requested functionality

Baseline requirements elicitation and the assessment of presently available Test Cases have yielded the following functional requirements for this Building Block:

Baseline functionality related to "Matchmaking"

- describe a relationship between different entities and that can be enriched with additional metadata
- connected case studies (CLARITY Demonstration Cases) via "Smart Links" to product portfolios of Climate Service Providers as well as to the underlying data and models and their provenance metadata
- provide references to external information sources (documentation, papers, websites, etc.).
- Climate Twins matrix should not only to be based on climate (false-positive aspect of climate change: it's getting warmer) but also on sectoral impact (negative effects)

Functionality requested by CSIS Test Cases related to "Matchmaking"

- support for "Smart Links" that describe a relationship between different entities and that can be enriched with additional metadata
- connected case studies (CLARITY Demonstration Cases) via "Smart Links" to product portfolios of Climate Service Providers as well as to the underlying data and models and their provenance metadata
- provide references to external information sources (documentation, papers, websites, etc.).
- Climate Twins matrix should not only to be based on climate (false-positive aspect of climate change: it's getting warmer) but also on sectoral impact (negative effects)

Functionality related to "Matchmaking" requested by DC Test Cases

- from TC DC1: The Scenario Transferability Component could be used for matchmaking functionality: If the user is in need of a specific hazard map (input: hazard type) for a specification location (input: spatial location) and resolution, the Scenario Transferability Component could query the Catalogue of Data Sources & Models the Marketplace and then and propose a) a local (climate / geophysical / ....) model that is able to generate such a hazard map, b) a list of required input data types (models needs a DEM, model needs cordex climate data, ...) by the model, c) a list of potential data sources that are available for free and for sale and c) CS providers that are able to produce the hazard maps "offline".

Baseline functionality related to "Scenario Analysis and Comparison"

- Comparison of extreme heat event indicators (e.g. tropical nights, summer days/heat days, Kisely index) based on 10 year time slice (decadal) data provided by SMHI.
- Comparison of wind speed patterns based on 10 year time slice (decadal) data provided by SMHI.
- Comparison of extreme precipitation patterns based on 10 year time slice (decadal) data provided by SMHI.
- Display of frequency pattern result maps.

Functionality related to Scenario Analysis and Comparison requested by DC Test Cases

- from TC DC1: Display results of the map (no adaptation) in a table format (needs to be displayed together with the map results)

5.2.2 Exploitation Requirements assessment

The assessment of the Exploitation Requirements [11] identified the following concrete technical and functional implications on this Building Block:

- from "Demonstrate and communicate the (co-)benefits of Climate Services": The implementation of the Demonstration Cases must follow a common methodology that is supported by tools (ICT Climate Services) that are able to generate data-driven insights, e.g. in the form of (standardised) indicators that can be easily visualised (chart, diagram.)
- from "Follow a multi-sectoral approach that crosses the boundary of climate sciences": The scope of the Scenario Transferability concept could be extended beyond basic climate indicators so that end users could also discover "twin" regions within other sectors e.g. where the probability of certain hazards is similar to their actual project region. Furthermore, the Scenario Transferability concept could also be applied to the Catalogue of elements at risk and adaptation options so that the end users project being assessed can be matched to other projects that share the same elements at risk (covering a variety of sectors). The same could be true for adaptation options. By the use of Scenario Transferability, end users can search for and find other projects with the same proposed or already implemented adaptation options, in order to investigate further and learn from the experiences already made.
- from "Provide a user-friendly, intuitive and context-aware discovery and communication infrastructure for Climate Service": Discovery and matchmaking (Scenario Transferability) should not be limited to the CSIS (Marketplace) but also provide links to partner portals like Climate-ADAPT (http://climate-adapt.eea.europa.eu/) or Upstream Climate Services like SWICCA (http://swicca.climate.copernicus.eu/). Thereby, contextual information (e.g. spatial location, climate hazard, sector, ...) should also be used (e.g. by means of HTTP GET parameters or deep links) to direct the user to relevant information (e.g. guidance documents) and data (provenance).

5.2.3 Technology support

Figure 26 gives an overview on the technological possibilities and the related open-source frontend and backend software components that have been selected for the Technology Support Plan.
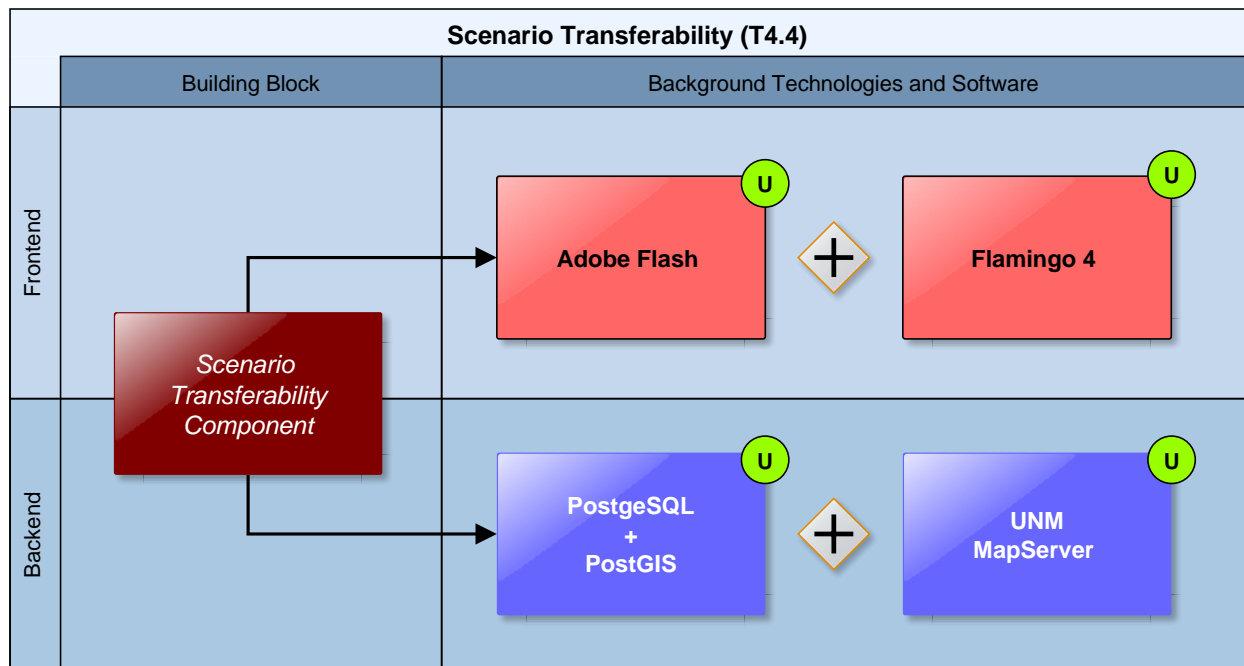
Figure 26: Scenario Transferability Component Technology Support

The original Climate Twins prototype (Annex 1) was based on the following components:

The back end consists of a **PostrgreSQL** relational database running the **PostGIS** extension (see 7.3.2). The database holds the climate comparison matrices derived from AIT's climate simulation runs analysing data from the **COSMO-CLM (COnsortium for Small-scale MOdelling - Climate Local Model)** model which had been embedded into the ECHAM5/MPIOM global model. The model results are climate data on an hourly basis from 1960 to 2100 in a raster with a resolution of 0.165 (approx. 18 to 20 km).

The front end is using a (at that time Adobe Flash© based) Map Viewer (**FlamingoViewer**). The viewer is visualising the results of the Climate Twins request via WMS maps served by an **UMN Mapserver** instance running on the same server.

Flamingo 4 is an open source geo content management solution. It allows non-technical administrators to manage the way geospatial data is published in the Flamingo 4 web-viewer. The web based viewer can be configured by dragging and dropping components in a layout.

https://github.com/flamingo-geocms/flamingo/wiki

Adobe Flash is a deprecated multimedia software platform used for production of animations, rich Internet applications, desktop applications, mobile applications, mobile games and embedded web browser video players. Flash displays text, vector graphics and raster graphics to provide animations, video games and applications. It allows streaming of audio and video, and can capture mouse, keyboard, microphone and camera input. Related development platform Adobe AIR continues to be supported.

https://en.wikipedia.org/wiki/Adobe_Flash

> **MapServer** is an Open Source platform for publishing spatial data and interactive mapping applications to the web. Originally developed in the mid-1990's at the University of Minnesota, MapServer is released under an MIT-style license, and runs on all major platforms (Windows, Linux, Mac OS X). MapServer is not a full-featured GIS system, nor does it aspire to be.

http://mapserver.org/

Since the above technologies (Adobe Flash© and UMN MapServer) can be considered rather outdated, it is not feasible to re-use them within CLARITY. We will therefore focus on the re-use of the data base matrices and the comparison algorithms used within the Climate Twins application and serve the results via a RESTful web service e.g.
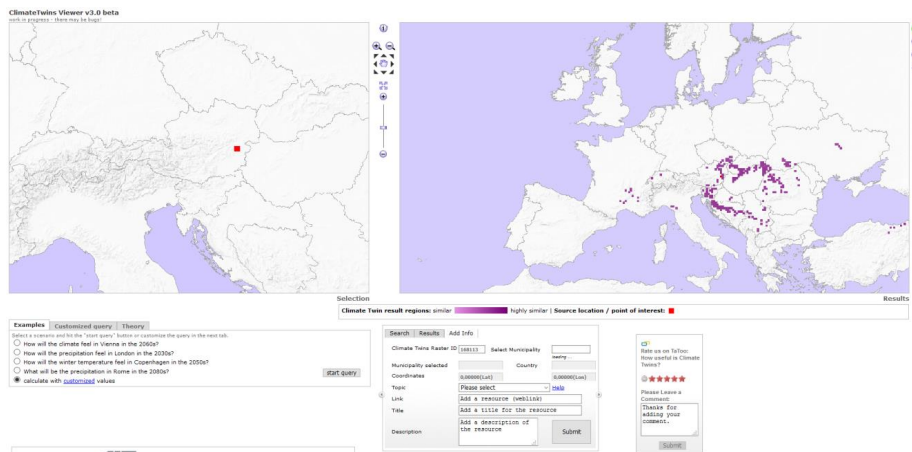
Figure 27: Climate Twins Prototype Web Application

6 Scenario Analysis, Decision Support and Report Generation (T4.5)

Figure 28 provides an overview of the Building Blocks that are covered byT4.5.
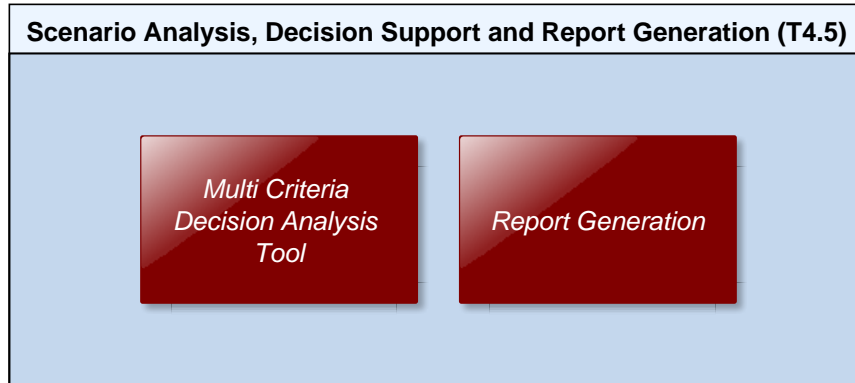
Figure 28: T4.5 Building Blocks

According to the CLARITY work plan, the software provided by this task will support the analysis and comparison of scenario candidates (options) regarding performance indicators that can be defined by the end user. Indicator based decision support functionalities will be provided using concepts and software of the CRISMA FP7 project. The software will address the issue of assessing the results and helping the users to find a compromise solution that satisfies the multiple and often opposed requirements of the key stakeholders.

6.1 Multi Criteria Decision Analysis Tool

The Multi Criteria Decision Analysis Tool supports the analysis and comparison of (adaptation) scenarios regarding performance indicators that can be defined by the end user and thus leverages what-if decision support to investigate the effects of adaptation measures and risk reduction options in the specific project context, and allows the comparison of alternative strategies. Thereby the tool provides multi-criteria ranking functions to compare and rank different scenarios and corresponding adaptation plans according to different criteria and their relative weight and level of importance.

6.1.1 Requested functionality

Baseline requirements elicitation and the assessment of presently available Test Cases have yielded the following functional requirements for this Building Block:

Baseline functionality

- a highly interactive and user-friendly decision support tool
- supports state of the art Multi-Criteria Decision Analysis (MCDA) methods
- helps the decision maker and strategic planner to perform multi-criteria ranking of scenarios
- compares Indicators (quantity) derived (e.g. aggregated by an expert-provided Indicator Function) from complex and usually not easily comparable scenario data (e.g. outputs of impact models)
- compares Criteria (quality) derived from Indicators by defining a level of satisfaction for each Indicator (qualification)
- performs ranking of scenarios with respect to a user-defined decision strategy (e.g. Ordered Weighted Averages)

- implements different weighting strategies

Functionality requested by DC Test Cases

- from TC DC1: This Building Block should allow the following: 1. selection of the "weight" of predefined performance criteria (e.g. cost, avoided impacts, other co-benefits, etc.); 2. ranking of alternative scenarios following the selected criteria.
- from TC DC4 080: The Multi-Criteria-Analysis Decision Support Tool is used to help the user on decision making based on standardised indicators derived from impact scenario data.

6.1.2 Exploitation Requirements assessment

The assessment of the Exploitation Requirements [11] identified the following concrete technical and functional implications on this Building Block:

- from "Establish trust in Climate Services and their providers": Uncertainty should be quantifiable, e.g. derived from statistical properties. Then, uncertainty could be considered as an indicator that can be transformed (normalised) to criteria. This way, uncertainty could be incorporated into Multi Criteria Analysis.
- from "Follow a multi-sectoral approach that crosses the boundary of climate sciences": Depending on the type of project as well as the sector and fields of interest of end users, the importance of different parameters will vary. E.g. For most project managers, financial parameters/indicators and information will be of higher interest, than climatic indicators and information by itself, while end users with a focus on risk assessment in order to keep people save will value indicators about the occurrence and intensity of climate related hazards higher, than financial parameters. In order to provide pinpointed information for all relevant parties, it must be ensured that the results and provided information suits their respective needs. If there is the need to rank different scenarios, this could be e.g. done by implementing a weighing system for indicators (automatic per type of end user or end users set the weighting factors according to their preferences) for the Multi Criteria Analysis. With indicators, being part of the results provided to end users, those indicators must address all possible questions related to Climate Services end users might have. Therefore, indicators need to cover a wide variety of topics (climate, air quality, financial, social, etc.).
- from "Use, define and promote open standards for data and services": A simple (KISS principle) standardised format for Indicators that are relevant for the Multi Criteria Decision Analysis must be defined. Technically, (impact) model output must be transformed (e.g. by an aggregation or Indicator Function) into a standardised Indicator Set so that the Indicators can easily be compared or visualised by the respective tools.

6.1.3 Technology support

Figure 29 gives an overview on the technological possibilities and the related open-source frontend and backend software components that have been selected for the Technology Support Plan.
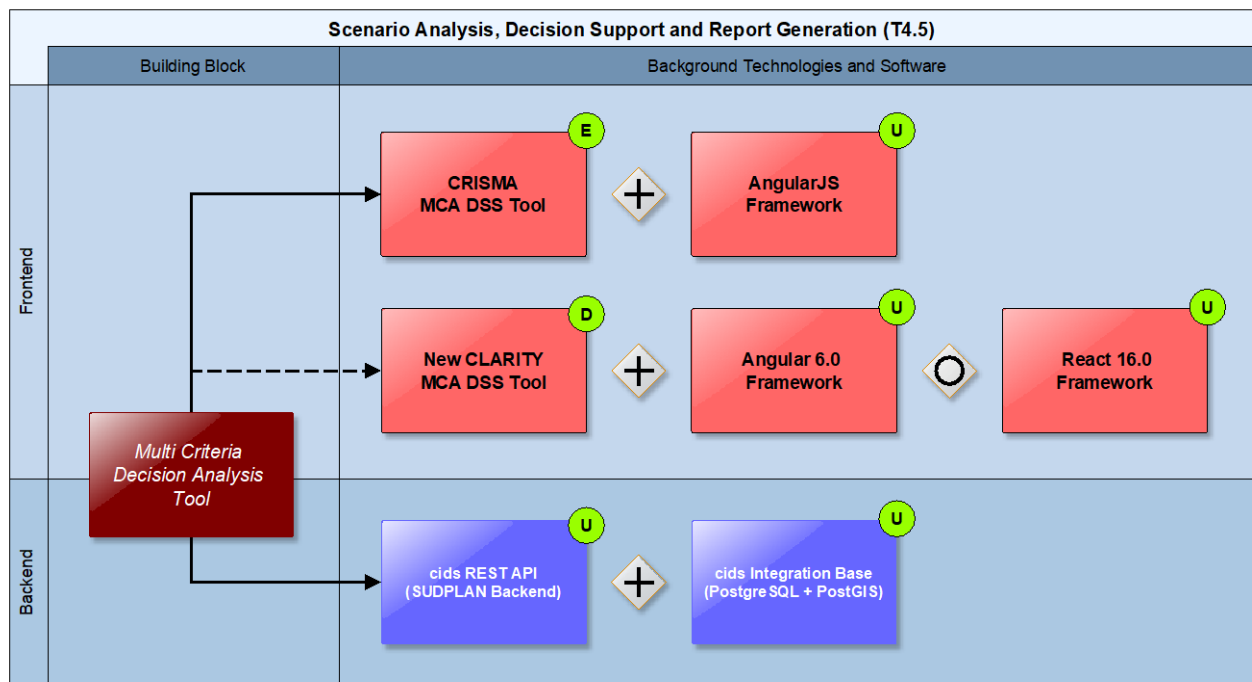
Figure 29: Multi Criteria Decision Analysis Tool Technology Support

As described in Annex 1, the **Multi Criteria Decision Analysis (MCDA) Tools** (https://github.com/crismaproject) of the CRISMA project (https://crisma-cat.ait.ac.at/) are developed as open-source **HTML5/AJAX** widgets which makes them directly usable as generic ICT Climate Services. They rely on a simple standardised **JSON** (JavaScript Object Notation) data format which fits perfectly into CLARITY's data driven approach and, in combination with the **RESTful API** deployed on top of a **PostgreSQL** database, is also compatible with the Integration RDBMS (7.3) backend of the Scenario Management (4.3) and UI Integration Platform (7.5) Building Blocks, respectively.

> **JSON** (JavaScript Object Notation) is a lightweight data-interchange format. It is easy for humans to read and write. It is easy for machines to parse and generate. It is based on a subset of the JavaScript Programming Language, Standard ECMA-262 3rd Edition - December 1999. JSON is a text format that is completely language independent but uses conventions that are familiar to programmers of the C-family of languages, including C, C++, C#, Java, JavaScript, Perl, Python, and many others. These properties make JSON an ideal data-interchange language.

https://www.json.org/

As the CRISMA tools have been implemented on basis of the **AngularJS** 1.0 JavaScript framework, it must be noted, that version 1.0 has been superseded by **Angular** 5.0 in 2017 and version 1.0 reached end of life in 2016. Although AngularJS 1.0 is still actively maintained by the community on GitHub (https://github.com/angular/angular.js/), no new plugins and libraries are being developed for version 1.0 and existing libraries and plugins don't receive new feature or security updates for AngularJS 1.0 in most cases.

> **AngularJS** is a toolset for building the framework most suited to your application development. It is fully extensible and works well with other libraries. Every feature can be modified or replaced to suit your unique development workflow and feature needs. Read on to find out how.

https://angularjs.org/

Depending on additional functionality that is requested for the Multi Criteria Decision Analysis Tool, it might therefore be necessary to base further developments of the tool on more recent JavaScript Frameworks like **Angular 6.0** or **React 16.0**. A detailed discussion of this topic can be found in the description of the planned usage of the CRISMA Multi Criteria Decision Analysis Tool in in Annex 1.

6.2 Report Generation

The result of a climate adaptation study is a report that could be (semi-)automatically generated. Report Generation should enable the user to easily access and download draft and final reports packages at the end of the project assessment process. Such report packages should include automatically generated documentation (with embedded supporting tables, graphs and maps of the area under study) along with all the datasets (Data Package, see 4.2) used in the study. In this way, the packages generated can be further used in other stages of the planning project.

The (semi-)automatic Report Generation depends on well-defined inputs that can be validated, aggregated and visualised. Therefore, technical standards for the respective input formats must be adopted by CLARITY Data Packages and communicated to external stakeholders that want to use the CLARITY Report Generation functionality for their Expert Climate Services.

6.2.1   Requested functionality

Baseline requirements elicitation and the assessment of presently available Test Cases have yielded the following functional requirements for this Building Block:

Baseline functionality

- The Report Generation component must be able to produce downloadable PDF files.
- The component will be able to access information of the case study, and export this information to a dedicated document.
- The component must be able to include both text and graphical information available for the study.

Functionality requested by CSIS Test Cases

- from US-CSIS-100: The Report Generation Component should be automatically generated based on the available data and users' decisions. This must be a credible report so that it can be added to project documentation
- from US-CSIS-100: The report should also contain the information that is needed for auditing the decision making process later on. For example, the list of all actions, inputs, outputs and decisions.

Functionality requested by DC Test Cases

- from US-DC1-100: The results of CLARITY simulations and climate services can be visualized as synthetic document (e.g. PDF with text and images.)
- from TC DC1: The Report Generation Building Block should allow to acquire in a single document the results of the simulation and MCDA.
- from TC DC4 090: The Report Generation Building Block can show a preliminary report with the results obtained in the project and allows for the inclusion of new information for the generation of the final report.

6.2.2   Exploitation Requirements assessment

The assessment of the Exploitation Requirements [11] identified the following concrete technical and functional implications on this Building Block:

- from "Follow a multi-sectoral approach that crosses the boundary of climate sciences": Besides the possibility to produce a general/summarized report which contains the most important information, the ability of Reporting Generation to produce additional extended focus reports which addresses certain sectors (climate, adaptation, financial, people, etc.) in more detail, could contribute to always providing the most valuable information to end users without overloading them with information.
- from "Consider the role of new regulatory frameworks in stimulating the emergence of Climate Services": Simple templates for reports must be defined. This requires an assessment of regulatory frameworks and their requirements. Besides the omnipresent EU-GL, this includes for example also the methodology for tracking climate adaptation finance of Multilateral Development Banks
- from "Consider the role of new regulatory frameworks in stimulating the emergence of Climate Services": (semi-) automatic Report Generation depends on well-defined input that can validated, aggregated and visualised. Therefore, technical standards for the respective input formats (Data Packages) must be defined and communicated to external stakeholders that want to use CLARITY Report Generation functionality for their Expert Climate Services.
- from "Provide a user-friendly, intuitive and context-aware discovery and communication infrastructure for Climate Service": Reporting Generation should enable the user to easily access and download draft and final reports packages at the end of the project assessment process. Such report packages should include automatically generated documentation (with embedded supporting tables, graphs and maps of the study area) together with all the datasets (Data Package) used in the study in order to be further used in other stages of the planning project.

6.2.3 Technology support

Figure 30 gives an overview on the technological possibilities and the related open-source frontend software components that have been selected for the Technology Support Plan.
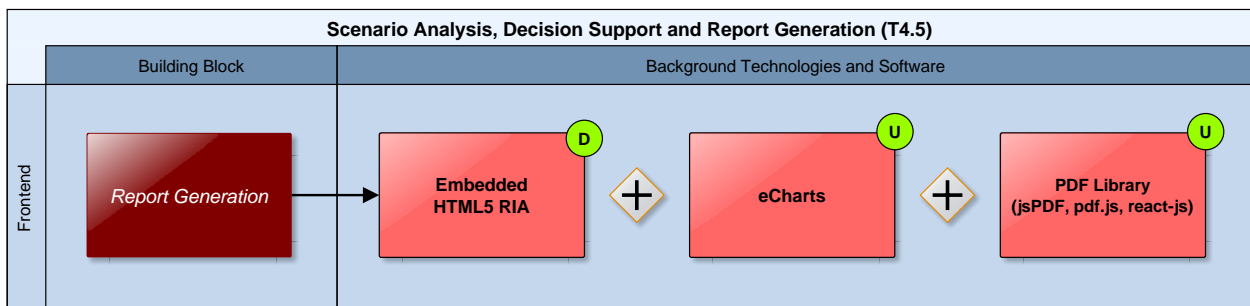

Figure 30: Report Generation Technology Support

The Report Generation tool is meant to provide a PDF report based on the elements and results of the study done for a certain area under a set of selected conditions. This tool must have access to all the available information for the project and depending on the technology used for the Scenario Management Building Block (6.2) it may be needed to develop a middleware library to retrieve the information from the Integration RDMBS (7.3) or the Data Repository (7.4).

In terms of creating the report itself, a JavaScript library that allows for customization of charts and graphs is **eCharts**. It has a map component and the capability of allowing the user to interact with the charts generated. Being a JS library it can be easily integrated on different platforms and web applications. Both SVG and Canvas, are supported in eCharts.

> **eCharts** is a free, powerful charting and visualization library offering an easy way of adding intuitive, interactive, and highly customizable charts to your commercial products. It is written in pure JavaScript and based on zrender, which is a whole new lightweight canvas library.

https://github.com/ecomfe/echarts

Using both the graphs and charts generated and customized with eCharts and the text existing in the system there are several JavaScript-based libraries that can be employed for the generation of the final report, among these are: **jsPDF**, **pdf.js** or **react-js** among others. The proper choice will be determined by the ease of integration with the User Interface Integration platform.

7   Integration, Infrastructure and Marketplace (T4.1, T1.4 and T5.4)

Figure 31 provides an overview of the Building Blocks that are covered byT4.1, T1.4 and T5.4.

Integration, Infrastructure and Marketplace (T4.1, T1.4 and T5.4)

Marketplace	*UI Integration Platform*	*Integration RDMBS*
Container Engine and Cloud Infrastructure	*Integration and Development Platform*	*Data Repository*
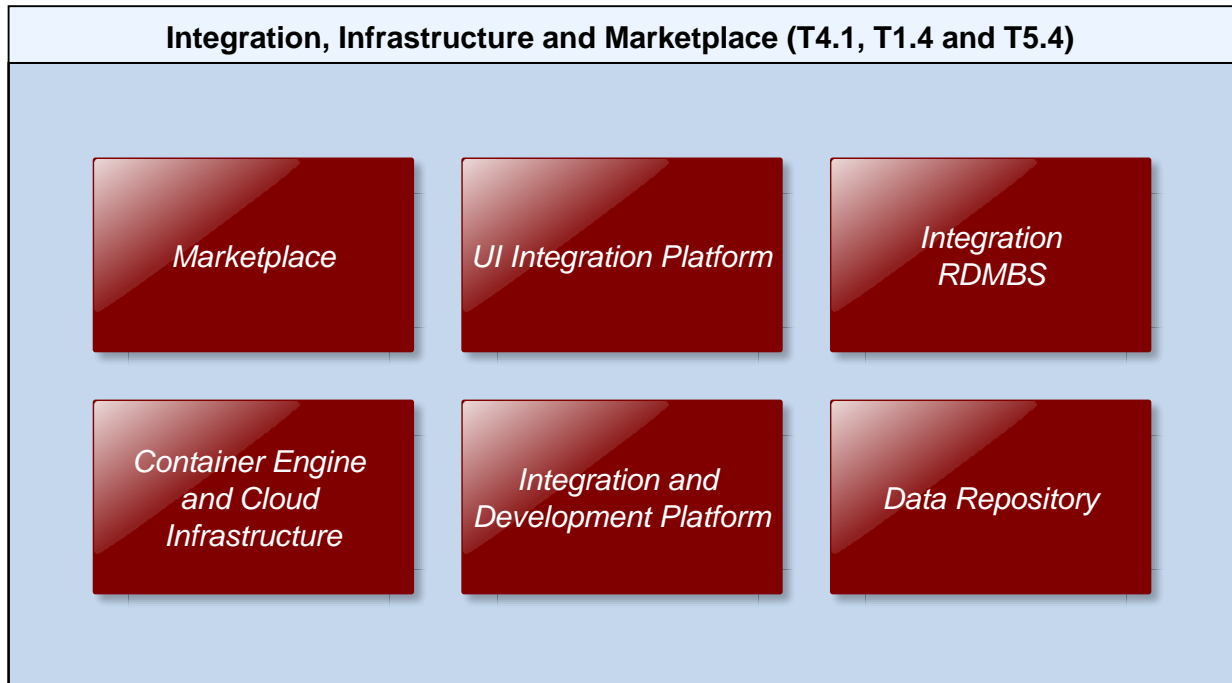
Figure 31: T4.1, T1.4 and T5.4 Building Blocks

Besides the Building Blocks that can be related directly to the different Tasks of WP4 "Technology Support", there several Building Blocks that are provided by T1.4 "Industrialization and Support" and T5.4 "Climate Service Marketplace". While T1.4 provides the necessary repositories for hosting of the CLARITY software code, data and services as well as a set of tools to support the development of industrial-quality code, the objective of T5.4 is to provide a web based platform to support exploitation activities of the project.

7.1   Container Engine and Cloud Infrastructure

The CSIS is envisioned to be composed of a set of (micro) services that can independently be deployed as isolated containers either on a self-hosted physical server that provides its own container engine or in a virtualized environment offered by a cloud hosting provider. For this purpose, a Container Engine and Cloud Infrastructure Building Block must be part of the CSIS Architecture.

The approach of containerising services makes CSIS developments relatively independent of technological constraints regarding background technology of ICT Services. Accordingly, CLARITY's technology support team is free to choose whatever technology or software fits best into CSIS Architecture as long as the requirements (functional, exploitation, etc.) are met and interoperability through well-defined APIs and standards is guaranteed.

As stated in D1.1 "Initial workshops and the CLARITY development environment" [2], having a micro services architecture for CLARITY CSIS, will allow having heterogeneous technological stacks and different deployment processes. Micro services are appropriate as architecture for CLARITY CSIS purposes and fits very well with a continuous integration platform, indeed it allows having heterogeneous technological

stacks and different deployment processes for each software component. It will also bring autonomy on the development process of every consortium partner who will be working on a different CSIS component while having the confidence on not face big issues later on doing the different CSIS components integration.

Accordingly, for most ICT services the CLARITY technology support team will be able to use ready-to-use containers that are available for popular open source solutions like CKAN (3.2.3), PostgeSQL with PostGIS (7.3.2), GeoServer (7.4.3), Drupal 8 (7.5.2) and many more.

7.1.1   Requested functionality

The Container Engine and Cloud Infrastructure Building Block and the approach described above can provide the following baseline functionality and benefits:

- Independent developments.
- Independent deployments.
- Different software stacks.
- Fault tolerance.
- Scalability and re-usability.
- Ease security monitoring.
- Business oriented components.

7.1.2   Exploitation Requirements assessment

The assessment of the Exploitation Requirements [11] identified the following concrete technical and functional implications on this Building Block:

- from "Develop a viable business ecosystem, business model and secure access to funding": Guaranteeing the long-term sustainability of the CSIS, which can be achieved by the provision of a technological infrastructure that ensures maintainability and extensibility beyond the end of the project.
- from "Develop a viable business ecosystem, business model and secure access to funding": Adopting state of the art cloud and container technologies to be able to transfer the complete CSIS to new hosting environment.
- from "Develop a viable business ecosystem, business model and secure access to funding": maximising the usage open source software for the implementation of ICT Climate Services to avoid licensing costs.
- from "Develop a viable business ecosystem, business model and secure access to funding": Minimizing dependencies to software and data that cannot be used after end of the project due to licensing or data protection issues.

7.1.3   Technology support

Figure 32 gives an overview on the technological possibilities and the related open-source backend software components that have been selected for the Technology Support Plan. Since technology support for this Building Block is provided by T1.4 "Industrialization and Support", a more detailed description is provided in D1.1 "Initial workshops and the CLARITY development environment" [8].
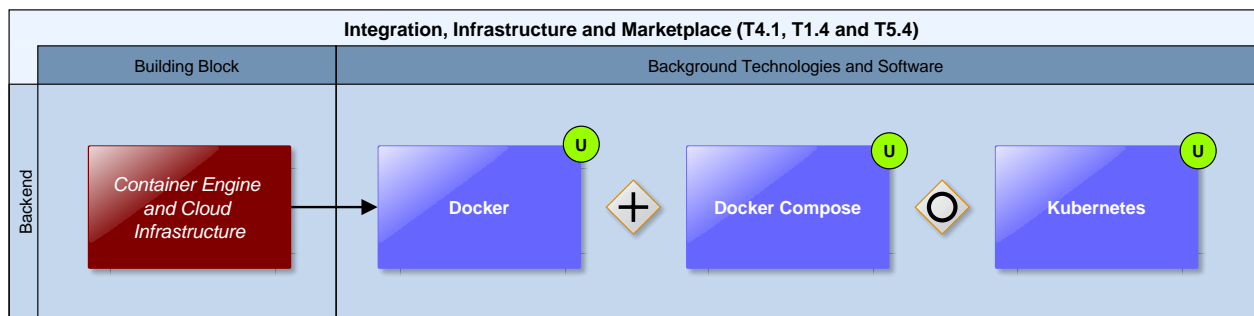
Figure 32: Container Engine and Cloud Infrastructure Technology Support

Regarding containerisation, **Docker** is the choice to achieve having such micro services architecture since Docker container engine is able to encapsulate lightweight runtime environments and provide good portability, performance, ease of replication, environment isolation, high availability and scalability as some of its main features.

> **Docker** is a software technology providing operating-system-level virtualization also known as containers, promoted by the company Docker, Inc. Docker provides an additional layer of abstraction and automation of operating-system-level virtualization on Windows and Linux. Docker uses the resource isolation features of the Linux kernel such as cgroups and kernel namespaces, and a union-capable file system such as OverlayFS and others to allow independent "containers" to run within a single Linux instance, avoiding the overhead of starting and maintaining virtual machines (VMs).

https://en.wikipedia.org/wiki/Docker_(software)

To coordinate, monitor and manage such container infrastructure an automation technology is highly recommendable. **Docker Compose** seems to be appropriate as first approach because its simplicity but depending on the project needs it may change to **Kubernetes**.

> **Kubernetes** is a portable, extensible open-source platform for managing containerized workloads and services, that facilitates both declarative configuration and automation. It has a large, rapidly growing ecosystem. Kubernetes services, support, and tools are widely available. Google open-sourced the Kubernetes project in 2014.

https://kubernetes.io/docs/concepts/overview/what-is-kubernetes/

This kind of tools are able to provisioning hosts, instantiating a set of containers, link containers, expose services and scale the container cluster.

About the underlying hardware infrastructure there are two approaches under consideration:

- **Local server**
  CLARITY partners ATOS or AIT can provide a dedicated development and deployment server (64 GB RAM, 8 cores, 8 TB hard drive) where the tools will be available for automatizing the different CSIS components' code compilation, testing, and integration. Initially this is the option to be used unless project development requires a more powerful infrastructure.
- **European Grid Infrastructure (EGI)**
  EGI is a foundation providing access to computing services across Europe by using grid computing techniques. It links computing centres in different European countries to support international research activities in different disciplines. EGI offers to deploy and scale Docker containers on demand (https://www.egi.eu/services/cloud-container/), offering guaranteed computational

resources in a secure and isolated environment with standard API access, without overhead of managing the operative system for an improved performance, ideal for development work. This option fits well with technical CLARITY ideas so it can be further explored if it is finally needed.

> **EGI** is a federated e-Infrastructure set up to provide advanced computing services for research and innovation. The EGI e-infrastructure is publicly-funded and comprises hundreds of data centres and cloud providers spread across Europe and worldwide. EGI delivers advanced computing services to support scientists, multinational projects and research infrastructures. The EGI Services are provided by EGI's federated cloud providers and data centres. The services can be requested by everyone involved in academic research and businesses via the EGI Marketplace.

https://www.egi.eu/about/

7.2   Integration and Development Platform

As described in D1.1 "Initial workshops and the CLARITY development environment" [2], the purpose of this Building Bock is to provide a continuous integration platform allowing every consortium partner to be equipped with the tools and measures for best practices in software engineering. One of the most important factors on a successful IT project is to develop high quality software. Thereby, an appropriate development infrastructure and best practices are crucial in development in a distributed environment.

"Continuous integration is a software engineering practice in which isolated changes are immediately tested and reported on when they are added to a larger code base. The goal of CI is to provide quick feedback so that if a defect is introduced into the code base, it can be identified and corrected as soon as possible. Continuous integration software tools can be used to automate the testing and build a document trail." [13]

7.2.1   Requested functionality

Baseline requirements elicitation has yielded the following functional requirements for this Building Block:

- support the development of industrial-quality code
- provide a consistent development toolset for
  - source code management
  - dependencies management
  - build automation
  - automated testing
  - continuous integration
  - release management

7.2.2   Exploitation Requirements assessment

The assessment of the Exploitation Requirements [11] identified the following concrete technical and functional implications on this Building Block:

- from "Develop a viable business ecosystem, business model and secure access to funding": provision of a development environment and continuous integration system that eases common software maintenance tasks, e.g. bug fixes.

7.2.3   Technology support

Figure 33 gives an overview on the technological possibilities and the related open-source frontend and backend software components that have been selected for the Technology Support Plan. Since technology

support for this Building Block is provided by T1.4 "Industrialization and Support", a more detailed description is provided in D1.1 "Initial workshops and the CLARITY development environment" [8].
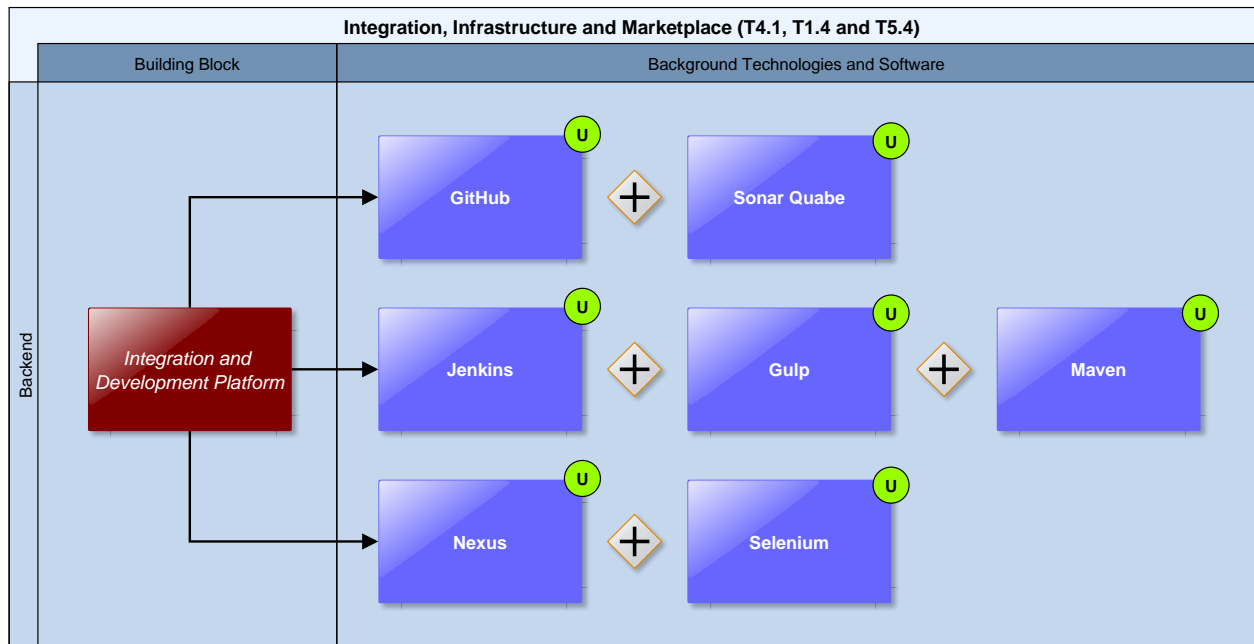

Figure 33: Integration and Development Platform Technology Support

The technology stack of the Integration and Development Platform is briefly described below. The platform itself is realised by means of different **Docker** containers hosted in the CLARITY Container Engine and Cloud Infrastructure (7.1).

> **GitHub** is a web based version control repository. It provides bug tracking, features request, wiki, issue tracking, task management, etc. It is easily integrated with other tools like Jenkins among others making it a good choice for CID (Continuous Integration & Delivery)**.**

https://github.com/

> **Jenkins** is an open source automation server. It is Java based and runs under servlets containers to automatize software development processes, providing integration services. Its functionality can be easily extended by specific plugin, allowing its integration with many other different tools.

https://jenkins.io/

> Sonatype **Nexus** is a repository manager for software "artefacts" required for development. It collects and manages software dependencies making easy to distribute software components for a collaborative software development environment.

https://www.sonatype.com/nexus-repository-oss

> **SonarQube** is an open source platform for continuous code quality inspection, to perform automatic reviews and code. It manages rules, exclusions, alerts, thresholds and allows combining different metrics. It covers main topics of code quality like duplications, unit tests, complexity, potential bugs, coding rules, etc.

https://www.sonarqube.org/

> **Selenium-Grid** is a software-testing framework for web applications. It allows running parallel tests on different machines and even different web browsers at once. All this features make it appropriate for distributed environment tests execution.

https://www.seleniumhq.org/projects/grid

> **Gulp** is an Open Source JavaScript build system working over NodeJS to automatize common development tasks like code minifying, web browser reload, source code validating and image compression among others**.**

https://gulpjs.com/

> Apache **Maven** is an Open Source management and build tool for Java projects based on XML configuration files. It uses a Project Object Model (POM) to describe the software project, its dependencies, modules and external components. It downloads modules dynamically from repositories and it is capable of upload artefacts to the final repository after building.

https://maven.apache.org/

7.3　Integration RDMBS

The Integration RDMBS is the central relational database management system for management and integration of common and shared information stored as relations (in tabular form). It is used as the storage back end of the UI Integration Platform (7.5) and the Scenario Management Building Block (4.3) and stores, among others, the individual infrastructure project configurations and the associated assessment and adaptation planning information created by end users. Thereby, it is important to highlight, that the actual datasets generated during the EU-GL/CLARITY adaptation planning process (hazards maps, model outputs, ...) are not stored in this Integration RDMBS but in general in a separate Data Repository (7.4). The Integration RDBMS Building Block may offer several different databases, each suitable for a different purpose. Therefore, also other Building Blocks that are not directly related to UI Integration Platform, the like Marketplace (7.6) for example, may use the RDMBS as storage back end for their relational data. This allows for easy sharing of common data without the need to introduce additional Building Blocks or APIs.

7.3.1　Requested functionality

Baseline requirements elicitation and the assessment of presently available Test Cases have yielded the following functional requirements for this Building Block:

Baseline functionality

In addition to the common features of a modern Relational Database Management System (e.g. provide relational operators to manipulate the data in tabular form, replication, security, ...), the Integration RDMBS must support storing, processing and querying of spatial data.

Functionality requested by CSIS Test Cases

- from TC-CSIS-0050: The Integration RDMBS BB exposes a REST API towards the user workspace and the Project Master Data databases and provides the following functionalities: get Project Instance from User Workspace, update Project Instance in User Workspace, create Project Option Instances in User Workspace, get Project Option Types for Project Type from Project Master Data, add new Project Option Type to Project Master Data (Project Option Types).

- from TC-CSIS-0060: Static (project types, project option types, sector types, ...) project information as well as concrete instances of projects created by end users (workspace) are stored in this RDMBS.
- from TC-CSIS-0065: Provider Profiles and Portfolios should be stored and managed by this Building Block. It is realised by the PostgreSQL RDBMS database backend of the UI Integration Platform (Drupal) and possibly also the Marketplace Building Block.
- from TC-CSIS-0900: Retrieve information concerning the current project being assessed (e.g. project type) that will be also included in the Data Package.

Functionality requested by DC Test Cases

- from TC DC2 P1 : Database that connect projects to elements at risks, hazards and information in specific datasets.

7.3.2 Technology support

Figure 34 gives an overview on the technological possibilities and the related open-source backend software components that have been selected for the Technology Support Plan.
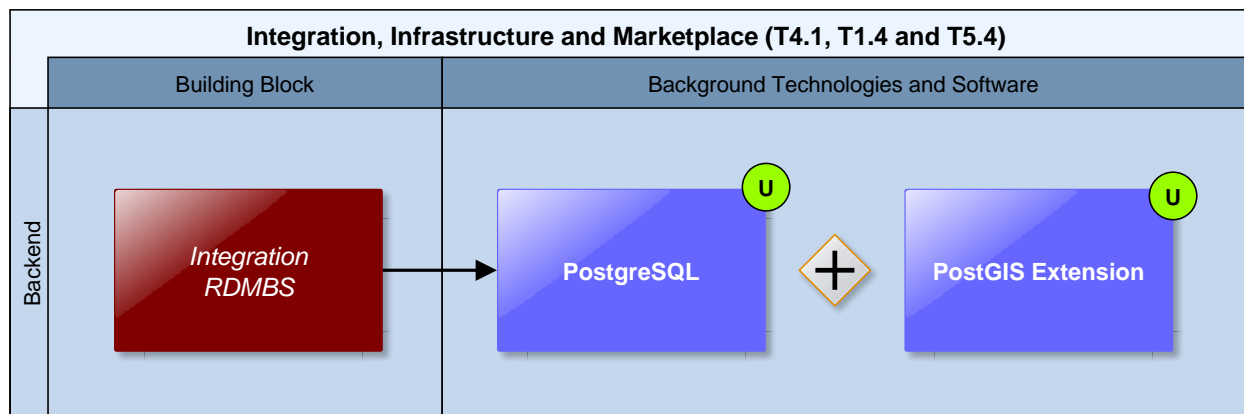
Figure 34: Integration RDMBS Technology Support

PostgreSQL, one of the most widely used RDMBS, has been selected as the actual implementation of the Integration RDMBS.

PostgreSQL is a powerful, open source object-relational database system. It has more than 15 years of active development and a proven architecture that has earned it a strong reputation for reliability, data integrity, and correctness. It is fully ACID compliant, has full support for foreign keys, joins, views, triggers, and stored procedures (in multiple languages). It also supports storage of binary large objects, including pictures, sounds, or video. It has native programming interfaces for C/C++, Java, .Net, Perl, Python, Ruby, Tcl, ODBC, among others, and exceptional documentation.

https://www.postgresql.org/about/

As open-source software, it can not only be used free of charge, it is also the default RDBMS of the **cids Integration Base** (4.3.3) and a supported database backend of **Drupal 8** (UI Integration Platform). Moreover, in combination with the **PostGIS** extensions it supports storage of spatial data and numerous spatial operations including spatial queries.

PostGIS is a spatial database extender for PostgreSQL object-relational database. It adds support for geographic objects allowing location queries to be run in SQL. In addition to basic location awareness, PostGIS offers many features rarely found in other competing spatial databases such as Oracle Locator/Spatial and SQL Server.

https://postgis.net/

Since a relational database management system is per definition generic, no adaptation or development activities are needed apart from the design and specification of individual data models. The data models, especially the cids integration base DDL can be easily extended as needed. Moreover, the ability to implement **stored database procedures** opens wide possibilities for further extensions, e.g. to develop (simple) impact models directly on the level of the RDMBS.

CLARITY partner CIS provides a custom **PostgreSQL 9.x+ PostGIS 2.x Docker image** (https://hub.docker.com/r/cismet/cids-integration-base/) that automatically creates a new cids Integration Base on basis of the *cids-init* database schema DDL. Alternatively, the **mdillon/postgis** Docker image (https://hub.docker.com/r/mdillon/postgis/) that is based on the official PostgreSQL Docker image (https://hub.docker.com/_/postgres/) can be used to initialize an empty PostgreSQL RDBMS Docker container and to create the cids Integration Base database with help of the cids-init script afterwards.
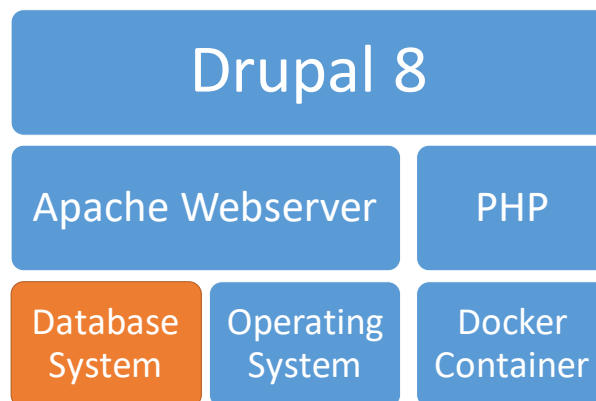
Figure 35: Containerised Drupal System

In addition, there is also an official Docker image for **Drupal 8** available (https://hub.docker.com/_/drupal/), so that an entire Drupal system can be containerised (Figure 35) with help of the Container Engine and Cloud Infrastructure Building Block (7.1). Moreover, thanks to the availability of separate Docker images for the Integration RDMBS, separate containers for frontend and backend can be instantiated as shown in Figure 36. This facilitates the usage of the CLARTIAY Drupal system's database backend in a different contexts, e.g. for the provision of an additional **RESTful APIs** as explained in the Technology Support Plan of the Scenario Management System (4.3.3).
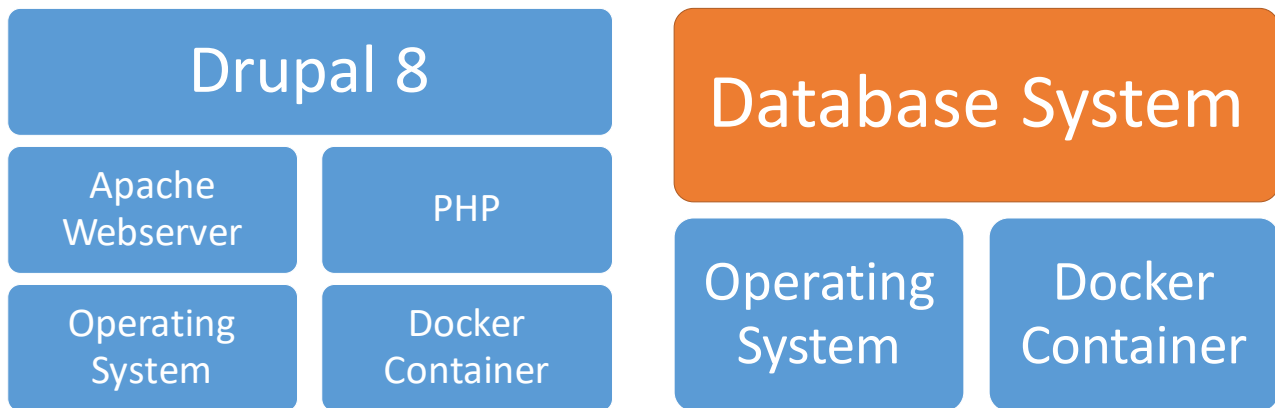
Figure 36: Role of Integration RDMBS in Drupal Architecture

7.4 Data Repository

This Building Block represents a set of generic data repositories that can be used to store, manage, and retrieve different types of (file based) datasets. Among others, this Building Block is used to facilitate the sharing of datasets between users and providers of Climate Services. Different types of data repositories can be used to easily serve data in standards compliant way so that other Building Blocks and Climate Services may use them for further processing like viewing (e.g. Map Component Building Block, see 5.1) or editing. Information about the actual datasets that are managed in different data repositories can be stored in a dedicated metadata catalogue (3.2) to facilitate discoverability and dissemination of data.

7.4.1 Requested functionality

Baseline requirements elicitation and the assessment of presently available Test Cases have yielded the following functional requirements for this Building Block:

Baseline functionality

- store and manage all types of "data" (file based cloud storage)
- access control (if we need to store confidential or sensitive demonstrator specific data or "paid" data)
- facilitate sharing of data between users and providers of Climate Services (store and retrieve data related to "Expert Studies")
- standards-based data access protocols (HTTP, WMS, OpenDAP, ...)

Functionality requested by CSIS Test Cases

- from TC-CSIS-0900: Data generated on each step of the pre-feasibility study (e.g, RA-Hazard, Impact, Vulnerability maps, etc.) should be registered in the data repository (e.g., GeoServer). References (URLs) to these datasets will be added to the Data Package descriptor.

Functionality requested by DC Test Cases

- from TC DC1: The simulation scenario results (indicators and maps) generated by the expert during offline simulations must be uploaded to the Data Repository so that it is accessible for Scenario Analysis and MCDA. This includes Indicators and spatial data. Spatial data uploaded to the data repository should be made available as WMS layer so that it can be shown in the Map View Building Block. If requested by the user, also the "raw model output" could be uploaded by the expert (e.g. for further offline analysis or validation by the end user)

- from TC RA: To retrieve the exiting hazard map, links to the hazard maps could point directly to the files or to layers in a Geoserver service (Data Repository).
- from TC DC4 010: The climate broker (CS Provider) makes data available requested by the end user (e.g. local hazard data generated by a micro climate model) through the Data Repository.
- from TC DC4 050: The Data Repository will contain the elements at risk available. It may offers a standards-based OGC WFS-T interface that can be used to update and modify and the attributes and spatial extent of elements at risk which are represented as GML features.

7.4.2   Exploitation Requirements assessment

The assessment of the Exploitation Requirements [11] identified the following concrete technical and functional implications on this Building Block:

- from "Offer free basic Climate Services based on free and Open Data": Technology support must provide Data Repositories that are not only able to store several Gigabytes of climate data but also provide standardised machine-level access (OpenDAP, WMS) to other ICT services and (impact) models. In order to reduce the storage capacity, a service data-broker may be used; this service would offer access to data stored by servers external to CSIS in an easy and transparent way for the user.
- from "Demonstrate and communicate the (co-)benefits of Climate Services": ICT Climate Services must produce tangible outputs for end users, e.g. reports and data in standard formats like SHP, NetCDF, PDF, ODF, etc.
- from "Co-design Climate Services engaging a community of users, providers, purveyors and researchers": allow external stakeholders participating in co-design of Expert Climate Services to easily request and exchange information needed to perform a climate adaptation study. This includes for example secure cloud storage facilities that are suitable for exchanging confidential and private data.
- from "Offer commercial fit-for-purpose tailored services targeting specific sectors and user groups": Easy technical facilities for external service providers to develop their Climate Services according to CLARITY conceptual and technical standards must be offered. This includes for example convenient data (e.g. study results and model outputs) upload facilities that enable Climate Service providers that deliver their result in the standardised data formats recognized by CLARITY.
- from "Offer commercial fit-for-purpose tailored services targeting specific sectors and user groups": Data repositories (Thredds, GeoServer, etc.) for secured and controlled access must be provided and technically integrated into the CSIS Infrastructure. Thereby, data protection is an important issue as such data exchanged between providers of paid Expert Services and the users of such services will in most cases not be made public, so secured access to the data repositories must be ensured.

7.4.3   Technology support

Figure 37 gives an overview on the technological possibilities and the related open-source backend software components that have been selected for the Technology Support Plan.
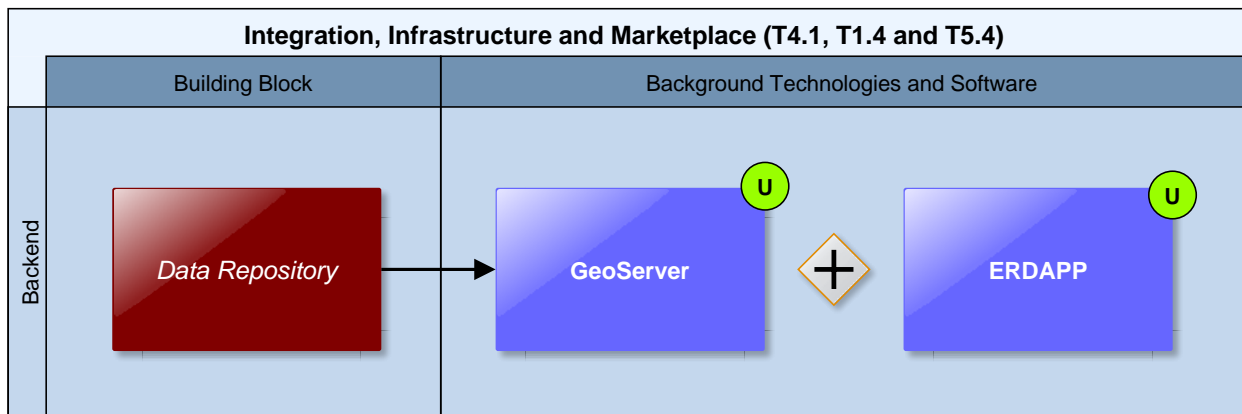
Figure 37: Data Repository Technology Support

The CLARITY Data Management Plan [9] and the demonstrator specific data collection in D2.1 "Demonstration and Validation Methodology" [14] identified the following major data formats that are relevant for CLARITY Climate Services and that should be made accessible in a standards-compliant way:

- **Network Common Data Form (NetCDF)**
  NetCDF is an abstraction that supports a view of data as a collection of self-describing, portable objects that can be accessed through a simple interface. Array values may be accessed directly, without knowing details of how the data are stored. Auxiliary information about the data, such as what units are used, may be stored with the data. Generic utilities and application programs can access netCDF datasets and transform, combine, analyse, or display specified fields of the data. The development of such applications has led to improved accessibility of data and improved re-usability of software for array-oriented data management, analysis, and display.
  https://www.unidata.ucar.edu/software/netcdf/docs/netcdf_introduction.html
- **ESRI Shapefile (SHP)**
  A shapefile stores -nontopological geometry and attribute information for the spatial features in a data set. The geometry for a feature is stored as a shape comprising a set of vector coordinates.
  https://www.esri.com/library/whitepapers/pdfs/shapefile.pdf
- **Enhanced Compression Wavelet (ECW)**
  ECW is a proprietary wavelet compression image format optimized for aerial and satellite imagery. It was developed by Earth Resource Mapping, and is now owned by Intergraph part of Hexagon AB. The lossy compression format efficiently compresses very large images with fine alternating contrast while retaining their visual quality.
  https://en.wikipedia.org/wiki/ECW_(file_format)
- **Geographic Tagged Image File Format (GeoTIFF)**
  GeoTIFF is a public domain metadata standard which allows georeferencing information to be embedded within a TIFF file. The potential additional information includes map projection, coordinate systems, ellipsoids, datums, and everything else necessary to establish the exact spatial reference for the file. The GeoTIFF format is fully compliant with TIFF 6.0, so software incapable of reading and interpreting the specialized metadata will still be able to open a GeoTIFF format file.
  https://en.wikipedia.org/wiki/GeoTIFF

With respect to the data integration approach of the SUDPLAN Scenario Management System described in Annex 1 and Technology Support Plan of the Map Component Building (5.1.2), datasets available in the aforementioned raster and vector data formats will be made available via OGC service interfaces. These standardised interfaces are mainly:

- **Web Feature Service (WFS)**
  The Web Feature Service (WFS) represents a change in the way geographic information is created, modified and exchanged on the Internet. Rather than sharing geographic information at the file level using File Transfer Protocol (FTP), for example, the WFS offers direct fine-grained access to geographic information at the feature and feature property level.
  http://docs.opengeospatial.org/is/09-025r2/09-025r2.html

- **Web Map Service Interface (WMS)**
  The OpenGIS® Web Map Service Interface Standard (WMS) provides a simple HTTP interface for requesting geo-registered map images from one or more distributed geospatial databases. A WMS request defines the geographic layer(s) and area of interest to be processed. The response to the request is one or more geo-registered map images (returned as JPEG, PNG, etc) that can be displayed in a browser application.
  http://www.opengeospatial.org/standards/wms

- **Web Map Tile Service (WMTS)**
  A WMTS enabled server application can serve map tiles of spatially referenced data using tile images with predefined content, extent, and resolution.
  http://www.opengeospatial.org/standards/wmtshttp://www.opengeospatial.org/standards/wmts

Several free and open source solutions available implement (no only) the respective OGC standards and support the different data formats commonly used and produced by Climate Service. For CLARITY, the popular products **GeoServer** and **ERDAPP** have been selected.

> **GeoServer** is an OGC compliant implementation of a number of open standards such as Web Feature Service (WFS), Web Map Service (WMS), and Web Coverage Service (WCS).Additional formats and publication options are available including Web Map Tile Service (WMTS) and extensions for Catalogue Service (CSW) and Web Processing Service (WPS).

http://geoserver.org/

> **ERDDAP** is a data server that gives you a simple, consistent way to download subsets of gridded and tabular scientific datasets in common file formats and make graphs and maps.

http://coastwatch.pfeg.noaa.gov/erddap/information.html

7.5   UI Integration Platform

CLARITY's common User Interface Integration Platform is the unified entry point to the CSIS (http://www.myclimateservice.eu/). It integrates the different frontends (user interfaces) of CLARITY Building Blocks and ICT Climate Services, respectively, with the Climate Services Marketplace (7.6) and the demonstrator showcases and promotes Expert Climate Services. The UI Integration Platform must combine different independently developed interactive JavaScript/HTML5 applications into a common user interface that acts and looks more like one integrated Rich Internet Application (RIA) rather than a portal or website. Moreover, the different Building Blocks to be integrated may potentially use different technologies such as pure client-side HTML5/AJAX technologies (Angular, React, ...), server-side technologies (Servlets, Java Server Pages, PHP) or even a mixture of both. The reason for this need comes not only from the fact, that the Building Blocks are developed by different CLARITY partners, but also from the necessity to maximise the re-use of existing components (catalogue, map viewer, e-commerce engine, ...), etc. Thereby, the UI Integration Platform should also provide some basic functionality (user management, per-user customisation, user workspace, etc.) out-of-the box, to let developers concentrate on the development of functionalities actually requested by end users.

7.5.1   Requested functionality

Baseline requirements elicitation and the assessment of presently available Test Cases have yielded the following functional requirements for this Building Block:

Baseline functionality

- host independently developed Building Block UIs (RIAs - rich internet applications, widgets, portlets, etc.)
- non-intrusiveness: the constraints imposed on the development of Building Block UIs that enable them to participate in the platform must be kept a at minimum. Ideally, it should be possible to wrap an independently developed RIA into a widget/portlet/etc. complainant to the specification of the platform with minimal effort.
- user management and customization options with (optional) user authentication and authorization. To lower the entry hurdle registration must remain optional at the cost of limited functionality for unregistered users - the usual portal / CMS features like extensibility, high performance, scalability, security management, support for mobile devices
- user interface design guidelines and default layout specifications (CSS files) should be provided

Functionality requested by CSIS Test Cases

- from TC-CSIS-0000: The Scenario Management Component and the project management user interfaces, respectively, are either embedded (e.g. as iframe) in the UI Integration Platform (Drupal System) or directly as part of the UI Integration Platform (e.g. Drupal Module or View).
- from TC-CSIS-0900: The UI Integration Platform should provide a button to the end-user to start the Data Package Export Wizard, which will automatically compile and present to the user the data used so far in the study while at the same time presenting to him a form to enable him to indicate further sources of information that needs to be included.
- from TC-CSIS-0010: The UI Integration Platform (Drupal 8) provides all user profile management facilitates (registration, login, approval, ...) and especially support for custom user profile types, or at least roles: end users ("buyer" = project planner, climate resilience manager) and provider ("seller", "expert" = CS or data provider / purveyor).
- from TC-CSIS-0031: Either the Marketplace Building Block or the UI Integration Platform should enable the CS provider to create and manage its detailed service portfolio. Also search for specific Climate Service types (sectoral, spatial, etc.) and for the purpose of matchmaking (proposing fitting Expert CS to users during Climate Adaptation Study).
- from TC-CSIS-0010 : The UI Integration Platform (Drupal 8) has also to offer some APIs that enables other Building Blocks like the Marketplace to access and interact with the user profiles. e.g. to search for specific user types (sectoral, spatial, etc.) for the purpose of matchmaking (finding a suitable "Expert").

Functionality requested by DC Test Cases

- from TC DC1: The UI Integration Platform must provide the possibility for user and expert to exchange context-specific messages through the CSIS, e.g. by creating comments, question and answers.

7.5.2   Technology support

Figure 38 gives an overview on the technological possibilities and the related open-source frontend and backend software components that have been selected for the Technology Support Plan.
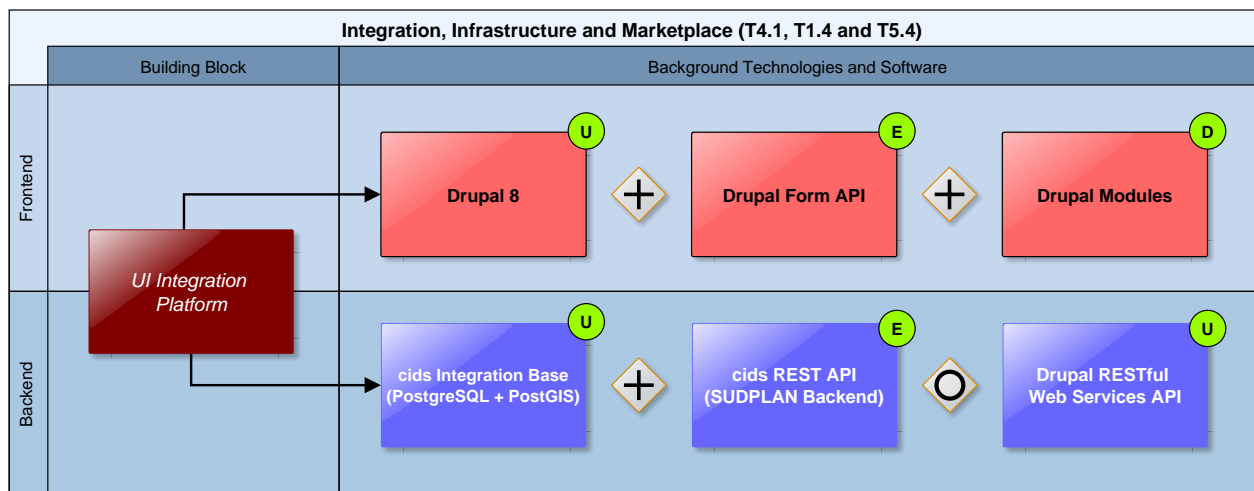
Figure 38: UI Integration Platform Technology Support

Since the UI Integration Platform is a central components that needs to integrate all Building Blocks of the CSIS Architecture (2.1), three different approaches towards technology support have been evaluated:

1) **Portal-based approach**

   Choose a technological platform that acts like a portal or mashup platform whereby existing components (CLARITY Building Blocks developed as widgets or portlets) are combined into one integrated Rich Internet Application. Ideally this also allows the use of third-party components that comply with a certain standard (e.g. Java Portlet Specification) supported by the technological platform. The advantages of this approach are, that potentially also different technologies (Java Portlets and HTML5/JS widgets) could be combined in one platform and that the platform also provides rich functionality (events, inter-component-communication, data storage, user and permission management, user profiles, logging, ...) that can be used by the integrated components (e.g. by calling the a REST web service or JavaScript API that is provided by the platform). The main disadvantage may be, that complexity and restrictions imposed on the components could complicate or the delay their development. In addition, the maintenance and installation effort should not be underestimated. An example for such a platform is Liferay (https://www.liferay.com/).

2) **CMS-based approach**

   Choose a content management system (CMS) and integrate the CLARITY Building Blocks either as independent HTML5/JS widgets (if possible) or develop CLARITY Building Blocks as CMS-specific modules. This approach is similar to the portal-based approach, also regarding advantages and disadvantages. Though, there is an important differences. A CMS is generally based on a thin client architecture whereby the majority of business logic resides on the server-side and many synchronous server request result in a full reload of the website when it's content changes. A modern Rich Internet Application follows generally a thick client architecture whereby a large part of the business logic resides on client-side (JavaScript) and asynchronous server requests (AJAX) lead to no page reload at all. Therefore such a web application is also called Single Page Application (SPA). The possibilities for integrating SPAs into a CMS or a making a CMS behave like a SPA may thus be limited. Examples for popular CMS are Drupal (https://www.drupal.org/) and WordpPress (https://wordpress.com/).

3) **JavaScript Framework-based approach**

   Agree on one client-side JavaScript Framework and choose a common boilerplate or template project ("dashboard") that is the outline or frame where the unified components (e.g. CLARITY

Building Blocks developed as NPM (Node Package Manager) modules) are combined into one Single Page Application. Consequently, all developers of UI Building Block must use the same JavaScript Framework as the UI Integration Platform. The main advantage is the flexibility in developing the single components and their coherent appearance, layout and behaviour. The disadvantage is that no other Single Page Application can be integrated easily (probably only as iframe), though the usage of common JavaScript libraries (e.g. leaflet.js) is nevertheless possible. Another disadvantage is that common base functionality for user management, etc. has possibly to be developed from scratch. There are, however, also existing libraries that can be used for that purpose. Examples for such frameworks are React (https://reactjs.org/) or Angular (https://angular.io/).

Based on the expertise available in the CLARITY consortium, the requested functionality both on the UI Integration Platform and integrated Building Blocks as well as the availability of background technologies and software, the CLARITY technology support team decided to follow a combination of the CMS and JavaScript Framework-based approach:

The powerful CMS **Drupal 8** is used as the overall UI Integration Platform. Drupal is for example also used for CLARITY's coordination platform (https://cat.clarityCLARITY-h2020.eu/) and the Worldbank's Climate and Disaster Risk Screening Tools (https://climatescreeningtools.worldbank.org/).

> **Drupal** is an open-source (free) content-management framework. Drupal has great standard features, like easy content authoring, reliable performance, and excellent security. But what sets it apart is its flexibility; modularity is one of its core principles. Its tools help you build the versatile, structured content that dynamic web experiences need. It's also a great choice for creating integrated digital frameworks. You can extend it with any one, or many, of thousands of add-ons. Modules expand Drupal's functionality. Themes let you customize your content's presentation.

https://www.drupal.org/about

New Building Block user interfaces (frontends) can be developed in the **PHP** programming language as **Drupal Modules** and/or with help of the **Drupal Form API**. This applies for example to the Data Dashboard Building Block (4.1).

> **PHP**, which stands for "PHP: Hypertext Preprocessor" is a widely-used Open Source general-purpose scripting language that is especially suited for web development and can be embedded into HTML. Its syntax draws upon C, Java, and Perl, and is easy to learn. The main goal of the language is to allow web developers to write dynamically generated web pages quickly.

https://secure.php.net/manual/en/preface.php

Some Building Blocks that are based on existing background software and technologies like the Multi Criteria Decision Analysis Tool (6.1) or the Map Component (5.1) will be provided as **HTML5/AJAX RIAs**. They can be embedded as HTML **iframe** into the UI Integration Platform.

> The <**iframe**> tag specifies an inline frame. An inline frame is used to embed another document within the current HTML document. The iframe element represents a nested browsing context. The src attribute of the <iframe> tag gives the address of a page that the nested browsing context is to contain. The attribute, if present, must be a valid non-empty URL potentially surrounded by spaces.

https://www.w3.org/TR/html5/semantics-embedded-content.html#the-iframe-element

Communication with the Integration RMBMS (7.3) which serves as the backend of the UI Integration Platform is then performed with help of a **RESTful Web Services API**.

> Representational state transfer (**REST**) or RESTful web services are a way of providing interoperability between computer systems on the Internet. REST-compliant Web services allow requesting systems to access and manipulate textual representations of Web resources using a uniform and predefined set of stateless operations.

https://en.wikipedia.org/wiki/Representational_state_transfer

7.6 Marketplace

The Marketplace Building Block represents a collaborative web platform where urban infrastructure or transport projects could check their climate-proof capabilities and get valuable information for decision making by the Climate Services available in the Marketplace. An infrastructure project or climate resilience manager, as a Marketplace customer, can register into the Marketplace to create and describe his infrastructure project details, and even provide related data to ease being evaluated. Also being part of the Marketplace could allow a customer to access different services and/or data provided by other Marketplace users. Other users can register into the Marketplace as data or service (human/software) providers by describing each service or data set metadata within a personal services portfolio. A 'matchmaking' functionality available in the Marketplace enables customers to find suitable Expert Climate Services (e.g. tailored advisory services) and relevant climate data and ICT Climate Services (e.g. software) available in the Marketplace to be used as inputs on the EU-GL compliant workflow provided by CSIS in order to find available adaptation measures that could minimise the impact on the infrastructures under study. This defines the Marketplace meeting point where infrastructure project managers, climate experts and climate data and services providers can meet and communicate to collaborate on assessing about climate impact.

7.6.1 Requested functionality

Baseline requirements elicitation and the assessment of presently available Test Cases have yielded the following functional requirements for this Building Block:

Baseline functionality

- Public Service Provider Catalogue
  - service provider profiles signals professionalism, reputation and trustworthiness
  - links to clients and case studies (demonstrators)
  - portfolio with links to Expert Climate Services
  - rich set of meta-data for matchmaking and discovery functionality
- Public Expert Climate Services Catalogue
  - clear and detailed description (in relation to CLARITY Methodology) of the (tailored) Expert Climate Services including information on costs (rough estimate)
  - may contain not only advisory, consulting, modelling, development, … services but also local data
  - associated with a Service Provider Portfolio
  - rich set of meta-data for matchmaking and discovery functionality
- Customer Inquiries
  - user can create private inquiries
  - inquiries are only visible to registered providers. (business model: buy subscription to see inquiries)
  - an "order list" can be generated by expert workflow tool ("Scenario Management") as simple requirements specification for an Expert Climate Service
- Expert Offer

- o provider can make an offer, provide a contract specification, etc.
- o provider can request access to the user's workspace in expert workflow tool, e.g. down- or upload data
- o offers are (easily) comparable since the must follow the requirements specification

Functionality requested by CSIS Test Cases

- from [TC-CSIS-0030]: The Marketplace needs to access and show user profile information that is stored in the common user data catalogue (expectedly the PostgreSQL Drupal back-end). If the Drupal Backend DB is separate Docker instance, the Marketplace Building Block can possibility (read-only) access this database directly.
- from [TC-CSIS-0030]: The Marketplace Building Block has also to offer some APIs that enables other Building Blocks like Scenario Management to access and interact with service portfolios, e.g. to search for specific Climate Service types (sectoral, spatial, etc.) and for the purpose of matchmaking (proposing fitting Expert Climate Service to users during Climate Adaptation Study).
- from TC-CSIS-0031: Either the Marketplace Building Block or the UI Integration Platform should enable the Climate Service Provider to create and manage its detailed supplier profile.

Functionality requested by DC Test Cases

- from TC DC1: The request (specification) to perform alternate (adaptation) scenarios for scenario comparison created by the Scenario Management Building Block can optionally be added as "customer inquiry" to the Marketplace so that Climate Service Providers (Experts) can make an offer through the Marketplace.
- from TC DC1: The Marketplace must provide the possibility fora user to order an expert service for running an urban climate model (e.g. MUKLIMO 3) and to request the model output in a standardised format (e.g. NetCDF) that is supported by the CLARITY CSIS.
- from TC DC1: The Marketplace has furthermore to support the user in ordering data needed as input or a specific model, if the data cannot be provided by the user and the data is not available for free in the Catalogue of Data Sources and Simulation Models.
- from TC DC4: The Marketplace must provide a way for a user to contact a Climate Broker. Additionally, the Climate Broker will need to get the parameters of the request received and send the results (or notify) to the end user. The Climate Broker should also be listed on the Marketplace.
- from TC DC4: The Marketplace Building Block provides the possibility to assign an assessment to a Climate Broker.
- from TC DC4 010: The Marketplace Building Block is used to store and publish standardised order specifications from end users (Climate Service Customer) that can be used by Climate Brokers (Climate Service Suppliers) to prepare an individual offer for a tailored Expert Climate Service (e.g. generate local data with urban climate model).
- from TC DC4 010: The Climate Broker (Climate Service Supplier) receives the request to perform an assessment from an end user and communicate with them.

7.6.2 Exploitation Requirements assessment

The assessment of the Exploitation Requirements [11] identified the following concrete technical and functional implications on this Building Block:

- from "Demonstrate and communicate the (co-)benefits of Climate Services": clearly advertise benefits for end users and dissemination experts should formulate and communicate these benefits, e.g. in form of online presentations and infographics (http://www.visualisingdata.com/resources)

- from "Demonstrate and communicate the (co-)benefits of Climate Services": IT infrastructure and technology support as well as a Marketplace for Expert Climate Services is needed in the CSIS so that it is also beneficial for external Climate Service Providers to offer/provide their tailored Climate Service on the CLARITY CSIS.
- from "Establish trust in Climate Services and their providers": Climate Service providers must disclose information on which data or methods they used to develop their Climate Service and how they dealt with uncertainties. This relates mainly to the Climate Service Provider Portfolios in the Service Catalogue / Marketplace
- from "Co-design Climate Services engaging a community of users, providers, purveyors and researchers": integrate with the CLARITY community and the Marketplace be able to involve also new stakeholders (e.g. data providers) during all phases of the co-design process
- from "Offer commercial fit-for-purpose tailored services targeting specific sectors and user groups": Technical specifications include for example an Information Model for Expert Climate Services that clearly defines the service level agreements and that can be related to elements of a Climate Service Providers Service Portfolio or a Service Catalogue in the CLARITY Marketplace.
- from "Offer commercial fit-for-purpose tailored services targeting specific sectors and user groups": Easy technical facilities for external data and service providers to join the CLARITY Community & Marketplace and to offer their Climate Services must be provided. This includes for example functionalities for creating Service Provider Profiles and Service Portfolios and to link them with other relevant information available in the CSIS. Thereby, rich meta-information is important to describe providers and services and to put into regional and sectoral context.

7.6.3   Technology support

Figure 39 gives an overview on the technological possibilities and the related open-source backend software components that have been selected for the Technology Support Plan.
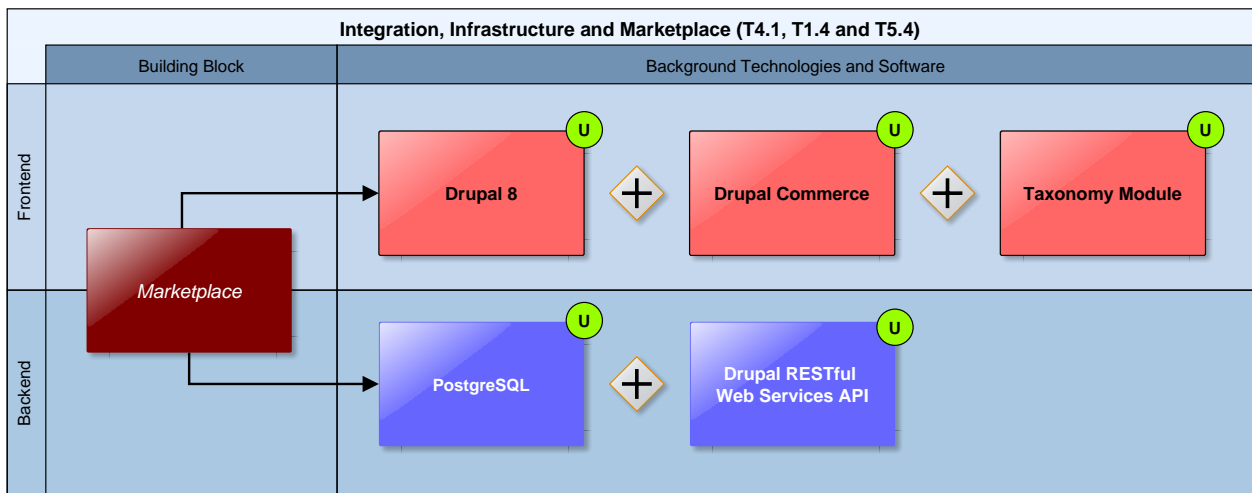
Figure 39: Marketplace Technology Support

A content management system (CMS) provides a reliable starting point for a Marketplace like web portal, and specifically **Drupal** (see 7.5.2) being open source (under GNU/GPL license) looks as a suitable option to develop the CLARITY Marketplace. It is widely used and has lots of modules extending its capabilities and also has a large developer community. One of those modules is **Drupal Commerce** providing shopping cart and different payment methods are supported, also subscriptions and recurring payments, sell file

downloads, invoice generation and email notifications as well as sale reports. All this could be useful for a Marketplace like web portal where Climate Services Suppliers will interact with infrastructure project managers.

Drupal Commerce is used to build eCommerce websites and applications of all sizes. At its core it is lean and mean, enforcing strict development standards and leveraging the greatest features of Drupal and major modules like Views and Rules for maximum flexibility. The core Commerce systems make no hard-coded assumptions about your business model, privileging developers and site builders at the core level to build custom eCommerce solutions to suit.

https://www.drupal.org/project/commerce

Drupal also provides a robust user management and login system allowing different privileges for different users. Mainly there will be customers (project managers and climate resilience managers) and suppliers (climate expert advisors or climate data or software services providers). It will be useful to define different kind of permissions depending on the data that a customer can access or the infrastructure projects a climate services provider can access should be restricted and controlled. Drupal website contents can be classified by using **taxonomies** and also assign contents to the appropriate users in the system, this allows definition of climate infrastructure project and providers climate services portfolios and its metadata.

Taxonomy, a powerful core module, gives your sites use of the organizational keywords known in other systems as categories, tags, or metadata. It allows you to connect, relate and classify your website's content. In Drupal, these terms are gathered within "vocabularies". The Taxonomy module allows you to create, manage and apply those vocabularies. Taxonomy can be used in workflow, to customize defined sections of your website with different themes or to display specific content based on taxonomy terms. Taxonomy should be driven by the business requirements of your website, with an eye towards possible future functional expansion.

https://www.drupal.org/docs/7/organizing-content-with-taxonomies/organizing-content-with-taxonomy

Drupal also provides search functionalities that can ease the discovery of services for the different customers looking for data or advice within the CLARITY Marketplace. In the same way a messaging system can be defined to ease collaboration between different users and tasks can be assigned to different users, even a task status can be set to allow an appropriate infrastructure climate project management. Drupal works with templates and **PHP** to allow data management with MySQL or **PostgreSQL**, indeed there are **Docker** images on the Docker Store to ease Drupal deployment into a Docker container with all the required components as described in chapter 7.5.2. Drupal works against a PHP endpoint under an Apache web server where all PHP requests are received and then interactions with Drupal database model can happen, but also data in the database model can be accessed directly through a direct database connection or a **RESTful API**. Integration with JavaScript Frameworks like **Angular** and **React** could be done as already seen in the UI Integration Platform Building Block (see 7.5), there are three different choices and the combination of CMS-based approach and JavaScript Framework-based approach seems to be the most suitable approach for CLARITY Marketplace.

8   Conclusion

The innovative character of CLARITY products and services demands for an implementation strategy that must be based mainly on combination, integration and adaptation of existing background technologies and software rather than entirely new developments. The primary objective of the Technology Support Plan is therefore to minimise individual development effort and to maximise re-use of existing background when creating CLARITY products and services. For this purpose, the CLARITY technology support team first performed a critical assessment of the background technologies inherited from former Research & Development projects regarding their principal suitability for the implementation of the envisaged innovative products and services. To fill the gaps of essential Building Blocks not considered in the initial CLARITY work plan and to supplement initially foreseen background that does not offer a sufficient level of technological readiness or fitness for purpose, the team selected market-ready technologies and software components for the implementation of the respective Building Blocks.

The current absence of detailed product specifications, which is inherent to the agile development approach followed by CLARITY, requires some degree of flexibility in the planning process and may involve some contingencies. Therefore, the initial Technology Support Plan laid out in D4.1 provides only preliminary conclusions and suggestions that will be detailed in future revisions of this document (D4.3 & D4.4 "Technology Support Report"). Among others, the technology support reports will take into account consolidated, harmonised and streamlined user requirements, detailed Product Visions that are validated by a business plan and reusable results of related project and initiatives as soon as they become available.

The present Technology Support Plan in conjunction with the respective User Stories and Test Cases serves as the "Product Backlog" of T1.3 "Climate Services Co-Creation", which is in its simplest definition "a list of all things that needs to be done within the agile product development cycle" [11].

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Annex 1: Description of background from previous projects

This annex provides a brief overview of the tools and technologies that are inherited from previous projects and explains the initial plan for using and/or extending these inputs in WP4 "Technology Support". According to WP4's general approach explained in section 1.2 and the CLARITY Architecture presented chapter 2.3, the tools and technologies listed in this annex represent Software Components that may be suitable for the realisation of one or more functional Building Blocks.

As the identification and specification of Building Blocks and their expected functionality is work in progress and likely to change because of CLARITY's agile approach, the technical possibilities are constantly reconsidered as the project matures. Accordingly, the information provided in this Annex represents a snapshot in the project development, not a final plan. Furthermore, the current Technology Support Plan considers mainly those Software Components that were inherited from previous projects and that were mentioned in the workplan of the project. The identification and assessment of additional technologies and tools is already in progress and takes place in CLARITY's coordination platform (https://cat.clarityCLARITY-h2020.eu/).

1. AIT EMIKAT (Environmental Catalogue)

Description of the background technology or software

EMIKAT is a data management and modelling system for spatially resolved data. The system allows the integration of data (e.g. from surveys, calculation models or statistics) as well as the definition and analysis of model scenarios. Scenarios allow a comparative examination of model results corresponding to different versions of data inventories – for example the overall effects of trends in emission generating activities and pollution control measures or the influence of different calculation models on estimated results.
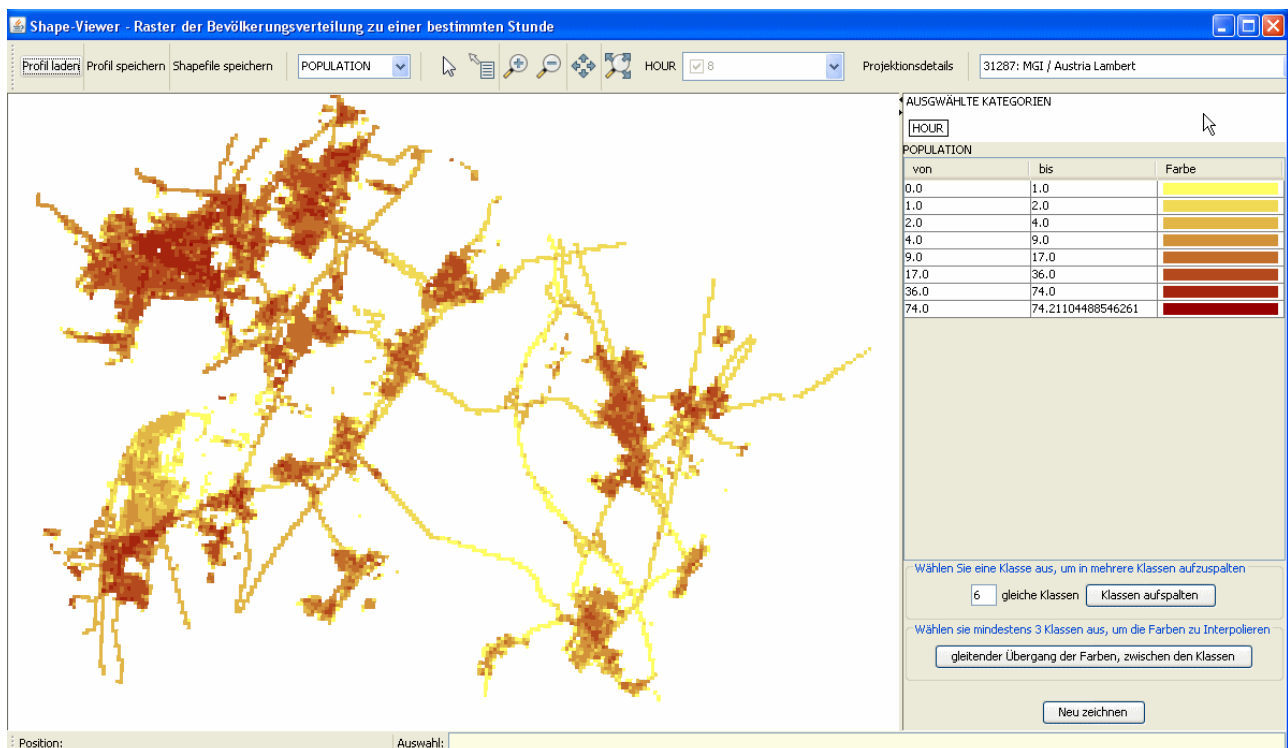

Figure 40: EMIKAT visualisation (and calculation) example from the CRISMA project

Although initially developed to deal with emission data, air pollutant emission inventories and emission/immission modelling in regions and municipalities, the system is fully generic and capable of handling many types of data and models with spatial or temporal properties. EMIKAT is productive since several years and is consequently updated and maintained by AIT to fit the customer's needs.

EMIKAT can be used to develop various models. This was demonstrated also in the CRISMA project, by using EMIKAT as a software base for the population exposure model. Simulations are based on calculation models that use input data from different scenarios in order to facilitate impact comparison. The integrated metadata editor supports the definition of new data objects as well as respective domains and models. The lightweight client can be used to specify indicator models. Technically, indicator models in EMIKAT consist of a set of cascaded SQL-Queries. Data and metadata are stored in an Oracle database.

General features provided by EMIKAT:

- Version-specific administration of datasets
- Creation and comparison of different scenarios
- "What-if" simulations of control measures
- Calculation of indicators and results on the basis of input data and assumptions
- Continuous organization of all data inventories according to multiple criteria
- Consideration of the spatial and temporal distribution
- Calculation of point, line and area results
- Result visualization on map or tables
- Central administration of datasets with decentralized access for several users

Technically EMIKAT is based on a server-client architecture. The lightweight Java Web-Start client can be used to import data, manage scenarios, create and edit models as well as to display derived results. Depending on the application domain new objects and data types can be created in the metadata editor. The Tomcat Application Server hosts the EMIKAT backend which uses ORACLE RDBMS as persistence layer. The system supports OGC-WFS and –WMS.

Planned usage in CLARITY

The system is fully generic and capable of handling many types of data and models with spatial or temporal properties. This was demonstrated also in the CRISMA project, by using EMIKAT as a software base for the population exposure model.

In CLARITY, EMIKAT will likely be used for the implementation of the "Catalogue of Elements at Risk and Adaptation Options" within Task 4.2 (see 3.1). The system is capable of handling geo-data (e.g. points, lines, grids, political areas, etc.) which could be especially relevant for the handling of the elements at risk (e.g. points for building locations, lines for roads/transport networks, grids for population densities, etc.). EMIKAT already provides some data import routines, e.g. for CSV, Excel, Shape files, etc.

Current works focus on how the system is best integrated into the overall CLARITY CSIS workflow and whether it will be used for both the management of the element at risk types during the pre-feasibility study workflow or only for the management of element at risk inventories during the more advanced / expert-part workflow of CSIS.

For the use in CLARITY, the respective data structures as well as the required communication with the other building blocks (REST-, WFS-Interface) will be set up. EMIKAT is running on AIT-Server. The contents/data and tables can be adapted and expanded as required. If required, additional background functionality can be expanded in accordance with AIT. Current exports/communication can be via WFS or WMS service results (OGC compatible Geoserver Datastore), REST interface, Shape Files, Excel tables or CSV.

For a more detailed description of EMIKAT, please refer to the project website www.emikat.at.

2. SUDPLAN Scenario Management System

Description of the background technology or software

The Scenario Management System of the European Project FP7-247708 SUDPLAN – "Sustainable Urban Development Planner for Climate Change Adaptation" (http://www.sudplan.eu/) is a framework for developing easy-to-use planning, prediction, decision support and training tools, for the use in an urban context, based on a what-if scenario execution environment. It is the platform on which a concrete Application (or SUDPLAN System) is built and consists of the three distinct Building Blocks (Figure 41) SMS Framework, Model as a Service Integration, and Advanced Visualisation that are described in detail in the SUDPLAN deliverables D3.3.3 - Integrated Scenario Management System V3 [15] and D3.2.3 - Product Implementation V3 [16].
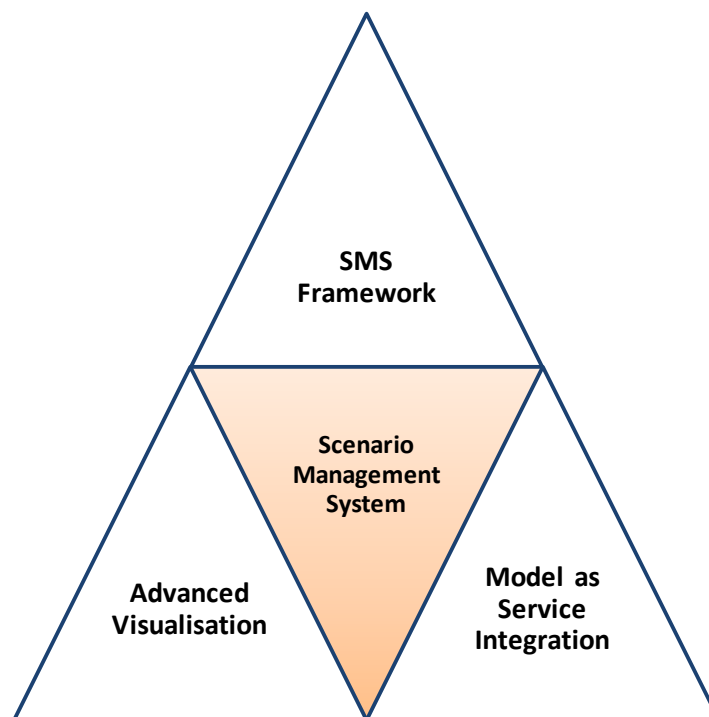
Figure 41: SUDPLAN SMS Building Blocks [15]

The SMS is an integration and development platform that is be able to facilitate the implementation climate change induced urban development planning tools (so called SUDPLAN Applications). The goal to provide a flexible and adaptable framework for the development of planning tools is supported by the separation of the SUDPLAN System into several architectural layers as shown in Figure 42.
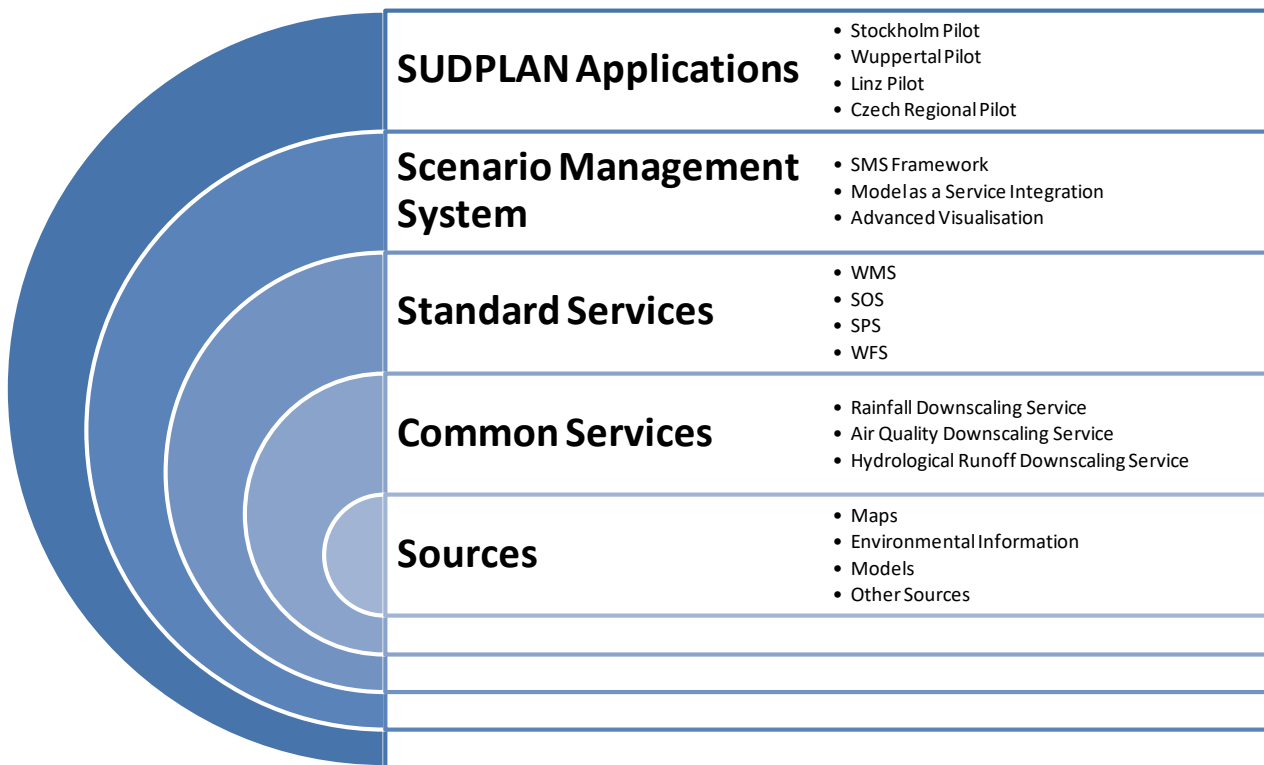
Figure 42: SUDPLAN Layered Architecture [15]

The top-level layer, the SUDPLAN Application itself, is the result of development, extension, customisation and configuration of the underlying SMS. The SMS comes with several Building necessary to provide common scenario management tasks including data integration, model management and execution, basic and advanced visualisation, and comparison of various temporal and spatial data sets, etc. It therefore relies upon standard services for data access and model management and thus greatly facilitates the task of integrating new models and data sources.

As shown in Figure 43, several services specified by the Open Geospatial Consortium (OGC) are supported by the SMS: Sensor Planning Service (SPS), Sensor Observation Service (SOS), Web Map Service (WMS) and Web Feature Service (WFS).
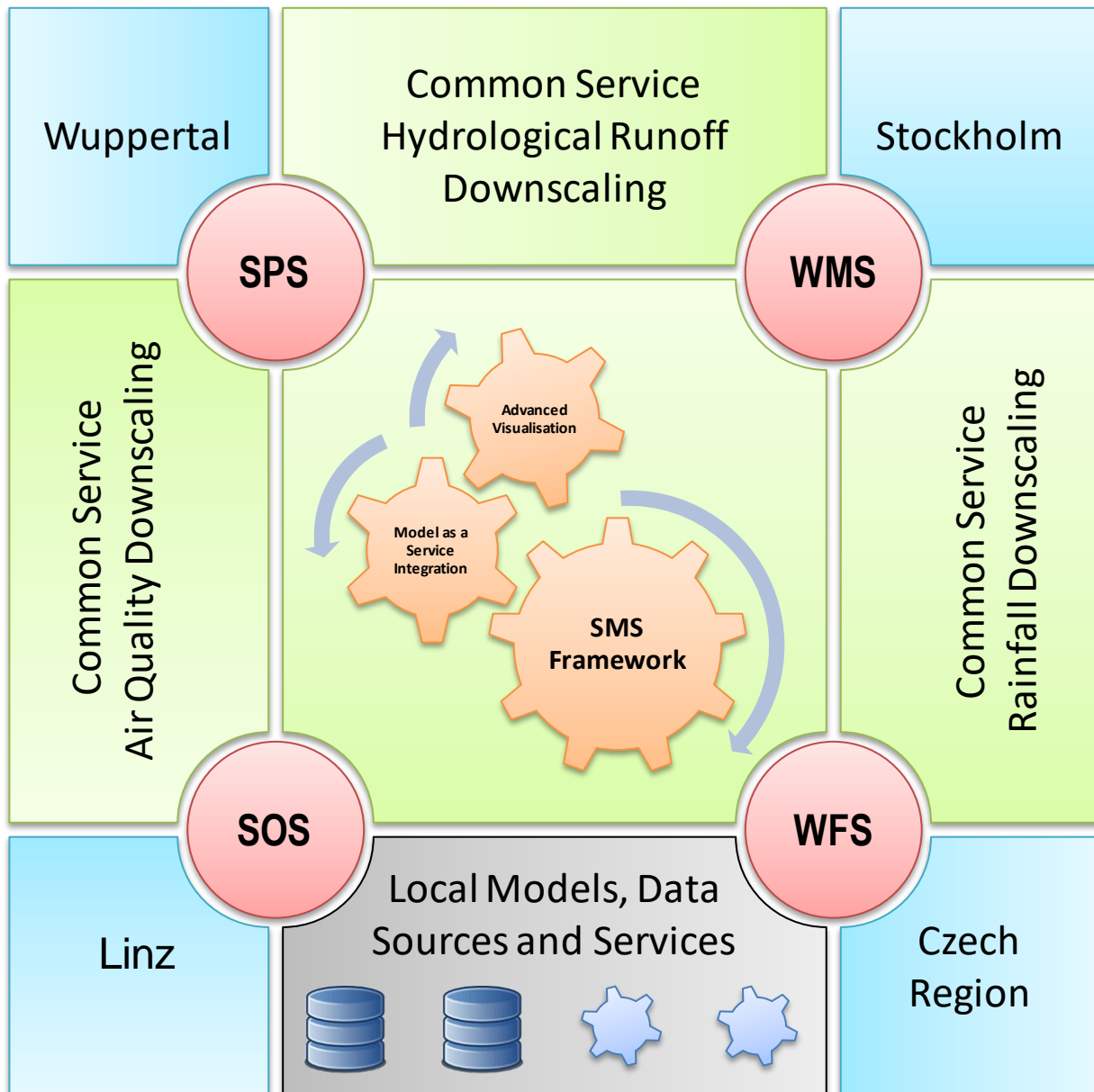
Figure 43: OGC Services Integration [15]

The **Scenario Management System Framework** is the central component providing common SMS and integration functionality. Together with the Building Blocks for the integration of models through standardized service interfaces and for advanced visualisation capabilities it provides the basis for site-specific implementations of SUDPLAN Applications and the necessary workflows to support the use of models as a basis for decision making. The core functionalities provided by the SMS Framework include, for example, navigation, search, visualisation and manipulation of arbitrary (geospatial) data.

Additional tools for the management of models, i.e. asynchronous model execution, result storage, parameterisation and basic model result visualisation (such as 1D time series, and 2D maps) are available. The generic core of the SUDPLAN SMS Framework is based on the cids geo-integration platform (https://www.cismet.de/en/cidsReadme.html) offered by CLARITY partner cismet GmbH.

The **Model as Service Integration** components provide the means to control model implementations and access model results via standardised web services. The selected standards are members of the OGC SWE [17] family, specifically WMS (Web Map Service), SOS (Sensor Observation Service) and SPS (Sensor Planning Service), which are used for model result access and model control. This part of the SMS can be used to access the corresponding common services as well as to encapsulate local models as in some of the four pilot applications of SUDPLAN. Technically a new climate-, hazard- or impact models is wrapped as OGC SPS so that it can be exposed as web service and executed remotely. The output of the model can be provided via OGC WMS of SOS. While the Model as Service Integration components provide a standardised access interface for model execution and data retrieval, wrapping a particular model requires nevertheless a certain amount of development and data transformation effort.

Planned usage in CLARITY

The SUDPLAN SMS is not a tool that is able to manage any kind of climate change-, impact- or adaptation scenarios; instead, it is a framework for the development of tailored scenario management systems. As observed in chapter 4, custom model and data integration is a task that cannot be fully automated and instead of generic solutions tailored ones in form of Expert Climate Service must be provided.

The SUDPLAN SMS may therefore only be suitable for the development, provision or support of SUDPLAN Applications as Expert Climate Services related to impact scenario assessment as described in section 3.3 of CLARITY's Science Support Plan [7].
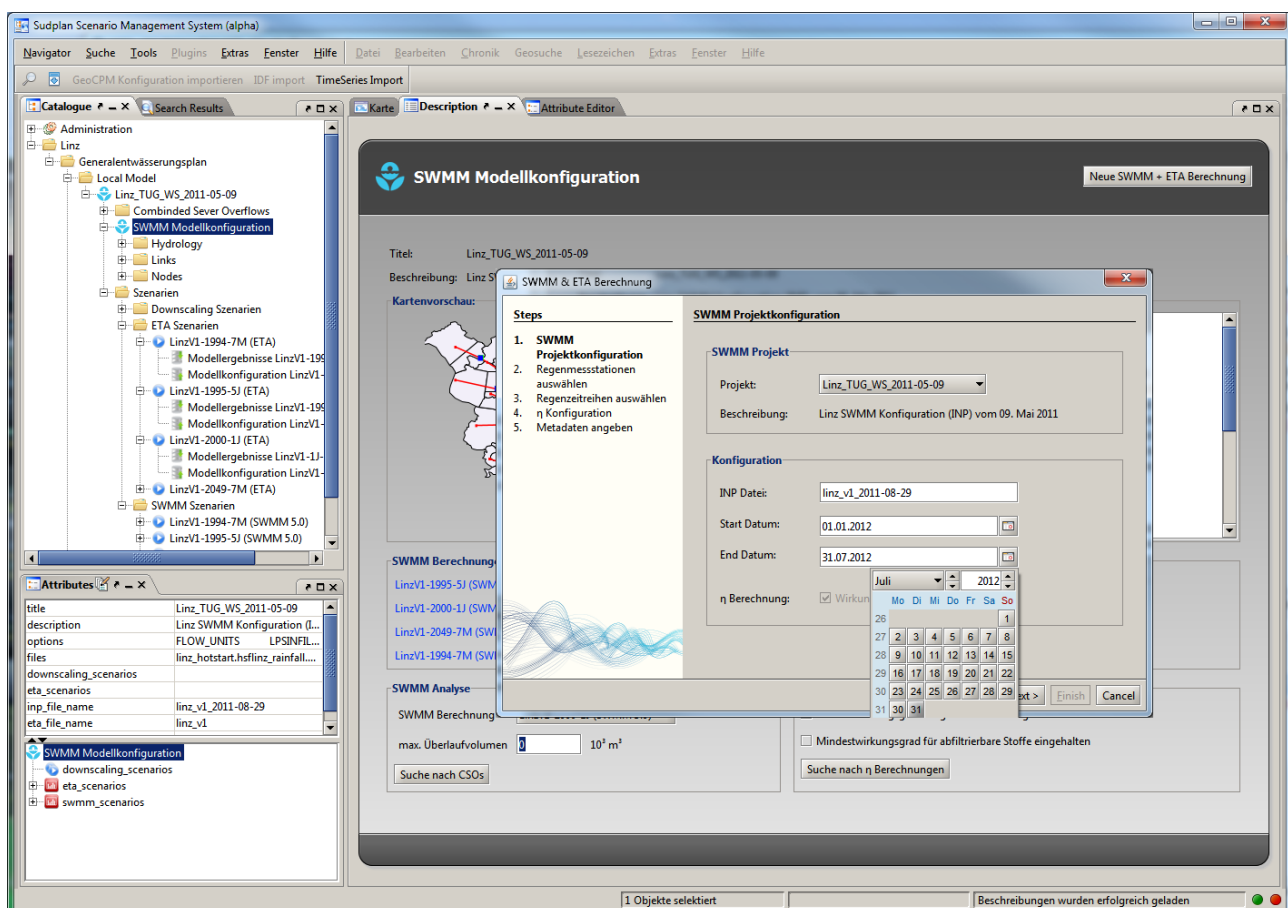

Figure 44: User Interface of a SUDPLAN Application [18]

Figure 44 shows an example of a user interface for calibrating and executing a Storm Water Management Model (SWMM) for the Linz Pilot Application [18] developed with help of the SUDPLAN SMS. However, this covers just a fraction of the whole functionally provided by the SUDPLAN Linz Pilot Application and the capabilities of the SMS Framework.

Similar SUDPLAN Applications could be developed for each of the four CRISMA Demonstration Cases on basis of the SUDPLAN SMS Framework. However, it must be admitted that the kinds of applications that can be developed with help of the SUDPLAN SMS are complex expert systems and desktop applications. Hence, there is a disparity both with Exploitation Requirements and with the overall CLARITY Product Vision: CLARITY should deliver user-friendly, intuitive and easy to use tools that are not targeted at an expert audience [11].

Moreover, current User Stories and Test Cases [2] do not explicitly suggest that such complex applications may be actually needed. Instead, end users expect tailored climate advice from experts and not to be bothered with the selection, calibration, execution and interpretation of certain climate- or impact models. This leads to the conclusion that the SUDPLAN SMS is more suitable for the development of Scenario Management Applications that may be used by Climate Service Suppliers instead of Climate Service Customers. Conversely, the development of highly customised applications for Climate Service Providers to support them in providing their services to end users may be in conflict with project goals to develop innovative products and services for CLARITY's main end user target groups (project planners and climate resilience managers). Furthermore, such an application would only useable in the context of a specific Demonstration Case by a modelling expert that is familiar with respective models, the preparation of their input data and the interpretation of their output data. In an analogous manner, during preliminary assessment of climate service market conditions as part of Exploitation Requirements elicitation and during CLARITY end user workshops [2] it soon became clear that CLARITY should not produce a complicated scenario management system oriented towards a specialist and academic audience nor a detailed scenario management framework and four site-specific prototypes.

Another fact that should not go unmentioned is, that the front-ends and user interfaces, respectively, of the SUDPLAN SMS are developed as Java Web Start Desktop Application. Oracle, the vendor of Java Web Start technology stated in 2016 that "modern browser vendors working to restrict or reduce the support of plugins like Flash, Silverlight and Java in their products" [19]. Developers of Rich Internet Applications (RIA) are therefore migrating their legacy and browser-plugin based applications to modern technologies like HTML5 and AJAX (Asynchronous JavaScript and XML). Irrespective of the observation made in the previous paragraph that a complex SMS application may not be suitable for CLARITY's main end user target groups, it is not advisable to base the development of sustainable products on technologies that dropped out on the path to longevity. However, the aforementioned technical limitations account mainly for the front-end part of the SUDPLAN SMS Framework. The respective server components that are provided by the cids geo-integration platform and several OGC services, respectively, are implemented as XML- and JSON-based restful web services, up-to-date technologies used for the implementation service orientated architectures.

In conclusion, the server-side components of the SUDPLAN Scenario Management System Framework can be used in CLARITY to support Climate Service Providers in offering (ICT) Climate Services for model execution (if needed) and data access via standardised restful web service interfaces. For various reasons, the framework should not be used to develop complex and site-specific scenario management applications. Instead, an end-user centred more general and lightweight scenario management approach following the EU-GL methodology [1] adapted by CLARITY [7] and realised with help of sustainable and modern web technologies should be pursued as suggested in section 4.3.3.

3. CRISMA Multi Criteria Decision Analysis Tool

Description of the background technology or software

The Decision Support Concept which is the basis for the Multi Criteria Decision Analysis (MCDA) Tools to be adopted by CLARITY as generic ICT Climate Services has been developed in the European Project FP7-284552 CRISMA – "Modelling crisis management for improved action and preparedness" (http://www.crismaproject.eu/). The original concept has been introduced in the CRISMA Deliverable D44.3 "Simulations tool for crisis management strategies and planned actions V2" [20]. CLARITY's Science Support Plan [7] explains how this concept relates to the EU-GL's [1] and thus CLARITY's overall methodology. The general idea of the concept in relation to the MCDA DSS Tools is to:

a) let a domain expert (Climate Service Provider, e.g. modelling expert, scientist, IT professional) produce (impact and adaptation) scenarios in support of the decision;

b) let a domain expert provide aggregated but representative information about the scenarios (indicators) in a standardised format;

c) support a decision maker (Climate Service Customer, e.g. project planner or climate resilience manger) in defining an explicit decision strategy (criteria, priorities, "Andness" and "Orness" of the ranking function [21]); and

d) provide generic tools to assist in comparing and ranking of (impact and adaptation) scenarios according to the decision strategy.

The MCDA concept consist of the following elements to support the decision maker:

1) a set of representative scenario **indicators** consisting of aggregated scenario information;

2) a **criteria function** mapping each element of the indicator set to satisfaction;

3) a **level of satisfaction** in a normalised scale (0-1 or 0%-100%);

4) a **ranking function** mapping normalized indicator sets to values; and

5) corresponding scalar values (**ranks/score**).

Indicators are calculated by applying aggregation algorithms (indicator functions) to the computational output of (impact and adaptation) scenarios ("model output"). Indicators may refer to hazard, vulnerability, impact or adaptation aspects like exposure/vulnerability reduction measures and associated costs and benefits of climate change adaptation scenarios. Indicators should be expressed in measurable, replicable and reasonably easy to interpret units. Consequently, comparison and analysis of individual indicator values enables the decision maker to explore the effects of changes in adaptation strategies based on the output of different scenarios. The usability of indicators for decision makers can be improved by normalizing the indicators to a (0-1 or 0%-100%) scale and assigning a level of satisfaction to the normalized indicator value. Qualified and normalised indicators are called (decision) criteria. Criteria are calculated by a criteria function.

Lost Buildings

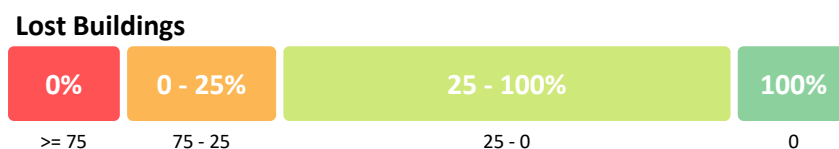| 0%	0 - 25%	25 - 100%	100%
>= 75	75 - 25	25 - 0	0

Figure 45: Criteria Function Example [22]

Figure 45 shows an example of a custom criteria function where the absolute number of lost buildings in an impact scenario (geophysical hazards) is mapped to a level of satisfaction ranging from 0 to 100%. In this example, the user has decided that losing more than 75 buildings is unacceptable and thus assigned 0% satisfaction to all "lost buildings" indicator values that are higher or equal to 75.
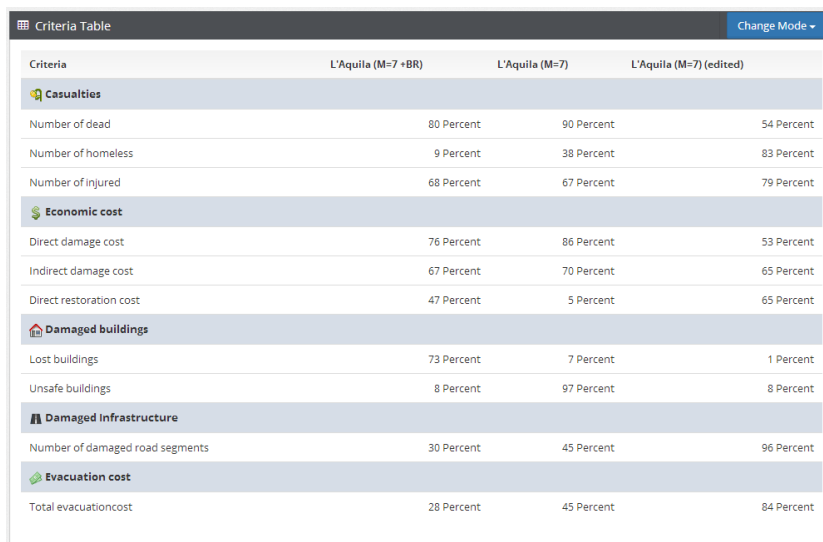
The representation of the key characteristics of a scenario as a set of simple numerical indicators and the possibility for algebraic comparison of such indicators allows the provision of generic tools (ICT Climate Services) for indicator-based scenario comparison and analysis by the CRISMA framework. Those tools can support the decision maker in defining a decision strategy by:

1) Mapping performance indicators to decision criteria (defining the level of satisfaction for each indicator)

2) Defining priorities by assigning weights to indicators

3) Defining the level of level of "Andness" and "Orness" of the ranking function [21] through the parametrization of the Multi Criteria Decision Analysis (MCDA) method proposed by Yager [23] to be considered when computing the rank of an impact scenario

Thanks to indicator and criteria based MCDA concept which provides an abstraction from not easily comparable domain and site-specific output data of various models, the CRISMA project was able to develop a set of generic MCDA Tools that can be further exploited by CLARITY. These tools have been implemented on basis of the AngularJS (https://angularjs.org/) JavaScript front-end web application framework as HTML5 Single Page Internet Applications. They are available under an open source license as a GitHub project (https://github.com/crismaproject/). These tools can be categorised in Scenario Analysis and Comparison and Multi Criteria Analysis and Decision Support.

These tools can be categorised into Scenario Analysis and Comparison Tools and Multi Criteria Analysis and Decision Support Tools. Each of the tools consists of several separate and independent widgets (self-contained graphical user interface components) which are briefly described in the following:

As indicator and criteria data have the same format, both of them use the same visualisation facilities which are provided by the Scenario Analysis and Comparison Tools. Those Widgets provide a plain table-like visualisation for all values. Figure 46 shows the normalised indicators (criteria) of three example scenarios in a tabular form.

Criteria	L'Aquila (M=7 +BR)	L'Aquila (M=7)	L'Aquila (M=7) (edited)
📋 Casualties			
Number of dead	80 Percent	90 Percent	54 Percent
Number of homeless	9 Percent	38 Percent	83 Percent
Number of injured	68 Percent	67 Percent	79 Percent
💲 Economic cost			
Direct damage cost	76 Percent	86 Percent	53 Percent
Indirect damage cost	67 Percent	70 Percent	65 Percent
Direct restoration cost	47 Percent	5 Percent	65 Percent
🏠 Damaged buildings			
Lost buildings	73 Percent	7 Percent	1 Percent
Unsafe buildings	8 Percent	97 Percent	8 Percent
🏛 Damaged Infrastructure			
Number of damaged road segments	30 Percent	45 Percent	96 Percent
🔖 Evacuation cost			
Total evacuationcost	28 Percent	45 Percent	84 Percent

Figure 46: Table Widget [24]

Additionally, they provide a bar chart visualisation to give an impression on how much the single values differ. The Scatter Plot Widget presented in Figure 47 allows users to correlate individual indicator and criteria values.
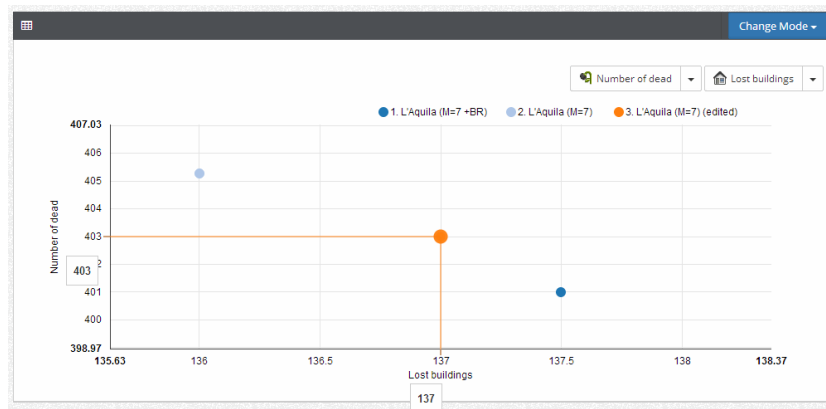

Figure 47: Scatter Plot Widget [24]

Moreover, the Radar Chart Plot Widget is able to visualise the data as spider charts in order to give a fast impression of the overall performance of the different scenarios.
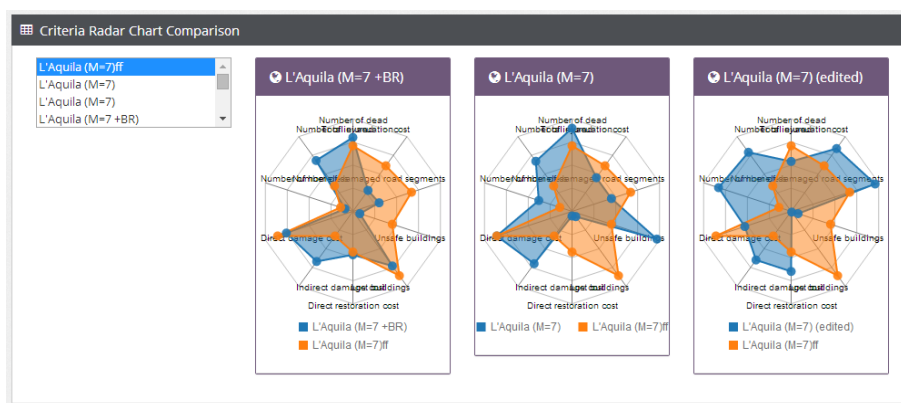

Figure 48: Radar Chart Plot Widget [24]

Figure 48 shows the data as spider charts in order to support the quick assessment of the overall performance of the selected scenarios. In addition a "reference scenario" (in the example L'Aquila (M=7) visualised in orange) can be selected

The indicator vector is mainly based on quantities calculated from a scenario. As already observed, to be effectively used in a decision support context indicators need to be qualified. Here qualification basically means assigning a level of satisfaction to the indicator data. The "normalised" indicators (criteria) can be better used as decision criteria. For this purpose, the Criteria Function Definition Widget depicted in Figure 49 allows the definition of functions converting indicator values to criteria.
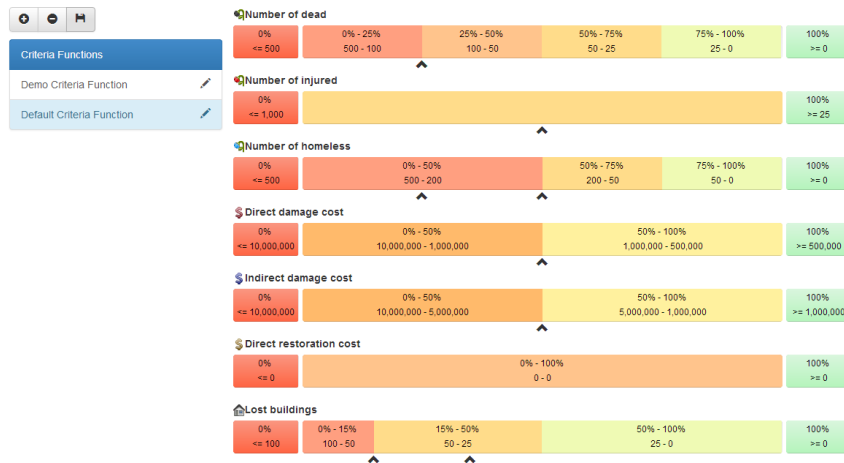
Figure 49: Criteria Function Definition Widget [24]

While the Scenario Analysis and Comparison Tools allows a comparison of indicators and criteria for different scenarios, the Multi Criteria Analysis and Decision Support Tools allows a ranking of different scenarios with respect to a specific decision strategy. In this it adds supplemental decision support functionalities. The tools are composed of two different widgets: The Decision Strategy Widget and the Decision Ranking Widget.

The Decision Strategy Widget (Figure 50) allows one to define a weighting strategy for different criteria. In this way, a weighting factor can be assigned to each indicator. This factor scales the contribution of the particular criteria to the overall scenario rank. An additional weighting factor can be selected to weigh criteria in relation to the achieved level of satisfaction. This is done according to the OWA method [25].
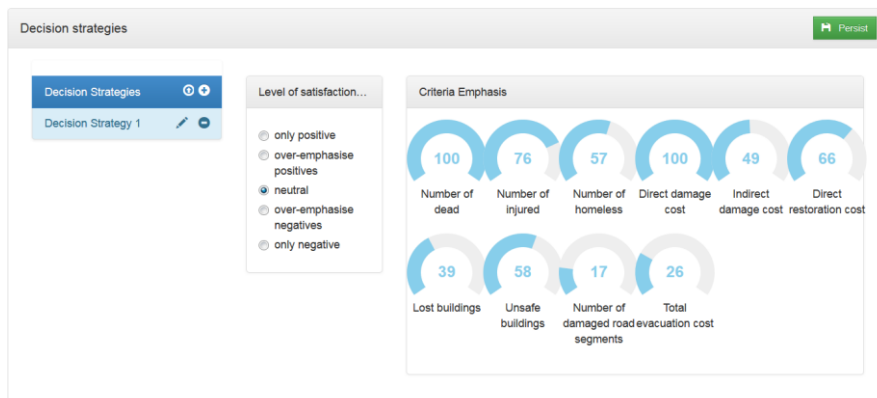

Figure 50: Decision Strategy Definition Widget [24]

The Decision Ranking Widget (Figure 51) allows the selection of a previously defined decision strategy and criteria function. It applies the selection to the available scenarios and produces a ranking.
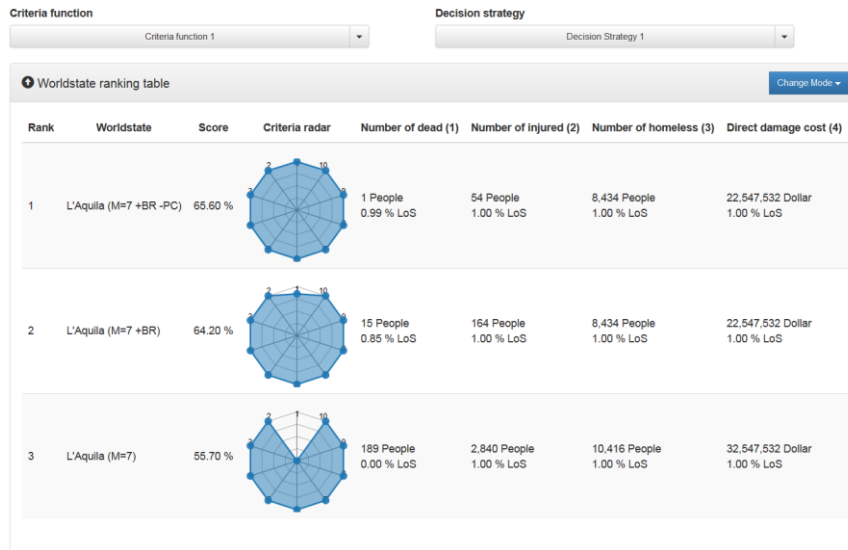
Figure 51: Decision Ranking Widget [24]

Planned usage in CLARITY

The CRISMA MCDA Tools are developed as generic HTML5/AJAX widgets which makes them directly usable as generic ICT Climate Services. They rely on a simple standardised JSON (JavaScript Object Notation) data format which fits perfectly into CLARITY's data driven approach. An example of an indicator vector in JSON format is depicted in Listing 1. In the example, the two categories "casualties" and "cost" are shown. While the general structure of the indicator data is not expected to change in CLARITY, additional extensions both regarding the data format as well the graphical user interface may be necessary depending on upcoming requirements from end user workshops, business cases and the overall agile development cycle. Nevertheless the general MCDA concept may not only useful for the comparison and ranking of adaptation scenarios resulting from Impact Scenario Analysis [7], but probably also for (pre-feasibility) Risk Assessment and general climate scenarios.

```
{
        "casualties": {
                "displayName": "Casualties",
                "iconResource": "flower_16.png",
                "noOfDead": {
                        "displayName": "Number of dead",
                        "iconResource": "flower_dead_16.png",
                        "unit": "People",
                        "value": "15"
                }
        },
        "cost": {
                "displayName": "Economic cost",
                "iconResource": "dollar_16.png",
                "directDamageCost": {
                        "displayName": "Direct damage cost",
                        "iconResource": "dollar_direct_16.png",
                        "unit": "Euro",
                        "value": "22547532"
                },
                "indirectDamageCost": {
                        "displayName": "Indirect damage cost",
                        "iconResource": "dollar_indirect_16.png",
                        "unit": "Euro",
                        "value": "58453689"
                }
        }
}
```

Listing 1: Indicator Vector data format

As tools have been implemented on basis of the AngularJS 1.0 JavaScript framework, it must be noted, that version 1.0 has been superseded by Angular 5.0 in 2017 and version 1.0 reached end of life in 2016. While this does not mean that the CRISMA MCDA Tools will stop to work, it could be problematic to develop the existing open source tools further for CRISMA. Although AngularJS 1.0 is still actively maintained by the community on GitHub (https://github.com/angular/angular.js/), no new plugins and libraries are being developed for version 1.0 and existing libraries and plugins don't receive new feature or security updates for AngularJS 1.0 in most cases. Probably considerable development effort would therefore be required to add additional features to the CRISMA MCDA Tools, e.g. other types of advanced diagrams. Another issues is, that the build- and dependency management tools Grunt (https://gruntjs.com/) and (https://bower.io/) used by CRISMA MCDA Tools' build environment have been discontinued. This is in particular a problem since Bower is unable to leverage libraries from the npm software registry (https://www.npmjs.com/) and an increasing number of libraries are not available on bower. Depending on adaptations and additions that must be made to the CRISMA MCDA Tools in CLARITY, it must be decided whether the development can continue on basis of the original JavaScript Framework and the related build environment, or if the tools must be ported to a new framework and build environment. Candidates for new frameworks are for example Angular 6.0 (https://angular.io/) which will be released in March 2018 and React 16.0 (https://reactjs.org/) which has been released in September 2017. The related build environment could be based on Webpack (https://webpack.js.org/), Babel (https://babeljs.io/) and Yarn (https://yarnpkg.com/) which would fit seamlessly into the CLARITY Development Environment described in Annex 3 of D1.1 "Initial Workshops and the CLARITY Development Environment" [2].

The CLARITY MCDA Tools support the Ordered Weighted Averages (OWA) method which is based on multi-criteria aggregation operators proposed by Yager [26]. OWA is characterized by a vector of ordered weights in addition to the importance weights assigned to each criterion. Using OWA, normalized indicator values are multiplied with a corresponding level of importance. Depending on upcoming user requirements additional ranking methods could be supported by the CLARITY MCDA Tools. An example of JSON-based data format of an OWA decision strategy used within the Decision Strategy Definition Widget (Figure 50) is depicted in Listing 2.

```json
[{
        "name": "Decision Strategy 1",
        "criteriaEmphases": [{
                "indicator": {
                        "displayName": "Number of dead",
                        "iconResource": "flower_dead_16.png",
                        "value": "0",
                        "unit": "People"
                },
                "criteriaEmphasis": 100
        },
        {
                "indicator": {
                        "displayName": "Number of injured",
                        "iconResource": "flower_injured_16.png",
                        "value": "0",
                        "unit": "People"
                },
                "criteriaEmphasis": 100
        },
        ],
        "satisfactionEmphasis": [0.1,
        0.1
}]
```

Listing 2: Decision Strategies data format

If additional decision strategies besides the OWA method must be supported, a standardised data format as well as respective user interfaces must be developed.

4. Climate Twins

Description of the background technology or software

The assumption of Climate Twins is the following: Climate change means that the future climate in one region will become similar to the present/past climate in other regions in the world Hence, the Climate Twins application prototype has been developed to explore the possibility of raising public awareness about future climate changes through identifying so called "twin regions", which show today a similar climatological situation as the user's region of interest will face in the future. Looking at these "Climate Twin regions" shall provide an impression of how the climate might look like in the future, when comparing, e.g., the temperature of a region of interest to a region in the south of Europe today.

The prototype's projection of future climate parameters 'temperature' and 'precipitation' is based on COSMO-CLM (COnsortium for Small-scale MOdeling - Climate Local Model) until 2100 on a 18 km-grid. A comparison of "similar climate" parameter profiles is possible between the future in the region of interest and the present/past in all other European regions. The results can be visualised across Europe in a web-based graphical user interface (Figure 52), i.e. each click on a location in the interactive map triggers a database query and array comparison of future with current climate indicators from the selected grid cell related to the respective municipality. The comparison results of the query are stored in a 2nd map view of the database, displayed in the application's second window (right hand side of Figure 54).
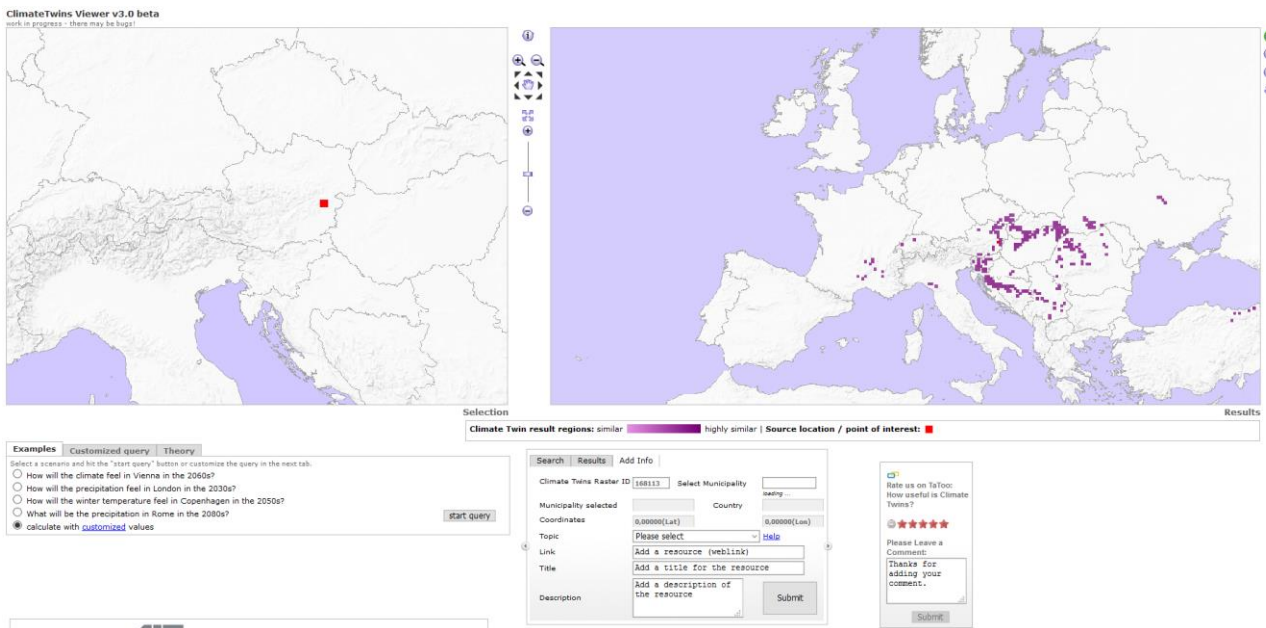

Figure 52: Climate Twins Web-Interface

Underlying Technology

The prototype's implementations is based on HTML and is integrating a FlamingoViewer (http://firstflamingo.nl/mapviewer/), an Adobe Flash© based library for web mapping applications which can consume OGC based web services like WMS etc.. The Climate Twins comparison data is stored in a PostgreSQL database and the web interface connects to the server backend via Java Servlets (for client/server communication) running in Tomcat. The maps are then rendered by a UMN Mapserver instance running on the same server.

Workflow of comparison process

Climate can be seen as a statistical collection of various climate variables. These variables are either measured or modelled in various time steps and therefore come as a list of values which can be transformed into similarity arrays in Climate Twins (see Figure 53).

id	precip_scenario	precip_control	temp_scenario
239034	{1,2,1,0,2,0,0,4,5,10,4,2}	{4,1,1,1,1,0,0,2,7,10,2,5}	{11.28,14.15,19.8,25.3,30.73,36.72,39.93,38.09,32.99,24.89,16.82,11.94}
145049	{126,112,97,78,48,24,17,31,63,83,113,130}	{135,119,79,58,56,30,19,38,67,106,118,114}	{11.24,11,11.26,12.24,13.99,16.2,18.26,19.33,17.98,16.13,13.83,12.21}
239035	{1,2,1,0,4,0,0,4,5,11,6,3}	{4,1,1,1,1,0,3,6,11,2,5}	{10.88,13.71,19.33,24.8,30.24,36.22,39.42,37.57,32.48,24.37,16.35,11.54}
239036	{1,3,1,0,7,0,0,3,7,13,8,3}	{5,1,1,1,0,1,0,3,6,11,3,5}	{10.59,13.37,18.96,24.39,29.82,35.78,39,37.11,32.03,23.93,15.98,11.23}
145050	{124,110,95,75,47,24,18,34,64,82,111,128}	{133,116,76,57,55,29,19,39,66,104,117,113}	{11.2,10.97,11.22,12.22,14.01,16.24,18.31,19.38,18,16.13,13.8,12.18}
239037	{1,3,1,0,5,0,0,3,6,14,8,3}	{4,1,1,1,0,0,0,3,5,10,2,4}	{10.53,13.29,18.87,24.29,29.74,35.69,38.91,37.01,31.92,23.81,15.89,11.16}
62002	{140,108,97,76,57,43,40,59,76,113,111,131}	{138,110,108,97,72,53,46,65,84,112,126,126}	{7.04,6.62,7.12,7.94,9.3,10.61,12.1,12.65,11.98,10.53,9.14,7.95}
62003	{149,112,104,82,62,47,44,63,82,121,117,137}	{144,116,111,101,75,57,51,70,93,120,132,132}	{7.08,6.68,7.19,8.01,9.39,10.7,12.19,12.71,12,10.55,9.16,7.99}
62004	{157,115,107,86,64,50,48,67,87,128,121,143}	{148,120,114,103,77,60,54,75,101,125,137,135}	{7.12,6.73,7.26,8.08,9.47,10.79,12.27,12.77,12.03,10.58,9.19,8.02}
62005	{163,116,110,88,66,52,52,71,93,131,127,146}	{151,124,116,104,78,63,57,81,105,131,143,139}	{7.16,6.78,7.32,8.14,9.55,10.87,12.35,12.82,12.05,10.6,9.21,8.05}
62006	{167,120,113,89,68,53,56,75,97,132,130,149}	{154,124,116,107,80,66,60,84,107,135,146,140}	{7.21,6.83,7.38,8.2,9.62,10.95,12.42,12.86,12.07,10.61,9.23,8.08}
89021	{162,129,116,94,71,60,60,80,115,140,136,169}	{159,139,119,98,82,64,73,88,114,139,150,155}	{8.38,7.87,8.35,9.16,10.68,12.02,13.58,14.27,13.35,12.07,10.59,9.3}
155173	{23,24,39,51,67,56,50,40,39,34,38,28}	{17,21,26,44,70,79,68,50,49,40,40,27}	{-1.41,0.79,4.61,10.26,16.1,21.63,23.94,21.89,17.45,10.15,4.48,0.63}
89022	{167,132,119,97,73,62,62,80,115,143,136,174}	{164,142,121,100,84,66,74,89,117,139,150,159}	{8.46,7.95,8.44,9.27,10.78,12.11,13.66,14.35,13.41,12.13,10.65,9.36}
89023	{170,136,119,98,74,63,64,81,118,148,137,175}	{167,144,124,99,86,68,76,90,117,141,150,161}	{8.54,8.04,8.53,9.37,10.88,12.21,13.75,14.42,13.47,12.19,10.71,9.43}
155174	{33,36,58,78,92,76,68,55,52,49,54,41}	{26,31,40,69,102,107,89,71,68,58,58,40}	{-1.9,0.14,3.79,9.27,14.9,20.3,22.65,20.64,16.45,9.47,4.01,0.17}
89024	{174,138,120,100,75,66,65,83,119,149,139,177}	{169,146,125,101,88,69,77,92,118,142,152,164}	{8.62,8.12,8.63,9.48,10.99,12.3,13.83,14.5,13.53,12.25,10.76,9.49}

Figure 53: Climate Similarity Arrays in Climate Twins

A statistical distribution of these values can be described by three main attributes: dispersion (measure of variability), skewness (measure of asymmetry) and kurtosis (measure of peakedness) or by aggregations like mean, median or range.

There are various ways to quantify these properties but especially measuring skewness and kurtosis is challenging and the results are not always satisfactory. By using conventional methods major problems must be faced as climate data is rather not normally distributed. Furthermore the results must be combined to a single attribute afterwards which also leads to problems in weighting them in an appropriate manner [27].

Figure 54 shows the logic behind the combination of single r-values to an overall similarity value. The most important part is that every single seasonal r-value must exceed a certain similarity threshold so that every overall similarity is mapped. If two locations match perfectly in three of four seasons but not in the fourth season, there is no point in declaring the two locations similar to each other.

As the declaration of similarity in Climate Twins is a subjective one and up to some point an arbitrary process, so is the definition of the similarity thresholds in the application. The thresholds should of course be tight enough to provide a reliable result but on the other hand wide enough so that an acceptable amount of Climate Twin regions can be found. Furthermore an applicable threshold also depends on the indicator used and the category number.
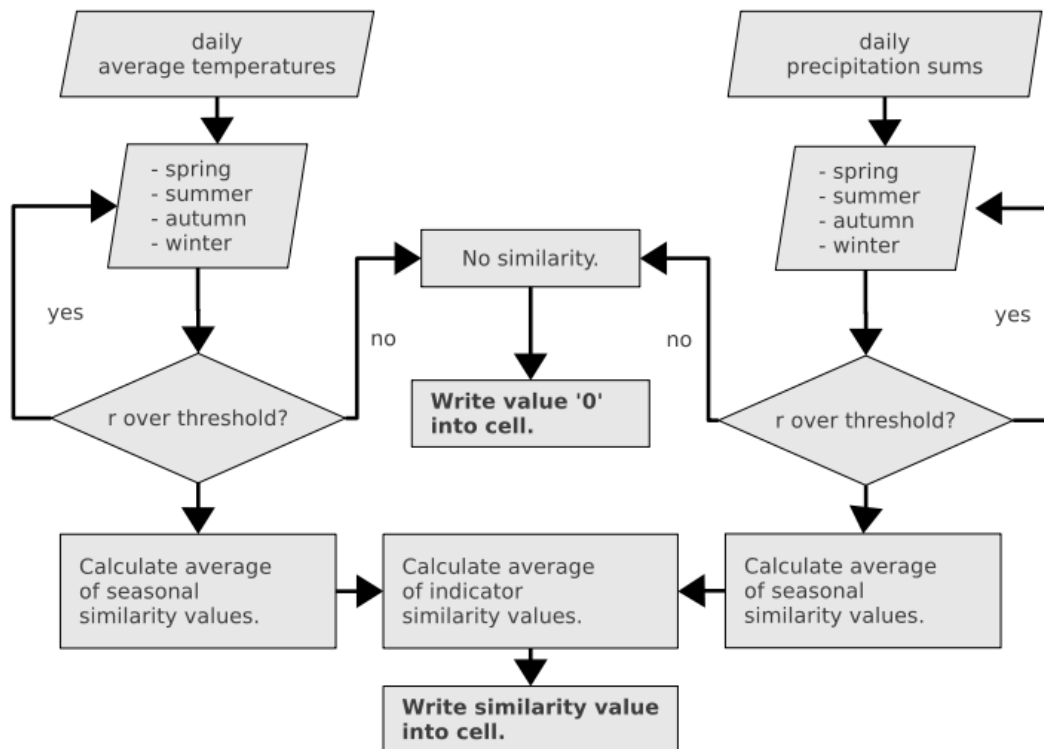
Figure 54: Climate Twins' Logical Structure

The logic of combining r-values while defining similarity between two locations depicted in Figure 54 is scalable, i.e. any number of indicators can be implemented as long as respective similarity thresholds are applied. The above similarity values are then written into a result table in the data base and visualised on a raster grid in the map, showing similar regions for the parameters set.

Planned usage in CLARITY

Since the prototype's technology is too old to be re-used in CLARITY (see Underlying Technology section), CLARITY will make use of the prototype's idea and apply it not only to climate data but will go beyond this and introduce new indicators to be able to do a comparison of e.g. CLARITY's elements at risk and project types stored in the database in order to let a future CLARITY users be pointed more easily to regions/cities and projects in Europe that are facing similar problems than the user does or which are already dealing with them.