D2.4 CLARITY Demonstrators implementation and validation report v2

WP2 – Demonstration & Validation

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CLARITY Project Overview

Urban areas and traffic infrastructure linking such areas are highly vulnerable to climate change. Smart use of existing climate intelligence can increase urban resilience and generate added value 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 CLARITY.eu.

Executive Summary

This report presents the work done in the four CLARITY Demonstration Cases (DCs) in Italy, Sweden, Austria and Spain, designed to showcase the potential of the proposed "Expert" services in relation to different hazards and urban infrastructure in the three first cases and in relation to different hazards and transport infrastructure in the last one.

CLARITY follows in fact a two-level analysis approach in delivering climate services for urban adaptation: (1) a self-service screening (CSIS, see D1.3 and D4.2), able to perform a semi-automatic impact assessment report with a limited input from the users' side, and (2) a variety of "Expert Services", intended as individual and professional consulting and advisory services, providing detailed information tailored on specific end-users needs.

CLARITY Expert Services are based on a variety of models and simulation tools offered by CLARITY experts and third parties through the CLARITY Marketplace (https://myclimateservices.eu/en/h2020/CLARITY-marketplace) which connects service providers and users to co-design user-tailored solutions in relation to different categories of hazards and urban infrastructure project. In this way, the CLARITY service users can minimize the cost and efforts required to perform an adequate adaptation planning, while also maximizing the visibility of the relevant expert offers and streamlining the communication between the end users and the climate change experts.

Both "Screening" and "Expert" services implementation follows the logical workflow defined by the EU-GL, aimed at providing an integrated modelling approach (Section 2) able to produce detailed impact quantification on selected elements at risk (e.g. population, buildings, transport infrastructure, economic sectors, etc.) under the effect of extreme weather events in context of climate change, based on high resolution climate projections and analyses.

The Expert services for the four DC areas are being co-designed with local stakeholders, engaged with different participatory methods in a series of end-users workshops, which allowed to define the specific needs of end-users in relation to the urban infrastructure projects object of the demonstrators (Section 3), and implement the data collection activity required to feed the "Expert" models and algorithms, so to allow the development of the first tests and simulations (Section 4).

Given the diversity of issues faced by the CLARITY DCs - in terms of models and data availability, stakeholder engagement process implementation, complexity of simulations and urban projects at hand, awareness level of stakeholders in relation to climate change adaptation measures in urban areas and how to integrate them into ordinary infrastructure planning and design activities - the progress of the demonstrators is of course neither linear nor uniform. However, the EU-GL modelling and decision-making framework constitutes a reference followed in the four DC contexts, aimed at ultimately align the DCs in terms of process and results, so to provide an homogeneous overview of CLARITY climate services potential.

The stakeholders of the four CLARITY Demonstration Cases 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. Stakeholders categories include public officials and national to local administrations representatives, service providers, practitioners in the field of urban planning and design, local communities. CLARITY Expert Services will be validated against stakeholders' requirements, also in terms of business and exploitation perspective, through a series of questionnaires submitted during the project workshops, as well as online, to the stakeholders engaged in the 4 DC areas (Section 5).

The conclusions highlight the progress achieved and next steps towards DCs finalization (Section 6), to be reported in D2.4, which will focus on risk/impact assessments on the baseline of the identified project areas, on the development and integration of adaptation measures responding to the main risks identified, the comparative assessment of alternative intervention scenarios, and the final validation report.

1 Introduction

This deliverable reports on the outcomes of the final round of CLARITY demonstrators' implementation, providing feedback to WP1, WP3 and WP4. It also reports the outcomes of the evaluation and validation process, including feedback from potential end-users external to the consortium.

Based on the methodological approach outlined in D2.1 and D3.1-D3.2, and building upon the completion of data collection activities reported in D2.2, this document illustrates the implementation of the demonstration activities in the case study areas. The planning, set-up and execution of the demonstrators involved all relevant stakeholders and provided two iterations for each demonstrator.

The first iteration was reported in D2.3 and focuses on the link between the identified modelling workflows and the key objectives arising from the urban infrastructure projects object of the three of the four Dcs, being the fourth focused on transport infrastructures. The main outcomes from the workshops conducted with local end-users and stakeholders within each DC (**Table 1**) highlighted the compliance of the proposed solution to the requirements reported in D1.1 and D1.2, the compatibility of the CLARITY climate services with current procedures, practice and needs in each of the project in the demonstrator areas, and the identified priorities of application of CLARITY solution for each location.

On the three urban demonstration case areas, pilot urban plans projects currently in development phase were selected with the support of local stakeholders. They were object of specific simulation and assessment workflows, responding to the specific requests from those same stakeholders, in order to identify any needed revision to improve climate resilience conditions.

Table 1: End-user workshops conducted/planned since M12 to support the co-design and implementation of CLARITY DCs.

DC1	DC2	DC3	DC4
October 2018	March 2018	October 2017 Linz planning dep. workshop	October 2018
April 2019	September 2018	May 2018 Linz planning dep. Workshop	Oct – Dec 2019
June 2019	October 2019	October 2018 planning dep. Workshop	February 2020
December 2019	January 2020	June 2019 Linz councellor workshop	March 2020
January 2020	July 2020	July 2019 WS and press conference	April 2020
June 2020		October 2019 planning ep. Workshop	May 2020
		March 2020 workshop Tabakfabrik	July 2020
		July 2020 webinar Linz	September 2020
		July 2020 webinar for all DCs	
		September 2020 WS and press conference	

Where applicable, the possible links between CLARITY DCs with existing funding programmes, such as the European Structural and Investment Funds (ESIF) and the European Regional Development Fund (ERDF), were identified, with the aim of supporting DC end-users in mobilizing additional or follow-up resources to implement the demonstrators.

A major focus of D2.4 concerns the reporting about the status of activities implemented to meet the main objectives of WP2, in particular:

- Monitor the implementation of CLARITY demo cases, demonstrate the fulfilment of requirements and the application potential of the tools by illustrating DCs implementation in terms of narrative and objectives of the specific urban infrastructure projects in the 4 demonstrator areas, as consolidated following the end-user workshops (Section 3), as well as in terms of modelling and simulation activities carried out to showcase the features of CLARITY Expert Services (Section 4).

- Collect climate scenarios and tailor them to the specific needs of the demonstration cases → by outlining for each DC area the main hazards considered, and discussing the methods to define the selected reference values (e.g. of temperature and precipitation), as a result of climate projections downscaling with RCMs and their transformation into input for risk and impact modelling, considering the urban microclimate variables through the "local effect" modelling, where needed.
- Deliver exposure and vulnerability data to CLARITY models (WP3) and tools (WP4) for each DC by discussing the connection between collected data and modelling workflows as defined in WP3, and reporting about the results of tests carried out so far, showing how the collected data (T2.2) are being integrated in the CLARITY Expert workflows, becoming input of the diverse models and tools applied in the context of the 4 demonstrators.

2 Demonstrators implementation

CLARITY's overall objective is to support the integration of Climate Change Adaptation measures within urban and transport infrastructure planning and design processes. The project aims to provide an operational eco-system of climate services to calculate the expected effects of CC-induced hazards on urban areas and transport networks, including what-if decision support functions to investigate the effects of adaptation measures and risk reduction options in the specific infrastructure project context, allowing the comparison of alternative strategies.

As outlined in D3.2, CLARITY methodology has been developed according to the IPCC-AR5 approach, which reconnects the climate risk/impact modelling to the more consolidated modelling framework from DRR (Disaster Risk Reduction) domain.

Each of the infrastructure projects selected in the four demonstrators will ultimately align their implementation with respect to such framework, so to provide an harmonized overview of CLARITY Expert Services and deploy consistent data packages which will support the exploitation of CLARITY solutions towards potential end-users, as well as towards data/models purveyors and service providers to be engaged through the CLARITY Marketplace.

2.1 Modelling and simulation status at M36

As stated in D2.3 WP2 provided a harmonised methodology for data collection across the different Demonstration Cases (D2.1) linking end-user's requirements from WP1 with modelling and software needs in WP3 and WP4.

The implementation of the DCs included the full definition of modelling workflows and the completion of related data collection activities (including metadata), as well as the definition of relevant urban and transport infrastructure projects that were to be tested in the four DCs.

In the first iteration of the DCs implementation, a major effort was devoted to embedding local microclimate analysis as additional refining step in the conventional GCM-RCM (Global Climate Model - Regional Climate Model) downscaling approach. To this aim, different models and tools were used in the four demonstrators, both as example applications of commercial products (e.g. MIKE, MUKLIMO, ENVI-MET, Solweig), or as experimental models and tools developed within CLARITY and other EU projects (e.g. PLINIVS HW/FL Simplified Models, SAFELAND Landslide model, Green Area Factor). The microclimate ("local effect") assessment, represented a major focus for all urban DCs, since urban adaptation measures are able to modify urban microclimate by acting on key parameters related to the urban morphology (terrain, vegetation, building density, etc.), land use (residential, industry, transport network, open spaces, etc.) and surface type (e.g. albedo, emissivity, green fraction, runoff coefficient, etc.). The assumption was that only this kind of locally tailored analysis would allow for a proper identification of specific planning and design specifications, to be integrated within urban infrastructure projects, aimed at reducing the impact of extreme weather events in a climate change perspective.

In the second and final iteration of the DCs implementation, the DCs also focused on the identification of exposure of Elements at risk (e.g. population, buildings, infrastructure, etc.) and their classification in vulnerability classes. For each element at risk, specific vulnerability functions were defined in relation to the identified vulnerability classes, and results were presented where available.

The finalized selection of specific project areas in the four DCs (see Section 3) streamlined the next modelling steps, towards risk/impact assessment and adaptation measures integration, which were carried out in the identified spatial domains, providing a portfolio of example application at different scales (building, district, city, region) and domains (urban development, urban regeneration, transport infrastructure design and maintenance).

A detailed analysis of the results obtained with the models used in CSIS in comparison with the results obtained with other available models used in the expert studies carried out in each DC has allowed the validation of the models used and their adjustment and improvement during these last months. These results have been transferred to the system and with them a better characterization of the vulnerability functions and the risk posed by the different hazards in each study area has been achieved.

This validation study focused mainly on local effects associated with heat waves and floods and was carried out mainly in Naples, where more detailed results were available from the study undertaken during the project.

Finally, a great effort has been made to implement the functionality associated with the incorporation of adaptation options in the studies and in the modification that these actions imply in the calculation of impacts on the areas under study.

As per the project description and requirements, the project follows the EU Non-paper Guidelines for Project Managers (EU-GL), as such these guidelines have been implemented into the system, so the workflow moves organically through its different steps. This will be explained in better detail below.

Which steps and sub-steps are available in the study and what they do can be easily configured through “study templates”. Several study templates have been defined for different types of studies, most notably the “Basic screening”, “Advanced Screening: Urban Infrastructure”, “Advanced Screening: Traffic Infrastructure” and the “Expert: Urban infrastructure”. The most relevant characteristics of these study types are:

Study Type	Description
Basic screening	Allows the users to compare the existing hazard and exposure data sets and explore the vulnerabilities and adaptation options anywhere in Europe. Over 20 hazard indices are provided for several periods and future climate scenarios. However, the hazard resolution is limited to 12x12 km2, which isn't enough to capture the urban climate variations. No impact calculations are performed, but the comparison of the hazard intensity with positions of the elements at risk can be used as a proxy for risk/impact.
Advanced Screening: Urban Infrastructure	Allows the user to perform on the fly calculation of local hazards, exposure and impact on the fly for a selection of European cities and regions where the relevant input data is available. The resolution is 500x500m2, which is enough to capture the urban climate variations. However, the calculation is limited to "heat urban islands" use case, with "flooding" still in development. Like in the basic screening, the Advanced screening – Urban infrastructure also allows the users to explore the characteristics of the main adaptation options anywhere in Europe. An additional step for assessing the impact of adaptation options is still in development. More information on Advanced Screening: Urban Infrastructure is provided in section 2.2.
Advanced Screening: Traffic Infrastructure	Allows the user to perform the advanced screening for the traffic infrastructure. Currently limited to Spain, the extension to the rest of the Europe is in development. This screening is conceptually similar to the Advanced Screening: Urban Infrastructure but targets a different type of infrastructure and a different group of users. It is also very different in terms of the technology used and showcases how the (HML5) software can be embedded in the CSIS workflow. More information on Advanced Screening: Traffic Infrastructure is provided in section.
Expert: Urban infrastructure	Similarly to the "basic screening", this workflow relies on pre-made data sets and no calculations are performed on the fly. However, the expert study relies on data packages that were specifically made for this study and therefore no a-priory assumptions are made on the available steps or data. Typically, such data packages provide high resolution data for a limited study area. They may also provide data corresponding to hazards, elements at risk, impacts and impacts of the adaptation options that aren't available in the screening data packages. Main use case for the "Expert: Urban infrastructure" study type is therefore preparing one or more reports on a previously conducted expert study.

A more detailed description of the studies and of the Expert: Urban Infrastructure one can be found on the document D1.4 CLARITY CSIS v2.

The implementation of the Demonstrators is, to a great extent, common for the most part, especially in the case of the Demonstrators dealing with Urban Infrastructures. The Transport Demonstrator, although following the same guidelines and workflow, is somewhat different due to its particularities. These two approaches will be detailed below.

3 Demo cases demonstrators: implementation and validation

This section illustrates the final results for each Demo Case, focusing on the implementation steps in relation to the EU-GLs as incorporated in CLARITY methodology, and documenting the use of Expert Services from the perspective of end-users in relation to the planning objectives and governance processes aimed at integrating climate adaptation in urban (DC1, DC2, DC3) and transport (DC4) infrastructure projects. The main hazards and element at risk targeted are outlined, providing a description of the urban infrastructure projects studied in the DCs and addressing multi-scale (e.g. regional to urban to neighbourhood) simulation objectives where relevant). The section also documents about the main outcomes from end-user workshops relevant for DC implementation and technical validation of CLARITY output.

3.1 DC1

3.1.1 Overview

The goal of DC1 - Napoli “Multi-scale Climate-Resilient Urban Planning” is to evaluate the benefit of integrating adaptation strategies in urban plans and redevelopment/retrofitting projects in the Metropolitan City of Naples, with a specific focus on the Municipality of Naples, its Capital city.

To provide support to urban planning and design activities in effectively integrating climate adaptation measures, DC1 focuses on sample areas representative of recurring climate-related hazards in the Metropolitan area. In particular a selection of key areas for developing climate adaptive planning within Naples’ Municipality has been performed and several scales of application and different projects have been defined: Municipality of Naples on heat and flood hazards (as capital city of the Metropolitan area) and the Municipality of Castellammare di Stabia on landslide (as example application replicable in the 12 municipalities around Vesuvius).

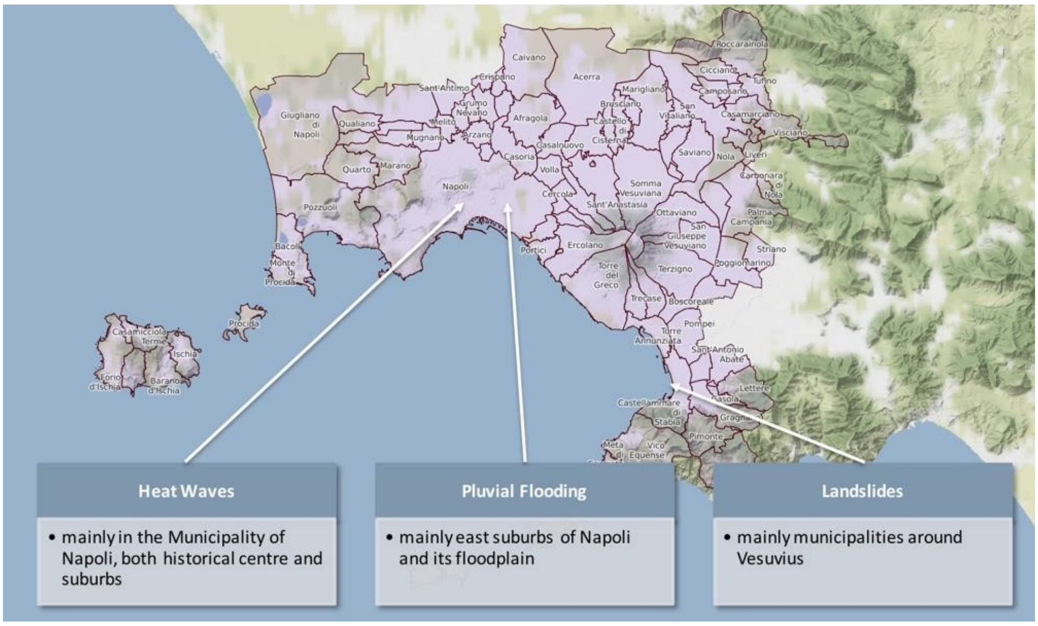


Figure 1: DC1 focus areas

DC1 implementation follows the CLARITY modelling workflow as defined in WP3, which follows the 7-steps approach as outlined by the updated EU-GL approach (see D3.3). Through dedicated models provided by the CLARITY Expert teams involved (PLINIVS, ZAMG) and data provided by local teams (PLINIVS, NAPOLI) Hazard carachterization, Exposure assessment, Vulnerability analyses, Impact assessment and Adaptation options identification, appraisal and integration have been developed in relation to Heat Wave, Flooding and Landslide risks in the area (Figure 2).

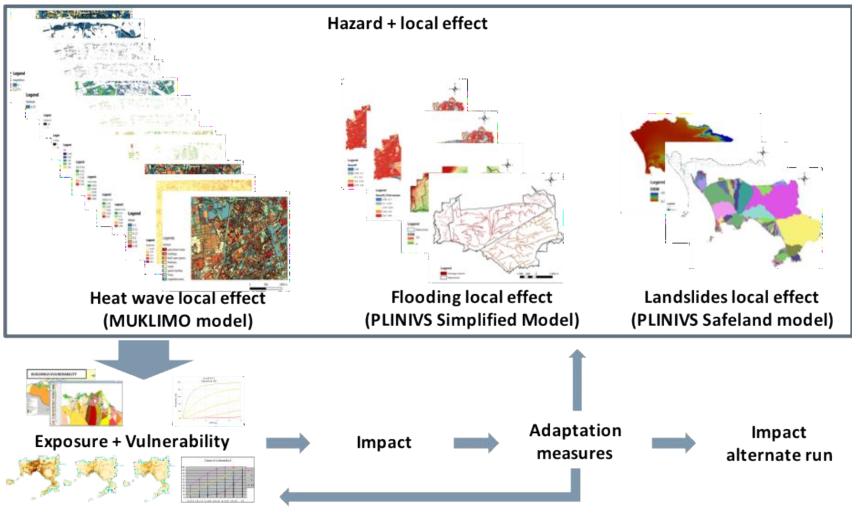


Figure 2: DC1 modelling workflow scheme.

In policy terms, on a broader urban governance level, the main objective of Naples demonstration case is to support public administration at Metropolitan and Municipal level in developing the local adaptation plan based on EU Directives and the National Strategy for Climate Change Adaptation. The implementation of the Adaptation Plan is based on the information acquired through the climate services provided by CLARITY. The DC1 implementation has allowed end-users to acquire a set of design guidelines which, according to future plans beyond CLARITY, can be further integrated to tackle the multi-risk conditions (climate, seismic, hydrogeological, volcanic) of the Metropolitan area, so to promote an integrated approach to Climate Change Adaptation and Disaster Risk Reduction within public policies and private investments.

Table 2: Relation between the main Hazards and elements at risk in DC1

	Heat	Flood	Landslide
People	+++	n/a	++
Buildings	n/a	++	+++
Roads	n/a	+	++

While in the period M1-M12 the DC1 end-user workshops and meetings with stakeholders of the Metropolitan City of Naples have mainly focused on the identification of end-user requirements/stories and on specific issues related to the data collection activity (see D2.2), since M13, the DC1 end-user workshops have been devoted to identifying the main ongoing urban projects object of the demonstrator implementation.

Following the results of the workshops of April and December 2019, the overall logic of DC1 has been consolidated, with the aim of providing a coherent multi-scale climate-resilient planning and design framework in which hazard/impact simulations, and the identification/appraisal of suitable adaptation strategies and measures – even when performed with different models and tools depending on the needed detail of information across the scales of intervention – show a consistency in the results, which can be transferred from the strategic planning level up to the detailed neighbourhood scale design.

During the DC1 Workshop in January 2020, the Technical Departments of the Municipality of Naples have identified the general framework that defines the potential contribution of CLARITY climate services in the context of a multi-scale integrated urban adaptation planning.

The climate change profile for Napoli area is at the base of all planning documents and it is based on the regional downscaling and bias correction provided by ZAMG, with a focus on extreme heat and precipitation events in the period 2020-2100 in terms of frequency according to the different RCPs. Three levels of planning are identified, with specific projects based on ongoing official activities already ongoing carried out by the

Municipality of Naples: 1. Strategic level – Napoli Sustainable Energy and Climate Action Plan (SECAP); 2. City planning – Update of Napoli City Plan (PUC); 3. District planning – Ponticelli Urban Regeneration Plan (PRU).

In this context the support to the implementation of the project “Hydraulic works on Monte Faito slopes in the Municipality of Castellammare di Stabia”, which was previously identified as possible focus area, has been discarded since the the project is currently stalled. The work implemented in CLARITY, and documented in D2.3, has been delivered as a baseline for a future follow-up collaboration according to the new timeline of the project, which should be inserted in the next ERDF funding period 2021-2027. The landslide case is therefore excluded from D2.4 content.

Table summarizes the identified projects M39. The priority index refers to the current status of project implementation carried out by the Technical Departments of the Municipality of Naples. In the context of CLARITY, the highest priority has been given to the projects for which official deadlines are set in 2020, therefore requiring the results of Expert Services to be integrated in the official project documentation.

Table 3: DC1 project areas.

Project	Hazard(s)	Funding	Priority
Naples Sustainable Energy and Climate Action Plan (SECAP)	Heat Wave / Flood	Municipality of Naples	XXX
Naples City Plan (PUC)	Heat Wave / Flood	Municipality of Naples	XXX
Ponticelli Urban Regeneration Plan (PRU)	Heat Wave / Flood	National / EU (ESF 2007/2013)	XXX
Tram / BRT infrastructure with green areas arrangement (east Naples)	Heat Wave / Flood	EU (ERDF 2014/2020)	XX
Soccavo-Pianura local area plan	Heat Wave / Flood	Municipality of Naples	XX
Miano local area plan	Heat Wave / Flood	Municipality of Naples	XX
Municipality of Naples Building Code update (City Level incentives to private action)	Heat Wave / Flood	Municipality of Naples	Possible follow-up
Hydraulic works on Monte Faito slopes in the Municipality of Castellammare di Stabia	Landslides	EU (Cohesion Fund 2007/2013)	Possible follow-up

The Annex 1 illustrates the final results of DC1, focusing on the multi-scale approach to urban adaptation in relation to the Heat Wave and Flooding hazards, in line with the priorities as expressed by the end-users involved in the DC implementation. The main achievements of DC1 consist in the possibility of exploring the impact of climate-related hazard on the selected elements at risk with a progressive level of detail, always taking into account the “local effect” determined by the urban microclimate and the specific features of local settlements, as well as the definition of exposure parameters for the three hazards considered. The levels of detail range from a 250x250m mesh overlapped to the territory for city-wide analyses, up to a 1x1m and 3D representation for neighbourhood scale simulations.

3.1.2 Technical validation

The CLARITY aim of translating climate information into actionable results in terms of adaptive design and resilience-based planning has been successfully validated from the end-user perspective through the several workshops conducted within DC1, whose results are reported in the sections of this deliverable. However, a major lesson learned is to improve the ability to explicitly link climate adaptation to other “urban challenges” as expressed by local stakeholders (e.g. housing needs, social cohesion, financial constraints), which will be taken into account in the development of ad hoc multi-criteria and cost-benefit analysis tools, co-designed with NAPOLI stakeholders.

A major feedback from Napoli end-user concerns the wide consensus of different stakeholders’ groups that in the field of Urban infrastructure planning and design, despite the interest in climate and change issues, the integration of adaptation measures is not always considered within territorial planning and urban development actions at regional and local level. This results sometimes in a lack of awareness local stakeholder about the cost/benefits from effective adaptation and mitigation measures into urban planning and building/public space design activities. Other priorities of public officials and local communities linked to urban infrastructure development, such as housing needs, public space quality, social cohesion, scarce budget for design and maintenance, etc. are often overarching compared to climate adaptation.

At the level of potential end-users, such as local administrations in charge of urban regeneration or transport infrastructure projects, a main challenge is due to the difficulty to align the EU project timing with that of ordinary activity of city/region planning departments. This affects the co-development process, making inevitable to define some implementation steps internally to the project consortium, which can only be validated afterwards by the involved users.

A father challenge concerns how to manage the possible conflicts between the Stakeholders, when different levels of governance (e.g. local and national) do not have often the same objectives and/or priorities.

"Local effect" analysis

As mentioned, the sole analysis of data derived from the observation of past events recorded by local weather stations and projected in the future through statistical “downscaling” of Regional Climate Models (RCM) cannot capture the microclimatic variability linked to the settlement characteristics of the urban environment. The urban morphology and the land cover greatly influence the thermal stress conditions and the ability to absorb rainwater, resulting in a significant diversification of the main hazard parameters.

In order to provide a support for urban planning, specific models have been developed that are able to capture the "local effect" (see D3.3), and therefore to provide more precise information on the climate adaptation strategies to be implemented in different parts of the city.

The thermal stress variation in the different city areas is simulated through the mean radiant temperature (T_{MRT}) indicator, which is widely validated in the literature as representative of the perceived outdoor comfort (see D3.3). This is essentially derived from (1) air temperature; (2) surface temperature; (3) urban morphology and surface characteristics of buildings and open spaces. Although T_{MRT} does not consider wind as a parameter, normally extremely low wind speeds are recorded during heat waves, and therefore the simplification adopted, widely recognized in the scientific literature (see D3.3), it is suitable in relation to the objectives of the simulation.

In addition to the data processed by ZAMG and PLINIVS-LUPT related to climate observations and projections, and to the new GIS database developed by the City of Naples and PLINIVS-LUPT, it was necessary to acquire data on surface temperatures in heat wave conditions, to support the assumptions done in the HWLEM based on elaborations from ENVI-MET and SOLWEIG models (see D3.3). During the calibration of the model, the information developed was reworked starting from Landsat satellite data from 19 July 2015, corresponding to a 3-day heat wave with maximum temperatures of about 36-37 °C . Further data used for calibration were collected during the 5-day heat wave with maximum temperatures of about 34-35°C of 28-31 July 2020 through aerial and field surveys.

The model also allowed to develop further simulations related to the perceived discomfort conditions, through the UTCI indicator (Universal Thermal Climate Index), as well as simulations on the expected impacts on human health, including the increase in mortality (currently being calibrated). The UTCI represents the main indicator of thermal stress in urban open spaces and can be referred to a scale of discomfort linked to the different ranges observed (Table). The damage classes are calibrated with reference to the weak population groups (children under 15 and seniors over 65) for the Naples climate zone.

Table 4: Classes of damage from thermal stress related to UTCI values, referring to weak population groups (children under 15 years and elderly over 65 years) for the Naples climate zone.

D0	No Damage	26
D1	Level of caution (moderated heat stress)	32
D2	Level of caution (strong heat stress)	38
D3	Damage (very hard heat stress)	46
D4	Extreme damagee (extreme heat stress)	> 46

The UTCI maps corresponding to the T_{MRT} maps, highlighting the extremely critical potential health impacts correlated with heat stress in the future.

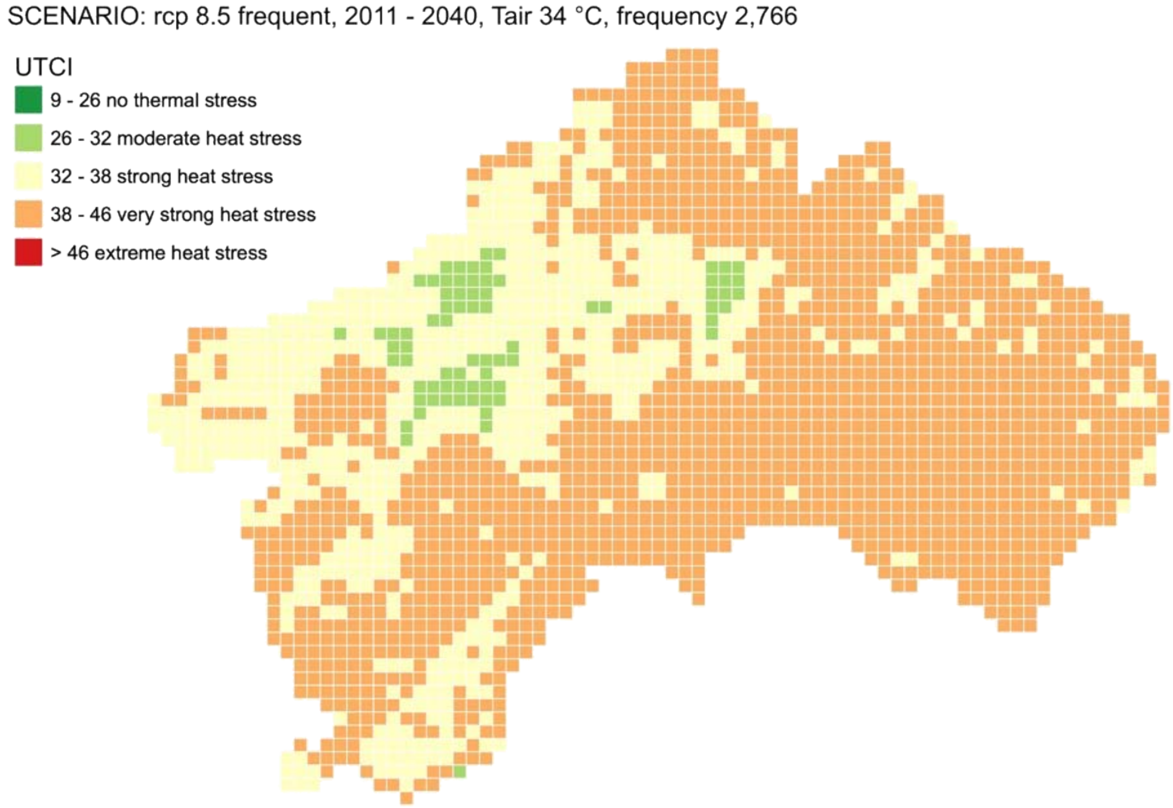


Figure 3: Universal Thermal Climate Index (UTCI) map for a typical day of heat wave with air temperature of 34 ° C (on 250x250m grid). (Source: PLINIVS-LUPT, CLARITY).

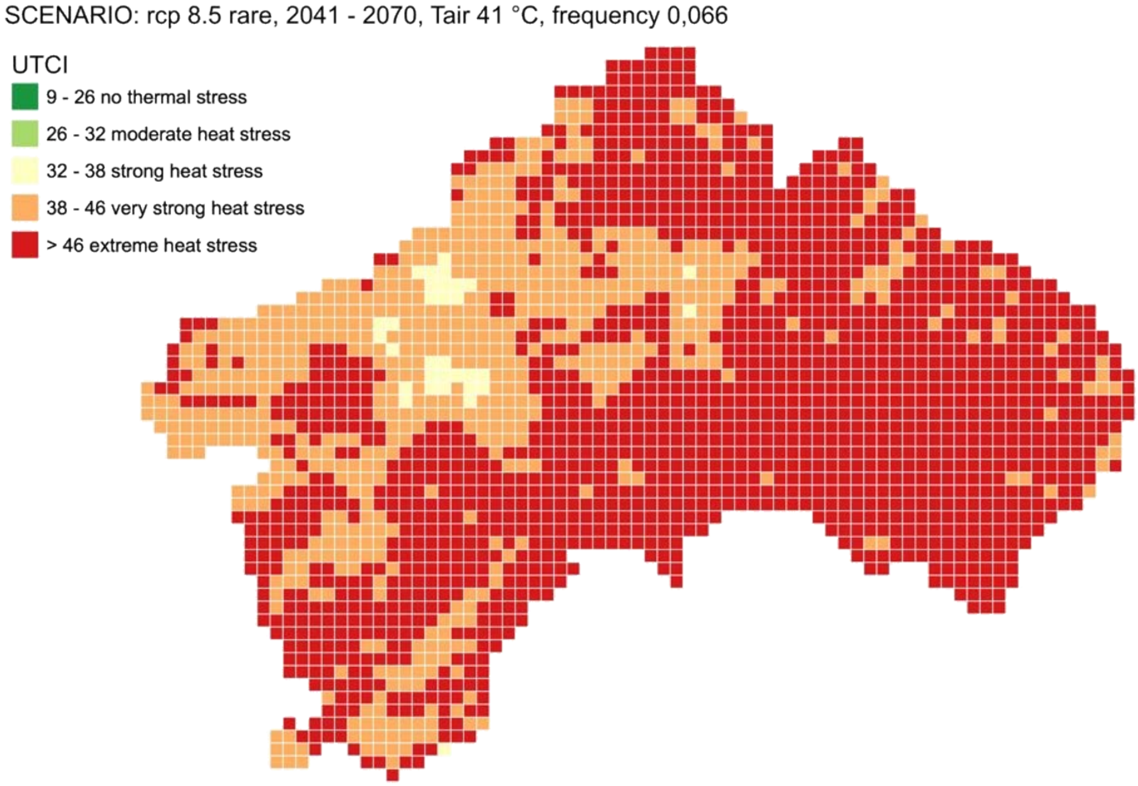


Figure 4: Universal Thermal Climate Index (UTCI) map for a typical day of heat wave with air temperature of 41 °C (on 250x250m grid). (Source: PLINIVS-LUPT, CLARITY).

Each cell of the grid can be analysed more in detail, so to determine in which extent the specific land uses and the building-open space configurations system contribute to determining higher T_{MRT} values and therefore higher heat outdoor discomfort and associated health risks. The following figures show some example results related to urban areas in the ancient city centre, in the west (Rione Traiano) and east (Ponticelli) areas.

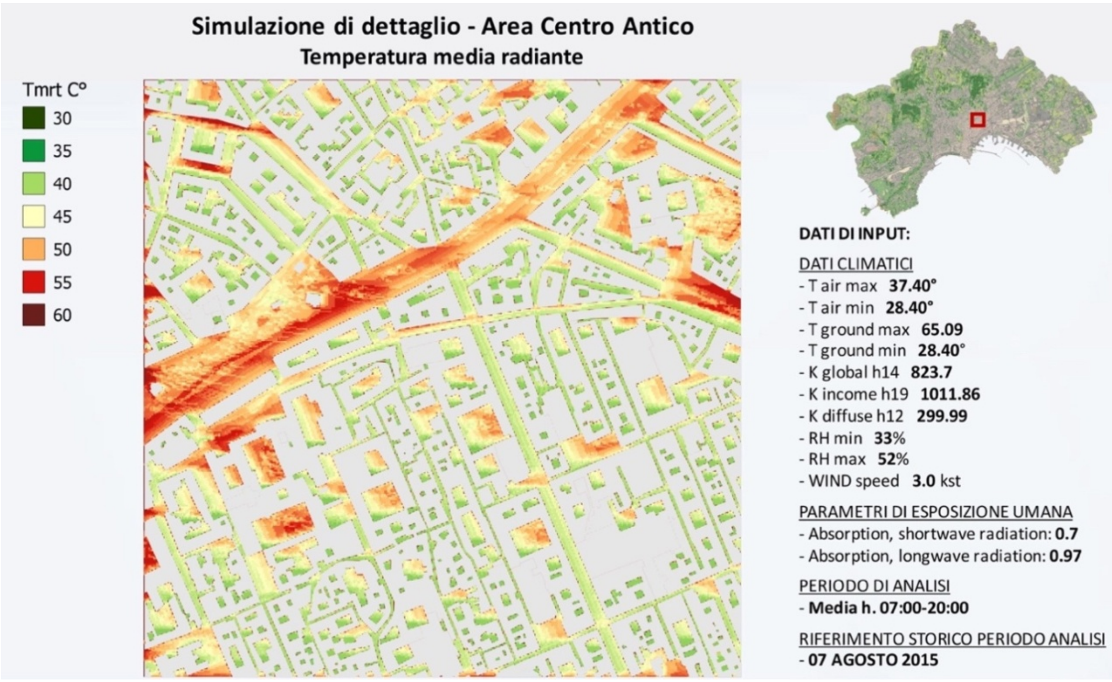


Figure 5: Detailed analysis of the Mean Radiant Temperature in an area of the ancient center, for a typical heat wave day with air temperature of 37 °C. (Source: PLINIVS-LUPT, CLARITY).

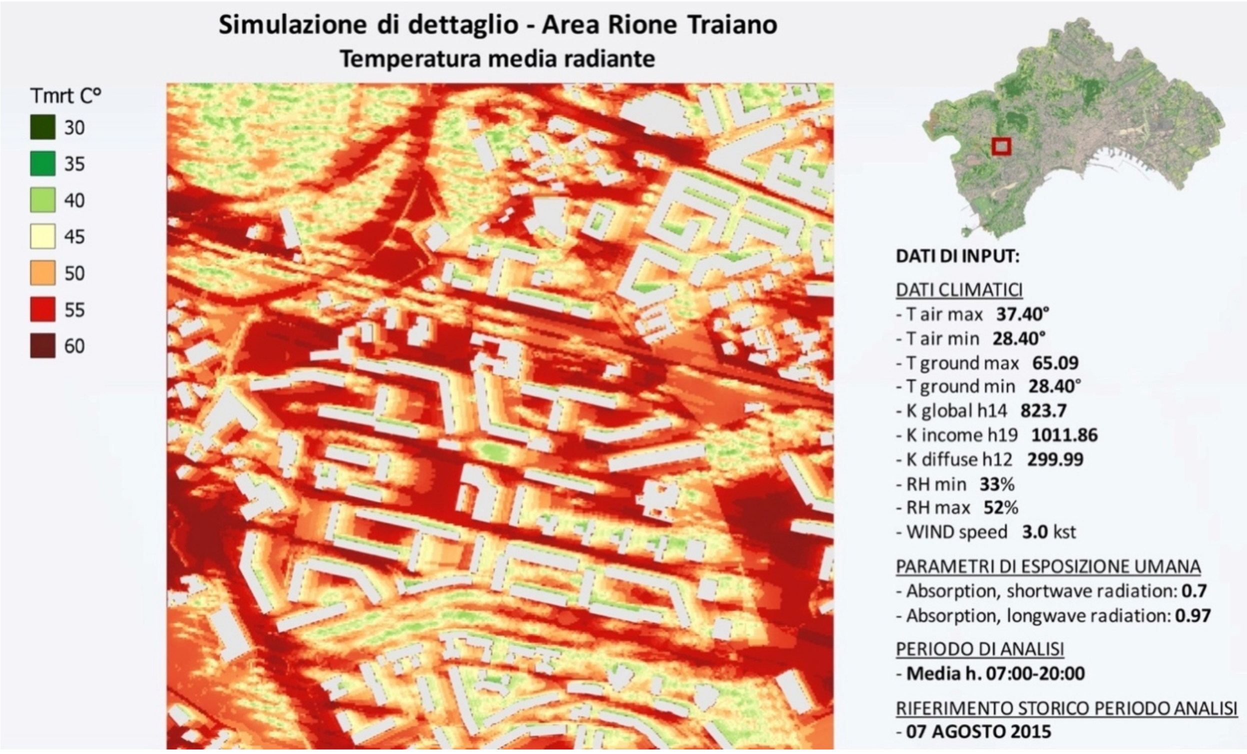


Figure 6: Detailed analysis of the Mean Radiant Temperature in an area of the ancient center, for a typical heat wave day with air temperature of 37 °C. (Source: PLINIVS-LUPT, CLARITY).

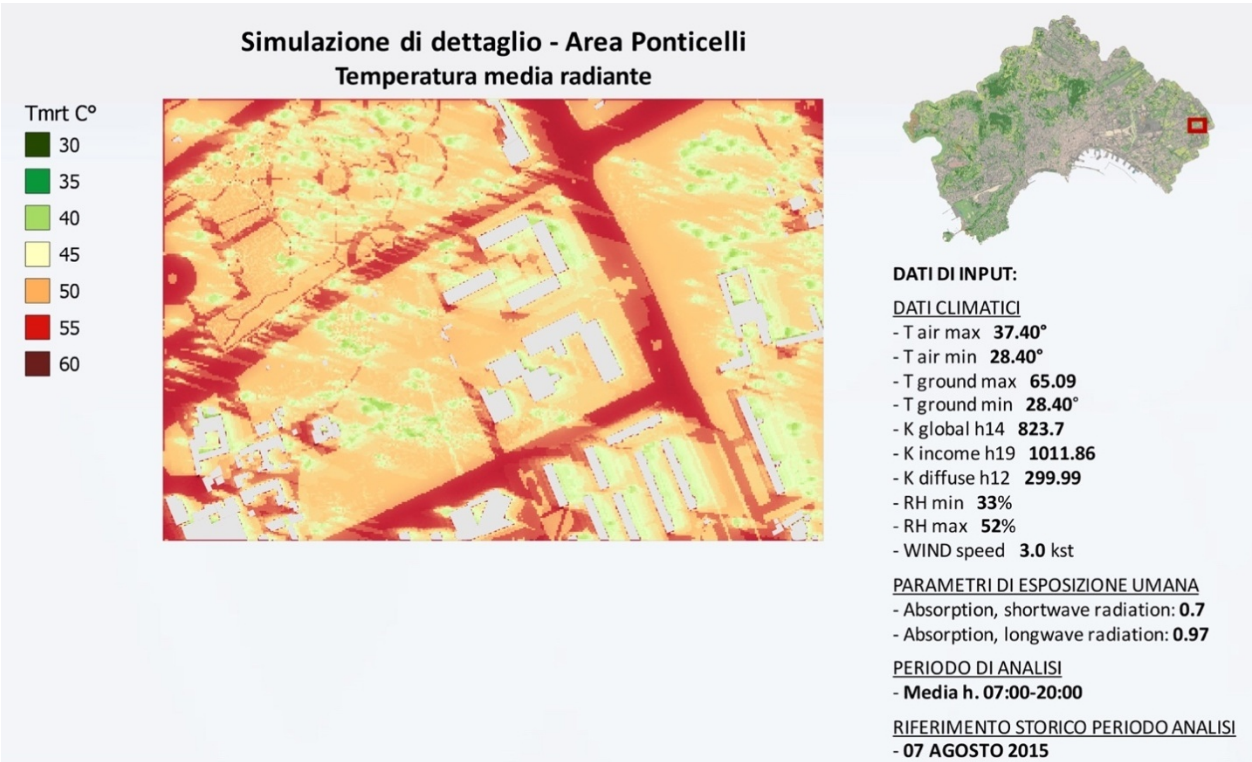


Figure 7: Detailed analysis of the Mean Radiant Temperature in the Ponticelli area, for a typical day of heat wave with air temperature of 37 °C. (Source: PLINIVS-LUPT, CLARITY).

Such detailed analyses allow to highlight some aspects that link urban morphology and land use to microclimatic conditions. In the ancient center area, the building density determines shading conditions that reduce thermal stress. In bigger squares, differences between cooler green areas and overheated asphalt roads can be noticed. Within the courtyards of historic buildings, differences can be observed between the smaller, cooler ones due to greater shading. The presence of green areas and trees represents a thermal stress reduction factor in the larger courtyards. In Rione Traiano and Ponticelli areas, the greater distances between the buildings and the reduced presence of trees cause a high overheating, especially in the case of Ponticelli, from the large green areas present in some blocks.

With reference to extreme precipitation, the hazard indicators used in the model are the depth (water depth, in mm) and speed (flood velocity, in m/s) of the rainwater not absorbed by sewage systems, which determine the occurrence of surface flooding. The main variables are linked to the absorption capacity of urban surfaces, calculated on the basis of the run-off index, as well as the morphology of the water catchment areas present in the city area, and therefore from the orographic characteristics, which determine the presence of "channels" (streams) of water run-off.

Most of the city's sewer system follows the natural orography, and almost all the natural streams are today converted in urban roads, in which most of the rainwater is channelled. The sewage system efficiency is a crucial condition determining the urban flooding in the case of heavy rain. Several studies (e.g. H2020 RESCCUE project) have shown that, not only is the capacity of the sewer itself important, but also its maintenance condition of manholes in urban areas. This information is almost impossible to acquire without performing local surveys for data collection and detailed flood hazard 2D-analyses. A possible approach to include this parameter, although in an approximate way, has been experimented for the Naples area. In relation to the urban adaptation objectives, together with the maintenance and adaptation of the sewage systems, the drainage capacity of urban surfaces is of particular importance, and must be balanced in relation to the specific characteristics of each river basin and other hydraulic characteristics (including the height of the groundwater, very near to the surface in some areas of the city).

In DC1 the CLARITY FLEM (see D3.3), developed by PLINIVS-LUPT has been applied, producing as output a preliminary proxy of the probability for urban areas to get flooded in case of heavy rain, based on the following data:

- Runoff coefficient for each land use type
- Urban watersheds / basins
- Digital Elevation Model
- Digital Surface Model
- Flow accumulation streams for each watershed
- Emergency calls related to flooding events

A first assessment of the propensity of urban areas to flooding was made by integrating the above parameters and assigning to each of them a “risk coefficient”, returning an overall picture at city level that allows to highlight the areas with the greatest probability of flooding in case of extreme precipitation events. As documented in D3.3, the procedure aims at identifying four main parameters for each cell of the analysis grid that contribute to the flooding probability due to land use, urban orography and hydrology:

1. Runoff coefficient
2. Relative elevation in the watershed
3. Presence of flow accumulation streams
4. Sewage system efficiency

The map has been validated by the Municipality of Naples, following a comparative analysis of urban areas included as having a high risk of flooding in the official plan of the local river basin authority, available at the following link http://www.difesa.suolo.regione.campania.it/content/view/130/110/.

3.1.3 Strategic planning - Napoli Sustainable Energy and Climate Action Plan (SECAP)

DC1 provides a major input for the update of Naples Municipality Sustainable Energy Action Plan (SEAP), due by 2020 and to be converted into a Sustainable Energy and Climate Action Plan (SECAP), being Napoli among the signatories of the Covenant of Mayors for Climate & Energy.

DC1 support to Napoli SECAP has been prepared in accordance with the guidelines of the Covenant of Mayors for Climate and Energy (2016) and by the Joint Research Centre of the European Commission (2018) to support public administrations in the transition from the "SEAP" to the "SECAP".

In particular, the following subsections have been drafted according the suggested SECAP structured as proposed by JRC:

- Climate Change Risk and Vulnerability Assessment methodology
- Vulnerabilities of the local authority or region
- Expected climate impacts in the local authority or region

Climate Change Risk and Vulnerability Assessment (RVA) methodology

The Municipality of Naples has indicated that in the Napoli SECAP the RVA, defined in the JRC guidelines as “expected weather and climate events particularly relevant for the local authority or region”, needs to be compliant with the CLARITY methodology (D3.3), selected as suitable approach to orient climate change adaptation and mitigation measures, as well as to bridge the SECAP with other relevant risk planning instrument at Regional or Metropolitan City level, in the perspective of an integrated multi-risk approach at the base of local urban governance.

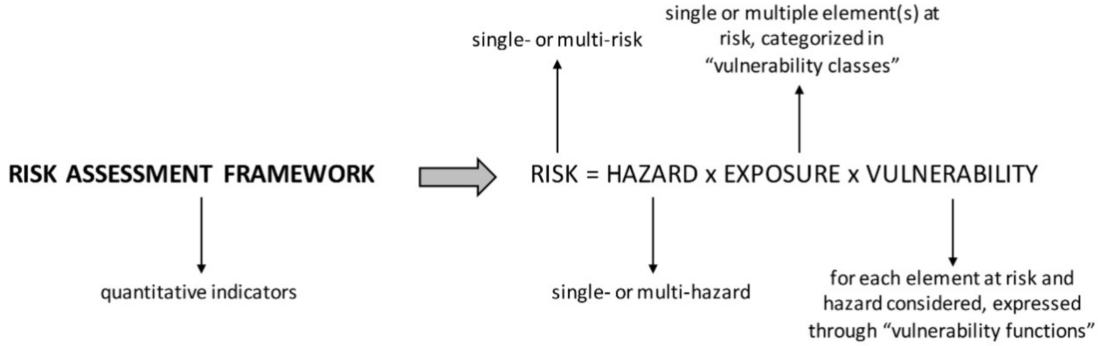


Figure 8: Risk and Vulnerability Assessment framework compliant with CLARITY methodology, as defined for the Napoli SECAP (Source: PLINIVS-LUPT, CLARITY).

In Napoli SECAP the indicators adopted to assess vulnerability are subdivided, in compliance with the JRC guidelines in two categories: "Socio-Economic Vulnerability" and "Physical and Environmental Vulnerability".

The vulnerability is defined as the probability that an element at risk, belonging to a vulnerability class, experiences a level of damage, according a predefined damage scale, as a response to a hazard event of given intensity. It is expressed in terms of a vulnerability matrix that indicates the percentage of a certain type of element at risk belongs to each vulnerability class for the investigated local effect in the considered area. To be compliant with the JRC guidelines, however, the Vulnerability indicators as requested in the SECAP template (section “Vulnerabilities of your local authority or region”) include all the relevant parameters related to the calculation of exposure of elements at risk, as well as heat wave and flood local effects, as fundamental “Socio-economic” and “Physical & environmental" variables”. It should be noted that this do not influence the RVA methodology adopted, which is instead based on CLARITY approach, as outlined in the previous section. The list of vulnerability-related indicators is reported in Annex 1.

Expected climate impacts

The SECAP requires the identification of assets and people at risk from climate change impacts, targeting the "impacted policy sectors" and identifying specific impact indicators for each sector considered.

The impact assessment is performed in relation to the vulnerability classes for the relevant elements at risk which in CLARITY have been defined as follows:

- Heat wave: population (health diseases and mortality increase); energy (increase in building cooling costs)
- Flooding: roads (cleaning and repairing costs); buildings (cleaning and repairing costs; content losses)

Different levels of damage for those elements have been identified.

Population is classified in two vulnerability classes (A: over 65; under 15; B: 15-65). Table shows the damage classification related to people's health during heat waves.

Table 5: Damage classification of heat stress on population in relation to UTCI.

D0	No Damage	20	26
D1	Moderate heat stress (fatigue, discomfort)	26	32
D2	Strong heat stress (heat cramps, exhaustion)	32	38
D3	Very strong heat stress (heat cramps, heatstroke)	38	46
D4	Extreme heat stress (heatstroke, sunstroke)	> 38	> 46

These values can be used to determine expected hospitalization costs during heat waves. D5 damage level corresponds to death and is also calculated in terms of mortality rate increase during heat waves following the methodology described in D3.3, as a function of Apparent Temperature.

A similar classification has been carried out also for the elements at risk in the case of flooding (roads, residential and non-residential buildings). The damage is expressed in terms of economic impact and includes the costs for repairing the structural damage and, in the case of buildings, the losses due to the damaged "content" of ground floors and underground spaces (Table , Table , Table).

Table 6: Damage classification of flooding on roads in relation to Water Depth.

D0	No damage	0
D1	Very low damage (0,2 €m^2)	0,001-0,11
D2	Low damage (1 €/m^2)	0,12-0,29
D3	Medium damage (3 €/m^2)	0,3-0,49
D4	High damage (6 €/m^2)	0,5-1
D5	Very high damage (9 €/m^2)	> 1

Table 7: Damage classification of flooding on residential buildings in relation to Water Depth.

D0	No damage	0
D1	Very low damage (0,2 €m^2)	0,001-0,004
D2	Low damage (1 €/m^2)	0,005-0,05
D3	Medium damage (25 €/m^2)	0,06-0,19
D4	High damage (84 €/m^2)	0,2-0,8
D5	Very high damage (270 €/m^2)	> 0,8

Table 8: Damage classification of flooding on non-residential buildings in relation to Water Depth.

D0	No damage	0
D1	Very low damage (0,2 €m^2)	0,001-0,004
D2	Low damage (1 €/m^2)	0,005-0,05
D3	Medium damage (16 €/m^2)	0,06-0,19
D4	High damage (55 €/m^2)	0,2-1
D5	Very high damage (247 €/m^2)	> 1

About the expected energy consumption variation due to changes in winter and summer temperature, a forecast estimate is provided based on the analysis of the variation of HDD and CDD indicators. Trends in energy consumption for heating and cooling foreseen in the reference periods for the RCP4.5 and RCP 8.5 scenarios, mainly referring to the consumption of gas for civil use in the winter and to the electricity consumption for air conditioning in the summer, which currently represent the energy sources used in maximum prevalence in the metropolitan area of Naples.

These estimates support SECAP implementation not only in the "Adaptation" section, but also in relation to "Mitigation", correlating the energy consumption with the corresponding GHG emissions from the civil sector in relation to the expected climate change scenarios. Uncertainties have been considered in relation to variation in global climate trends, considering decreasing confidence intervals towards 2100.

For each of the expected impact on the identified policy sectors, CLARITY Expert Services allow to determine the value of the impact-related indicators through the impact scenario analysis, thus defining according to the qualitative scales indicated in the SECAP template the Likelihood of Occurrence (Unlikely, Possible, Likely), Expected Impact Level (Low, Moderate, High) and the Timeframe (Current, Short-, Medium-, Long-Term).

As a follow up project, impact scenario analyses can be carried out by using the following correlation between CLARITY scenario taxonomy and SECAP template:

- Likelihood of Occurrence
  - Rare (CLARITY) = Unlikely (SECAP)
  - Occasional (CLARITY) = Possible (SECAP)
  - Frequent (CLARITY) = Likely (SECAP)
- Timeframe
  - 2011-2040 (CLARITY) = Current (SECAP)
  - 2011-2040 (CLARITY) = Short-Term (SECAP)
  - 2041-2070 (CLARITY) = Medium-Term (SECAP)
  - 2071-2100 (CLARITY) = Long-Term (SECAP)
- Expected Impact Level
  - Very Low-Low (CLARITY) = Low (SECAP)
  - Medium (CLARITY) = Moderate (SECAP)
  - High-Very High (CLARITY) = High (SECAP)

3.1.4 City planning – Update of the Napoli City Plan (PUC)

The project concerns the update of the City Plan for the Municipality of Napoli, which will contain a specific focus on climate change adaptation, as outlined in the official preliminary planning document "Napoli 2019-2030. Città, Ambiente, Diritti e Beni comuni. Piano Urbanistico Comunale. Documento di Indirizzi" (Comune di Napoli, 2019-2030).

Heat Wave and Flood hazards need to be mapped for the entire urban area, with a specific design focus on the implementation of a "green belt" able to reconnect the "Parco delle Colline" area with East and West Napoli areas. This will imply the definition of a green infrastructure with a strong east-west backbone and smaller "fingers" that allow urban green patterns and street tree canopies to penetrate towards the city centre.

Figure 9 shows some of the base planning documents shared by the Municipality of Napoli relevant for CLARITY, referred to the historical, landscape, hydrogeological and service infrastructure constraints with which the proposed climate adaptation measures will have to comply.

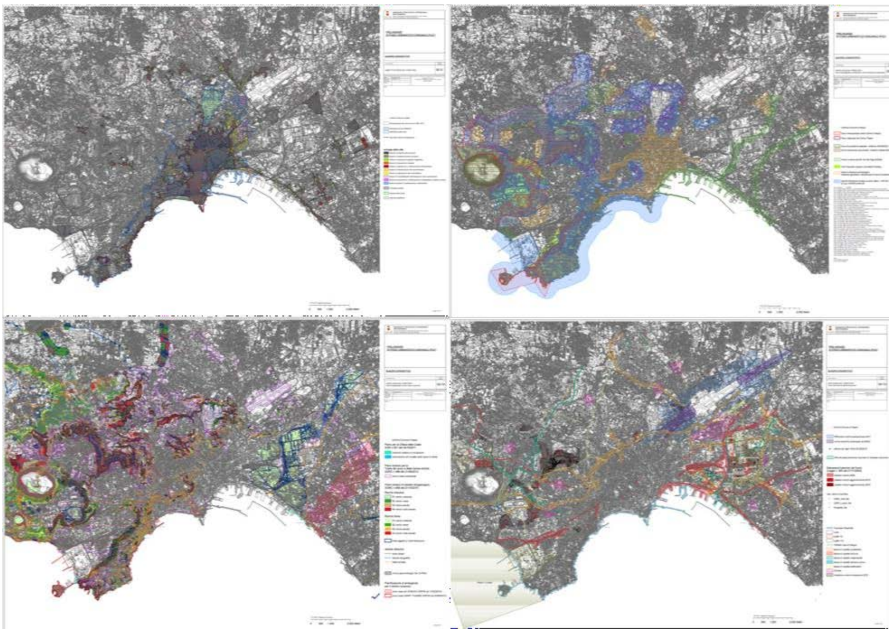


Figure 9: Napoli City Plan 2019. Historical (top left); landscape (top right); hydrogeological (bottom left) and service infrastructure (bottom right) constraints for urban planning (source: Municipality of Napoli).

The Expert Services allows to produce the climate risk analysis on a 250x250m grid, evaluating the risks of heat waves and flooding for various reference events. Information already integrated (Feb. 2020) in the update of the Naples PUC (available at http://www.comune.napoli.it).

CLARITY modelling of current Heat Wave stress will serve as a starting analysis, to determine which areas need greening actions aimed at the continuity of green infrastructures, and suggest the needed land use changes in the new City Plan, as well as guidelines to redesign street sections to increase the vegetation coverage according to traffic levels.

Simulations at different scales are expected to support the development of criteria and guidelines for urban forestation (dimensioning of planting indexes and selection of plant species in relation to the reduction of climate impacts).

Overall, heat waves and flooding hotspots identified will suggest criteria and guidelines to revise City Plan zoning according to the identified climate risks and expected impacts.

The update of the Municipal Urban Plan for the city of Naples provides since the preliminary document "Naples 2019-2030. Cities, Environment, Rights and Common Goods "a specific focus on climate adaptation.

CLARITY simulations support the definition of specific planning criteria based on the climatic risks identified in the different city areas and the identification of areas that require targeted actions (of waterproofing, urban forestry, changes in land use and green infrastructure continuity). Specific guidelines concern the design criteria for adaptation measures for buildings and open spaces to integrate the plan guidelines and to support the levels of implementation planning.

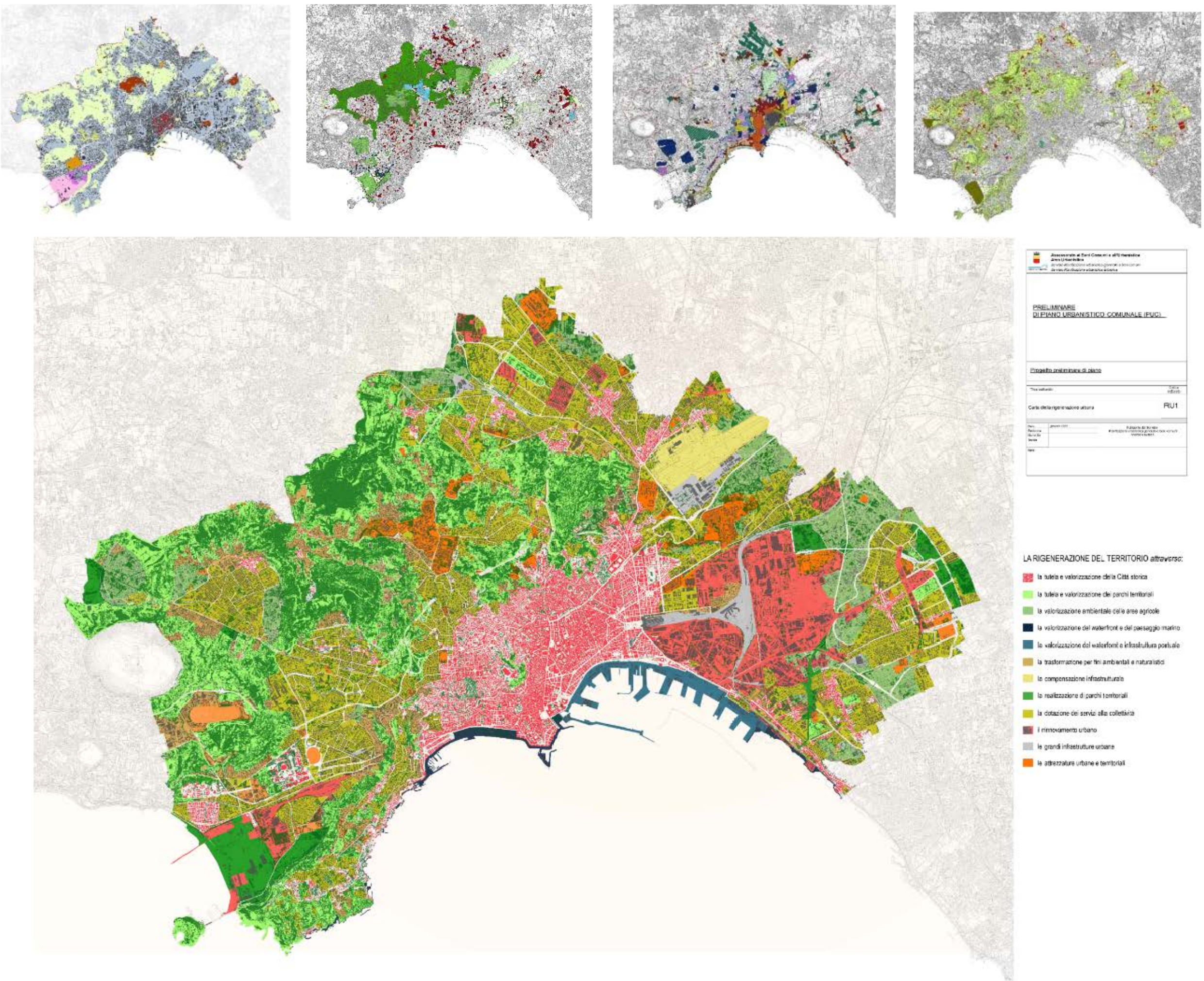


Figure 10: PUC knowledge framework: Top – Protected and redevelopment areas; Territory historical structure; Agricultural land use; Urban and neighbourhood equipment; Bottom: Urban regeneration map (source: Municipality of Naples)

From this perspective, the Municipality of Naples foresees:

- diffuse and zero kilometres alternative forms of energy production;
- give priority to environmental remediation processes of industrial sites, especially those of East Naples, starting with the oil deposits relocation, as well as the recovery and conversion of soils subject of illegal landfill;
- implementation of urban forestation actions starting from large paved areas in order to reduce the heat island phenomenon, also recovering the possibility of sustainable use by citizens;
- to contrast, through the urbanistic instrument, alteration phenomena of the social and economic fabric of the city and ensure greater protection of the UNESCO historic centre;
- development of sustainable mobility through adequate and integrated infrastructure systems compatible with the territories.

The aim is to study the fragility of the urban fabric monitored in a multi-risk perspective by investigating scenarios, highlighting critical issues and choosing sustainable solutions.

The domains of application of the knowledge bases and scenario assessment tools proposed by CLARITY include heterogeneous areas. Adaptation and design interventions of infrastructures, urban spaces and equipment for urban regeneration are diversified according to their future destination, and in particular in historical areas they will become more meticulous and punctual interventions, characterized by a less intensive use of green.

In case of bare soil adaptation strategies will provide for more intensive interventions that become an opportunity for climate adaptation strategies, urban reforestation and new neighbourhood equipment creation.

Climate adaptation strategies for the City of Naples

The goal of integrating climate adaptation measures into urban planning is a strategic priority at an international level. The available literature allows one to identify a series of adaptation measures in response to the impacts of extreme temperature and precipitation events that can be implemented at the local level based on an accurate analysis of the expected climate change scenarios. The assessment of the effectiveness of these measures can be linked to a series of indicators that define the contribution of each measure to the control of the urban microclimate.

Within CLARITY, a systematization of relevant literature resulted in the identification of a catalogue of most recurring adaptation measures, classified according to their ability to provide climate benefits in terms of:

1. reduction of impacts from heat waves, acting on the surface temperatures of buildings and open spaces and obtaining an improvement in the conditions of perceived thermal stress and the reduction of the Urban Heat Island (UHI);
2. reduction of the impacts of flood events, acting on the capacity of urban surfaces to guarantee adequate rainwater drainage and storage.

In relation to both categories of climate risk, however, it is worth highlighting the additional benefits associated with some types of adaptation measures, in particular green infrastructures such as green roofs, bioswales, trees or urban green areas, which contribute to carbon sequestration and climate mitigation (i.e. reducing CO_2 emissions), in terms of a local contribution to global warming.

The solutions "inspired and supported by nature" (NBS-Nature-Based Solutions) represent in this sense a priority in the international agendas on the issues of climate resilience and sustainable development, precisely for the ability to simultaneously provide environmental, social and economic benefits through systemic interventions adapted locally and resource efficient. NBS provide additional benefits related to "ecosystem services" which can be defined as "the direct and indirect contributions of ecosystems to human well-being". In addition to climate adaptation and mitigation, ecosystem services convey additional environmental benefits for cities, such as reducing air pollution and increasing biodiversity, but also social benefits such as higher quality public spaces and fewer health impacts.

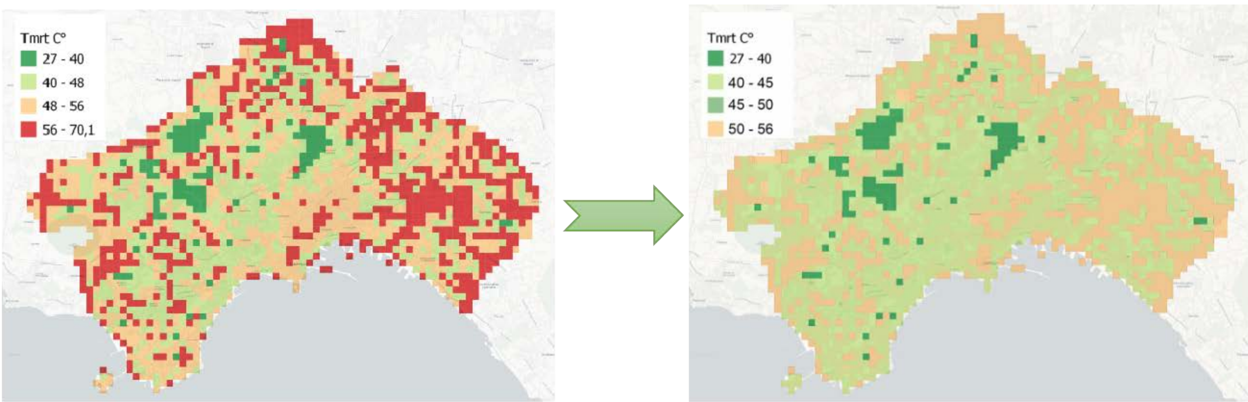
City-wide simulations on have been carried out to test the effect of adaptation measures in reducing the local effect hazard for heat waves and floods. Figure 11 shows an example of these calculations, focused on long-term “ideal” adaptation strategies towards 2050, which can represent a strategic adaptation planning vision to be phased over time in relation to established priorities for urban regeneration.

The Adaptation Measures Technical Cards (see D3.3 Annex III: Adaptation Measures Technical Cards) have been translated in Italian and used to support the co-design of adaptation strategies with local stakeholders in relation to the different planning levels identified.

The costs of adaptation strategies/measures implementation is a crucial information to support local programming, planning and design processes. Cost-benefit analyses have been carried out both on city-wide strategies and on specific areas, thus providing decision makers and technical departments with a structured information useful to negotiate funding allocation at national and regional level, especially in the context of ERDF 2021-2027 (Napoli is among the EU Convergence Regions, with a relevant allocation of funding) and in the light of the EU Green Deal and the Recovery Fund.

While the city-wide adaptation costs might seem a huge figure to support, if phased in e.g. 10 years to support EU Adaptation Strategy towards 2030, consists of only 3% of the GDP of the Metropolitan City of Naples, representing at the same time an investment with a high potential of leveraging local economy in the Green Deal perspective.

When breaking down the figure focusing on specific areas (see following section) the costs are perfectly in line with similar urban regeneration interventions. The possibility of analyzing climate adaptation potential together with such detailed control of financial expenditure allows a proper phasing of PUC sub-projects.



Adaptation costs (“ideal” strategies towards 2050)	€/m^2	€ tot Napoli
Open spaces	€ 49,38	€ 2.153.138.128,29
Buildings	€ 216,26*	€ 13.514.906.677,95
Maintenance and enhancing of sewage systems	€ 35,00	€ 2.842.172.459,38

***per m^2 of surface cover**

Figure 11: Example of the cost-benefit assessment of “ideal” long-term adaptation strategies.

Adaptation strategies integration in specific areas

Based on the results of the city-wide climate hazard analyses and their correlation with urban redevelopment priorities as defined by the PUC, specific adaptation plans have been developed in city areas identified for “large infrastructure urban project” and “small infrastructure urban project”, calculating their performance in terms of heat stress reduction and the corresponding costs. The four areas have been identified within the end-user workshops as follows:

1. Miano IACP
2. Miano Alifana
3. Soccavo
4. Pianura

The adaptation project of the sample areas was developed together with the Municipality of Naples. Once the strategies applied return the optimal results in terms of UTCI and T_{MRT}, they are accounted for in detail on the basis of the surfaces and the corresponding cost analyses. Cost analyses are done on individual costs, studied for each adaptation measure based on the percentage of land use modified. A detailed explanation of the specific adaptation plans can be found in Annex 1.

3.1.5 District planning - Ponticelli Urban Regeneration Plan (PRU)

The Ponticelli area will represent a district scale focus about urban adaptation to Heat Wave and Flooding. The end-user workshop of January 2020 has confirmed that the Ponticelli area is appropriate and in line with the Urban Regeneration Programme (PRU) work schedule. The willingness to collaborate to deepen the issues related to climate adaptation in the sub-areas of the project is confirmed.

Following specific requests of the Municipality of Naples, in order to provide support to the implementation of the Ponticelli Urban Regeneration plan, further expert analyses have been produced in this area of the city, assessing the effect of different configurations of building and open spaces, as well as of different surface covers, starting from the baseline projects developed by the Social Housing Department, in charge of implementing the plan.

Simulations have been carried out using Solweig model in combination with an original parametric workflow developed in Grasshopper, based on the combination of available plug-ins based on validated models such as Ladybug, Honeybee and Envimet.

PRU is focused on a residential and mixed-use development in 9 areas (“sub-areas”) of the Ponticelli district. CLARITY simulations are expected to address design choices concerning buildings layouts, surface materials and vegetation patterns. The current stage of development implemented by the Municipality provides the main quantitative data for new buildings (residential and services), roads and public spaces, as well as limits in terms of built volumes and standards for green areas and public services.

CLARITY support concerns detailed simulations on such project areas, based on Morphological and functional Project-guide approved in 2018 and on the planning and design layouts proposed by the Municipality. Dedicated co-design workshops have been implemented to streamline the integration of adaptation measures in the Plan, where alternative design scenarios aimed at minimizing impacts from heat waves in terms of heat discomfort of population and energy consumption of buildings are proposed by the CLARITY DC1 team.

Ponticelli's PRU represents a focus on the implementation plan of the CLARITY tools, supporting the evaluation of the technical-design alternatives developed on the basis of general planning guidelines in terms of volumes and urban planning standards.

CLARITY simulations are in this case carried out in a three-dimensional environment with a 1-5m resolution, in order to evaluate in detail the design choices (layout and materials used) for buildings, paved and vegetated open spaces.

The proposed parametric design workflow is intended to facilitate the implementation of analyses on any design proposal developed by the Municipality Departments and/or external consultants. Specific guidelines have been drafted to prepare 3D drawings using Rhinoceros (which is a widely used 3D modelling software used in architecture and urban design) so that the design layouts can be directly analysed through the CLARITY Grasshopper components.

The current state and design layouts are drafted according the CLARITY land use categories (including the land uses corresponding to adaptation measures), so that the different parameters affecting T_{MRT} and UTCI are directly attributed in Grasshopper. the land uses that characterize the territory, thus defining its current state. Climate data are stored in EPW files corresponding to current climate and to future projected scenarios.

The T_{MRT} and UTCI analyses refer to the 24h average in a heat wave period, as the greatest climate-related hazard in the area is caused by excessively high temperatures. The area is in fact located on the eastern part of the slopes of Vesuvius, characterized by a prevalence of permeable green surfaces and thus not particularly prone to flooding. Furthermore, at the centre of the PRU area is located a major branch of the East Naples sewage system, which has a very high capacity and is usually able to drain rainwater even in case of extreme precipitation events. However, a high surface run-off in the PRU area (which could be worsened by converting the current green areas into buildings and paved open spaces) is likely to aggravate pluvial flooding conditions in the nearby neighbourhood of Barra and S. Giovanni, located downstream of Ponticelli on a plain area almost at sea level. For this reason, solutions to maximise rainwater infiltration, as well as rainwater harvesting and reuse, have been proposed in the design of adaptation strategies.

Simulation output in Grasshopper allows to carry out analyses of the technical solutions for buildings and opens space to assess their climate performance with a detail adequate to a neighbourhood scale design (5x5m grid resolution). The design solutions are defined with reference to the adaptation measures and combined into suitable strategies, accounting for their climate benefits and co-benefits as reported in the Technical Cards of Adaptation measures (see D3.3).

The comparisons among different design layouts in terms of T_{MRT} or UTCI allow to support the selection of the final reference solutions, which will be included in the final version of the PRU as technical documentation for the Public Tenders for the implementation of the project.

Further analyses useful to support district planning implementation include the 3D analysis of surface temperature, including open spaces and building envelopes and building energy performance assessment . Together with the integration of adaptation measures aimed at improving outdoor comfort, Near Zero Energy Building solutions are proposed to guarantee indoor comfort while minimizing energy consumption (with a specific focus on summer behaviour of buildings), through a combination of passive solutions (e.g. thermal mass of opaque envelope, green roofs/facades, sunshading systems, etc.) and high efficiency technical systems (e.g. heat pumps).

As for outdoor comfort simulations, building energy consumption can be calculated for current or future climate.The expected total, heating and cooling consumptions with current climate, considering three possible alternatives for the building envelope and three alternative for HVAC systems.

3.2 DC2 - Fostering adaptation of large scale infrastructure in Sweden to local climate change effects

3.2.1 Overview

The use case is coordinated by SMHI and based on exploring data from two Copernicus Climate Change Services (C3S) projects, SWICCA (on water management) and Urban SIS (on urban climate and air quality). We also make use of and further develop the Green Area Factor tool used by Stockholm city for planning the cities development. The demonstration focused on two sites in Sweden (the County of Jönköping and Stockholm city), where the use of indicators (in the scope of flooding, heat waves, and air/water pollution) in the process of building-up resilience on multi-million-euro development projects has been tested.

The urban case is represented by Stockholm, the capital of Sweden with an urban population of nearly 1 million inhabitants and 2.4 million inhabitants living within the Greater Stockholm. The city is growing fast and new housing is needed. Extensive impervious sealing of surfaces and human densification are important drivers of the urban microclimate and how it will respond to climate change in the future. At the same time, Stockholm city is located at the border between the large lake Mälaren and the Baltic Sea, thus highly sensitive to future changes in precipitation and river runoff as well as lake and sea levels.

For Stockholm our work has been concentrated around two major use cases:

- **Flooding of the city centre of Stockholm:** This goal examines the future flooding risk for parts of the city centre of Stockholm. The goal is to model the urban flooding situation, as well as a future scenario, with and without adaptation measures. The adaptation measures to be analysed are suggested by a group of stakeholders (city planners, water managers, park managers etc.) in a reference group. This will allow to evaluate the effects of adaptation measures, analyse risks associated with high precipitation and perhaps provide input to the Green Area Factor – investigating the potential mutually beneficial effect of increased amount of green areas which may have a flood reducing effect.
- **Urban vegetation in Stockholm as a climate adaptation tool:** The focus is to optimize the role of urban vegetation in Stockholm as a climate adaptation tool. In particular we have validated validate the Green Area Factor (GAF) in Stockholm, add and combine air pollution in the GAF, add and combine hydrology in the GAF.
- **Climate and health indicators for Stockholm**: Analysing the impacts of climate change and future land use (including large scale infrastructure projects) on the health of the population and the status of the environment.

The regional scale perspective is given by the County of Jönköping, which is situated in the middle of Southern Scandinavia and includes large areas of the south Swedish highlands, as well as large parts of the second largest fresh water reservoir in Sweden, the Lake Vättern. The municipality of Jönköping with its residential city is situated at the very southern border of the lake. Due to lake tilting (geological influence) in combination with high water levels the lake may reach hazardous levels for the city. Modelled minimum levels for new construction has been set but older parts of the city need further risk decreasing acts. The configuration of the city entails large closed areas when heavy precipitation occurs. Also, River Tabergsån runs through the city centre and has its outlet in lake Vättern, implying that fluvial flooding may be an additional problem, particularly if this coincides with high lake levels, causing backwater effects.

For Jönköping we have focused our work around the following study:

- **Flooding of the city centre of Jönköping:** This goal examines the future flooding risk for the city of Jönköping. The goal has already been explored in SWICCA and by the Swedish Civil Contingencies Agency. For more information about the original user story see http://www.swicca.eu/start/implemented-cases-of-local-change-adaptation/impact-based-flood-risk-assessment-in-present-and-future-climate/. The goal in CLARITY is to extend the study by adding information on lake level rise, higher resolution of climate information and combined effects of events including entrapped areas arriving in a multi-risk assessment (i.e. risk and vulnerability assessment of multiple climatic hazards) and flood mitigation measures, as well as developing methodologies for risk inventories.

Table 9: Relation between the main Hazards and elements at risk in DC2

	Heat	Flood
People	+++	+
Buildings	n/a	++
Transport infrastructure	n/a	++
Vital societal functions	+	+++

3.2.2 Validation

As described above, the work in DC2 has been done as several subprojects each of them exploring how results can be adapted or produced in close cooperation with end users. Technical and scientific validation of the data and services has been performed within each of these subprojects. Here we give an overview on the validation done for each of them.

Flooding of the city centre of Stockholm

In an early stage of CLARITY, a limited area in the city centre of Stockholm prone to pluvial flooding was identified. Thereafter a wide range of possible adaptation measures have been defined taking into account suggestions from a reference group containing representatives from different end-users. All suggested adaptation measures have then been selected for preliminary analysis in SCALGO (a less-time consuming methodology than doing a full, high-resolution hydrodynamic modelling in MIKE) to select the most efficient measures for incorporation in the MIKE model. This work has been performed in close collaboration with a reference group composed of stakeholders with different competences. From a scientific perspective one goal has been to validate the methodology of comparing the SCALGO tool with MIKE modelling. The work is further described in D3.3 section 3.2.1.2. Although some limitations (eg. regarding the dynamical properties) SCALGO was shown to be very effective in the process of deciding the potential benefit of different adaptation measures, which were then modelled with the more time (and work-) intensive MIKE modelling.

Urban vegetation in Stockholm as a climate adaptation tool

This part of DC2 work consist of two different studies, complementing and giving input to further development of and validation of the Green Area Factor tool.

The first study has investigated the role of urban vegetation in regulating air temperature in Stockholm through the definition of a hypothetical urban planning scenario, as described below:

- a “black city” scenario, where all forms of vegetation in the city were removed. This scenario quantifies the cooling currently induced by Stockholm´s vegetation and can be compared with scenarios for the city today and with the scenarios described in section 1.1.2.3 representing planned future expansion of Stockholm.

The results give a valuable benchmark for estimating the value of green infrastructure in GAF. This work is further described in D2.3 section 2.4.5 and D3.3 section 3.2.2.3

The second study evaluates this impact of green infrastructure on air pollutants. Trees and other vegetation absorb and capture air pollutants, leading to the common perception that they, and trees in particular, can improve air quality in cities and provide an important ecosystem service for urban inhabitants (Samson et al., 2019).

Air quality can be affected both positively (improved) and negatively by urban green infrastructure (UGI). The effect depends on many different factors like e.g. the pollutant being considered, type of vegetation and if the focus is on a local scale (street canyon) or urban scale (Grote et al., 2016)This complexity is the reason why air quality is not considered as a criterion in the GAF used in Stockholm.

In order to improve the knowledge and implement air quality in GAF, dispersion model simulations of a street in central Stockholm have been undertaken. Concentrations of particulate matter (PM10) were calculated for a situation with and without trees and all other factors being the same. This work is further described in D3.3 section 3.2.2.4.

Climate and health indicators for Stockholm

Two urban planning scenarios for the city/region future development of Stockholm were produced by SMHI in cooperation with StockCity, as described below:

- "city 2030" scenario: the planned construction of 140 000 new homes by 2030, including one of Europe´s largest urban development areas: the 'Stockholm Royal Seaport'. In this master plan, the urban densification reduces the amount of vegetation in the intervened areas but the changes affect only the city;
- "region 2050" scenario: promotes the growth of the impervious surfaces in the region, mostly by increasing the density of buildings or constructing in areas that are currently occupied by forests. This scenario was calibrated against the regional development plan (RUFS 2050) and foresees a significant expansion and densification of the city.

This work is further described in D2.3 section 4.2.2 and D3.3 section 3.2.2.3. and in the scientific article Amorim et al. (2020) https://doi.org/10.1016/j.uclim.2020.100632

In addition we make use of

- Population data described earlier was combined in the C3S project Urban SIS with 1 km resolution climate data downscaled with Harmonie-AROME for estimating heat induced mortality in different time periods.

This work is further described in D2.3 section 4.2.4 and D3.3 section 3.2.2.2. Validation of the approach was thoroughly done within the project Urban SIS D441_Lot3.5.1, where the validation report is available here: https://urbansis.eu/wp-content/uploads/2017/07/C3S_D441_Lot3.5.1_201706_Validation_climate.pdf

Flooding of the city centre of Jönköping

A methodology for assessing and evaluating the combined risk of multiple future flood risks has been developed in DC2 for Jönköping (CABJON). Available datasets and models with different scales has been used to analyse joint probabilities and to conduct a multi-risk assessment for river floods, flooding from the lake and extreme rain. The risk mapping has then been combined with geodata of locations of vital societal functions and critical infrastructure, to be able to assess the consequences of the respective and joint events. The methodology is GIS-based and could be further developed into a tool also to be used by other authorities. It is supposed to help municipalities to develop and prioritize adaptation measures to climate change and to serve as a basis for future infrastructure and urban planning.

The pluvial flooding model shows the outcome of the flood mitigation measures that have been performed during the last few years, as a similar modelling task was made earlier – before the intense flooding situation in 2013, where flowpaths and flooded areas showed a slightly different result than the current modelling.

An additional study has been performed to investigate the downstream effects of plans to extend the amount of industrial areas in the southern (upstream) parts of the Tabergsån catchment, implying that paved areas will replace forest and farmland. The River Tabergsån eventually flows through the city centre of Jönköping and the case-study has been performed to analyze the eventual consequences (increased flooding risk) downstream (in the city) of the upstream activities of increasing the amount of impervious area and shows that the effects on the city is likely to be minimal. As basis for this study the Swedish hydrological model S-HYPE has been used. This model is continuously developed and validated by SMHI and is used by many Swedish authorities as a basis for measures and reporting. More information about S-HYPE can be found here, https://www.smhi.se/forskning/forskningsomraden/hydrologisk-forskning/s-hype-hype-modell-for-hela-sverige-1.560. The validation of the model is available online: https://vattenwebb.smhi.se/modeldiff/.

High resolution future hydrological data for Sweden

In CLARITY, the HYPE model is employed in DC2 to explore the risk of flooding in the Stockholm and Jönköping urban areas associated with intense precipitation and possible lake level changes. The model is setup for the southern part of Sweden to run at hourly time steps to enable the simulation of discharge and runoff at a temporal resolution relevant for the assessment of flooding due to intense precipitation events. As the focus is on urban settings, detailed urban land cover information is incorporated in the model by making use of the Urban-Atlas land cover data. A description of the approach and a validation of the model are given in D3.3 section 3.2.1.1.

3.3 DC3 - Urban heat waves, urban heat islands, extreme precipitation in Linz

3.3.1 Overview

Hazard characterisation on city level – urban climate modelling

The hazards considered by Linz Planning Authorities are

- Heat exposure – heat waves and heat urban heat islands
- Ventilation
- Urban densification in combination with growing heat exposure
- Urban densification in combination with ventilation

As the goal of the City of Linz is to assess the interaction of urban densification with climate risk, the DC3 implementation aims to demonstrate results of CLARITY Expert Services in assessing climate risk and vulnerability and the impact of integrating adaptation measures related to urban planning and urban redevelopment.
Urban densification and urban growth are affecting the urban microclimate development, specifically with respect to heat island phenomenon and air flow. Considering local climate conditions, the influence of urban densification is expected to increase, requiring adaption activities to better direct the urban dynamics with respect to future climate change with a specific focus on heat waves, and urban ventilation.
The planning support will focus on the population as major element at risk due to climate change and due to change in surface properties (increased sealing) and buildings (increased building height) which increases heat trapping and decrease ability of ventilation.

The application intends to link climate data, vulnerability assessment and potential adaptation/mitigation options across the city scale and the neighbourhood scale.
The neighbourhood scale is considered for selected neighbourhood which are expected to show the climate related affects either due to climate change or due to urban densification and extension or due to both. its surroundings and a zoning plan. A vegetation layer has been derived from satellite image classification.

General model input data are partly available from open data sources on a European level, like Urban Atlas 2012 land cover data, a 30 m digital elevation model and a 20 m soil sealing layer. Besides that, the province of Upper Austria provides 10 m digital elevation model data for Linz and

Datasets are be used to calculate different scenarios according to the user stories and considering the following measures: unsealing of land, roof greening and tree cover densification. Furthermore, the effects of new settlement areas on urban climate can be simulated and different adaptation scenarios can be calculated to make recommendations in terms of resilient urban planning.

The following figure shows several data sets and derived indicators compiled for Linz and surroundings by merging, extracting or aggregating various data sets as basis for urban climate modelling and microclimate modelling.

Modelling

Within the implementation of DC3, the dynamical urban climate model MUKLIMO_3 is used for hazard characterisation and evaluation of climate adaptation options on city level at a spatial resolution of 100 m. With an area of approximately 19x20 km2, the domain covers the entire city of Linz and its surroundings, thus enabling a complete analysis of urban heat island effects, reflecting the differences in temperature distribution in the densely built-up areas compared to their surroundings. The model simulations are based on a digital elevation model provided by the European Environment Agency and land use data from Urban Atlas (2012). To obtain more precise results, Urban Atlas land use data were combined with city-specific local datasets related to building properties and vegetation parameters that were provided by the city administration of Linz and processed by AIT.

A dynamical-statistical downscaling approach, called the cuboid method is used to investigate urban heat load distribution and to identify hot spot areas that result from urban heat island effects. By combining high resolution urban climate simulations with long term climate information from monitoring stations or regional climate projections, several climate indices, like the mean annual number of summer days, hot days and tropical nights, are derived for 30-year current and future climate periods. This refers to the (heat) hazard characterisation step from the EU-GL methodology. Figure 12 shows the results for one climate index (number of summer days) for the historical climate period 1971-2000, as well as for two future periods (2021-2050, 2071-2100) considering the representative concentration pathway RCP8.5 based on an ensemble of regional climate projections from EURO-CORDEX.

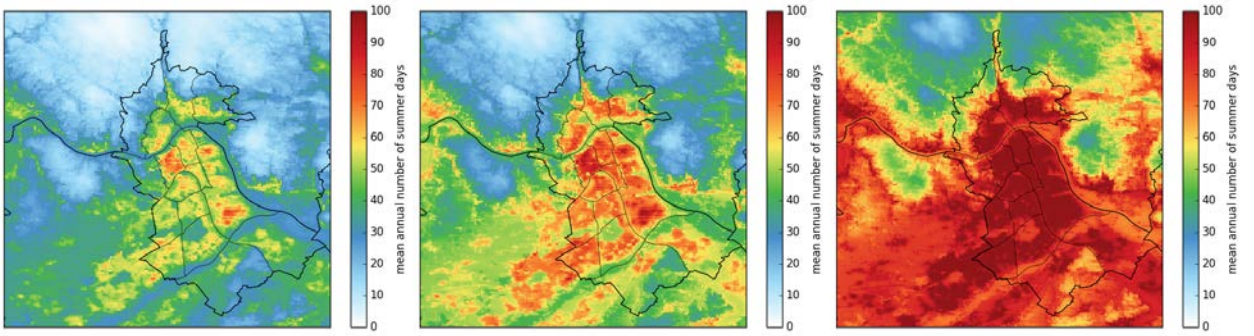


Figure 12: Mean annual number of summer days (Tmax ≥ 25 °C) derived from the cuboid method, based on long-term climate information from EURO-CORDEX regional climate projections (ensemble mean) for the emission scenario RCP8.5. Left: Historical baseline (1971-2000); Middle: Future period 2021-2050; Right: Future period 2071-2100.

Climate adaptation on city level – urban climate modelling

By changing the physical parameters of specific land use classes that are used as input for the urban climate model, i.e. by implementing different adaptation measures, the resulting cooling potential for each of these measures can be assessd by comparing climate indices for the reference period 1971-2000 based on the modified land use to the original results. Thus, the cooling potential can be expressed in terms of a reduction of the mean annual number of summer days. Figure 13 shows examples for two different adaptation measures (increased albedo of roofs and roof greening).

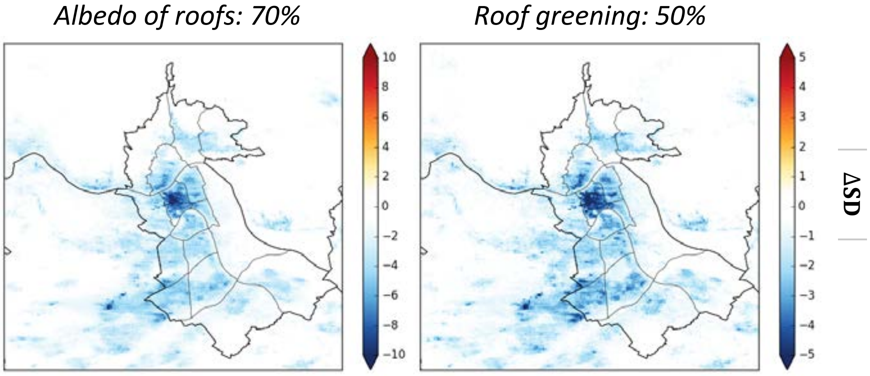


Figure 13: Cooling effect of different adaptation measures, indicated by the difference in the mean annual number of summer days ($\Delta\mathbf{SD}$) for the reference period 1971-2000. Left: Increased albedo of roofs (from 30% to 70%, all residential/industrial areas); Right: Roof greening (50% of all buildings in residential/industrial areas)

Urban microclimate modelling and adaptation measure tests and assessment

The Microclimate modelling and assessment workflow is shown in the following table:

Table 10: The Microclimate modelling and assessment workflow

1. Provide urban land use and building elevation model of current state 2. Simulate current and future urban climate (1km resolution) over time (hourly data for the years over the decades 2010-2020 to 2020-2030 and 2040-2050) 3. Extract hat island patterns and extreme heat event characteristics from current and future urban climate simuilations as boundary conditions for microclimate modelling 4. Identify highly exposed areas as case study areas for microclimate modelling 5. Prepare 3D city and surface model of case study areas (set of street blocks) for microclimate modelling 6. Simulate the microclimate for reference days during heat episodes for the case study areas. 7. Discuss adaption measures for open space and built environment for the case study areas 8. Adapt 3D city and surface model to provide the model framework to model effects of adaptation measures 9. Simulate the microclimate for adapted case study areas for the reference days 10. Compare before /after results 11. Discuss results, when agreed the measues will be realized, if not new adaptation measures shall be modelled – back to step 8

Microclimate simulations presented here, are carried out by Solweig, ENVI_MET ® and Grasshopper ® with the Ladybug plugin. All tools enable a comprehensive assessment of heat trapping and air circulation under different climate conditions and allow to assess the uncertainty range of results.

The following figure shows again the demonstration cases for heat exposure and climate adaptation impact assessment.

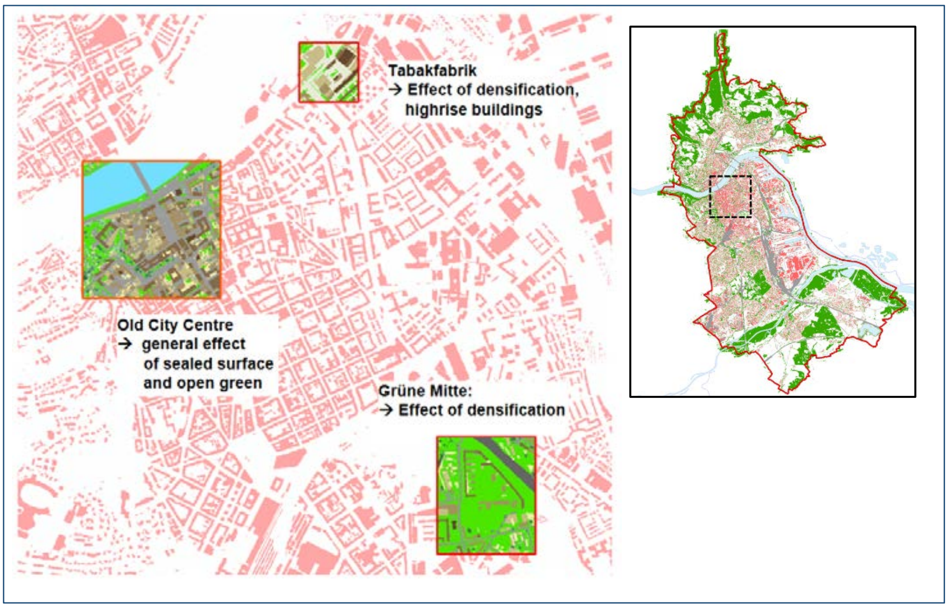


Figure 14: Case study areas for heat exposure assessment and adaptation measure tests

The following figures shows heat exposure results during a severe heat wave in August 2014. by use of MRT as exposure indicator.

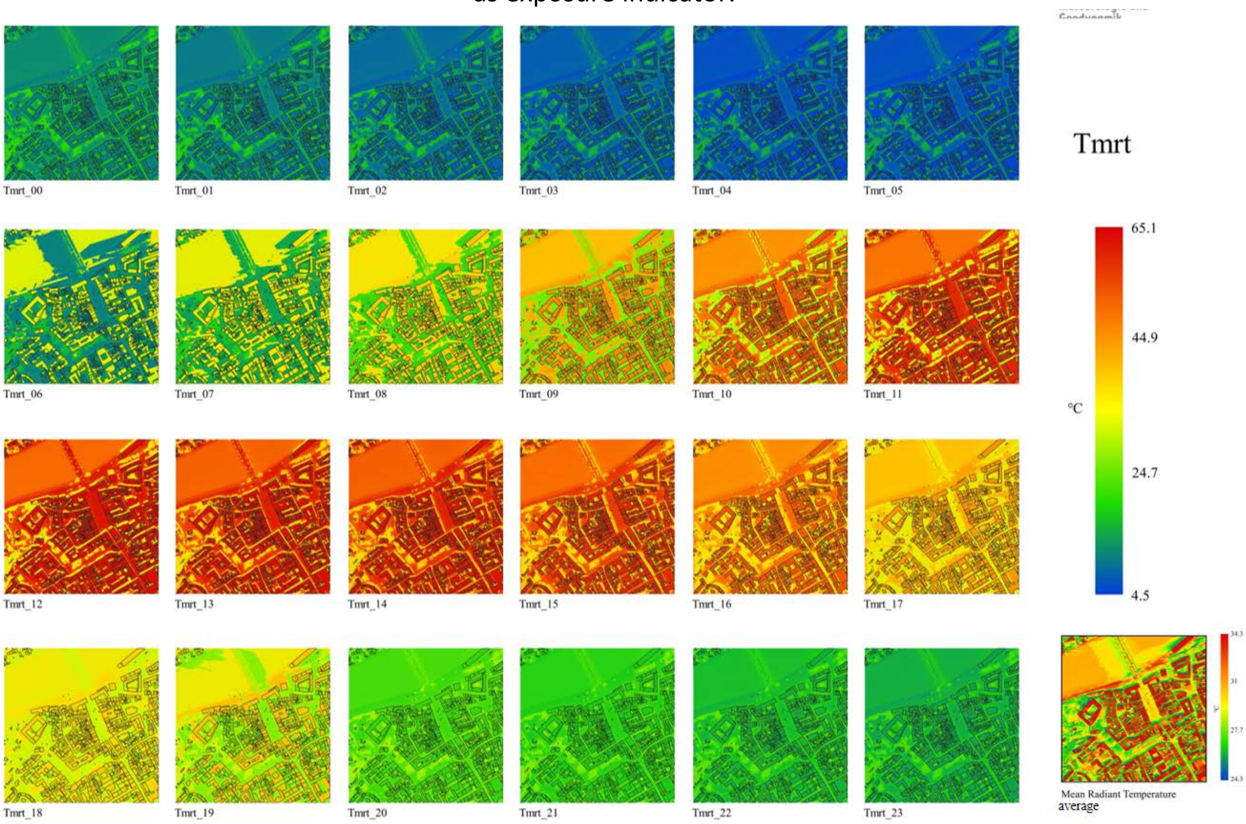


Figure 15: Linz Old City Centre: MRT - Distribution of diurnal variation

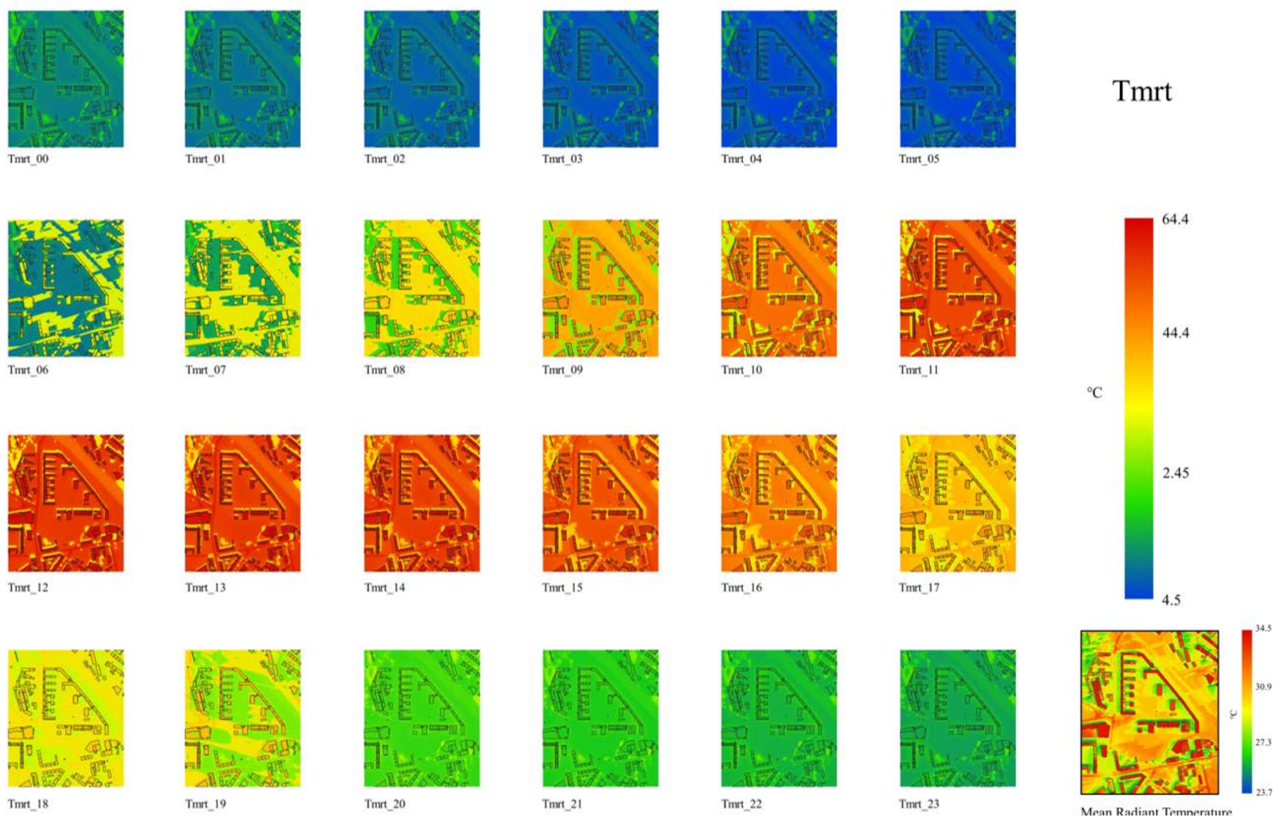


Figure 16: Linz Grüne Mitte: MRT – Distribution of diurnal variation

The next figure shows the impact of urban densification as well as climate adaptation measures for Linz Tabakfabrik.

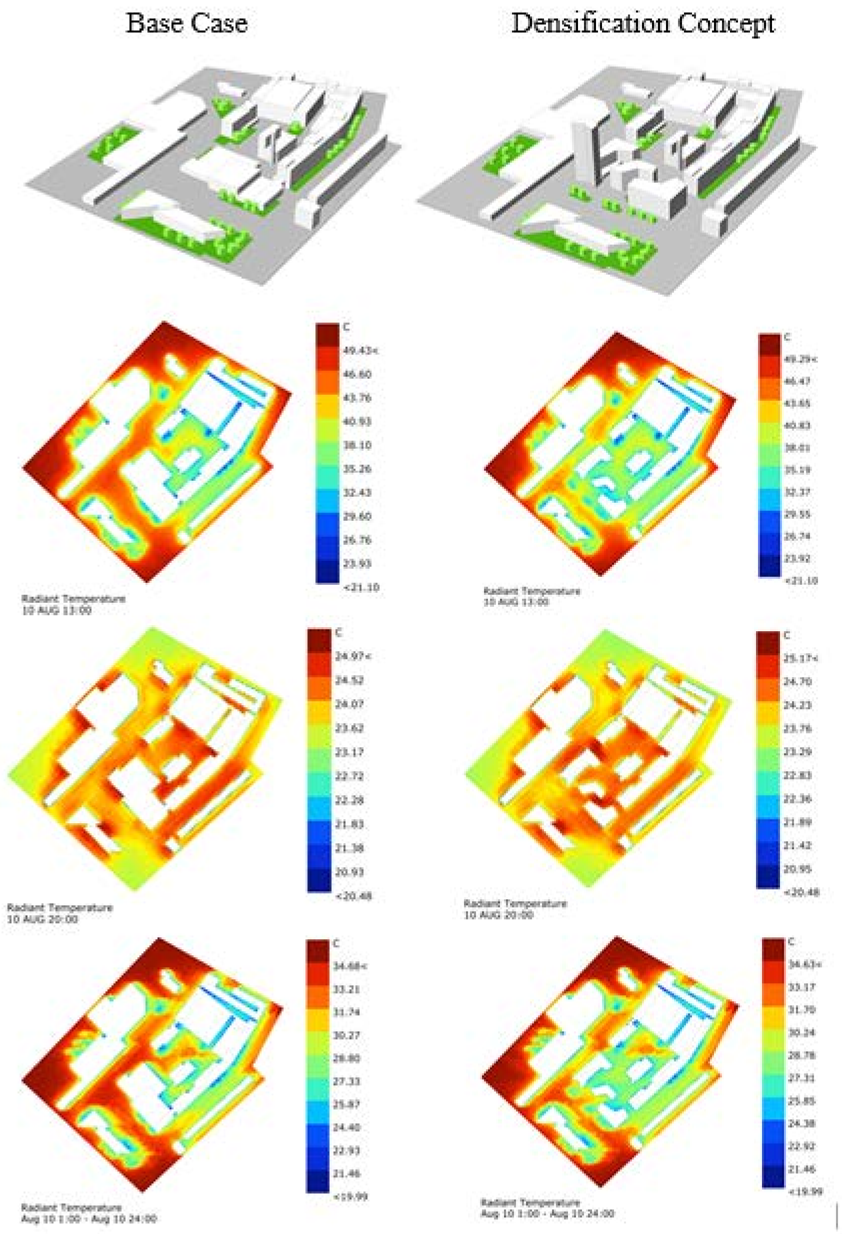


Figure 17: Linz Tabakfabrik development: 3D view of base case and densification scenario (top row), differences in heat exposure for base case and the densification concept accompanied by nature based solutions: Mean radiant temperature (MRT) – diurnal variation.

The further analysis refers to ventilation

The following figure gives an overview of the wind field analysis depicting the effect of the “Haselgraben” a fresh air source in the north of Linz.

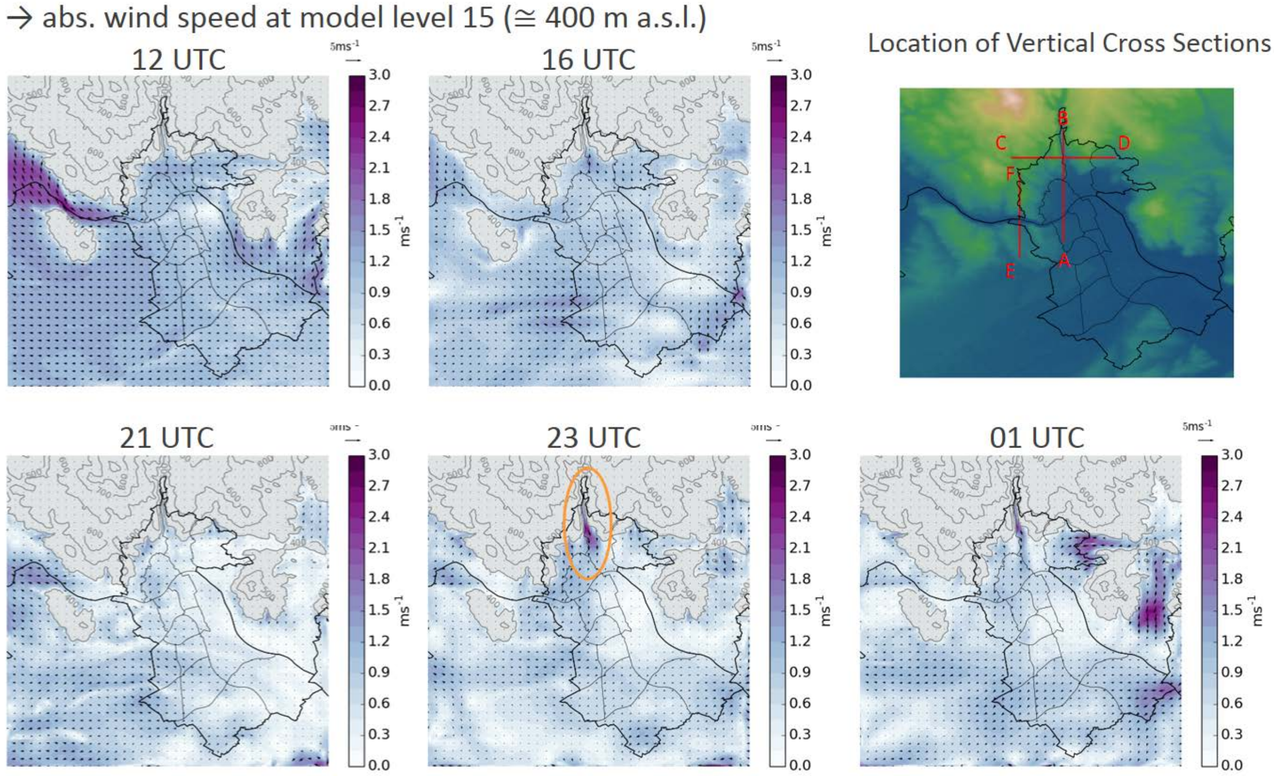


Figure 18: Linz Haselgraben – fresh air source in the north of Linz.

Thus, the DC3 implementation will finally allow end-users to acquire a set of design guidelines applicable to the multi-risk conditions (climate, and urban design) of the Metropolitan area of Linz, to promote an integrated approach to Climate Change Adaptation and Disaster Risk Reduction within public policies and private investments.

- Exposure and vulnerability assessment
  - Here additional data have been collected to allocate the elements at risk. Appplicatin will be carried out in the next period.

All models applied here require experts to assess impact and adaptation options.

3.3.2 Validation

The DC3 validation process has been carried out in following ways.

CSIS validation related to Linz.
Functional and usability validation carried out by users belonging to the project team, specifically AIT, City of Linz and ZAMG and Smart Cities Consulting (SCC). The system is tested, and it has been verified that all the designed functionality has been implemented. It has also been tested that final users can add new use cases similar to the one used for the Pilot Project. From AIT's and Linz municipalities' point of view, the functionality referring to the analysis of heat exposure on population has been examined.
UHI hot spots have been addressed through hot summer day - and tropical night frequency patterns in the city and adaptation options have been elaborated. Results for the Linz region through

MUKLIMO_3 (100x100m resolution) have been compared to CSIS results carried out through EMIKAT modelling results for a coarse spatial resolution (500x500m) which covers entire Europe. The visual comparison of the results obtained by MUKLIMO_3 (Figure 12) with those obtained with Advanced Screening (Figure 19 below) clearly indicates that the variation of the results is similar both in terms of the spatial variation and in terms of the variation of results with the climate scenario. Since the two models deliver different type of results (maximal yearly T_{MRT} versus number of summer days) we have decided against performing fully fledged correlation calculation like the one in Naples. However, comparisons with both historical data and results of other models on several sample locations clearly indicate that the results are plausible and provide a good starting point for project (pre-)assessments. Moreover, we are confident that even better results can be obtained if the models are fine-tuned for a single region, as opposed to using the same parameters for all European regions.

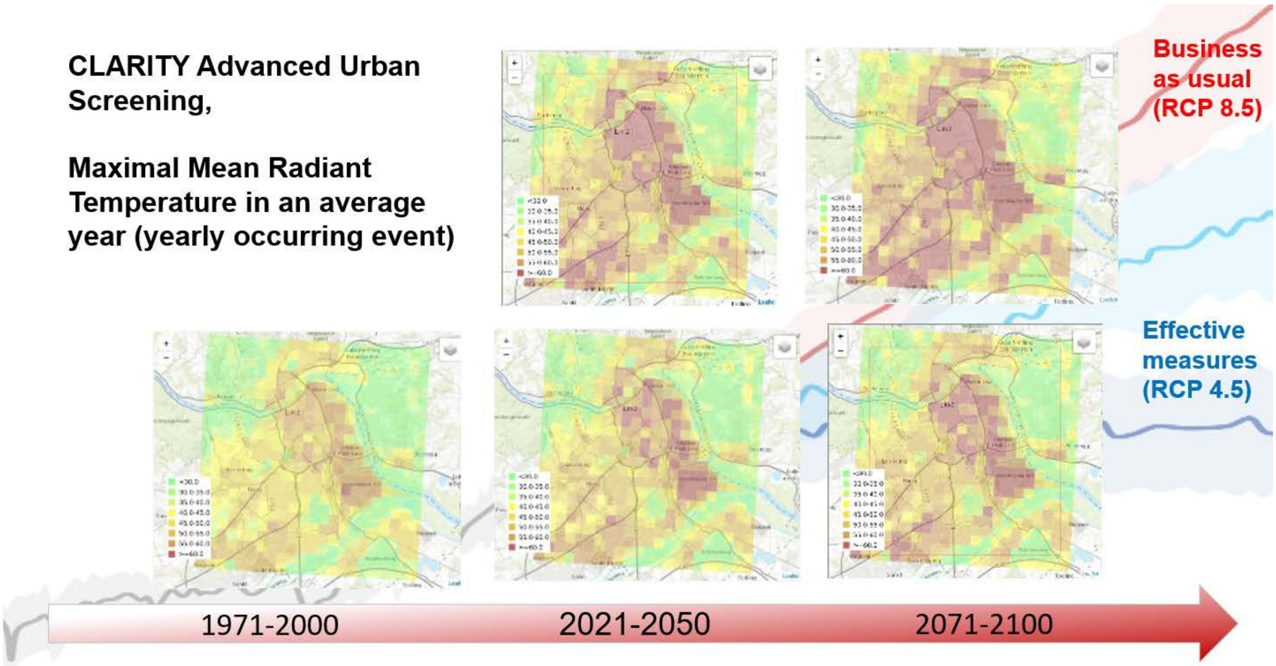


Figure 19: Advanced Screening example in Linz – maximal summer temperatures in different scenarios

Microclimate simulation validation.

Functional validation has been carried out by AIT team with contributions of the City of Linz. The simulation results are validated based on measurements to explore the uncertainty range of the simulation depending on different surface ad building façade properties.

Validation of micro-climate simulations was conducted through comparison of model results (temperature, solar radiation, wind, moisture) with monitoring data at test sites (through a monitoring campaign during summer/autumn 2019 carried out by two weather station in the shade and the sun at Tabakfabrik Linz and through monitoring of surface temperature with an infrared scanning device over selected heat days and selected sample surface points (in shade and sun) in August 2019 at AIT campus.

The monitoring campaign with weather stations have been organized by AIT, data storage and analysis were conducted by AIT, Infrared measurements and data comparison have been also carried out by AIT staff.

External validation.

Several meetings took place and local workshops and public presentations have been carried out in Linz during summer 2019 and spring to summer 2020 to evaluate the plausibility of the outcomes as seen by the public. Contributors were AIT, ZAMG and CCS.

Press conferences have been carried out in July 2019 as well as in September 2020 involving the public, policy makers and local stakeholders. The press conferences have been organized by the City of Linz, presentations and interview contributions came from AIT.

Due to Corona Virus restrictions during spring and summer 2020, instead of local workshops, webinars have been conducted to exhibit the results, referring to CSIS tool, to urban climate simulations (based on MUKLIMO-3 and to microclimate simulations (applying Grasshopper tools).

The webinars are structured into.

- Short introduction
- Results presentations showing the different result scales – urban scale – street block scale. The presentation of results was conducted through
  - slides presenting maps of heat load) as indicator and
  - an interactive web-based demonstration tool
    using the Mean Radiant Temperature (MRT) as indicator
- Feedback
  This was asked orally and through written statements.

Microclimate monitoring

A specific microclimate monitoring campaign has been carried out to validate modelling results with observation data. Monitoring has been carried out for the Tabakfabrik Linz site as this allows to consider different location characteristics and allows to place the monitoring equipment in a secure private street environment, similar to a public area.

Two specific locations have been selected to compare the variation of air temperature, radiation, wind and humidity over the day in a shaded and sun-exposed location (see Figure 20). The monitoring took place during August and October 2019. An earlier start was unfortunately not possible as we have to wait for acceptance to let finance the campaign by money provided through CLARITY project funding.

Figure 20: Locations of the monitoring campaign at Tabakfabrik Linz: top: areal view, bottom: street view; left square in the upper image and lower left image: shaded place, right square in the upper image and lower right image: sunny place.

A further monitoring exercise has been conducted at AIT Vienna research campus serving as a test site with different surface and wall characteristics. Monitoring has been carried out with a thermal infrared camera to examine surface temperature variations at different surface properties and sun exposure over day (Figure 22).

1	Asphalt sun	Parkinglot 65
2	Asphalt shadow	Parkinglot 62
3	Gravel (sun)	
4	Grass sun	near gravel
5	Grass under tree	
6	Window and Facade East	GG4
7	Window and Facade North	GG5
8	Window and Facade West	GG6
9	Window and Facade South	GG7
10	Asphalt South	Parkinglot 16
11	S/W GlassFacade	GG4
12	Tree (202)	behind GG6
13	Grass under tree (202)	behind GG6
14	Tree crown (202)	behind GG6
15	Tree asphalt (sun and shade)	
16	Facade	GG6
17	Energy Base	GG6
18	Terrace concrete	GG6
19	Terrace wood	GG6
20	Terrace greening	GG6
21	Terrace greening	GG6

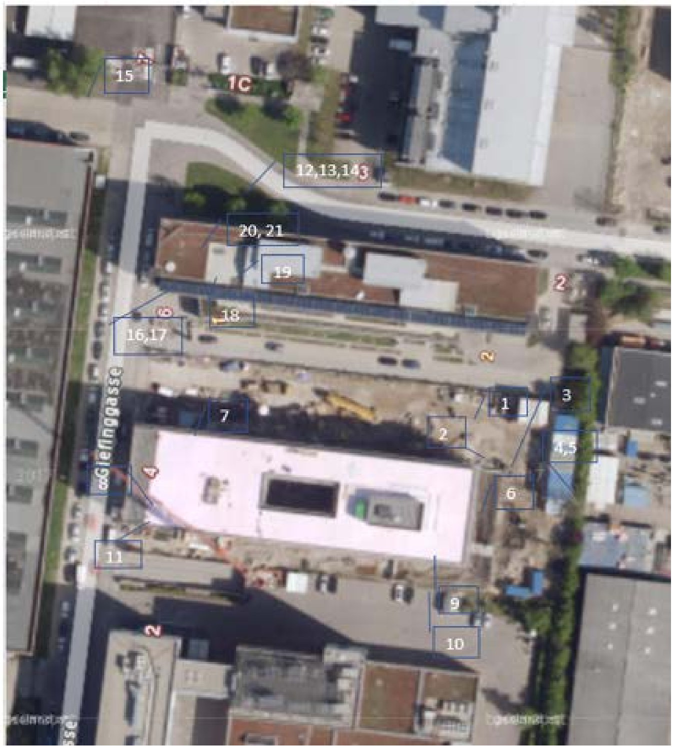


Figure 21: Locations of surface temperature monitoring at AIT research campus:
Top left: surface characteristics of the monitoring spots, top left real: aerial view of th test site,

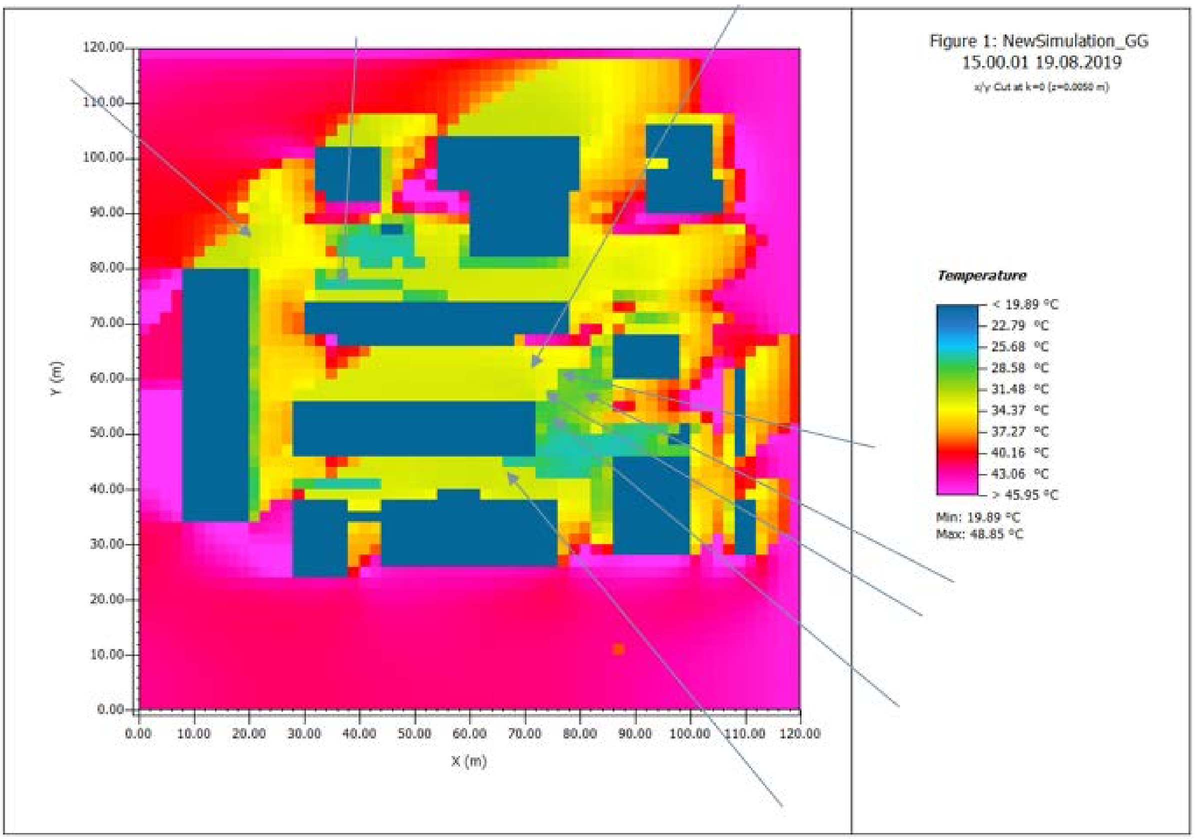


Figure 22: Locations of surface temperature monitoring at AIT research campus:
Top left: surface characteristics of the monitoring spots, top left real: areal view of th test site, bottom: modelled surface temperature of a certain day and a certain time and observation locations

Results

- through comparison of model results (temperature, solar radiation, wind, humidity) with monitoring data at TabakfabrikLinz test during August to October 2019 and
- through monitoring of surface temperature using an infrared scanning device over selected heat days and selected sample surface points (in shade and sun) in August 2019 at AIT campus as test site.

The real time monitoring campaign at Tabakfabrik Linz carried out with weather stations, remotely connected to a database have been planned by AIT and impemented by a private company, data storage and analysis were conducted by AIT. Comparison of observations versus model results have been also carried out by AIT team.
Infrared observations of surface temperature and comparison of observation data versus model results have been also carried out by AIT team.

Figure 21 shows radiation as well as ambient air temperature during the monitoring campaign for the shaded and the sunny location.

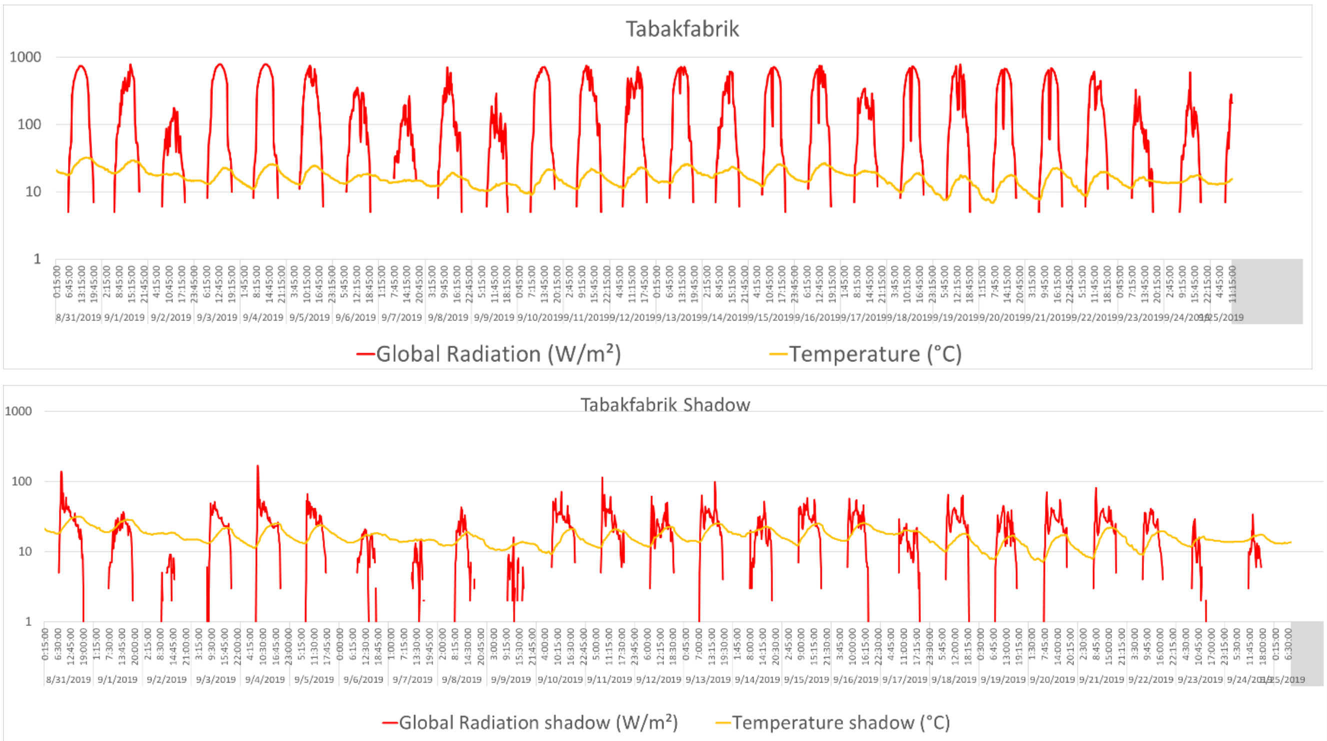


Figure 23: Monitoring campaign: global radiation and ambient air temperature in the sun versus in the shade (log scale: W/m2 solar radiation versus °C temperature).

The following Figure 24 shows the comparison of the air temperature at the sunny test location versus the shaded test location. Figure 25 shows the comparison of the solar radiation at the sunny test location versus the shaded test location:

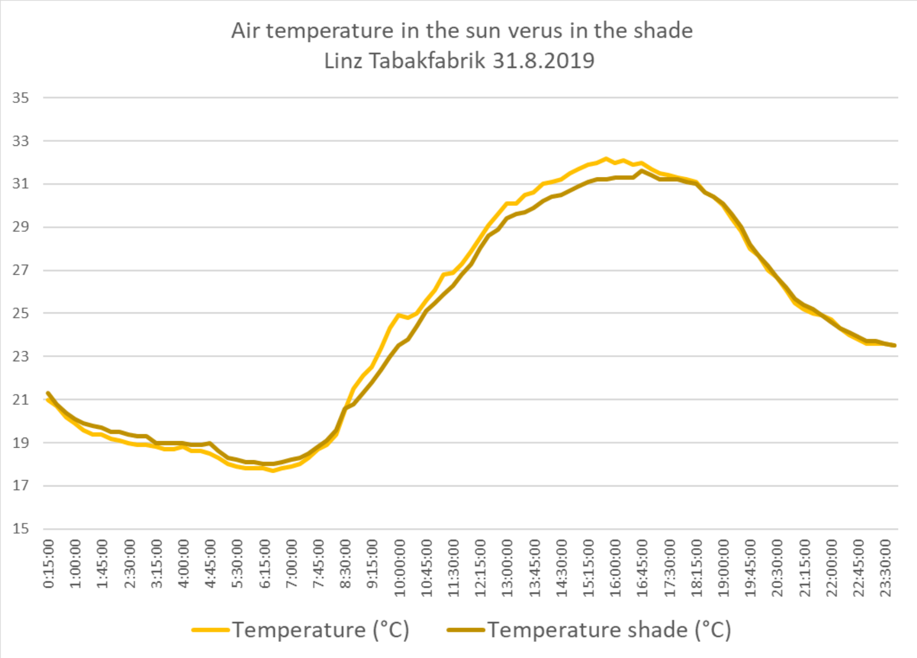


Figure 24: Monitoring campaign: ambient air temperature on a sample day: in the sun versus in the shade

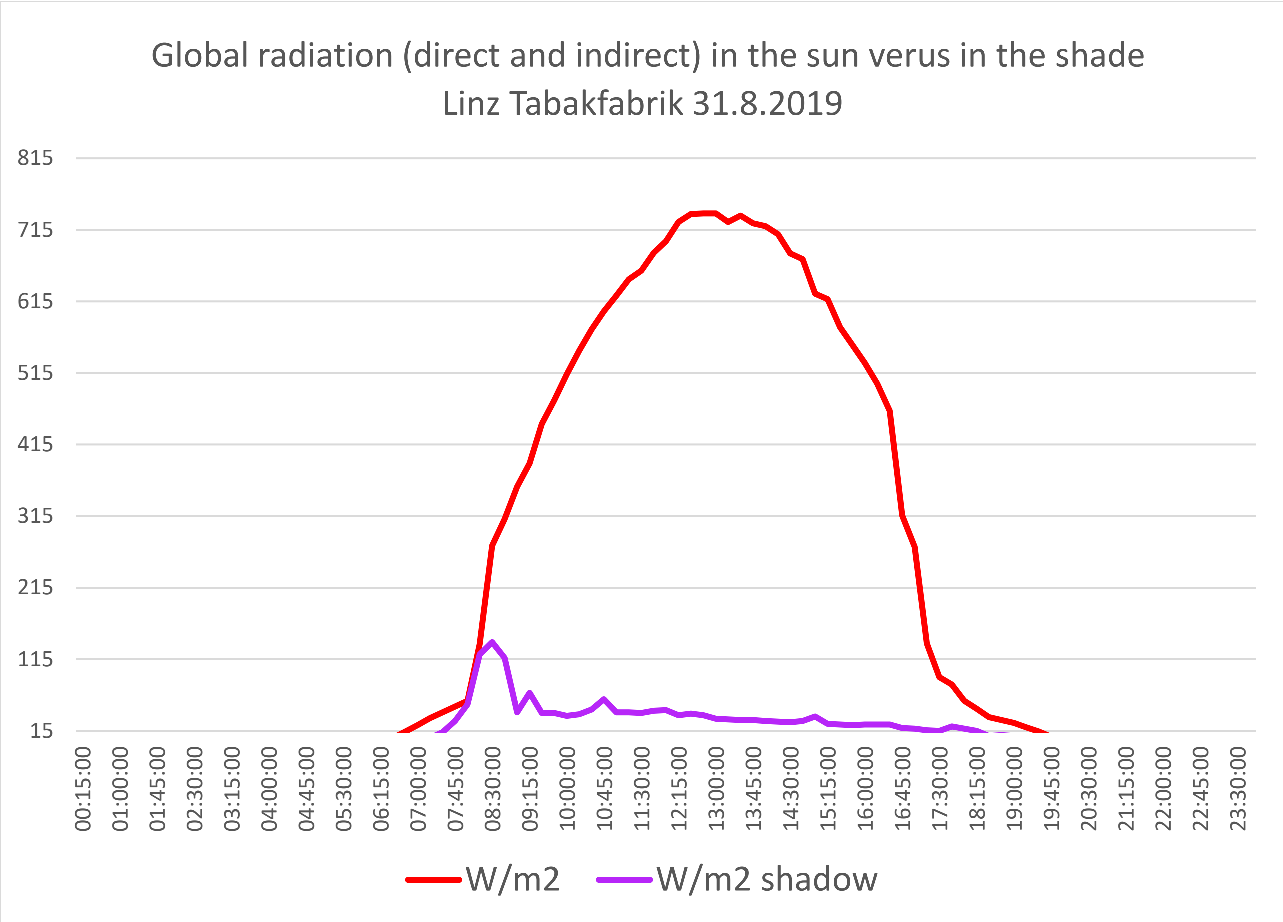


Figure 25: Monitoring campaign: global radiation on a sample day: in the sun versus in the shade.

Table 11 allows a comparison of temperature and global radiation results for specific timeslots.

Table 11 Comparison of temperature and global radiation results for specific timeslots.

Temperature (°C)	Tabakfabrik	Tabakfabrik Shadow
night 0:15-5:00	13,7	13,9
early morning 5:15-9:00	13,0	13,1
late morning 9:15-11:30	16,4	16,0
noon 11:45-14:30	19,5	19,1
early afternoon 14:45-16:30	20,9	20,4
late afternoon/evening 16:45-20:00	19,3	19,4
night 20:15-24:00	16,1	16,3

Global Radiation (W/m²)	Tabakfabrik Sonne	Tabakfabrik Schatten
night 0:15-5:00	0,0	0,0
early morning 5:15-9:00	41,6	8,7
late morning 9:15-11:30	362,9	24,2
noon 11:45-14:30	432,3	24,4
early afternoon 14:45-16:30	369,6	21,4
late afternoon/evening 16:45-20:00	49,6	7,3
night 20:15-24:00	0,0	0,0

Figure 24 proves that the ambient air temperature does not show much differences between shadow and sunny locations. Figure 23 shows instead the high difference of solar radiation between sunny and shaded test locations. Thus, radiative temperature is an appropriate indicator to consider thermal impact differences.

For microclimate modelling ENVIMET and Grasshopper/Ladybug tools have been applied. Model validation for ENVIMET und Ladybug results has been conducted through surface temperature observations for different surfaces in shaded and sunny locations.

The following figure 24 shows the surface temperature variation for 3 hours at the AIT test site, modelled through Grasshopper/Ladybug.

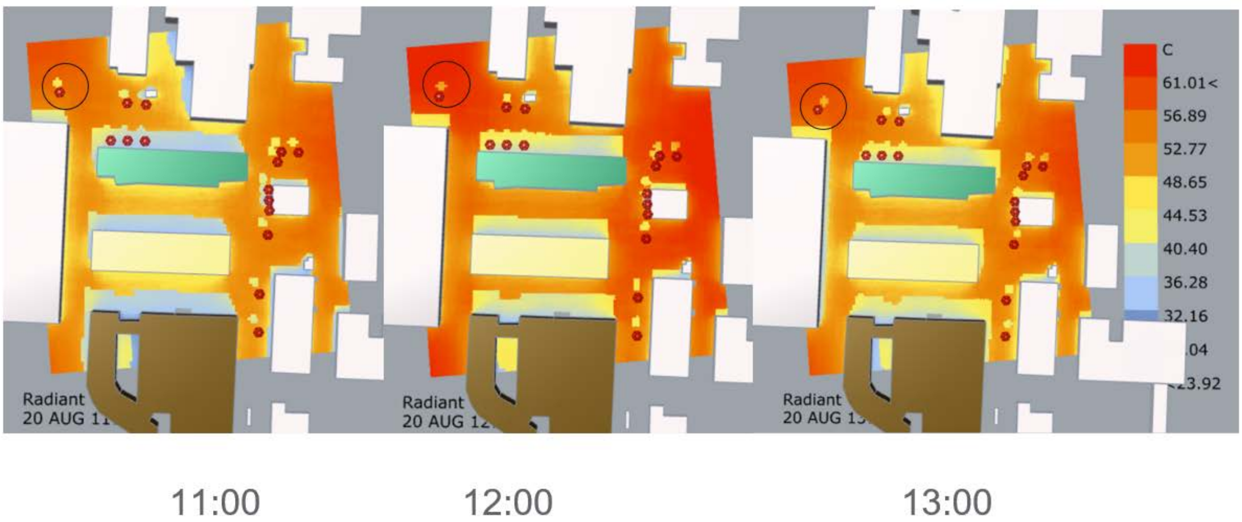


Figure 26: Surface temperature variation for 3 hours atr AIT test site

Figure 25 shows the observed and modelled temperature and MRT variation for 24 hours. It allows to compare monitored surface temperatur and modelled mean radiant temperature by the two models for asphalt surface in sun and shade.

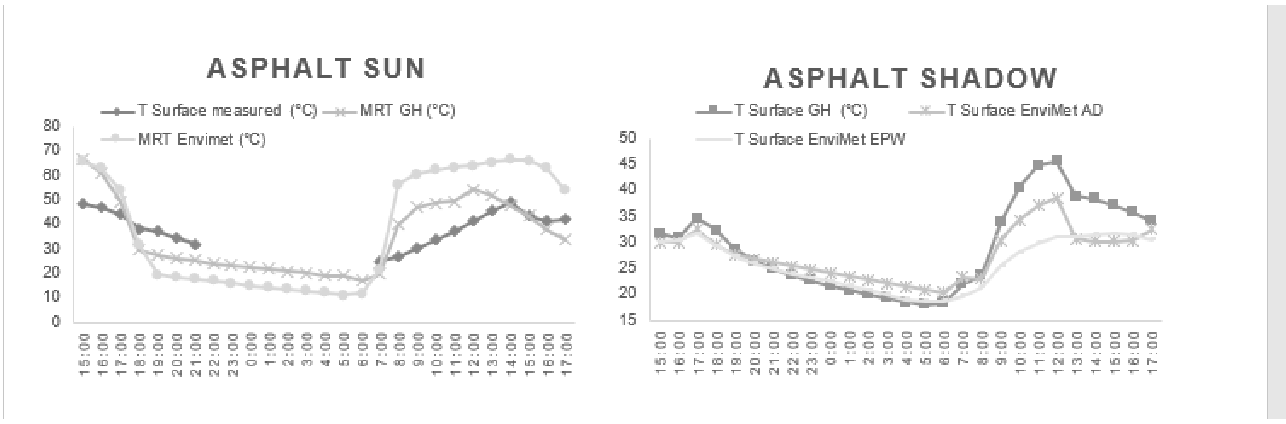


Figure 27: Observed surface temperature and modelled mean radiant temperature by the two models for asphalt surface in sun and shade over a specific day.

The results show changing coincidence – ENVIMET model results are better on asphalt surfaces, Grasshopper/ Ladybug results better on grass surfaces. Results in sunny places show higher correlation than results in shaded places.

Table 12 Correlation coefficients of observed versus modelled surface temperature - different surface properties

	Surface Temperature (°C)	
	Measured/Envimet	Measured/Ladybug
Asphalt sun	0.7510	0.7270
Asphalt shadow	0.4351	0.5463
Grass sun	0.3729	0.8993
Grass shadow	0.4600	0.1684

Figure 26 shows further details:

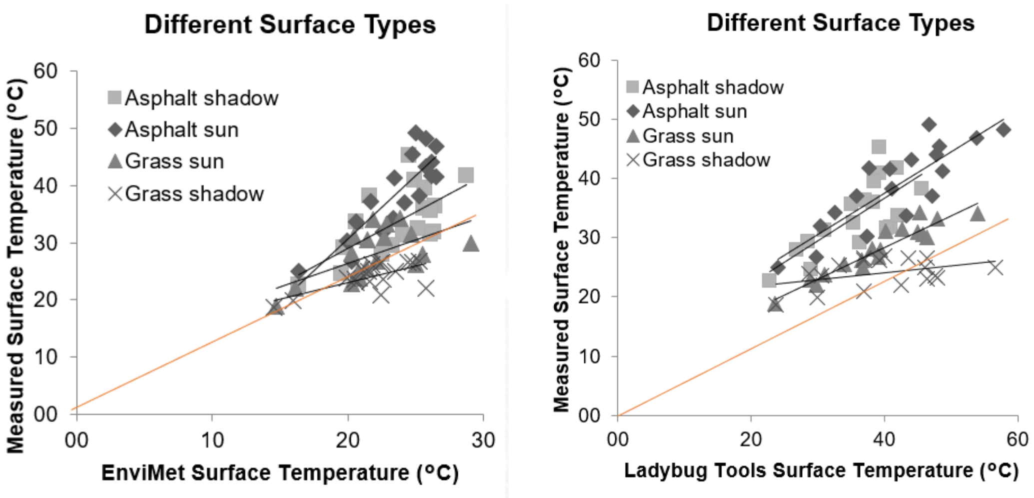


Figure 28: Comparison of observed versus modeled surface temperature for different surface properties and sun exposure

ENVIMET Results: asphalt model results on sunny spots are 10 to 15 % higher than the observations. Asphalt model result in shadow areas are more similar to observations. Grass model result on sunny spots show higher coincidence with observations. Results in shadow areas are more similar to observations.

Grasshopper ladybug results show higher general variation but are more close to the observations – all model results applied in the applications are taken from the Grasshopper/Ladybug tool.

Summary:

- EnviMet simulates lower values in MRT and surface temperature than Ladybug tool
- Ladybug results have more variation in the temperature curve than ENVIMET results
- Grass locations show lower temperature as simulated and are closer to ENVIMET surface temperature
- Asphalt locations temperature is closer to Ladybug tool's surface temperature.

Therefore, all micro-climate model results depicted in the expert study are finally taken from the Grasshopper/Ladybug tool.

Table 13: Datasets and Model output for DC3 implementation.

Models	**Datasets – sources**
RCM (regional downscaling)	(models output already available at EURO-CORDEX database)
COSMO-CLM (regional downscaling)	• Reclip-century simulations 1959 to 2015 10km resolution for Alpine Space, 10km resolution for Alpine Space, 4km for Austria, based on ECMWF ERA-40 & ERA Interim-forcing data • IPCC A1B Reclip-century simulations 2010 to 2100, 10km resolution for Alpine Space, 4km for Austria, based on HADCM3 A1B climate simulations • Based on this - CLARITY simulations at 1x1km resolution to be carried out for Greater Linz area area.
MUKLIMO_3 (heat - urban microclimate)	• Historical meteo data – ZAMG, RCM scenarios EURO-CORDEX

	• Digital Elevation Model: 1m DEM for the City of Linz (2009), 5m DEM for Upper Austria (2009), 30 m for Europe from EEA • Land cover data (CORINE & Urban Atlas 2006, 2012), Zoning Plan for Upper Austria (2017) • Mean building height estimated from LIDAR data for the City of Linz (2009), LIDAR point cloud data, providing altimeter information for the City of Linz (2011) and derived 3D-Building model (LOD 2) and footprint model for the city of Linz (2011) • Building typology classification; Wall area index; Fraction of impervious surface between buildings;– data from City of Linz, Copernicus Land Monitoring Data • Vegetation parameters (Vegetation cover and height information) – based on areal photo classification and storey information at building level from Linz; EU Urban Atlas •
Micro-climate Simulation tools: ENVI-met 4.0, SOLWEIG and Grasshopper - Ladybug plugins), Monitoring data	Input different for ENVI-met, SOLWEIG and Grasshopper plugins) • 10 m digital elevation model • Soil sealing shares • Normalized digital surface model • 3D City model (building footprints with height information - LOD1) • Tree inventory • Street network • Gridded building height and vegetation height layers at 2m resolution for selected case study areas in Linz • Validation of micro-climate simulations was conducted through comparison of model results (temperature, solar radiation, wind, moisture) with monitoring data at test sites (through a monitoring campaign during summer/autumn 2019 carried out by two weather station in the shade and the sun at Tabakfabrik Linz and through monitoring of surface temperature with an infrared scanning device over selected heat days and selected sample surface points (in shade and sun) in August 2019 at AIT campus.

3.4 DC4 - Transport Infrastructure in Spain

3.4.1 Overview

The implementation of DC4 aims to incorporate natural risks in the context of Climate Change into the design and management of the transport infrastructure; it aims to provide the user with a tool that facilitates the risk assessment of a road project in the face of climate variability and change. It will address the needs of several types of potential users who in turn will demand different climate information with a different focus. The study area for this pilot case is a section of the A2 highway that connects Madrid with Barcelona (**Figure 27**). This four-lane highway section is 73 km long, running from Guadalajara city (PK62) to Alcolea del Pinar (PK-135), sitting in the province of Guadalajara.

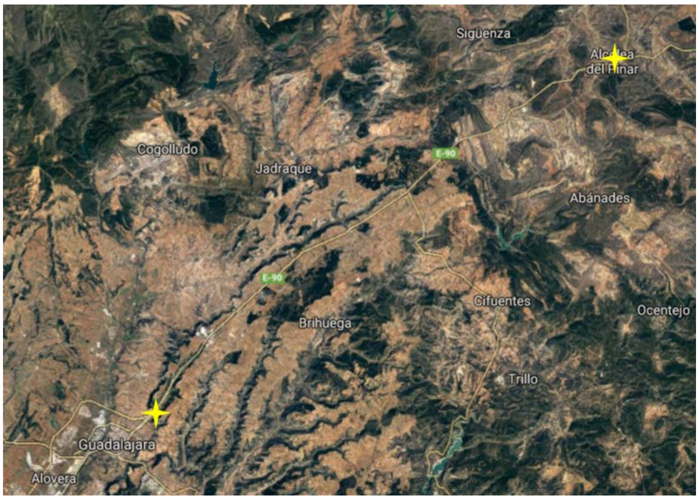


Figure 29: Section 2 - Highway A2

The particularities of the concession and the problems that this section presents, of which the daily oscillation of temperature, the gusts of strong cross winds and the snowfalls can be highlighted, make it a representative example whose analysis can be extrapolated to other countries of the European Union with similar characteristics.

There has also been selected a subset of railways which includes 3,143 km of the high-speed train network (AVE). It is expected that climate change will entail negative impacts in both railways and highways in all stages of the life-cycle of these infrastructures (planning, design, construction, maintenance, and exploitation).

In parallel, several climatic projections and climate change scenarios have been developed by the Spanish Meteorological Agency (AEMet, Ministry of Environment) as part of the PNACC (Plan Nacional de Adaptación al Cambio Climático). These include three emission scenarios (SRES-A2, SRES-A1B and SRES-B1) defining 2050 and 2100 as temporal horizons. These scenarios have highlighted several factors that need to be taken into consideration when studying the effect of climate change on the transport infrastructures. These relevant factors are:

- The average air temperature will increase about 2ºC in summer and 1.2ºC in winter.
- The maximum and minimum temperatures will show more extreme values and the variation will be higher than for average temperature.
- The number of frost days will be reduced.
- The daily thermal oscillation will be broader.
- It is expected than around the next mid-century the number of heat waves will double.
- The relative humidity will generally diminish by a 5%.
- Total cloudiness will be reduced for all regions, with the exception of those in the North-East of Spain.
- Annual accumulated precipitation will decrease in all regions: about 5% in the North and in the East, and around 10% in the South and in the West.
- The number of intense rainfall events will increase most likely entailing floods.
- The number and length of drought episodes will increase, particularly in summer.

During each of the phases in the life cycle of roads there are different considerations to be taken into account in this regard. In the planning and design phases of roads, it is especially important to identify the areas most sensitive to the conditions mentioned and, based on that, to adapt or re-design the proposed routes within the admissible limits as well as to use the most appropriate materials or construction techniques. On the other hand, in the operation phase, the emphasis is on the need to know in advance the expected seasonal episodes in order to implement the appropriate conservation strategies, while having the necessary information to adapt, modify or restrict the operation to ensure the safety and profitability of the same.

The DC4 implementation will allow end users to acquire a set of design guidelines applicable to the multi-risk conditions (climate and transport network design) of the Spanish Road Network and specifically to the selected highway section managed by ACCIONA. In order to achieve a better understanding of the intended use of the data and activities within this Demo Case, a classification according to the business process they will solve has been done. Additionally, all the data identified will be included in a table related to the user stories in which they are needed.

All the spatial framework data gathering is being performed into WP2 tasks and will be completed by M18. It will all be reported in D2.2.

Business processes taken into consideration are:

- Operation of the management and maintenance concession for a highway section.
- Simulation for an invitation to tender for the management and maintenance concession of a highway section.
- Simulation for an invitation to tender for the construction/design of a new highway section.
- Recommendations on Regulations/Revision of design conditions.
- Monitoring of fires, bridges, drainage, and slopes (landslides).

Starting from the "critical climate parameters", an exercise has been carried out to determine the specific indicators to be calculated, differentiating those referred to at the first level (screening) and those that will be the object of a specific study for the pilot case (expert assessment).

Within the first level, the study of temperature, precipitation, wind, drought, fire risk and landslide risk variables is foreseen. For each of the climate indices associated with these variables, climate change projections will be obtained with sufficient precision to determine whether the threat in a given area is likely to increase or decrease. In particular, to implement the demonstrator the following data have been used (Table 14):

Table 14: Data set implemented in Transport Demonstrator

Models	Datasets – sources
Statistical Downscaling in hazard module	• Meteorological observation data. Hourly resolution – Aemet • Mid term meteorological forecasting. Resolution: 6h/1 degree – NOAA • Mid term meteorological forecasting. Resolution: 6h/0.28 degree – ECMWF
Modelling of future climate scenarios in hazard module	• EURO-CORDEX ensemble climate simulations. 0.11 resolution – Cordex
Modelling of hydrology hazard and corrections of several variables	• Digital elevation Model. Resolution: 2 and 5 meters – PNOA
Modelling of wildfire in hazard module	• Spanish forest fuel model. Scale: 1/100.000 – MAPAMA
Climate data	• Climate Forecast System (CFSv2). Scale: variable – NOAA • Current climate data – AEMet.
Ensemble climate simulation	• ECMWF System4. Scale: 1 degree – Copernicus
Climate data prediction	• Decadal models outputs (CMIP5 – CMIP • AEMet-Spanish official projections – AEMet • CMIP5 climate projections – CMIP
Input exposure element	• Detailed highway design. Scale: 1/500 – ACCIONA • Spanish Transport Network layers. Scale: 1/25000 – IGN • Traffic volume of Spanish roads – CEDEDX • Detailed drainage systems. Scale: 1/500 – ACCIONA • Detailed Slopes design. Scale: 1/500 – ACCIONA

The following is a brief description of the methodology used in the development of the hazard, vulnerability and risk calculations and their particularities:

Hazard

With regard to the climate conditions foreseen for the future, the current projections indicate a change in several indices concerning precipitations, temperatures, and heat waves. The projections of greatest interest are available in the Change Scenario Viewer Climate (http://escenarios.adaptecca.es/) developed for Spain by the Ministry for Ecological Transition, where data related to the two horizons of the evaluation 2048 and 2098 can be found.

Considering the long-term scale, the relevant information is climate data provided at decadal scales. The approach has been providing support to bidding companies and infrastructure designers (most elements of the road infrastructure have a design life of more than 30 years).

Potential climate hazards for transport networks and climate variables or indexes that need to be considered for long-term threat analysis were identified and have been described in D2.3 along with the preliminary results on the climate projections.

Exposure

The elements at risk can not defined in the same as it is done in the demonstrators for urban infrastructure. In the case of transport nfrastructures, they refer to all single elements of the infrastructure. Due to the existence of a very high number of elements in a road infrastructure that should be analized, a list of potential elements at risk has been defined. Also, this work is based in a screening exercise performed by CEDEX for Spanish Ministry of Ecological Transition (https://www.adaptecca.es/sectores-y-areas/transporte).

Finally, attention has to be paid to the traffic flow in the case of transport infrastructure. A problem in a road element will probably also affect traffic flow and this has to been also accounted for.

For the purpose of identifying the list of elements at risk is in the DC4, several working sessions were scheduled with the technicians from ACCIONA in charge of the A-2 in Guadalajara road maintenance. During these working sessions the specific elements of A-2 road section under evaluation were assessed in the light of climate change projections. Note that indirect hazards such as negative effects related to salt spread (winter maintenance) have not been considered.

The main elements at risk identified in DC4 have been described in detail in D2.3. It is interesting to note that every element is already vulnerable in the present climatic conditions.

Vulnerability

The vulnerability is defined as the probability that an element at risk experiences a level of damage, according to a predefined damage scale, as a consequence of a hazard event of a given intensity.

In the case of DC4 is not possible to define vulnerability classes because there is a wide spread of typologies for each element at risk. Also, it is not possible to define vulnerability functions because a lot of statistical data is needed in order to define these functions and theses data are not available.

As has already been described in section 2 of this document, the methodology adopted within DC4 proposes to assess the vulnerability by means of expert judgement based on different perspectives.

Probability represents how likely the identified climate hazards are to occur within a given timescale (e.g. rare, unlikely, possible, likely, almost certain) . The severity accounts for the consequence of the hazardous event occurring in terms of the intensity over time. The level of risk is calculated by combining the possible level of affectation with the probability of occurrence of that type of event. A more detailed explanation can be found in D2.3.

Impact / Risk

During the implementation of this demonstrator case, an assessment was performed. This assessment assumed that not major construction works were going to take place, only routine maintenance; except in the case of road pavements, which are usually upgraded every 10-15 years (approximately). The main results from this assessment were:

- Risk level associated to the three slopes identified remain constant in the period of analysis (80 years). The highest risk has been found for the slope from pk 72+900 to 73+150 (medium for the slope itself and high for traffic conditions).
- Risk level associated to the structure in pk 63+775 is expected to increase in the future. This increase is more related to the deterioration of the structure because the passage of time than to climate change. If no action is taken in the short term, risk level can be high for the structure and medium for traffic conditions.
- Risk level related to drainage works is expected to remain low.
- The increase in intense rainfall can impact channelling of Valle de Torija stream. Risk level will increase from low to medium, although this will not have any impact on the traffic conditions because it is far enough from the carriageway.
- Risk level associated to road pavements remain low. Problems related to presence of water in the surface are not expected to be specially affected by more intense rainfall. Also, problems related to rutting might not have a relevant impact due to the fact that new pavements will be built taking into account the increase of maximum temperatures (harder bitumen).

In relation to the affection to traffic condition by ice and snow, risk level will decrease. On the contrary, heat waves will be more intense (longer and higher maximum temperatures). As a consequence, the risk level associated to fires will increase. But it will remain low taking into account that the efforts from the administration will be encompassed to this increase in the hazard. In relation to fog, it is expected that the risk will remain low (although no projections were available when doing this assessment).

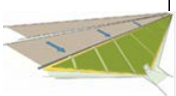
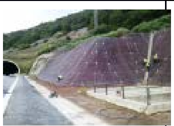
Adaptation Options

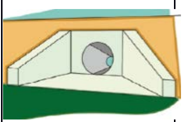
Adaptation options for the transport infrastructure focus on the short, medium and long term and be complemented by environmental management, planning and disaster risk management tools.

Adaptation options in the transport sector may generally be divided into engineering (structural) options and non-engineering options. Each of these options is described in detail in D2.3. Note that a decision not to act, or to maintain a business as usual approach ("do nothing" option) should also be retained as a possible option.

Some of the adaptation options identified that are already available in the system are:

Table 15: Examples of Adaptive Measures implemented in the Transportation Demonstrator

ADAPTATION		TOWARDS WHICH HAZARD	VARIATION ON VULNERABILITY OF ELEMENT AT RISK	COST		CO-BENEFITS
				NEW	RETROFITTING	
	Afforestation of slopes with drought-resistant	Falling materials and erosion as a consequence of intense rainfall	++	€	€	Improves stability of slope Biodiversity Air quality
	Implementation of erosion control blankets or other type of protection (drains, berms,	Falling materials and erosion as a consequence of intense rainfall	++	€€	€€	Improves stability of slope

ADAPTATION		TOWARDS WHICH HAZARD	VARIATION ON VULNERABILITY OF ELEMENT AT RISK	COST		CO-BENEFITS
				NEW	RETROFITTING	
	anchors, gunite or others)					
	Reduce the slope of the cut	Falling materials and erosion as a consequence of intense rainfall	+++	€(Soft soils) €€ (Rock soils)	€€ €€€	Improves stability of slope
	Improvement of road maintenance resources	Falling materials and erosion as a consequence of intense rainfall	++		€€	Improves road performace Social and economical importance
	Improve of longitudinal and transversal drainage	Insufficient transversal drainage due to intense rainfall	+++	€€	€€€	Improves drainage
	Alternative mixtures (modified bitumen) for bituminous pavements and surface courses	Formation of pavement rutting as a result of elevated pavement temperatures	++	€€	€€	Improves ride quality for the driver
	Porous pavements	Traffic conditions due to intense rainfall	++	€€	€€	Improves ride quality for the driver (no splash and spray)
	Increase surveillance of the section in case of unfavourable weather conditions	Traffic conditions due to snow	++	€€	€€	Improve road management Social and economical importance
	De-icing agents that cause the least possible damage to pavements and the environment.	Traffic conditions due to snow	++	€	€	Improve road management Social and economical importance Less affection to environment

ADAPTATION		TOWARDS WHICH HAZARD	VARIATION ON VULNERABILITY OF ELEMENT AT RISK	COST		CO-BENEFITS
				NEW	RETROFITTING	
	Allow alternative routes in case of road closure	Traffic conditions due to snow	++	€	€	Improve road management Social and economical importance

3.4.2 Validation

The development of the system prototype (interface and functionality) was coordinated by METEOGRID and this process was supported by the other partners (definition, validation and implementation). The validation tasks had a double objective; (I) to corroborate that the system requirements met the expectations defined for the pilot, (II) to ensure a logical and friendly interface and (III) to ensure the correct implementation of the reference methodology.

The validation of the Transport Demonstrator has been performed in collaboration with partners that, due to their activity, are also potential users of the platform and also with external users. The first set of users have provided feedback and useful information throughout the implementation during specific meetings as well as providing inputs for the whole duration of the project but more frequently on the last months.

On the one hand, the interested parties have carried out several tests in the demonstrator for each of the stages of its development with the aim of corroborating the operability of the system for each of the planned functionalities. These user tests have also had a bug inspection task with the aim of confirming that the system requirements are adequately met. The validation process consisted in running the Demonstrator in a recurring manner as close as possible to how it will run when it is in production. This test was preceded in all cases by explanatory presentations for the user before use. The results obtained were collected by the development team and considered for inclusion.

The transport demonstrator has been created with a "light" usage approach through reusable blocks that make it intuitive to use and easy to implement. The validation tasks have sought to confirm this fact, mainly by reviewing these aspects:

- The tool must allow to guide the user in the climate analysis following a workflow based on the EU-GL
- The tool must allow an effective interaction between existing resources and databases and the user's information needs.
- The tool must generate reports that collect the information generated during the analysis process.
- The tool must allow the selection of the type of study that suits the user's conditions (basic or expert study).
- The system must have a "matchmaking" system for the proposed Expert Climate Services based on the characteristics and previous analysis already carried out.
- The analysis options and functionalities must meet the expectations previously defined by the user (analysis elements, set of threats, display of layers, etc.)
- Information exchange functions should be done under widely agreed interoperability frameworks.
- The system must provide a simple, intuitive and user-friendly interface.

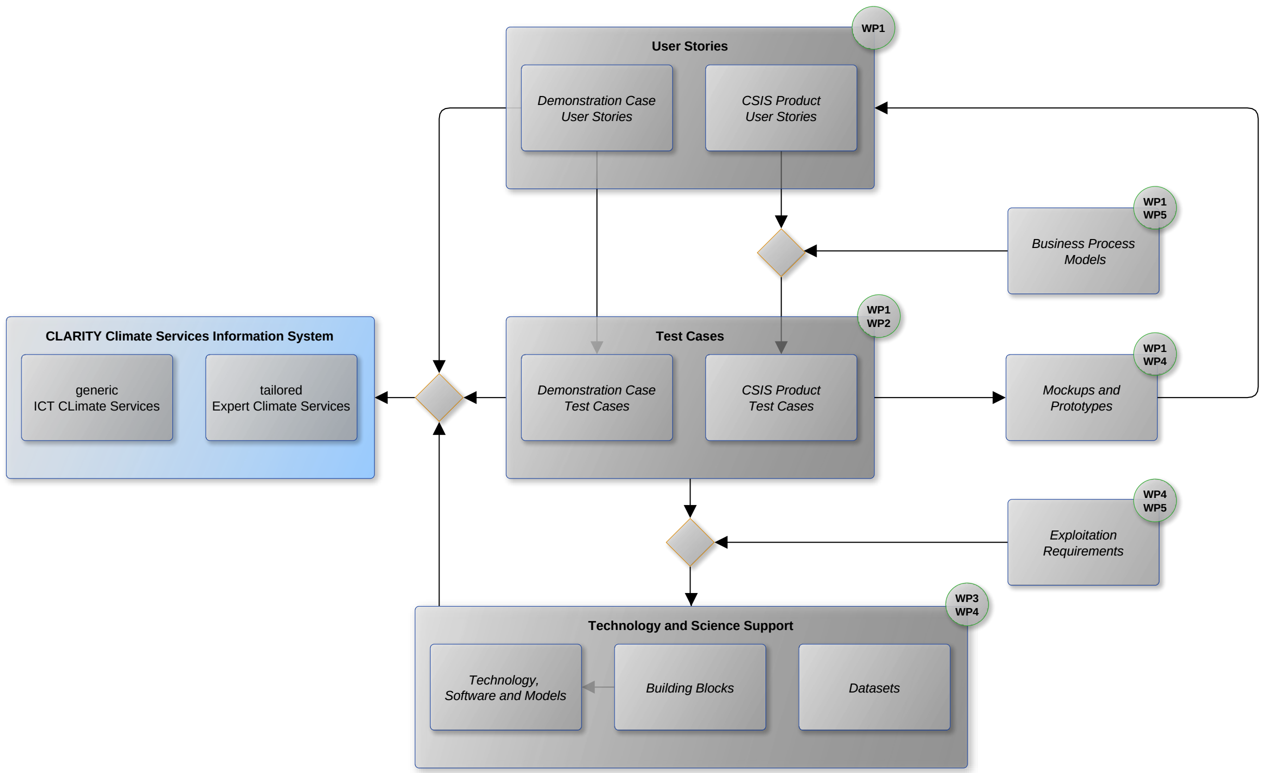


Figure 30: Relationship between tests case and work packages.

As for external users, several workshops and meetings have been organised during the last year to gather impactful feedback that could potentially focalise the last steps of the implementation to better consider their needs and account for their experiences. These events have also gathered information on the usability of the platform and its feasibility for the purpose for which it has been designed.

On a later stage, the Demonstrator Case has been expanded to consider the railway infrastructure in addition to the highway infrastructure already implemented.

Use Case Validation

The demonstration case of the Spanish pilot has also been validated by the interested partners. In this case, the validation has aimed to confirm the compliance with the requirements of the climate results and their adequacy in design studies, maintenance or infrastructure management, specifically for the section selected within the pilot.

For this purpose, the interested partners have carried out various tasks to test the results:

- Exercises have been carried out to contrast results and test for errors between existing climate information and that generated by the CLARITY project. This was intended to corroborate the validity of the data, the absence of computational or other errors.
- Consistency analysis between the expected impacts for the short, medium and long term and the results obtained through the transport module with expert criteria.
- An exhaustive bibliography review has been carried out on the road elements that can potentially be affected by the climatic conditions; as well as their main impacts associated to each case. The objective has been to adapt the available analysis options to the most evident uncertainty frameworks at present.

On the other hand, the system has been tested in cases applied to the Spanish railway network, particularly in the section that runs through Talavera de la Reina, in the province of Toledo in Spain. In this case, a specific database loading module has been developed to incorporate the network layout and its vulnerable elements, which have been adapted to the case study of the railroad network. In this additional validation process, meetings have been organised with the interested parties in special sessions. These sessions have been organized by Acciona, as the entity that validates the usefulness of the data in projects it leads; and have been coordinated by CEDEX to ensure that the study was adapted to the requirements that the Ministry requests from road maintenance bidders.

In addition, after these meetings, it was decided that reference layers should be loaded to reflect flood zones in various return periods, as well as land uses, because of their usefulness in assessing changes in vulnerability and, consequently, in the probability of affecting the railway.

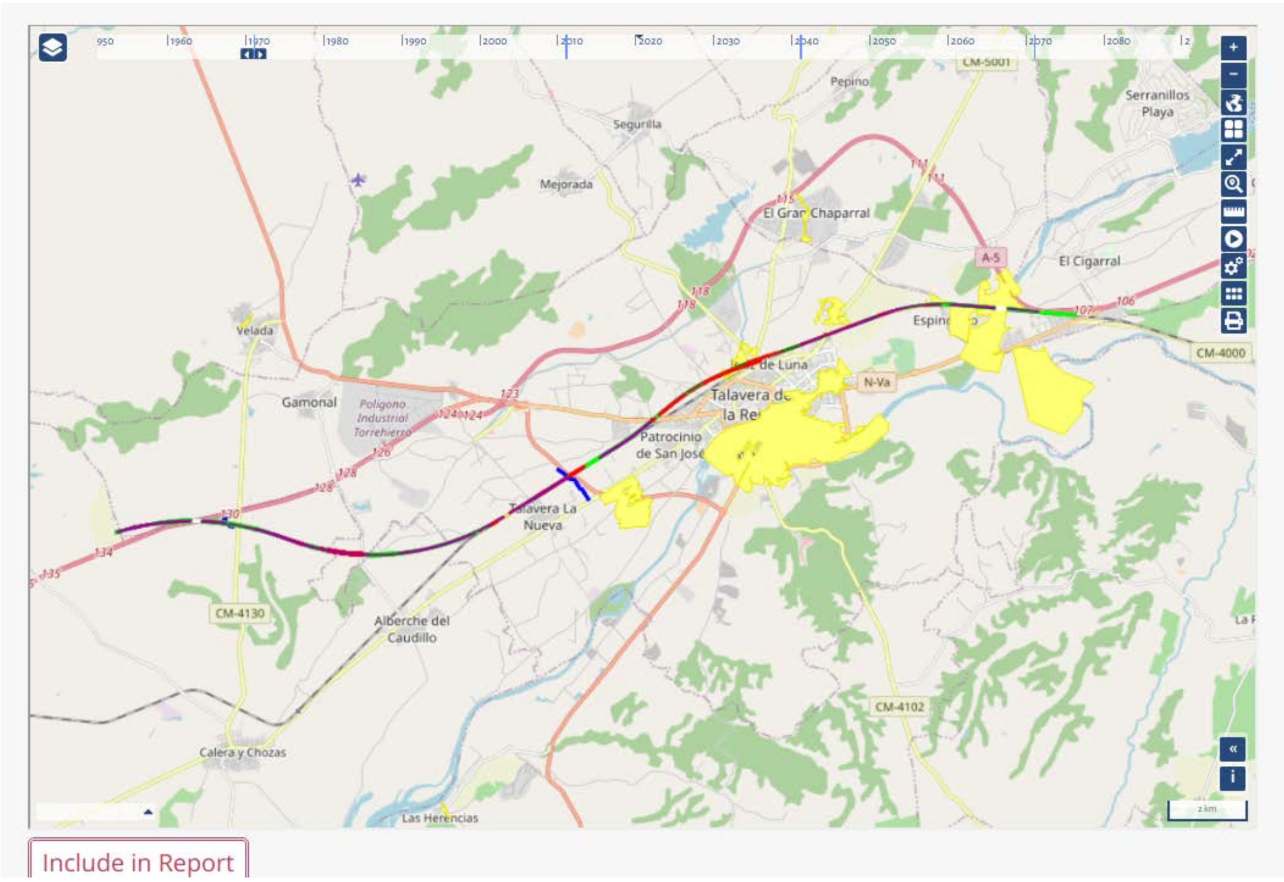


Figure 31: Case study applied to railroads in the section that runs through the municipality of Talavera de la Reina (Toledo)

4 CSIS Validation

4.1 Technical Validation

Technical validation of integrated CSIS and its Building Blocks was performed by means of unit tests, integration tests and user acceptance tests with the aim to increase overall software quality, stability and value proposition.

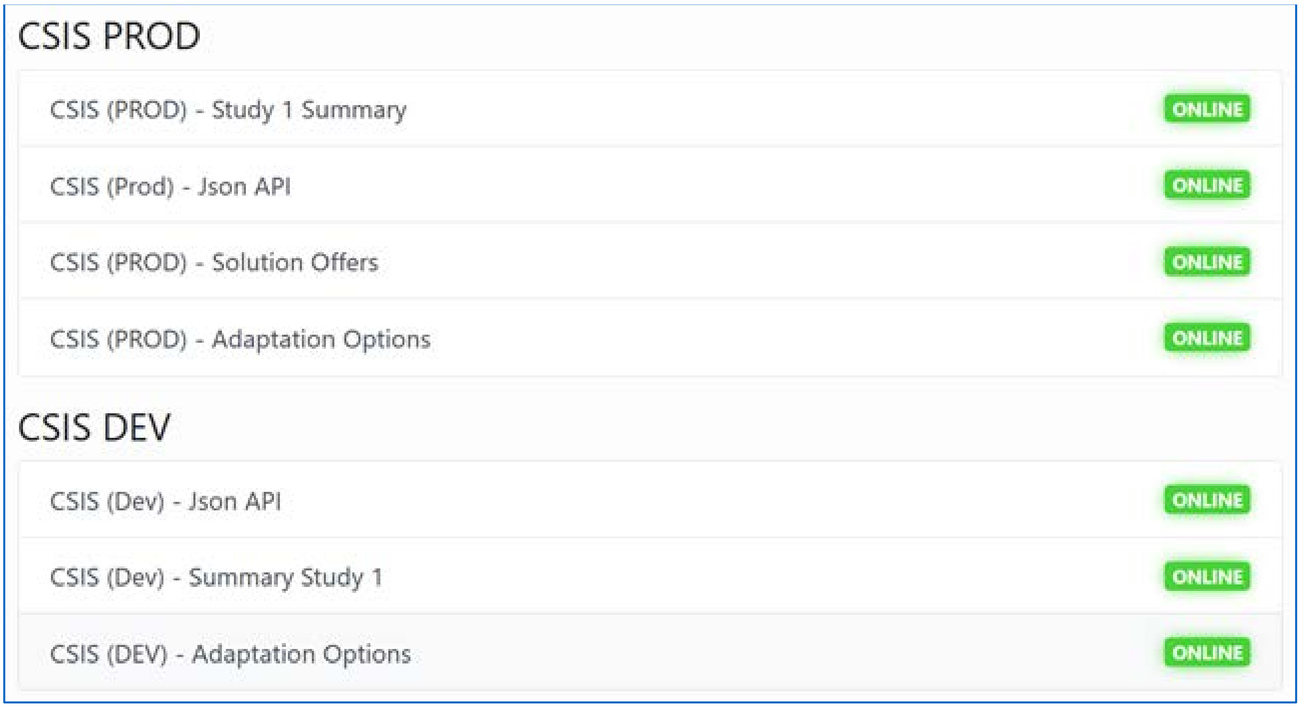
Actual tools used for implementing CSIS technical validation concept include:

- Service monitoring for detecting any service disruptions and for initiating appropriate remediation measures.
- Automated unit- and integration tests based **cypress.io** to ensure that user interfaces as well user interactions are working as specified.
- User Acceptance Tests.

4.1.1 Service Monitoring

The following CSIS Services are monitored with help of **statping**, a status page and monitoring server for websites, applications and web services:

- CSIS Production System
- CSIS Development System
- EMIKAT REST API
- EMIKAT GeoServer
- ATOS GeoServer
- CLARITY CKAN



The statping monitoring service is deployed as a docker container on a dedicated machine. It is itself again monitored by a cypress.io-based test specification that is executed on Jenkins CI. Developers are notified by email and a new issue is posted in repository csis-technical-validation when one of the monitored services fails.

Unit tests

Automated unit tests for several apps that are build on Jenkins CI and that are deployed together with CSIS Drupal Containers are performed on Jenkins CI. These include:

- CSIS Helpers JS Module
- Map Component
- Simple Table Component
- Scenario Analysis

S	W	Name ↓	Last Success	Last Failure	Last Duration	Fav
		csis-cypress	26 min - #666	2 hr 26 min - #665	3 min 24 sec	
		csis-dev-cypress	2 hr 12 min - #126	12 min - #127	3 min 7 sec	
		csis-helpers-js	5 days 1 hr - #19	11 days - #10	1 min 37 sec	
		emikat-cypress	2 hr 26 min - #278	N/A	24 sec	
		health-check-cypress	7 hr 38 min - #105	N/A	23 sec	
		map-component	3 days 1 hr - #41	1 mo 3 days - #32	19 min	
		profiles-cypress	1 hr 20 min - #553	N/A	27 sec	
		simple-table-component	4 days 1 hr - #29	N/A	15 sec	

Icon: S M L

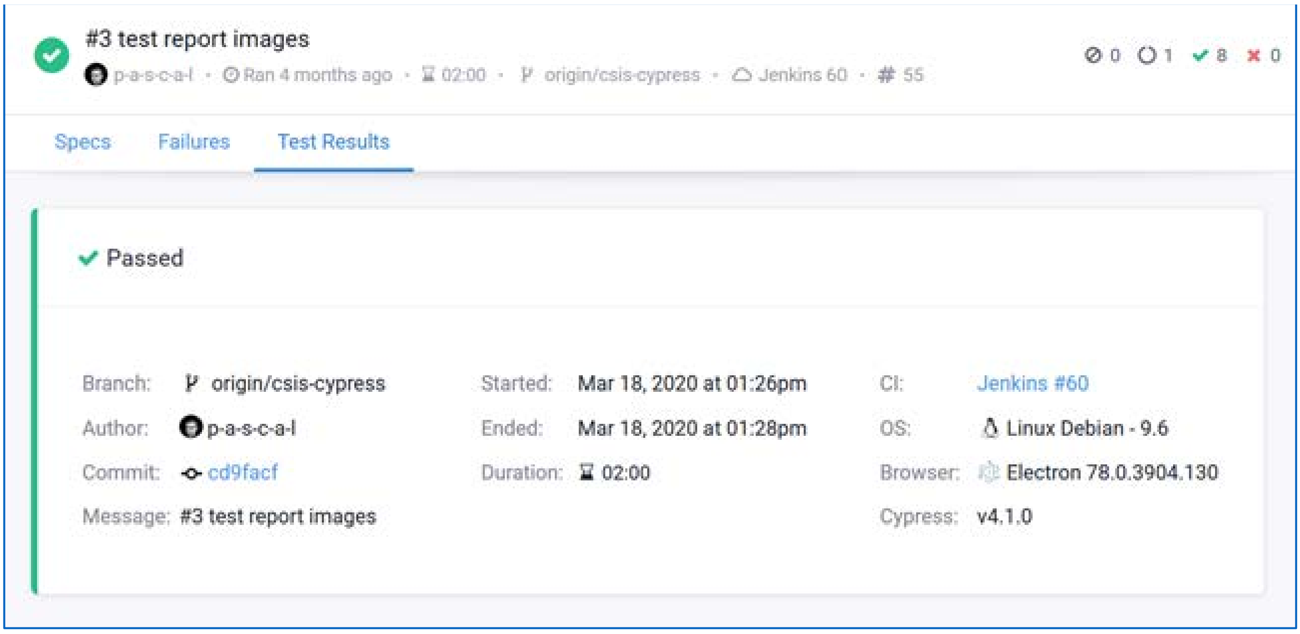
Legend RSS for all RSS for failures RSS for just latest builds

If any of the unit tests fails, developers are notified by email and a new issue is posted in the respective repositories.

4.1.2 Integration Tests

UI Integration tests are performed against the CSIS development and production system as well as the myclimateservices user portal and the AIT EMIKAT status page. The tests are performed with help of cypress.io and executed on Jenkins CI. The test specifications are maintained in repository csis-technical-validation in the following branches:

- profiles-cypress
- csis-cypress
- csis-dev-cypress
- emikat-cypress



If any of the test fails, the CI system will automatically post a new issue in the repository csis-technical-validation.

4.1.3 User Acceptance Tests

To ensure that CSIS, especially the novel climate screening tool, is "fit for purpose", that is, it delivers the proposed value, the CSIS Testing Team performed acceptance test following the Acceptance Test Specification. Feedback was collected with help of the GitHub platform by means of testing issues in a specific repository: csis-technical-validation.

The Testing Team was formed by one or two testers from each of the members of the consortium. In total, there were seventeen feedback issues created reporting on usability, bugs, results validation, and general feedback.

4.2 Scientific Validation

The Scientific Validation has been performed focusing on several aspects of the system. It has covered the Local Effects results and models involved in their calculation, it has also covered the different perspectives, models and data used for each of the Demonstrator cases for most of the relevenat steps as described in the EU-GL.

This information has already been extensively presented on D3.3, so this section contains only a summary of the information contained there.

4.2.1 Local Effect Validation

The EURO-CORDEX data at 0.11° resolution as it stands is too coarse to analyse the impacts of climate change at the urban/city scale. Therefore, there is a need to provide information on finer spatial scales through the application of downscaling techniques. Section 2.2.1 of Deliverable 3.2 outlined the physical principles behind the downscaling methods to be used to calculate the local effect for heat waves and flooding. What is presented in the following concerns refinements to the heat model in its calibration and validation (Sections 2.1.2.1 – 2.1.2.2). The flood model was simplified using a similar approach to that used within DC1, and is still under development (Section 2.1.2.3).

4.2.1.1 Heat wave events as input for local effect calculation

Although several definitions of heat waves exist in the literature ([4], [5], [6]) , including those calculated in the list of climate indices, a suitable definition of heat waves had to be used to relate them to the excess mortality rate for the local effect calculation, e.g. [7]. Accordingly, a heat wave which has a detrimental effect on health is defined as *a period of at least two consecutive days and to have maximum daily temperatures equal to or exceeding the 95th percentile of the daily maximum temperature during the warm season (April – September) of the baseline period*. The rate of occurrence of a heat wave is classified as occurring either:

- Once per year (frequent event; probability of occurrence in a year = 1.0),
- Once in 5 years (occasional event; probability of occurrence = 0.2), or
- Once in 20 years (rare event; probability of occurrence = 0.05).

Heat wave events of the three rates of occurrences have been calculated for each EURO-CORDEX grid point in Europe. As an aside it should be noted, that the definition of such events is not unique – it is possible that a heat wave of longer duration with a lower maximum daily temperature has similar probability of occurrence as a heat wave of a shorter duration but with a higher maximum daily temperature. In such cases, the latter type of (intense) heat wave event with the greater maximum daily temperature is used, with the idea being that heat wave intensity *may* be more of a major driver of heat wave associated mortality compared with duration.

4.2.1.2 Heat wave local effect at screening level

The accuracy of the heat wave local effect model (HWLEM) developed by PLINIVS-LUPT has been evaluated by comparing its results against those from the validated SOLWEIG tool[8] in two ways:

1. By running the HWLEM from within the Demonstration Case of Naples (DC1), and
2. By running the HWLEM within the CSIS as a screening level study.

From the outset it is to be expected that the margin of error will be lower using the first comparison than for the second. This is because the land use data currently available within CSIS is of lower resolution than that available within DC1, and that the georeferencing method is different.

A calibration of the parameters used in the model has been performed on the DC1 version of the HWLEM, following the comparison on sample areas characterized by different land uses distributions (see following section). The adjusted parameters are then transferred to the CSIS version of the model.

4.2.1.3 Calibration of the Heat wave local effect model

The DC1 version of the heat wave local effect model is based on a specific land use classification . The calculation of the Mean Radiant Temperature (T_{MRT}), which is an important variable used for the thermal comfort (see Section 2.2.1 of D3.2 for more information), requires as input albedo, emissivity, sky view factor, vegetation shadow, surface temperature, among others. Values of these quantities have been specified for each land use class for Naples.

A series of preliminary tests were conducted by varying one of the key parameters mentioned previously on sample areas in Naples. It was found that the major discrepancies in the results concern the value of surface temperature (Ts). To better calculate this parameter, the HWLEM uses a table that correlates, for each land use class, Ts to the air temperature (Ta) and the solar radiation for each land use class. The correction of this value, originally attributed through literature, has been performed using another validated model, ENVI-met v4.0, which is able to parameterize that relationship for relevant land use classes . This refinement step allows Ts to be calibrated in the DC1 version of the HWLEM, the results of which are shown in Figure 3. Here values obtained through SOLWEIG, ENVI-met and the PLINIVS-DC1 HWLEM are shown for 24 test points (x-axis) corresponding to four different land use classes.

The new run of the HWLEM following this first calibration step (“T_{MRT} PLINIVS 2” in the graphs shown in the following pages) produced values of T_{MRT} values in better agreement with SOLWEIG in the cases of sunny areas. To improve the HWLEM in shaded areas, the values of the transmissivity parameter Ts were further calibrated.

4.2.2 Validation of results

This section illustrates the steps performed first to validate the PLINIVS-DC1 version of the Heat Wave Local Effect Model (HWLEM) against the results obtained with SOLWEIG, which is a model well regarded in the literature as a validated model, and then discusses the validation of the CSIS version of the HWLEM.

PLINIVS-DC1 Heat Wave Local Effect Model Validation

The SOLWEIG and PLINIVS-LUPT models measure outdoor thermal comfort using T_{MRT} as a main indicator. The difference between the two models is that the PLINIVS-LUPT HWLEM uses vector input data and produces output data on a 250 m × 250 m grid, while the SOLWEIG model uses raster data both as input and output. This allows a 3D analysis of radiation flux through the use of a DSM (Digital Surface Model) of the urban environment and to dynamically simulate local microclimate conditions based on regional climate data and urban morphology information. To allow a comparison, the results of the respective models have been homogenized by computing SOLWEIG results on the same grid 250 m × 250 m as for the PLINIVS-LUPT HWLEM (**Figure 30**).

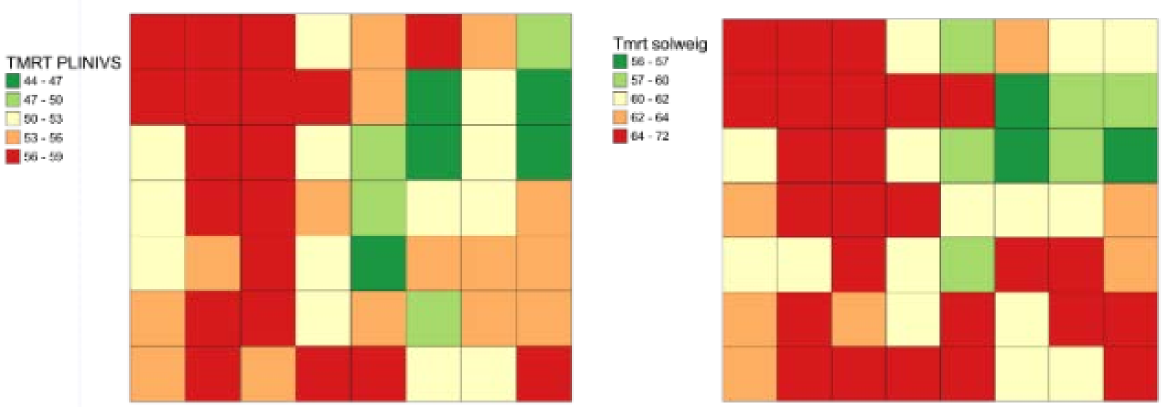


Figure 32: Comparison of T_{MRT} from PLINIVS-DC1 HWLEM (left) and SOLWEIG (right) before the calibration for 56 sample points.

Before the calibration, a comparison of the models shows that the values of T_{MRT} from the PLINIVS-LUPT HWLEM are lower than those from SOLWEIG for all sample points analysed (**Figure 31**).

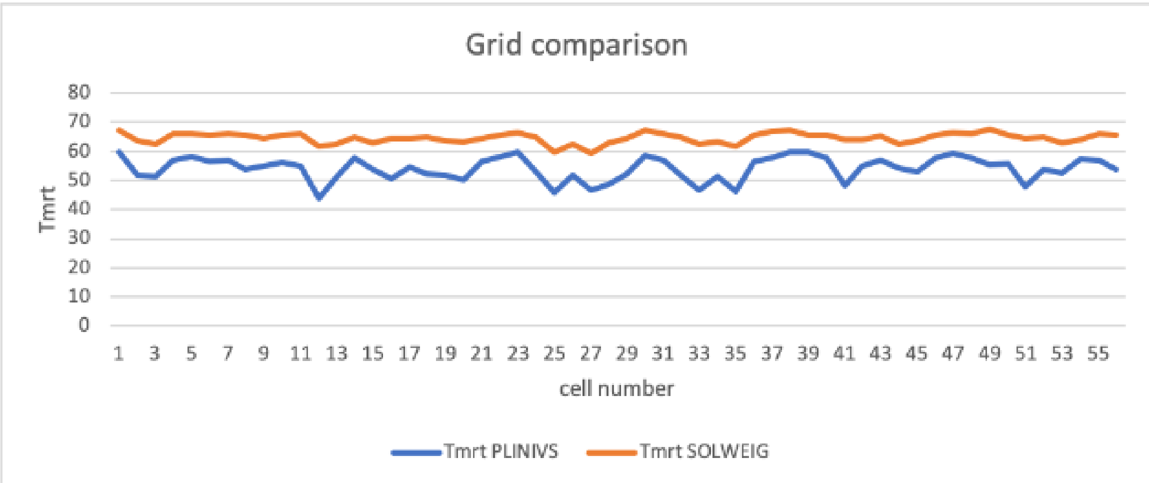


Figure 33: Comparison of T_{MRT} values (y-axis) from the PLINIVS-DC1 HWLEM and SOLWEIG before the calibration for each of the 56 cells (x-axis) in the analysed sample.

Implementing the calibration process described in Section 2.1.2.2.1 along with the further calibration of parameters related to the influence of buildings and trees shadow on T_{MRT} values within the HWLEM produced results much were more aligned to those from SOLWEIG (**Figure 32** and **Figure 33**).

Through the calibration, the T_{MRT} results from the PLINIVUS-LUPT HWLEM show about 46% of the analysed cells deviate by less than ±2.5 °C from SOLWEIG, 25% between ±2.5 - 5 °C and 18% between ±5 – 7.5 °C. For the samples cells analysed, on average, the T_{MRT} from the PLINIVS-LUPT HWLEM is approximately 3.6 °C lower than SOLWEIG. In general, the most marked differences are found in cells that with a prevalence of trees and vegetated areas land uses. In the next developments of the model further calibration will be conducted to improve the matching of PLINIVS HWLEM results with the reference SOLWEIG model.

These results are considered satisfactory for the purpose of highlighting the areas for which the urban context conditions determines an aggravation of the heat wave hazard, and as such the PLINIVS-HWLEM is considered appropriate for its use within CLARITY. The validation and calibration process will be in any case continued in the next months adding further sample cells in the database and analysing the results to determine possible further refinement of the values adopted for the model parameters.

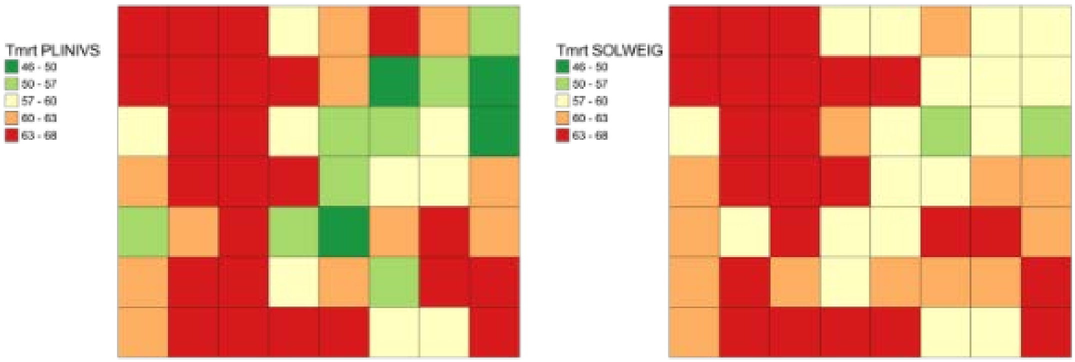


Figure 34: Comparison of T_{MRT} from PLINIVS-DC1 HWLEM (left) and SOLWEIG (right) after the calibration, for 56 sample cells.

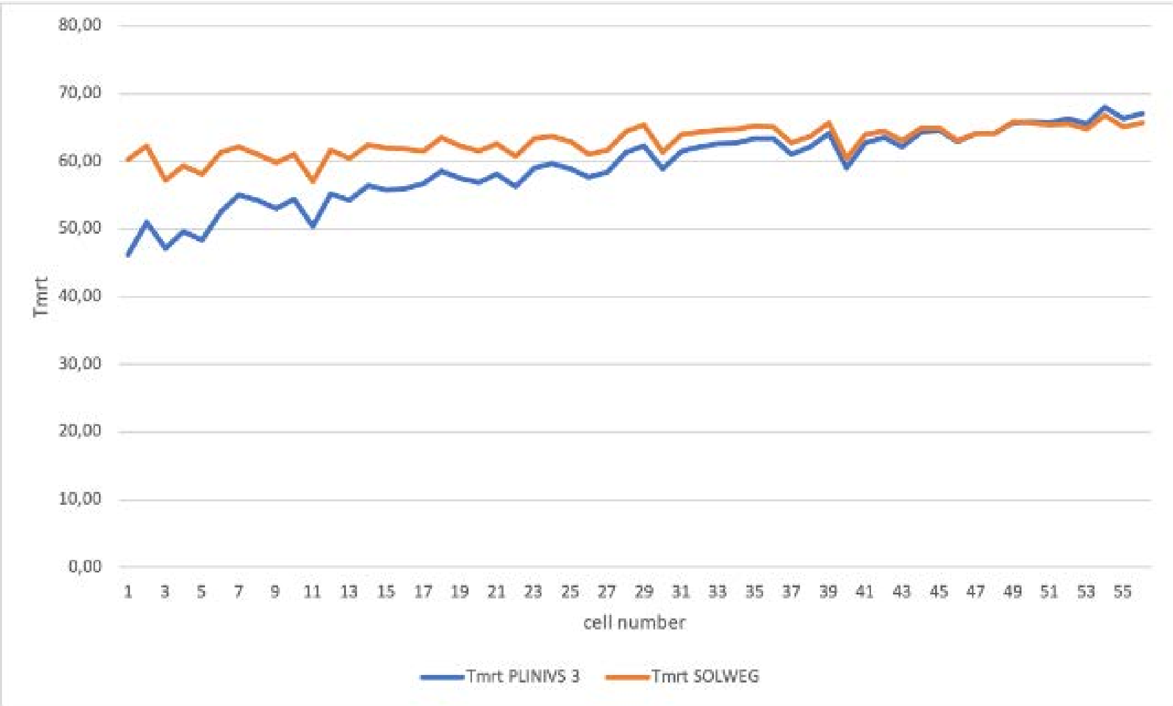


Figure 35: As in **Figure 31** but after the calibration steps have been implemented

4.2.2.1 CSIS Heat Wave Local Effect Model Validation – Post Calibration

The CSIS HWLEM validation can be performed using the CSIS for any given European city included in the CSIS database with the results obtained for the same urban area, both through on site measurements (provided that key input parameters such as global radiation, air temperature, air humidity, etc. are the same used for the CSIS calculation) and/or by applying a validated model able to calculate the T_{MRT} values depending on meteorological and land use data.

A number of reference heat wave events (i.e. combination of time period, RCP scenario and frequency) have been randomly selected on the CSIS to perform the comparison between the CSIS HWLEM and PLINIVS HWLEM, namely:

1. Historical, frequent;
2. 2011-2040, RCP4.5, occasional;
3. 2011-2040, RCP8.5, frequent;
4. 2041-2070, RCP8.5, rare.

Although the CSIS HWLEM and PLINIVS HWLEM use the same logical model (i.e. the Solar LongWave Environmental Irradiance Geometry model - SOLWEIG) to estimate the heat wave hazard including spatial variations due to relevant microclimate variables, the algorithms implemented to calculate T_{MRT}, which are based on pan-European open data in the case of CSIS HWLEM and on detailed land use information in the case of PLINIVS HWLEM, do show some differences that are reflected in the models' results. This directly affects the specific attribution of land-use-dependent parameters (e.g. emissivity, albedo, Ts/Ta, etc.) in each cell. Another difference is associated with CSIS HWLEM considering building shadow ratios dependent on built-up densities, while PLINIVS HWLEM calculates shadow masks depending on actual building heights (which is information currently not available for all cities in Europe through reliable open data sources). The third, and perhaps most important, difference is that for the CSIS HWLEM and PLINIVS HWLEM use different coefficients in the calculation of Incoming Short-Wave Solar Radiation fraction and Diffuse Short-Wave Solar Radiation fraction – 0.27×G for Diffuse and 0.77×G for Incoming in CSIS, while PLINIVS use 0.30×G for Diffuse and 0.70×G for Incoming (where G is the global solar radiation, fixed at noon of 21th June in both models).

When the results from the CSIS HWLEM and PLINIVS HWLEM were compared, discrepancies were found in some sample cells where the difference in land use attribution between the two models is more marked. In the sample area used for the comparison, these cells are located south of the study area, on the coastline, where the CSIS HWLEM model attributes to a large portion of these cells (> 10%) the land use "water", which is currently not included in the PLINIVS HWLEM classification (**Figure 34**).

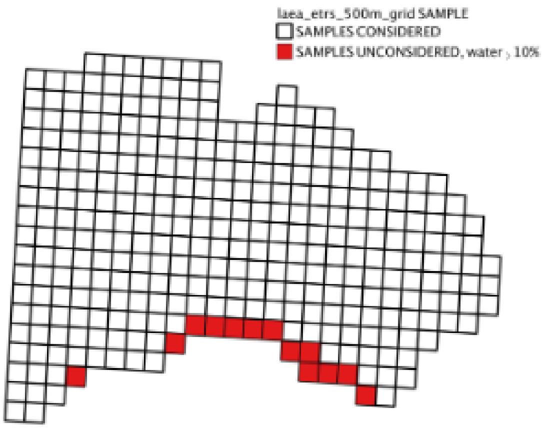


Figure 36: Sample cells excluded by the comparison for relevant discrepancy in land use attribution**.**

The comparison between CSIS HWLEM and PLINIVS HWLEM was performed twice, before and after the calibration of the Ts parameter (see Section 2.1.2.2.1). In the following paragraphs these two CSIS results are indicated as T_{MRT} CSIS 1 / DELTA 1 and T_{MRT} CSIS 2 / DELTA 2. "DELTA" indicates the differences in T_{MRT} resulting from the CSIS HWLEM and PLINIVS HWLEM calculations. The following figures show the results of the comparison for the 310 cells examined for the 4 Scenarios (A, B, C, D).

As explained in D3.3 (section 2), the results obtained following the calibration of Ts parameter in the CSIS HWLEM are considered acceptable, with a mean underestimation of the T_{MRT} always below 5°C for all scenarios.As explained above, this is mainly due to a different value of the Incoming/Diffuse Short-Wave Solar Radiation fraction. In fact, when performing the comparison applying the same Diffuse and Incoming short-wave fraction solar radiation values, the Delta (mean) is 0.2 °C (**Figure 35**).

T_{MRT} PLINIVS 2	T_{MRT} CSIS 2	DELTA 3
62.9 °C	63.1 °C	0.2 °C

Scenario: 2011-2040, RCP4.5, occasional. (Tair 39 °C)

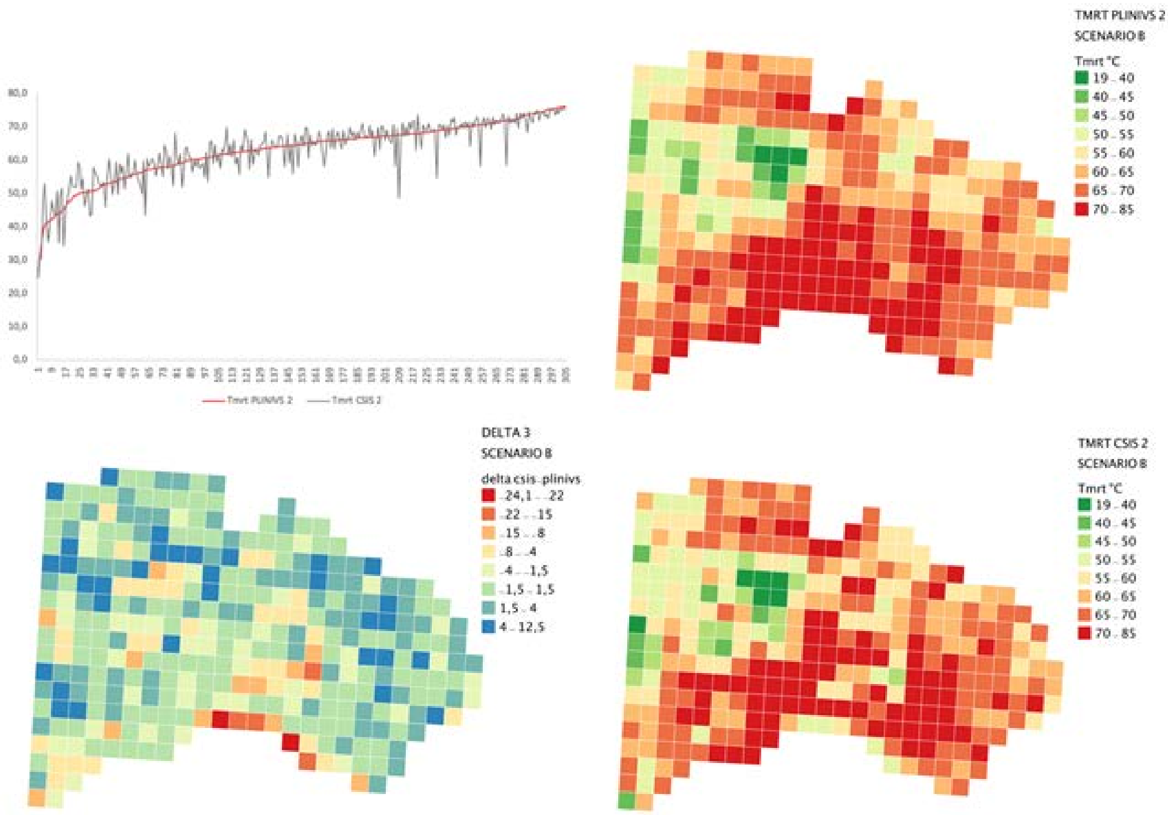


Figure 37: Comparison graph, T_{MRT} and Delta maps for Scenario B, with homogenization of Diffuse and Incoming fraction short-wave solar radiation among CSIS HWLEM and PLINIVS HWLEM. On the left the graph represents the T_{MRT} difference in the sample cells between PLINIVS HWLEM and CSIS HWLEM. The maps on the left show the difference (Delta) in the results before (CSIS 1) and after (CSIS 2) the calibration of the Surface Temperature parameter in CSIS HWLEM. The maps on the right represent the T_{MRT} values from PLINIVS HWLEM and the CSIS HWLEM before (CSIS 1) and after (CSIS 2) the calibration of the Surface Temperature parameter.

Further calibration of CSIS HWLEM parameters should allow a better alignment with PLINIVS HWLEM results (which have been validated against SOLWEIG in the native UMEP software environment). A major achievement, considering the above mentioned difference in the algorithms implemented for the two models within CLARITY, is that the difference in the results is always constant.

4.2.2.2 Urban pluvial flooding local effect at screening level

In the context of the CLARITY CSIS, the flooding hazard is considered in relation to the effect of intense and/or prolonged rainfall which generates a runoff volume greater than the capacity of existing drainage system. A simplified approach has been proposed for the CSIS flood local effect model (FLEM), which produces as output a preliminary proxy of the probability for urban areas to get flooded in case of heavy rain. This alternative model is based on the following data, to be collected and classified for each European city present in the CSIS.

- Runoff coefficient for each land use type
- Urban watersheds
- Digital Elevation Model
- Digital Surface Model
- Flow accumulation streams for each watershed
- Emergency calls for flooding (optional)

The procedure aims at identifying four main parameters for each cell of the analysis grid that contribute to the flooding probability due to land use, urban orography and hydrology:

1. Runoff coefficient
2. Relative elevation in the watershed
3. Presence of flow accumulation streams
4. Sewage system efficiency (optional)

A detailed description of the method as well as the results obtained is offered in D3.3.

4.3 Usability and Utility Validation

Within the duration of the CLARITY project towards the end and when authoritative results and the digital tools were available there were performed five **end user webinars** with regional context in English as well as local language (German, Italian, Spanish). All webinars were recorded and can be continuously watched at the respective event websites and at https://www.gotostage.com/channel/climate-adaptation

Webinar	Participants	Registered
CLARITY für Klimaresilienz - "In meiner Region: Linz/Österreich"	6	7
Climate Services as emerging market - latest trends	29	39
Análisis de vulnerabilidad y riesgo frente a cambio climático en infraestructuras de transporte. Proyecto CLARITY	31	40
In my region: urban heat adaptation in Southern, Central and Northern Europe	20	26
CLARITY for Climate Resilience La pianificazione multi-scalare dell’adattamento climatico urbano – Il caso di Napoli	24	47

From 110 persons attending the webinars 54 provided feedback by reacting to a poll at the beginning of the webinar taking part in a survey at the end of the respective webinar; not all respondents answered all questions. Registered persons are relevant for further dissemination activities since they provided their email addresses with registration, are provided with webinar summaries and can be invited for future events.

The survey questions were the same for all webinars with implementation and scientific related content. The webinar " Climate Services as emerging market - latest trends" had a slightly different questionnaire since a different, more strategic business minded audience was expected and present.

These are the summarized results from the inquiries:

Question	Options for answer	Result	Comment
How satisfied are you with the webinar content?	Score from 0-10; "terrible" to "outstanding"	8,33	Weighted average, 39 answers
How satisfied are you with the presentation style and quality?	Score from 0-10; "terrible" to "outstanding"	8,49	Weighted average, 39 answers
How can we collaborate in the future?	• I want to attend future CLARITY4Climate webinars. • I wish to contribute to future webinars. • I would like to discuss further dissemination/business opportunities. • I would like to test the service(s) that were presented in this webinar. • Please do not contact me in the future.	59% 11% 4% 26% 0%	46 answers in total; encouraging that a quarter of the respondents commits to testing.
How likely are you to use or recommend the solutions(s) presented in this webinar?	Score from 0-10; "definitely not" to "definitely yes"	8,30	Encouraging score; corresponding to valuation of content.
Was this webinar useful related to expected future challenges and developments and/or your daily work routine?	Yes/No	6/6	This question was only asked in the "CS Emerging Markets..." webinar; all respondents answered positive.

Poll-Question	Options for answer	Results	Comment
Who is with us today?	• Scientist/Developer • Business/Finances • City/Regional planning • Decision maker • Other	15 4 7 1 12	Given the nature of the project this distribution of participants was expected; unfortunately no specifications on "Other" received.

5 Conclusions

WP2 has shown the potential of CLARITY climate “Expert Services” offers in different climatic, regional, infrastructure and hazard contexts. So far, the main achievement of the DCs include the full definition of modelling workflows and the completion of related data collection activities (including metadata), the definition of relevant urban infrastructure projects to be tested, and in most of cases the completion of the hazard modelling steps with a specific focus on urban microclimate variability, the definition of exposure and vulnerability of elements at risk. These final moths has been devoted to the development of the urban infrastructurure projects at hand in a climate-resilient perspective, providing support to the end-users in investigating the effects of adaptation measures and risk reduction options in the specific project context and enabling the comparison of alternative strategies.

In parallel, work has been done on the completion of the specific “data packages” related to the different geographical contexts of the DCs, which include all the hazard, exposure and vulnerability datasets needed to perform risk/impact analyses. Such site-specific data and user-tailored elaborations has been made available through the CLARITY CSIS to all the future users under subscription, so to provide an intermediate level of analysis between the “Screening” and the “Expert Services”, by providing simulations within the CSIS environment based on the local data packages instead of the lower resolution pan-European datasets. As an example of the versatility of the system to incorporate expert studies from other organisations, different studies have been generated with the results obtained in the RESCCUE project (Barcelona and Bristol completed and Lisbon in progress) and the associated datapackages have been incorporated.

The co-development approach adopted for DCs implementation, other than allowing the needed knowledge-exchange and data production processes, is also relevant to bridge science and practice domains in the field of urban adaptation, emphasizing the need to deliver scientific information related to Climate Change Adaptation and Distater Risk Reduction in a way that is accessible to end-users, especially to local authority departments in charge of planning and design processes.

In this sense, the project aim of translating climate information into actionable results in terms of adaptive design and resilience-based planning is being actually validated by the end-user perspective expresses within the workshops. As an example, a major lesson learned is to improve the abilty to explicitly link climate adaptation to other “urban challenges” as expressed by local stakeholders (e.g. housing needs, social cohesion, financial constraints), which will be taken into account in the development of multi-criteria and cost-benefit analysis tools.

In the field of Urban infrastructure planning and design in fact, despite the interest in climate and change issues, the integration of adaptation measures is not always taken into account within territorial planning and urban development actions at regional and local level. This results sometimes in a lack of awareness of local stakeholder about the cost/benefits from effective adaptation and mitigation measures into urban planning and building/public space design activities.

Other priorities of public officials and local communities linked to urban infrastructure development, such as housing needs, public space quality, social cohesion, scarce budget for design and maintenance, etc. are often overarching compared to climate adaptation. A futher challenge concerns how to manage the possible conflicts between the stakeholders, when different levels of governance (e.g. local and national) do not have often the same objectives and/or priorities.

The finalization of two important steps has contributed to increase the effectiveness of co-creation process among “Experts” and “End-users”, namely: (1) the completion of hazard modelling steps with a resolution level able to capture the urban microclimate variations in the four demonstration case areas, and (2) the definition of pilot urban infrastructure projects and the development of detailed simulations on those areas. This aspect has increased awareness and motivation on end-users side, which have been fully engaged in supporting the DCs implementation. Last year developments have consisted in calculating the vulnerability and, consequently, the impact for the hazards considered. Finally, the adaptation options have been chosen on the base of risk and impact assessments of the projects at hand, supporting users through multi-criteria and cost-benefit parameters in order to navigate alternative adaptation choices. Thus, the second and final iteration of CLARITY Demonstration Cases have showcased to complete functionalities, operational environment and workflows of the proposed solutions.

Since the Expert services for the four Demonstration Case have been co-designed with local stakeholders in a series of dedicated end-users workshops, a major task has been the full harmonization of the four DCs with respect to the overall CLARITY logic.

In terms of EU-GL step implementation, the CLARITY developments have mainly consisted in:

- calculating hazard related indices that can be used in adaptation studies in any European city;
- the definition, implementation and integration of hazard/risk models that allow the study of local effects of heat waves and floods on any European city;
- identify and characterise the main elements exposed both in urban areas and for transport infrastructure;
- calculating the vulnerability and, consequently, the impact for the hazards considered;
- identifying the adaptation options on the base of risk and impact assessments of the projects at hand;
- supporting users through multi-criteria and cost-benefit parameters to navigate alternative adaptation choices.

The appraisal and integration of adaptation options is strongly connected to the impact model, thanks to their ability to reduce local hazard intensity (e.g. reduced heat through green cover increase) and/or vulnerability of elements at risk (e.g. protection of groundfloors and basements of buildings from flood), as well as to modify the exposure (e.g. by modifying the spatial distribution of elements at risk).

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D2.4 CLARITY Demonstrators implementation and validation report v2

Annex 1 Detailed application and validation report of the DC1 demonstrators

WP2 – Demonstration & Validation

Deliverable Lead: PLINIVS

Dissemination Level: Public

Deliverable due date: 31/05/2020

Actual submission date: 09/09/2020

Version 1.0

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730355

Annex 1 Detailed application and validation report of the DC1 demonstrators

The goal of DC1 - Napoli "Multi-scale Climate-Resilient Urban Planning" is to evaluate the benefit of integrating adaptation strategies in urban plans and redevelopment/retrofitting projects in the Metropolitan City of Naples, with a specific focus on the Municipality of Naples, its Capital city.

To provide support to urban planning and design activities in effectively integrating climate adaptation measures, DC1 focuses on sample areas representative of recurring climate-related hazards in the Metropolitan area. In particular a selection of key areas for developing climate adaptive planning within Naples' Municipality has been performed and several scales of application and different projects have been defined: Municipality of Naples on heat and flood hazards (as capital city of the Metropolitan area) and the Municipality of Castellammare di Stabia on landslide (as example application replicable in the 12 municipalities around Vesuvius).

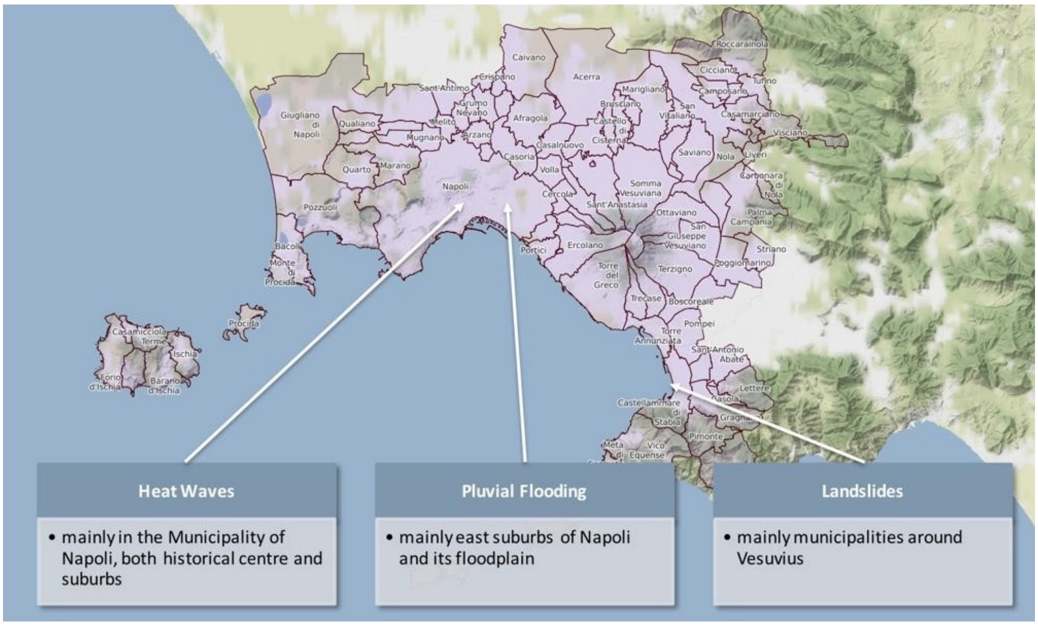


Figure 1: DC1 focus areas.

DC1 implementation follows the CLARITY modelling workflow as defined in WP3, which follows the 7-steps approach as outlined by the updated EU-GL approach (see D3.3). Through dedicated models provided by the CLARITY Expert teams involved (PLINIVS, ZAMG) and data provided by local teams (PLINIVS, NAPOLI) Hazard characterization, Exposure assessment, Vulnerability analyses, Impact assessment and Adaptation options identification, appraisal and integration have been developed in relation to Heat Wave, Flooding and Landslide risks in the area (Figure 3).

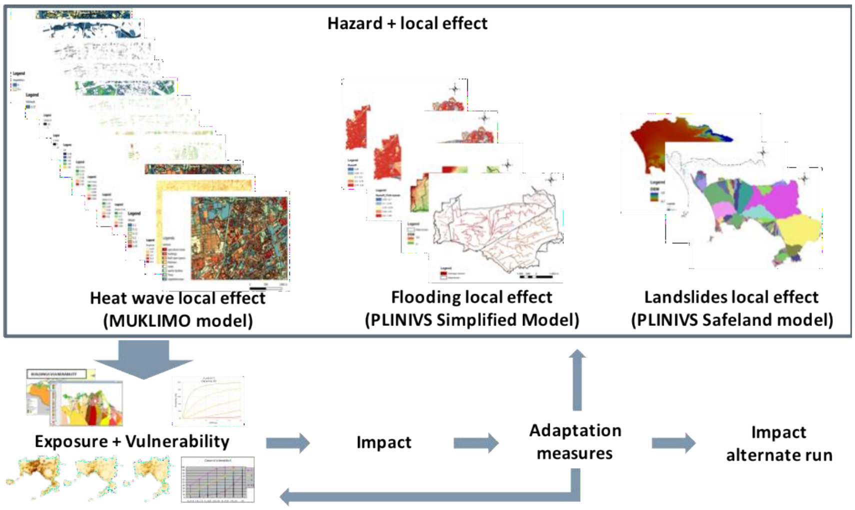


Figure 2: DC1 modelling workflow scheme.

In policy terms, on a broader urban governance level, the main objective of Naples demonstration case is to support public administration at Metropolitan and Municipal level in developing the local adaptation plan based on EU Directives and the National Strategy for Climate Change Adaptation. The implementation of the Adaptation Plan is based on the information acquired through the climate services provided by CLARITY. The DC1 implementation has allowed end-users to acquire a set of design guidelines which, according to future plans beyond CLARITY, can be further integrated to tackle the multi-risk conditions (climate, seismic, hydrogeological, volcanic) of the Metropolitan area, so to promote an integrated approach to Climate Change Adaptation and Disaster Risk Reduction within public policies and private investments.

Table 1: Relation between the main Hazards and elements at risk in DC1

	Heat	**Flood**	**Landslide**
People	+++	n/a	++
Buildings	n/a	++	+++
Roads	n/a	+	++

While in the period M1-M12 the DC1 end-user workshops and meetings with stakeholders of the Metropolitan City of Naples have mainly focused on the identification of end-user requirements/stories and on specific issues related to the data collection activity (see D2.2), since M13, the DC1 end-user workshops have been devoted to identifying the main ongoing urban projects object of the demonstrator implementation.

Following the results of the workshops of April and December 2019, the overall logic of DC1 has been consolidated, with the aim of providing a coherent multi-scale climate-resilient planning and design framework in which hazard/impact simulations, and the identification/appraisal of suitable adaptation strategies and measures – even when performed with different models and tools depending on the needed detail of information across the scales of intervention – show a consistency in the results, which can be transferred from the strategic planning level up to the detailed neighbourhood scale design.

During the DC1 Workshop in January 2020, the Technical Departments of the Municipality of Naples have identified the general framework that defines the potential contribution of CLARITY climate services in the context of a multi-scale integrated urban adaptation planning. Figure 4 summarizes such framework, highlighting the need to use the same approach for technological support across the different planning phases/stages relevant in the context of the city of Naples, as to enhance the coherence of concepts, methods and assessments at the levels of Strategic Planning, City Planning and Urban Design.

The climate change profile for Napoli area is at the base of all planning documents and it is based on the regional downscaling and bias correction provided by ZAMG, with a focus on extreme heat and precipitation events in the period 2020-2100 in terms of frequency according to the different RCPs. Three levels of planning are identified, with specific projects based on ongoing official activities already ongoing carried out by the Municipality of Naples: 1. Strategic level – Napoli Sustainable Energy and Climate Action Plan (SECAP); 2. City planning – Update of Napoli City Plan (PUC); 3. District planning – Ponticelli Urban Regeneration Plan (PRU).

Figure 3: DC1 multi-scale logic as co-designed within 2019 end-user workshops.

In this context the support to the implementation of the project "Hydraulic works on Monte Faito slopes in the Municipality of Castellammare di Stabia", which was previously identified as possible focus area, has been discarded since the project is currently stalled. The work implemented in CLARITY, and documented in D2.3, has been delivered as a baseline for a future follow-up collaboration according to the new timeline of the project, which should be inserted in the next ERDF funding period 2021-2027. The landslide case is therefore excluded from D2.4 content.

Table 2summarizes the identified projects M39. The priority index refers to the current status of project implementation carried out by the Technical Departments of the Municipality of Naples. In the context of CLARITY, the highest priority has been given to the projects for which official deadlines are set in 2020, therefore requiring the results of Expert Services to be integrated in the official project documentation.

Table 2: DC1 project areas.

Project	Hazard(s)	Funding	Priority
Naples Sustainable Energy and Climate Action Plan (SECAP)	Heat Wave / Flood	Municipality of Naples	XXX
Naples City Plan (PUC)	Heat Wave / Flood	Municipality of Naples	XXX
Ponticelli Urban Regeneration Plan (PRU)	Heat Wave / Flood	National / EU (ESF 2007/2013)	XXX
Tram / BRT infrastructure with green areas arrangement (east Naples)	Heat Wave / Flood	EU (ERDF 2014/2020)	XX

Soccavo-Pianura local area plan	Heat Wave / Flood	Municipality of Naples	XX
Miano local area plan	Heat Wave / Flood	Municipality of Naples	XX
Municipality of Naples Building Code update (City Level incentives to private action)	Heat Wave / Flood	Municipality of Naples	Possible follow-up
Hydraulic works on Monte Faito slopes in the Municipality of Castellammare di Stabia	Landslides	EU (Cohesion Fund 2007/2013)	Possible follow-up

The following sections illustrate the final results of DC1, focusing on the multi-scale approach to urban adaptation in relation to the Heat Wave and Flooding hazards, in line with the priorities as expressed by the end-users involved in the DC implementation. The main achievements of DC1 consist in the possibility of exploring the impact of climate-related hazard on the selected elements at risk with a progressive level of detail, always taking into account the "local effect" determined by the urban microclimate and the specific features of local settlements, as well as the definition of exposure parameters for the three hazards considered. The levels of detail range from a 250x250m mesh overlapped to the territory for city-wide analyses, up to a 1x1m and 3D representation for neighbourhood scale simulations.

The choice of the reference grid has been agreed with the local end-users, and it is the same grid used by local authorities and civil protection to perform risk and impact assessment of other relevant natural hazards in the area, such as earthquakes and volcanic eruptions. This will allow to harmonize the output derived from CLARITY modelling workflow with that from seismic and volcanic risk impact assessments already available for the Metropolitan City of Naples, thus allowing the identification of existing multi-risk conditions, as well as the development of potential integrated strategies for climate change adaptation and disaster risk reduction in the area. Such an approach increases the end-users awareness towards the need of implementing holistic resilience-based urban planning and design interventions, streamlining funding allocations in relation to the diverse sources of risk and the urban infrastructure developments in place or programmed. Table 3 shows the main datasets used as input for the modelling workflow of DC1 related to Heat Wave and Flood risks, the model owners/responsible and the data providers.

Table 3: DC1 models and datasets categories/providers (detailed information on data and metadata storage is included in D2.2).

Models	**Datasets – sources**
MUKLIMO (heat - urban microclimate) (ZAMG)	• Meteorological data (temperature, wind speed, relative humidity) – NAPOLI • Mean building height; Building typology classification; Wall area index; K-value of the building walls and roofs; Area heat capacity of the building walls and roofs – PLINIVS • Fraction of impervious surface between buildings; Surface roughness of the non- built-up areas – PLINIVS • Vegetation parameters (Tree height, Stem height, Leaf area density, Leaf area index, Vegetation height of the canopy layer, Tree cover, Vegetation cover) – PLINIVS • Albedo of the walls, roofs and impervious parts of the canopy layer – PLINIVS • Land Use – Urban Atlas, NAPOLI
PLINIVS Heat Wave Local Effect Model (HWLEM) (PLINIVS)	• Meteorological data (temperature, wind speed, relative humidity) – NAPOLI • Frequency and intensity of Heat Wave events 2020-2100 – ZAMG • Global, diffuse and direct radiation information – PLINIVS • Vegetation parameters – PLINIVS • Surface Temperature, albedo, emissivity and tansmissivity of each Land Use category – PLINIVS • Hillshade buildings and vegetation – PLINIVS • Land Use – NAPOLI / PLINIVS

PLINIVS Flood Local Effect Model (FLEM) (PLINIVS)	• Precipitation data – NAPOLI • Frequency and intensity of Extreme precipitation events 2020-2100 – ZAMG • DSM; DTM – NAPOLI (Lidar) / PLINIVS • Land Use – NAPOLI / PLINIVS • Urban Basins; Flow direction; Flow accumulation (sewage overload); Run-off – PLINIVS
PLINIVS HW / FL Vulnerability model (PLINIVS)	• Mortality rate information – EUROSTAT • Heat Wave parameters data – PLINIVS • Buildings economic damage level – PLINIVS • Flow velocity – PLINIVS • Flow depth – PLINIVS
PLINIVS HW / FL Impact model (PLINIVS)	• MUKLIMO / PLINIVS HWLEM/FLEM output; PLINIVS HW / FL Vulnerability model output; PLINIVS HW / PF Exposure model output

1.1.1 Technical validation

The CLARITY aim of translating climate information into actionable results in terms of adaptive design and resilience-based planning has been successfully validated from the end-user perspective through the several workshops conducted within DC1, whose results are reported in the sections of this deliverable. However, a major lesson learned is to improve the abilty to explicitly link climate adaptation to other “urban challenges” as expressed by local stakeholders (e.g. housing needs, social cohesion, financial constraints), which will be taken into account in the development of ad hoc multi-criteria and cost-benefit analysis tools, co-designed with NAPOLI stakeholders.

A major feedback from Napoli end-user concerns the wide consensus of different stakeholders’ groups that in the field of Urban infrastructure planning and design, despite the interest in climate and change issues, the integration of adaptation measures is not always considered within territorial planning and urban development actions at regional and local level. This results sometimes in a lack of awareness local stakeholder about the cost/benefits from effective adaptation and mitigation measures into urban planning and building/public space design activities. Other priorities of public officials and local communities linked to urban infrastructure development, such as housing needs, public space quality, social cohesion, scarce budget for design and maintenance, etc. are often overarching compared to climate adaptation.

At the level of potential end-users, such as local administrations in charge of urban regeneration or transport infrastructure projects, a main challenge is due to the difficulty to align the EU project timing with that of ordinary activity of city/region planning departments. This affects the co-development process, making inevitable to define some implementation steps internally to the project consortium, which can only be validated afterwards by the involved users.

A futher challenge concerns how to manage the possible conflicts between the Stakeholders, when different levels of governance (e.g. local and national) do not have often the same objectives and/or priorities.

1.1.2 Climate change profile for the City of Naples

Naples, as many urban areas in the Mediterranean Europe, has already been facing in recent years a significant climatic variation compared to the 1971-2001 “historical” reference period. The last few years have shown a constant increase in the minimum and maximum temperatures (to which more frequent episodes of heat waves are associated), while seasonal precipitation patterns have seen an increasingly marked alternation between periods of drought and extreme events characterized by high rainfall concentrated in a few hours (which cause episodes of superficial flooding, even critical ones). The available simulations referring to future scenarios (until 2100), confirm these trends, with uncertainties related to the intensity of the expected climate change related to different of GHG emission scenarios on a global scale.

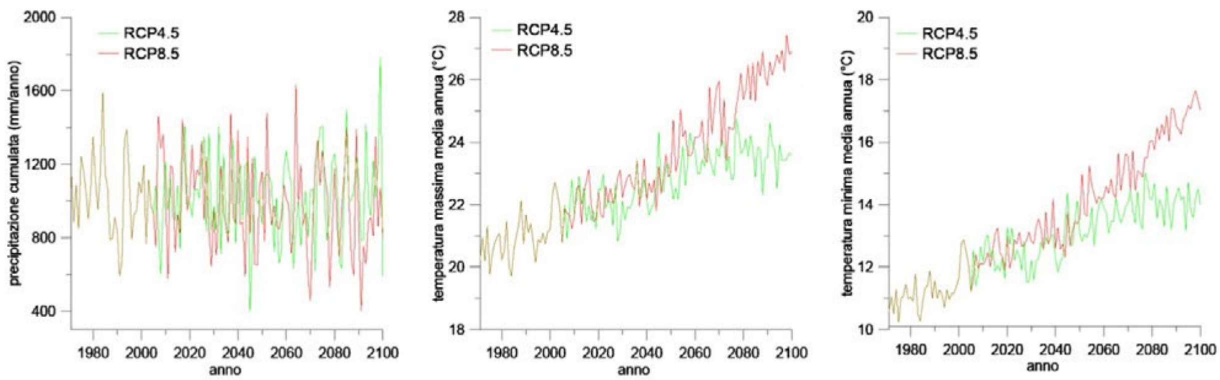


Figure 4: Annual averages in the period 1971-2000 of rainfall and air temperatures for the city of Naples. For the 1971-2000 period, annual cumulative precipitation values (left), average maximum (centre) and minimum temperature (right) are elaborated from Capodichino Station; for 1971-2005, models are forced through observational datasets (20C3M) while for 2006-2100 the concentration scenarios RCP4.5 (green) and RCP8.5 (red) are considered. Source: CMCC – Centro Euro mediterraneo sui Cambiamenti Climatici.

Annual average values elaborated with statistical methods from observations on single weather stations (Figure 5), however, do not allow the representation of the critical issues that cities face regarding climate change. It is necessary to have more precise information about the frequency of extreme temperatures and precipitation events (often concentrated in limited periods of the year and therefore not represented by annually averaged values) and to consider how the impacts of these extreme events can be aggravated by specific urban characteristics, such as the urban heat island effect and surface run-off conditions.

CLARITY has therefore focused on defining these aspects, identifying in detail the increase in frequency of heat waves and heavy rainfall until 2100, and by elaborating an accurate modelling of urban morphology and land use to capture the effect of built environment features on the urban microclimate.

The processing of the different datasets through the simulation models developed by the PLINIVS-LUPT Study Centre for CLARITY allows the identification of the expected levels of hazard related to heat waves and surface flooding. This information forms the basis of the corresponding impact models, currently being calibrated, which will allow one to identify the effects of heat waves on the population (in terms of impacts on human health, including the increase in mortality), and the effects of flooding on buildings (in terms of interruption of road networks and economic damage to property or production activities).

1.1.2.1 Heat waves

Heat waves occur when high temperatures are recorded for several consecutive days, often associated with high humidity, strong solar radiation and absence of ventilation. These weather-climatic conditions can represent a risk to the health of the population (Source: Italian Ministry of Health, 2019).

Figure 6, Figure 7 and Figure 8 show the results for the mean annual number of summer days, hot days and tropical nights, respectively, for the baseline period 1971-2000. These are based on urban climate simulations at 250 m resolution and an ensemble of historical (uncorrected) EURO-CORDEX simulations listed in Table 4. Urban Atlas land use data11 complemented with CORINE land cover data12 and standardized representative parameters regarding building structure, percentage of soil sealing and vegetation information were used as input for the urban climate simulations.

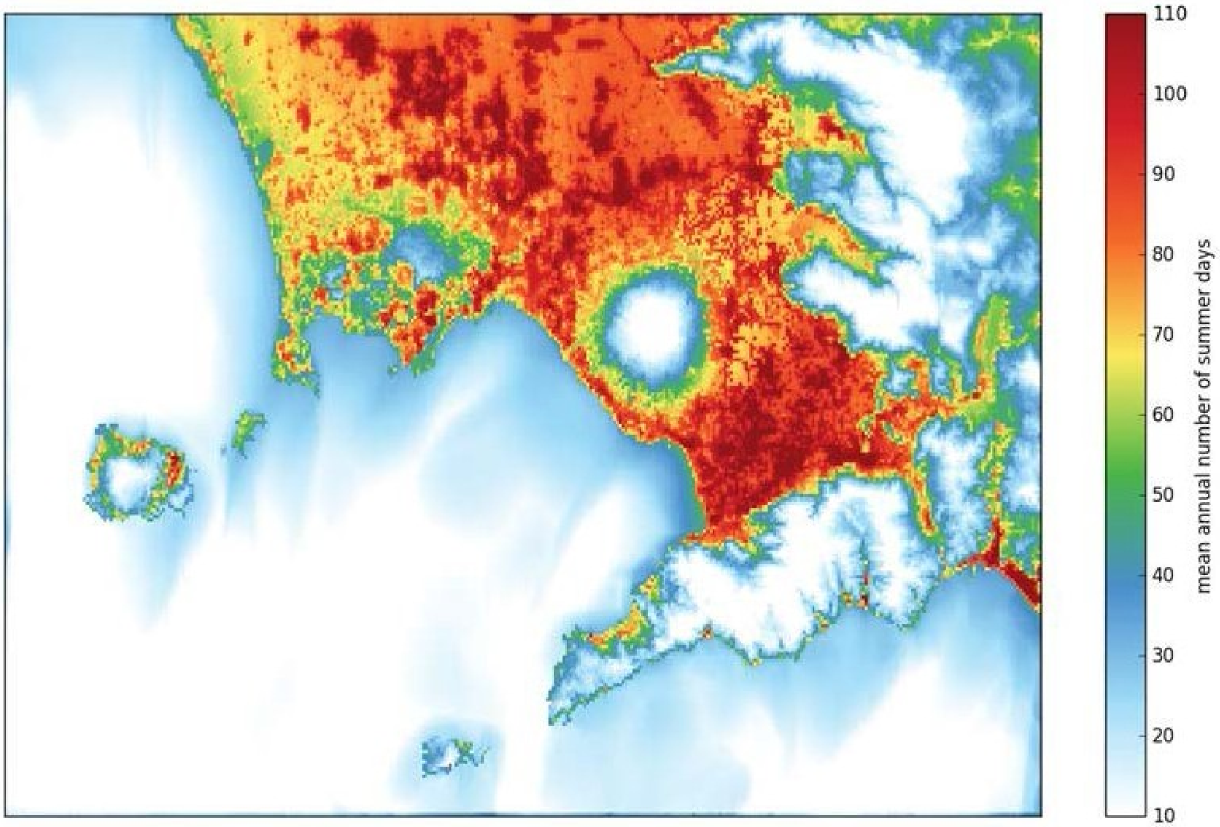


Figure 5: Mean annual number of summer days (daily maximum temperature > 25°C) derived from the cuboid method and MUKLIMO_3 urban climate model results, based on long-term climate information from EURO-CORDEX regional climate historical scenarios for the period 1971-2000.

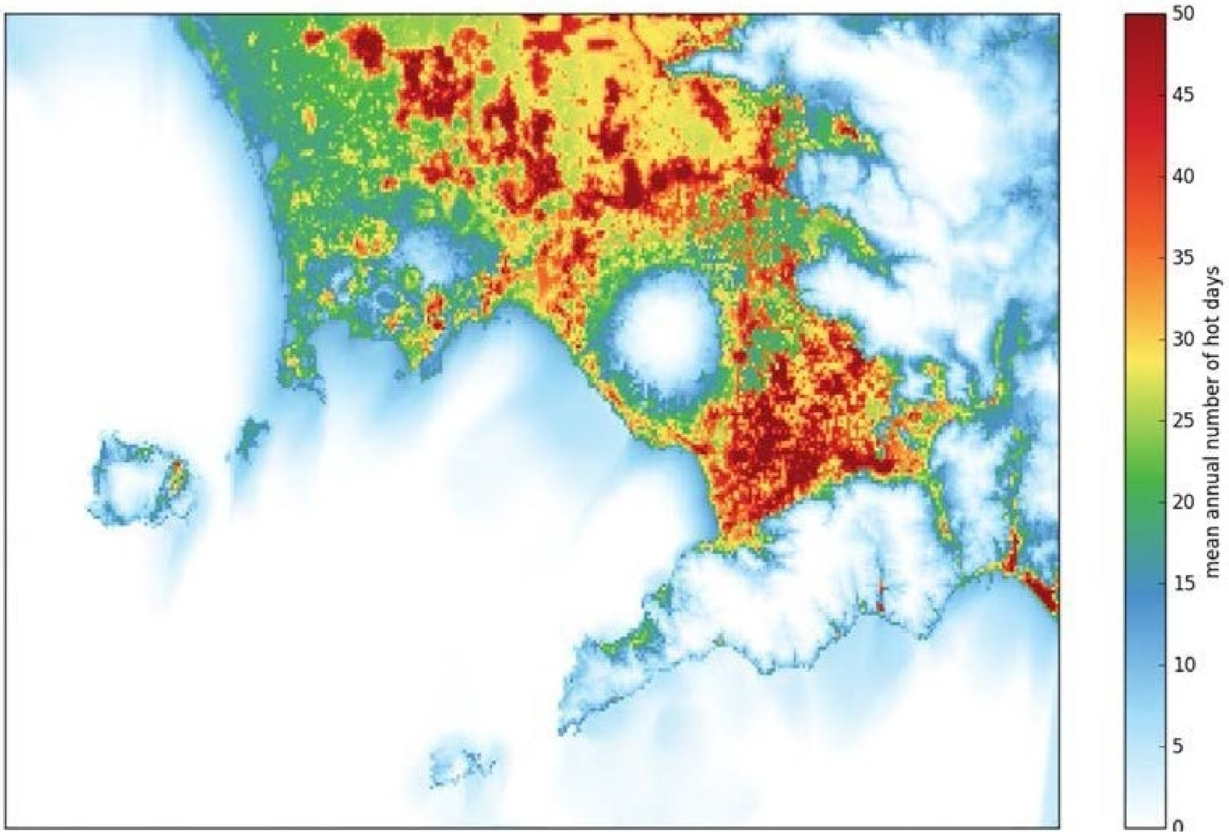


Figure 6: Annual average number of hot days (daily max. temperature > 30 °C), period 1971-2000.

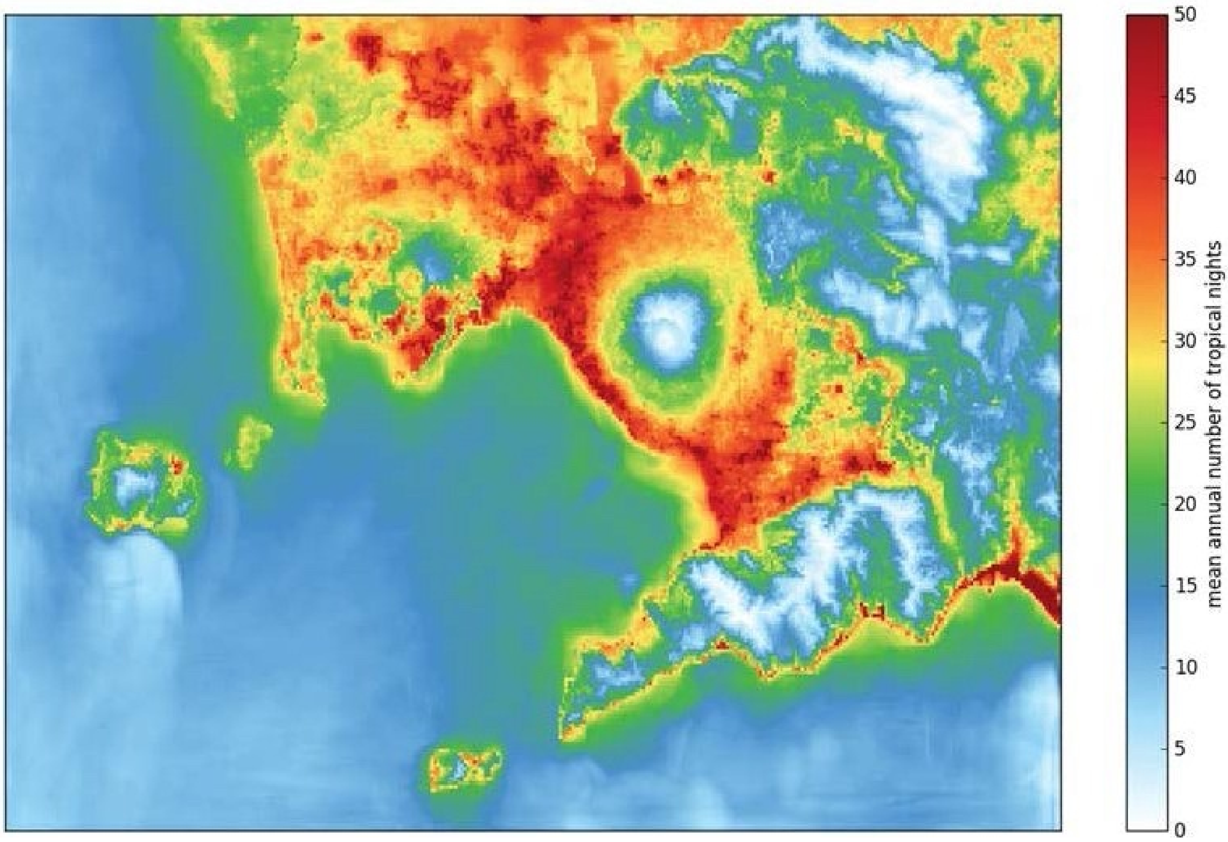


Figure 7: Annual average number of tropical nights (daily min. temperature > 20 °C), period 1971-2000.

Table 4: EURO-CORDEX model configurations used as input for the derivation of urban climate indices.

Institute	Driving GCM	RCM
DMI	ICHEC-EC-EARTH	HIRHAM5
	NCC-NorESM1-M	HIRHAM5
KNMI	ICHEC-EC-EARTH	RACMO22E
SMHI	CNRM-CERFACS-CNRM-CM5	RCA4
	ICHEC-EC-EARTH	RCA4
	IPSL-IPSL-CM5A-MR	RCA4
	MOHC-HadGEM2-ES	RCA4
	MPI-M-MPI-ESM-LR	RCA4

Analysis of EURO-CORDEX data produced estimates of the number of events expected in the period 2011-2100, starting from the historical series referring to the period 1971-2011. The projections were made with reference to two main Representative Concentration Pathways: RCP8.5 (which reflects the current global warming trend) and RCP4.5 (which reflects a scenario of gradual reduction of emissions on a global scale). The graphs (Figure 9, Figure 10, Figure 11) show the summary of some extreme events as significant for the Naples area, being similar to recorded thresholds in the last 5 years, and the most likely in the future, i.e. heat waves lasting 3, 6, and 9 days, with temperatures of 34-38°C. The data for the period 1971-2011 shows the number of events that have actually occurred, while the events that will occur in the period 2018-2100 refer to the RCP4.5 (left) and RCP8.5 (right) emission scenarios. The three curves in each panel represent the threshold temperatures: 34 °C (blue), 36 °C (grey), 38 °C (orange).

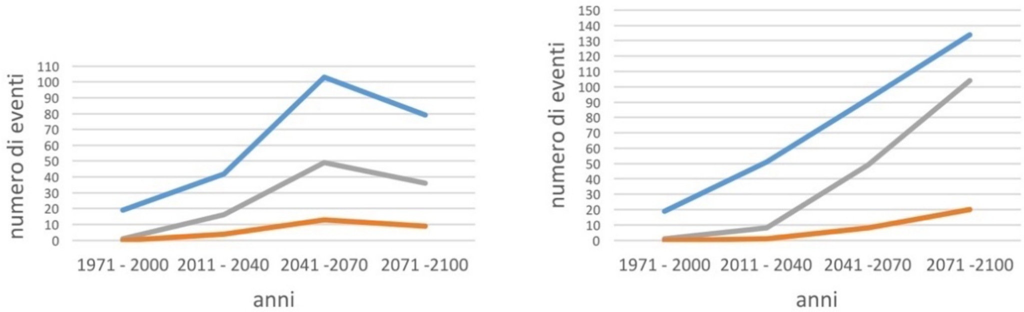


Figure 8: Heat waves lasting 3 days for the period 1971-2100. (Source: ZAMG / PLINIVS-LUPT, CLARITY).

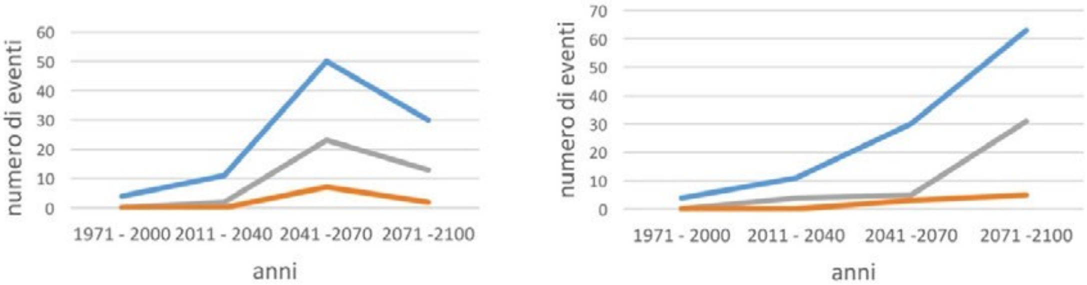


Figure 9: Heat waves lasting 6 days for the period 1971-2100 (Source: ZAMG / PLINIVS-LUPT, CLARITY).

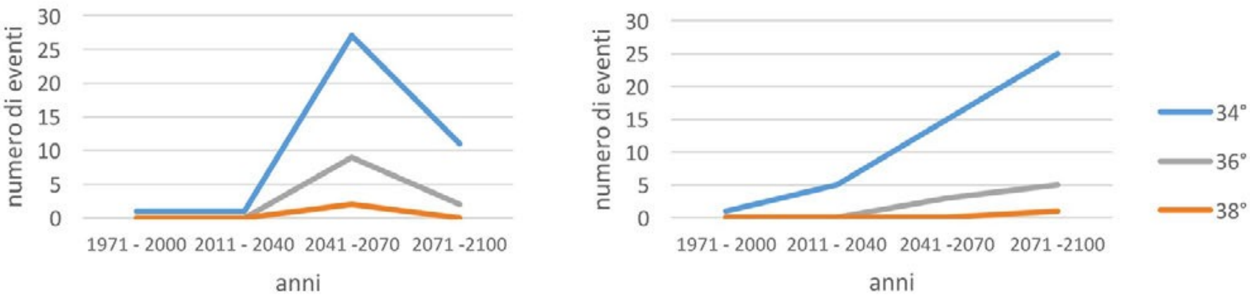


Figure 10: Heat waves lasting 9 days for the period 1971-2100. (Source: ZAMG / PLINIVS-LUPT, CLARITY)

The analysis of the data shows that similar events recorded in recent years (36 °C for periods even longer than 6 consecutive days) will increase significantly in terms of frequency and intensity in the next thirty years, up to the second half of the century at intensity levels so far not occurred (over 9 consecutive days with temperatures above 38 °C).

1.1.2.2 Extreme precipitation

As for the heat waves, the increased extreme precipitation events represent a signal of the ongoing climate change. Similar events will be more frequent and more intense in the future, with high amounts of rain in limited periods of time, which indicate the transition towards sub-tropical and tropical climatic conditions. The projection of sub-daily precipitation is scientifically complex and accordingly observations of the daily trends are assimilated into time periods of less than 6 hours, which is a recurring characteristic in the case of Naples. Figure 12 shows the number of expected events in which the amount of rain exceeds the minimum threshold observed in recent storms in Naples (all above 30 mm / day but concentrated in a few hours). The analysis of the data shows that events similar to those recorded in recent years will increase significantly in terms of frequency and intensity in the next thirty years, up to, in the second half of the century, levels of intensity which have not yet occurred (100 mm / day).

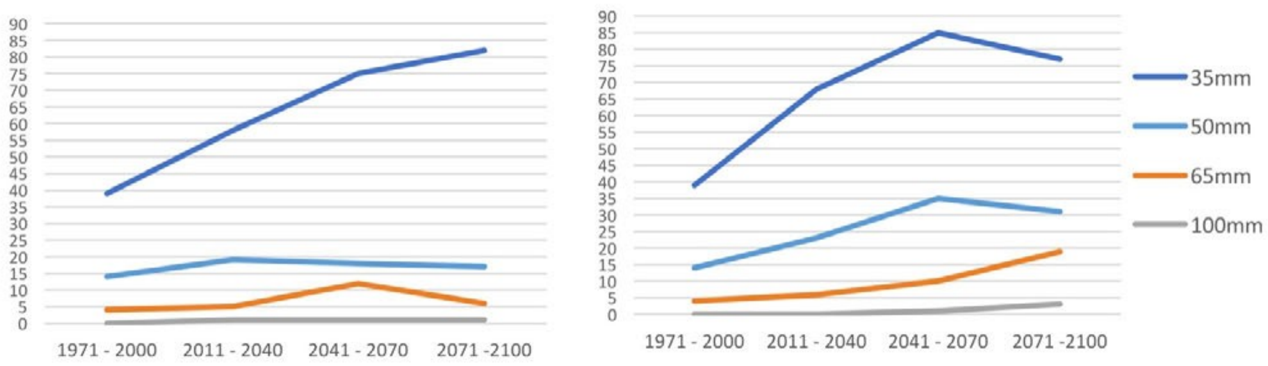


Figure 11: Extreme precipitation events for the period 1971-2100. The data for the1971-2011 period show the number of events that have actually occurred, while the events that will occur in the period 2018-2100 refer to the RCP4.5 (left) and RCP8.5 (right) emission scenarios. (Source: ZAMG / PLINIVS-LUPT, CLARITY project).

1.1.2.3 Seasonal variations in winter and summer temperatures

To support SECAP implementation further indicators that allow to evaluate the trend of temperatures in winter and summer have been extracted from the public database developed within the project (https://zenodo.org/communities/clarity/) and further processed to provide forecast estimates in relation to energy consumption for heating and cooling of buildings in relation to the expected climate change scenarios, namely:

- Tn10p: average number of days in which the minimum daily temperature is less than the 10th percentile of the minimum daily temperatures on a five-day window.

- Tx75p: number of days in which the maximum daily temperature is higher than the 75th percentile of the maximum daily temperatures during the warm season of April-September of the period 1971-2000.

The datasets are based on a set of EURO-CORDEX simulations of the daily temperatures close to the surface. All the data of the ensemble are "bias-corrected" compared to the daily observation dataset on the E-OBS grid. The results (set mean and standard deviation) are available for historical (1971-2000) and future (2011-2040, 2041-2070, 2071-2100) and for the representative concentration patterns RCP2.6, RCP4.5 and RCP8.5.

The bias-corrected simulations of the EURO-CORDEX climate model used are the following:

- CLMcom-CCLM4-8-17 / ICHEC-EC-EARTH, CLMcom-CCLM4-8-17 / MOHC-HadGEM2-ES
- DMI-HIRHAM5 / ICHEC-EC-TERRA
- KNMI-RACMO22E / ICHEC-EC-EARTH, KNMI-RACMO22E / MOHC-HadGEM2-ES
- SMHI-RCA4 / ICHEC-EC-EARTH, SMHI-RCA4 / MOHC-HadGEM2-ES

The maps and table data referring to the above-mentioned indicators are shown in the following pages.

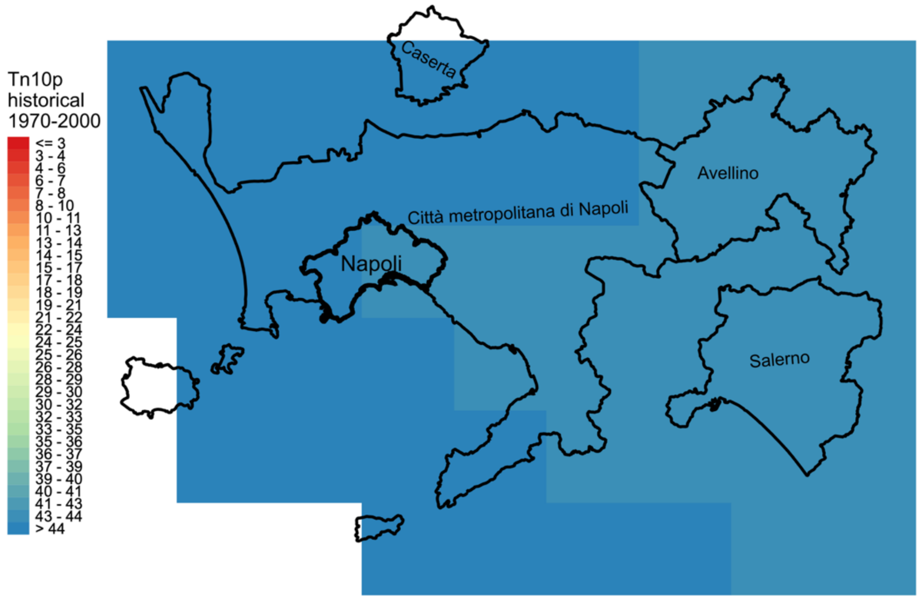


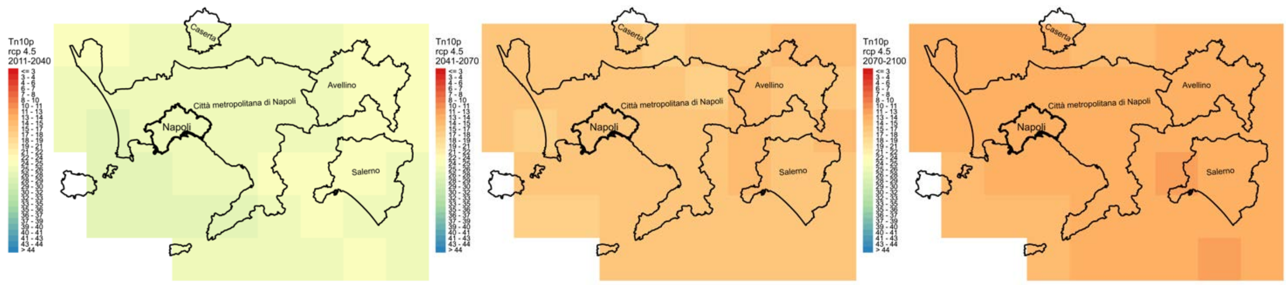
Figure 12: Tn10p: Elaboration from historical data 1970-2000.

RCP 2.6

2011 – 2040 **2041 – 2070** **2071 - 2100**

RCP 4.5

2011 – 2040 **2041 – 2070** **2071 – 2100**

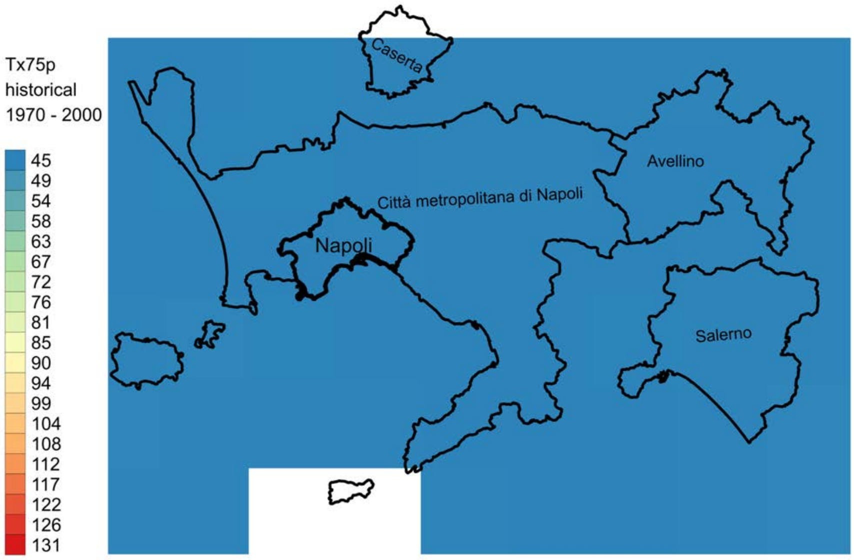


RCP 8.5

2011 – 2040 **2041 – 2070** **2071 - 2100**

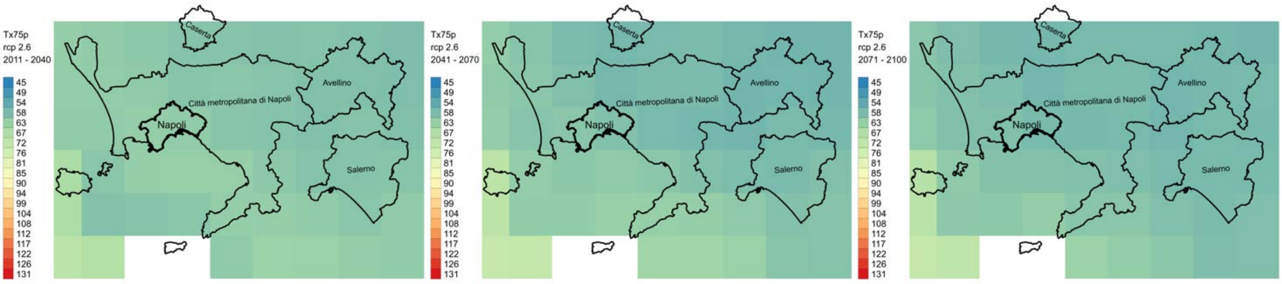
Figure 13: Tn10p: Projections based on EURO-CORDEX data.

Figure 14: Tx75p: Elaboration from historical data 1970-2000.



RCP 2.6

2011 – 2040 **2041 – 2070** **2071 - 2100**



RCP 4.5

2011 – 2040 **2041 – 2070** **2071 – 2100**

RCP 8.5

2011 – 2040 **2041 – 2070** **2071 - 2100**

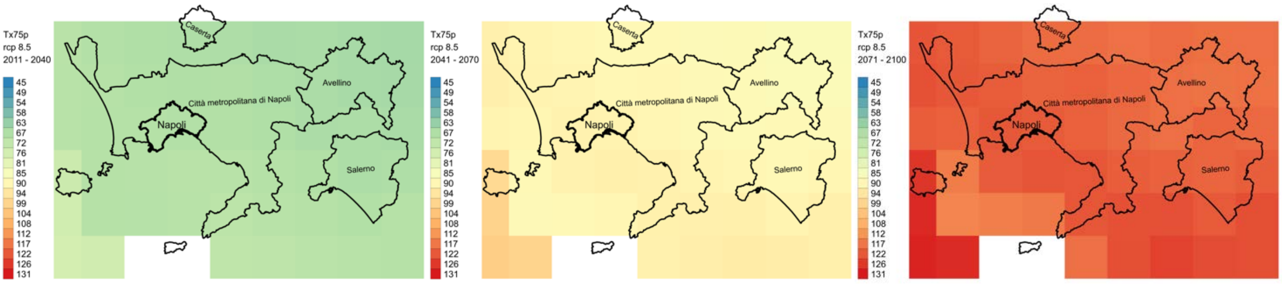


Figure 15: Tx75p: Projections based on EURO-CORDEX data.

Table 5: Tn10p and Tn75p indicators elaborated from EURO-CORDEX

Tn10p	historical 1970 - 2000: 44,4		
	2011 - 2040	**2041 - 2070**	**2071 - 2100**
RCP 2.6	32	23	25
RCP 4.5	26	17	14
RCP 8.5	22	10	3

Tx75p	historical 1970 - 2000: 46		
	2011 - 2040	**2041 - 2070**	**2071 - 2100**
RCP 2.6	62	60	58
RCP 4.5	67	83	87
RCP 8.5	69	92	122

These indicators were extracted with the same method from a dataset of observed data for the period 2012-2019, from Naples Capodichino weather station, in order to verify the deviation from the historical analysis period considered by EURO-CORDEX (1970-2000), with more recent data affected by the ongoing climate change. As can be seen in Table 6, the elaboration shows values close to the EURO-CORDEX estimates for the period 2011-2040, congruent with the expected trends, considering that the baseline period corresponds to the first forecasting EURO-CORDEX decade, and that going towards 2040 the Tn10p indicator will continue to decrease, while the Tx75p indicator will continue to grow.

Table 6: Tn10p and Tn75p indicators elaborated from Capodichino Weather Station.

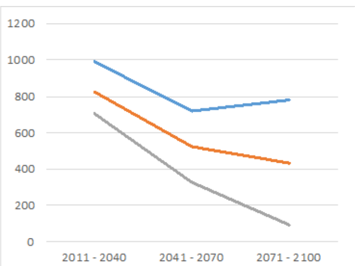
Tn10p (2012-2019)	25,75
Tx75p (2012-2019)	51,75

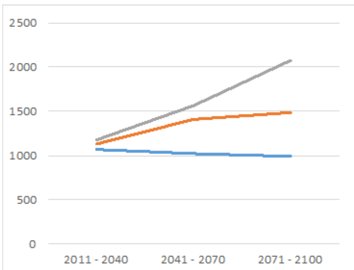
For the same 2012-2019 reference period, two additional indicators are extracted, directly related to the estimate of the energy needs for buildings heating and cooling, defined below:

- HDD (Heat Degrees Day) - used to determine building heating schedule at Metropolitan City level.
- CDD (Cool Degrees Day) - used to determine building cooling schedule at Metropolitan City level.

They are calculated, in a simplified way, by operating the difference between the average value of the daily temperature and a predetermined value. In the case of Naples the value is 18.3 °C (commonly used as an outdoor temperature threshold which guarantees indoor comfort conditions both in summer and in winter without the need for heating / cooling systems), and the indicator shows the difference with the average value of the temperature detected by the station itself for the various months. In winter, the resulting Degrees Day (DD) correspond to the heating need for indoor spaces, while in summer they represent the cooling need.

Table 7: HDD and CDD climate indicators elaborated from Naples Capodichino Weather Station and LUPT Weather Station.





HDD	historical 1970 – 2000: 1389		
	2011 - 2040	**2041 - 2070**	**2071 - 2100**
RCP 2.6	987	714	780
RCP 4.5	827	521	432
RCP 8.5	702	323	93

CDD	historical 1970 – 2000: 772		
	2011 - 2040	**2041 - 2070**	**2071 - 2100**
RCP 2.6	1057	1014	990
RCP 4.5	1128	1405	1476
RCP 8.5	1168	1551	2065

1.1.2.4 "Local effect" analysis

As mentioned, the sole analysis of data derived from the observation of past events recorded by local weather stations and projected in the future through statistical “downscaling” of Regional Climate Models (RCM) cannot capture the microclimatic variability linked to the settlement characteristics of the urban environment. The urban morphology and the land cover greatly influence the thermal stress conditions and the ability to absorb rainwater, resulting in a significant diversification of the main hazard parameters.

In order to provide a support for urban planning, specific models have been developed that are able to capture the "local effect" (see D3.3), and therefore to provide more precise information on the climate adaptation strategies to be implemented in different parts of the city. The first essential element of information is the creation of a GIS database of land use that contains all parameters necessary for the "local effect" simulations. The datasets shared by the City of Naples (currently used for planning purposes at various levels have been verified and corrected (in terms of geometries and intended uses) through comparisons with recent high-resolution satellite images (Pleiades 2018 data), and integrated with the input parameters required by the models.

The resulting land use map (Figure 17) is extremely detailed, and adds to the geometric and morphological data of buildings and open spaces also essential elements not present in ordinary cartographies, such as the presence of trees and the characteristics of albedo, emissivity and run-off of the different urban surfaces.

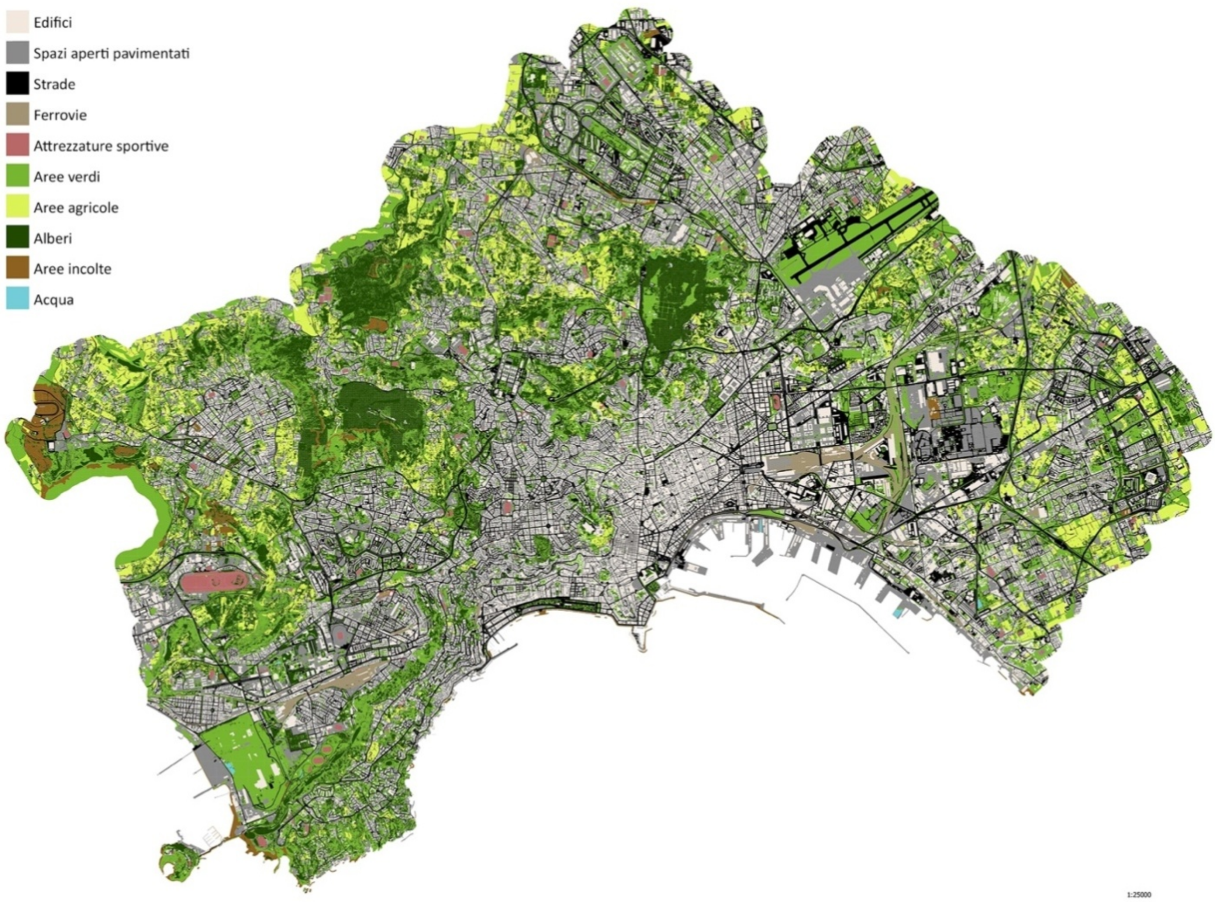


Figure 16: Reworked land use map used by simulation models of the “local effect” for heat waves and floods (Source: Municipality of Naples / PLINIVS-LUPT, CLARITY).

The thermal stress variation in the different city areas is simulated through the mean radiant temperature (Tmrt) indicator, which is widely validated in the literature as representative of the perceived outdoor comfort (see D3.3). This is essentially derived from (1) air temperature; (2) surface temperature; (3) urban morphology and surface characteristics of buildings and open spaces. Although Tmrt does not consider wind as a parameter, normally extremely low wind speeds are recorded during heat waves, and therefore the simplification adopted, widely recognized in the scientific literature (see D3.3), it is suitable in relation to the objectives of the simulation.

In addition to the data processed by ZAMG and PLINIVS-LUPT related to climate observations and projections, and to the new GIS database developed by the City of Naples and PLINIVS-LUPT, it was necessary to acquire data on surface temperatures in heat wave conditions, to support the assumptions done in the HWLEM based on elaborations from ENVI-MET and SOLWEIG models (see D3.3). During the calibration of the model, the information developed was reworked starting from Landsat satellite data from 19 July 2015, corresponding to a 3-day heat wave with maximum temperatures of about 36-37 °C (Figure 18). Further data used for calibration were collected during the 5-day heat wave with maximum temperatures of about 34-35°C of 28-31 July 2020 through aerial and field surveys (Figure 19).

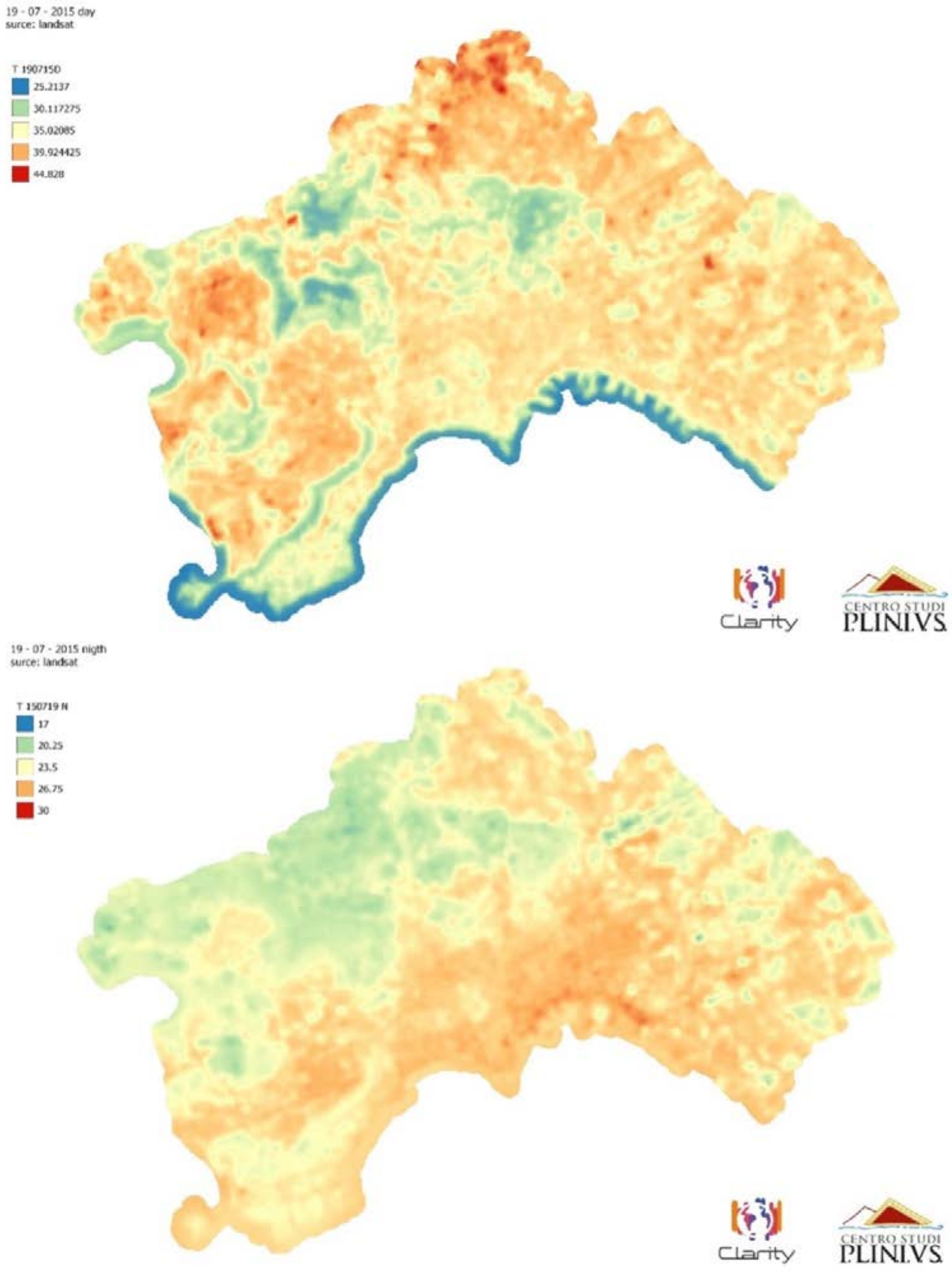


Figure 17: Landsat Surface temperature data in Naples of 19 July 2015 (top=day; bottom=night), corresponding to a 3-day heat wave with max. temperatures of about 36-37 °C.

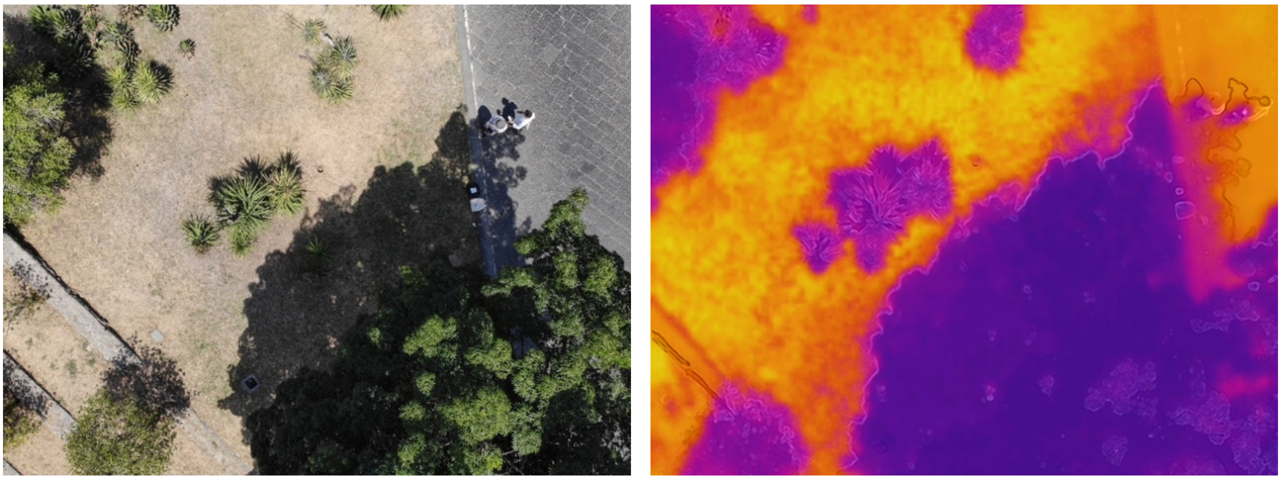


Figure 18: Surface temperature from thermal camera mounted on drone in Naples, 31 July 2020, corresponding to a 5-day heat wave with max. temperatures of about 34-35 °C (Source: PLINIVS-LUPT).

The processing of the model's input parameters allows to carry out simulations according to different air temperature ranges expected in the City of Naples, as derived from climate projections. As an example, Figure 20 shows the Tmrt values related to a "typical" heat wave, of no particular intensity, but which has a high probability of occurring considerably more often in the coming years, as the event of 28-31 July 2020 demonstrated. Figure 21 shows a critical event with air temperature 41°C, classified as "rare" for the period 2041-2070.

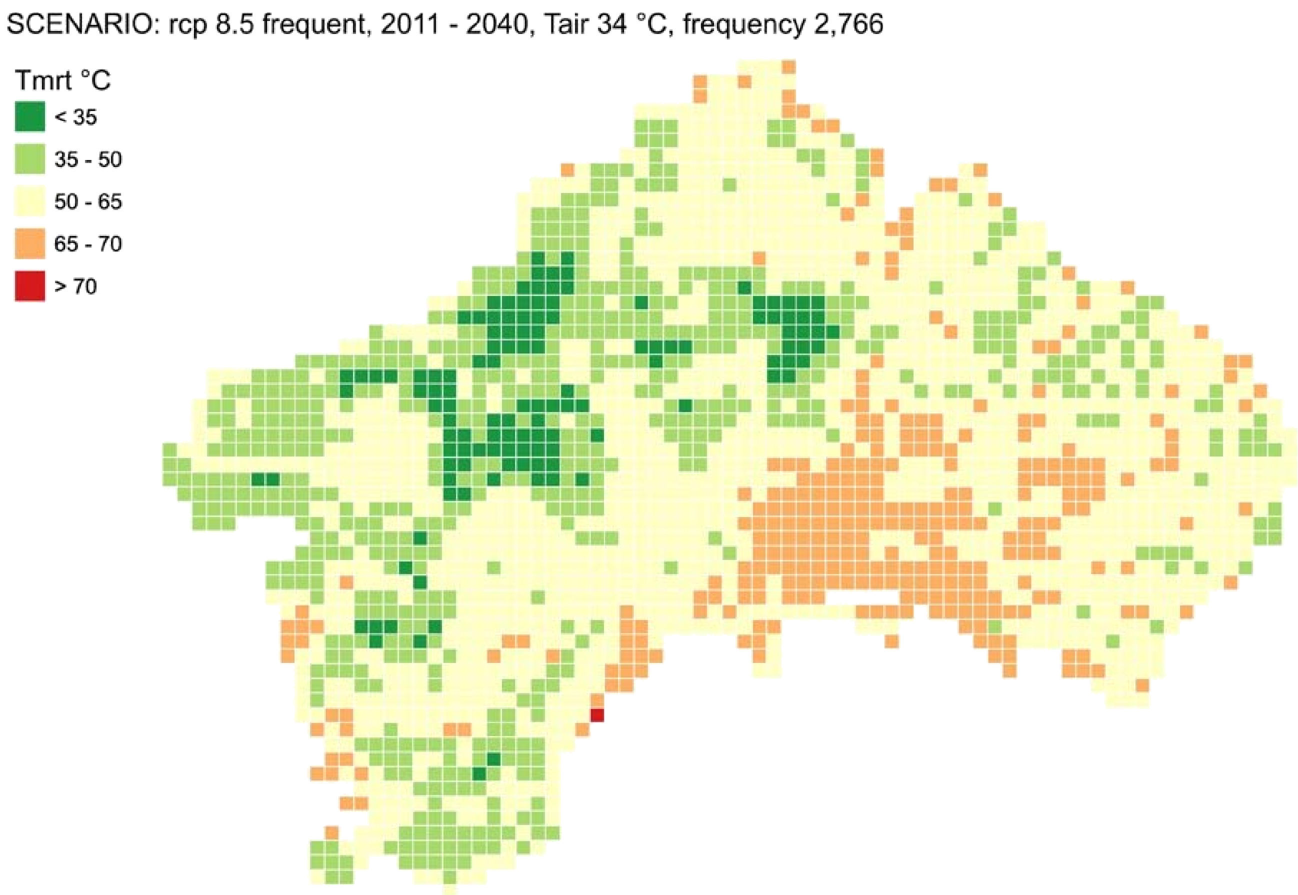


Figure 19: Mean Radiant Temperature map for a typical day of heat wave with air temperature of 34 °C (on grid 250x250m). (Source: PLINIVS-LUPT, CLARITY).

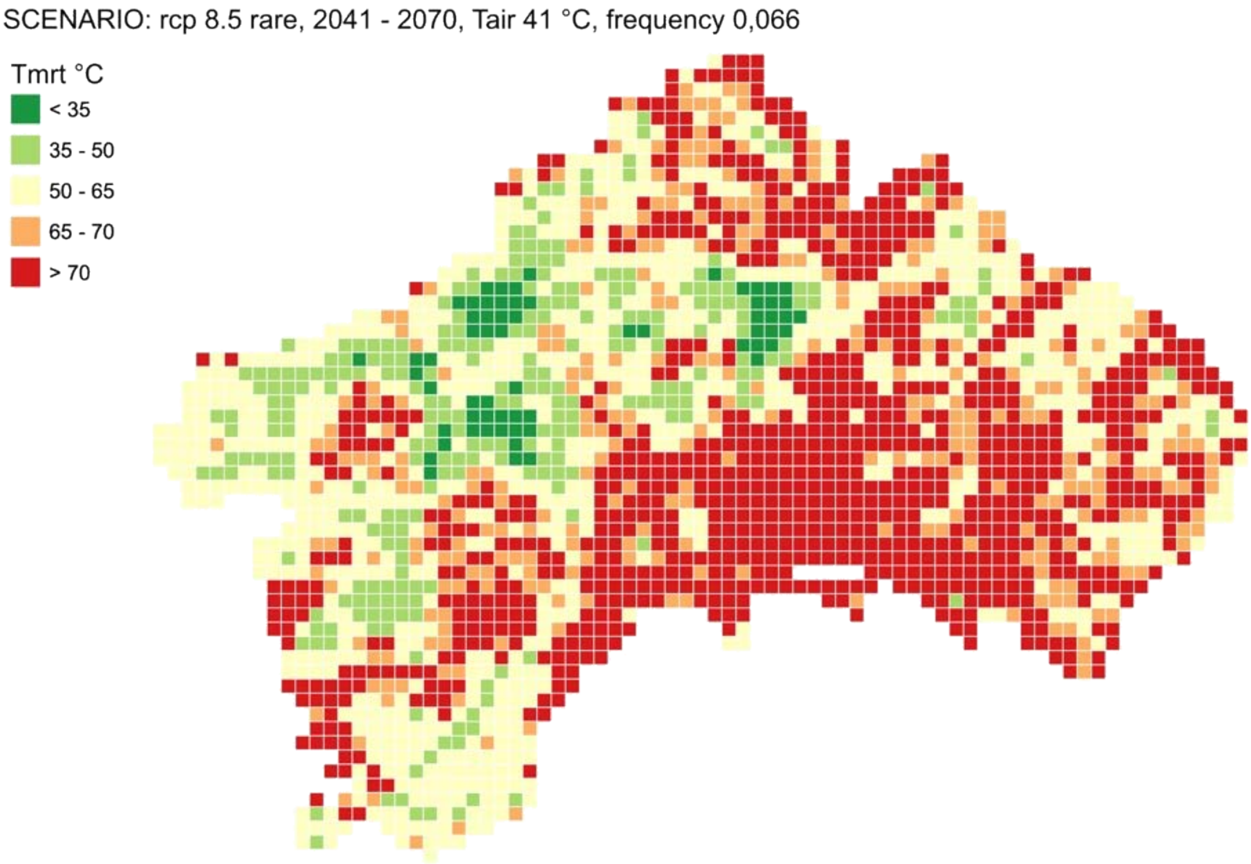


Figure 20: Mean Radiant Temperature map for a typical day of heat wave with air temperature of 41 °C (on grid 250x250m). (Source: PLINIVS-LUPT, CLARITY).

The model also allowed to develop further simulations related to the perceived discomfort conditions, through the UTCI indicator (Universal Thermal Climate Index), as well as simulations on the expected impacts on human health, including the increase in mortality (currently being calibrated). The UTCI represents the main indicator of thermal stress in urban open spaces and can be referred to a scale of discomfort linked to the different ranges observed (Table 8). The damage classes are calibrated with reference to the weak population groups (children under 15 and seniors over 65) for the Naples climate zone.

Table 8: Classes of damage from thermal stress related to UTCI values, referring to weak population groups (children under 15 years and elderly over 65 years) for the Naples climate zone.

D0	No Damage	26
D1	Level of caution (moderated heat stress)	32
D2	Level of caution (strong heat stress)	38
D3	Damage (very hard heat stress)	46
D4	Extreme damagee (extreme heat stress)	> 46

Figure 22 and Figure 23 show the UTCI maps corresponding to the Tmrt maps in Figure 20 and Figure 21, highlighting the extremely critical potential health impacts correlated with heat stress in the future.

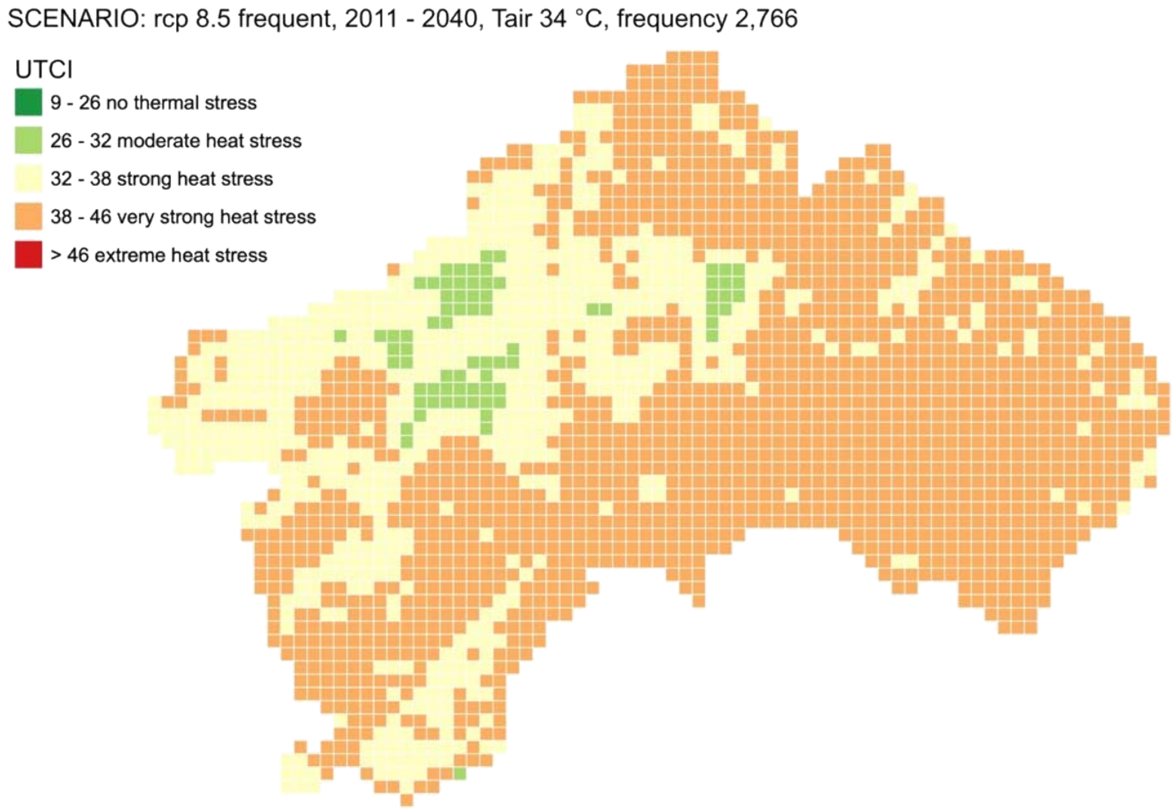


Figure 21: Universal Thermal Climate Index (UTCI) map for a typical day of heat wave with air temperature of 34 ° C (on 250x250m grid). (Source: PLINIVS-LUPT, CLARITY).

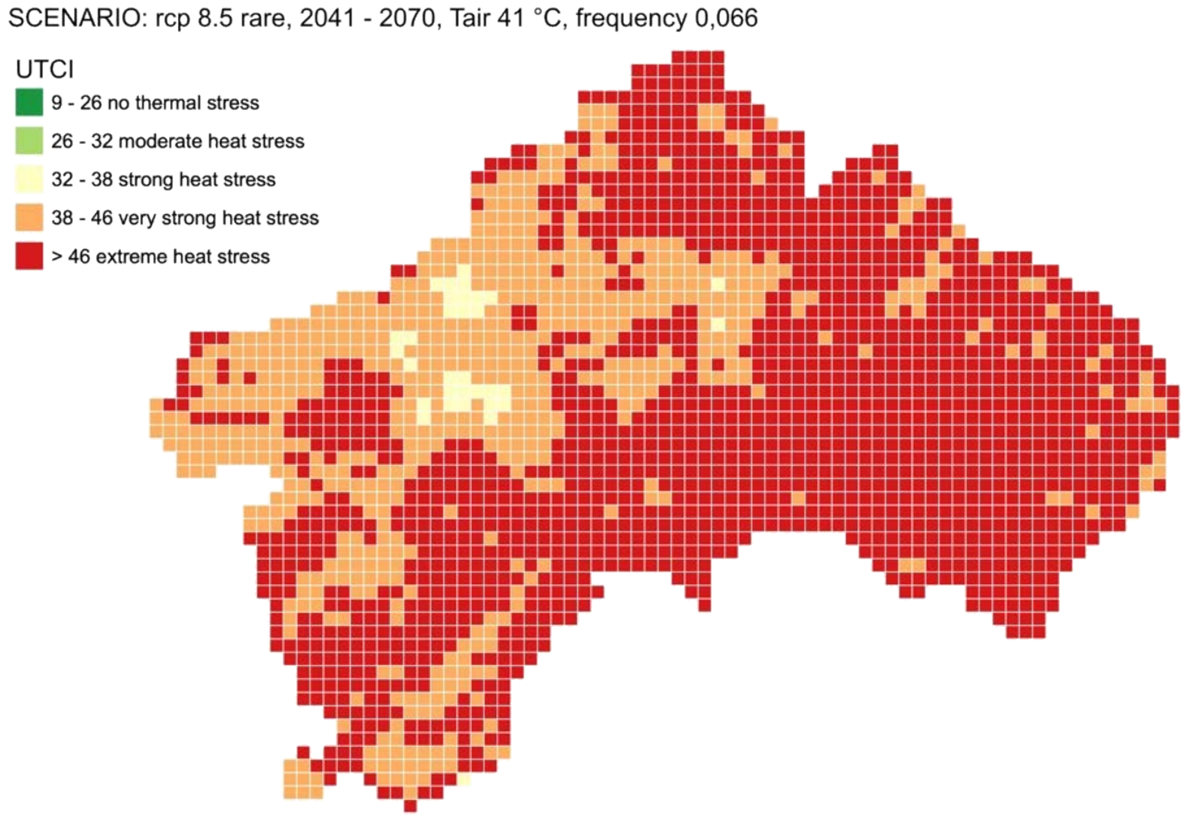


Figure 22: Universal Thermal Climate Index (UTCI) map for a typical day of heat wave with air temperature of 41 °C (on 250x250m grid). (Source: PLINIVS-LUPT, CLARITY).

Each cell of the grid can be analysed more in detail, so to determine in which extent the specific land uses and the building-open space configurations system contribute to determining higher Tmrt values and therefore higher heat outdoor discomfort and associated health risks. The following figures show some example results related to urban areas in the ancient city centre, in the west (Rione Traiano) and east (Ponticelli) areas.

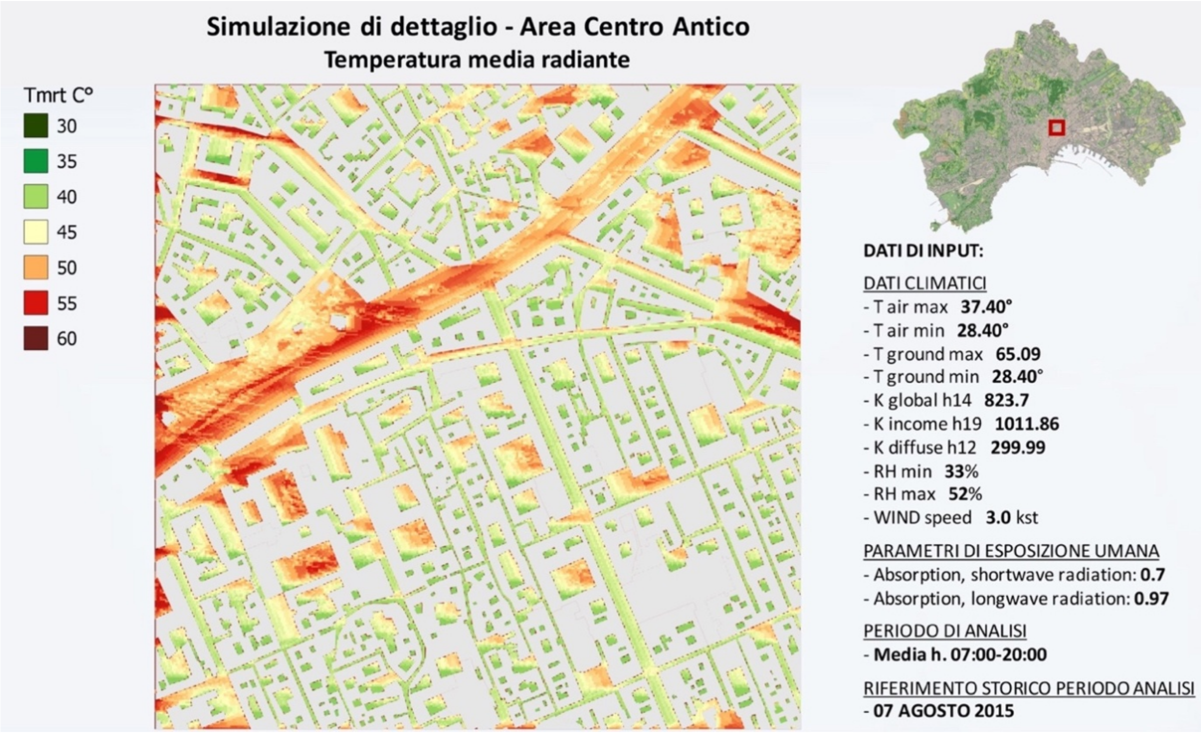


Figure 23: Detailed analysis of the Mean Radiant Temperature in an area of the ancient center, for a typical heat wave day with air temperature of 37 °C. (Source: PLINIVS-LUPT, CLARITY).

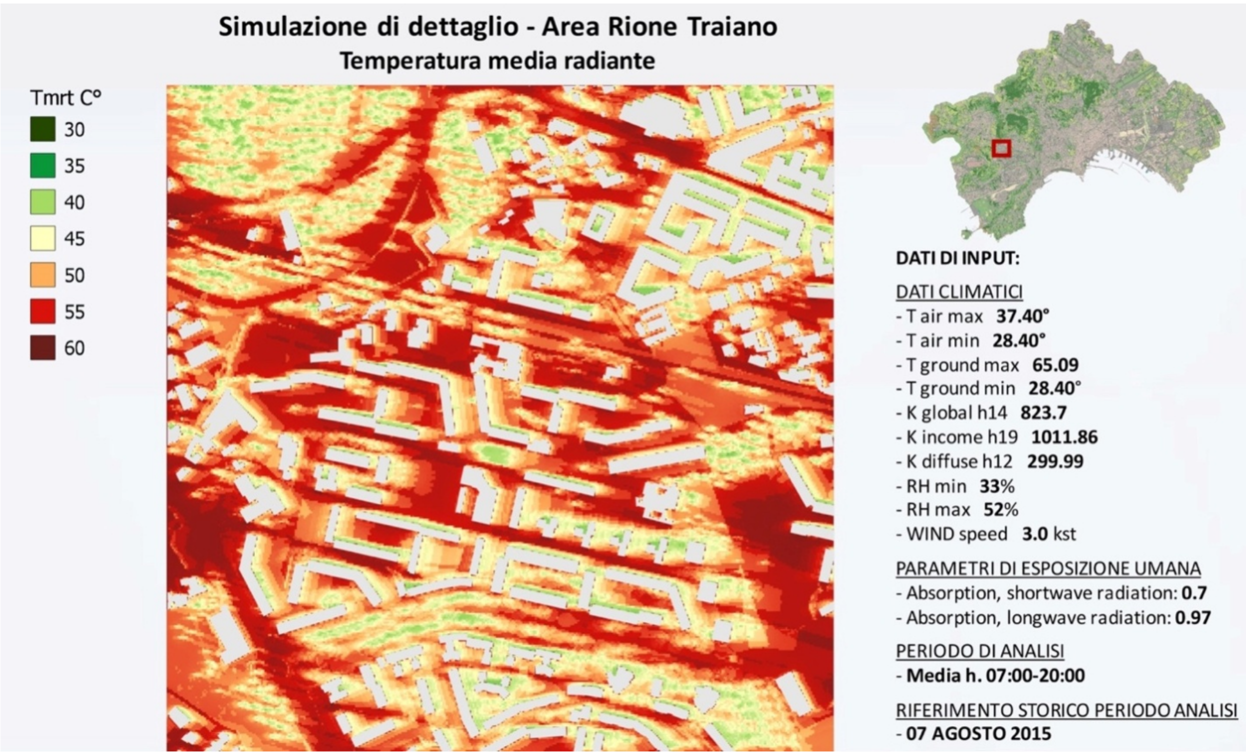


Figure 24: Detailed analysis of the Mean Radiant Temperature in an area of the ancient center, for a typical heat wave day with air temperature of 37 °C. (Source: PLINIVS-LUPT, CLARITY).

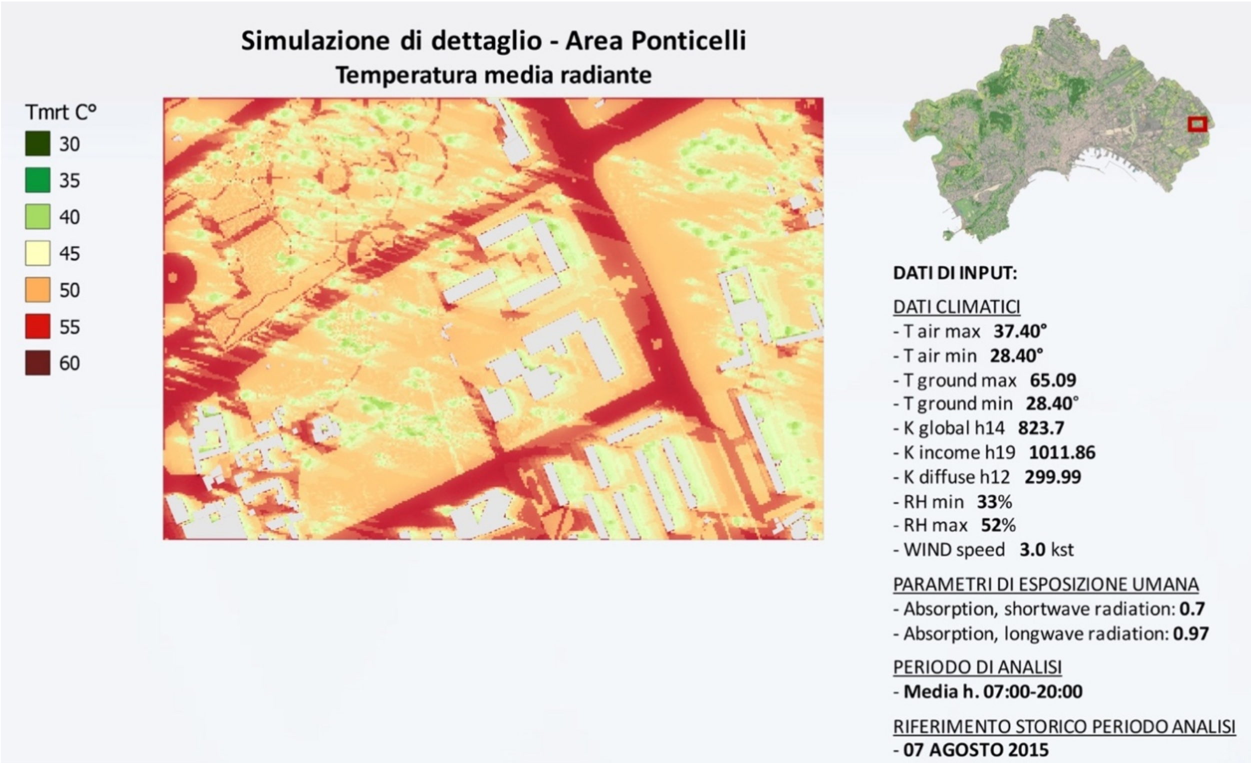


Figure 25: Detailed analysis of the Mean Radiant Temperature in the Ponticelli area, for a typical day of heat wave with air temperature of 37 °C. (Source: PLINIVS-LUPT, CLARITY).

Such detailed analyses allow to highlight some aspects that link urban morphology and land use to microclimatic conditions. In the ancient centre area, the building density determines shading conditions that reduce thermal stress. In bigger squares, differences between cooler green areas and overheated asphalt roads can be noticed. Within the courtyards of historic buildings, differences can be observed between the smaller, cooler ones due to greater shading. The presence of green areas and trees represents a thermal stress reduction factor in the larger courtyards.In Rione Traiano and Ponticelli areas, the greater distances between the buildings and the reduced presence of trees cause a high overheating, especially in the case of Ponticelli, from the large green areas present in some blocks.

With reference to extreme precipitation, the hazard indicators used in the model are the depth (water depth, in mm) and speed (flood velocity, in m/s) of the rainwater not absorbed by sewage systems, which determine the occurrence of surface flooding. The main variables are linked to the absorption capacity of urban surfaces, calculated on the basis of the run-off index, as well as the morphology of the water catchment areas present in the city area, and therefore from the orographic characteristics, which determine the presence of "channels" (streams) of water run-off.

Most of the city's sewer system follows the natural orography, and almost all the natural streams are today converted in urban roads, in which most of the rainwater is channelled. The sewage system efficiency is a crucial condition determining the urban flooding in the case of heavy rain. Several studies (e.g. H2020 RESCCUE project) have shown that, not only is the capacity of the sewer itself important, but also its maintenance condition of manholes in urban areas. This information is almost impossible to acquire without performing local surveys for data collection and detailed flood hazard 2D-analyses. A possible approach to include this parameter, although in an approximate way, has been experimented for the Naples area. In relation to the urban adaptation objectives, together with the maintenance and adaptation of the sewage systems, the drainage capacity of urban surfaces is of particular importance, and must be balanced in relation to the specific characteristics of each river basin and other hydraulic characteristics (including the height of the groundwater, very near to the surface in some areas of the city).

In DC1 the CLARITY FLEM (see D3.3), developed by PLINIVS-LUPT has been applied, producing as output a preliminary proxy of the probability for urban areas to get flooded in case of heavy rain, based on the following data:

- Runoff coefficient for each land use type
- Urban watersheds / basins
- Digital Elevation Model
- Digital Surface Model
- Flow accumulation streams for each watershed
- Emergency calls related to flooding events

A first assessment of the propensity of urban areas to flooding was made by integrating the above parameters and assigning to each of them a “risk coefficient”, returning an overall picture at city level that allows to highlight the areas with the greatest probability of flooding in case of extreme precipitation events. As documented in D3.3, the procedure aims at identifying four main parameters for each cell of the analysis grid that contribute to the flooding probability due to land use, urban orography and hydrology:

1. Runoff coefficient
2. Relative elevation in the watershed
3. Presence of flow accumulation streams
4. Sewage system efficiency

Figure 27, Figure 28, Figure 29 and Figure 30 show the above mentioned parameters and their classification in the Naples area, while Figure 31 shows an example of the final result obtained for the Naples area.

The map has been validated by the Municipality of Naples, following a comparative analysis of urban areas included as having a high risk of flooding in the official plan of the local river basin authority, available at the following link http://www.difesa.suolo.regione.campania.it/content/view/130/110/.

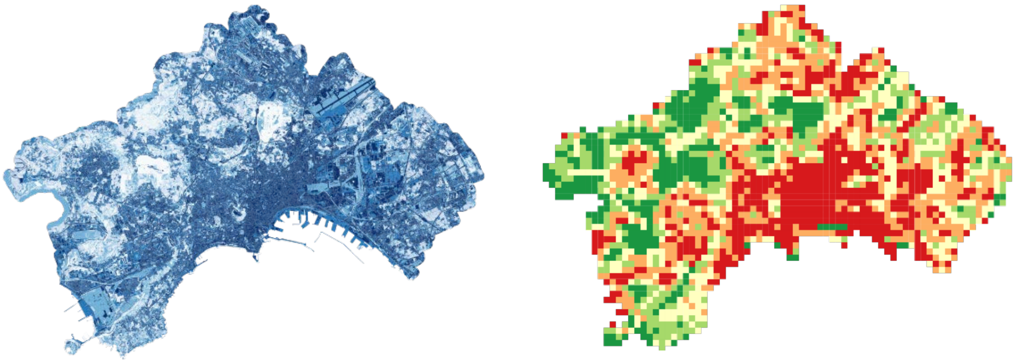


Figure 26: Naples area showing (left) runoff coefficient, and (right) its classification of imperviousness on a scale (1-5).

Figure 27: Naples area showing (left) the elevation from the DEM, (centre) urban watersheds, and (right) classification results.

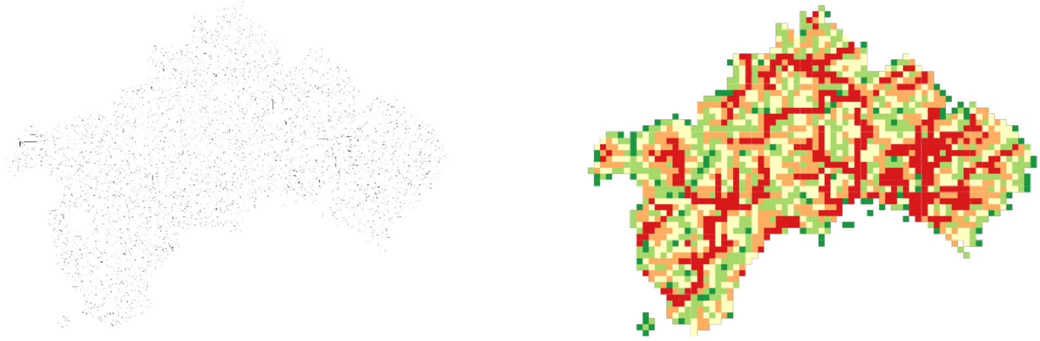


Figure 28: Naples area showing (left) flow accumulation streams, and (right) classification results.

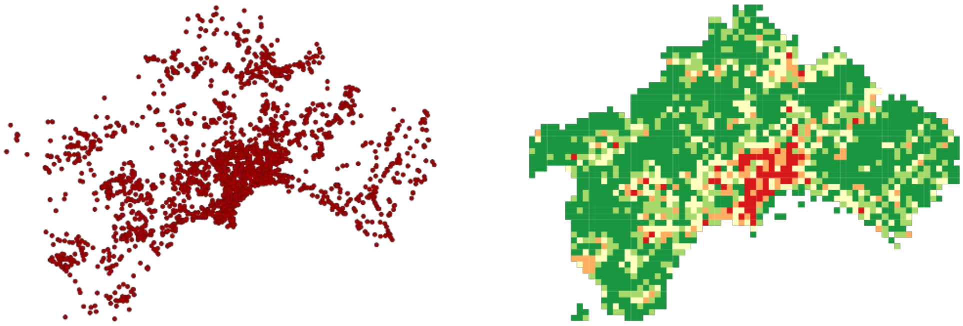


Figure 29: Naples area showing (left) number of emergency calls recorded, and (right) classification results. Almost all of the calls are concentrated at the "minor" branches of the run-off channels, which often correspond to sewer branches with a lower flow rate.

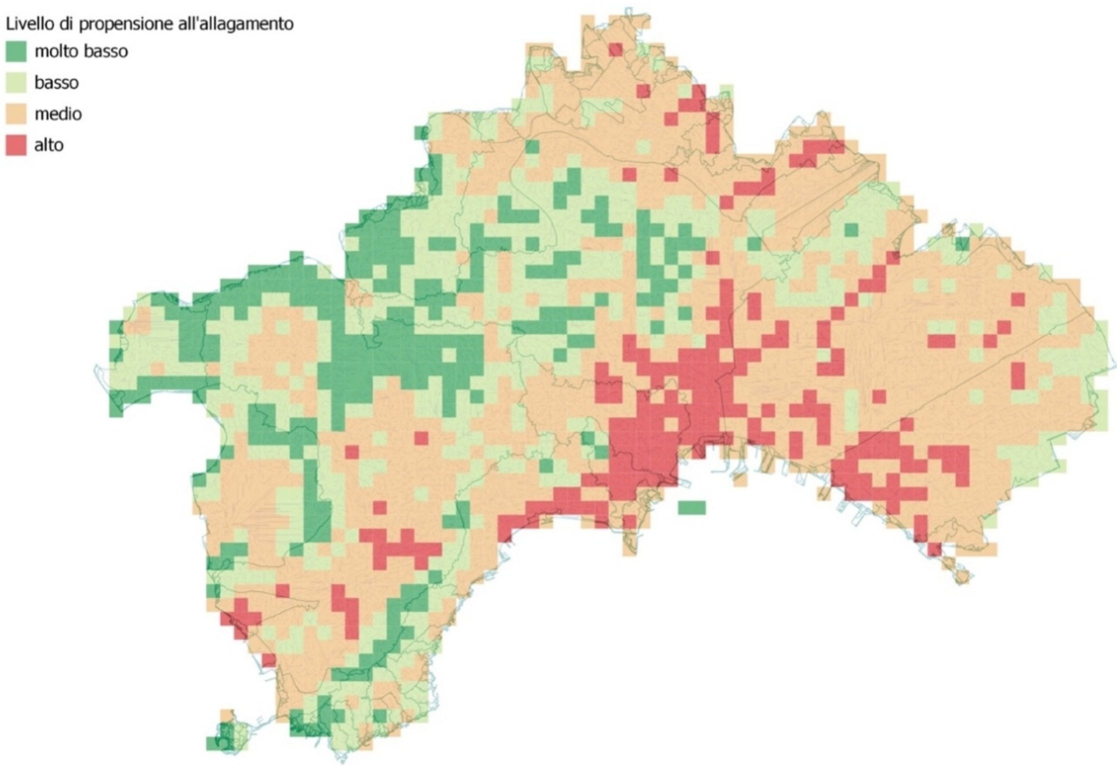


Figure 30: Classification of the Naples area according to hazard level: (dark green = very low; light green = low; orange = medium; red = high (Source: PLINIVS-LUPT, CLARITY).

1.1.3 Strategic planning - Napoli Sustainable Energy and Climate Action Plan (SECAP)

DC1 provides a major input for the update of Naples Municipality Sustainable Energy Action Plan (SEAP), due by 2020 and to be converted into a Sustainable Energy and Climate Action Plan (SECAP), being Napoli among the signatories of the Covenant of Mayors for Climate & Energy.

DC1 support to Napoli SECAP has been prepared in accordance with the guidelines of the Covenant of Mayors for Climate and Energy (2016) and by the Joint Research Centre of the European Commission (2018) to support public administrations in the transition from the "SEAP" to the "SECAP".

In particular, the following subsections have been drafted according the suggested SECAP structured as proposed by JRC:

- Climate Change Risk and Vulnerability Assessment methodology
- Vulnerabilities of the local authority or region
- Expected climate impacts in the local authority or region

1.1.3.1 Climate Change Risk and Vulnerability Assessment (RVA) methodology

The Municipality of Naples has indicated that in the Napoli SECAP the RVA, defined in the JRC guidelines as “expected weather and climate events particularly relevant for the local authority or region”, needs to be compliant with the CLARITY methodology (D3.3), selected as suitable approach to orient climate change adaptation and mitigation measures, as well as to bridge the SECAP with other relevant risk planning instrument at Regional or Metropolitan City level, in the perspective of an integrated multi-risk approach at the base of local urban governance.

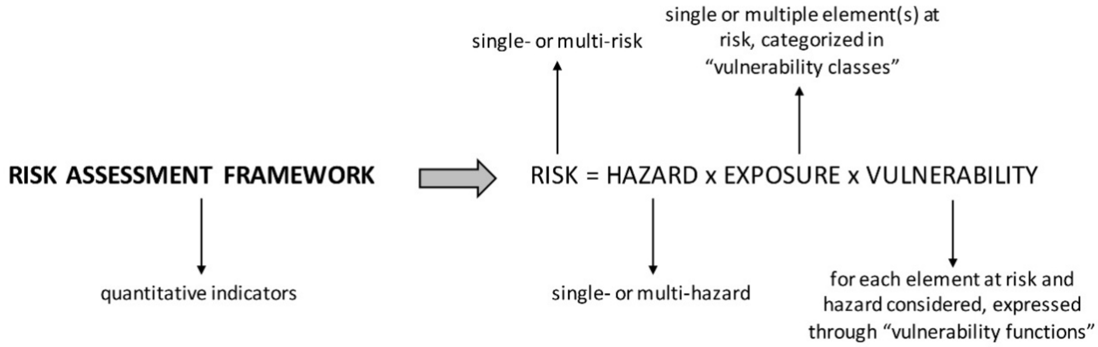


Figure 31: Risk and Vulnerability Assessment framework compliant with CLARITY methodology, as defined for the Napoli SECAP (Source: PLINIVS-LUPT, CLARITY).

According to JRC, “Risk and Vulnerability Assessment (RVA) determines the nature and extent of a risk by analysing potential hazards and assessing the vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend”. The hazard map (e.g. CLARITY “local effect” maps for heat wave and flood) is combined with the vulnerability and the exposure information to quantify the number of assets and vulnerable communities at risk.

In the “risk assessment framework”, vulnerability – as originally defined in risk science and theory of decisions (UNDRO, 1980; UN DHA, 1993; Coburn et al., 1994) – is a mathematical function defined as the degree of loss to a given element at risk, or set of such elements, expected to result from the impact of a hazard of a given magnitude. It is specific to each hazard/element at risk combination and expressed on a “damage scale” (from no “damage” to “total damage”).

Such approach considers vulnerability as one of the three components of Risk, defined as a product (in terms of probabilistic convolution) of hazard (H), exposure (E) and vulnerability (V), according to the known relation R=HxExV. This conceptual framework is also adopted by the IPCC Fifth Assessment Report – with a radical shift compared to AR2, AR3 and AR4 assessment frameworks – further exploring the meaning of this equation: "Risks from climate change impacts arise from the interaction between hazard (triggered by an event or trend related to climate change), vulnerability (susceptibility to harm) and exposure (people, assets or ecosystems at risk)" (IPCC, 2014). Vulnerability is then defined here as "susceptibility to harm" of a given "exposed element" (people, assets, ecosystems) under the effect of a given hazard (be it rapid- or slow-onset). In other words, the vulnerability represents "the propensity or predisposition to be adversely affected" (IPCC, 2014).

In CLARITY methodology this definition is formalized as "the probability of a given element at risk, classified as part of a specific vulnerability class, to be affected by a level of damage, according to a prefixed scale of damages, under a given hazard intensity".

Vulnerability assessment involves first identifying all the elements which may be at risk from a particular hazard. The opportunities and constraints to determine accurate quantitative vulnerability indicators heavily depends on the availability of data to organize exposure information into coherent and reliable "vulnerability classes". The vulnerability analysis frameworks may thus change according to data availability and resolution, with significant variations connected to the spatial scale of the analysis (global, national, regional, local). For instance, the identification of building construction typologies at international level would require the harmonization of several national datasets (where existing), and information derived from national datasets (in Italy derived e.g. through ISTAT) are generally more fuzzy and less reliable than local datasets built through surveys on site, which can obviously performed only for limited spatial domains. Indeed, the increased availability of data from satellite, remote sensing and IT mapping tools represents a relevant resource which can have a huge impact in the upgrade of vulnerability analysis methodologies in the next years.

The vulnerability classes represent homogeneous categories of elements at risk grouped according the expected level of damage experienced according specific hazard conditions, thus constituting an essential linkage among "exposure" and "hazard". In this sense, exposure represents the distribution of the probability that a given element (people, buildings, infrastructures, economy, environment, etc.) of assigned characteristics (of qualitative and quantitative type) occupies in a given time a given geographical area (Zuccaro et al., 2018).

Each "vulnerability class" can be then associated to a "vulnerability function". They express the probability that elements in a given "vulnerability class" exceed a certain level of damage, given a level of hazard magnitude. Vulnerability functions can be obtained through three different approaches, depending on the information available: "empirical methods" evaluate the 'observed vulnerability curves' through the statistical correlations of the damage caused by past events on samples of elements exposed of specific typology under the action of a given intensity; "mechanical methods" evaluate the 'calculated vulnerability curves' through statistical processing of the results obtained by analytical approaches conducted on a sample of models representing the elements at risk examined subject to a representative set of hazards; hybrid methods evaluate the curves combining analytical approaches and observations of damage caused by past events (Calvi et al., 2006, Zuccaro et al. 2018a; Zuccaro et al. 2018b).

The elements at risk against which the risk and/or impact of hazard(s) can be assessed are diverse and the identification of hazard and exposure is the first step to build up a coherent vulnerability analysis, determining for each of the exposed elements (e.g. individual, community, assets, systems, etc.) the relevant vulnerability factors in relation to the hazard(s) considered, which can be of physical, social, economic and environmental type.

If the vulnerability denotes the "the degree of loss to a given element at risk (or set of elements) resulting from a given hazard at a given severity level" or in other words "relationship between the severity of hazard and the degree of damage caused" (UN DHA, 1993; Coburn et al., 1994), it can then be represented as "hazard-loss relationship", "damage function", or "vulnerability function". These relationship/functions can be developed in the form of vulnerability curves or damage probability matrices, and obtained for diverse hazard/element at risk correlations, starting from the wide scientific literature or performing dedicated specialist studies (Coburn and Spence, 1993; Woo, 1999; Spence et al. 2005; Huizinga et al., 2017).

The vulnerability of an element is usually expressed as a percentage loss (or as a value between 0 to 1) for a given hazard severity level. The measure of loss used depends on the hazard(s) and the element(s) at risk considered, and accordingly may be measured e.g. as a ratio of the numbers of killed or injured to the total population, as a repair cost or as the degree of physical damage defined on an appropriate scale (Cardona et al., 2008). In a large number of elements, like building stock, it may be defined in terms of the proportion of buildings experiencing some particular level of damage (Coburn et al. 1994, Zuccaro et al. 2018a).

For more general socio-economic purposes and macro-level analyses, vulnerability is a less-strictly- defined concept. The "risk governance framework" incorporates considerations of both the intrinsic value of the elements concerned and their functional value in contributing to the environmental and socio-economic resilience in general and to emergency response and post-disaster recovery in particular. In many cases it is necessary (and sufficient) to settle for a qualitative classification in terms of "high", "medium", and "low" or explicit statements concerning the disruption likely to be suffered. The same AR5 complements the previous definition adding that vulnerability "encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt" (Oppenheimer et al., 2014). This second part of the definition recovers key terms - "coping capacity", "adaptive capacity" - which in the previous IPCC-ARs were considered as components of vulnerability together with hazard and exposure, thus generating a misunderstanding with respect to the more consolidated framework derived from disaster risk science. AR5 clarifies that the concept of "sensitivity" is considered as a synonym of "susceptibility to harm", and thus finally realigned with the definition of vulnerability in the risk assessment framework. This aspect was clarified for the first time in the IPCC Special Report released in 2012, between AR4 and AR5, when analogies among definitions in DRM and CCA domains are discussed, pointing out that "susceptibility/fragility (in disaster risk management) or sensitivity (in climate change adaptation)" is understood as the physical predisposition of human beings, infrastructure, and environment to be affected by a dangerous phenomenon due to lack of resistance, but also because of the predisposition of society and ecosystems to suffer harm as a consequence of intrinsic and context conditions, making it plausible that such systems once impacted will collapse or experience major harm and damage due to the influence of a hazard event (Cardona et al., 2012).

This dual complementary vision of vulnerability is explicitly connected to the assessment goals, context and methods: "Quantitative approaches for assessing vulnerability need to be complemented with qualitative approaches to capture the full complexity and the various tangible and intangible aspects of vulnerability in its different dimensions. It is important to recognize that complex systems involve multiple variables (physical, social, cultural, economic, and environmental) that cannot be measured using the same methodology" (Cardona et al., 2012). In the CLARITY methodology, the inclusion of co-benefits attached to the different adaptation strategies/measures are intended to tackle such factors.

A final clarification is needed to precise the difference between "risk" and "impact": The risk is the probability that a given damage level (e.g. on people, building, infrastructure, etc.), because of an hazard event (understood as a potentially damaging physical event, phenomenon or human activity characterized by its location, intensity, frequency and probability), is reached in a given period of time, in a specific geographic area. Thus, risk has to be intended as a cumulative assessment that considers the total potential damages that can be induced in the same area by several events (with different intensities or return periods) in a prefixed time window (Zuccaro and De Gregorio, 2013). The impact scenario, instead, represents the probabilistic distribution, in a given geographic area, of the damage induced by a single hazard event with an assigned probability of occurence (assumed as reference hazard scenario). The equation used for risk assessment can then be extended to impact scenario analyses, resulting in Iref_event = Href_event x E x V, with H assumed as reference event (Zuccaro et al. 2018a; Zuccaro et al. 2018b).

1.1.3.2 Vulnerabilities of the local authority or region

In Napoli SECAP the indicators adopted to assess vulnerability are subdivided, in compliance with the JRC guidelines in two categories: "Socio-Economic Vulnerability" and "Physical and Environmental Vulnerability".

As outlined in the previous section, the vulnerability is defined as the probability that an element at risk, belonging to a vulnerability class, experiences a level of damage, according a predefined damage scale, as a response to a hazard event of given intensity. It is expressed in terms of a vulnerability matrix that indicates the percentage of a certain type of element at risk belongs to each vulnerability class for the investigated local effect in the considered area. To be compliant with the JRC guidelines, however, the Vulnerability indicators as requested in the SECAP template (section “Vulnerabilities of your local authority or region”) include all the relevant parameters related to the calculation of exposure of elements at risk, as well as heat wave and flood local effects, as fundamental “Socio-economic” and “Physical & environmental" variables”. It should be noted that this do not influence the RVA methodology adopted, which is instead based on CLARITY approach, as outlined in the previous section. The list of vulnerability-related indicators is reported in Table 9.

Table 9: Vulnerability indicators as requested in the SECAP template, section “Vulnerabilities of your local authority or region”.

Vulnerability Type	Vulnerability Description	Vulnerability-related indicators
Socio-Economic	Current population	N. of inhabitants
Socio-Economic	Projected population 2030/2050	N. of inhabitants
Socio-Economic	Population density	People per km2
Socio-Economic	Projected population density 2030/2050	People per km2
Socio-Economic	Share of sensitive age population groups (elderly 65+; young 15-)	%
Socio-Economic	Share of low-income population groups	%
Socio-Economic	Average days of hospitalization for heat-related diseases	n.
Socio-Economic	Average hospital stay cost per day	€
Socio-Economic	Labour hourly production	€
Socio-Economic	Average rehabilitation cost for residential / public / industrial buildings from flood	€/m^2
Socio-Economic	Average roads cleaning costs from flood (including manholes cleaning incidence)	€/m^2
	Current energy consumption per capita	kWh
	Projected energy consumption per capita 2030/2050	kWh
Socio-Economic	Gross Local Product (GLP) / Local Value-Added (LVA)	€
Physical and Environmental	Land use type - Roads	m^2
Physical and Environmental	Land use type - Railways	m^2
Physical and Environmental	Land use type - Residential buildings	m^2
Physical and Environmental	Land use type - Non-Residential buildings	m^2
Physical and Environmental	Land use type - Built open spaces	m^2
Physical and Environmental	Land use type - Sports facilities	m^2
Physical and Environmental	Land use type - Agricultural areas	m^2
Physical and Environmental	Land use type - Bare soil	m^2
Physical and Environmental	Land use type - Vegetated areas	m^2
Physical and Environmental	Land use type - Water	m^2
Physical and Environmental	Albedo of urban surfaces	% (0-1)
Physical and Environmental	Emissivity of urban surfaces	% (0,8-0,99)
Physical and Environmental	Transmissivity of vegetated/artificial canopies	% (0-1)
Physical and Environmental	Sky View Factor	% (0-1)
Physical and Environmental	Hillshade green fraction	% (0-1)

Physical and Environmental	Surface Temperature of urban surfaces in relation to solar radiation/air temperature	%
Physical and Environmental	Run off coefficient	% (0-1)
Physical and Environmental	Watersheds	m^2
Physical and Environmental	Relative altimetry	m
Physical and Environmental	Streams density	% (0-1)

1.1.3.3 Expected climate impacts

The SECAP requires the identification of assets and people at risk from climate change impacts, targeting the "impacted policy sectors" and identifying specific impact indicators for each sector considered.

The impact assessment is performed in relation to the vulnerability classes for the relevant elements at risk which in CLARITY have been defined as follows:

- Heat wave: population (health diseases and mortality increase); energy (increase in building cooling costs)
- Flooding: roads (cleaning and repairing costs); buildings (cleaning and repairing costs; content losses)

Different levels of damage for those elements have been identified.

Population is classified in two vulnerability classes (A: over 65; under 15; B: 15-65). Table 10 shows the damage classification related to people's health during heat waves.

Table 10: Damage classification of heat stress on population in relation to UTCI.

D0	No Damage	20	26
D1	Moderate heat stress (fatigue, discomfort)	26	32
D2	Strong heat stress (heat cramps, exhaustion)	32	38
D3	Very strong heat stress (heat cramps, heatstroke)	38	46
D4	Extreme heat stress (heatstroke, sunstroke)	> 38	> 46

These values can be used to determine expected hospitalization costs during heat waves. D5 damage level corresponds to death, and is also calculated in terms of mortality rate increase during heat waves following the methodology described in D3.3, as a function of Apparent Temperature, using the curve in Figure 33.

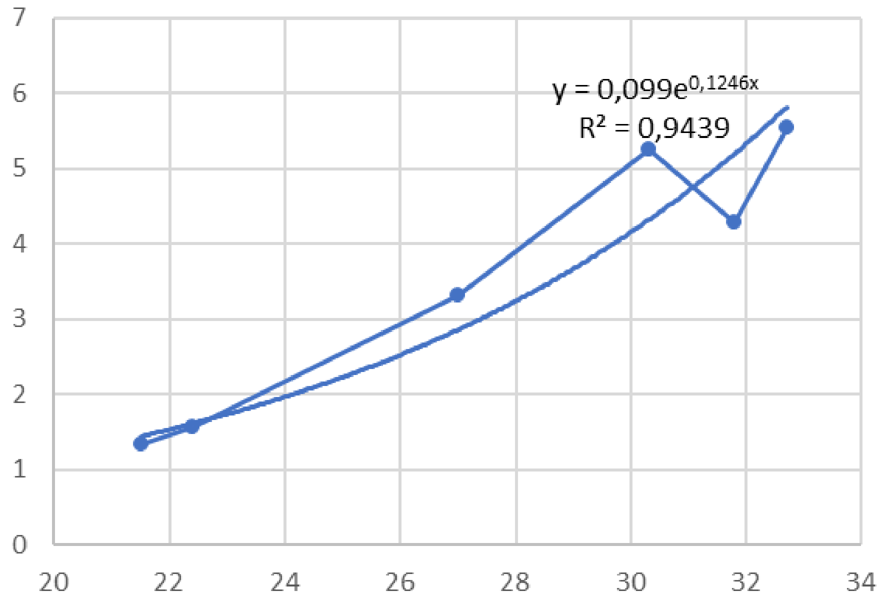


Figure 32: Mortality rate increase as a function of Apparent temperature. Percentage change in natural mortality is reported on the y-axis, while the Apparent temperature is reported on the x-axis. (adapted from Rothman et al., 2014; Baccini et al., 2008; D'Ippoliti et al., 2010; CLARITY)

A similar classification has been carried out also for the elements at risk in the case of flooding (roads, residential and non-residential buildings). The damage is expressed in terms of economic impact and includes the costs for repairing the structural damage and, in the case of buildings, the losses due to the damaged "content" of groundfloors and underground spaces (Table 11, Table 12, Table 13).

Table 11: Damage classification of flooding on roads in relation to Water Depth.

D0	No damage	0
D1	Very low damage (0,2 €m^2)	0,001-0,11
D2	Low damage (1 €/m^2)	0,12-0,29
D3	Medium damage (3 €/m^2)	0,3-0,49
D4	High damage (6 €/m^2)	0,5-1
D5	Very high damage (9 €/m^2)	> 1

Table 12: Damage classification of flooding on residential buildings in relation to Water Depth.

D0	No damage	0
D1	Very low damage (0,2 €m^2)	0,001-0,004
D2	Low damage (1 €/m^2)	0,005-0,05
D3	Medium damage (25 €/m^2)	0,06-0,19
D4	High damage (84 €/m^2)	0,2-0,8
D5	Very high damage (270 €/m^2)	> 0,8

Table 13: Damage classification of flooding on non-residential buildings in relation to Water Depth.

D0	No damage	0
D1	Very low damage (0,2 €m^2)	0,001-0,004
D2	Low damage (1 €/m^2)	0,005-0,05

D3	Medium damage (16 €/m²)	0,06-0,19
D4	High damage (55 €/m²)	0,2-1
D5	Very high damage (247 €/m²)	> 1

These vulnerability matrices have been elaborated using as main source the vulnerability curves developed by JRC and illustrated in Figure 34.

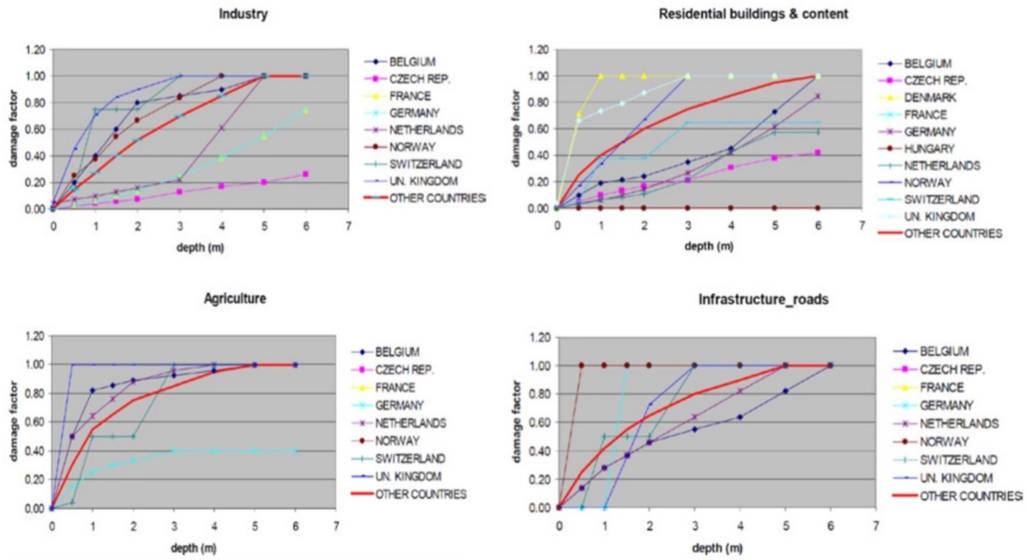


Figure 33: Flood vulnerability curves (Source: Huizinga et al.,2017).

About the expected energy consumption variation due to changes in winter and summer temperature, a forecast estimate is provided based on the analysis of the variation of HDD and CDD indicators. Trends in energy consumption for heating and cooling foreseen in the reference periods for the RCP4.5 and RCP 8.5 scenarios, mainly referring to the consumption of gas for civil use in the winter and to the electricity consumption for air conditioning in the summer, which currently represent the energy sources used in maximum prevalence in the metropolitan area of Naples.

These estimates support SECAP implementation not only in the “Adaptation” section, but also in relation to “Mitigation”, correlating the energy consumption with the corresponding GHG emissions from the civil sector in relation to the expected climate change scenarios. Uncertainties have been taken into account in relation to variation in global climate trends, considering decreasing confidence intervals towards 2100.

Table 14: Estimates of changes in energy consumption for building heating / cooling, the colors refer to the confidence intervals related to the trend of global climatic trends (green = very likely; red = very uncertain).

	2011-2040	2041-2070	2071-2100
Reduction of gas consumption for civil heating			
RCP 4.5	-4%	-35%	-46%
RCP 8.5	-13%	-60%	-89%
Increase of electricity consumption for civil air conditioning			
RCP 4.5	22%	38%	41%
RCP 8.5	25%	43%	58%

Table 15 illustrates the CLARITY contribution to the Napoli SECAP for the section “Expected impacts in your local authority or region”, as requested by the template of the Covenant of Mayors for Climate and Energy (https://www.covenantofmayors.eu/IMG/xlsx/SECAP_Template.xlsx).

For each of the expected impact on the identified policy sectors, CLARITY Expert Services allow to determine the value of the impact-related indicators through the impact scenario analysis, thus defining according to the qualitative scales indicated in the SECAP template the Likelihood of Occurrence (Unlikely, Possible, Likely), Expected Impact Level (Low, Moderate, High) and the Timeframe (Current, Short-, Medium-, Long-Term).

As a follow up project, impact scenario analyses can be carried out by using the following correlation between CLARITY scenario taxonomy and SECAP template:

- Likelihood of Occurrence
    - Rare (CLARITY) = Unlikely (SECAP)
    - Occasional (CLARITY) = Possible (SECAP)
    - Frequent (CLARITY) = Likely (SECAP)
- Timeframe
    - 2011-2040 (CLARITY) = Current (SECAP)
    - 2011-2040 (CLARITY) = Short-Term (SECAP)
    - 2041-2070 (CLARITY) = Medium-Term (SECAP)
    - 2071-2100 (CLARITY) = Long-Term (SECAP)
- Expected Impact Level
    - Very Low-Low (CLARITY) = Low (SECAP)
    - Medium (CLARITY) = Moderate (SECAP)
    - High-Very High (CLARITY) = High (SECAP)

Figure shows an example of such “scenario dependent” variables which will be integrated in the Napoli SECAP.

Table 15: Impacted policy sectors and impact indicators as requested in the SECAP template, section “Expected impacts in your local authority or region”.

Impacted Policy Sector	Expected Impact(s)	Likelihood of Occurrence	Expected Impact Level	Timeframe	Impact-related indicators
Buildings	• Flood impact on buildings	Scenario dependent	Scenario dependent	Scenario dependent	• Economic impact for structural and content damage of residential buildings • Economic impact for structural and content damage of non-residential buildings
Transport	• Flood impact on road network	Scenario dependent	Scenario dependent	Scenario dependent	• Economic impact for road cleaning and repairing
Energy	• Heat wave impacts on energy consumption	Scenario dependent	Scenario dependent	Scenario dependent	• Energy demand increase during heat waves
Land Use Planning	• Urban Heat Island	Scenario dependent	Scenario dependent	Scenario dependent	• Mean Radiant Temperature of urban areas
Health	• Heat wave impacts on population • Heat wave impacts on national health service	Scenario dependent	Scenario dependent	Scenario dependent	• Heat stress levels on weak population groups • Mortality rate increase during heatwaves • Hospitalization costs in relation to heat-related diseases

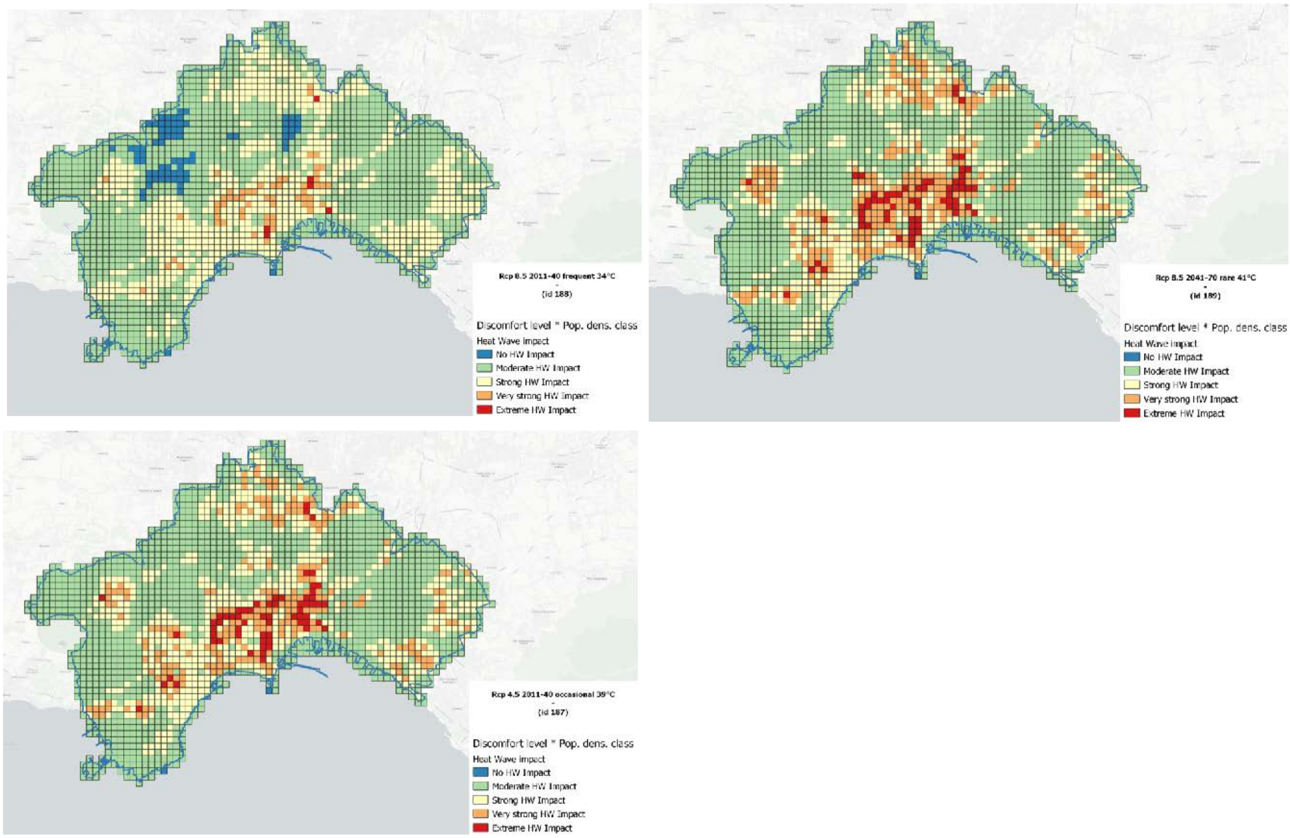


Figure 34: Example of simulations related to the impact indicator "Heat stress levels on weak population groups" for the scenarios "Rare/2011-2040" (top-left), "Occasional/2011-2040" (bottom-left), "Rare/2041-2070" (top-right).

1.1.4 City planning – Update of the Napoli City Plan (PUC)

The project concerns the update of the City Plan for the Municipality of Napoli, which will contain a specific focus on climate change adaptation, as outlined in the official preliminary planning document "Napoli 2019- 2030. Città, Ambiente, Diritti e Beni comuni. Piano Urbanistico Comunale. Documento di Indirizzi" (Comune di Napoli, 2019-2030).

Heat Wave and Flood hazards need to be mapped for the entire urban area, with a specific design focus on the implementation of a "green belt" able to reconnect the "Parco delle Colline" area with East and West Napoli areas. This will imply the definition of a green infrastructure with a strong east-west backbone and smaller "fingers" that allow urban green patterns and street tree canopies to penetrate towards the city centre.

Figure 36 shows some of the base planning documents shared by the Municipality of Napoli relevant for CLARITY, referred to the historical, landscape, hydrogeological and service infrastructure constraints with which the proposed climate adaptation measures will have to comply.

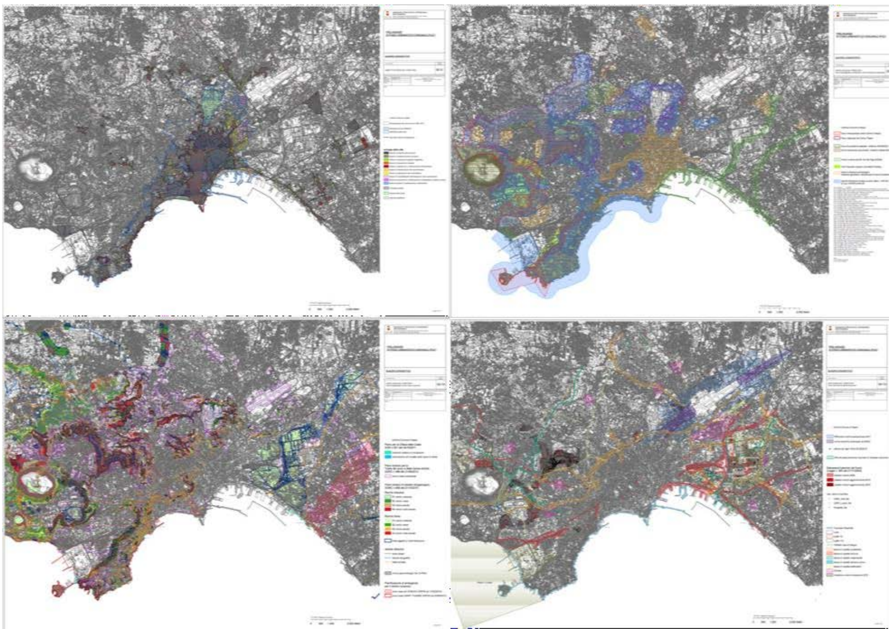


Figure 35: Napoli City Plan 2019. Historical (top left); landscape (top right); hydrogeological (bottom left) and service infrastructure (bottom right) constraints for urban planning (source: Municipality of Napoli).

The Expert Services allows to produce the climate risk analysis on a 250x250m grid, evaluating the risks of heat waves and flooding for various reference events.Information already integrated (Feb. 2020) in the update of the Naples PUC (available at http://www.comune.napoli.it).

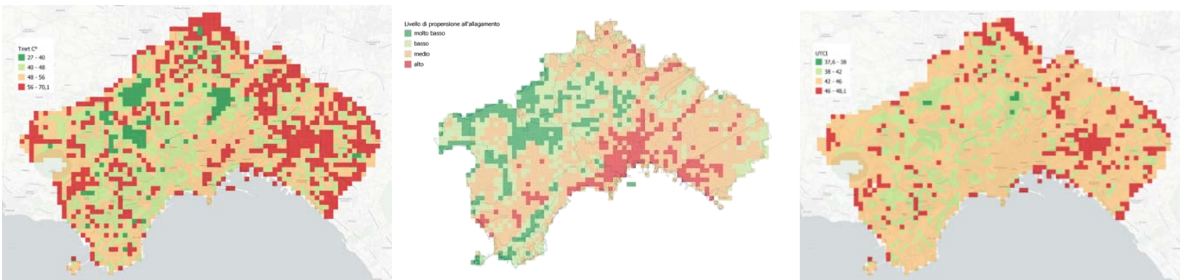


Figure 36: Implementation state of current forecast; Territory historical structure; Agricultural land use; Urban and neighbourhood equipment, urban regeneration map (source: Municipality of Naples)

CLARITY modelling of current Heat Wave stress will serve as a starting analysis, to determine which areas need greening actions aimed at the continuity of green infrastructures, and suggest the needed land use changes in the new City Plan, as well as guidelines to redesign street sections to increase the vegetation coverage according to traffic levels.

Simulations at different scales are expected to support the development of criteria and guidelines for urban forestation (dimensioning of planting indexes and selection of plant species in relation to the reduction of climate impacts).

Overall, heat waves and flooding hotspots identified will suggest criteria and guidelines to revise City Plan zoning according to the identified climate risks and expected impacts.

The update of the Municipal Urban Plan for the city of Naples provides since the preliminary document "Naples 2019-2030. Cities, Environment, Rights and Common Goods "a specific focus on climate adaptation.

CLARITY simulations support the definition of specific planning criteria based on the climatic risks identified in the different city areas and the identification of areas that require targeted actions (of waterproofing, urban forestry, changes in land use and green infrastructure continuity). Specific guidelines concern the design criteria for adaptation measures for buildings and open spaces to integrate the plan guidelines and to support the levels of implementation planning.

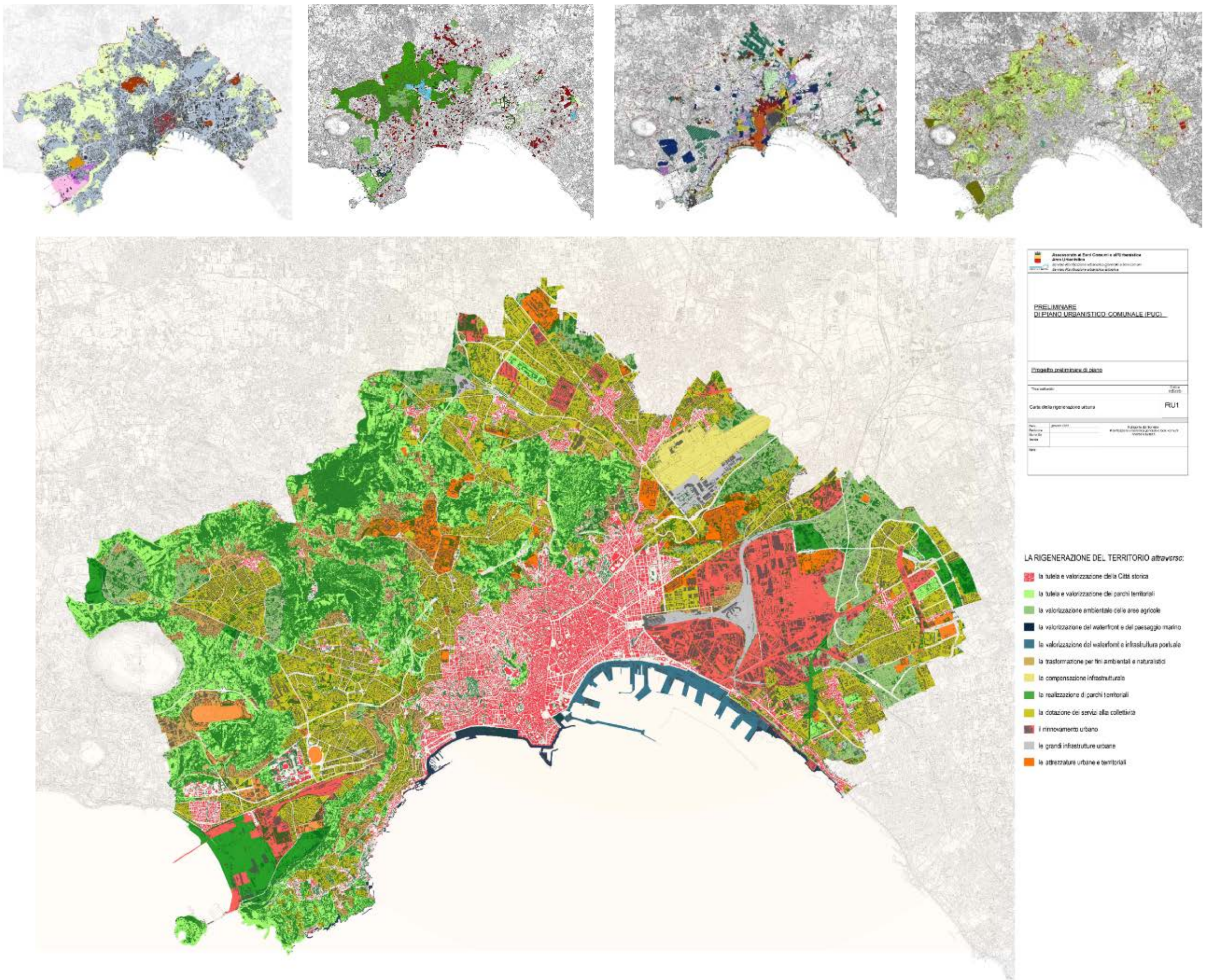


Figure 37: PUC knowledge framework: Top – Protected and redevelopment areas; Territory historical structure; Agricultural land use; Urban and neighbourhood equipment; Bottom: Urban regeneration map (source: Municipality of Naples)

From this perspective, the Municipality of Naples foresees:

- diffuse and zero kilometres alternative forms of energy production;
- give priority to environmental remediation processes of industrial sites, especially those of East Naples, starting with the oil deposits relocation, as well as the recovery and conversion of soils subject of illegal landfill;
- implementation of urban forestation actions starting from large paved areas in order to reduce the heat island phenomenon, also recovering the possibility of sustainable use by citizens;
- to contrast, through the urbanistic instrument, alteration phenomena of the social and economic fabric of the city and ensure greater protection of the UNESCO historic centre;
- development of sustainable mobility through adequate and integrated infrastructure systems compatible with the territories.

The aim is to study the fragility of the urban fabric monitored in a multi-risk perspective by investigating scenarios, highlighting critical issues and choosing sustainable solutions.

The domains of application of the knowledge bases and scenario assessment tools proposed by Clarity Clarity include heterogeneous areas. Adaptation and design interventions of infrastructures, urban spaces and equipment for urban regeneration are diversified according to their future destination, and in particular in historical areas they will become more meticulous and punctual interventions, characterized by a less intensive use of green.

Figure 38: Large infrastructure urban project Alifana line, Miano: CLARITY supports the project with the climate performance assessment of a standard design compared to an adaptive design.

In case of bare soil adaptation strategies will provide for more intensive interventions that become an opportunity for climate adaptation strategies, urban reforestation and new neighborhood equipment creation.

Figure 39: Small infrastructure urban projects (historical city centre (pedestrian areas, waterfront redevelopment, ex Cirio areas, Leonardo Bianchi): CLARITY supports the project with the climate performance assessment of a standard design compared to an adaptive design.

1.1.4.1 Climate adaptation strategies for the City of Naples

The goal of integrating climate adaptation measures into urban planning is a strategic priority at an international level. The available literature allows one to identify a series of adaptation measures in response to the impacts of extreme temperature and precipitation events that can be implemented at the local level based on an accurate analysis of the expected climate change scenarios. The assessment of the effectiveness of these measures can be linked to a series of indicators that define the contribution of each measure to the control of the urban microclimate.

Within CLARITY, a systematization of relevant literature resulted in the identification of a catalogue of most recurring adaptation measures, classified according to their ability to provide climate benefits in terms of:

1. reduction of impacts from heat waves, acting on the surface temperatures of buildings and open spaces and obtaining an improvement in the conditions of perceived thermal stress and the reduction of the Urban Heat Island (UHI);
2. reduction of the impacts of flood events, acting on the capacity of urban surfaces to guarantee adequate rainwater drainage and storage.

In relation to both categories of climate risk, however, it is worth highlighting the additional benefits associated with some types of adaptation measures, in particular green infrastructures such as green roofs, bioswales, trees or urban green areas, which contribute to carbon sequestration and climate mitigation (i.e. reducing CO_2 emissions), in terms of a local contribution to global warming.

The solutions "inspired and supported by nature" (NBS-Nature-Based Solutions) represent in this sense a priority in the international agendas on the issues of climate resilience and sustainable development, precisely for the ability to simultaneously provide environmental, social and economic benefits through systemic interventions adapted locally and resource efficient. NBS provide additional benefits related to "ecosystem services" which can be defined as "the direct and indirect contributions of ecosystems to human well-being". In addition to climate adaptation and mitigation, ecosystem services convey additional environmental benefits for cities, such as reducing air pollution and increasing biodiversity, but also social benefits such as higher quality public spaces and fewer health impacts.

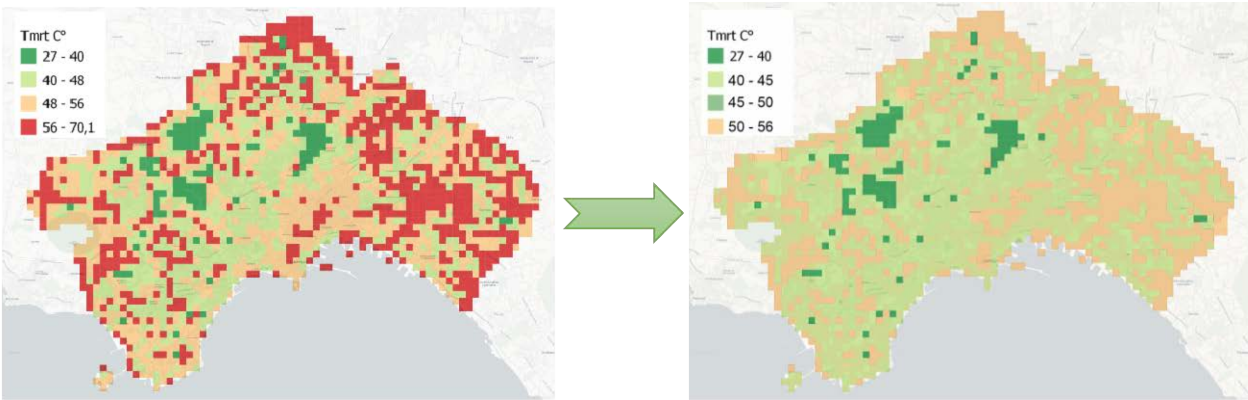
City-wide simulations on have been carried out to test the effect of adaptation measures in reducing the local effect hazard for heat waves and floods. Figure 41 shows an example of these calculations, focused on long-term “ideal” adaptation strategies towards 2050, which can represent a strategic adaptation planning vision to be phased over time in relation to established priorities for urban regeneration.

The Adaptation Measures Technical Cards (see D3.3 Annex III: Adaptation Measures Technical Cards) have been translated in Italian and used to support the co-design of adaptation strategies with local stakeholders in relation to the different planning levels identified.

The costs of adaptation strategies/measures implementation is a crucial information to support local programming, planning and design processes. Cost-benefit analyses have been carried out both on city-wide strategies and on specific areas, thus providing decision makers and technical departments with a structured information useful to negotiate funding allocation at national and regional level, especially in the context of ERDF 2021-2027 (Napoli is among the EU Convergence Regions, with a relevant allocation of funding) and in the light of the EU Green Deal and the Recovery Fund.

While the city-wide adaptation costs might seem a huge figure to support, if phased in e.g. 10 years to support EU Adaptation Strategy towards 2030, consists of only 3% of the GDP of the Metropolitan City of Naples, representing at the same time an investment with a high potential of leveraging local economy in the Green Deal perspective.

When breaking down the figure focusing on specific areas (see following section) the costs are perfectly in line with similar urban regeneration interventions. The possibility of analyzing climate adaptation potential together with such detailed control of financial expenditure allows a proper phasing of PUC sub-projects.



Adaptation costs (“ideal” strategies towards 2050)	€/m^2	€ tot Napoli
Open spaces	€ 49,38	€ 2.153.138.128,29
Buildings	€ 216,26*	€ 13.514.906.677,95
Maintenance and enhancing of sewage systems	€ 35,00	€ 2.842.172.459,38

***per m^2 of surface cover**

Figure 40: Example of the cost-benefit assessment of “ideal” long-term adaptation strategies.

1.1.4.2 Adaptation strategies integration in specific areas

Based on the results of the city-wide climate hazard analyses and their correlation with urban redevelopment priorities as defined by the PUC, specific adaptation plans have been developed in city areas identified for “large infrastructure urban project” and “small infrastructure urban project”, calculating their performance in terms of heat stress reduction and the corresponding costs. The four areas have been identified within the end-user workshops as follows:

1. Miano IACP
2. Miano Alifana
3. Soccavo
4. Pianura

The adaptation project of the sample areas was developed together with the Municipality of Naples. Once the strategies applied return the optimal results in terms of UTCI and Tmrt, they are accounted for in detail on the basis of the surfaces and the corresponding cost analyses. Cost analyses are done on individual costs, studied for each adaptation measure based on the percentage of land use modified. Total costs refer to the cells corresponding to the project area, marked with a black boundary in Figure 42Figure 43 and following.

The following pages illustrate the results of the analyses carried out.

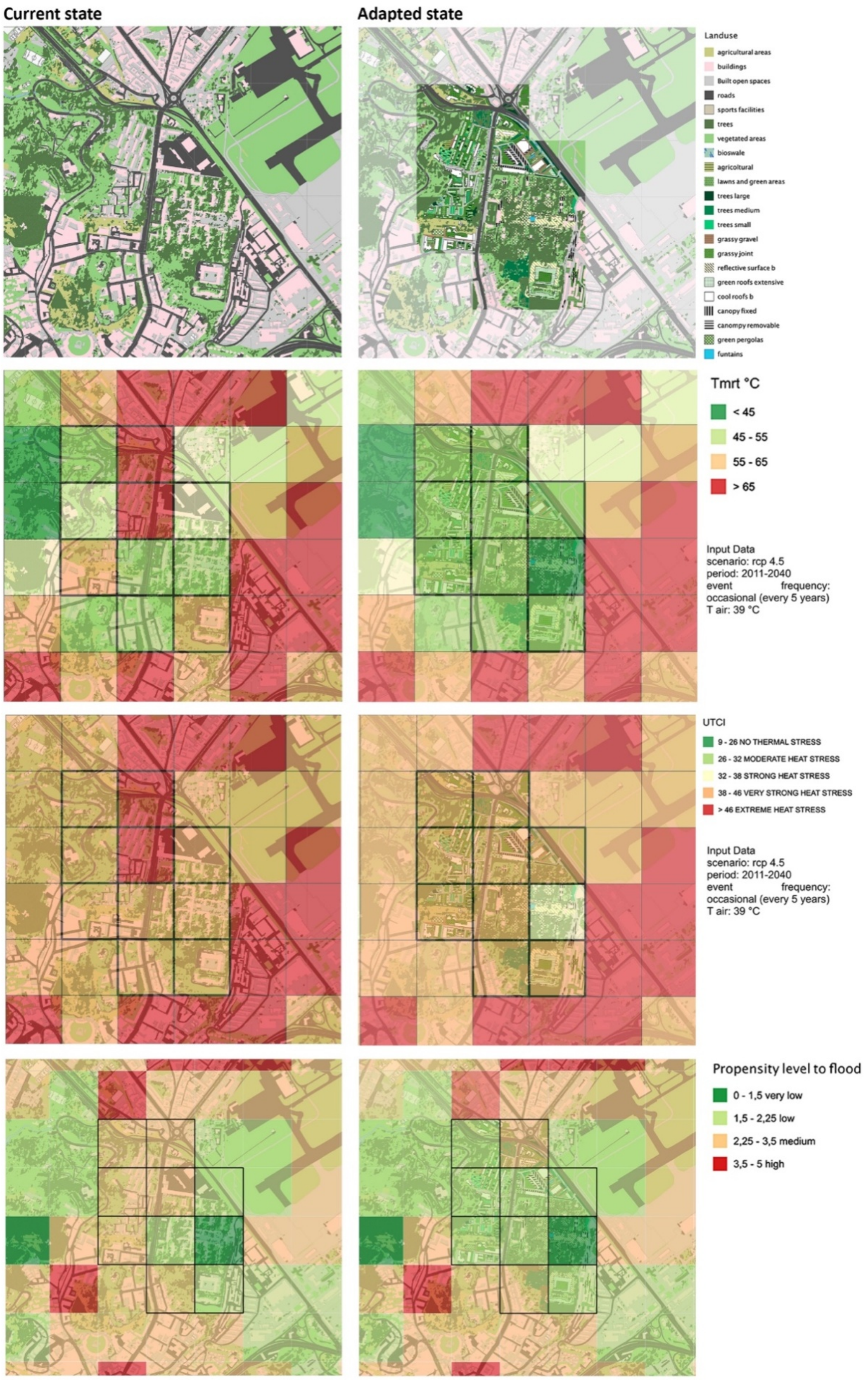


Figure 41: Sample area, Miano IACP: land use, Tmrt, UTCI, flooding probability - current and adapted (Input Data Scenario: RCP 4.5; Period: 2010-2040; Event frequency: occasional).

Table 16: Detailed analysis of different land uses in the Miano IACP sample area (Source: PLINIVS-LUPT, CLARITY).

Current state		
Land use class	**m²**	**%**
agricultural areas	14469	2,3%
buildings	109871	17,1%
Built open spaces	146600	22,8%
roads	103448	16,1%
trees	164556	25,6%
vegetated areas	103526	16,1%
TOTAL	**642470**	**100%**

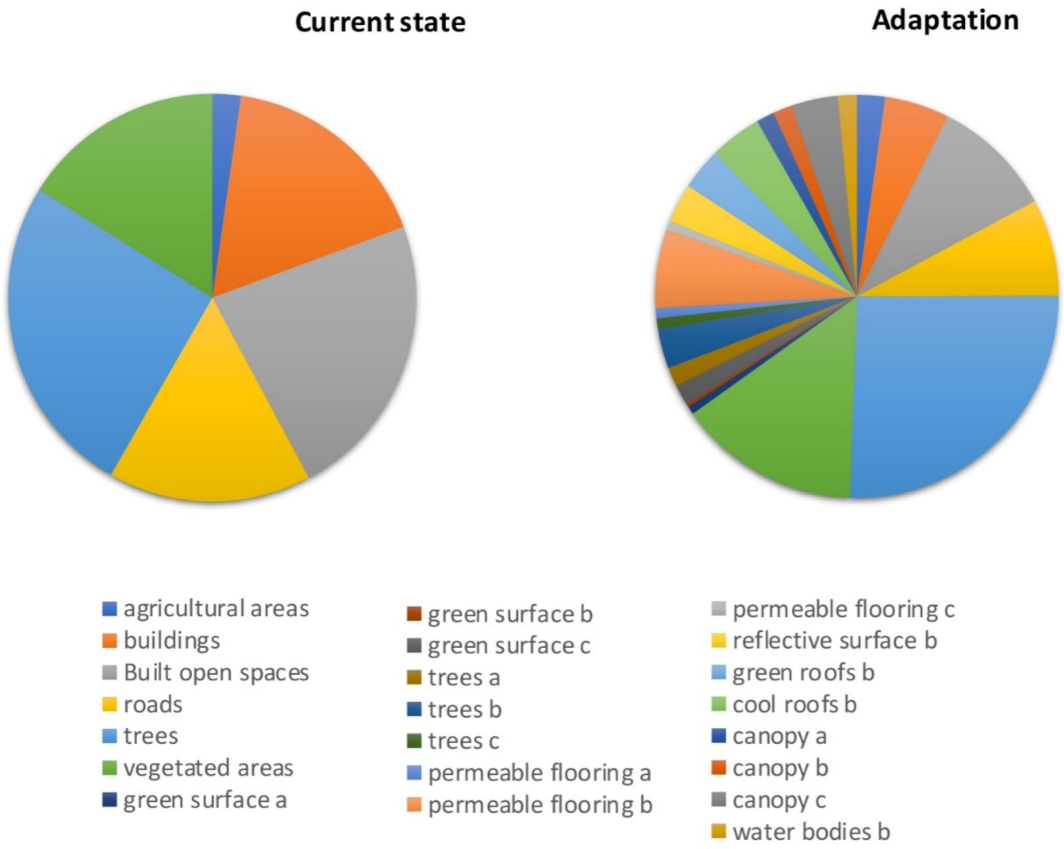


Figure 42: Detailed analysis of different land uses in the Miano IACP sample area (Source: PLINIVS-LUPT, CLARITY).

Table 17: Detailed analysis of different land uses and adaptation measures costs in the Miano IACP sample area (Source: PLINIVS-LUPT, CLARITY project).

Adaptation plan				
	Land use class	**m^2**	**%**	**€**
Current land use	agricultural areas	14469	2,3%	-
	buildings	33230	5,2%	-
	Built open spaces	62596	9,7%	-
	roads	50037	7,8%	-
	trees	164556	25,6%	-
	vegetated areas	93478	14,5%	-
Adapted land use	green surface a	4261	0,7%	€ 649.742,54
	green surface b	1592	0,2%	€ 51.747,82
	green surface c	10690	1,7%	€ 347.415,66
	trees a	9830	1,5%	€ 4.263.566,43
	trees b	20435	3,2%	€ 5.364.083,28
	trees c	5461	0,8%	€ 525.617,75
	permeable flooring a	5284	0,8%	€ 369.874,87
	permeable flooring b	40516	6,3%	€ 1.418.070,65
	permeable flooring c	4672	0,7%	€ 11.679,03
	reflective surface b	20077	3,1%	€ 301.159,90
	green roofs b	21478	3,3%	€ 1.181.264,50
	cool roofs b	26922	4,2%	€ 111.724,63
	canopy a	9299	1,4%	€ 2.092.224,73
	canopy b	9830	1,5%	€ 847.798,51
	canopy c	23930	3,7%	€ 2.093.838,02
	water bodies b	9830	1,5%	€ 368.608,05
	TOTAL	**642470**	**100,0%**	**€ 19.998.416,36**

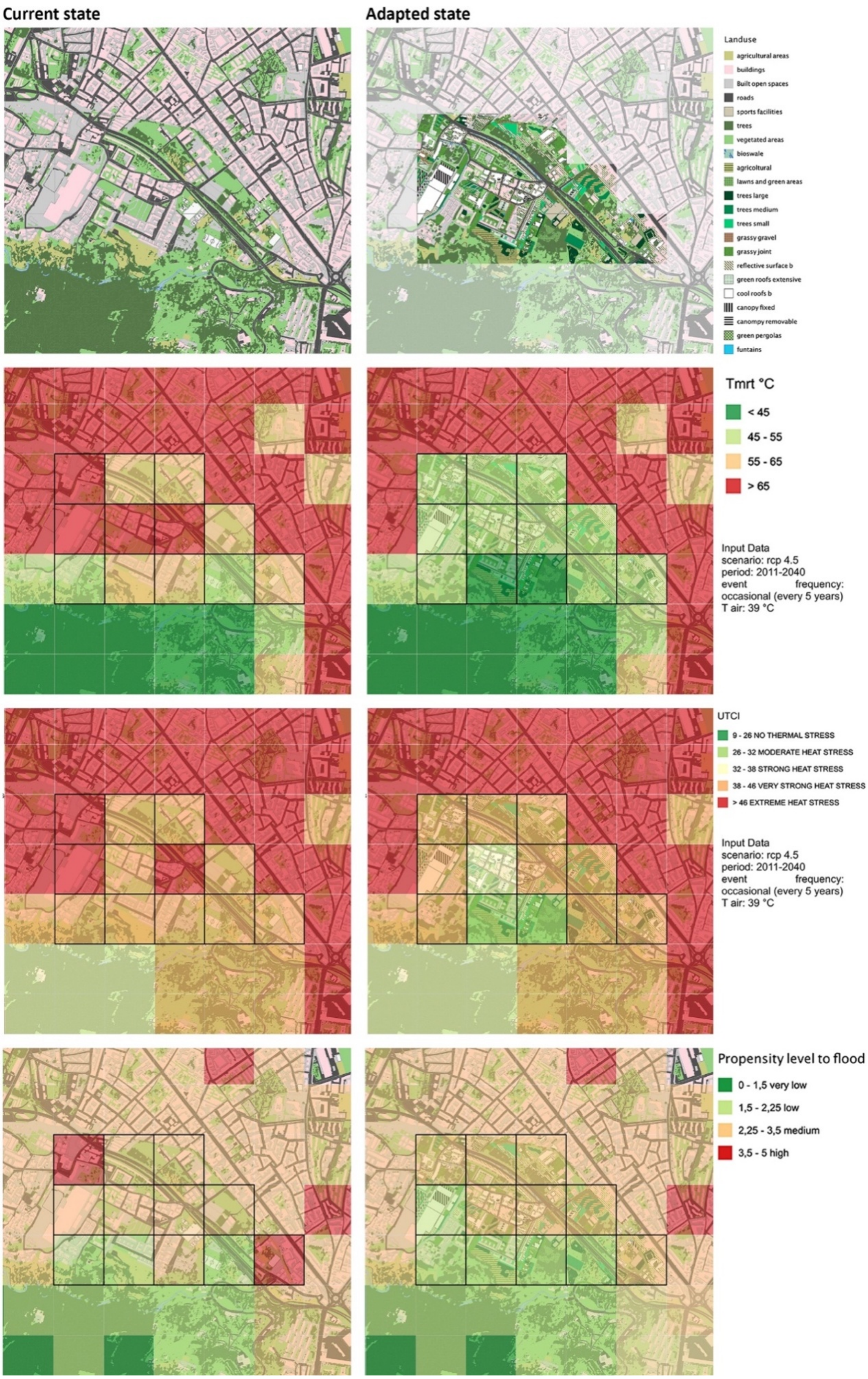


Figure 43: Sample area, Miano Alifana: land use, Tmrt, UTCI, flooding probability - current and adapted (Input Data Scenario: RCP 4.5; Period: 2010-2040; Event frequency: occasional).

Table 18: Detailed analysis of different land uses in the Miano Alifana sample area (Source: PLINIVS-LUPT, CLARITY).

Current state		
Land use class	**m²**	**%**
agricultural areas	16382	2,2%
buildings	127031	16,9%
Built open spaces	240351	32,0%
roads	100763	13,4%
sports facilities	11097	1,5%
trees	124321	16,6%
vegetated areas	110469	14,7%
cool roofs b	15218	2,0%
canopy a	4936	0,7%
TOTAL	**750568**	**100,0%**

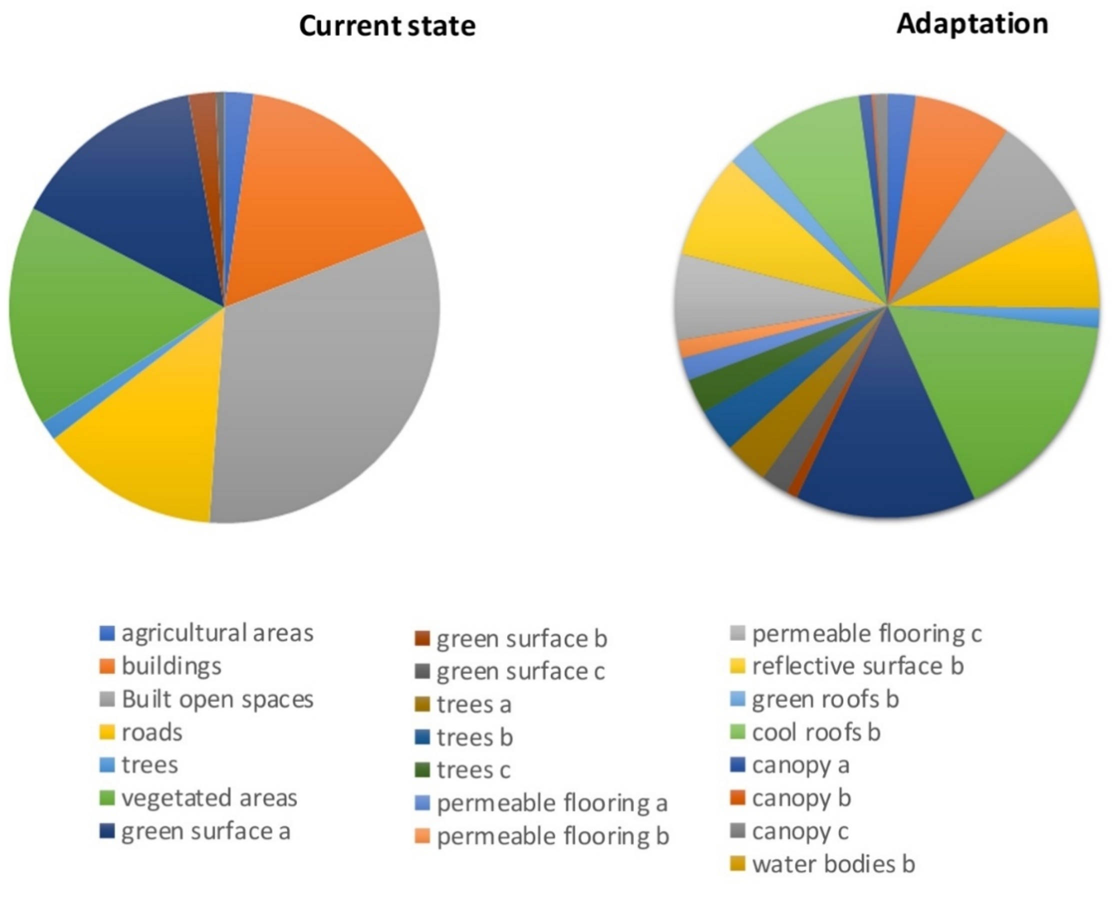


Figure 44: Detailed analysis of different land uses in the Miano Alifana sample area (Source: PLINIVS-LUPT, CLARITY).

Table 19: Detailed analysis of different land uses and adaptation measures costs in the Miano Alifana sample area (Source: PLINIVS-LUPT, CLARITY).

Adaptation				
	Land use class	**m²**	**%**	**€**
Existing land use	agricultural areas	16257	2,2%	-
	buildings	55434	7,4%	-
	Built open spaces	59514	7,9%	-
	roads	57950	7,7%	-
	sports facilities	11097	1,5%	-
	trees	124321	16,6%	-
	vegetated areas	103469	13,8%	-
Adapted land use	green surface a	6362	0,8%	€ 970.269,81
	green surface b	15666	2,1%	€ 509.156,96
	green surface c	25129	3,3%	€ 816.684,17
	trees a	25109	3,3%	€ 10.891.025,11
	trees b	19841	2,6%	€ 5.208.313,08
	trees c	12913	1,7%	€ 1.242.872,68
	permeable floring a	10285	1,4%	€ 719.939,88
	permeable floring b	49082	6,5%	€ 1.717.855,32
	reflective surface b	60055	8,0%	€ 900.832,06
	green roofs b	15093	2,0%	€ 830.114,34
	cool roofs b	66802	8,9%	€ 277.226,87
	canopy a	7344	1,0%	€ 1.652.293,43
	canopy b	1522	0,2%	€ 131.240,65
	canopy c	7132	1,0%	€ 624.062,06
	water bodies b	192	0,0%	€ 7.205,01
	TOTAL	**750568**	**100,0%**	**€ 26.499.091,42**

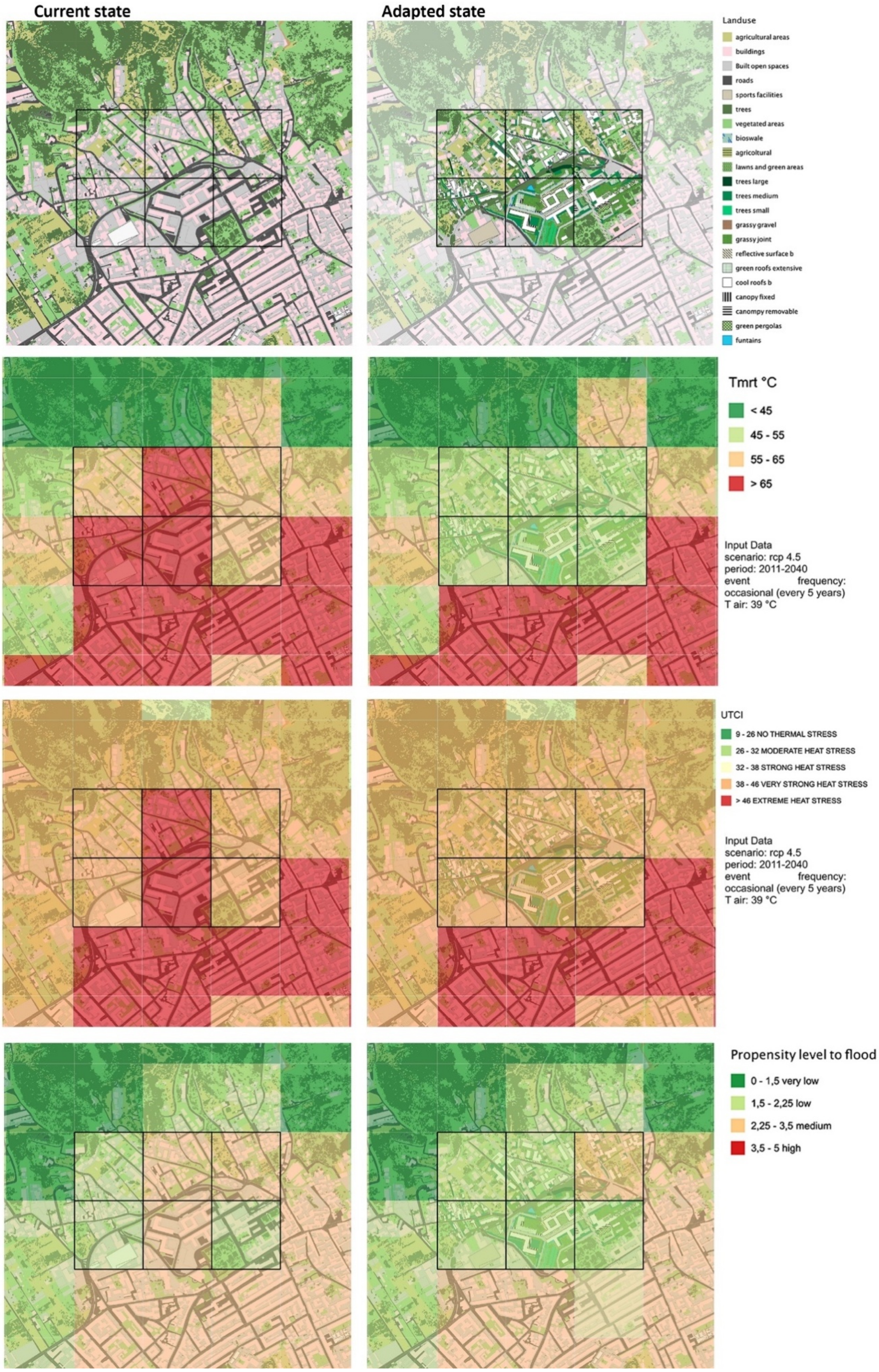


Figure 45: Detailed analysis of Land use, TMRT, UTCI, Flooding in the Pianura sample area, for a typical day of heat wave with an air temperature of 39 °C. (Source: PLINIVS-LUPT, CLARITY).

Table 20: Detailed analysis of different land uses in the Pianura sample area (Source: PLINIVS-LUPT, CLARITY).

Current state		
Land use class	**m²**	**%**
agricultural areas	24898	6,6%
buildings	89243	23,8%
Built open spaces	119838	31,9%
roads	45566	12,1%
sports facilities	6502	1,7%
trees	47246	12,6%
vegetated areas	42061	11,2%
TOTAL	**375353**	**100,0%**

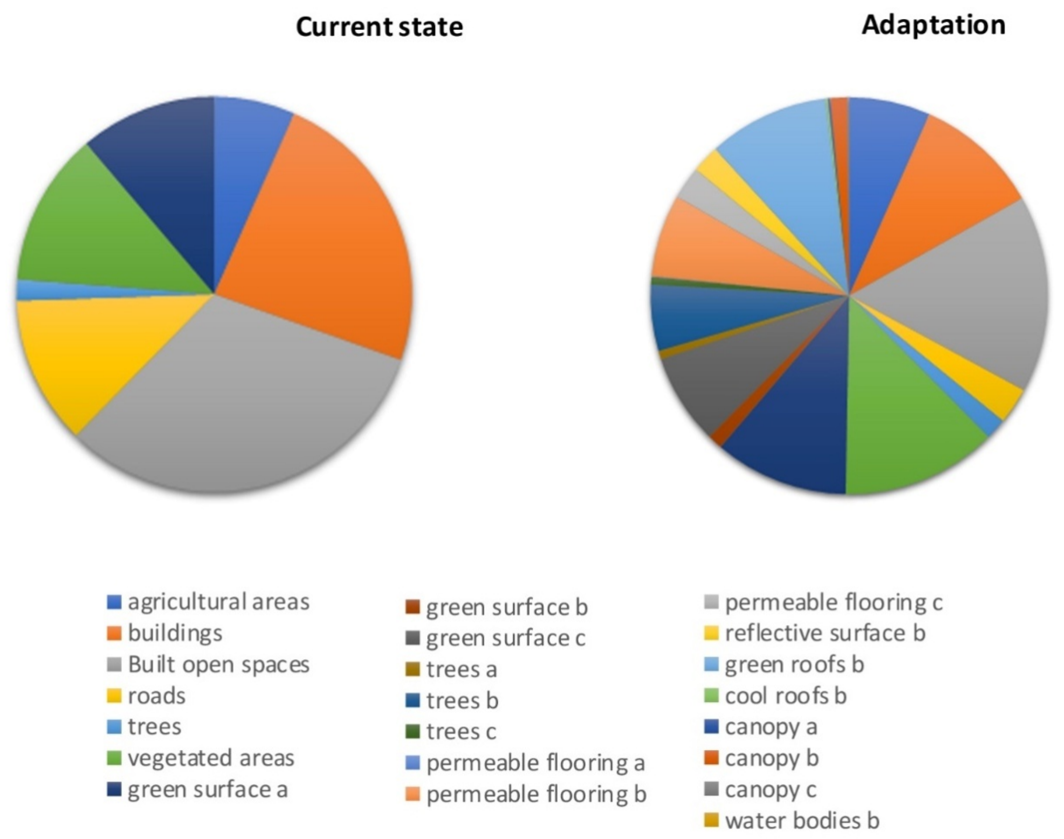


Figure 46: Detailed analysis of different land uses in the Pianura sample area (Source: PLINIVS-LUPT, CLARITY project).

Table 21: Detailed analysis of different land uses and adaptation measures costs in the Pianura sample area (Source: PLINIVS-LUPT, CLARITY project).

Adaptation				
	Land use class	**m²**	**%**	**€**
Existing land use	agricultural areas	24898	6,6%	-
	buildings	38311	10,2%	-
	Built open spaces	60295	16,1%	-
	roads	11133	3,0%	-
	sports facilities	6502	1,7%	-
	trees	47554	12,7%	-
	vegetated areas	41082	10,9%	-
Adapted land use	green surface a	4549	1,2%	€ 693.677,23
	green surface c	27763	7,4%	€ 902.282,65
	trees a	2549	0,7%	€ 1.105.814,75
	trees b	20228	5,4%	€ 5.309.806,28
	trees c	2351	0,6%	€ 226.252,49
	permeable floring a	213	0,1%	€ 14.909,82
	permeable floring b	25290	6,7%	€ 885.141,60
	reflective surface b	9990	2,7%	€ 149.853,43
	green roofs b	8520	2,3%	€ 468.577,31
	cool roofs b	36983	9,9%	€ 153.480,28
	canopy a	771	0,2%	€ 173.437,21
	canopy b	672	0,2%	€ 57.972,01
	canopy c	5317	1,4%	€ 465.228,76
	water bodies b	382	0,1%	€ 14.320,88
	TOTAL	**375353**	**100,0%**	**€ 10.620.754,71**

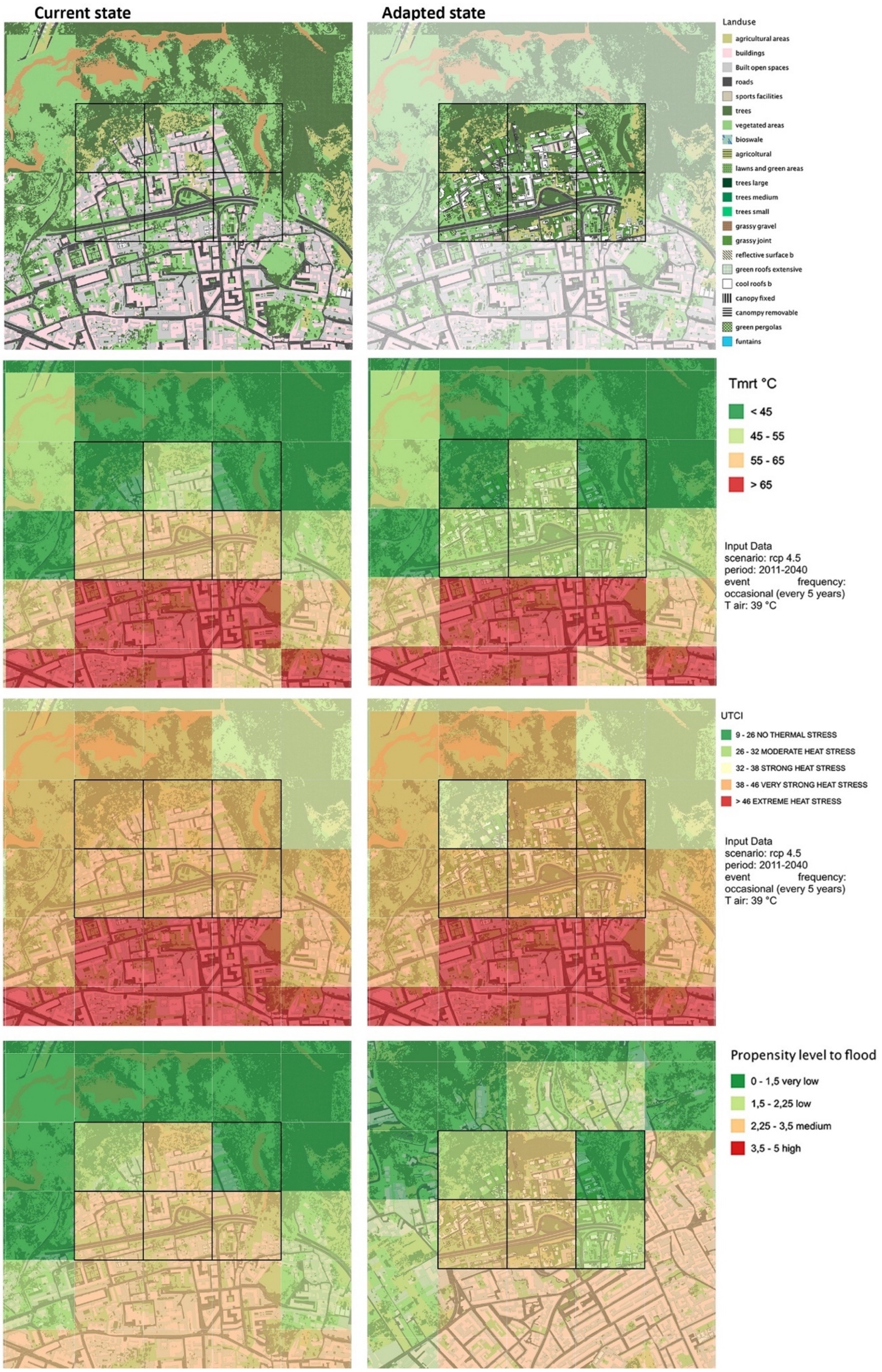


Figure 47: Detailed analysis of Land use, TMRT, UTCI, Flooding in the Soccavo sample area, for a typical day of heat wave with an air temperature of 39 °C. (Source: PLINIVS-LUPT, CLARITY project).

Table 22: Detailed analysis of different land uses in the Soccavo sample area (Source: PLINIVS-LUPT, CLARITY project).

current state		
Land use class	**m²**	**%**
agricultural areas	40416	10,8%
Bare soil	288	0,1%
buildings	45639	12,2%
Built open spaces	44991	12,0%
roads	39625	10,6%
sports facilities	3841	1,0%
trees	135709	36,2%
vegetated areas	64840	17,3%
TOTAL	**375349**	**100,0%**

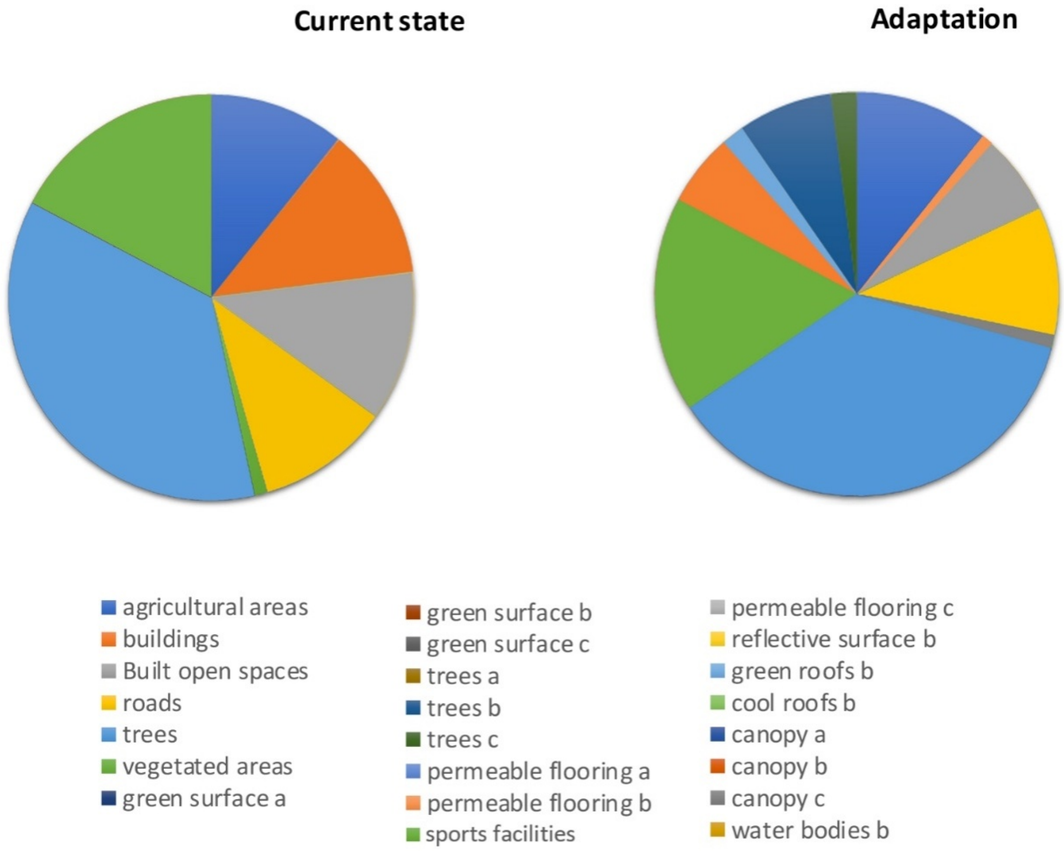


Figure 48: Detailed analysis of different land uses in the Soccavo sample area (Source: PLINIVS-LUPT, CLARITY).

Table 23: Detailed analysis of different land uses and adaptation measures costs in the Soccavo sample area (Source: PLINIVS-LUPT, CLARITY project).

Adaptation				
	Land use class	**m²**	**%**	**€**
Existing land use	agricultural areas	40416	10,8%	-
	Bare soil	288	0,1%	-
	buildings	2814	0,7%	-
	Built open spaces	23962	6,4%	-
	roads	38805	10,3%	-
	sports facilities	3841	1,0%	-
	trees	135709	36,2%	-
	vegetated areas	64840	17,3%	-
Adapted land use	permeable floring b	21849	5,8%	€ 764.705,34
	green roofs b	6559	1,7%	€ 360.727,26
	cool roofs b	28500	7,6%	€ 118.274,26
	canopy c	7766	2,1%	€ 679.532,83
	TOTAL	**375349**	**100,0%**	**€ 1.923.239,70**

1.1.5 District planning - Ponticelli Urban Regeneration Plan (PRU)

The Ponticelli area will represent a district scale focus about urban adaptation to Heat Wave and Flooding. The end-user workshop of January 2020 has confirmed that the Ponticelli area is appropriate and in line with the Urban Regeneration Programme (PRU) work schedule. The willingness to collaborate to deepen the issues related to climate adaptation in the sub-areas of the project is confirmed.

Following specific requests of the Municipality of Naples, in order to provide support to the implementation of the Ponticelli Urban Regeneration plan, further expert analyses have been produced in this area of the city, assessing the effect of different configurations of building and open spaces, as well as of different surface covers, starting from the baseline projects developed by the Social Housing Department, in charge of implementing the plan.

Simulations have been carried out using Solweig model in combination with an original parametric workflow developed in Grasshopper, based on the combination of available plug-ins based on validated models such as Ladybug, Honeybee and Envimet.

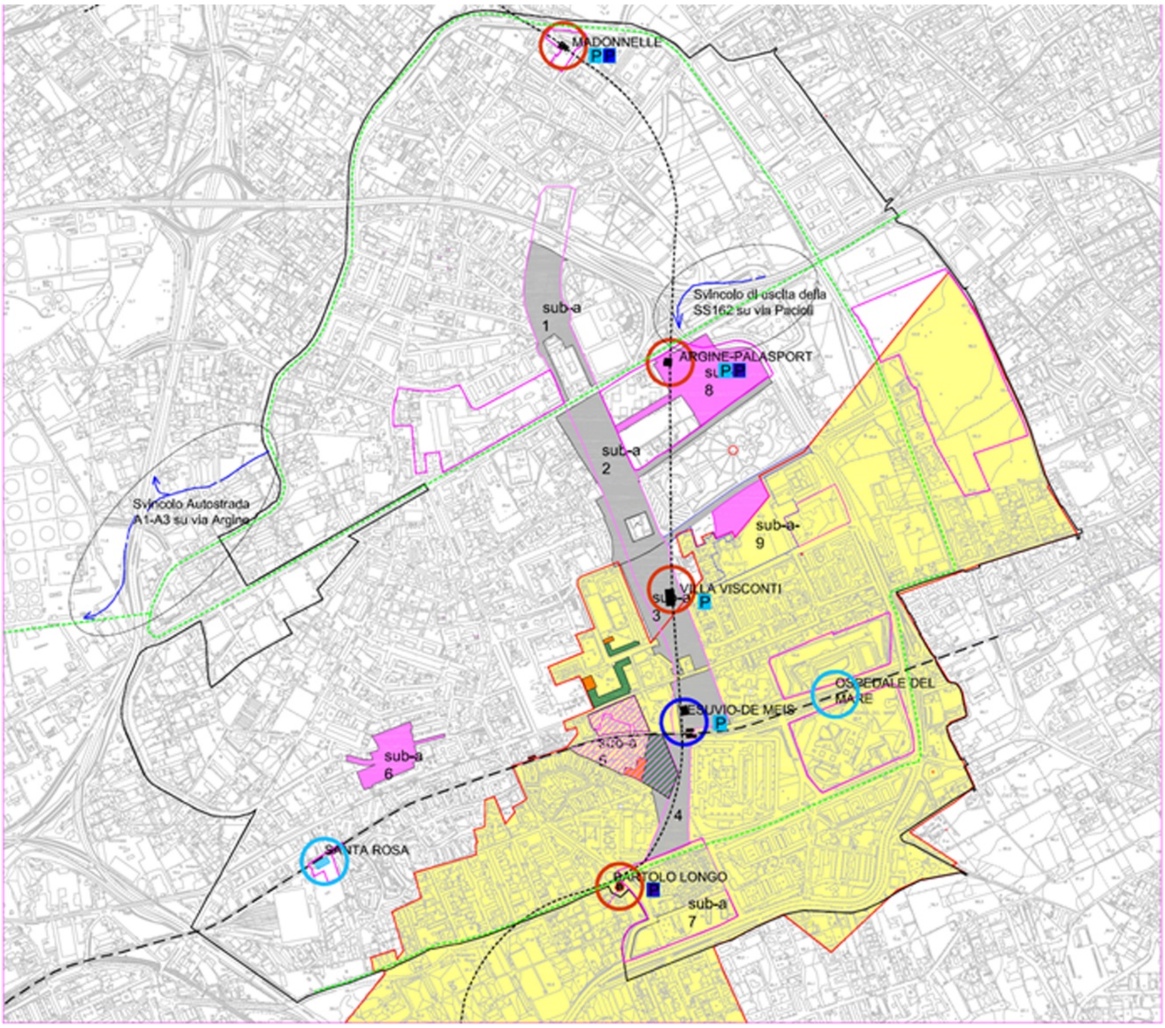


Figure 49: Ponticelli Urban Regeneration Plan (PRU) 2018. Project areas identification (sub-ambiti) and Vesuvius Volcanic Risk Red Zone delimitation (in yellow) (source: Municipality of Napoli).

PRU is focused on a residential and mixed-use development in 9 areas ("sub-areas") of the Ponticelli district. CLARITY simulations are expected to address design choices concerning buildings layouts, surface materials and vegetation patterns. The current stage of development implemented by the Municipality provides the main quantitative data for new buildings (residential and services), roads and public spaces, as well as limits in terms of built volumes and standards for green areas and public services (Table 24).

Table 24: Ponticelli Urban Regeneration Plan, quantitative data.

SCENARIO 1 + RESIDENZA. Proposta di revisione Pru Ponticelli - MAGGIO 2018 - parametri urbanistici insediamenti integrati residenzial-terziari

			STANDARD RESIDENZA MINIMI				STAND. TERZIARIO MIN.		STAND. AGGIUNT.MIN		STAND. TOT. MINIMI		STAND. EFFETT.		STAND. TOT.EFFETT.		STAND. TOT.EFF
Sub-ambito		abitanti	Sup. a Standard residenz. minima mq				Standard terz. minima		Sup.Standard aggiuntiva		Sup.Standard tot. Min.		Sup. Standard effettivi		Sup. Standard effettivi		SUB-AMBITO
			Istruzione	Int. Comune	Parco	Parcheggio	Parco	Parcheggio	Parco	Parcheggio	Parco	Parcheggio	Istruzione	Int. Comune	Parco	Parcheggio	
1	priv./soc.	284	1.420,00	710,00	2.840,00	710,00	3.381,00	3.381,00	4.552,00	2.276,00	6.221,00	4.091,00	0,00	0,00	8.545,00	6.071,00	14.616,00
2	priv./sociale	451	2.255,00	1.128,00	4.510,00	1.128,00	5.362,00	5.362,00	6.700,00	3.350,00	9.872,00	6.490,00	0,00	0,00	19.440,00	10.819,00	30.259,00
3			0,00	0,00	0,00	0,00	7.922,51	7.922,51	5.717,10	2.858,55	7.922,51	7.922,51	0,00	0,00	20.454,00	3.021,00	23.475,00
4			0,00	0,00	0,00	0,00	7.526,00	7.526,00	5.600,00	2.800,00	7.526,00	7.526,00	0,00	0,00	16.749,00	4.141,00	20.890,00
5	erp	263	1.313,00	656,00	2.625,00	656,00	4.000,00	4.000,00	5.170,00	2.585,00	6.625,00	4.656,00	0,00	1.914,00	19.130,00	8.982,00	30.026,00
6 A	erp	150	750,00	375,00	1.500,00	375,00	0,00	0,00	1.536,00	768,00	1.500,00	375,00	0,00	2.000,00	1.817,00	1.330,00	5.147,00
6 B	erp	227,5	1.137,00	569,00	2.275,00	569,00	0,00	0,00	2.399,00	1.326,00	2.275,00	569,00	0,00	0,00	4.674,00	1.895,00	6.569,00
7	erp	195	976,00	488,00	1.952,00	488,00	5.029,00	5.029,00	6.026,00	3.013,00	6.981,00	5.517,00	0,00	4.966,00	15.400,00	8.938,00	29.304,00
8	erp	500	2.500,00	1.250,00	5.000,00	1.250,00	2.560,00	2.560,00	7.450,00	3.725,00	10.920,00	4.650,00	5.367,00	3.139,00	12.720,00	9.300,00	30.526,00
	priv./soc.	336	1.680,00	840,00	3.360,00	840,00											
9	erp	425	2.125,00	1.063,00	4.250,00	1.063,00	2.834,00	2.834,00	10.169,00	5.084,00	10.804,00	4.827,00	4.226,00	6.287,00	25.858,00	8.650,00	45.021,00
	priv./soc.	372	1.860,00	930,00	3.720,00	930,00											
totale erp																	
totale priv.																	
Totale			16.016,00	8.009,00	32.032,00	8.009,00	38.614,51	38.614,51	55.319,10	27.785,55	70.646,51	46.623,51	9.593,00	18.306,00	144.787,00	63.147,00	235.833,00

CLARITY support concerns detailed simulations on such project areas, based on Morphological and functional Project-guide approved in 2018 (Figure 51) and on the planning and design layouts proposed by the Municipality. Dedicated co-design workshops have been implemented to streamline the integration of adaptation measures in the Plan, where alternative design scenarios aimed at minimizing impacts from heat waves in terms of heat discomfort of population and energy consumption of buildings are proposed by the CLARITY DC1 team.

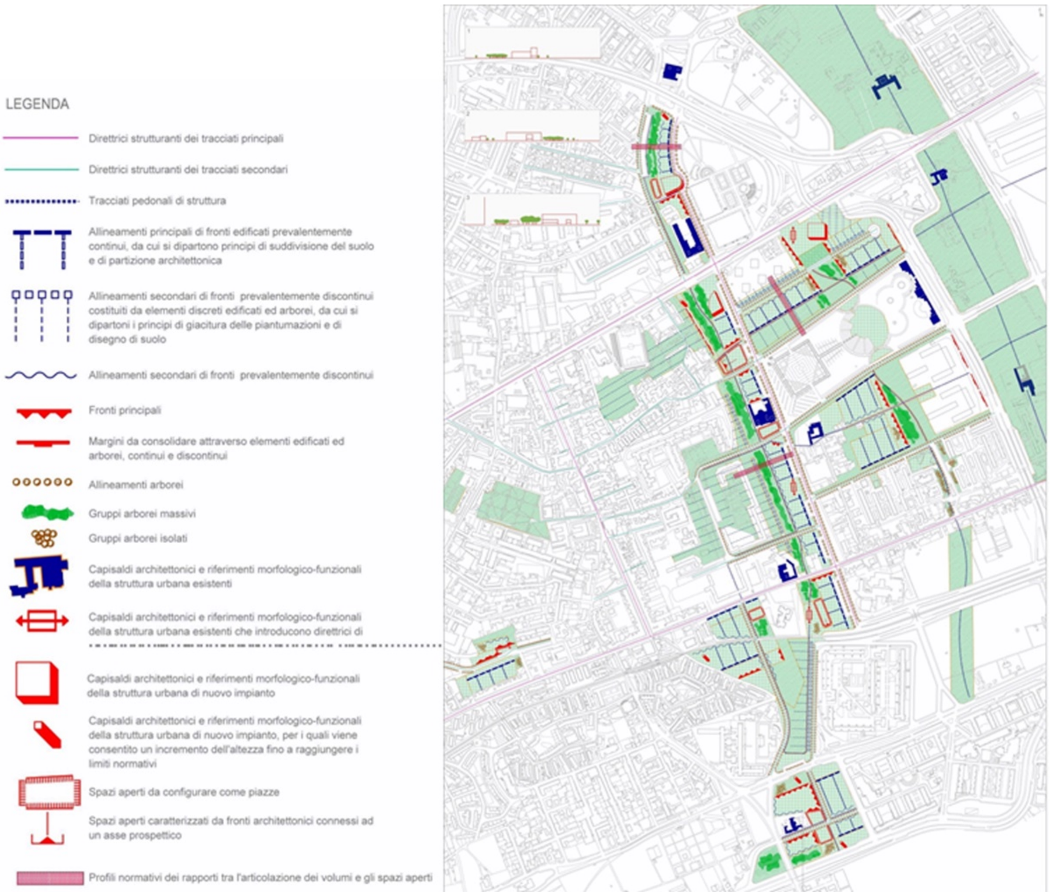


Figure 50: Ponticelli Urban Regeneration Plan (PRU) 2018. Morphological and functional Project-guide. (source: Municipality of Napoli).

While the PRU action (and corresponding funding) is limited to these 9 portions of the district, the demonstrator aims to provide a district level masterplan which also includes areas external to the PRU perimeter (e.g. including public roads), so to give a comprehensive vision of climate adaptation design principles at the district scale, and delivering to the end-user a planning document which can support further request for funding at national and EU level.

General urban planning data, defined by the City Plan (PUC) can be summarized as follows:

- land area: 160,000 m
- building volume ratio not higher than 4 cubic meters / square mete
- maximum achievable volume 640,000 cubic meters
- area for public facilities not less than 345,000 m^2
- road network: 20,000 m^2
- residential building must be max 60% of the realizable volume, equal to 384,000 cubic meters
- public facilities sizing: open public spaces, or public spaces arranged in green spaces, extension cannot be less than 50% of the CIS surface; PRU will be able to change its location, based on an organic urban configuration, and provide for a partial construction, in any case not less than the limits set by the D.Lgs 1444/68.

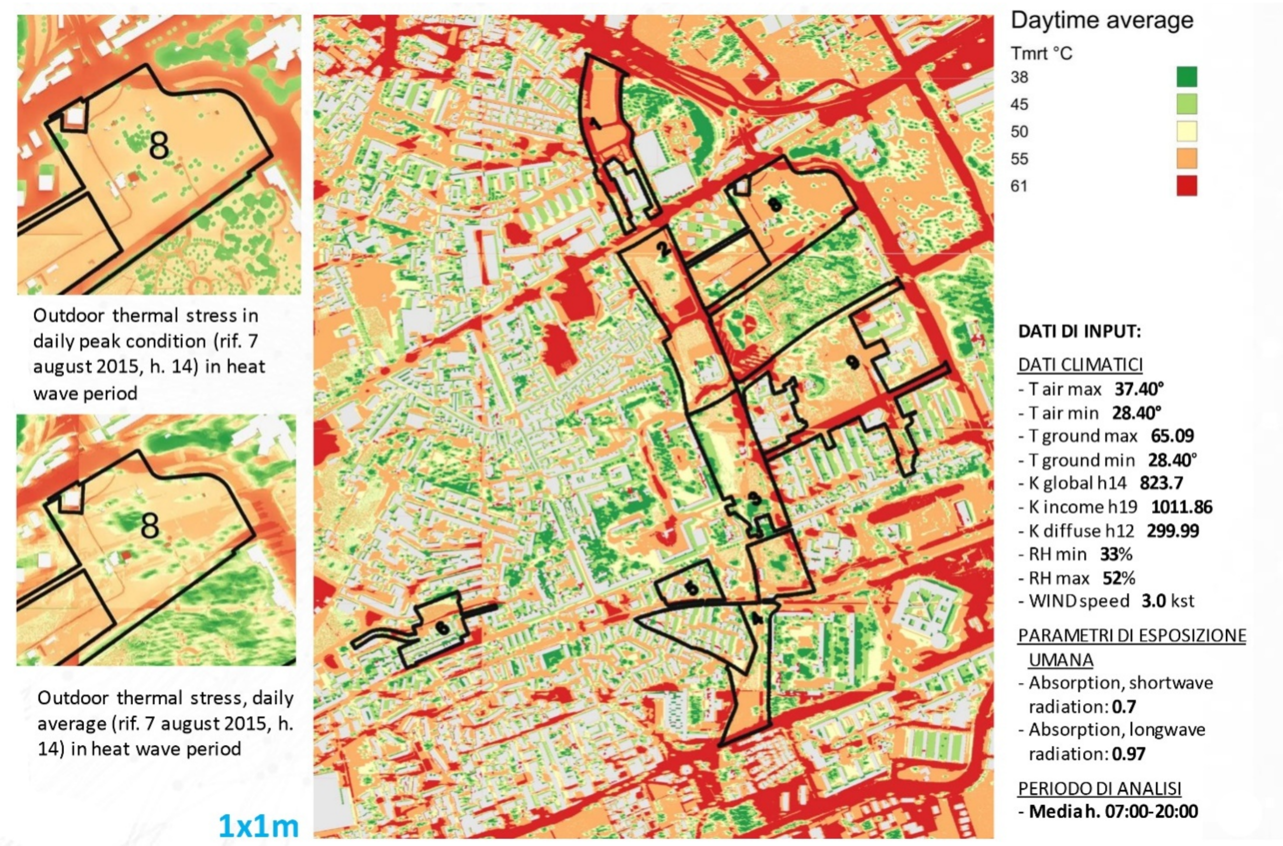


Figure 51: Detailed Tmrt simulation with the Solweig model in the PRU area (right) and zoom on sub-area 8 (left), current condition, referred to the August 2015 heat wave. (Source: PLINIVS-LUPT, CLARITY).

Ponticelli's PRU represents a focus on the implementation plan of the CLARITY tools, supporting the evaluation of the technical-design alternatives developed on the basis of general planning guidelines in terms of volumes and urban planning standards.

CLARITY simulations are in this case carried out in a three-dimensional environment with a 1-5m resolution, in order to evaluate in detail the design choices (layout and materials used) for buildings, paved and vegetated open spaces.

Figure 53 and Figure 54 show a detail of the current land use and the Tmrt simulation on the 250x250 grid used for the PUC analyses in the area of the PRU (marked in Figure 54 with a black perimeter) and the Ponticelli historic centre, eastward of PRU area. It can be noticed that most of the areas within the PRU perimenter show good Tmrt values in the current state. This because most of these areas are currently unbuilt, with a prevalence of vegetated areas and portions of agricultural fields. This aspect is of great interest, since the challenge in this area is to design new mixed use/residential buildings and public spaces which do not undermine the current good performance in terms of heat stress, becoming a local model for a climate-resilient new urban development.

Figure 52: Detailed land use in Ponticelli area (Source: PLINIVS-LUPT, CLARITY).

Figure 53: Tmrt analysis in Ponticelli area (Source: PLINIVS-LUPT, CLARITY).

Different project scenarios for some PRU sub areas have been co-designed with the Municipality of Naples, and for each design solution Tmrt and UTCI analysis have been carried out and compared with the current state analysis.

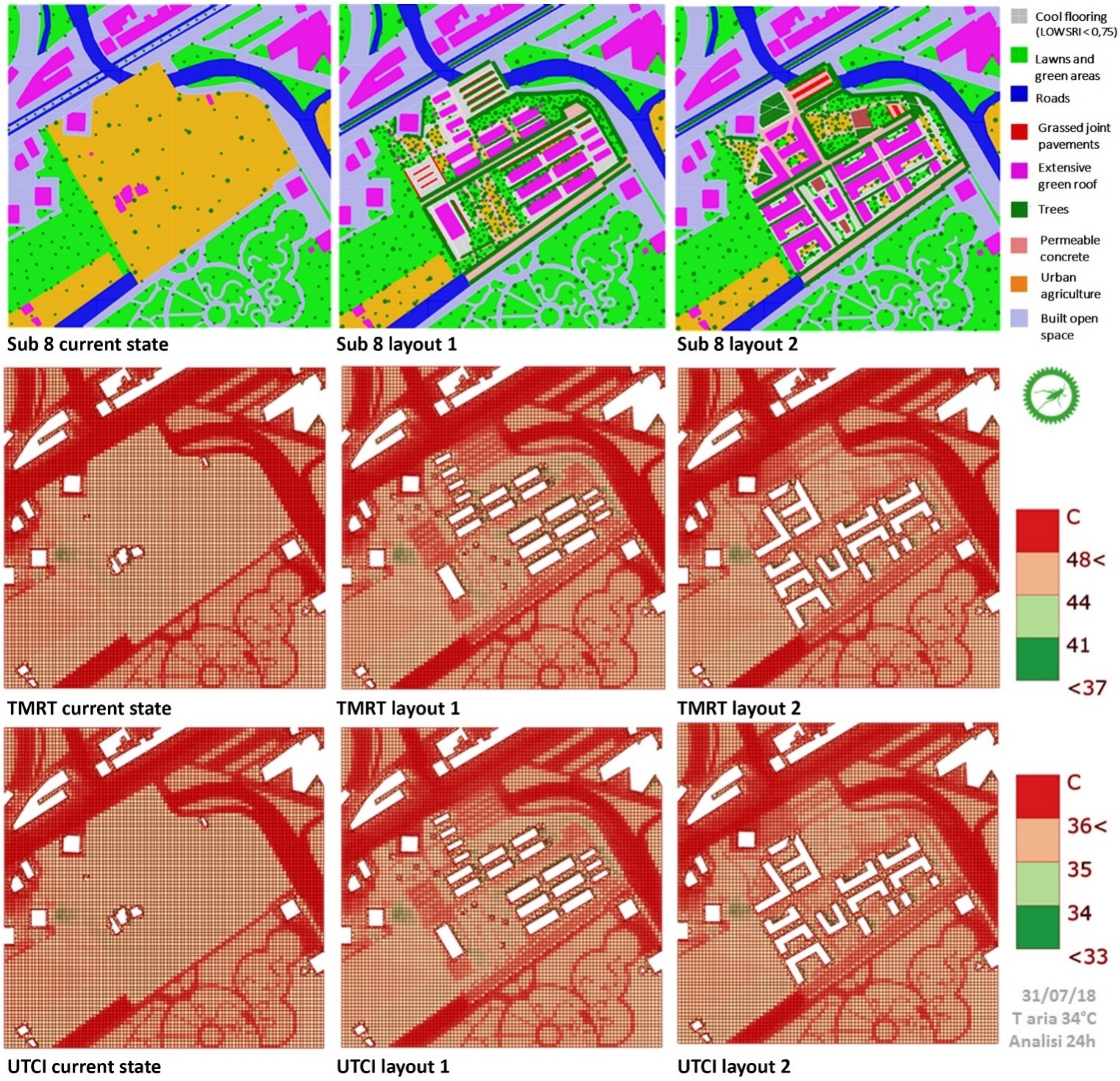


Figure 54: Detailed Tmrt and UTCI simulations with the Grasshopper model in the PRU sub-area 8, referred to the July 2018 heat wave. (Source: PLINIVS-LUPT, CLARITY).

The proposed parametric design workflow is intended to facilitate the implementation of analyses on any design proposal developed by the Municipality Departments and/or external consultants. Specific guidelines have been drafted to prepare 3D drawings using Rhinoceros (which is a widely used 3D modelling software used in architecture and urban design) so that the design layouts can be directly analysed through the CLARITY Grasshopper components.

The current state and design layouts are drafted according the CLARITY land use categories (including the land uses corresponding to adaptation measures), so that the different parameters affecting Tmrt and UTCI are directly attributed in Grasshopper. the land uses that characterize the territory, thus defining its current state. Climate data are stored in EPW files corresponding to current climate and to future projected scenarios.

The Tmrt and UTCI analyses refer to the 24h average in a heat wave period, as the greatest climate-related hazard in the area is caused by excessively high temperatures. The area is in fact located on the eastern part of the slopes of Vesuvius, characterized by a prevalence of permeable green surfaces and thus not particularly prone to flooding. Furthermore, at the centre of the PRU area is located a major branch of the East Naples sewage system, which has a very high capacity and is usually able to drain rainwater even in case of extreme precipitation events. However, a high surface run-off in the PRU area (which could be worsened by converting the current green areas into buildings and paved open spaces) is likely to aggravate pluvial flooding conditions in the nearby neighbourhood of Barra and S. Giovanni, located downstream of Ponticelli on a plain area almost at sea level. For this reason, solutions to maximise rainwater infiltration, as well as rainwater harvesting and reuse, have been proposed in the design of adaptation strategies.

Simulation output in Grasshopper allows to carry out analyses of the technical solutions for buildings and opens space to assess their climate performance with a detail adequate to a neighbourhood scale design (5x5m grid resolution). The design solutions are defined with reference to the adaptation measures and combined into suitable strategies, accounting for their climate benefits and co-benefits as reported in the Technical Cards of Adaptation measures (see D3.3).

The comparisons among different design layouts in terms of Tmrt or UTCI (Figure 56) allow to support the selection of the final reference solutions, which will be included in the final version of the PRU as technical documentation for the Public Tenders for the implementation of the project.

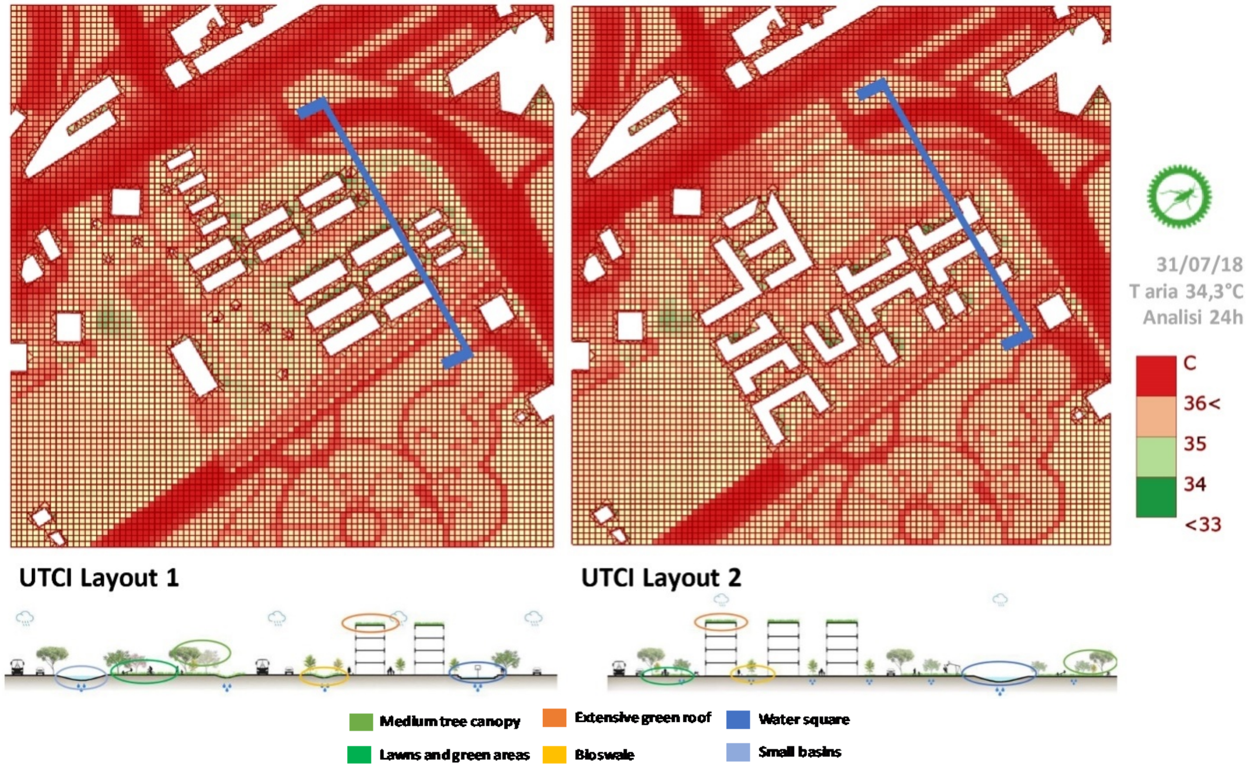


Figure 55: Detailed UTCI simulations for two different design layouts in PRU sub-area 8. Project sections highlight the adaptation measures applied with reference to the Technical Cards implemented within CLARITY (Source: PLINIVS-LUPT, CLARITY).

Further analyses useful to support district planning implementation include the 3D analysis of surface temperature, including open spaces and building envelopes (Figure 57) and building energy performance assessment (Table 25). Together with the integration of adaptation measures aimed at improving outdoor comfort, Near Zero Energy Building solutions are proposed to guarantee indoor comfort while minimizing energy consumption (with a specific focus on summer behaviour of buildings), through a combination of passive solutions (e.g. thermal mass of opaque envelope, green roofs/facades, sunshading systems, etc.) and high efficiency technical systems (e.g. heat pumps).

As for outdoor comfort simulations, building energy consumption can be calculated for current or future climate. Table 25 shows the expected total, heating and cooling consumptions with current climate, considering three possible alternatives for the building envelope and three alternative for HVAC systems.

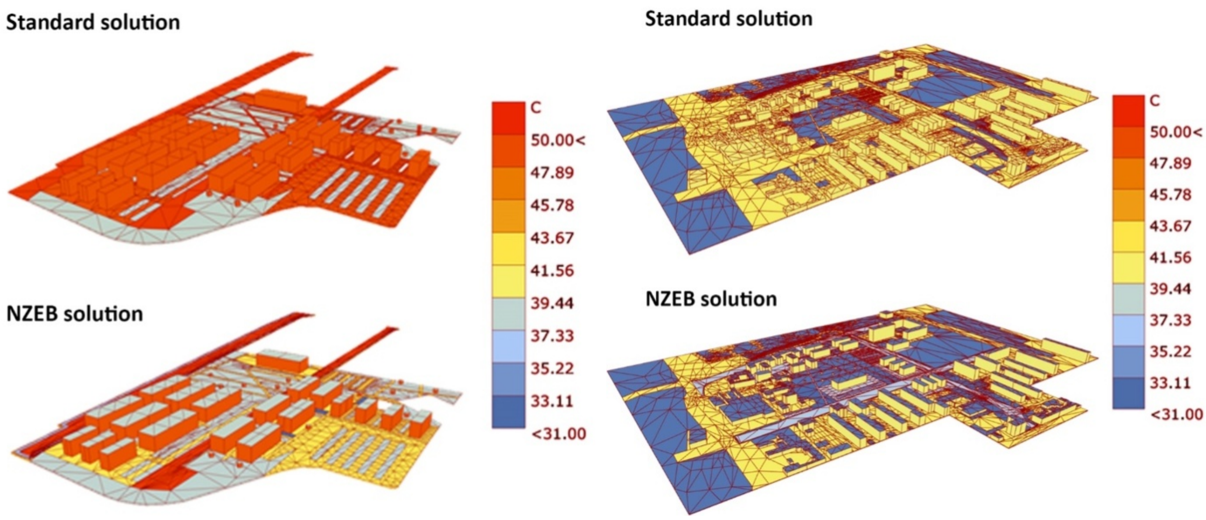
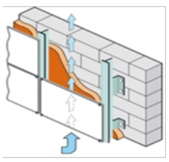
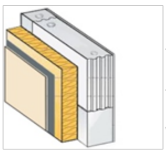
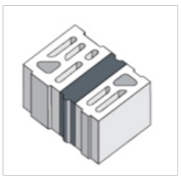


Figure 56: Detailed surface temperature simulations for "Layout 1" in PRU sub-area 8 (left) and 9 (right), comparing a standard design with climate-resilient solution integrating adaptation measures for open spaces and NZEB principles for buildings (Source: PLINIVS-LUPT, CLARITY).

Table 25: Buildings energy consumption (Source: PLINIVS-LUPT, CLARITY project).







BUILDING ENVELOPE	HVAC SYSTEM		
	Condensing boiler	Condensing boiler + A/C	Heat Pump
VENTILATED FACADE			
Annual consumption [kWh/m2]	30,52	23,27	12,79
Cooling [kWh/m2]	18,51	9,12	9,12
Heating [kWh/m2]	12,01	14,15	3,67
EXTERNAL INSULATION			
Annual consumption [kWh/m2]	30,43	23,29	12,74
Cooling [kWh/m2]	18,34	9,05	9,05
Heating [kWh/m2]	12,09	14,24	3,69
MULTI-LAYERED BLOCK			
Annual consumption [kWh/m2]	30,77	24,49	12,47
Cooling [kWh/m2]	17,82	8,33	8,33
Heating [kWh/m2]	12,95	16,16	4,14

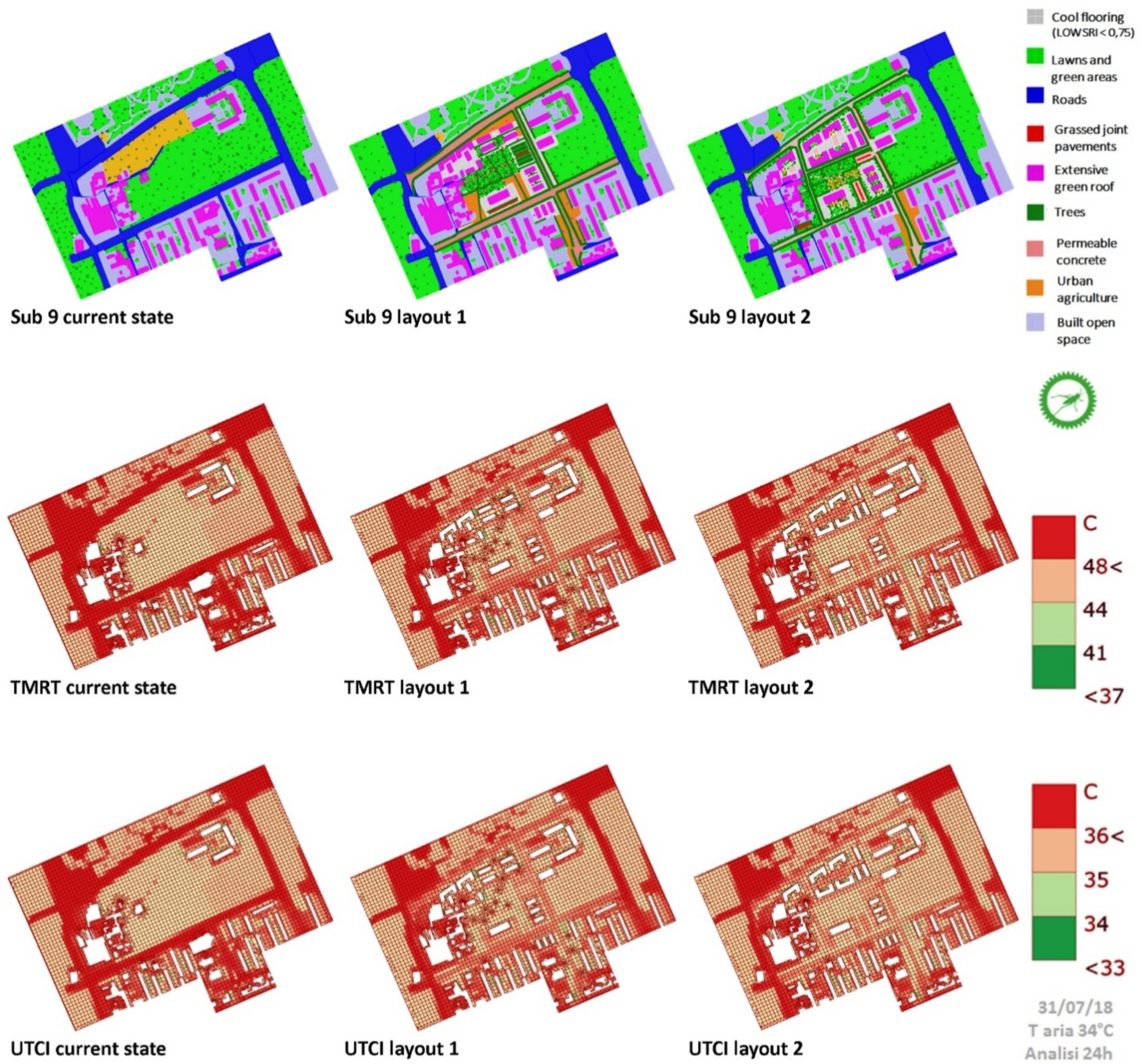


Figure 57: Detailed Tmrt and UTCI simulations with the Grasshopper model in the PRU sub-area 9, referred to the July 2018 heat wave. (Source: PLINIVS-LUPT, CLARITY).