D2.1 Reference Architecture for CLIMABOROUGH Platform

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0.3	26.06.2023	Final Version
0.4	05.12.2023	Updated version due to a change of partner

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List of abbreviations

AI - Artificial Intelligence

API - Application Programming Interface

DKSR - Data Competence Centre for Cities and Regions

DT - Digital Twin

ETL - Extract, Transform, Load

GHG - Greenhouse Gas

HTTPS - Hypertext Transfer Protocol Secure

IAM - Identity and Access Management

IMT - Institut Mines-Telecom

IoT - Internet of Things

JSON - JavaScript Object Notation

KPI - Key Performance Indicators

LIST - Luxembourg Institute of Science and Technology

LSTM - Long Short Term Memory

MIM - Minimal Interoperability Mechanisms

MQTT - Message Queuing Telemetry Transport

NGSI-LD - Next Generation Service Interface-Linked Data

OUP - Open Urban Platform (by DKSR)

SFTP - Secure File Transfer Protocol

UPF4CN - Urban Planning Framework for Climate Neutrality

WP - Work Package

XML - Extensible Markup Language

0. Executive Summary

The following deliverable 2.1. provides an overview of the development state and purpose of the CLIMABOROUGH platform, which aims to support cities in their climate neutral transition by monitoring the performance of procured solutions and the development of a concept for assessing cities individual climate neutrality. The platform serves as a data platform, integrating different and diverse data sources as a first step to make them accessible to stakeholders such as city representatives, citizens, and solution providers. Foreseeable, at the end of the project there will not be a comprehensive climate neutrality assessing platform set up, but a prototype and a technological concept for further development.

The deliverable emphasizes the platform's functional components and technological approaches, highlighting the data provided by cities and the technical requirements for data ingestion. It acknowledges that the document represents the current status of the project and will evolve as the project progresses.

The CLIMABOROUGH platform aligns with the project's vision of adopting circular technology principles and integrating existing solution prototypes for climate neutrality in cities. It aims to facilitate urban and strategic planning practices and support cities in addressing their specific challenges through data collection and analysis. The platform aims to bridge gaps between cities and services, start-ups, the investment community, and stakeholders, recognizing that a systemic transformation is necessary for effective climate actions.

Overall, the report outlines the current state of the CLIMABOROUGH platform and emphasizes the need to narrow down its purpose and tasks. The platform architecture will be developed further through a cooperative working modus with cities and project partners. This report gives an early baseline overview of the current status of the CLIMABOROUGH architecture and platform. It focuses on the functional components of the platform and its technological approaches based on the technologies brought in the project by the partners. It gives first insights on the data provided by the cities and the technical requirements to ingest data in the platform. As the project is still in an early stage, this can be considered as a living document which will evolve by progress of the project.

The upcoming tasks include conducting co-designing solution-specific KPIs, aligning with the Urban Planning Framework for Climate Neutrality, setting up a cloud environment, evaluating data standards and comparable platforms and technologies, and clarifying the service offer of the platform to solution providers.

1. Introduction

Data is a crucial element in sustainable urban planning and city development aiming to prepare our city for the effects of climate change. In times of climate crisis, It is not enough to create master plans or policies without understanding the potential effects on the whole urban system. CLIMABOROUGH aims for revealing systematic dependencies within the climate neutral transition of cities. As urban systems are complex interwoven in climate dynamics and the whole earth system, it is impossible to describe those systems comprehensively. But we can use abstract models to describe logical functionalities. All those models need data. Hence, data platforms are key technologies to open up needed data in order to process them to valuable information and knowledge for decision makers. Consequently, the CLIMABORUGH project uses a data platform. The platform integrates the technical representable results of all work packages. It aims to make project results applicable and graspable for various stakeholders such as city representatives, citizens, and solution providers.

1.1. Purpose of the CLIMABOROUGH Platform

CLIMABOROUGH provides a data platform to ingest, process, and analyze specific data sources. The project wants to support the cities in understanding systemic dependencies in the climate neutrality transition. Therefore the aim of the CLIMABOROUGH platform is:

1) to measure the **performance of the procured solutions (solutions KPI)** in their specific urban domain e.g. energy, mobility, waste to circularity.
2) to use an **Urban Planning Framework for Climate Neutrality (UPF4CN)** to identify gaps between the status quo and an optimal future scenario in climate neutral transition of cities.
3) to provide a **Digital Twin**, which will show the functioning of a particular city and a particular phenomena (e.g., traffic, pollution, etc.) over time. It will also show the variation of key performance indicators (KPIs) (possibly according to changed policies).

1.2. Connecting the Platform to the Project Vision

CLIMABOROUGH believes that it is important to adopt “**circular technology principles**” - thus reuse and combine existing solution prototypes for climate neutrality in cities - as to innovate urban and strategic planning practices as a framework in which actions and initiatives for achieving that goal should converge. This means going beyond real life experimentation and collective strategic learning to achieve “a systemic transformation (…), supported by customized climate services, accompanied by a more strategic, holistic and long-term climate investment approach, together with a new city governance for climate action”.

These goals have a double impact on the project and then on the development of a supporting software platform. On one side, there is the need for creating a software framework for incrementally introducing, supporting, and promoting the development and usage of best practices and tools for facilitating urban planning. On the other side, there is the need for helping the cities to cope with their specific challenges by collecting and analyzing the relevant data representing the transformation of the urban environment.

In doing so, CLIMABOROUGH has the ambition to close the gaps between cities and services, between cities and start-ups, between cities and the investment community, and between cities and their stakeholders. "MORE OF THE SAME IS NOT ENOUGH". This is the principle CLIMABOROUGH adopts as a basis to make evident that the climate neutrality mission implementation will be less effective unless synergized and integrated with other actions to produce a sounder impact on urban climate.

1.3. The Urban Planning Face of the Platform

One of the ambitions of CLIMABOROUGH is to contribute to the innovation and improvement of tools and approaches to urban planning by exploiting data analysis and openness of (data) platforms. This approach should consider and help with some major objectives that are current challenges of the urban planning:

- **INTRODUCE A NON-SILOED URBAN INNOVATION.** This means the ability of the platform to collect data and to provide functionalities and models that are not limited to a single specific sector but are easily integrated with other sectors, phenomena, and activities. An action or policy should be considered in its completeness and in its full contribution to the goal of climate neutrality. For example, if a waste recycling policy introduces a higher carbon footprint with respect to the gains obtained by recycling, its detrimental effects on the global climate footprint of the city should be highlighted.
- **REDUCE LEGAL AND ADMINISTRATIVE BURDENS.** This means fostering the transparency of new policies and the transformation of administrative processes with the help of data. The aim is to empower decision makers with data-based insights into the systemic effects of the climate neutrality transition.
- **IMPROVE CROSS-SECTORAL COORDINATION IN CITIES.** In this case, the adoption of cross-sectorial policies and actions should be made possible by the platform and it should also show the relationships and the beneficial effects on a global level.
- **MAKING URBAN PLANNING COMPREHENSIVE.** Urban planning is complex and its effects on citizens are, sometimes, difficult to represent clearly. Having a platform based on data may result in a more effective and practical way of representing and sustaining the necessity for particular policies and actions.

In general terms, the platform should support the urban planning activities by means of collection of historical data that characterize the **Urban Planning Framework for Climate Neutrality (UPF4CN)** (proposed by WP1). The **UPF4CN** is still to be fully defined, but it is a combination of measurements that will provide a clear benchmark for evaluating the progression of cities towards carbon neutrality.

1.4. The Cities' Challenges Face of the Platform

The cities involved have identified different challenges. They will also act in such a way to improve in the "challenged" areas in terms of policies as well as in terms of procured solutions coping with the identified problems. This process should be supported by different types of data:

- Some data pertaining to the problem domain itself. e.g. some cities coping with parking and traffic issues should measure the parking availability and also the intensity of traffic.
- Data for measuring the effectiveness of the procured solution and related policies. For instance, in the case of waste management and recycling, some key performance indicators can be used e.g. the percentage of waste recycled per citizen, the average weight of recycled material per capita, and the like.

These data and KPIs need to be defined in accordance with the challenges and sometimes specialized according to the specific city.

The platform will be used as a means to collect data of a few selected cities and for providing measures and KPIs supporting services and tools for the climate neutrality evaluation.

2. City-related requirements on CLIMABOROUGH Platform

The project is adopting a particular approach:

- On one side, there is an urban planning view that pushes towards a top down approach for planning and monitoring global phenomena occurring in an urban environment;
- On the other side, the cities with their challenges tend to have a bottom up approach from specific problems to a more organic move towards climate neutrality.

This duality means that there are different levels of requirements. In order to cope with complexity, CLIMABOROUGH has focussed on limited problem domains that are at the center of the project vision: Energy, Mobility, Waste to Circularity. Still, they comprise a very broad set of issues, but they are useful to frame the particular city needs into a problem domain. The CLIMABOROUGH project is then defining a set of requirements that range from peculiar and specific urgencies of a city to general challenges that are the target for many of them.

2.1. City Challenges

The following chapter briefly touches upon the challenges formulated by each city, reflecting the status as of late June 2023 (first version of this deliverable). Based on their challenges, cities are divided into two thematic areas (hubs). The first hub addresses the shift "from isolated energy and mobility systems to integrated services" while the second hub concentrates on the transition "from waste to circularity".

It also lists available data sources that are relevant to address the challenges, mentioned by the cities in a survey conducted by WP3 and during the city challenge meetings.

Examining the challenges and desired solutions expressed by the cities allows us to understand the specific requirements necessary for monitoring their progress and evaluating the effectiveness of potential solutions. Through this analysis, we can gain insights into the types of data and KPIs needed from cities to effectively track their advancements and assess the efficacy of the proposed measures.

The aim of the chapter is to understand what requirements result from the formulated challenges for the platform. The information collected therefore forms an important basis for the platform architecture proposed by WP2.

2.1.1. Hub 1 - Mobility and Energy

Athens (Greece)

The focus in Athens is to address climate change by improving the indicator of the quality of urban life. A cultural shift is needed to support the city's journey towards a better environment. Athens aims to reduce energy consumption in buildings through measures such as lowest energy buildings and smart grids, also focusing on citizens' behavior change and their contribution to climate neutrality.

The IT company of the City of Athens, called DAEM, supports the development of IT solutions and services for the city and its citizens. Their proposed solution for the open procurement of CLIMABOROUGH is a mobile application that promotes active citizenship and behavioral change. It aims to engage citizens in environmental protection and facilitate dialogue with the city. The application will include features like creating data sets and visualizations that are accessible to the city and citizens' entrepreneurial initiatives. It is also envisioned to incorporate gamification and focus on specific neighborhoods in Athens depending on the applications that will be submitted in the tender.

Based on the provided information, the city of Athens has data related to emissions, stationary transportation, and waste, including CO_2, N_2O, and CH_4. No specific information is provided in the survey document regarding missing data for the city.

Differdange (Luxembourg)

Differdange aims to achieve 100% local and sustainable electricity production by 2030 (excluding industrial consumption), with the support of its population and private sector. Data and IT platforms are crucial to effectively communicate this long-term goal and understand the potential of renewable energy. These platforms can provide better data visualization, compare future scenarios, and assess the city's existing infrastructure for renewable energy development, such as available rooftop surfaces.

The envisioned solution for Differdange involves a socio-technical system that enhances the city's engagement with energy data. This system aims to increase the city's influence and credibility in promoting renewable energy to citizens and industry. It includes data visualization solutions for ongoing developments and future simulations. Additionally, citizen engagement tools are necessary to engage Differdange's diverse and growing population effectively.

Based on their response, Differdange collects data through traffic sensors (including cross-border traffic), air quality sensors, consumption monitoring (water, energy, waste), socio-demographic indicators, and precipitation monitoring. According to the city workshop, as further resources, they will work on having maps and data of available rooftop surfaces. No specific information is provided in the survey document regarding missing data for the city.

Grenoble-Alpes (France)

Grenoble-Alpes Métropole is working on a development project called GRANDALPE 25. This project aims to transform a district with 30,000 inhabitants and 40,000 jobs into an active living space, an innovative economic hub, and a leader in new mobility. The objective is also to serve as a demonstration of the ecological transition and utilize all available resources to create a city that operates without relying on fossil fuels. Within this project, the Metropole is developing a new way of doing the "Fabrique de la ville" with 3 main areas of work:

(a) promoting the voice of citizens in its development
(b) mixing culture and art in the project
(c) developing tactical urbanism.

The goal is to initiate temporary activities and projects involving various stakeholders such as companies, social and solidarity economy actors, artists, and citizens, in order to provide a preview of the territory's transformation. The proposed solution is to develop a platform that serves the following purposes:

- Providing an inventory of the metropolitan territory by collecting data on factors such as waterproofing, vegetation, and heat islands.
- Making this information available to all stakeholders involved in development projects to enhance their initiatives.
- Ensuring that the data is regularly updated to evaluate the impact of projects on relevant indicators.
- Allowing for the modeling of different scenarios to assess their potential impact on the indicators.
- Making the collected information accessible and understandable to citizens, helping them understand the significant development decisions being made.

Based on the information shared, Grenoble has a diverse range of data. They have data on energy production and consumption, covering the entire Metropole, available on an annual basis. Additionally, they collect data on transport, including vehicle-kilometers traveled, mode shares, and infrastructure, covering Metropolitan France and adjacent areas. Their data collection efforts extend to waste and wastewater, encompassing production, collection, and treatment processes. The city also maintains a territorial planning system with continuous information updates. Moreover, they have a biodiversity observatory. Lastly, related to economy, their data collection includes observations on commercial ground floors. It was mentioned that the estimation of imported emissions (SCOPE 3) and sealing levels in sectors beyond individual buildings require further research and data collection.

Sofia (Bulgaria)

Sofia faces challenges such as high levels of harmful emissions and noise pollution. One of the contributing factors to these issues is the significant car traffic, including a large number of old cars (e.g. diesel vehicles). The city center, with its diverse activities, attracts a substantial amount of car traffic, but the inadequate street network and limited parking options add to the problem. Therefore, the primary goal of this city is to address the issues of air quality and CO_2 emissions by eliminating wandering of personal cars in search of parking places in the city center.

Their proposed solution is an innovative digital service that allows citizens to plan their movements in the city using public transport or suggested green routes, promoting alternative transportation methods to reduce reliance on personal cars.

The city of Sofia has mentioned that it is collecting data on traffic, air quality, and some other sources. A discussed issue is that the city's data is decentralized and owned by various actors, requiring their approval for use and analysis and the data formats vary. It was also mentioned that there is a lack of data regarding the presence of specific vehicles and the ownership information of private partners.

2.1.2. Hub 2 - From Waste to Circularity

Cascais (Portugal)

Cascais faces the challenge that the municipal waste separation system, especially with regard to household waste, is not yet mature, causing pollution in the city. Therefore, in order to achieve carbon neutrality and meet European recycling targets, the city aims to improve household waste streams, especially for waste with recycling potential (e.g. biowaste or textile waste). By separating household waste in a more intelligent way (e.g. through selective waste bins) and by tracking the waste streams, the city wants to ensure that the collected waste is properly forwarded for recycling and the production of new products.

Their proposed solution is to encourage citizens and households to appropriately segregate textile and/or organic waste.

According to the city, it has sensors to measure air pollution and meteorological sensors to measure climate. This implies that Cascais can draw on several environmental data, including weather data (temperature, air humidity, wind direction, wind speed, visibility, solar radiation, and weather condition) and air quality data. The city mentioned that it also has data on waste, e.g. on certain waste streams. However, the city lacks data on waste streams for textiles as well as on organic waste.

Ioannina (Greece)

Ioannina is located at a lake called Pamvotida which has a small, inhabited island that lies within the lake on it. Because of this peculiarity, Ioannina is a popular attraction for tourists, who regularly visit the island. As a result, the city has on the one hand an increased amount of waste generated by tourists (including the island area) and on the other hand a high oil consumption, due to tourist transport services that are provided by boat. In order to let Ioannina become a climate neutral city, it aims to protect its ecosystem, including the lake and the island.

Ioannina aims to collect data on the lake's water quality and to develop a monitoring tool to understand how pollution is causing greenhouse gas emissions. Their solution involves data collection, environmental monitoring, and promoting behavior change among tourists, small boat owners, etc. An application could be developed to track human activities contributing to the lake's emissions, used by tourists, residents, restaurants, and hotels. The gathered data will support the municipality's decision-making for lake protection and reducing the city's carbon footprint. The city seeks to establish a collaborative co-creation mechanism among local stakeholders.

Currently, it is unclear what kind of data the city has. Interestingly, however, Ioannina is in the process of creating an emissions inventory. However, to address the challenge, Ioannina lacks data on waste on the island (e.g. volume of waste in the area of interest, types of waste separated, waste collection fleet information), lake quality/ scope of pollution (e.g. the volume of sediment in the lake, seasonal changes, impact of urban wastewater) as well as the number and exchange rate of tourists/visitors at specific intervals.

Maribor (Slovenia)

Maribor, which is the second largest city in Slovenia, built and opened a new automated sorting plant for the municipal waste in 2018. The city has planned to upgrade the plant capacity (which is at 52,000 tonnes/year) by reducing the mixed waste. To enhance the proportion of waste collection and recycling, minimize landfill waste, and subsequently decrease greenhouse gas emissions from biodegradable waste and methane emissions from outdated landfills, certain measures are proposed. These measures involve implementing a socio-technical system that encourages waste separation at its origin and effective management of collected waste fractions by individuals.

This can be accomplished through informative campaigns, heightened awareness, and effective communication with the public, along with the adoption of innovative strategies to drive behavioral change, including social imitation, gamification, and various incentives.

To address the challenge, Maribor can build on the following data: Air quality, traffic, waste collection, energy use (including measurement of $CO2$ emissions) as well as climate data. However, what the city misses is localized data on energy use in different sectors that would enable them to monitor their greenhouse gas emissions.

Torino (Italy)

In the City of Turin, a significant amount of WEEE (Waste Electrical and Electronic Equipment) and textile waste remains unrecycled, particularly small WEEE and non-wearable textiles. Despite a widespread net of dedicated collection points, the opportunity to reuse and recycle (partially or totally) such materials within the city boundaries are very limited. On one hand, this is due to a lack of awareness and involvement from key stakeholders such as citizens and businesses in properly disposing of this type of waste. On the other hand , the monitoring of the entire waste collection process is challenging, which makes it difficult to gather meaningful data that the city and its authorized company can utilize to identify areas that require intervention and develop new, more efficient disposal strategies that favor circular actions and can be shared with the relevant stakeholders.

Their proposed solution is a novel monitoring tool for services that generates data, helping the city to gain a better understanding of areas that require intervention, map key stakeholders involved, and be informed and promote relevant initiatives in the city. The tool shall also provide evidence of the value generated through proper disposal and showcase opportunities to recycle and reuse locally, while actively engaging citizens and other important stakeholders in sorting WEEE and textile waste. Certain data that are currently unavailable will most likely be collected through the participation of citizens and stakeholders. As a result of the analysis of data and gaining a deeper understanding of the problem, awareness-raising campaigns will be developed and targeted towards key players identified, such as large-scale distributors.

Regarding available data, Torino has information on stationary energy, transport, industrial processes and the use of products. Additionally, the city has annual data for electric and textile waste. What's still missing is data on citizen behavior, the reuse of textile and WEEE waste at local level, especially from private companies and stakeholders (e.g. NGOs).

2.1.2. Research on Open City Data

A good understanding of the data that the cities have is essential for the successful operation of the CLIMABOROUGH platform. To achieve this, an extensive analysis was undertaken, focusing on open data accessible for the cities. Further details about the open data portal discussed in the next section. The study involved comparing the city's open portal data with information obtained from previous surveys on the city data. The survey data provided insights into various aspects of the city's challenges, including energy, waste, transportation, air pollution, and public services. By juxtaposing the survey results with the data obtained from the open portal, a comprehensive picture was formed regarding the alignment between the identified challenges and the data available. The results of this analysis will contribute to a better understanding of the strengths and limitations of the city's open data initiative and serve as a foundation for future data-driven decision-making processes to tackle the city's challenges effectively.

2.1.3. Derived Data Sources

Based on the mentioned survey (responses from the cities in "CLIMABOROUGH - TEMPLATE for the cities"), the cities' challenges and solutions, as well as the results of the research on available open data (e.g. on open data portals), the relevant data sources that the platform needs to deal with are diverse. This means that they are also characterized by a wide variety in terms of ownership, formatting, temporal availability, and scope.

However, the data sources can be functionally distinguished as follows:

- **Cities' Data** are the data collected and available from the different cities. They may be related to general KPIs for measuring the Climate Maturity Index, as well as related to the specific challenges that the individual city is involved in. They are characterized by different formats and styles, different collection means, and periods. They can have different characteristics that are not present in other cities' data sets. They also may be injected or collected into the CLIMABOROUGH infrastructure in different ways. In addition, they can be "voluminous" and as such, they may be limited in time and space in the CLIMABOROUGH infrastructure.
- **Solution Provider Data** are data created and used by the Procured Solutions. They can be used in order to measure some KPIs and then evaluate, and assess the impact of these solutions on the City. They may also be used in some specific services offered by the CLIMABOROUGH platform. They could even be stored (for

very specific cases) in the CLIMABOROUGH data infrastructure. They are mainly intended for usage by external applications.

- **Additional (Open) Data Sources:** The **European Data Portal** is containing valuable data related to the CLIMABOROUGH partners. Typically the data show some level of similarity between cities, but still they need to be aligned and harmonized in order to be comparable and compatible. Another additional data source can be **climate related sources** such as Copernicus. Here, the partners of WP1, especially Hereon, will provide more detailed expertise in the next phase of the project.

Technically we distinguish between two data types described in the following. The need for it is derived from technical architecture. We will go into this topic in detail in chapter 4:

- **Real-time data** is collected for real time measures of entities or events in the city (e..g. traffic intensity, parking space availability, and so on). In most cases real time data is provided by sensor systems or IoT-devices. They are characterized by different formats and specifications, different time availability, and different ownership. They will be collected and injected into the CLIMABOROUGH platform for a limited and well scrutinized set of use cases. We expect real-time data mostly as solution provider data.
- **Historic data** is static data, which will be collected only once or in long intervals. This data can come from various systems such as existing management systems, it can be statistical data, geographical information, plans or maps. We expect that most data will be historic. They will be provided by solution providers, cities and additional data sources.

3. CLIMABOROUGH Key Performance Indicators

The effective measurement and evaluation of performance is crucial in addressing city challenges and the respective climate neutral transition. This section aims to provide a comprehensive understanding of Key Performance Indicators (KPIs) for the CLIMABOROUGH platform.

In order to conceptualize the platform architecture, it is necessary to define some rules for analyzing and processing the data. In the following chapter, we propose a KPI-framework that was produced in cooperation with WP1 and is derived from the Urban Planning Framework for Climate Neutrality (UPF4CN). It serves as the foundation for the analytics layer of the CLIMABOROUGH platform.

In the following, we show a draft version of the UPF4CN, which is still under development by WP1. The framework builds a core element of CLIMABOROUGH. It is based on insights of science in the fields of urban planning, climate services, and climate governance research. A comprehensive research approach is based on this framework and will be described in detail in Deliverable 1.1 (WP1), as it aims at supporting cities to evaluate, boost, operationalize, monitor, and finally realize their individual transition to climate neutrality. Due to the complexity of theoretical concepts at the basis of UPF4CN, the CLIMABOROUGH platform as a technological tool and product will only represent parts of it. In short, the UPF4CN consists of three main elements:

- The **Climate Urban Metabolism**, representing the urban systems' capacity and the ecosystem capacity to achieve climate neutrality at the *status quo*;
- The **Urban Climate Strategy**, representing goals and actions set by the cities. Additionally, it takes into consideration the issue of the coping capacity (or the "healthiness") of the governance tools and practices related to climate neutrality management: the climate strategy governance.
- The **Climate Strategic Assessment** aims to support cities in assessing the success of the implemented climate neutrality strategies and specific measures/solutions.

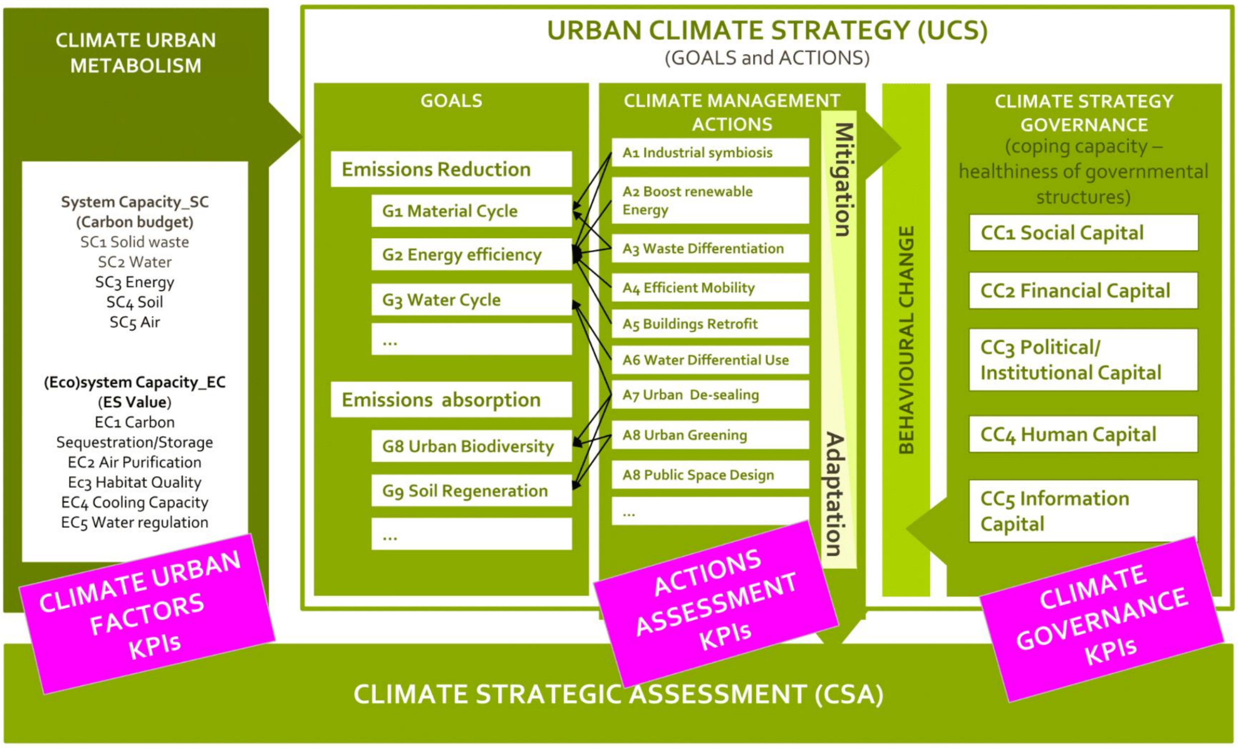

Figure 1: Draft version of Urban Planning Framework for Climate Neutrality (UPF4CN) with related types of KPIs.

Throughout this first project phase, we went through an iterative KPI development process to come up with the state of KPIs presented in the following. Further information on the KPI development can be found in ANNEX A.

Based on UPF4CN we derived three sets of KPIs:

CLIMATE URBAN FACTORS KPIs: They are related to the Climate Urban Metabolism. The KPIs address both the characteristics of urban systems concerning the capacity to control emissions (e.g. solid waste, water, energy, soil, and air management), as well as ecosystem capacities related to the capacity to produce/emulate ecosystem services (e.g. carbon sequestration/storage, air purification, habitat quality, cooling capacity, water regulation).

MEASURES/SOLUTIONS ASSESSMENT KPIs: They are related to actions put in place by cities. The KPIs account for the impacts of actions combined within the framework of an Urban Climate Strategy and address both the reduction and the absorption of emissions (key goals of any climate mitigation strategy). KPIs under this group have the scope to measure the potential impacts of actions such as urban de-seiling, waste differentiation, or efficient mobility into the Climate Urban Factors. The specific solutions' impact monitoring is part of the action assessment KPIs and will be represented by the Action Assessment Tool (Reference Architecture - Chapter 4).

CLIMATE NEUTRALITY GOVERNANCE KPIs: Related to climate strategy governance. The KPIs consider the coping capacity and the "healthiness" of a governmental structure from the perspective of climate management and climate neutrality achievement. Actions included in an Urban Climate Strategy are not enough to guarantee the forecasted desirable impacts if the governance practices in place and the available governance tools are not suitable to enable cities to transition to climate neutrality. Cities are hence required to adapt their organizational structures and decision making processes to guarantee such coping capacity. This capacity can be described by a categorization of the available tangible and intangible resources into “capitals”: social, financial, institutional/political, human, and information. Foreseeably, the CLIMATE GOVERNANCE KPIs will not be part of the CLIMABOROUGH platform, at least in its first version; they will rather constitute the set of KPIs at the basis of the “Climate neutrality governance self-assessment tool” for cities (see D1.1).

The indicators refer to different capitals, intended as categories of tangible and intangible resources supporting and potentially enabling the implementation of measures for climate neutrality achievement.

Table 1: The three sets of KPIs and some example indicators.

CLIMATE URBAN FACTORS KPIs	ACTIONS ASSESSMENT KPIs	CLIMATE GOVERNANCE KPIs
<u>SYSTEM CAPACITY</u> **SC1 Solid Waste** • Waste management • Percentage of differentiated waste • Percentage of reuse adoption • Amount of un-differentiated waste • ... **SC2 Water** • Water management • Percentage of differentiated use • Percentage water loss in pipelines • Percentage of water runoff • .... **SC3 Energy** • Total energy production	**Cleaner and efficient energy** • Pushing the shift to renewable energy • Funding for solar panels installation • Microgrid infrastructure • Activation of energy communities • Reduce energy consumption • Improving buildings turmeric resistance • Smart urban lighting infrastructures • Adoption of low consumption lighting infrastructure • ... **Clean and efficient mobility** • Reduce traffic volume	**Social capital** • Number of civic organizations acting for climate and collaborating with the PA • Number of citizens involved in climate related initiatives • ... **Financial capital** • Tied investments on climate related actions • Percentage of private investments targeting climate strategic actions • ... **Political/institutional capital** • Presence of local adaptation and local mitigation plans

• Percentage of energy consumption from renewable sources • Percentage of energy derived from fossil fuels • Total energy consumption • Energy consumption for mobility • Building efficiency • Energy consumption by industry • … **SC 4 Soil** • Soil pollution • Total land consumption • … **SC 5 Air** • GHG total emission per capita • Traffic emissions • Industrial emissions • Residential emissions • Air Quality Index (AQI) • PM10 concentration • Nitrogen Dioxide (NO2) • Ozone (O3) • … **<u>ECO-SYSTEM CAPACITY</u>** **EC1 Carbon Sequestration/Storage** • Amount of carbon stored in 4 different carbon pools • Amount of sequestered carbon over time • … **EC2 Air Purification**	• Amount of car and bike sharing opportunities • Accessible public transports • Bike lane creation • Incentives for electric vehicle adoption • … **Urban de-seiling** • Surface to be de-paved from asphalt • Volume of death soil to be removed from the surface • … **Urban greening** • Urban forestation • Green roofs • …	• Presence of a department with specific responsibilities competences related to climate neutrality management • Presence of cross-sectoral plans related to climate neutrality • … **Human capital** • Level of education and background studies of local government employees (or collaborators) • Presence of a figure (Resilience officer; Climate manager; etc.) with specific competences and skills for climate neutrality management in the local government • … **Information capital** • Level of differentiation by user of the available climate services: user-driven climate services • Availability of climate services in the local language • Presence of local government policies and/or plans for climate information management • …

• SO2 removed annually • NO2 removed annually • PM2.5 removed annually • PM10 removed annually • O3 removed annually • ... **EC3 Habitat Quality** • Extent of habitat quality • Habitat degradation • ... **EC4 Cooling Capacity** • Index of heat mitigation based on shade • Evapotranspiration • Albedo • Air temperature • Quantity and quality of urban green areas • Imperviousness • Building intensity / density • ... **EC5 Water regulation** (Urban Flood Risk Mitigation) • Reducing runoff production • Slowing surface flows • Creating space for water (in floodplains or basins) • Retention volumes • ...		

In the next project phase WP1 and WP2 will work even more closely in order to align UPF4CN and the CLIMABOROUGH Platform in detail. Both the framework and the technical platform have a high level of complexity. Therefore, the task of alignment is not an immediate one but rather a progressive one.

In order to shed light on the complexity of these issues and tools, we provide the following few definitions:

- **Climate Neutrality** is "the targeted reduction of GHG emissions and GHG avoidance in own operations and across the community in all sectors to an absolute net-zero emission level at the latest by 2050. In parallel to this, cities, towns and regions must adapt to climate change and enhance climate resilience across all sectors" (https://iclei.org/climate_neutrality/). This term, unlike the term "carbon neutrality", hence keeps together both climate mitigation and adaptation.
- **Climate Adaptation** means anticipating the adverse effects of climate change and taking appropriate actions to prevent or minimize the damage they can cause, or taking advantage of opportunities that may arise. Examples of adaptation measures include large-scale infrastructure changes, such as building defenses to protect against sea-level rise, as well as behavioral shifts, such as individuals reducing their food waste. In essence, adaptation can be understood as the process of adjusting to the current and future effects of climate change. (EEA)
- **Climate Mitigation** means making the impacts of climate change less severe by preventing or reducing the emission of greenhouse gasses (GHG) into the atmosphere. Mitigation is achieved either by reducing the sources of these gasses — e.g. by increasing the share of renewable energies, or by establishing a cleaner mobility system — or by enhancing the storage of these gasses — e.g. by increasing the size of forests. In short, mitigation is a human intervention that reduces the sources of GHG emissions and/or enhances the sinks. (EEA - https://www.eea.europa.eu/help/faq/what-is-the-difference-between)

Cities, towns, and regions must adapt to climate change and enhance resilience across all sectors. Therefore we understand climate mitigation and climate adaptation together as climate neutrality. Due to the high complexity of this topic, the CLIMABOROUGH platform as a digital tool only can focus on parts of this holistic approach. As described already in Chapter 1, the CLIMABOROUGH platform aims…

- to measure the **impact of the procured solutions** on climate mitigation - CO2 emissions reduction (in the specific urban domain e.g. energy, mobility, waste to circularity).

This aim "only" focuses on issues related to climate mitigation. As we want to achieve and broaden our view on climate neutrality, this aim would not be enough. In order to take climate adaptation, and hence climate neutrality, into focus, we will, based on the UPF4CN, propose a digital tool that focuses on…

- **identifying gaps between the status quo and an optimal future** scenario in climate neutral transition of cities. This tool could support measuring the impact of implemented solutions on climate adaptation (cities vulnerability reduction/climate resilience improvement).

The project distinguishes between the UPF4CN and the digital tool (represented by the service layer of the CLIMABOROUGH platform). The digital tool has to set a focus, as it will not be able to show the whole complexity of the UPF4CN. We will propose a plan to, step by step, enrich the tool with new functions/KPIs fed by practical implementations in cities (e.g. procured solutions) to ultimately be able to show systemic effects (CLIMABOROUGH will probably only be able to show a prototype and a concept how to reach this ultimate goal). In parallel, the UPF4CN will learn and grow with new information about cities and science.

In summary, aligning WP1 and WP2 means to take climate adaptation into consideration as well. Adaptation is more challenging to be measured than mitigation, because the available data is rather qualitative. In contrast, mitigation related data is quantitative. Here, we need many different indicators with many different units. Data sources might be surveys or policies on top of the city data sources and the data of solution providers.

4. Description of Available Technologies of Partners

4.1. DKSR (Data Competence Centre for Cities and Regions) and Open Urban Platform (OUP)

The **Data Competence Centre for Cities & Regions (DKSR)** is a spin-off of the Fraunhofer "Morgenstadt" Initiative to support cities and regions with infrastructure, technology, and know-how for data-based transformation. DKSR has been available to municipalities in Germany and in the EU since 2021. The combination of the four partners - Fraunhofer-Gesellschaft, Deutsche Telekom, [ui!] and axxessio - and their complementary core competencies delivers a holistic approach that focuses on the data sovereignty of the municipality and municipal enterprises. It helps cities to build and operate a sustainable digital infrastructure. The DKSR builds on a business model that leverages the power of open standards, an open-source urban data platform, and an open ecosystem of cities and suppliers of digital solutions.

The **DKSR Open Urban Platform** is the open source version of the UrbanPulse platform from The Urban Institute ui!. It is an open urban real-time platform for cross-domain data integration and match-making. The OUP is a real-time sensor data platform that follows the vision of Open Urban Platforms as expressed by the European Innovation Partnership Smart Cities and Communities EIP (now SCM) and defined in DIN SPEC 913571. OUP is for cities, municipalities, utilities, and enterprises that want to use new and existing urban data sources to create innovative value-added services. To this end, the OUP enables both small and large cities and businesses to efficiently integrate new and existing data sources, process and analyze data in near real-time, and ultimately share the data with various stakeholders. Unlike many other platforms, OUP is cloud agnostic and can run in the cloud, in container environments Kubernetes, or in the local data center. Depending on the requirements, cloud-based services or open source technologies can be used for these purposes. The platform code can be found on GitHub.[1]

OUP has a scalable microservice architecture for data processing and analysis, with a dedicated connector framework for easy integration of sensors and other urban management systems. Ultimately, OUP provides fully integrated access to urban sensor data from the different urban domains based on smart services. Thus, OUP combines the multiple data sources of a city to better visualize and understand them and to better respond to all the needs of a city. Municipal administration, companies, and individuals can use the information collected, generated, and provided by OUP to optimize their individual decisions and improve their digitalized services and processes.

The core services are written in Java and can run on different (virtual) infrastructures. The platform consists of different types of modules that provide specific services to the other modules of the platform. To provide a service, the modules can leverage existing Software-as-a-Service (SaaS) technologies (e.g., databases, storage, and connectivity). Due to its modular architecture, the platform supports a scale-up strategy by increasing the virtual resources of a node (CPU, memory, etc.). as well as a scale-out strategy where individual modules can be deployed multiple times on different nodes. The main functional requirements are a holistic view of the data of different (urban) domains (mobility, energy, environment, and administration), in order to identify optimization opportunities.

[1] https://github.com/DKSR-Data-Competence-for-Cities-Regions/DKSR-Open-UrbanPulse

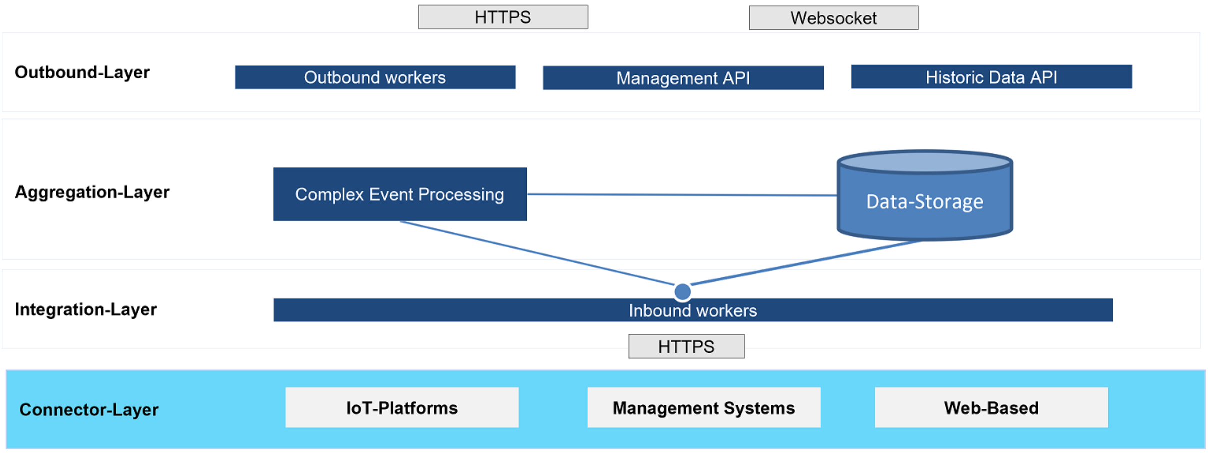

Figure 2: Main architectural components of the Open Urban Platform.

Connector Layer

The Connector Layer is the data ingestion layer for the OUP platform. It enables the consumption of data from various IoT platforms, management systems, and web-based services. Using HTTPs, it communicates the data to the core OUP.

Integration Layer

This layer is the interconnection for the connector layer, which, using the HTTPs connections, enables the OUP core to consume the data and events coming from the connector layer.

Aggregation Layer

This layer enables to store the data consumed in a database that is built into the platform. It allows for querying, processing, and exposing the data stored. Further, using complex event processing mechanisms, it allows further analysis, manipulation, aggregation, and refinement of data stored.

Outbound Layer

Once the data is stored, the Outbound Layer enables the data to be accessed using the REST and WebSocket interfaces. The OUP Management API allows for accessing the various modules and entities exposed by the OUP and the Historic Data API allows for querying the historic data stored. The real-time data stored on the platform is accessible via WSS and HTTPs interfaces while the historic data is available through HTTP interfaces.

4.2. LIST (Luxembourg Institute of Science and Technology)

LIST is a mission-driven Research and Technology Organization (RTO) that develops competitive and market-oriented product/service prototypes for public and private stakeholders.

LIST is developing BESSER (Figure 3), a low-code platform to create all types of software systems, including smart software systems. By smart software system we refer to any system that embeds intelligent components, either in the front-end (e.g. chatbots) or in the back-end (e.g. predictive maintenance components). BESSER is defined as a core platform providing common functionality useful in most domains with a number of vertical extensions, tailoring the BESSER modelling primitives and generators to specific verticals, such as smart cities and climate data. In this sense, BESSER covers aspects such as:

- Data modelling and generation
- Data import/export across several formats, including (semi)structured sources
- UI modelling, including conversational interfaces and its deployment on a number of target platforms (web, telegram etc.)
- Automatic dashboard modelling and configuration among other useful components.

BESSER is released as an open-source platform, allowing for commercial extensions. This model is ideal in the context of this project as it will facilitate the reuse of BESSER by all the companies and SMEs interested in creating a commercial ecosystem around the project results. The low-code nature of the platform and its no-code components (enabling even non-tech people to input their climate data and see the resulting dashboards) will also facilitate the reuse of such results.

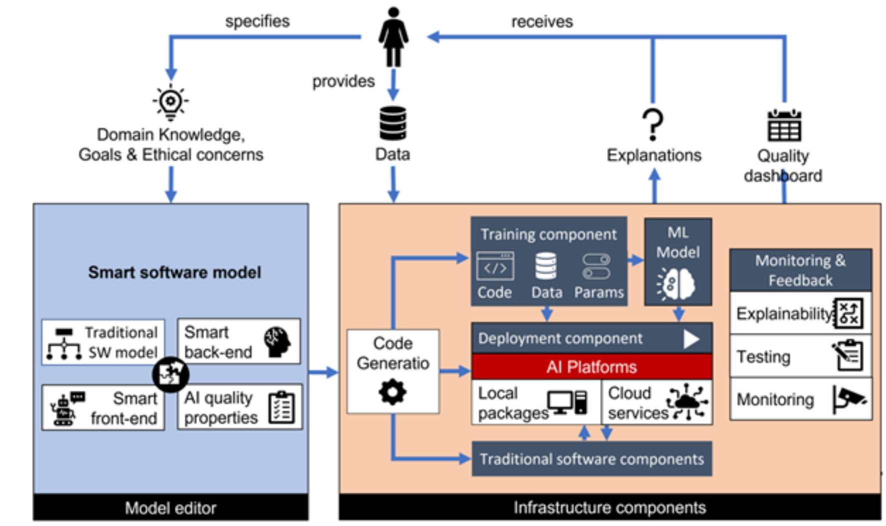

Figure 3: BESSER Architecture

4.3. IMT (Institut Mines-Telecom) and Digital Twin Architecture

The Data Intelligence and Communication Engineering (DICE) is a research group within the Institut Mines-Telecom (IMT) and the Institut Polytechnique de Paris. Its goals are to carry out research activities in these major areas:

- Artificial Intelligence algorithms and the possible application in natural language processing, social media, smart city, and IoT domains.
- Digital Twin and IoT architectures and development of advanced services in different application domains (from smart cities to system management).
- Edge-Cloud continuum management, orchestration, and optimization of resources with particular reference to the strategies for improving the usage of available resources for satisfying specific Service Level Agreement, SLA, levels.
- Data collection, organization, and formatting of simple sensor system measures (General Purpose sensing), information fusion and inference from different related sources (Synthetic Sensing), and prediction/reasoning on synthetic data.

These activities find one major use case in the smart city problem domain. IMT is working towards the definition of an architecture for the Digital Twin (DT) that exploits a basic set of sensing capabilities (general-purpose sensing is the ability to use simple and low cost video, audio, and environmental sensing capabilities) and uses AI to extract from these data, very detailed information. This valuable information is then arranged and formatted according to specific data models (e.g., those defined by FIWARE to constitute a "descriptive level" of the Digital Twin). The behavior and the way of working of the DT should be described in a prescriptive part. Once again, AI helps in "predicting" the possible future behavior of the Digital Twin as defined by descriptive and prescriptive modeling.

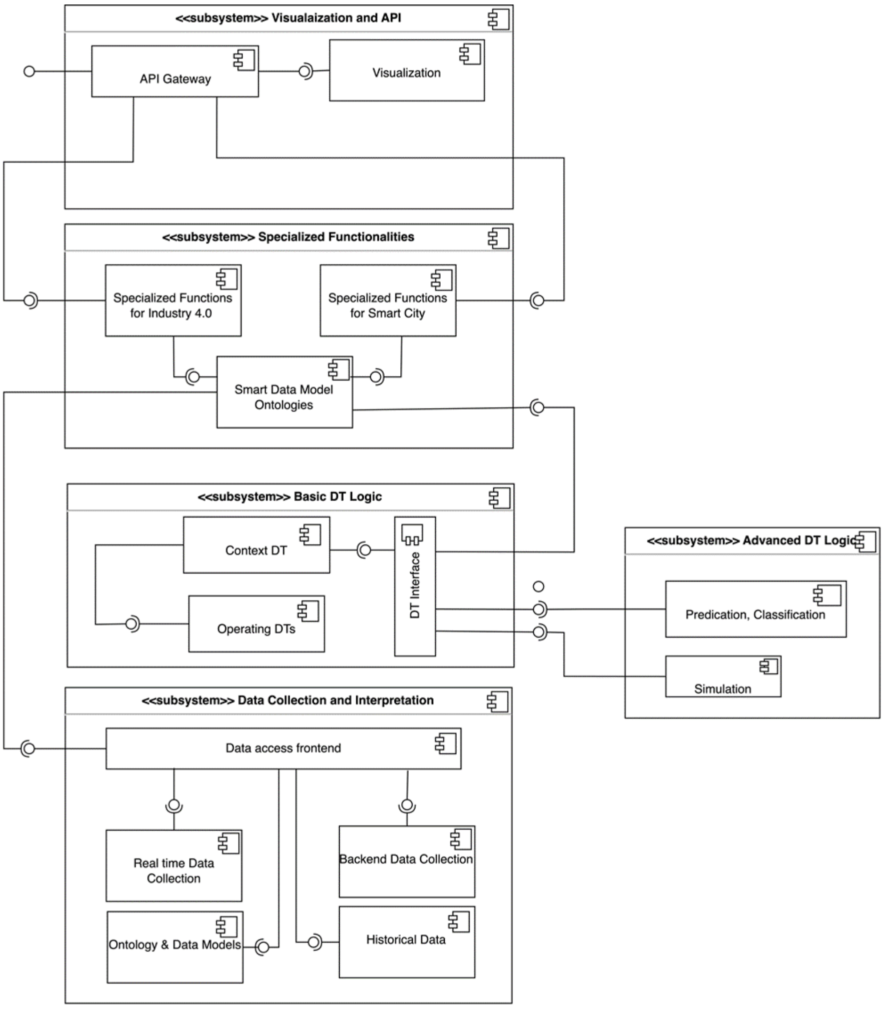

Figure 4: Digital Twin Reference Architecture - An IMT view on a software architecture supporting the Digital Twin. (Reference architecture for a Digital Twin).

This architecture represents in the form of functional blocks the properties, the capabilities, and the interactions supporting the implementation of a Digital Twin. The different functional blocks are:

Data Collection and Interpretation. It is needed in order to collect, organize, format, and store the data and the information used for feeding the Digital Twin representation. It constitutes the descriptive model of the DT.

Basic DT logic. This subsystem represents the prescriptive side of the DT architecture. The functionalities are representing and modeling the expected and designed behavior of the DT mimicking the physical object. Here two major modeling are needed: one representing the operating Digital Twins (representing physical objects) working and acting in the specific context. This holistic approach is needed in order to understand and represent how the DTs will react and will impact the actual context of usage. Variations in the context can influence the behavior of objects in it and vice versa.

Advanced DT Logic. This subsystem represents the "intelligent" capabilities associated with a DT representation. There are typical AI related functions such as those useful to classify and predict events or objects, as well as others related to the ability to simulate and test the DT behavior under different conditions.

Specialized Functionalities. These are additional functionalities needed to better represent or interact with elements of the chosen problem domain. In a specific smart city case, some prediction techniques, and some additional aggregation or modeling of resources can take place. Special “reasoning” based functions could also be introduced in order to support “What If?” strategies and simulation related to the smart cities.

Visualization and APIs. This subsystem is intended for “representing” the DT by means of visualization of its behavior or as a mens to pass existing data and information to external systems that can use them for additional goals or for visualization in already existing systems. An Application Programming Interface is possible in order to control and command the activation of DT functionalities and to receive information and data from it.

This architecture should be framed in a larger one taking advantage of edge and cloud computing capabilities. As an example of it the architecture defined by IMT within the C2JN French National Project could be considered (Figure 6).

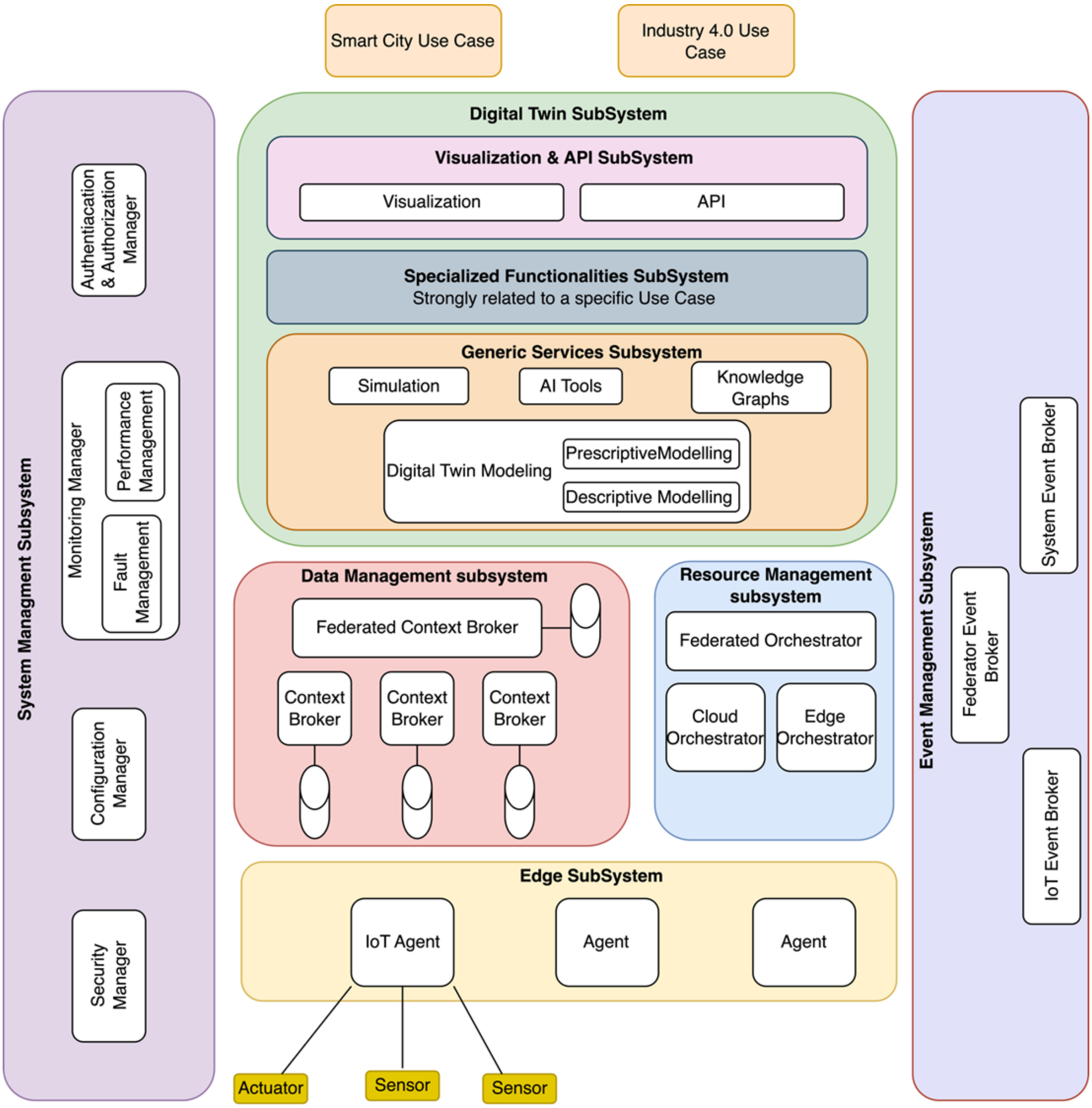

Figure 5: General architecture - An edge-cloud computing general architecture for a general purpose DT representation.

This architecture is based on the FIWARE Context Broker functionalities, on the ability to pass data by means of KAFKA and using a PubSub mechanism as well as other needed functionalities such as the resource orchestration, the security and the management of a largely distributed system. These functionalities are out of scope in this document.

With respect to data acquisition and transformation, it is worth mentioning how IMT is reconstructing the data about traffic intensity in cities that do not have a specific infrastructure. By fusion of different data such as traffic origin destination matrix (provided by TomTom and Google) as well as the information about the paths and the delay of public transportation (RATP of Paris is providing these data), AI can provide the means (synthetic sensing) to derive traffic intensity values from these raw data. Once collected and produced, these data can feed a DT of the specific urban area. Additional functions can be applied on the DT in order to implement strategy like “What - If-scenarios” applied to the closing or personalization of specific data. The traffic intensity data created by synthetic sensing could be helpful to support these analyses in the presence of sparse sensing infrastructure.

IMT brings to the project the know-how about data acquisition and collection from different sources and environments, data formatting and modeling into usable sets of data, the ability to derive synthetic data with high accuracy from general purpose data, the ability to represent at the descriptive and prescriptive level different physical objects and context, the ability to apply AI technique to predict the future behavior of the DT and, last but not least, the ability to visualize or share the relevant information represented as a DT.

5. Reference Architecture

5.1. Status Quo of Architecture Development & Obstacles

In this chapter, we describe the status quo of the reference architecture based on the projects' development and knowledge. In order to present a final deployable architecture, more detailed input of other work packages is needed. Particularly, for concepting a logical platform architecture, the methodology for analyzing the data into a comprehensive KPIs approach for the UPF4CN has to be finally designed. At this stage, we do not have the final information about this methodology.

5.2. Agile Development in phases

The Climaborough Platform is developed in an agile manner. Therefore we defined at least two development phases. In the first phase we concentrate on the development of the performance monitoring of the procured solutions and a digital twin prototype. In the second phase we intend to extend the Climaborough Platform for the monitoring & tracking of the city's progress in reaching climate neutrality i.e. **Urban Planning Framework for Climate Neutrality (UPF4CN)** and continue the development of the digital twin module. The second phase will not develop a comprehensive climate neutrality assessment tool, but a concept and a prototype of such for ongoing development after this project ends.

5.3. Functional Segments & Modules

Based on the partner technologies, we defined various segments and modules. A segment represents a processing step throughout a data lifecycle. A module represents a functional and/or technical element.

The **Data Ingestion Segment** ingests the various data sources into the CLIMABOROUGH platform. It consists of:

- **The Live Data Ingestion Module (phase 1)** is represented by the DKSR Open Urban Platform and its connectors for ingesting real time data.
- **The Historic Data Ingestion Module (phase 1)** is a Data Lake for processing and saving historic and/or static data based on to be established cloud data processing pipelines.

The **Analytics & Monitoring Segment** serves the methodological and technical core of the platform for analyzing and processing data. It consists of:

- **The Solutions KPI Engine Module (phase 1)** serves as an analytics approach for monitoring the performance of procured solutions based on to be defined KPIs per solution. The KPIs are based on the "Action Assessment KPIs" of WP1.
- **The Urban Planning Framework for Climate Neutrality (UPF4CN) KPI Engine Module (phase 2)** serves as the processing logic for a comprehensive analysis of the climate urban metabolism and optimally its systematic interdependencies. The KPIs are based on the "Climate Urban Factor KPIs" of WP1.
- **Digital Twin Prototype Module (phase 1 & 2)** is a framework for developing and customizing Digital Twin based applications. It can serve as a representation and

analysis means of collected data as well as a set of functions and services operating on these data.

The **Service Segment Module** serves as the visualization of KPIs and explainability of systemic effects during the urban climate transition. It enables stakeholders to interact with the processed data. It mainly consists of:

- **The Solutions Impact Dashboards Module (phase 1)** aims to visualize the Solution Performance Assessment and help cities and solution providers to monitor the impact of the implemented actions.
- **The Climate Neutrality Roadmap Module (phase 2)** helps to assess gaps in the climate neutrality transition of a city based on the Climate Urban Factors KPIs. Optimally it will provide a Roadmap of the city towards Climate Neutrality.

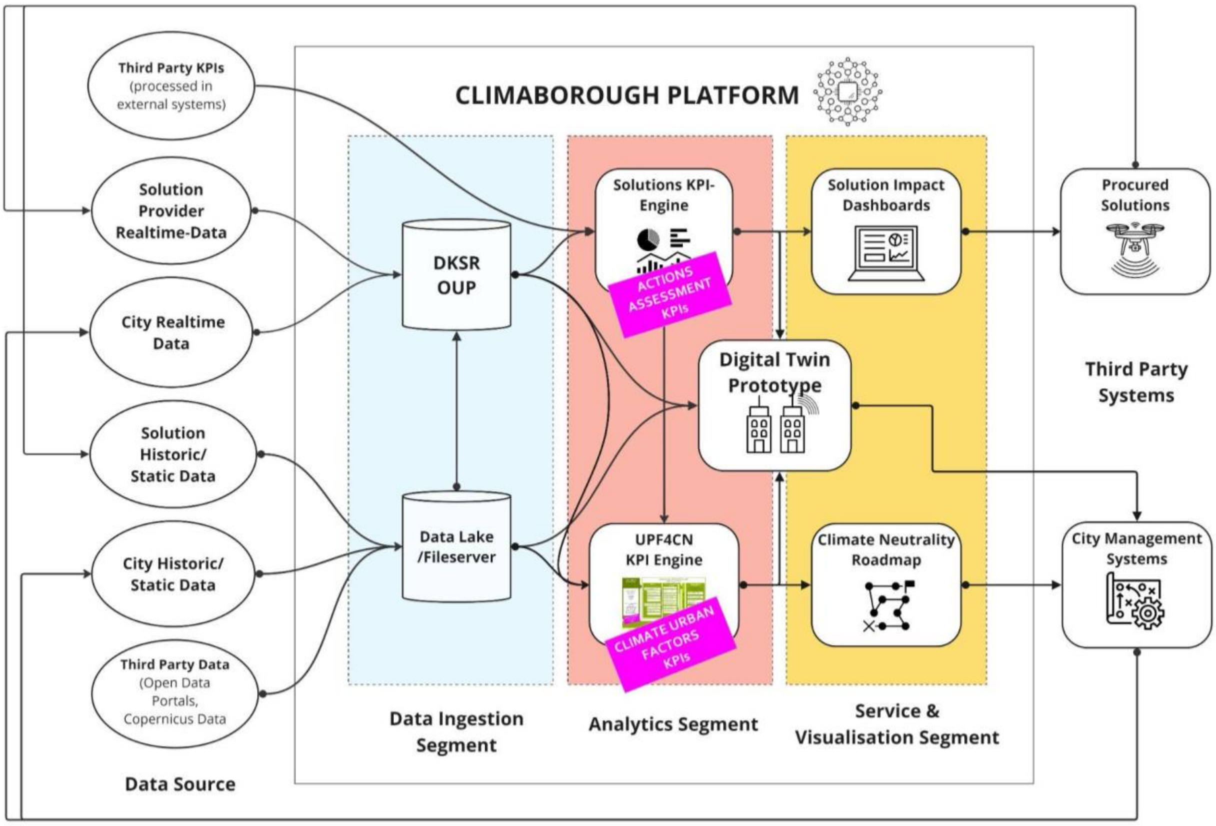

Figure 6: Functional Reference Architecture of CLIMABOROUGH Platform at the end of the project

5.2.1. Development & Operating Responsibilities

- The **Live Data Ingestion Module** will be operated by **DKSR** with the Open Urban Platform.
- The **Historic Data Ingestion Module** is provided by LIST and operated by DKSR as long as data formats are the ones recommended by WP2 partners in section 5.4.1. If

other data formats are provided, a case-by-case analysis will be carried out to determine whether they can be ingested and processed.

- The **Solutions KPI-Engine Module** will be set up and hosted by LIST and the AIDA infrastructure. DKSR will lead the operation of the module. As we will use a common development framework the other partners (IMT & LIST) will be able to join the operation as well.
- **Solution Impact Dashboards** will be operated by LIST and the BESSER platform.
- The responsibility of the organization operating the **Climate Neutrality Engine Module** and the **Climate Neutrality Roadmap Module** will be defined **later in the project in line with the technological and functional decisions** based on the results of the ongoing work done in collaboration with WP1, WP3, WP4 and WP5.
- The **Digital Twin Prototype Module** will be operated by **IMT** and its Digital City Twin Architecture.

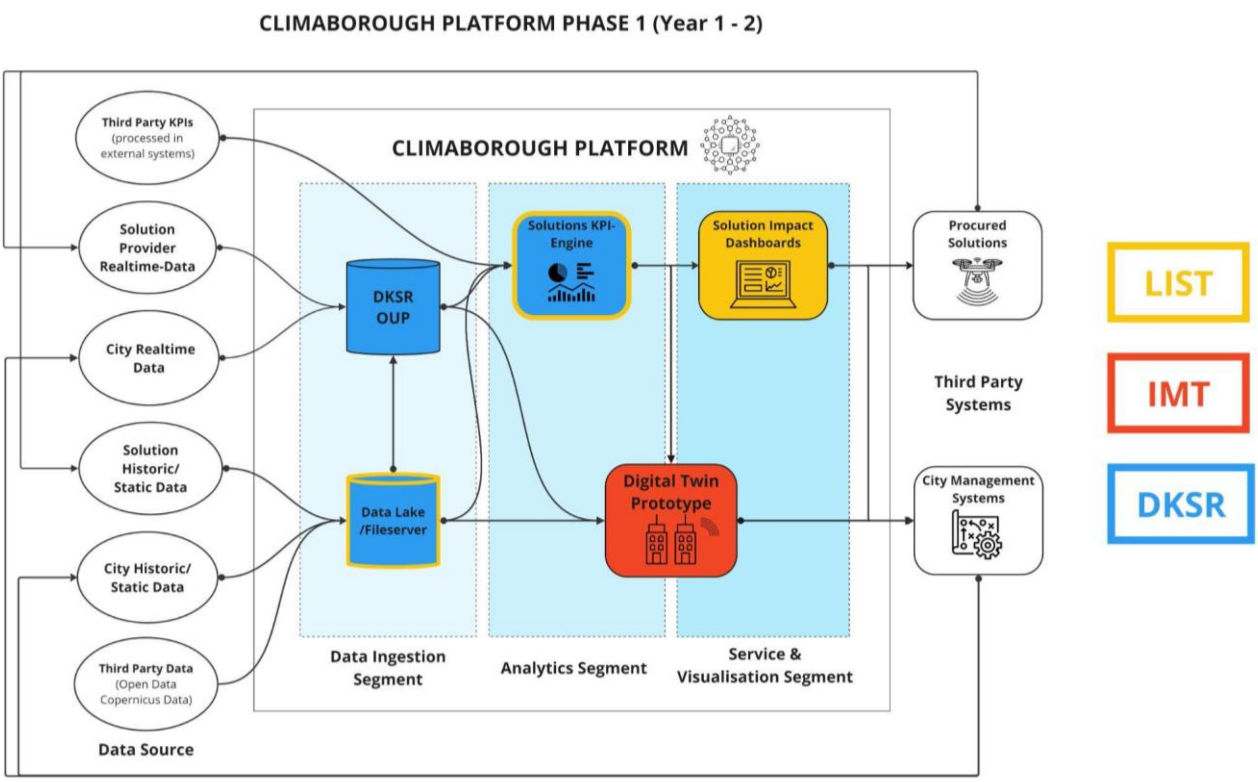

Figure 7: Functional components of CLIMABOROUGH platform and responsibilities in development phase 1: Year 1 & 2.

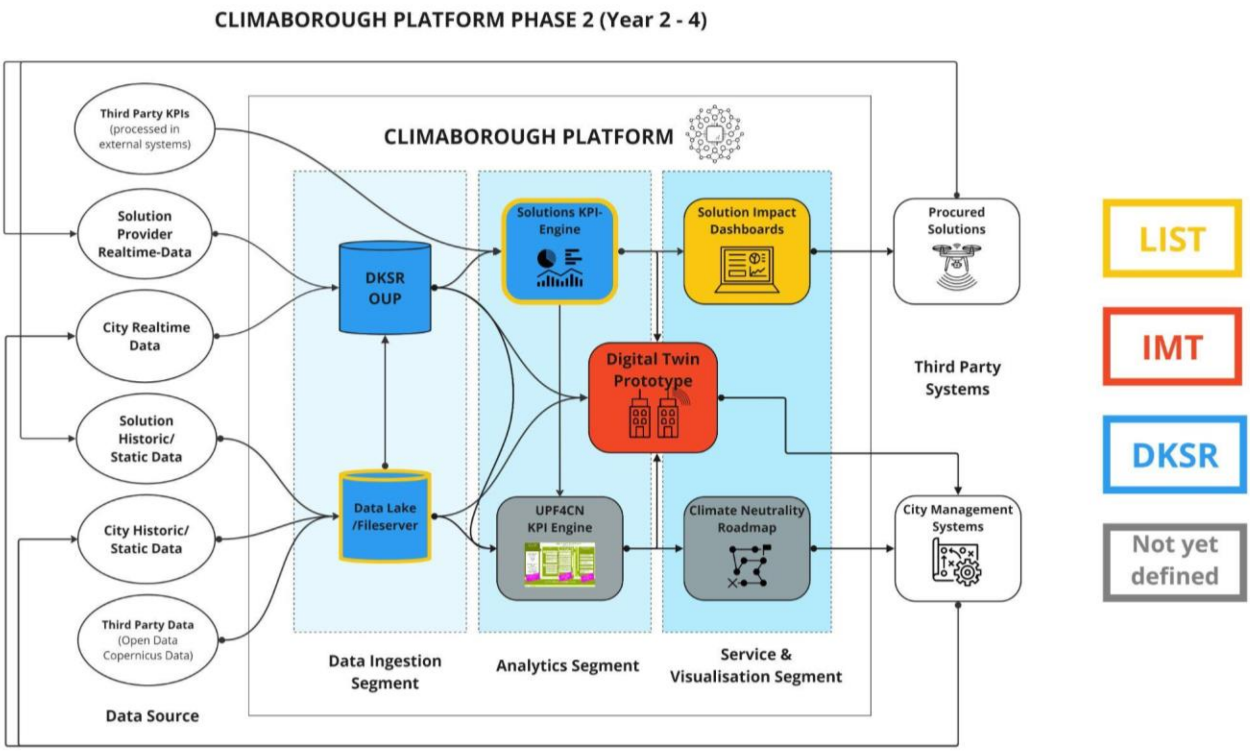

Figure 8: Functional components of CLIMABOROUGH platform and responsibilities in development phase 2: Year 3 & 4.

5.4. General Data Architecture

The CLIMABOROUGH project is characterized by a complex data architecture. In fact, there are different types of data flows intersecting and intertwining, a diversity of scope in data management and processing as well as a great diversity in data formats.

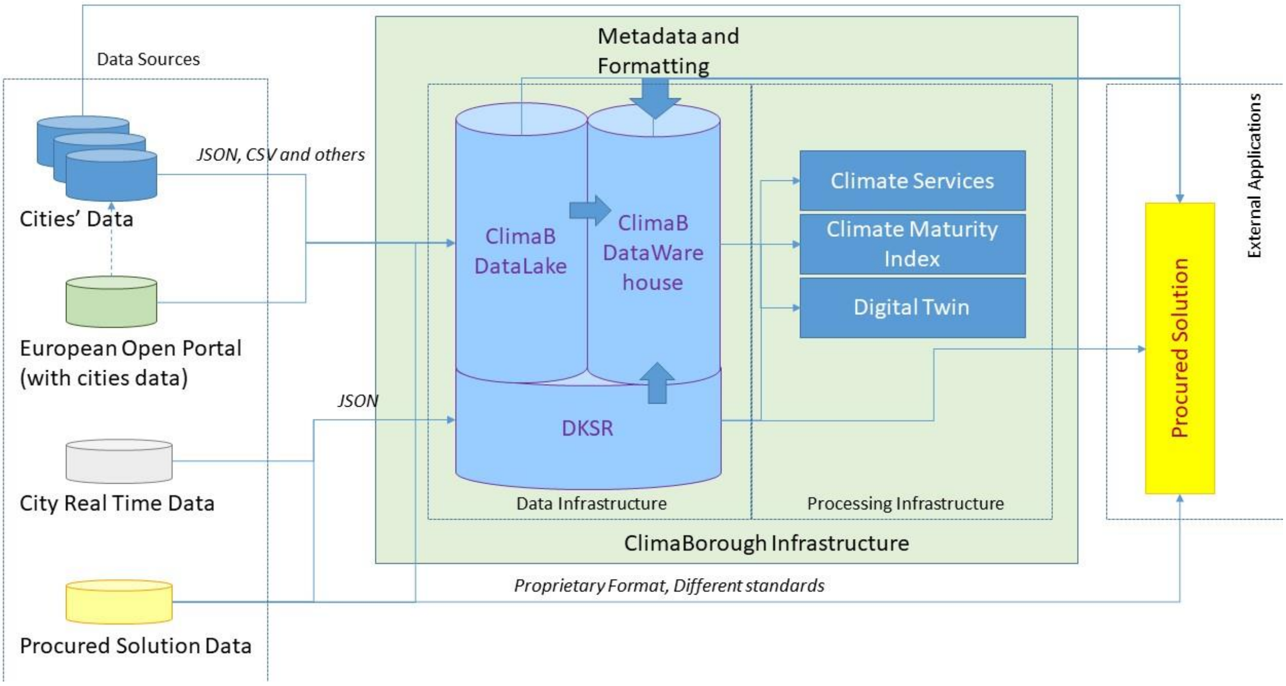

Figure 9: Data Architecture: Different flows of data needed to support the CLIMABOROUGH vision.

Three major subsystems are identified:

- **Data sources**, which represent the different sources of data that can be stored and processed by the CLIMABOROUGH platform.
- The **CLIMABOROUGH infrastructure** represents the storage, transformation, and processing capabilities of the CLIMABOROUGH platform.
- External solutions are the **procured solutions or other services** that can access the functionalities or data of CLIMABOROUGH infrastructure.

A more detailed description is provided in the following subsections.

5.4.1. CLIMABOROUGH Infrastructure

This subsystem is the bulk of the activities of WP2. Two major parts can be identified:

Data Infrastructure. The infrastructure contains the data that are the input to the entire platform. The unstructured and raw data are directly injected into the **CLIMABOROUGH data lake**. It is a collection of data (typically historical data) that may be further formatted and manipulated for further processing. Some specialized applications can directly access them if the format is known and appropriate for processing. The data lake can be seen as a collection of different cities' data (directly from the city or through the European Open Portal). They need to be harmonized and formatted through metadata and models. The minimal requirement for these data is to have them in some JSON-like formats. Additional and more complex formatting will be used if needed (e.g., the Digital Twin app will most likely use NGSI-LD formats). The well formatted data will be available through a broker or a general **data warehouse** function. For dealing with the complexity of real-time data, the infrastructure will use the storage and the functionalities (as well as the data formats) offered and supported by the **DKSR' OUP** platform. This will minimize the development time of CLIMABOROUGH by offering a ready solution for this purpose. It is important to note that real-time data can be used and requested either by internal services and applications or by external apps. In case of **historic or static data** coming from data sources such as cities or from EU data portals, the data would be processed using a data processing pipeline. This data processing pipeline would be hosted on a cloud service provider allowing the data to be transformed in required formats which then would be stored in the data warehouse or data lake.

Data. It is important to note that the flows of real-time data and procured solutions can also "bypass" the CLIMABOROUGH infrastructure. These are cases in which these data are needed "as they are" by external applications.

Processing Infrastructure. The processing infrastructure supports the different functionalities and apps made available by the CLIMABOROUGH platform. Depending on their goals and scope, they can use real-time data (formatted according to the OUP platform formats) or data warehouse supported ones (typically JSON, CSV, or NGSI-LD representations). Different types of applications and functions are supported by the infrastructure. These applications are not designed to share data with external ones, but in the future data-exchange mechanisms (through the data warehouse of defined APIs) could be defined in order to support the needs of external or internal applications.

External Applications. This is the realm of procured solutions or of existing, city specific applications. They can directly access the different types of data that the CLIMABOROUGH infrastructure will make available, as well as the other data sources. The choice is on the external solution application developers. It is under definition for each domain and related challenges, as well as for the global KPI, a set of information, data, and measures that could be required by external applications in order to monitor, evaluate and assess their effectiveness in coping with specific challenges and their direct contribution to the Climate Maturity Index.

In the following sections, some examples of data chains, related data curation, and improvements are provided.

5.5. Technical Description of Internal Data Transfer

5.5.1. Data Transfer from "Ingestion Layer" to the Processing Layer

Live Data Ingestion Module (DKSR OUP Outbound-API)

In the following, we describe the Outbound API of the DKSR OUP. It uses RESTful APIs for sending data out from the data platform through its Outbound Module. The data exposed is in JSON format and more specifically as a Flat JSON allowing the ingestion parsers to easily read data based on a predefined schema. In particular, DKSR enables Outbound APIs for connecting data sinks through:

- Use of WSS (secure websockets) for sending out live data
- Use of HTTPs for sending out historic (saved) data from the database.

The Outbound Interface of OUP connects the client side with the backend services. To ensure reusability, each analytics service and data source is designed as a service. Therefore, the OUP API can also be considered as a facade for the urban data sources and analytics services. The communication between the backend services and the client or participating applications is realized by a combination of a Websocket (WSS) based pub/sub system for event or live data and RESTful interfaces using HTTPs for persistent or historic data.

The APIs are managed through DKSR's Identity and Access Management (IAM) module allowing use-case and role-based access. The users are provided restricted credentials such as user ids and passwords or tokens through which users can access these API based data sources.

Historic Data Ingestion Module

Foreseeable through the in WP3 defined use-cases per city, many data sets need to be ingested, cleaned and structured after which the data would be saved in a required database (either OUP's or any other). Any operation in this regard will require using manual analysis and ETL processes using external tools such as NiFi, Camel, Kafka, Jupyter Hub etc. In the coming phase we will define the needed technology and how it interacts with the Processing Layer . These tools require effort for such manual ETL processes. Therefore we have a limitation in ingestion data sources from cities. The limitations are defined by the effort needed to build these ETL pipelines. In order to reduce effort we defined required data formats in section 5.4.1. If other data formats are provided, a case-by-case analysis will be carried out to determine whether they can be ingested and processed.

5.5.2. Data Transfer from "Solution-KPI Engine" to BESSER Platform (Inbound-BESSER Platform)

In the following we describe the Inbound-API of the **BESSER Platform.** It is able to ingest the structured data as described and present KPIs and dashboards described by the cities.

The injection can be done using the following canal:

The **PUSH Method**, if the system of the previous module is able to send it: Data can be transferred by uploading files to the KPI display platform. This can be done through HTTPS. File transfer is suitable for bulk data uploads or when a large amount of data needs to be imported, for example, historic data or transfers from the data lake. This data will then need to be formatted (if not yet the case) according to the chosen format. The KPI display platform also provides RESTful APIs and web services (called Proxies) that allow the data to be sent programmatically. The other counterparts can use these APIs to feed the system, sending data in a structured format such as JSON or XML. These APIs are secured with OpenId Connect (Upon authentication the identity provider generates an ID token containing claims about the user's identity, and this token is transmitted in the header of the request).

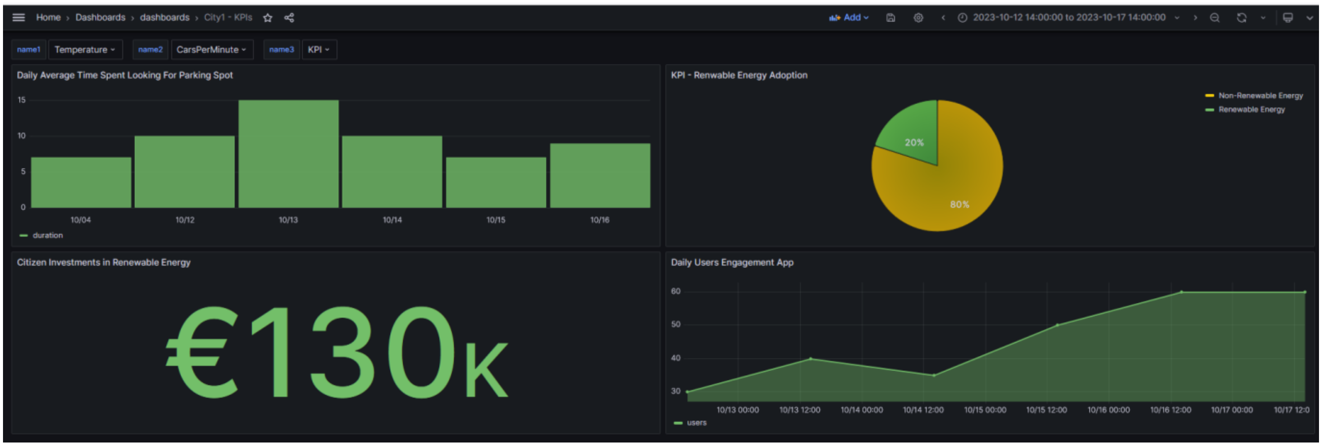

Figure 10: Example visualization of a KPI-Dashboard with the Open–Source Technology Grafana

The main features of the resulting thematic dashboard are:

- **Common Filtering:** The filters are applied globally on the whole dashboard, by selecting specific data or information based on the value of a criteria or specific conditions. It is used to narrow down the dataset and/or refine the results to determine correlation between some parameters or to see the influence of one parameter on the other.
- **KPIs and various charts:** Key Performance Indicators are measurable values that indicate the performance. These KPIs are often visualized through charts, graphs, or other data visualization techniques to provide a clear understanding of trends, patterns, and performance metrics.
- **Access Control:** Different users will receive different rights. Administrators might be able to change dashboards, while other users might only be able to interact with existing dashboards.

High level workflow of the expected solution. The user logs himself and sees the available dashboards that he can access on the portal. The base data is already computed but the user can specify additional parameters to change the visualizations.

Ingestion and export of the data through Proxies that do the conversion between the ingested data and the internal model, or the other way round expose the data for further use by another system. The KPI data used in the visualizations will be made available via a RESTful API interface. The RESTful API interface will be documented following the OpenAPI 3 specification.

5.5.3. Data Transfer from "Ingestion Layer" to Digital Twin (Inbound-IMT)

The Digital Twin has a double facet, on one side it is a means to collect and analyze the historical data from a specific challenge domain (e.g., data related to pollution) and it is also a means to provide some services. The envisaged services are related to predictions about the possible evolution of the phenomena. To this end, the Digital Twin needs to operate on historical information. Depending on the granularity of historical information, the "quantity" of stored data in the CLIMABOROUGH data lake could vary. Just to give a dimension of the problem, there is a large difference in terms of the size of data if a city provides the measurement of 10 pollutants every minute or if a city provides a daily measurement of a couple of them. Considering the experimental nature of the DT development, a meaningful size of data of some granularity will be considered during the course of the project. Different cities may provide this historical data not only at different times, but also in different formats. WP2 will choose for experimental purposes a city that is providing good quality data with an hourly frequency at least and with measure of some relevant pollutants. A time period of one year could be considered a good test for the capabilities of the project. With respect to the sources and formats of data, the WP2 wants to be practical and needs to focus on a specific format. One criteria of choice will, in fact, be the possibility of formatting these data according to a specific data model expressed in a formal way. As a formatting scheme we consider NGSI-LD data models as proposed by ETSI and FIWARE with particular reference to the Air Quality Data model or JSON-LD format. The preferred sources of this data are the cities directly, however in order to benefit from some homogeneity and some effective pre-processing of data, the DT could be fed with data related to the target city as stored in the European Data Portal. Typically the data there are JSON or CSV formatted. If the used format is not too far from the NGSI-LD data model, the ingestion process will capture the available historical data (e.g., from the European Open Portal) and will transform them into NGSI-LD in order to exploit additional capabilities (e.g., the description of properties of related data). The "curated" data will be stored in the data lake and accessed by the DT in order to provide a timely representation of the pollution data. In order to make sense of pollution data, also weather related data of the specific city will be collected from specialized sites and data providers, formatted, and injected into the FIWARE Air Quality Model for homogeneity and ability to manipulate them. Creating a data set like this one offers the ability to use the time series as input to prediction functionalities. The envisaged AI algorithms are Neural Networks such as Long Short Term Memory (LSTM) in order to take advantage of their capability of keeping track of periods of time and reusing past information for improving the prediction. However, due to the fast changing landscape of AI applications, other prediction algorithms can be considered in order to improve the results. Having access to a long period of time series allows the WP2 to have enough data for training, testing, and validation of results. This will yield a higher accuracy of the prediction. The selection of features on which to exert the prediction will be particularly important, in fact, certain pollutants or available data could be directly related to values or KPIs or measurement of interest for the Climate Maturity Index. If these kinds of relationships can be found, then this DT development could be a support tool for the UPF4CN to further elaborate on. The prediction of future values after the introduction of new strategies or policies operating on the "features" of the Neural Network could be used (if enough data for training are available) to predict the effects of them on some KPIs.

It is not essential for the DT to access real-time data for showing the past and current behavior and to predict the near future. However, their availability could increase the attractiveness of the DT experiment. It is important to mention that the real time data should use the same data format as the historical data or be formatted to that format before injecting them into the Digital Twin.

5.5.4. Scenarios for Data Ingestion & Processing

There are a few scenarios for ingesting and processing the various data sources into the CLIMABOROUGH platform. In the following, we describe the most possible scenarios based on the actual requirements.

In any case, the data should be preprocessed in a “Fact-Dimension” like structure. It would provide a structured and efficient way to store and analyze data for reporting and analysis purposes. This model will help in representing the data in a way that aligns with the analytical requirements of the business defined in the WP1.

Thus, we achieve the following:

- **Granularity and Aggregation:** Facts represent the measurable and numeric data points. They capture the business events or transactions that occur over time and are associated with dimensions, which provide context to the facts. Dimensions represent the descriptive attributes of the data, such as time, and location. By organizing data into facts and dimensions, it becomes easier to aggregate and summarize data at different levels of granularity, enabling faster and more efficient analysis.
- **Simplified Queries:** Using this common structured data allows for simplified and optimized queries to display the KPIs. Dimensions will act as entry points to filter and slice data based on significant attributes, while facts will provide the measures to be analyzed. This organization helps in writing queries that can easily navigate through the dimensional structure, improving query performance and user experience and allowing to compare and put in parallel the heterogeneous dataflow
- **Scalability and Flexibility**: The model offers scalability and flexibility. New facts can be added to the data lake without impacting existing data, and new dimensions can be introduced without affecting existing facts. This modular structure allows for easy expansion and modification of the data lake as business needs evolve (WP1).
- **Business Analytics:** This organization facilitates effective business analytics by providing a clear structure, data can be easily sliced and diced, allowing users to gain insights, discover trends, and perform multidimensional analysis. This helps businesses make informed decisions, identify opportunities, and optimize operations.
- Overall, organizing a **Data Warehouse** with facts and dimensions provides a powerful framework for storing, analyzing, and reporting on data. It enables efficient querying, data consistency, and scalability, and supports effective business analytics, making it a widely adopted approach in the field of data warehousing.

5.6. Modeling & Generating Dashboard (BESSER Platform)

BESSER-For-Clima will consist of a collaborative modeling process, the generation of the modeled artifacts and the deployment thereof.

Modeling:

In a first step, the planned system and its components will need to be modeled. As we will focus on creating dashboards for the different cities to visualize the KPIs which measure the provided solutions, the created Domain Specific Language (DSL) will contain the necessary elements. We plan to include the following primitive elements:

- **KPI**: We will provide a KPI primitive, which will be defined based on a chosen standard (e.g. FIWARE KPI). Solution-specific KPIs will extend the primitive KPI definition and (if needed) add additional relevant attributes.
- **City**: A City primitive will be added to clearly differentiate the dashboards and their content based on the cities.
- **Visualizations**: The Visualization primitive will represent different visualization types or techniques. The Visualization class will consist of subclasses of specific visualizations (e.g. 2D Graph, Histogram, PieChart, etc...).

Based on these primitive modeling elements, which make up the DSL, users will be able to define the needed KPIs, connect them to the corresponding cities and choose fitting visualizations. These primitives make up the so-called metamodel of the system. In non-technical terms, a metamodel is like a blueprint or a set of rules that describes how information or concepts can be structured and related to each other within a certain domain (In our case, we could talk about a Climaborough domain). It defines the types of elements, their attributes, and the relationships between them in a particular system or framework. It's a high-level model that helps us understand and organize different pieces of information or ideas in a consistent and standardized way, making it easier to communicate and work with complex systems or concepts. An example on how such a metamodel could look can be seen in Figure 11 (Note that the presented model does not represent the final product but rather acts as a simplified mock-up for the sake of understanding the main idea behind the planned DSL).

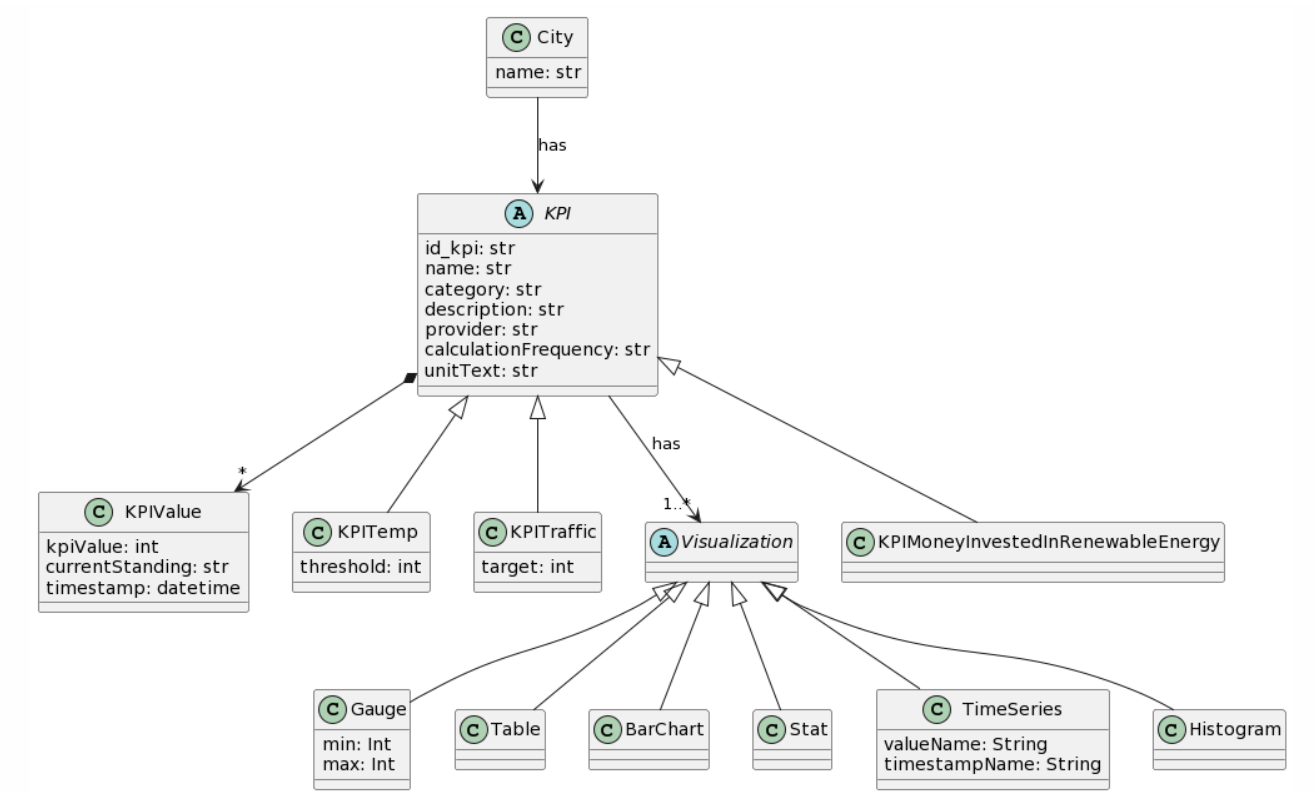

Figure 11: Example KPI Dashboard Metamodel

To represent the actual dashboard, we will now need to create a model using our DSL. This model will consist of a combination of different elements from our metamodel, thus in a way putting the pieces together while sticking to the defined rules in the metamodel and setting the attributes to desired values. An example on how such a model would look can be seen in Figure 12.

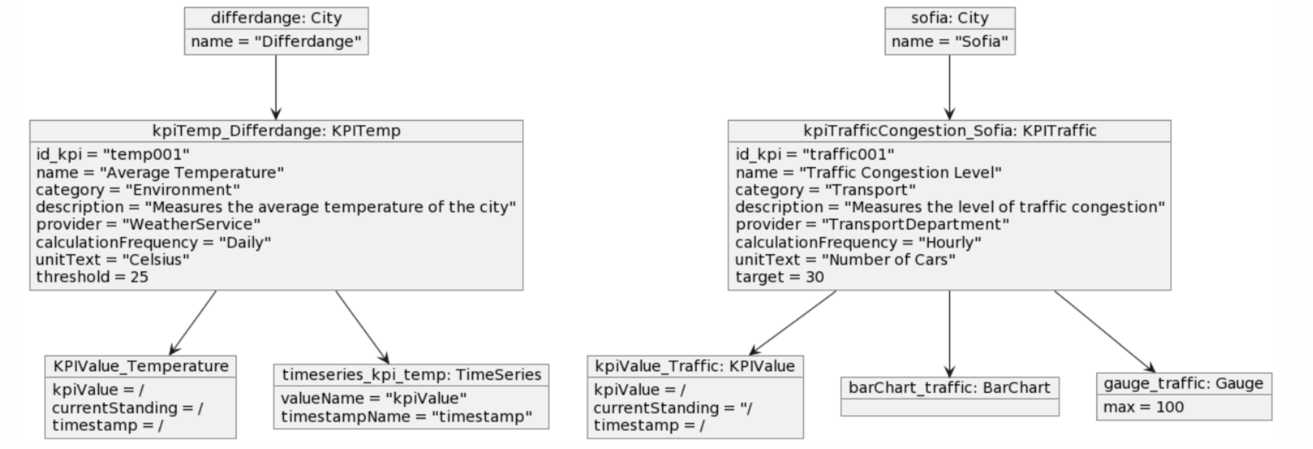

Figure 12: Example KPI Dashboard Model

Note again, that the goal here is to collaboratively develop the metamodel based on the defined KPIs between the cities and solution providers. The same goes for the model of the dashboard, which should define per city how the desired dashboard should look like with the different types of visualizations and adjustments.

Generation:

Once the model is ready, the code-generation process can start. The process itself is straightforward, as one will only need to input the path to the .txt file of the created PlantUML model in one line of code. Once the path is adjusted, the different generation scripts will need to be started and the deployment code will be generated. This includes in a first step:

- The relevant python classes and the database definitions.
- A REST API interface with the necessary calls to push and pull the KPI data.
- The dashboard definitions with the modeled visualizations

Deployment:

To deploy the generated software, a docker-compose file was prepared that contains the relevant docker-images (API Server, Database and Dashboard Platform). Additional parameters will need to be adjusted (such as database password, server address, etc…). Once adjusted, the docker-compose can be started and the different components will be running.

A simplified overview of the complete architecture can be seen in Figure 13.

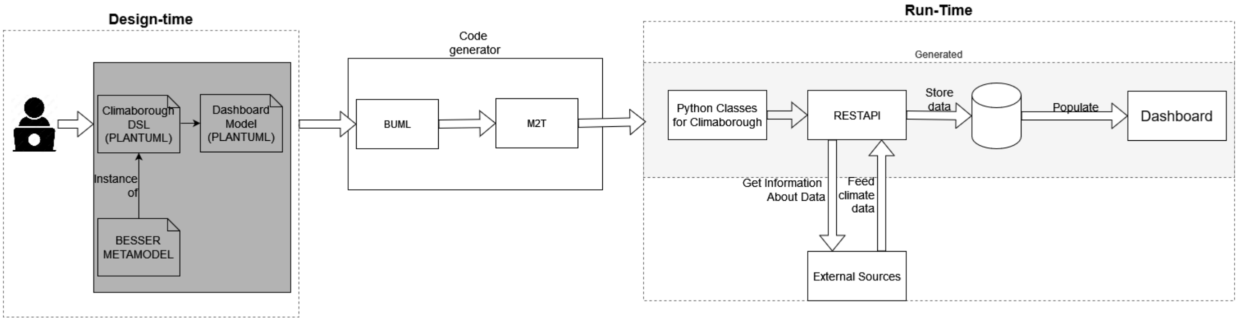

Figure 13: BESSER for CLIMA Architecture

5.7. Requirements on data formats

Requirements on Real-Time Data: "Real-time" or IoT data will be ingested into the CLIMABOROUGH platform via the DKSR OUP. In order to connect APIs and data sources to the OUP, a connector has to be developed (detailed description of technology in Chapter 3). The connector needs a specific data scheme in JSON-format. Third party systems like city management systems or sensor platforms have to provide all the described attributes in order to efficiently connect their data to the CLIMABOROUGH platform. An example data scheme for air quality/weather data is provided in Annex B.

Requirements on Historic Data: Historic or static data will be ingested via a Data Lake. From the actual state of information, we expect that there will be various heterogeneous historic/ static data sources provided by the cities and the solution providers. In order to most effectively handle the data ingestion by the CLIMABOROUGH platform, cities, and solution providers have to provide consistent semantics & syntax of their data sources. Some rules we can already define at this state of the project:

- The Data Lake can only consume data in the following data formats: txt, CSV, JSON, XML, Flatfile.
- Data providers should give description to the data sources and resp. data attributes.
- Per data source: The syntax and semantics of every data source have to be consistent.
- Units have to be defined consistently throughout the data source.

Example for consistent syntax of data sources (table and charts):

https://support.staffbase.com/hc/en-us/articles/360007108391-CSV-File-Examples

5.8. Cloud Infrastructure, Hosting & Security

The final cloud provider concept has to be defined when the final platform architecture is set. In the following we introduce a concept based on the Cloud Infrastructure of LIST.

5.8.1. AI & Data Analytics (AIDA) infrastructure supporting Climaborough

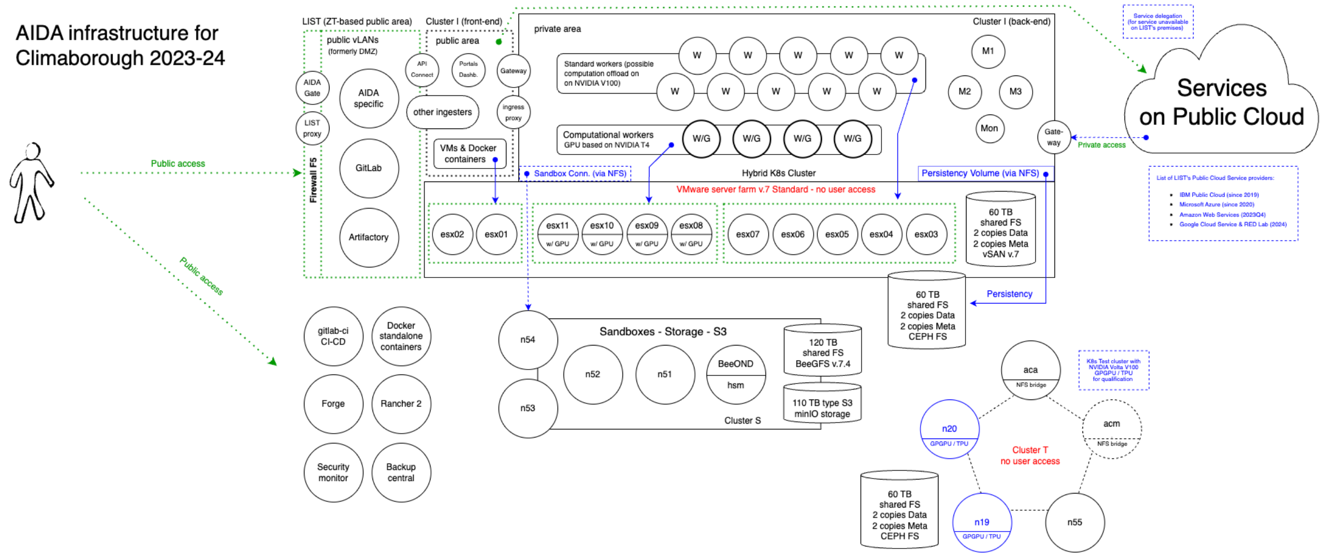

Figure 14: AIDA infrastructure envisioned for Climaborough

To provision the resources needed by the Climaborough project, the Artificial Intelligence, Data Analytics, and Visualization (hereafter, *AIDA*) infrastructure opens its Clusters I and S. Cluster I is installed atop a VMWARE ESXi farm (v7 Standard Edition) counting 11 servers. Each physical server of the farm is bi-processor (2 x Intel Xeon Gold 18c) with 768 GB RAM. Four servers sport a NVIDIA GPU card Tesla Turing T4 (2560 cores). The Cluster I front-end is assigned two ESXi servers and nine servers support the back-end. Functional modules will essentially run on a Kubernetes (K8s) cluster located in the "Cluster I (back-end)". The two "Cluster I (front-end)" servers host various virtual machines (VMs) and containers that instantiate either pass-thru mechanisms or data ingestion tools, deployed as needed by the project (see Annex E). Although security is enforced by multiple measures applied in the LIST Public Area–measures driven by the Zero-Trust paradigm (i.e. insulated vLANs, F5 BIG-IP firewall, Web Application Firewall with requests profiling, ports restrictions,...), the data ingested on the Cluster I front-end (public area) can only propagate to the Cluster I back-end (private area) via reverse-proxy modules enforcing data sanitization.

Each "W" worker instance of the K8s cluster has a computation capacity of 34 cores. Each of the "W/G" instances has a 68 cores capacity and a GPU access. Three masters (M1..3), a monitoring instance, and some specialized modules complete the infrastructure services.

The data ingested by the *Cluster I back-end* may go directly to the Open Urban Platform (OUP), in some scenarii or be stored in a *Data Lake* or transit through an *ingestion buffer*. In all these cases, persistency is provided by the Cluster S. Cluster S is a shared file-system (SFS) combining flat files storage (POSIX compliant), block storage (as HDFS), and objects storage (e.g. for bucket items) in a S3-compatible way (includes minIO, influxDB). Chunks of the SFS can be allotted statically or on-demand, for instance, via BeeGFS-On-Demand (BeeOND) or via specific Infrastructure-as-Code (IaC) scripting.

5.8.2. Operational Deployment of Climaborough components on AIDA

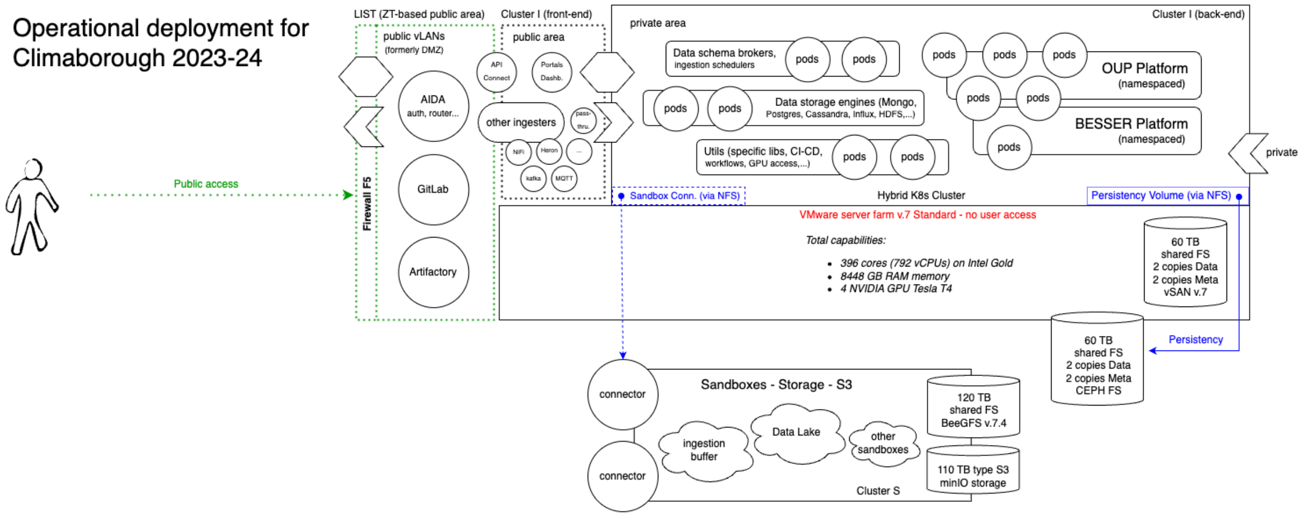

Figure 15: Climaborough components deployment on AIDA infrastructure.

The *Cluster I front-end* (public) will host multiple endpoints that represent a catalog of possible data ingestion tools or platforms, that cover specific use-cases (streamed data, fetch files,...), constraints (e.g. on data volume, velocity, variability,...), and so on.

The data ingested on the *Cluster I front-end* (public) will only propagate to the *Cluster I back-end* (private) via reverse-proxy modules that enforce sanitization, for instance, by checking SQL or code injection, schema format (HTTP, MQTT,...), OWASP compliance, RBAC control, session/token integrity/validity, and so on.

The data ingested by the *Cluster I back-end* may go directly to the Open Urban Platform (OUP), if they are “live data” and they fit one of the predefined schemes, Otherwise, if they are “historic data” (coming in a “batch files mode”) but yet complying with one predefined scheme, they can rest in a Data Lake, before a proper processing and transfer to the Solutions KPI-Engine. In other cases, an “ingestion buffer” is needed. This tank of data has a composite design; it holds various data structures that are the persistence layers of the data storage engines required to ingest data formats and schemes not handled by an out-of-the-box OUP. Specific modules called “Data schema brokers” will feed on this tank of data not readily usable by OUP and transform those data pieces so they can be ingested by OUP.

AIDA and its ecosystem offer many tools that support the activities of all its users and the specifics of their profiles: data providers, data engineers, data scientists, data officers, data analysts, developers, devOps, dashboard users, business analysts, executive officers, citizens, others.

5.8.3. Components for Deployment of the different technologies

DKSR Open Urban Platform uses Kubernetes based orchestration services and generic cloud configuration components which include the following elements:

- HELM charts
- Kubernetes Ingress and gateways
- Public and private IPs on cloud through NAT

- Managed databases from cloud providers (Postgres, ElasticSearch)
- Cloud-based security policies and encryption techniques
- CI/CD repositories over Gitlab/Github
- Containerisation techniques based on Docker

The named components will not be published as open source components as project results. But the code of the DKSR OUP will be published.

Normally, the DKSR OUP uses the Open Telekom Cloud (OTC) for hosting its services. The OUP is cloud agnostic. This means that hosting on other cloud providers is possible, but it needs time & resources for developers to implement it on unknown cloud systems.

OUP Connector components can be programmed based on use cases to preserve data privacy by anonymising data. The connectors ingest data on the cloud allowing a secure space for access of connector components. The data from connectors are securely sent to the central OUP platform through secure TLS channels and HTTPs based access. The OUP platform and its related services run usually on secure OTC Cloud Computing environments through virtualisation and abstraction using Open Cloud Stack and Kubernetes services. All data exchange within the cloud is through secure private IPs and only registered/authenticated users having secure private keys can access the computing environment.

All the data residing in the managed database services leveraged through cloud services are encrypted with security and firewall policies governing the traffic inflow and outflow. Most cloud providers allow fine granular security policies for separating and monitoring user traffic data. Finally, all access to Outbound APIs are monitored and administered for access through the IAM module restricting access for unauthorized users.

Basic / Minimum requirements for OUP on Cloud: These are the basic requirements for OUP running on a Cloud service with Kubernetes as the base for hosting and operation of DKSR Platform Services. These hardware requirements are on basic minimum level and during the progress of the project, if required autoscaling as a service should be available for the pods:

- 4 ECS/Nodes
- Per Node: 4vCPU mit 16 GB RAM => Total 16vCPU mit 64GB RAM
- Cloud Monitoring Services such as Azure Monitoring
- Database PostgreSQL – 1 vCPU + 4 GB RAM (Self-managed since no cloud provider used)
- ElasticSearch - 2 vCPU + 8 GB RAM (Self-managed since no cloud provider used)

Apart from these services, all required components would be deployed and supervised by DKSR through a secured connection to the Kubernetes cluster (certificates, keys etc.). Further DKSR will use its own CI/CD pipeline to deploy and manage its services. Since the exact details of the cloud service provided by the partner is not clear, exact estimation of the effort required for this deviation from the original plan would need to be considered during the project runtime. Any further effort required for the cloud operations would negatively affect the creation of connectors and any data analysis operations required.

BESSER platform should be cloud provider agnostic and should be possible to migrate from one provider to another with the minimum of effort. Therefore the requirements below are the minimum features needed to allow a simple deployment.

Therefore the easiest in terms of scalability, resilience, and deployment architecture should be based on Kubernetes based Orchestration services and generic cloud configuration components.

- Use of HELM charts
- Use of Ingresses
- Use of self hosted databases (both relational and No-SQL)
- Use of CI/CD over Gitlab or GitHub for the deployment
- Containerisation techniques based on Docker

IMT Digital Twin: The Digital Twin components will run on a cloud infrastructure. There are no particular requirements in terms of processing power or specialized functionalities. The DT will be developed in terms of chained microservices and they could be supported by existing Kubernetes infrastructure for orchestration and monitoring. The developments will be aligned with the specific infrastructure made available. An MQTT engine and the availability of a context broker are so far envisaged for access and transport of data. In any case, the solutions will be aligned with the available infrastructure.

For the definition of a **final cloud concept,** we need to specify the comprehensive cloud architecture. As well, we need to distribute the responsibilities. Especially which partner will provide the hosting environment on which cloud provider (e.g. OTC, AWS, Microsoft Azure, etc.). This will be decided in the next phase.

Cloud Platform Security

The cloud platform should be secured with OpenID Connect. OpenID Connect is an identity layer built on top of the OAuth 2.0 protocol that provides a way to authenticate and authorize users, and it also enables the secure exchange of identity information between an identity provider (such as Identity Server) and an API.

This security is achieved through following steps

1. **User Authentication:** The user wants to interact with the API and initiates the authentication process. He is then redirected to the authentication endpoint of Identity Server, which presents a login page to the user, and the scopes/consent needed.
2. **Issuing an ID Token:** After successful authentication and consent, Identity Server generates an ID token. This token contains claims about the user's identity, such as their unique identifier, name, email, and other relevant information.
3. **Token Validation:** The API backend receives the ID token and verifies its authenticity and integrity. This includes validating the token's signature using Identity Server's public key, checking the token's expiration, and ensuring that the token was issued for the requesting party.
4. **User Authorization and Access Control:** In addition to the ID token, OpenID Connect allows the user to request an access token that can be used to access

protected resources on behalf of the user. The requesting party can send this access token in API requests to authenticate and authorize the user.

5. **API Endpoint Protection:** The API verifies the access token sent by the requesting party to authenticate and authorize the user. This involves checking the token's signature, validating its expiration, and ensuring that the token has the necessary scopes/permissions to access the requested resource.

6. Conclusion

In this document, we described the status quo of the reference architecture of the CLIMABOROUGH platform. The deliverable shows the functional and technical requirements of the platform, the technologies the partners provide, and a schema for how to connect them to a comprehensive platform.

An important learning of this very intensive first project phase for WP2 is the need to focus the purpose of the platform. Data and technology have limitations. The CLIMABOROUGH platform can only measure clearly-defined data. In order to understand the systemic effects of climate neutral transitions other information such as opinions, policies and even emotions have to be taken into consideration. In the near future/ during this project, a technical infrastructure will not be able to measure this rather fuzzy information. Therefore, we need to focus and limit the tasks of the platform. It will be a digital tool to support cities in the climate neutral transition. As this task is huge and holistic we have to limit the possibilities in order to develop a tool which really supports cities. In order to understand in detail what the cities need, we will proceed with our cooperative working modus with cities and project partners.

For the next phase until the next deliverable (D2.2.), we will identify major tasks to define a comprehensive platform architecture and hence, to develop the prototype. In the following, we describe the upcoming tasks:

Data Inventory Workshop: WP2 will conduct a data inventory workshop with all leading cities to understand their available city data sources in depth and to identify the relevant technical experts in every city. The result will be a comprehensive data catalog per city with data formats. For the methodology, we will use the “5 Pools of Data” approach introduced by WP3. It is a pragmatic data model which helps municipal stakeholders to easily categorize their existing data in order to understand where the data might be produced and who within the city is responsible. The five pools are “Behind the Firewall”, “Open”, “Social”, “Sensor/IoT”, “Commercial” - Data.

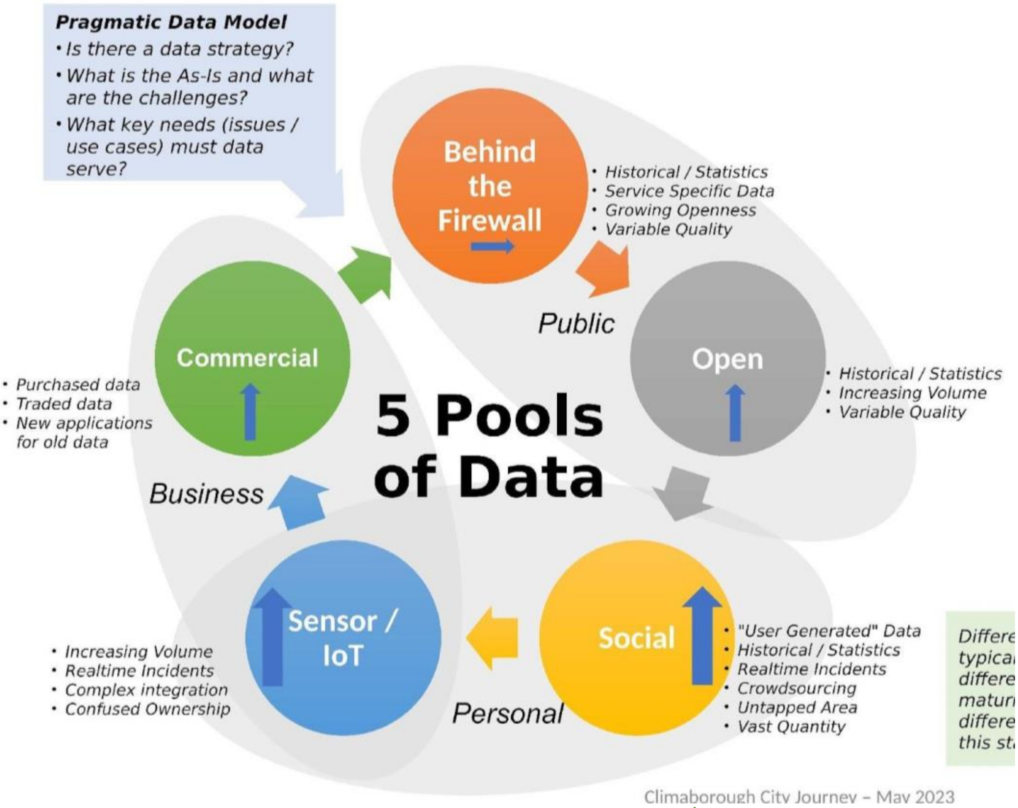

Figure 16: 5 Pools of Data (by WP3/UrbanDNA).

Co-Design of solution-specific KPIs: As soon as the cities have chosen their solution, we will conduct a co-design session to define the individual KPIs per solution together with cities and solution providers. The expected results will be individual strategies to measure the impact (CO_2 emissions) of the solutions over time. The solution-specific KPIs will be part of the Action Assessment KPIs.

Further Alignment with WP1: In the coming months we will work even closer together with WP1 to help define the UPF4CN and help to translate its logic into a technically applicable platform architecture.

Setting up a Cloud Environment: As soon as the platform architecture is defined, we will choose the cloud provider and set up a cloud environment for testing first prototypes.

Evaluation of Data Standards: In order to achieve acceptance and scalability of the CLIMABOROUGH platform, we will evaluate various data standards already existing in the domain of Smart City, Internet of Things, and climate neutrality. We have identified the FIWARE NGSI-LD Standard, the MIM Standard of Open Agile Smart Cities, and the DIN-Spec 91372 of the German Institute for Standardization for further evaluation.

Evaluation of Platforms & Technologies for potential cooperation: Additionally, we will evaluate technologies and start-ups which have comparable goals of monitoring climate neutrality. We have already identified "climate.view" and "futureproofed" as relevant solutions for further evaluation. We are already in touch with the "net.zero.cities portal" of the European Commission. As soon as a graspable technical product (architecture) is defined, we will evaluate if it is valuable to integrate the CLIMABOROUGH platform into net.zero.cities portal.

Clarification of Service Offer of CLIMABOROUGH Platform to Solution Providers: It is already defined that the CLIMABOROUGH platform will measure the impact (CO2 reduction) of solutions for the cities, but it is not fully clear how the platform could be supporting the solution providers. As soon as solution providers are defined, we will get in touch with them and assess added values for them.

7. Annex

Annex A - KPI Development

This section represents the earliest version of the KPI definition that has been used as an initial set of definitions for the alignment between WP1 and WP2. The new material is part of the deliverable, however, there is some value in the definition of the KPIs before the alignment. For this reason, the methodology and the initial list of KPIs is kept as additional material in this ANNEX.

KPI Development focuses on the process of selecting and defining Key Performance Indicators (KPIs) for monitoring and evaluating the performance of cities participating in the CLIMABOROUGH project. The KPIs are intended to measure various aspects of city functioning and address specific challenges and requirements. The section begins with an explanation of the KPI Selection Methodology. It states that the needs of the cities are the starting point for analysis, and requirements are identified to achieve a high level of generalization. The section then moves on to the Proposed Set of KPIs. It mentions that each city has a combination of common KPIs that are applicable to all cities and specific KPIs that are unique to each city and reflect their individual goals.

A.1 KPI Selection Methodology

The effective measurement and evaluation of performance are crucial in addressing city challenges and achieving desired outcomes. This section aims to provide a comprehensive understanding of Key Performance Indicators (KPIs) and their requirements within the framework of CLIMABOROUGH city challenges.

The identified challenges proposed by each individual city are the starting point of the analysis. They can point to three different issues: general issues related to climate monitoring, problem domain issues, or city specific ones. Figure 1 represents the type of requirements that the CLIMABOROUGH project is coping with.

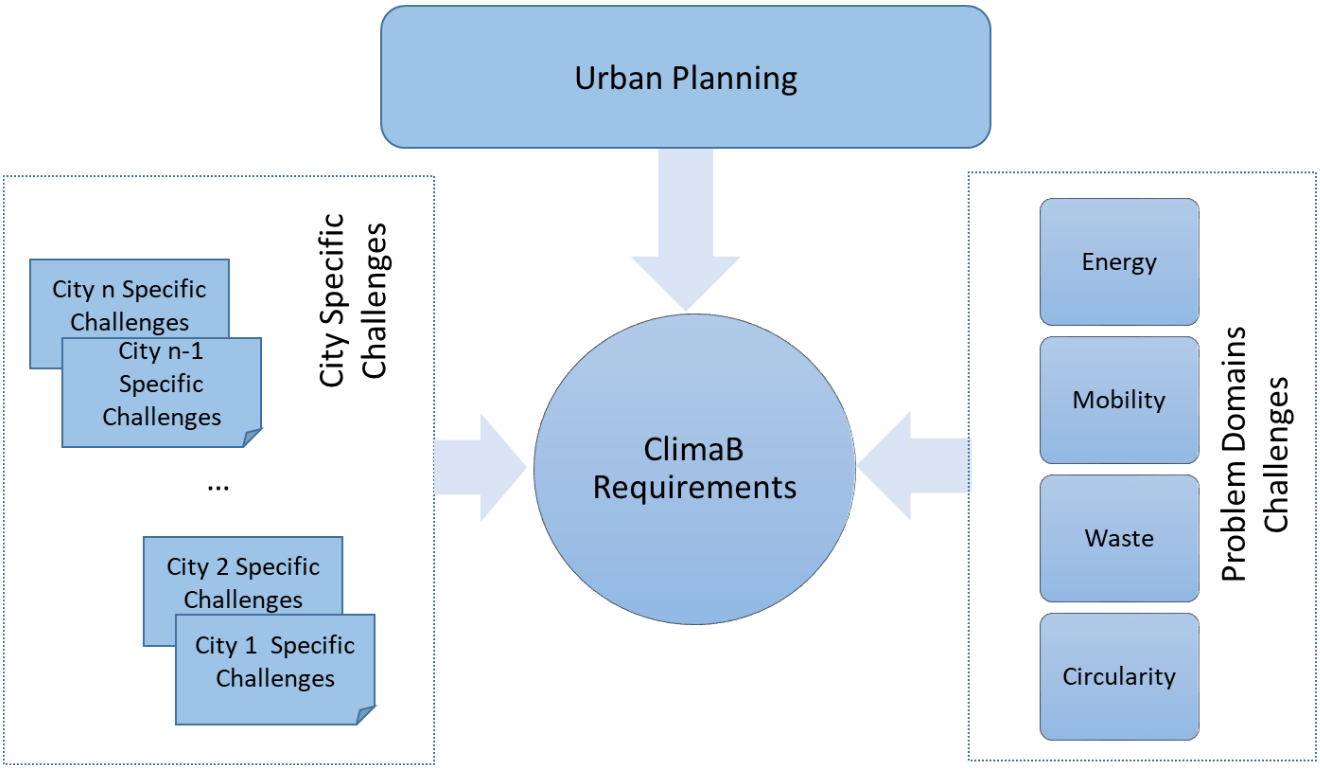

Figure 17 Annex A.1: CLIMABOROUGH platform: Requirements on KPIs - the different sources of requirements of the CLIMABOROUGH project.

The needs of the cities are the starting point of the analysis, and the requirements identified are structured to achieve the highest possible degree of generalization. The corresponding Key Performance Indicators (KPIs) are measures that will try to represent the current value of the city with respect to a measurement that is considered important (e.g., the traffic intensity per square kilometer, etc.). The attempt is to try identifying numerical measures that can help in monitoring relevant parameters (corresponding to specific challenges and requirements) so that the applications of actions, policies, and interventions can be evaluated and assessed over time.

Key Performance Indicators (KPIs) can be defined as quantifiable metrics used to measure and evaluate the progress, effectiveness, and impact of initiatives in tackling city challenges. In this methodology, we outline a systematic approach to defining KPIs based on city challenges and leveraging available data from open portals. It begins by identifying the key challenges faced by the city through a comprehensive analysis and engaging stakeholders to gather diverse perspectives in terms of the city survey. This is followed by exploring the data available on open portals to assess its quality and relevance for measuring KPIs and thereafter indicators are carefully selected to measure progress towards the objectives, ensuring they are meaningful and measurable. The process of identifying the KPI is shown in Figure 2 below and details of proposed KPIs are described.

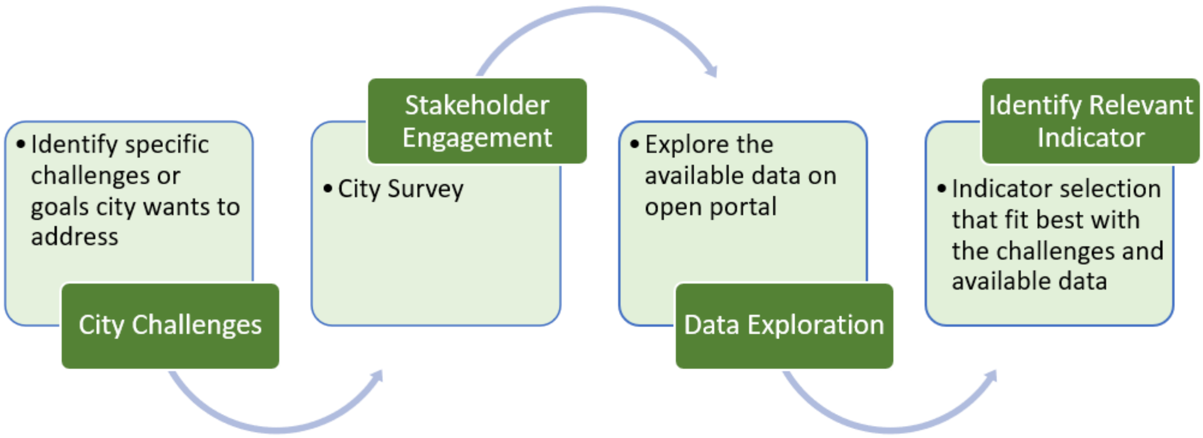

Figure 18 Annex A.2: KPI selection methodology.

A.2 Proposed Set of KPIs

For each city, there are KPIs that are common and some KPIs that refer to the challenge domains (mobility, energy, waste to circularity) that the city has identified and will cope with. These KPIs can share a well-defined and agreed upon structure and can be used by different cities in the project.

Furthermore, there are other KPIs that should reflect the specific goals and activities of the city. These KPIs are "specific" in nature and they reflect the unique goals that the cities are addressing.

In other terms, we have identified three different types of KPIs:

- **General City KPIs:** There is the need to monitor the city system to determine how the city is "behaving/reacting" to different policies and activities. For this goal, we propose an initial set of KPIs that are used to provide a global view in terms of some general values (valid for most of the cities).
- **Domain Specific KPIs:** In this category, the KPIs related to three domains fall: energy, mobility, waste to circularity. We also include one additional domain related to pollution in order to have a more precise aggregation of data and KPIs.
- **Specific KPIs:** The need to define KPIs and related data for monitoring specific activities of each city and how these activities and goals impact the city.

This set of KPIs has a high level of reusability for the first two classes of KPIs, while the last one is to be defined and used according to the specific needs of the city. These KPIs will not necessarily be supported and measured within the platform because they vary a lot from city to city and their construction and calculation can lead to a large need for specific and much focused activities that are not currently possible within the allocated resources in WP2.

Table 2 Annex A.1: Types of KPIs

General City KPIs	Domain Specific KPIs	Specific KPIs
• Percentage of renewable energy sources	**Energy**	**Grenoble solution specific KPIs**

(Percentage of energy derived from fossil) • Total energy consumption • Average traffic volume • Mobility modes and distribution • Air pollutants and distribution • Air Quality Index (AQI) • Greenhouse gas emissions • Carbon footprint of city activities • Water consumption • Weather conditions (average temperature, extreme weather events) • Urban Green Spaces (Green space per capita) • Value in M^2 M^3 of urban space recovered for human usage • City population • Number of active enterprises • Level of community awareness and engagement • Number of policies for climate neutrality • Amount and distribution of waste • Percentage of waste recycling • Health impacts • Climate risk assessment for the city/area • Policy implementation, adoption, and awareness • Awareness of the solution • Acceptance • Customer satisfaction • Accessibility of the solution	• Percentage of renewable energy adoption • Energy efficiency improvements • Carbon footprint reduction • Energy waste in infrastructure maintenance • Energy saved or shifted to renewable energy • Return on investment of the solution **Mobility** • Type of mobility (and percentages) • Modal shift to low-carbon transportation • Energy consumption in transportation sector • Energy saved for reduced vehicle usage in the city • Traffic volume of the city • Volume of reduced traffic (and not passed to other areas) • Volume of people sharing communication means and related reduced traffic/ emissions • Reduce the peak of people/vehicles in specific areas and better distribute them in the city • Parking spaces **Waste to Circularity** • Collected amount of waste • Resource recovery rate • Energy saved through recycling • Energy consumption in waste management • Water saved through recycling • Water consumption in waste management • Landfill space saved • Land use for waste management facilities	• Citizen engagement • Culture and art integration • Tactical urbanism development • Economic and social impact

	• Carbon footprint reduction • Carbon footprint of waste management • Collection efficiency • Global goal in collection and recycling (possible, expected, achieved in percent) • Valuable resource saving from waste (possible, expected, achieved in percent) **Pollution** • Particulate matter (PM2.5 and PM10) • Nitrogen Dioxide (NO2) • Ozone (O3) • Sulfur Dioxide (SO2) • Carbon Monoxide (CO) • Air Quality Index (AQI)	

Annex B - Example Data Scheme for OUP

- *"description": {*
- *"source":"source of the data provider",*
- *"cityName":"name of the city",*
- *"countrycode": "Two letter country code",*
- *"zipcode": "zipcode of the city",*
- *"lat":"latitude of the city",*
- *"lon":"longitude of the city",*
- *"dominentpol":"dominent particulate matter size in the city",*
- *"humidity":"refers humidity in the city",*
- *"co":"refers carbon monoxide in the city",*
- *"no2":"refers nitrogen dioxide in the city",*
- *"pressure":"refers air pressure in the city",*
- *"pm10":"refers particulate matter 10 type in the city",*
- *"pm25":"refers particulate matter 25 type in the city",*
- *"temperature":"measured temperature in the city in C",*
- *"temp_min": "Current minimum measured temperature in the city in C",*
- *"temp_max": "Current maximum measured temperature in the city in C",*
- *"windspeed":"refers wind speed in the city",*
- *"windgust":"refers wind gust in the city",*
- *"winddegree": "The deg of the wind",*
- *"timeRecorded":"refers time recorded for the data",*
- *"ozone": "refers ozone in the city",*
- *"dew": "refers dew in the city",*
- *"sulphurDioxide": "refers sulphur dioxide in the city",*
- *"sunrise": "Time of next sunrise in UTC?",*
- *"sunset": "Time of next sunset in UTC?",*
- *"visibility": "Visibility in metres",*
- *"weather_icon": "URL to icon that describes current weather condition",*

- *},*
- *"config": {*
- *"source":"string",*
- *"cityName":"string",*
- *"countrycode": "string",*
- *"zipcode": "double",*
- *"lat":"double",*
- *"lon":"double",*
- *"dominentpol":"string",*
- *"humidity":"double",*
- *"co":"double",*
- *"no2":"double",*
- *"pressure":"double",*
- *"pm10":"double",*
- *"pm25":"double",*
- *"temperature":"double",*
- *"temp_min": "double",*
- *"temp_max": "double",*
- *"windspeed":"double",*
- *"windgust":"double",*
- *"winddegree":"double",*
- *"timeRecorded":"double",*
- *"ozone": "double",*
- *"dew": "double",*
- *"sulphurDioxide": "double",*
- *"sunrise": "string",*
- *"sunset": "string",*
- *"visibility": "double",*
- *"weather_icon": "string",*
- *}*