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MISSION CE CLIMATE

D.3.4.2. Pilot testing of digital solution for monitoring of climate change in communities

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Table of contents

1. Introduction

This report summarizes the outcome of the pilot testing by three cities of the design of the digital solution (D.3.4.1.). The objective was to gain a better understanding of the feasibility for its uptake by communities by considering administrative and legal issues, looking at organizational models, data availability and compatibility. Hence, the design of the digital solution was evaluated by three communities, namely Dornbirn, Košice, and Pforzheim to establish its usability.

To enable the testing, a webinar was organized to provide the cities and other relevant stakeholders an overview of D.3.4.1. "Design of a digital solution for monitoring of climate change in communities". The webinar was organized by the Vorarlberg University of Applied Sciences and took place on the 16th of March. First, the deliverable D.3.4.1. "Design of a digital solution for monitoring of climate change in climate change communities" was explained. Afterwards, the highlights of three different climate resilience pilot projects were presented:

- Citizen science and participation (pilot project in Pforzheim)
- Climate data management (pilot project in Dornbirn)
- Climate data management (pilot project Košice)

Lastly, the questionnaire for testing the "Design of a digital solution for monitoring of climate change in communities" was discussed. The questionnaire was refined after the meeting and in three bilateral meetings filled-out with the three respective cities to learn more about the challenges and opportunities of implementing digital solutions in cities for climate monitoring. This report will highlight the main findings of the questionnaire.

2. Results

2.1. Administrative Feasibility

The objective of the first section was to understand the administrative processes in the respective municipalities and the willingness to adopt new digital solutions. Dornbirn and Pforzheim already had previous experiences with climate monitoring to some extent. For Košice, the pilot study within the Mission CE Climate project was the first time climate data was gathered.

In **Dornbirn**, sensor data on temperature, humidity and precipitation from various applications (departments: building construction, civil engineering and urban planning) is collected, processed, and archived centrally in the ‘City Monitor’. In addition, the data is presented in the form of dashboards for analysis. This service is provided by an external company - WEAVS GmbH.

The municipality of **Košice** currently possesses only the climate data and related processes, that come from the Mission CE Climate project. The data is measured by IoT weather stations, that are placed and operated in city’s cloud infrastructure.

In **Pforzheim**, climate data is assessed and managed through a combination of long-term historical records from sources like the German Weather Service (DWD) and real-time IoT sensors deployed citywide. These sensors monitor parameters such as temperature, humidity, air quality, and precipitation, with data collected on our central Smart City platform for analysis and public visualization. This approach enables us to identify local climate variations and inform resilience actions, as seen in our Community Climate Mission living lab.

The processes to adopt new digital tools or implement new software differ between the three cities.

In **Dornbin**, there is no standardized process for introducing new digital tools. The city’s IT department ensures the day-to-day operation of traditional administrative tools. For specific requests from individual city departments or city-affiliated organizations, the relevant departments usually commission external service providers.

In **Košice**, the decisions about new digital tools and software on the strategic level is based on the document “Conception of development of information technologies”. For partial decisions and individual solutions, there is the obligation to elaborate a Business Analysis as preparation for minor projects. Further, the city’s organizational structure clearly defines the responsibilities of each department. Requirements for implementing a digital solution may come from various sources—for example, from decisions made by local government bodies, from requirements set forth in the terms of reference for international projects in which the city acts as a project partner, or from various organizations under the jurisdiction of the local government. Based on this, the relevant department will contact other departments whose involvement is necessary. In the case of MISSION CE CLIMATE project, the Department of strategic development was involved as the initiator of further actions.

In Pforzheim, adopting new digital tools typically begins with pilot projects funded through programs like the Smart Cities Model Projects, involving testing, data evaluation, and iterative refinement. The process emphasizes citizen participation via dedicated platforms, cross-departmental collaboration, and alignment with sustainability goals before full rollout. For instance, IoT sensors and tools like waste robots were implemented after successful trials.

The primary point of contact for implementing and managing digital solutions like expanded LoRaWAN/IoT systems is Fabian Böpple, Project Manager for the Smart City funding program. He oversees initiatives from strategy to execution and can be reached via the city's Smart City team through our official website (www.pforzheim.de).

2.2. Legal Feasibility

The objective of this section was to establish whether there are any legal barriers or requirements that need to be considered. All three municipalities mentioned that there are no specific legal regulations or restrictions for climate monitoring. Further, data protection and data security are clearly set out in the cities and data privacy is managed in full compliance with the EU GDPR (DSGVO). However, climate data currently created is considered as publicly accessible.

In Dornbirn, based on the minimum legal requirements, individual departments may establish higher security requirements based on the nature of their work and data processing activities.

In Pforzheim, at the municipal level, the IoT deployments for climate monitoring follow Baden-Württemberg's smart city guidelines and federal funding requirements from programs like the Smart City Model Projects, which mandate sustainable and standardized tech use. Nationally, Germany's Energy Efficiency Act (EnEfG) governs energy-related aspects of digital infrastructure, including monitoring tools, with requirements for efficiency and renewable energy integration. EU-wide, the Data Act and environmental directives shape data handling in IoT systems, ensuring interoperability and minimal environmental impact.

Data privacy is managed in full compliance with the EU GDPR (DSGVO), Baden-Württemberg State Data Protection Act (LDSG), and TTDSG, prioritizing data minimization, purpose limitation, and user rights like access and erasure. For our LoRaWAN sensors, all transmissions are end-to-end encrypted, with anonymized aggregation of non-personal environmental data (e.g., temperature, air quality) on our secure central platform. Security features include robust network segmentation, regular audits, and citizen consent mechanisms where applicable, as demonstrated in our student IoT pilots and public dashboards.

Another important learning from the workshop and the questionnaire was that if the goal is to influence legislation through learnings or results from climate monitoring, the measured data must be created by officially certified devices and processes. Thus, depending on the objectives, the criteria for data quality and compatibility can vary significantly.

2.3. Organizational Feasbility

The objective of this section was to analyze organizational readiness and capacity. Therefore, we were interested in whether there are already existing teams or roles dedicated to climate monitoring and if not if there is enough capacity at the municipal level to maintain the sensor networks and other relevant infrastructure.

One of the bottlenecks of implementing climate monitoring in cities is the maintenance of sensor networks and relevant infrastructure. Here, a lack of resources is often an issue. The cities, currently, outsource these tasks to external partners. Another important challenge is the integration of 'external data' from federal, state and external providers, as there are no standardized interfaces and the readings from different types of sensors vary and differ from the results of calibrated (and significantly more expensive) systems. Data quality consistency across expanding networks and balancing citizen engagement with technical scalability can also pose hurdles. Overcoming these requires sustained cross-partner coordination.

In the city of **Košice**, there is a team dedicated to digital transformation of municipality and future creation of a digital twin of our municipality. The highest accent of this team is currently placed on the readiness of modern infrastructure for future development in regard of main legal duties of municipality.

In Slovakia, the municipality's responsibilities regarding air quality management are governed by Act No. 146/2023 on Air Protection. This area is not under the jurisdiction of the City of Košice. There is no team dedicated to climate monitoring, specifically.

One drawback or challenge to implement further climate monitoring is that mmunicipalities are not obliged to directly monitor climate by law. Regarding air quality monitoring, once the Slovak Hydrometeorological Institute issues a meteorological report — such as a smog alert — the municipality notifies the public of the smog alert in accordance with paragraph 12 section 9 of the Act No. 146/2023 on Air Protection. The City of Košice website publishes air quality data from the Slovak Hydrometeorological Institute, which uses official air quality monitoring stations for its measurements.

In **Dornbirn**, there is a dedicated unit (Digital Transformation) within the IT department. The Urban Planning Department has dedicated posts for environmental issues.

In **Pforzheim**, they have specialized teams including the Smart City project team, led by figures like Fabian Böpple, and the Climate Protection Department under Elias Weigel, Head of Climate Protection in the Environmental Protection Office. These groups collaborate with Stadtwerke

Pforzheim for IoT infrastructure and Pforzheim University students for pilots, handling monitoring and data analysis. Digital transformation is further bolstered by roles like Digital Transformation Officers within the municipality.

In Pforzheim, they have sufficient capacity through Stadtwerke Pforzheim's LoRaWAN network operations and their central data platform team, already managing over 50 sensors with plans for expansion. Partnerships with local universities provide additional expertise for upkeep and optimization, supplemented by low-maintenance, low-cost sensor designs. Full scalability would depend on project funding but aligns with our proven pilot-to-production model.

2.4. Data Availability and Quality

The objective of this section was to assess the availability, quality, and accessibility of relevant data in the three cities.

The city of **Pforzheim** collects real-time climate data including air temperature, humidity, air pressure, solar radiation, dew point, wind speed, precipitation, and soil moisture from ~50 sensors citywide. Additional parameters cover air quality, traffic impacts, and urban heat via standardized IoT setups, supporting comparisons between green and built areas.

Data transmits every 10 minutes to their central Smart City data platform, where it is aggregated, analyzed, and stored for optimization during test phases. Management involves iterative processing with partners like Stadtwerke and university teams for visualization and consolidation into a robust database.

Challenges include incomplete spatial coverage outside pilots, potential inconsistencies from non-uniform calibration during expansion, and reliability risks from unproven long-term sensor durability. Accessibility remains limited — data is internal during testing, with public dashboards planned but not yet fully rolled out, hindering real-time citizen use. Overall completeness lags for hyper-local microclimates, which requires standardization.

A digital solution should enable better-informed decisions for climate adaptation planning, such as urban greening and heat mitigation, while raising public awareness through accessible visualizations. Long-term, it would support predictive modeling for city development and legal compliance with CO_2 reduction targets (55% by 2030 vs. 1990).

For these goals, we need high reliability (99% uptime), completeness across key urban zones, and validated accuracy (±0.5°C for temperature) with standardized formats for interoperability. Timely, anonymized public access via APIs or dashboards is essential for awareness and decision-making.

In the city of **Košice**, temperature, humidity, barometric pressure, PM1, PM4, PM10, CO, NO_2, wind speed, wind direction, wind gusts are measured. The data is currently stored in a cloud database. The data is managed by several cloud applications to address the data complete flow from IoT device to visualisations. They face various issues, such as local power / internet connection outages, failure of sensors (invalid data). Further, IoT devices are not certified and calibrated by the local authority (high costs). Through a digital solution for climate monitoring better informed decision-making, support for legal changes and raising awareness in public could be achieved.

In **Dornbirn**, sensor data on temperature, humidity and precipitation from various applications (departments: building construction, civil engineering and urban planning) is collected, processed, and archived centrally in the 'City Monitor'. In addition, the data is presented in the form of dashboards for analysis. This service is provided by an external company - WEAVS GmbH. Further, through the scale-up of the pilot study, a new thematic focus is also monitored. By leveraging data and sensor technology, the dashboard brings together information from various different sources in regards to water management and makes it accessible and applicable. This allows authorities to monitor climate risks, while also enabling informed decision-making in the case of an emergency. As part of the measures described, selected climate resilience and disaster control-related content was integrated into and processed by the existing data and visualization platform of the city of Dornbirn (Citymonitor). The aim was to structure existing data sources, integrate additional relevant data points, and present them in such a way that they can be used in both operational and strategic contexts.

2.5. Technical Compatibility

The objective of this section was to evaluate the technical environment and integration needs. One common finding is that there exists a certain lock-in once certain infrastructure or software is implemented to enable technical compatibility, but also to ensure data compatibility.

In **Pforzheim**, environmental data from sensors feeds into their central Smart City data platform, which aggregates, analyzes, and visualizes metrics like temperature and humidity in test phases. This integrates with broader city IT via Cisco DNA and SD-Access for secure networking, supporting IoT gateways operated by Stadtwerke Pforzheim.

New solutions must comply with LoRaWAN protocol for low-power, long-range transmission, including end-to-end encryption and EU CE certification for low radiation. Additional mandates include GDPR-compliant data handling, standardized sensor formats (e.g., baugleiche Sensorik for comparability), and interoperability with open data platforms like CKAN.

Maintenance is handled collaboratively: Stadtwerke manages LoRaWAN gateways and solar-powered sensors, with our IT teams using custom monitoring and ticketing software for oversight. Pilots involve university students for testing, but full operations rely on iterative optimization during data evaluation phases, lacking dedicated 24/7 sensor teams.

The LoRaWAN network proves energy-efficient with long battery life and citywide coverage, delivering data reliably in pilots (e.g., every 10 minutes). However, vulnerabilities like urban signal hurdles, unproven long-term sensor durability, and scaling issues in non-pilot areas have been noted in a SWOT analysis. Urban deployments highlight low power as a strength but expose calibration inconsistencies during expansion

In **Košice** and **Dornbirn**, the integration of the pilot study worked out well and the maintenance of the sensor network is working as well. In **Košice,** the Azure infrastructure is stable. There are some issues with reliability of individual sensors, but after several adjustments of firmware the issues are less frequent.

2.6. Learnings from the pilot studies

In **Pforzheim**, the pilots shine in providing hyper-local, comparable data on urban heat islands and microclimates, enabling evidence-based planning for greening, flood prevention, and heat adaptation. Low-cost, low-power LoRaWAN unlocks scalable, radiation-minimal networks for broader Smart City apps like tree irrigation and waste management.

They learned that standardized sensors ensure reliable comparisons across sites (e.g., inner city vs. parks), while custom dashboards empower visualization and citizen insights. Iterative student-led testing highlights the value of multi-stakeholder collaboration for quick prototyping and long-term data utility.

Integration of raw data into actionable recommendations proved tough, alongside calibration inconsistencies and explainability for non-experts. Logistical hurdles like site access, signal coverage in dense areas, and transitioning from pilots to permanent infrastructure delayed full rollout.

Speak with our partners in the Smart City LoRaWAN Integration Labs@BW project: citysens GmbH (Ulm), Fichtner IT Consulting (Stuttgart), and SWP Stadtwerke Pforzheim. Nearby municipalities like Friedrichshafen, Neckarsulm, Neulingen, Ölbronn-Dürrn, and Ulm offer parallel experiences. Pforzheim University provides academic pilot perspectives.

Recommendation: Start small with student or partner pilots using LoRaWAN for cost-efficiency, prioritize data standardization and public dashboards for buy-in, and secure cross-departmental funding early to bridge pilot-to-scale gaps. Focus on citizen participation for sustained relevance and benchmark against urban vs. green sites for quick wins.

In **Košice, t**he biggest opportunity lies in turning climate data into a practical tool for both local decision-making and community awareness. The pilot shows strong potential for scaling to additional schools and other public spaces, while also supporting municipal planning through reliable, site-specific evidence. A particularly valuable opportunity is the combination of digital monitoring with education, because it not only improves climate resilience today, but also builds long-term climate literacy and engagement among future generations.

The pilot also showed that climate data must be communicated carefully and in context, so that schools or neighbourhoods are not stigmatized. One of the main lessons learned when creating education program is that co-creation is essential. Early involvement of school leaders and teachers significantly increased ownership, motivation, and the usability of results. Integrating data into education proved to be one of the strongest drivers of long-term sustainability. Another key learning is that technical details matter: sensor placement and installation quality directly affect data reliability. The set up a meaningful activity it is necessary to better prepare the budget and allocate personnel resources.

The pilot faced both technical and organizational challenges, mainly due to lack of experiences in implementing such project activities. On the technical side, some sensors required repositioning or replacement due to interference or defects, which highlighted the importance of careful commissioning and maintenance. On the organizational side, coordinating multiple schools with different needs and capacities required significant communication and flexibility. Another challenge was ensuring that the collected data was not only accurate, but also understandable and meaningful for non-expert users such as teachers, students, parents, and the wider public.

In **Dornbirn**, the main goal of the pilot project was to demonstrate the temperature reduction potential of nature-based solutions. Specifically, different climate data indicators (surface and air temperature, humidity) are collected to compare the perceived temperature on different surface types, as well as on places with and without shade from trees. To minimize external influences on the microclimate, all data collection for different surfaces and shading conditions will be conducted within the same park, ensuring consistent general weather conditions for accurate comparison.

Within the project time of Mission CE Climate, the pilot study has already been up-scaled. Through the risk workshop and the pilot study, the team for disaster control in Dornbirn expressed the interest in an improved access to data and especially, in data visualization to enable better-informed decision-making in emergencies. As part of the measures described, selected climate resilience and disaster control-related content was integrated into and processed by the existing data and visualization platform of the city of Dornbirn (Citymonitor). The aim was to structure existing data sources, integrate additional relevant data points, and present them in such a way that they can be used in both operational and strategic contexts.

The implementation was carried out with consistent consideration of the existing technical, organizational, and specialist framework conditions of the city of Dornbirn. The project built on existing sensor technology, existing data flows, and established processes.

Vorarlberg has always been exposed to natural hazards, such as flooding and thus, Vorarlberg already has a high level of protection against floods. Nonetheless, climate change intensifies the severity and the frequency of heavy rainfall. This makes the implementation of robust monitoring and early warning systems not just important, but urgent, which is exactly the focus of this scale-up initiative.

The integrated content contributes in particular to:

- making climate and disaster control-related information centrally available facilitating the use of data in daily workflows
- making findings from existing measurement and monitoring activities visible – also to citizens
- creating a basis for the further use of data in future projects and use cases
- Citymonitor acts as a central platform for consolidating, visualizing, and interpreting relevant data without replacing existing systems.

These three pilot studies demonstrate that effective climate monitoring in cities is not only feasible but also best initiated through small, focused pilot projects. These pilots open up new opportunities, generate valuable insights, and build awareness. As cities learn which data is needed—and at what quality—decision-making for scaling up becomes significantly easier and more informed.

3. Synthesis

This report highlights the testing of a digital solution for climate change monitoring in municipalities, carried out within the Mission CE Climate project. The pilots were implemented and assessed in three European cities: **Dornbirn (AT)**, **Košice (SK),** and **Pforzheim (DE).** The objective was to evaluate the feasibility, usability, and scalability of the proposed digital solution by analyzing administrative, legal, organizational, technical, and data-related dimensions.

The pilots demonstrate that digital climate monitoring solutions are both feasible and valuable for municipalities, especially when introduced through small, well-defined pilot projects. Each city started from a different maturity level in digitalization and climate monitoring, yet all were able to integrate sensor-based data collection and visualization into their local contexts.

Key findings show that administrative and legal barriers are generally low, as climate data is typically considered public information and GDPR compliance frameworks are already well established. However, organizational capacity — particularly for maintaining sensor networks, ensuring data quality, and coordinating across departments — emerged as a critical constraint. Most cities rely on external partners for infrastructure operation and data management.

From a technical perspective, the pilots underline the importance of building on existing platforms and standards (e.g. LoRaWAN, central city dashboards) to avoid lock-in and ensure interoperability. Data availability varies widely, but data quality, calibration, and comparability are decisive factors, especially if the data is to support legal decisions or policy change.

Overall, the pilots confirm that digital climate monitoring can support evidence-based urban planning, climate adaptation, disaster preparedness, and citizen awareness. Success depends less on technology alone and more on governance structures, stakeholder involvement, and clear alignment between data quality and intended use.

3.1. Recommendations

Below, you can find the key learning and recommendations that result from the testing of a digital solution for climate change monitoring in municipalities:

1. **Start small and scale incrementally** - small, focused pilot projects lower risk, create quick wins, and help municipalities learn what data is needed and at what quality.
2. **Align data quality with intended use** - Data requirements differ depending on objectives. For instance, if the objective is awareness-raising non-certified sensors suffice. However, if compliance and legislative influence are the objective, certified devices and higher data

quality are necessary. Defining clear objectives at the outset of the planning phase is essential.

3. **Organizational capacity is crucial** - sensor maintenance, data validation, and integration are resource-intensive.
4. **Build on existing structures and platforms** – New data should be integrating into existing city dashboards and IT systems rather than replacing them. Digital solutions should complement existing systems, not compete with them as this reduces costs, time, and training needs.
5. **Standardization and interoperability are essential -** Early technical choices can create long-term lock-in. Thus, taking enough time for the decisions at the beginning is important and where possible, open and widely adopted standards can be useful.
6. **External data integration remains challenging -** Differences between low-cost sensors and calibrated reference stations can create inconsistencies. Thus, this should be always a part of the planning phase – data integration.
7. **Reliability and maintenance should not be underestimated -** Technical challenges can include: Sensor failures and calibration issues, power and connectivity outages or signal coverage problems in dense urban areas. Thus, redundancy, monitoring, and maintenance should be accounted for from day one.
8. **Citizen participation increases impact—but needs careful preparation** - Public dashboards, citizen science, and educational use increase relevance and acceptance. However, communication is key here and thus, the objectives should be clear and the data must be put into context and communicate understandably.
9. **Digital Climate Monitoring Enables Strategic Value** – The pilots highlight that digital solutions can support climate adaptation, improve and support disaster risk management, enables better informed urban planning and enhances the transparency through public access to data. Climate monitoring becomes more valuable when directly linked to decision-making processes.

3.2. Final Takeaway

The pilots highlight the value of digital solutions for climate monitoring and confirm that the implementation and uptake of D.3.4.1. is feasible and valuable. Regarding the challenges the testing highlighted that technology is not the limiting factor in municipal digital climate monitoring. The decisive factors are governance, organizational readiness, data strategy, and stakeholder engagement. Municipalities that start small, build on existing systems, and align data quality with purpose can successfully implement and scale digital solutions for climate resilience.

4. Questionnaire

Administrative Feasibility

Objective: Understand the administrative processes and willingness to adopt new digital solutions.

- How is climate data currently assessed and managed in your municipality?
- What is the typical process for adopting new digital tools or software in your municipality?
- Who would be the main point of contact for implementing and managing this solution?

Legal Feasibility

Objective: Identify potential legal barriers or requirements.

- Are there specific regulations or laws in your municipality or country that govern the use of digital tools for climate monitoring?
- How is data privacy and security handled for digital solutions in your municipality?

Organizational Feasibility

Objective: Analyze organizational readiness and capacity.

- Are there existing teams or roles dedicated to climate monitoring or digital transformation?
- What are the biggest organizational challenges you foresee in adopting a digital solution for climate monitoring?
- Would there be enough capacity at your municipality for maintaining the sensor network and other relevant infrastructure?

Data Availability and Quality

Objective: Assess the availability, quality, and accessibility of relevant data.

- What types of climate-related data does your municipality currently collect?
- How is this data currently stored and managed?
- Are there any known issues with data quality, completeness, reliability, or accessibility?
- What would you like to achieve through a digital solution of climate monitoring (better informed decision-making, enable legal changes, raising awareness, etc.)?
- What data quality do you need for your respective objective?

Technical Compatibility

Objective: Evaluate the technical environment and integration needs.

- What IT systems or platforms are currently used for environmental or climate monitoring?
- Are there any technical standards or protocols that new digital solutions must comply with?
- How is IT support and maintenance handled for digital tools, sensor networks and other relevant infrastructure in your municipality?
- What experience do you have with reliability of sensor networks or other relevant infrastructure?

Learnings from the pilot study

Objective: Evaluate learnings from the already implemented pilot study

- Where do you see the biggest opportunities of the pilot study?
- What are the biggest learnings from the pilot study?
- What were challenges you faced?
- Are there other municipalities or partners you would recommend we speak with?
- What would you recommend other interested municipalities?