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The Contribution of Public Spaces to Climate Change Adaptation in Austrian Cities

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1 ABSTRACT

Cities and urban areas are particularly affected by the impacts of climate change, especially by rising temperatures and more frequent and heavier rainfall events. Adapting spatial development to the consequences of climate change is being increasingly anchored as a goal in Austrian and European policies and planning strategies. Larger cities are active in setting strategic climate change adaptation (CCA) goals and implementing measures at local scale. Urban green and blue infrastructure (UGBI) and their ecosystem services (ESS) are one of the most effective measures for coping with the consequences of climate change. Urban ecosystems are essential for the urban climate and urban residents due to their regulating (e.g. reduction of the urban heat island effect), supporting (e.g. increase in biodiversity), provisioning (e.g. water filtration) and socio-cultural (e.g. benefits for health, well-being, recreation) functions.

In built-up areas, public space is one of the most important spatial resource for implementing CCA measures and especially UGBI. While steering mechanisms on private properties often fail due to lack of authorisation, instruments or legal regulations, the planning and design of public space is the direct responsibility of cities as local planning authorities. However, in public space, CCA measures and UGBI have to compete with other demands and interests, such as recreation, social interaction and communication, mobility or energy production. As cities grow and densify, pressure on public space increases. Therefore, CCA and CCA measures – both for private and public spaces – need to be mainstreamed into policies at all levels and subsequently integrated into formal planning instruments and planning processes.

Our paper investigates the horizontal and vertical integration of CCA, and especially CCA in public space (streets, squares and parks), into Austrian planning-related policies on national, federal state and municipal level and critically reflects on the mechanisms for implementation in planning practice. The research is based on i) a comprehensive analysis of policy documents of four Austrian federal states (Vienna, Styria, Salzburg and Upper Austria) and cities (Vienna, Graz, Salzburg, Wels), and ii) expert interviews with members of federal state and municipal planning administrations. The policy documents include CCA strategies that have an impact on planning and explicit spatial development strategies. The results show a emerging manifestation of CCA in policy documents, though not yet consistently at all levels and in all municipalities. Measures for CCA in public space are mainly anchored at municipal level, as cities already operate actively out of a given urgency. Despite the integration of CCA measures into the strategic planning level, our research shows that implementation still faces obstacles in planning practice. Our study highlights the importance of political agenda setting for the realization of CCA measures in public space and discusses success factors and implementation gaps.

Keywords: planning instruments, public space, policies, climate change, green infrastructure

2 INTRODUCTION

Changes in temperature and precipitation patterns and their direct and indirect spatial impacts are the key challenges of climate change adaptation for cities and urban areas (Carter et. al. 2015). Public spaces need to be adapted to heat stress, heavy rainfall events, and increasing and prolonged periods of drought. (CCCA 2019).

2.1 Changes in climate signals and impacts on Austrian cities

Austrian cities are affected differently by the impacts of climate change, depending on their climate zone and physical and spatial structure. However, a similar trend can be observed in all of them.

In general, Austrian cities are affected more by climate change-induced temperature increases than rural municipalities. Compared to rural areas, the higher degree of sealed surface, the higher building density and the lower proportion of vegetation elements in cities result in more solar radiation being absorbed and stored and less thermal radiation being released into the atmosphere. The heat storage in buildings and surfaces

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during the day and the insufficient temperature reliese at night lead to urban heat islands (UHI): higher temperatures in cities than in the surrounding rural areas (Oke 1982, MA22 2015).

A comparison of temperature development in Austria in the periods 1969-1990, 1971-2000 and 1981-2010 shows a significant increase in heat days (days with a temperature above 30°C) and a similar picture for the cities of Vienna and Salzburg. In Vienna, the number of heat days increased from an average of 9.6 in 1996-1990 to 11.5 in 1971-2000 and 15.2 in 1981-2010 (record number of heat days: 42 in 2015). A similar picture can be seen in the City of Salzburg, where the number of heat days increased from an average of 5.8 in the period 1969-1990 to 8.0 and up to 10.4 in the period 1981-2010 (record number of heat days: 40 in 2015). In Graz, the number of heat days rose from an average of 3.4 to 6.6 and up to 11.5 (record number of heat days: 41 in 2003). No data is available for the city of Wels. In the nearby city of Linz, however, a doubling of the heat days can be observed over the same periods (ZAMG 2012). This trend has intensified again in the last ten years: Vienna recorded an average of 20.1 heat days, Salzburg 12, Graz 16.7, and Linz 15 (ZAMG 2021).

Rising temperatures in urban ares cause health problems (Patz et. al. 2005) and ecological consequences, increase energy and water consumption (Santamouris 2020) and exacerbate other environmental burdens such as air pollution (Sarrat et. al. 2006). Heat stress in public spaces can lead to health risks for humans and other species and reduce the quality of stay and frequency of use, negatively affecting the quality of life of urban residents (Sharifi & Boland 2017).

Changing precipitation patterns also affect public spaces. On the one hand, the increasing intensity of extreme rainfall combined with a high degree of sealed surfaces on streets and squares increases the inflow into the sewer system, which can lead to sewer overflows and flooding (Willems et. al. 2012). On the other hand, more frequent and longer dry periods have a negative impact on the vegetation – especially trees – along streets and squares (Jentsch & Beierkuhnlein 2008, Allen et. al 2010).

Auer et al. (2005) carried out a historical study for the Alpine region and Austria and recorded strong fluctuations in precipitation since 1800. The last decades show smaller fluctuations in annual precipitation totals, but regionally specific, partially opposing precipitation trends. The northwest of Austria was characterized by an increase, the south by a decrease in annual precipitation (ZAMG o.J). In general, however, the higher air temperature as a result of climate change leads to a higher evaporation rate and thus potentially to an increase in precipitation (Blöschl et. al. 2018). For Austria, it can be assumed that with the same annual precipitation total, there will be an increase in small-scale and large-scale rainfall extremes with shifts between winter and summer. Both processes together, i.e. the rise in precipitation intensity due to rising temperatures, and more frequent heavy rainfalls, lead to an increase in damage-causing extreme events (Chimani 2016).

At the same time, the drought frequency in the Alpine region is increasing, driven by a higher atmospheric evaporative demand due to rising temperatures (Trnka et al. 2016). Austrian cities are affected differently. In particular, the north-east of Austria, including Vienna, is traditionally a region of low precipitation and increasingly suffers from a negative water balance (potential evapotranspiration is higher than the annual precipitation) (Reniu 2018). The urban region of Graz is also strongly affected by drought (ibid).

Temperature and precipitation changes are expected to continue – depending on the underlying greenhouse gas emission scenarios. These changes have massive impact on urban public space. Therefore, measures to adapt to heat and, simultaneously regulate stormwater (improving water retention while maximising water available to plants) are urgently needed to achieve the necessary adaptation responses.

2.2 Urban green and blue infrastructure as an effective adaption measure

Several adaptation measures exist to counteract heat stress in cities and to deal with heavy rainfall events and droughts (Stanton-Geddes et al. 2020, de Wit et al. 2020, Oswald et al. 2020). One promising measure is to increase the share of urban green and blue infrastructure (UGBI). Numerous research projects have shown the various ecosystem services UGBI provides. Regulating services like shading, evaporation and evapotranspiration (water released to the atmosphere via plants and soil) lower air temperature and reduce heat loads in public spaces. Unsealed and greened areas support stormwater runoff. In addition to the benefits that can moderate the urban climate, UGBI such as trees, shrubs, green roofs or facades, streams or

ponds, provides other benefits: it promotes physical and mental health of urban residents or contributes to urban biodiversity (MEA 2005, TEEB 2010, Grunewald & Bastian 2013).

Climate change, on the otheer hand, also poses challenges for urban green spaces and UGBI (Alizadeh & Hitchmough 2019) by threatening the water supply. Higher temperatures lead to an increase in evapotranspiration and higher water demand. The trend toward more days with medium and high rainfall and fewer days with low to medium rainfall (Chimani et al. 2016) leads to reduced water availability for plants even if the total annual rainfall remains constant.

2.3 Spatial and technical measures

In addition to UGBI, technical and structural-spatial measures support the adaptation of public spaces. These include, for example, technical shading elements in places where tree plantings are not possible, or light-colored surface materials. The albedo (a measure of the reflectivity of surfaces), the thermal capacity (a measure of thermal storage capacity) or the runoff coefficient (ratio of the amount of runoff to precipitation received) of surface materials are decisive for temperature development or stormwater runoff (BBSR 2015, EPA 2008).

2.4 Challenges in the implementation of climate change adaptation measures in public spaces

Urban public spaces are potential "carriers" of adaptation measures by providing space for implementation. Numerous Austrian and European cities anchor the adaptation of public spaces to climate change as a strategic planning goal in policy documents, conduct pilot projects or develop new strategies and measures. Compared to private properties, cities have the ability to act in public space as it is (mostly) owned by them. However, despite their direct influence, cities face challenges in implementing adaptation measures. For example, public space is sealed to varying degrees depending on its size and use, or only accessible for certain measures (Figure 4). Furthermore, different functional and use demands collide in public space. They have to combine UGBI and mobility, provide spatial structures for stay and movement, serve social exchange as well as energy production (Becker 2014). These competing demands have to be negotiated and do not always favour CCA measures.

Although CCA, and especially CCA in public space, is increasingly anchored in policy documents, comprehensive implementation in planning practice often fails at the local level. It is unclear whether and to what extent goals and measures for CCA in public space are consistently anchored in CCA and spatial development strategies at all levels (from national to municipal) and eventually integrated into formal planning instruments and planning processes. Our paper addresses this gap and poses the following research questions: What goals and measures for CCA or CCA in public space do Austrian federal states and cities formulate in policy documents? What mandate do they thereby formulate for planning practice? Where are there implementation gaps?

3 MATERIAL AND METHOD

As outlined above, the aim of this paper is to analyse how CCA, and especially CCA of urban public spaces, is addressed in Austrian planning-related policies and to critically reflect the implementation process in planning practice. The data collection included two steps. First, we conducted a comparative content analysis of 23 policy documents (CCA strategies which have an impact on planning and explicit spatial development strategies. We took four Austrian federal states (Vienna, Styria, Salzburg and Upper Austria) and cities (Vienna, Graz, Salzburg and Wels) as an example) (Table 1). Vienna represents a special case, as it is both a federal state and a municipality. We also divided the Viennese documents into federal state and municipal documents, as they are comparable to the other examples at the respective planning levels. Following the policy cycle by Knoepfel et al. (2011), the subject of analysis was political agenda setting, i.e. the manifestation of CCA on the agenda of political and planning decision-makers. As policies we define "a series of intentionally coherent decisions or activities taken or carried out by different public […] actors […] with a view to resolving […] a problem that is politically defined as collective in nature" (Knoepfel et al. 2011, p. 24). Policies can therefore be understood as the content-related programming of political initiatives, which are expressed in goals and measures formulated in policy documents. We analysed these goals and measures as they define requirements for political and planning action and (nominal) spatial planning instruments. In a second step, we conducted interviews with 15 experts within administration of the four

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federal states and cities to discuss the integration of CCA goals and measures into planning instruments and planning practice. We analysed the policy documents as well as the interviews by using the method of qualitative content analysis (Mayring 2019, Kuckartz 2016, Schreier 2013, Gläser and Laudel 2010) and systematized and interpreted the relevant content and statements according to inductively developed analysis categories. The analysis was carried out horizontally (comparison of the four federal states and cities among each other) and vertically (comparison at different planning levels – from national to federal state to municipal). The content of our contribution focuses on goals and measures that can be influenced by spatial planning. Also, we focused on the most important public spaces that are (usually) owned by cities, namely streets, squares and parks. Semi-public or semi-private spaces, such as allotments or green spaces of residential buildings, can also implement CCA measures, but are not within a city's direct spehre of influence.

LEVEL	FEDERAL STATE/CITY	NAME OF POLICY DOCUMENTS AND YEAR
National	Austria	• Regierungsprogramm [Governments Agreement] (2020) • Österreichische Strategie zur Anpassung an den Klimawandel [Austrian Strategy for Adaptation to Climate Change] (2017) • Österreichisches Raumentwicklungskonzept [Austrian Spatial Development Concept] (2021)
Federal state	Vienna	• Regierungsübereinkommen [Governments Agreement] (2020) • Smart (Klima) City Wien Rahmenstrategie [Smart (Climate) City Strategy Vienna] (2022) • Klimafahrplan [Climate Roadmap] (2020)
City	Vienna	• Stadtentwicklungsplan [Urban Development Plan 2025] (2014) • Fachkonzept "Grün- und Freiraum" [Thematic Concept "Green and Open Spaces"] (2014) • Fachkonzept „Öffentlicher Raum" [Thematic Concept "Public Space"] (2014)
Federal state	Styria	• Regierungsübereinkommen [Governments Agreement] (2019) • Klimawandelanpassungsstrategie Steiermark [Climate Change Adaptation Strategy Styria] (2015) • Landesentwicklungsleitbild [Provincial Development Concept] (2013)
City	Graz	• Regierungsübereinkommen [Governments Agreement] (2021) • Grazer Klimawandelanpassung Aktionsplan [Climate Change Adaption Action Plan] (2022) • Stadtentwicklungskonzept 4.0 [Urban Development Concept] 4.0 (2020)
Federal state	Salzburg	• Regierungsübereinkommen [Governments Agreement] (2018) • Sazburger Landesentwicklungsprogramm [Salzburg Land Development Programme] (2021) • Strategie zur Anpassung an den Klimawandel Salzburg [Climate Change Adaptation Strategy Salzburg] (2017)
City	Salzburg	• Regierungsübereinkommen [Governments Agreement] (2019) • Initiative Smart City Salzburg [Smart City Salzburg Initiative] (2019) • Räumliches Entwicklungskonzept [Spatial Development Concept] (2007) (in revision)
Federal state	Upper Austria	• Regierungsübereinkommen [Governments Agreement] (2021) • Oberösterreichische Klimawandelanpassungsstrategie [Upper Austrian Climate Change Adaptation Strategy] (2013) • Oberösterreichische Raumordnungsstrategie [Upper Austrian Spatial Development Strategy] (2021)
City	Wels	• Örtliches Entwicklungskonzept [Local Development Concept] (2015) • Stadtregionale Strategie der Stadt Wels [City-regional Strategy Wels] (2016)

Table 1: Overview of analysed policy documents.

4 RESULTS

In the following section, we present how CCA manifests on the political angenda. First, we show whether and how CCA in general, and CCA in public space using UGBI in particular, is reflected in policy documents on different levels. Second, we illustrate what measures for CCA in public space are mentioned and set as mandates for political and planning action.

4.1 Agenda setting – analysis of policy goals on CCA and CCA in public space

With the ratification of the Paris Agreement in 2016, Austria committed to plan, implement and monitor measures to adapt to the impacts of climate change (UNFCCC 2015 – Paris Agreement Article 7 (9)). This mandate for Austrian policy and administration is reinforced by the adoption of the European Climate Adaptation Strategies (EC 2013, 2021) and the announcement of the European Green Deal (EC, 2019). Like most European countries, Austria has passed a national adaptation strategy accompanied by an action plan for implementation (BMNT 2017). The strategy identifies landscape-, urban- and spatial planning as key actors in CCA and names the climate-resilient design of public green and open spaces as well as the protection and expansion of UGBI as central goals and measures (BMNT 2017). The recently revised Austrian Spatial Development Concept includes the strategic goal of adapting spatial structures to climate change and aims at protecting and expanding green networks and strengthening their climate-related functions (ÖROK 2021). The concept emphasizes the importance of green and blue infrastructure and claims

that it should be given the same value as grey infrastructure. As a consequence of the (supra)national goals, adapting urban areas and public spaces to the impacts of climate change by using UGBI becomes part of the federal state and municipal agenda and is reflected in planning policies.

4.1.1 The overall goal of climate change adaption reflected in planning policies

The policy analysis reveals that the general need for adaptation to climate change is largely on the political agenda and has been incorporated into a majority of the policy documents on federal state and municipal level. All four federal states (Vienna, Styria, Salzburg and Upper Austria) and two cities (Vienna and Graz) directly address climate change adaptation as a future policy and/or planning task (Figure 1). Adaptation to climate change is strongly represented in the policy documents of the City of Vienna, the federal state of Styria and the City of Graz and less forcefully in the documents of the federal states of Salzburg and Upper Austria. In contrast, the planning goals of the City of Salzburg and the City of Wels refer to CCA only indirectly via planning principles that are not directly assigned to CCA but have an influence on it, such as inwards development, active land policy, sustainable land use or the protection of green spaces and natural assets. An analysis of the vertical integration shows that the principal goal of CCA is more frequently anchored in policy documents at federal state than at municipal level. While in the City of Vienna, the federal state of Styria and the City of Graz, the goal of CCA is consistently addressed at both, the federal state and municipal level, in Salzburg and Upper Austria the topic has so far only been taken up in policy documents at the federal state level. However, outdated planning strategies (City of Salzburg and City of Wels, planning strategies between 2007 and 2016) that are currently being revised, may be a reason for the lack of mainstreaming (Table 1).

Compared to the overall goal of climate change adaptation, CCA of public spaces is less prominent on the political agenda. While CCA generally manifests itself more frequently at federal state level, specific planning goals for adapting public spaces to the impacts of climate change tend to be formulated at municipal level. This pattern reflects the hierarchical distribution of competencies in the Austrian spatial planning system, where the most detailed spatial goals and measures are formulated at the lowest planning level. Direct references to CCA in public space are more prevalent in recently designed or updated policy documents, while earlier ones include indirect references. The City of Salzburg and the City of Wels set themselves the strategic goals of “creating green corridors", which are not directly formulated for CCA but address adaptation services and include public spaces. The policy documents of the City of Vienna, the City of Graz (municipal level), as well as the Salzburg Strategy for Adaptation to Climate Change and the Upper Austrian Spatial Planning Strategy (federal state level) include explicit goals for public spaces, as they will have to make a central contribution to CCA in urban areas. All of these documents highlight the use of UGBI as one of the key strategies to adapt public spaces to the impacts of climate change.

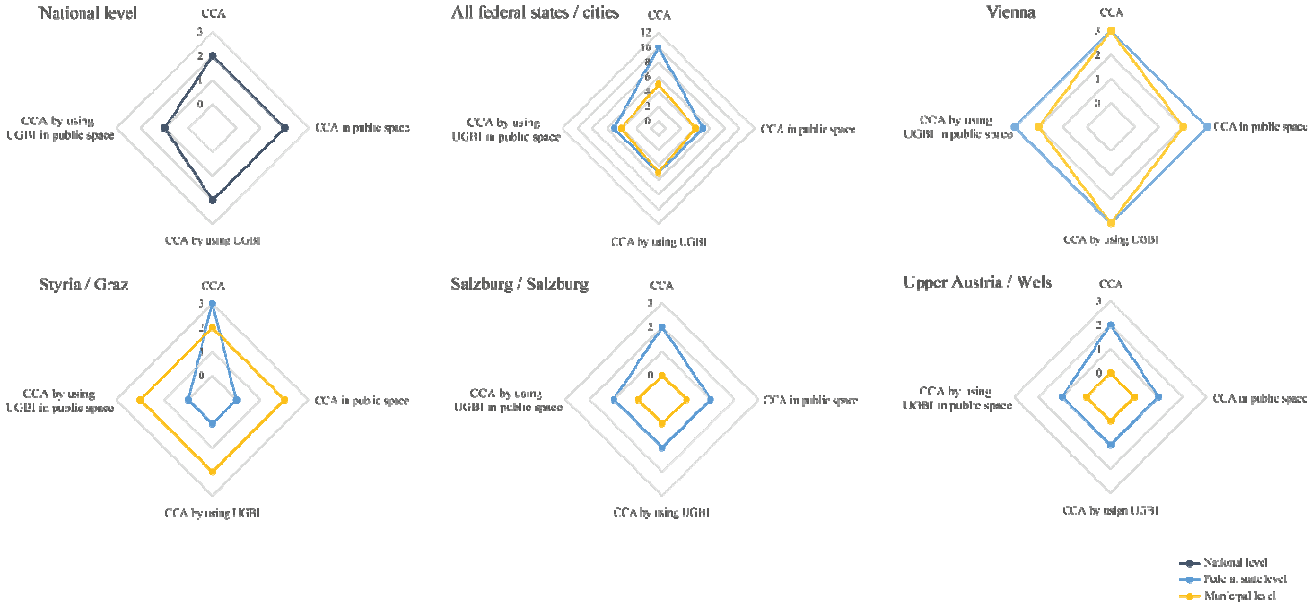

Fig. 1: Overarching goals on climate change adaptation (CCA), CCA in public space and CCA by using urban green and blue infrastructure (UGBI). Goals explicitly mentioned in the policy documents and strategies, at national level, as well as combined and individually for all four case studies at federal state and municipal level. Number of documents with explicit references.

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4.1.2 Policy goals related to CCA in public space and the use of UGBI

More specifically, the predominant goals formulated in the context of CCA, public space and UGBI are: the protection and expansion of public green and open spaces, climate-resilient design, interconnection and creation of public green and open space networks, increased use of green and blue infrastructure in public spaces, a fair provision of public green and open spaces, quality enhancement and the improvement of accessibility and availability (Figure 2). These goals are represented on both, federal state and municipal level, and illustrate three main approaches: i) safeguarding public green and open spaces as elements with positive climate impact per se, ii) implementing CCA measures in public green and open spaces or implementing a climate-resilient design, and iii) ensuring the social and spatial availability, accessibility and usability of climate-effective public green and open spaces.

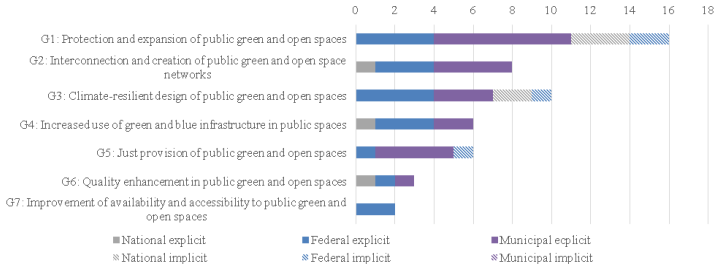

Fig. 2: Objectives related to climate change adaptation (CCA), urban green and blue infrastructure (UGBI) and public space mentioned in policy documents. Number of documents with explicit or implicit references.

4.2 CCA measures for public spaces mentioned in the policies

In addition to setting goals, the policy documents address CCA measures and thus define political and planning tasks. In relation to the objectives identified in 4.1.2, the measures can be divided into two broad categories: i.) land use management to protect and expand public green and open spaces per se and to regulate their spatial distribution, and ii.) measures for climate-sensitive design of public green and open spaces (Figure 3). The two categories address different spatial scales and planning levels, planning authorities and actors and require different steering instruments and mechanisms. The measures can be spatially applied in different types of public spaces (Figure 4).

4.2.1 Land use management

Land use management (i) is the most frequently mentioned measure related to public space and CCA. It serves to maintain and expand public space as resource to establish cold- and fresh air corridors, retention areas and vegetation elements providing ecosystem services. Spatial and urban planning are addressed as responsible stakeholders. Land use management supports the goals of protecting and expanding climate-effective public green and open spaces (G1), linking them to form continuous networks (G2), distributing them socially and spatially (G5) and improving their availability and accessibility (G7). The measure is explicitly included in the policy documents of all four fedederal states and cities – with exception of those of the City of Wels, in which land use management is also addressed, but not (yet) under the objective of CCA. Another measure closely related to land use management is the reduction of surface sealing. It is being pushed by all four federal states and cities – although not always explicitly under the goal of CCA.

4.2.2 Climate-sensitive design of public green and open spaces

In addition to safeguarding public spaces, the policy documents address the implementation of CCA measures in public spaces and their climate-resiliente designs (G3). The identified key measures are: a.) the use of green infrastructure (GI) (G4), b.) the prevention of soil sealing or unsealing surfaces, c.) rainwater management, d.) increasing the capcities for soil infiltration e.) the use of blue infrastructure, and f.) increasing albedo (Figure 3). Urban planning, green and open space planning and landscape architecture are addressed as actors in the implementation of these measures.

The use of urban green infrastructure (UGI) is a cost-efficient and particularly effective CCA measure (Pfoser et al. 2013). Vegetation elements in public spaces reduce heat stress through shading and evapotranspiration and decrease stormwater runoff by absorbing and capturing rainwater (Grunewald et al. 2013, BBSR 2015). The use of green infrastructure in public spaces is anchored as a key measure in policy documents on national level and very prominently in policy documents of the City of Vienna and the City of

Graz. Documents of the federal state of Salzburg implicitly refer to it. Specific UGI elements mentioned are trees (protection of existing trees and new plantings), followed by shrubs, mobile greening and façade greening on adjacent buildings. The policy documents also emphasize the conditions for vegetation elements to develop properly, such as choosing appropriate tree species, providing sufficient soil volume, tree pits or sufficient water supply.

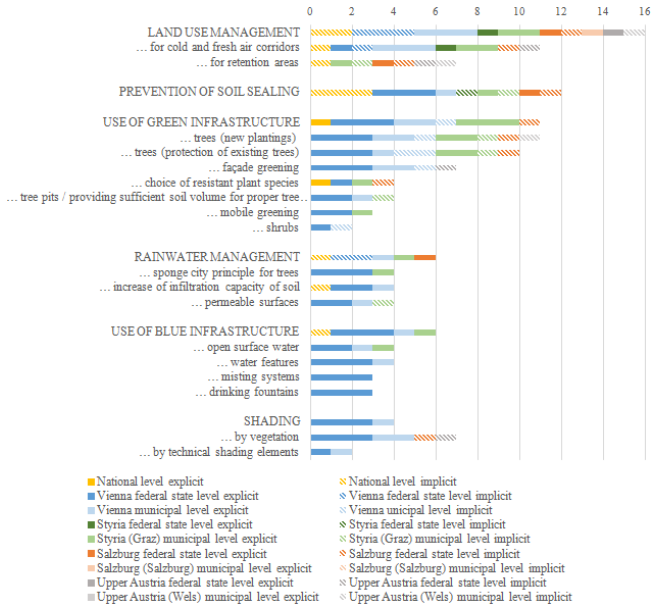

Fig. 3: Measures for the climate-resilient design of public space mentioned in policy documents. Number of documents with explicit or implicit references.

A high degree of sealed surfaces – as it is common in public spaces – discharges rainwater immediately into the sewage system, which can lead to flooding of streets and squares (Fini et al. 2017). The measure of unsealing surfaces or preventing soil sealing in the first place is therefore firmly anchored in policy documents. In general, preventing soil sealing is a fundamental principle of national, provincial, and municipal planning decisions and incorporated in many planning instruments and legislations. In the context of CCA and as a measure of adapting public spaces, it is especially mentioned in the policy documents of the City of Vienna and the City of Graz. Closely related to limiting the degree of soil sealing, but less prominent in the policy documents, are measures of rainwater management. Permeable surfaces or specific elements for rainwater management (e.g. infiltration beds or soil filters) can be used for this purpose (BBSR 2015, Grimm 2018). Rainwater management measures are explicitly anchored in the policy documents of the City of Vienna, the City of Graz and in Salzburg's Land Development Program. Policy documents at national level also include rainwater management measures – but not explicitly in connection with public space. Ideally, rainwater management not only helps to reduce stormwater runoff, but with proper planning makes water available to plants and provides them with water even during dry periods. The sponge city principle for trees, which temporarily stores water on site by infiltrating it into the root zone (Grimm 2018), is an example of such an element. Its implication is anchored in the policy documents of the City of Vienna and the City of Graz.

Water elements in various forms – for play, sensory experience, cooling down or drinking – are central measures for improving the quality of public spaces during heat waves (Almaaitah 2021). The creation of water bodies with open water surfaces, misting systems, drinking fountains or water features is clearly on the political and planning agenda on a national level (implicitly) and on municipal level especially in the City of Vienna and the City of Graz (explicitly).

The ability of materials to reflect sunlight – the so-called albedo – influences how strongly surfaces heat up (Zuvel-Aloise et al 2013). Darker surfaces tend to absorb more radiation and therefore store and re-emit higher temperatures. Increasing the albedo by choosing surface materials of lighter color is considered an important measure for reducing heat load in public open spaces. This measure is explicitly and implicitly promoted in the policy documents of the City of Vienna.

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In addition, the simple and effective measure of shading to regulate temperatures in urban spaces was repeatedly mentioned in policy documents (City of Vienna and federal states of Salzburg and Upper Austria). In particular, shading by vegetation is emphasized. Technical shading elements like pergolas are addressed in the policies of the city of Vienna.

Fig. 4: Measures for the climate-resilient design of public space according to their different spatial implementation options.

The mentioned measures express approaches to face the "collective problem" (Knoepfel et. al. 2011) of climate change and its impact on public space. However, their implementation in planning practice encounters obstacles, which are discussed in the next section.

5 DISCUSSION

The comparative policy analysis confirms that climate change adaptation is largely on the political agenda of the four federal states and cities analysed. CCA is strongly anchored as a central task of spatial planning and development – especially at federal state level. At municipal level, policies more frequently include concrete measures for CCA in public space. In general, it appears that recently published or revised policy documents have incorporated CCA, while the topic is mostly absent in the older ones. Vertical integration – i.e. mainstreaming CCA from national to municipal level – is therefore only evident in two of the four federal states and cities (Vienna, Styria and Graz). The policy documents of Salzburg and Upper Austria so far include only indirect goals and measures dealing with adaptation services. However, this can be attributed to the age of the documents. Especially local development concepts have long revision periods. Salzburg (actual concept from 2007) and Wels (actual concept from 2015) are currently revising their concepts and are going to elaborate CCA as central topics. The City of Salzburg is intensively dealing with the challenges of climate change in the revision and has analysed the current and future climate development as well as the concrete impacts in detail (Stadt Salzburg 2021). The City of Vienna recently evaluated its urban development concept published in 2014 and is preparing a revision. The evaluation concluded that CCA is a top priority and should be given greater consideration in the new concept (MA18 2020).

These developments show that climate change adaptation is currently experiencing high momentum in the field of spatial planning and development. On the one hand, this is due to the increasing awareness of climatic changes and the growing affectedness, and on the other hand, to the integration of the topic into higher-level policies and guidlines. The expert interviews discussed in the following section capture current developments and contexts that are not (yet) included in the policy documents and highlight implementation gaps in planning practice. In addition, the following section compares the results of the policy analysis with scientific literature.

5.1 Awareness of changes in climate signals to develop strategies and measures

Before strategies and measures can be developed, planning authorities need to identify and analyse changing climate signals and their spatial impacts on local level (Jiricka-Pürrer et al. 2021). The policy analysis as well as the interviewees confirm that CCA has “arrived” in Austrian spatial planning and development, since federal states and cities increasingly deal with changes in climate conditions and conduct at least exposure and in some cases vulnerability analysis. Larger cities have more opportunities to gain this knowledge due to their financial, personnel and technical capacities, while smaller cities mostly still lack reliable information on climate change factors and their impacts on local scale or do not have the capacities to process it and make resulting decision (Schindelegger et al. 2021, Kruse & Pütz 2014).

5.2 Vertical integration - from social aspiration to concrete implementation

As political agenda-setting does not only take place in formal processes, but also in socio-political discourses, the interviewees described how climate change adaptation has been established as an issue in spatial planning and development. In larger cities, the interviewees state, the discussion has been going on for about 10 years – originally under the topic of sustainable development and later as part of the smart city discourse. Other cities have initiated adaptation processes because they needed to respond to urgent risks from natural hazards or climate change impacts – such as sewer flooding during intensive rainfall events. In Graz, a city affected by air pollution, awareness of urban climate issues was raised much earlier, as keeping ventilation corridors open has been planning practice for many decades. In the last three to four years, CCA

has become a central issue in all four cities and is increasingly pushed politically. Growing pressure from civil society and the media is also responsible for putting CCA on the political agenda.

The (partial lack of) relevance or explicitness of overarching strategies were mentioned as challenges for vertical integration. Although spatial and urban planning are addressed as a key actors, the strategies usually lack a clear designation of competencies and responsibilities. Also, the overarching concepts are often too strategic and do not propose concrete measures that can be implemented directly at municipal level.

Other barriers to vertical integration of CCA are the lack of consistent guidelines and, most importantly, the lack of legally binding instruments. However, according to the interviewees, the situation is different when it comes to adapting public spaces to climate change. Participants emphasized that cities can mostly manage the implementation of adaptation measures themselves. They are the owners of the public space as well as the financiers who pay for the measures and the developers who implement them. Interviewees see challenges in the need to change internal standards and develop new comprehensive solutions.

5.3 Horizontal integration - differences in adaptation necessary

A horizontal comparison of policies across the four federal states and cities reveals an inhomogeneous picture in the anchoring of CCA and especially CCA in public space. The interviewees underpin this finding. The acceptance of climate change adaptation measures in public space within politics and administration varies. It ranges from positions that support climate change adaptation and are positive about increasing its political relevance, to a clear lack of political support. The fact that political will and the setting of overarching political goals are necessary to achieve progress in administrative action is mentioned by all respondents as an important and necessary basis.

According to the interviewees, a particular challenge arises from the combination of the affectedness of cities versus rural municipalities and the distribution of planning competencies in Austria. There exist only a few large cities in Austria. 71 Austrian municipalities count more than 10,000 inhabitants and are officially classified as cities. However, only six of them count more than 100,000 inhabitants (Vienna, Graz, Linz, Salzburg, Innsbruck and Klagenfurt (from 2022)). Since larger cities are particularly affected by the UHI effect, but there is only a small number of them per federal state, they are mostly left to their own to develop adaptation strategies and measures. "Since we are the only big city, there is a lack of strategies or guidelines at federal state level" (Interview 4). Conversely, employees of the administration at federal state level emphasize that, in line with the hierarchical structure of the Austrian planning system, the freedom of action of cities and municipalities should not be restricted by the federal states.

The impact of climate change varies across regions. In Austria there are four climate zones (Central European Transitional Climate, Pannonian Climate, Illyrian Climate and Alpine Climate) that expose cities to different climatic challenges (APCC 2014). Specific local climatic conditions, as well as different built-up spatial structures, also cause the four analysed cities studied to deal with urban climate to varying degrees. Authors (Birkmann et al. 2017, Juhola & Westerhoff 2011) emphasize the need to tailor strategies and measures to diverse exposures and vulnerabilities. Similarly, different building traditions require different measures.

5.4 Adaptation of public spaces as a major task

Newly released policy documents and strategies identify public space – streets, squares and parks – as important places for implementing adaptation measures. Climate-resilient public spaces are essential structural and spatial measures to realize climate-resilient cities (Damyanovic et al. 2021). Respondents from urban planning departments confirm that implementation in public space, i.e. within cities`own sphere of influence, is comparatively easy. The type of measures and their implementation differs between the urban stock and urban expansion areas. In built-up areas, it is mainly existing buildings are adapted, while in urban expansion areas there is more potential for designing and introducing new measures. In development areas, standards are increasingly changing and new construction methods are evolving. "New streets are now being designed 1.5 times wider than they used to be" (IP 2) to accommodate green infrastructure and rainwater management measures.

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5.5 Securing public green spaces and controlling land use

Protecting public green and open spaces by restricting land uses is a strategy mentioned by all cities. Large-scale measures like the protection of (public) green and open spaces as cold air corridors and retention areas for flood protection are usually achieved through regulations in local development concepts and zoning plans.

Increasingly, small-scale regulations – such as the orientation of roads or the design of road cross-sections – are being considered in zoning plans under the aspect of climate change adaptation (e.g., N-S oriented roads are more exposed to the sun; wider roads allow for more UGBI).

5.6 Redesign of streets and squares

Redesigning existing streets and equipping new streets with various adaptation measures are strategies pursued by all cities analysed. Differences exist in the level of detail of the implementation process: some cities conduct detailed exposition analyses to select locations, while others focus more on the quantity of implemented measures. "If we plant trees, we achieve a cooling effect through shading. No one will question this positive effect" (IP 2) vs. "We have to take a close look in order to set priorities" (IP 3). The four analysed cities implement numerous measures and pilot projects in streets and squares and partially evaluate their effects – either through monitoring (e.g. in Graz) or through specific evaluations like the "Climate Fit Roads" program in Vienna (Damyanovic et al. 2021).

5.7 Trees as particularly effective measures

The interviews confirmed that trees are one of the most cost-effective and efficient adaptation measures, especially in public space. However, the necessary changes to the streetscape and the spatial distribution to support urban green infrastructure is still a controversial discussion in planning practice: "Tree planting is important and should not be under discussion. But it is still being discussed. Always you and your trees, they say" (IP 1). The number of trees is questioned in the same way: "We should aim for a closed canopy, but..." or: "I would like to plan one parking lot for parallel parkers, maximum two for cross parkers, to achieve a distance of 5-6 m between two trees, so that the trees can grow to form a closed canopy cover" (IP 2).

5.8 Multiple demands on public space as a challenge

The context of climate change adaptation emphasizes that public green and open spaces in urban areas must serve multiple functions and uses. They have to combine green and blue infrastructure, act as natural air conditions and absorb water like sponges during heavy rainfall events. At the same time, they have to provide urban dwellers with high quality recreational spaces that, in the best case, are networked, easily accessible and equitably distributed. Public green and open spaces are places for exercise, everyday life activities, contemplation and social interaction (Gehl 2010). In terms of climate mitigation, public spaces must be places for smart energy production and provide spatial structures for climate-friendly mobility. This leads to a conflict of competing demands and requirements for public green and open space, which is becoming increasingly urgent due to growing urbanization and competition for land (Carter 2011).

In recent years, research interest in creating synergies between different function and uses in public green and open spaces has increased. Scientific literature and planning practice use different terms to address the coordination of multiple requirements. The German discussion refers to "multiple occupancy of spaces" or "multidimensional spaces" (Stokman et al. 2013, Kind et al. 2019). A commonly used term is "multifunctionality", which is prone to various definitions and interpretations. In space-time analyses, multifunctionality is used to express the occurrence of more than one activity in the same place and/or at the same time (Batty et al. 2004, Zivkovic et al. 2019). In urban planning and design, it refers to the overlapping of several uses in one place (Zivkovic et al. 2019). In green infrastructure planning, multifunctionality is associated with the multiple functions (economic, ecologic and social) and ecosystem services (regulating, provisioning, socio-cultural) that green and open spaces provide (Pauleit et al. 2014) to humans and the environment. Becker (2014) uses the term "multicoding" to emphasize the overlap of demands and ideas (codes) actors attach to urban public spaces according to their individual values and subject-specific perspectives. He intentionally does not speak of "functions", as they are "abstract and objective" but rather identifies actors and their interests that meet in public green and open space and need to be negotiated.

According to Becker's actor-centered concept (Becker 2014), multicoding requires an integrative and interdisciplinary planning approach, that is not yet common in municipal planning practice. Due to the sectoral planning logic in Austria, planning disciplines mostly operate within their own sphere of responsibility, while integrated planning processes are just being tested in cities and pilot projects (Juschten et al. 2021). The sectoral approach is also prevalent in the analysed climate change adaptation strategies, which specify sectoral fields of action.

Integrated and interdisciplinary planning requires appropriate institutional and administrative structures and needs personnel and financial resources (Schuchardt et al. 2020). Authors see a comprehensive understanding of green and open spaces and their multiple functions and services as a necessary prerequisite for designing and planning multifunctional spaces. Fluhrer et al. (2021) consider the ecosystem services approach, which emphasizes the multiple benefits of green infrastructure, helpful in developing a more holistic understanding. Hansen et al. (2019) call for a development of typologies and guidelines for planning and designing multifunctional green and open spaces, as well as systematic assessments in baseline surveys and evaluations that take into account the social, ecological and economic dimensions.

6 CONCLUSION

The first Austrian strategy for adapting to climate change was published ten years ago (BMFLUW 2012a and b). At that time, Austria was one of the first countries in the European Union to develop an action plan for implementation. The strategy identifies spatial planning and development, landscape- and urban planning as well as cities as drivers of adaptation. In particular, the protection and expansion of public spaces and urban green and blue infrastructure is mentioned as one of the key goals and strategies for adapting cities and urban areas. After more than ten years in which adaptation to climate change has been established as a second pillar alongside climate mitigation in climate policy, a lot has happened in the field of spatial planning and development. The policy analysis shows that CCA, and especially CCA in public spaces, is largely mainstreamed in policy documents that influence spatial development. Socially and (and partly also politically), maintaining quality of life in urban areas is closely linked to climate change adaptation measures. All four analysed federal states and cities have recognized climate change as a challenge for the development of public space. Heat, drought and heavy rainfall events are the direct consequences of climate change – with varying degrees of severity and spatial impact – and affect public space. The results underline that public space – especially in built up areas – is one of the last spatial reserves for adaptation and therefore represents a key field of action in all cities (Battisti & Santucci 2020, Matos & Costa 2018). When it comes to concrete implementation of adaptation measures in public space, it is mostly up to the cities to become active themselves.

6.1 Paper is patient – comprehensive implementation is still a long way to go

Strategies alone cannot achieve effective adaptation. Several Austrian cities have launched pilot projects to adapt public spaces and streets. However, a comprehensive implementation of adaptation measures is necessary to meet the challenges of climate change. Research and administration are asked to translate the experience from these pilot projects into standards to enable comprehensive implementation. In the future, public space will have to fulfill a variety of functions and uses. Becker's approach of multicoding (Becker 2014) raises awareness of the multiple actors and interests that claim public space. According to Becker, renegotiating the distribution of public space is a task that can only be implemented in an interdisciplinary and integrated manner. All sectors are called upon to contribute and work together to examine how public space can be used effectively and efficiently to achieve all goals.

6.2 The potential of urban green and blue infrastructure to create multifunctional public spaces

Public space must become more functionally efficient while withstanding the impacts of climate change and being a place to implement adaptation measures. The use of green and blue infrastructure creates synergy effects and supports multiple functions and uses in public space. While in Austrian cities every single tree planting was discussed intensively and dismissed because of the loss of parking lots for a long time, it is now taken for granted to plant trees in public spaces and to implement climate-resilient elements. Urban green and blue infrastructure provides a variety of ecosystem services and is – especially when synergy effects are taken into account – economically more efficient than monofunctional technical solutions.

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