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Article

Place-Based Climate-Proofing of Commercial and Industrial Areas: Inventory and Guidelines From a Regional Planning Perspective

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Abstract
In spite of all efforts to reduce greenhouse gases, climate change has become a new reality that requires regional planning to provide effective solutions. This article focuses on commercial and industrial areas (*Gewerbegebiete*), which are important but often overlooked spaces, by means of examples in the Berlin-Brandenburg region. The article investigates whether and how regional planning can help these areas adapt to climate change. Three commercial and industrial areas in different spatial settings are examined, using an inventory of place-based measures, general standards, and regional networking of planning actors. This inventory is based on a backcasting analysis that compares normative future images of climate-adapted commercial and industrial areas with their current local situation. Spatially differentiated guidelines for the adaptation of commercial and industrial areas are then developed from a regional planning perspective by "climate-proofing" regional plans. These guidelines provide both place-based and general solutions for integrating and governing climate adaptation measures and standards into existing frameworks using a hands-on regional planning approach.

Keywords
backcasting analysis; Berlin; Brandenburg; climate adaptation; climate-proofing; commercial areas; Germany; industrial areas; place-based; regional planning

Issue
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1. Introduction

Adapting to climate change is an urgent mission for regional planning as its consequences are already affecting various regions in the form of heat waves, droughts, storm damages, and flooding events (Beyschlag et al., 2021). Such events, however, vary regionally in their intensity whereby inequalities in living conditions are becoming increasingly common. Regional planning must find answers to how to assure equal living and working conditions (König et al., 2023). Despite their high need and potential for adaptation to climate change, commercial and industrial areas (*Gewerbegebiete*) are often given lower priority in regional planning (Schack et al., 2023). These areas provide employment, income, welfare, and high living standards, but are also responsible for a significant amount of land consumption, are highly sealed, and are often located in hazardous areas, making them vulnerable to the consequences of climate change (Benden et al., 2012).

While the importance and mutual interrelation of climate adaptation and the (re)development of commercial and industrial areas seems evident, these two fields are often considered separately by urban and regional planners. Despite a few notable exceptions (Birkmann & Fleischhauer, 2009; Breuer et al., 2020; European Commission, 2021a; Roost et al., 2021), little research or practical guidance is available. The theoretical objective

of this study is to bridge this gap and integrate the discourse on climate adaptation and on developing industrial areas by climate-proofing regional plans in a general sense. By identifying this new field of action, the study aims to accelerate climate adaptation processes for commercial and industrial areas and to promote a rethinking of the planning and construction of such spaces. Methodologically, the study rests on the backcasting analysis, which addresses complex problems in exploratory fields, and aims to link a desired future with the near future by asking the question: "What has to happen first?" (Bollien, 2021). In the present case, this methodology integrates findings from the individual case studies into guidelines for shaping the future. The underlying approach is both place-based and regional; it aims for an equally distributed and widespread utilisation of climate adaptation standards and measures. The standards and measures are summarised deductively from literature and expert interviews and proposed inductively through spatial test designs within selected case studies in the German states of Berlin and Brandenburg.

The article is organised as follows: Section 2 deductively outlines current observations and theoretical discourses related to climate adaptation and the (re)development of commercial and industrial areas. In Section 3, a normative vision of a climate-proof industrial area is presented and compared to three case studies from the Berlin-Brandenburg metropolitan area in order to inductively derive viable measures for climate adaptation. Section 4 provides an inventory of standards and measures for climate adaptation. The findings are compiled into a practical regional planning guide for climate-proof commercial and industrial areas in Berlin and Brandenburg, highlighting the regional level as the appropriate scale of action for climate adaptation of industrial areas.

2. (Re)Development, Regional Planning, and Climate Adaptation in Commercial and Industrial Areas

2.1. Current Strategies in Commercial and Industrial Areas in Germany

Discussions about the renewal of existing commercial and industrial areas and efforts to limit land consumption in commercial construction in Germany have a sobering tone (Freudenau, 2016; Oediger et al., 2020). Many conventional commercial and industrial areas—apart from modern science and technology parks—suffer from urban development deficits and a low-quality built environment (Suwala et al., 2021). Although issues are diverse and location-specific, regional planning research agrees that all areas older than 15 years require redevelopment measures (Roost et al., 2021). Researchers have identified three general needs for action in commercial and industrial areas in Germany (Hüttenhain, 2012; Senatsverwaltung für Stadtentwicklung, Bauen und Wohnen [SenStadt], 2020): *modernisation* and *preservation* (type 1) for brownfield areas in need of modernisation and safeguarding against non-industrial use in prosperous regions and inner-city areas; *new development* (type 2) for greenfield developments with high soil sealing in suburban areas; and *revitalisation* (type 3) for underutilised brownfields in stagnating, peripheral regions.

2.2. Climate Mitigation and Climate Adaptation in Commercial and Industrial Areas

In the 21st century, addressing the general needs for action in commercial and industrial areas must also take into account the consequences of climate change. This involves implementing standards and measures to mitigate and/or adapt to its detrimental effects. Climate adaptation measures describes the adjustment to the effects of climate change, while climate mitigation measures reduce emissions to make impacts of climate change less severe (Greiving et al., 2011; Marx, 2017, p. 9). Regardless of the urgency, climate adaptation measures face greater obstacles than those of climate mitigation, such as a lack of political determination and formal enforcement. Climate mitigation measures are usually juristically embedded in acts, regulations, and rules and are easier to implement through explicit targets such as emission figures (Freimann et al., 2013). Uncertainty about the consequences of climate change for specific areas makes it difficult for municipalities to invest in precautionary measures (Hasse, 2021; Reese, 2018). However, climate adaptation and mitigation are complementary (Marx, 2017), and adaptation efforts can never substitute vigorous climate mitigation action.

A tool for integrating both measures of climate mitigation and adaptation into governance practices is known as climate-proofing (see Section 3.3; European Commission, 2021a). The article elaborates on the concept of climate-proofing governance practices to improve climate adaptation within commercial and industrial areas from a regional planning perspective.

Commercial and industrial areas are referred to as the "black sheep of sustainability transitions" (Heimann, 2018, p. 224). They face enormous sustainability challenges, such as high energy emissions, underutilised plots, and excessive greenfield consumption (Benden et al., 2012). Many industrial areas are also vulnerable to climate change due to their location in floodplains and poor building quality. While some examples of sustainable and climate-proof architecture exist (e.g., Alnatura Campus in Darmstadt or the Lütvogt logistics hub in Wagenfeld; Djahanschah et al., 2020), implementation is lacking due to a reliance on voluntary initiatives and a lack of systematic coordination and funding.

2.3. Climate-Proofing of Existing Planning Thought and Concepts

Neither voluntary initiatives nor pilot projects are enough for proper climate adaptation in commercial and

industrial areas. Standards need to be set at higher levels, such as regional or national planning (Roost et al., 2021), to improve implementation and increase the unassailability assessment (*Abwägungsfestigkeit*; Diepes, 2018). Generally applicable standards for climate adaptation in (preparatory) land-use plans must clearly outline targets and limits to become legally binding (Baumüller, 2019; Reese, 2018). However, determining and verifying these standards require sophisticated climate models or monitoring tools that may overburden municipalities in terms of personnel and expertise (Bula et al., 2015). To avoid overburdening municipalities with complex and elaborate climate impact assessments, we propose integrating climate adaptation into existing plans and processes. This approach is inspired by the concept of "climate-proofing" (Birkmann & Fleischhauer, 2009). Climate-proofing can be understood as:

> A process that integrates climate change mitigation and adaptation measures into the development of (built) infrastructure projects….It sets out common principles (standards) and practices (measures) for the identification, classification and management of physical climate risks when planning, developing, executing and monitoring infrastructure projects and programmes. (European Commission, 2021a, p. 7)

The concept of climate-proofing was introduced in spatial planning as early as 2009. It was originally derived from development cooperation practice (European Union, 2016; Fröde et al., 2013). Climate-proofing is also increasingly discussed in the context of urban and regional planning as a tool for integrating climate mitigation and adaptation issues into spatial planning (Birkmann & Fleischhauer, 2009; Dosch et al., 2016; Fichter & Hintemann, 2012; Greiving et al., 2011). In contrast to the German strategic and environmental impact assessments (*strategische Umweltverträglichkeitsprüfung*), which primarily focus on climate mitigation and assess the impact of a pending project on the environment, the concept of climate-proofing works in the opposite direction. It examines the effects that climate change may have on the project. While researchers consider the formal environmental assessment a prerequisite, they also acknowledge that it is insufficient to ensure climate adaptation, since the negative impacts of climate change are not explicitly checked within this process (Reese, 2018).

2.4. Capitalist Imperatives and Place-Based Regional Planning of Commercial and Industrial Areas

Reflecting on capitalist imperatives affecting industrial development, this section outlines the theoretical foundations of our approach, explaining why commons strategies and regional planning are particularly effective in ensuring climate adaptation within commercial and industrial areas.

Recent research on global economic networks has emphasised the importance of examining both the regional context of regulatory frameworks and planning governance, as well as the trans-local interrelations between geographically distant industry locations vying for positions within global production networks (Beyer et al., 2020; Hagemann & Beyer, 2020; Suwala, 2021). The critical role played by industrial infrastructure, such as industrial zones that meet the environmental standards of transnational investors and buyers, and the role of multiple stakeholders in providing such infrastructure are particularly noteworthy (Beyer, Elsner, Hagemann, et al., 2021). A comparative view of commercial and industrial areas, taking into account both metropolitan hubs and rural hinterlands, reveals a connection between "left-behind" places and privileged spaces within global economic networks (Pike et al., 2023). For example, a logistics hub on the outskirts of a city is necessary to supply goods to the central consumption areas. This trans-local perspective can provide a systemic understanding of the interrelationships between spatial and economic factors, such as the availability of brownfields and greenfields or vacant and highly demanded areas, which goes beyond the narrow focus on land maximisation for corporate profit (Beyer, Elsner, & Hagemann, 2021). The power distribution among industrial spaces does not prioritise individual prosperity but rather global efficiency through competition, which allows for profits by means of spatial arbitrage (Hüttenhain, 2012). When a location cannot keep up with global competition, this is often attributed to endogenous factors, leaving locations to solve these problems themselves (Ouma et al., 2023; Suwala, 2023). However, the criteria for success and failure are typically determined exogenously by the global economic system, leading to a race to the bottom among municipalities to attract companies at the expense of the environment, without generating any significant spatial qualities (Funk & Leuninger, 2014; Hüttenhain, 2012).

The (neo-)capitalist economic order is not a given but rather a system that can be changed (Harvey, 1989). Regarding commercial areas as part of a network or region reveals place-based idiosyncrasies, power structures, and conflicts that can transform existing conditions beyond capitalist imperatives (Gualini & Bianchi, 2015; Hillier, 2002). Place-based approaches ensure a distinctive and regionally appropriate fit and the integration of climate adaptation principles into regional plans and regulations (König et al., 2023; Tödtling & Trippl, 2005). By recognising the mutual problem of exploitation in the global circuit and working together on a regional scale, intercommunal competition can be transformed into cooperation through approaches such as commercial pooling (*Interkommunale Gewerbegebiete*, *Gewerbeflächenpools*; Knieling et al., 2017; Ostrom, 1990). Regional regulations and planning are crucial for implementing climate adaptation measures in municipalities facing a two-fold problem of scale (Diekelmann,

2018; Greiving et al., 2011): The consequences of climate change and climate adaptation measures are not directly perceptible in space and time. Regional planning operates with longer time horizons than legislature terms. Additionally, regional planning instruments serve as the basis for many subsequent instruments, making the spatial scale an appropriate tool for addressing the long-term nature of climate adaptation measures (Hartz & Saad, 2020).

3. Analysis: Case Studies of Adapting Commercial and Industrial Areas to Climate Change in the Berlin-Brandenburg Region

3.1. Normative Vision of a Climate-Proof Industrial Area

The backcasting method is applied here to connect the theoretical considerations regarding the complex problem of climate adaptation in industrial areas with inductive explorations of climate adaptation measures in three typical commercial and industrial areas in Berlin and Brandenburg, with the goal of integrating them into guidelines for shaping the future. As a first step to linking a desired future with the near future, we created a normative vision of a climate-proof commercial and industrial area (Figure 1). This utopian image is based on a compilation of manifold climate adaptation standards and measures from current research and practical implementations (Baumüller, 2019; Benden et al., 2012; Diepes, 2018; Günther, 2013; Schack et al., 2023; Schramm et al., 2023; Sieber, 2019; Valentin et al., 2019), with a focus on spatial adjustments to buildings, urban design, and regional integration. By comparing this image to present realities and asking the question "What has to happen first?" we evaluated the feasibility, relevance, and steps required to achieve this long-term vision. A comprehensive list of all adaptation measures recommended in the literature can be found in the Supplementary File. Of course, the specific selection and application of measures depend on the unique conditions of each location.

3.2. Economic and Climate Change Dynamics in Berlin and Brandenburg

The Berlin-Brandenburg region in Northeastern Germany is characterised by interconnected but heterogeneous economic dynamics, with Berlin and its commuter belt experiencing rapid development, while peripheral areas

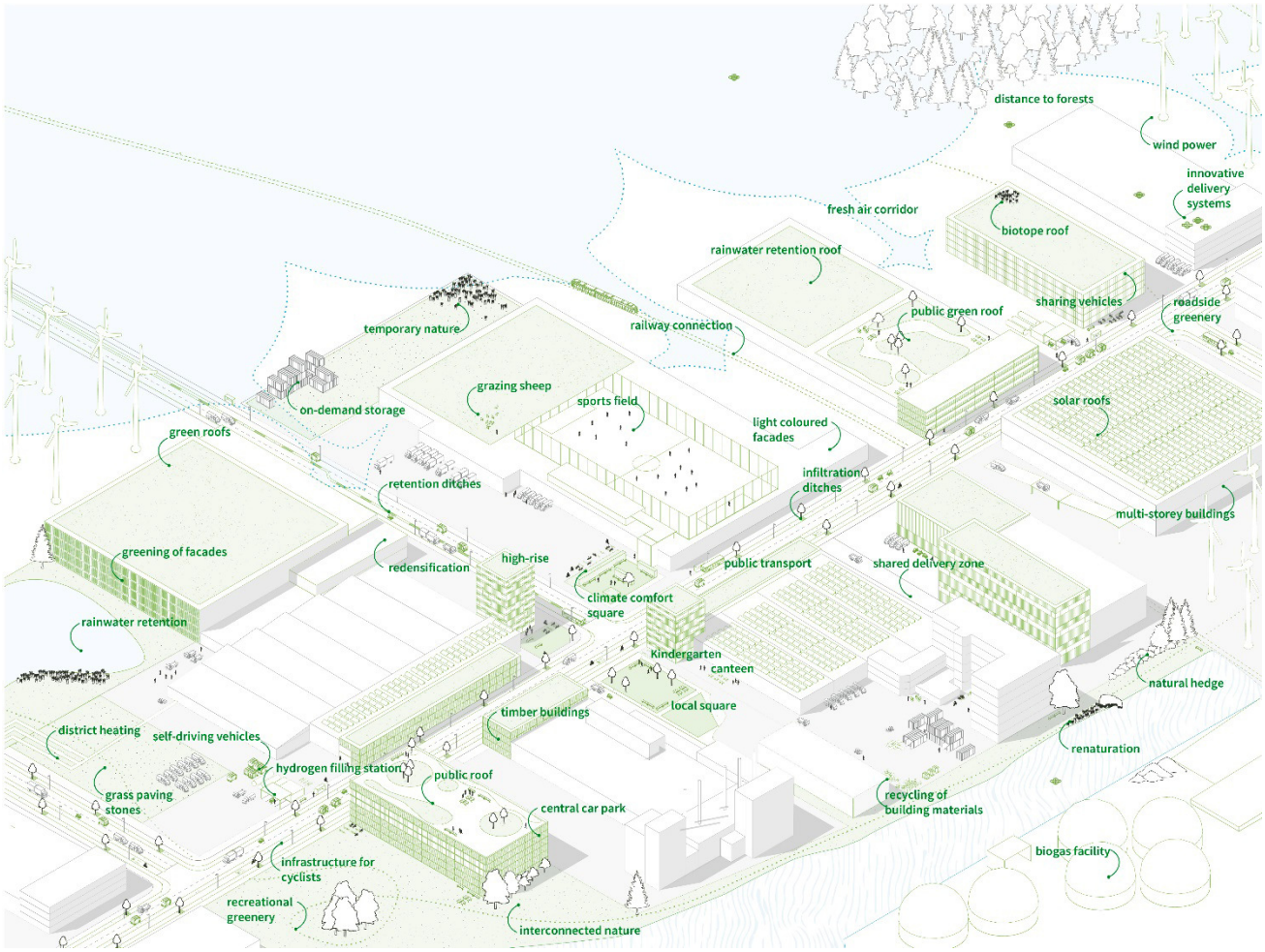

Figure 1. Normative image of a climate-proof commercial and industrial area.

of Brandenburg face stagnation (Kulke & Suwala, 2015). The administrative borders of the two federal states are of little relevance to the daily lives of residents, as the region virtually functions as one labour market area.

The entire region is considered highly vulnerable to climate impacts ("Klimawandel: Das erwartet Berlin und Brandenburg bis 2100," 2019). The average annual temperature has risen by approximately 1.3 °C since 1881 (Ministerium für Landwirtschaft, Umwelt und Klimaschutz, 2022; Senatsverwaltung für Mobilität, Verkehr, Klimaschutz und Umwelt, 2022), and extreme annual temperatures have become more frequent since 2000 (Märkische Allgemeine, 2021). Prolonged droughts and an increased risk of forest fires have been observed due to extended periods without rainfall (Senatsverwaltung für Mobilität, Verkehr, Klimaschutz und Umwelt, 2022). Insufficient winter snowfall jeopardises groundwater replenishment, while intensified heavy rainfall events lead to damaging floods (Kixmüller, 2018). These combined factors make the region an ideal location for the purposes of this study.

In principle, three different economic situations can be identified in the federal states of Berlin and Brandenburg: recovery, growth, and structural change. Accordingly, three different forms of land dynamics can be observed in commercial and industrial areas: land shortage, land consumption, and abundant land. Climate-proof regional planning is tasked with finding solutions for all three of these cases. To grasp the spectrum of these economic and land-use dynamics in Berlin and Brandenburg, we focused on areas located in proximity to the federal motorway A13, an essential lifeline for commercial and industrial areas (Figure 2). The motorway starts in the Berlin district of Neukölln and runs across the south-east of Brandenburg to Lusatia, connecting to Poland via the city of Cottbus and to the Czech Republic via Dresden. Along the A13, three commercial areas were singled out as exemplary case studies. These three areas have roughly the same size and are primarily characterised by manufacturing activities. The three selected examples also correspond to the general spectrum of needs for action in industrial areas defined in Section 2: *modernisation* and *preservation*, *new development*, and *revitalisation*.

3.3. Need for Modernisation and Preservation (Type 1): Grenzallee in Inner-City Berlin

The Grenzallee industrial area covers over 70 hectares of land and is located on the northern feeder road to major motorways in the Neukölln district, at the intersection of two waterways and the Berlin inner-city railroad ring

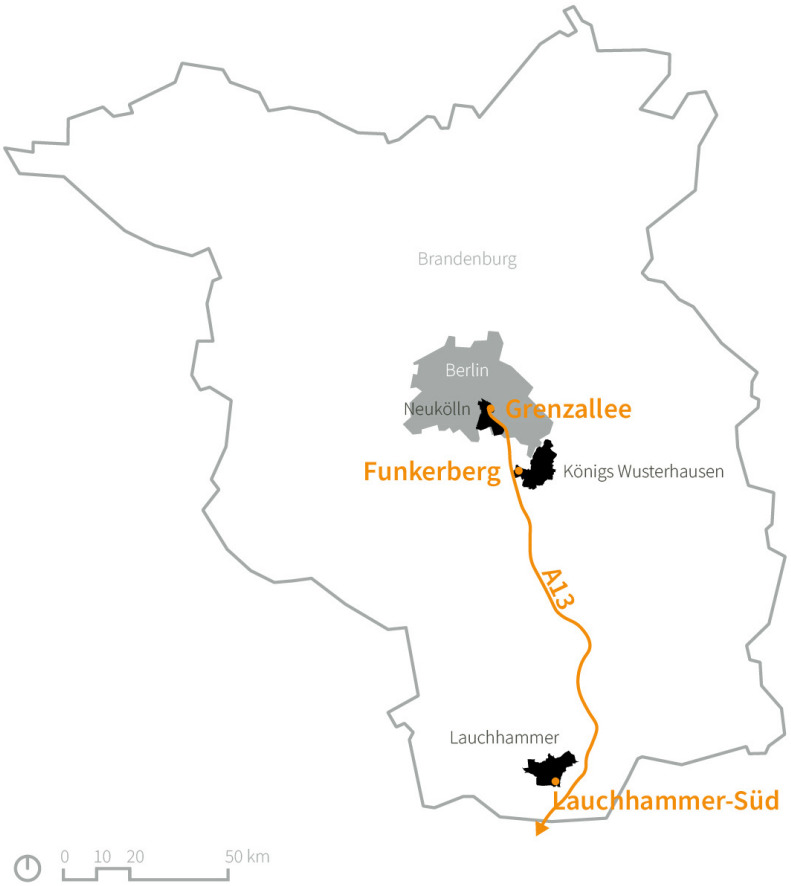

Figure 2. Location of the three case study sites (Grenzallee, Funkerberg, and Lauchhammer-Süd) within the Berlin-Brandenburg metropolitan region.

(see Figure 3). The area is situated on the outskirts of Berlin's inner-city and is bordered by tenement house districts and large-scale housing areas from the 1970s. With standard land values ranging between EUR 250 and EUR 350/m² (land ready for construction), the area accommodates over 50 manufacturing companies, most of which are individual parcel owners. Originally constructed as a mono-functional commercial site on the periphery of isolated post-war West-Berlin, it now enjoys a central location in Berlin's metropolitan context and is in high demand. However, the area is confronted by challenges associated with modernising its aged building stock and managing space constraints, while preserving its original function.

The Grenzallee industrial area is far from being adapted to climate change due to its outdated 1970s infrastructure. Both public spaces and existing buildings require renovation measures, including adjustments

Figure 3. Aerial view (from 2022) showcasing the major traffic connections and boundaries of the Grenzallee industrial area in Berlin.

to basic infrastructure like pavements and roads and the design of company premises. However, the area benefits from promising sustainability initiatives and supportive institutions on various scales. At the local level, the Südring e.V. business network facilitates stakeholder communication and cooperation. These channels are crucial for effectively managing existing commercial properties while initiating sustainability projects such as the New Green: Climate-Neutral Businesses in Neukölln (*Neu-Grün: Klimaneutrales Wirtschaften in Neukölln*; Breuer et al., 2020). Furthermore, the Grenzallee area has potential for future adaptation to climate change through initiatives implemented by both the municipality of Neukölln (e.g., by the district level officer for climate issues) and Senate departments of Berlin, including the Berlin Energy and Climate Protection Programme (*Berliner Energie und Klimaschutzprogramm*) at the city level.

3.4. New Pending Developments (Type 2): Funkerberg in Suburban Königs Wusterhausen

Funkerberg is a 100-hectare commercial and industrial area in the town of Königs Wusterhausen, located 35 km southeast of Berlin in the state of Brandenburg (see Figure 4). The area is fully marketed to 20 companies with a standard land value of EUR 120/m². The area is in the Berlin-Lusatia development corridor, 3 km east of the motorway junction (A13 and A10), 1 km from railroad (Berlin-Cottbus) and waterway access (Königs Wusterhausen harbour), and close to both the Berlin-Brandenburg Airport and the new Tesla factory. The Brandenburg part of the metropolitan region attracts many land-intensive businesses on greenfields. This creates the problematic evolution of rapid land consumption within commercial and industrial sites in suburban areas. This is exemplified by the development of the additional 50 hectares of commercial land that could be allocated according to the land-use plan on further agricultural land, and concerns expressed by the Brandenburg Economic Development Board regarding a shortage of commercial land in the future, calling for an intensified search for further expansion.

In newly developed areas, high benchmarks for climate adaptation measures are expected. However, Funkerberg falls short of these standards with no use of sustainable building materials and no land-saving urban design. The lack of efficient public transport connections also hinders the implementation of sustainable low-emission transport. Furthermore, funding guidelines

Figure 4. Aerial view (from 2022) showcasing the major traffic connections and boundaries of the Funkerberg industrial area in Brandenburg.

for new commercial and industrial areas do not take into account urban design or climate criteria (J. Glase, personal communication, 26 January 2022; Oliwkowski & Schmuck, 2018). The municipality prioritises financial surpluses over climate action plans, and exerting influence in the future will become increasingly difficult as parcels are sold to private investors, even if public property has been allocated lately based on the best development concept rather than to the highest bidder (*Konzeptverfahren*). Additionally, two commercial and industrial areas were developed north of the location in the municipality of Wildau (A10 shopping centre and Hoherlehme) before formal regional planning was established in the early 1990s in Brandenburg. Parts of these areas in Wildau are underused and have no spatial or functional relationship with the commercial areas in Funkerberg despite their proximity.

3.5. Need for Revitalisation (Type 3): Lauchhammer-Süd in Peripheral South Brandenburg

Lauchhammer-Süd, a 100-hectare commercial and industrial area, is located in southern Brandenburg, just 5 km west of the A13 motorway at 150 km south of Berlin and 50 km north of Dresden, the state capital of Saxony (see Figure 5). The area has a standard land value of EUR 8/m². While it is currently home to 25 companies, less than half of its area is being used for commercial purposes after a large company that produced rotors for wind turbines shut down in 2022. With the end of coal mining in the region in sight, Lauchhammer Süd is undergoing a transformation and serves as an example for the revitalisation (type 3) of commercial and industrial areas needed in the region of Lusatia. Despite the area's potential, the peripheral municipality of Lauchhammer has a surplus of commercial and industrial land, a common challenge in Lusatia.

Only very few measures can be identified in the Lauchhammer-Süd commercial and industrial area that contribute to climate-proofing, except for the water-permeable outdoor premises and tree-lined areas of the now-vacant wind turbine company. Although freight tracks offer a potential for future emission-free transportation, the existing plans fall short in terms of climate adaptation measures. In addition, there is a lack of emission-free mobility options for individual transport. The unregulated 1990s development of commercial and industrial areas like Lauchhammer-Süd opting for investors serves as an example of how such speculative endeavours can "lead to a dead end" (Funk &

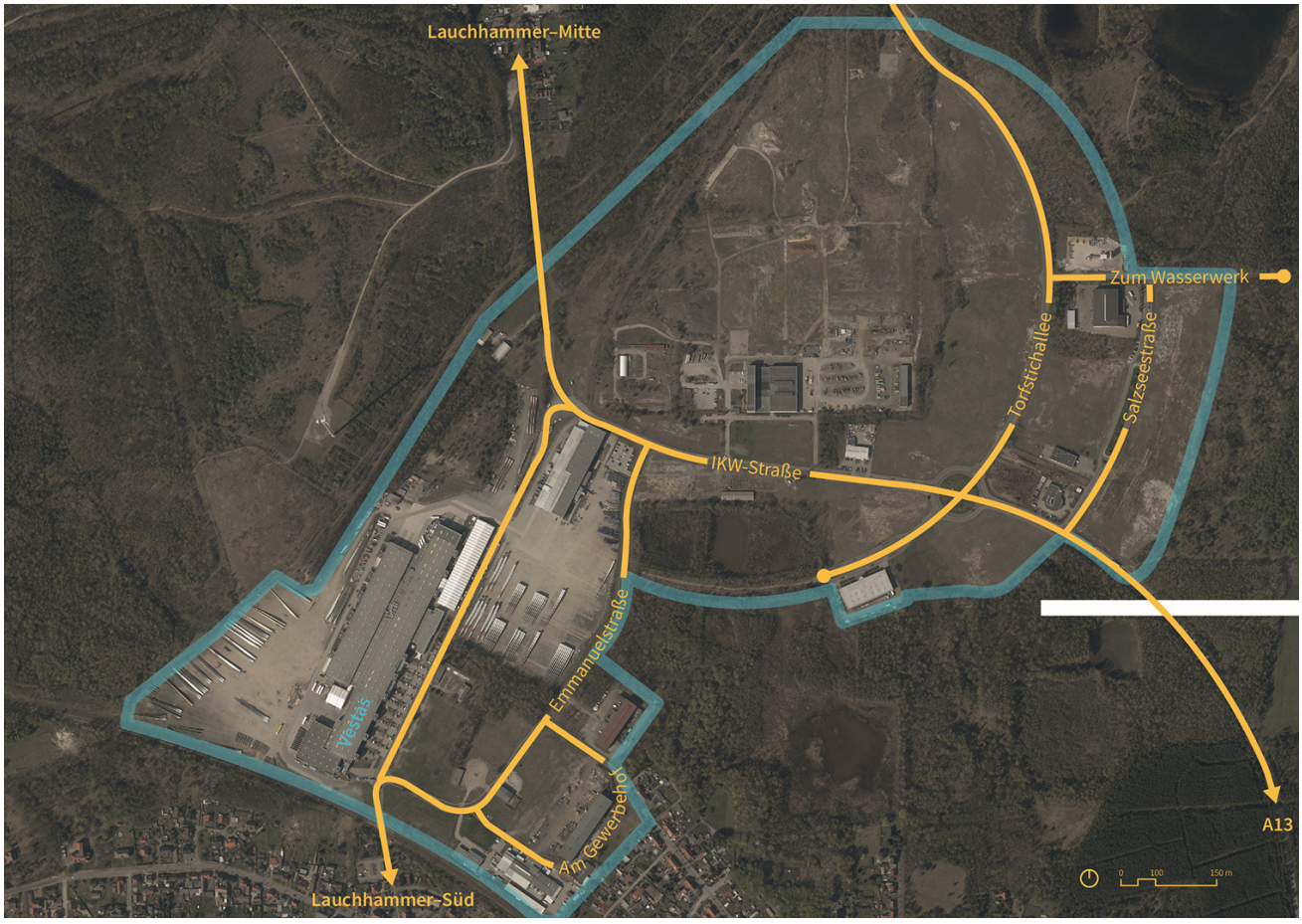

Figure 5. Aerial view (from 2022) showcasing the major traffic connections and boundaries of the Lauchhammer-Süd industrial area in Brandenburg.

Leuninger, 2014, p. 155). Another structural deficit is that buffers of around 50 hectares of commercial and industrial spaces in Lauchhammer-Süd are not located in one coherent area. In other words, the industrial area is not an option for large-scale investments and vacancies persist. The peripheral location of the municipality in southern Brandenburg is also challenging. Funding for the transformation of Lusatia is currently focused on other sites in the region, such as a former large-scale lignite-fired power plant in Spremberg or the Science Park in Cottbus. Lauchhammer will also miss out on investments in rail infrastructure (Wüpper, 2021) and a new cathode and battery recycling factory in Schwarzheide (Richter-Zippack, 2023).

3.6. Backcasting: Comparison of Normative Image With Test Designs

The description of the case study sites presented typical examples of the challenges encountered by industrial areas. Our analysis was based on a variety of sources, including statistics, documents, SWOT analyses, and expert interviews. In order to explore how these three areas can implement climate adaptation measures as proposed in the normative vision, test designs were developed for each site. These test designs serve as an integral step in the backcasting method, allowing us to assess the feasibility of implementing different aspects of the normative vision based on each specific type of area.

3.6.1. Backcasting Analysis of the Grenzallee Inner-City Area

Future developments in Grenzallee should support the area's redevelopment process, meet current commercial and industrial demands, and integrate measures to increase climate adaptation. Figure 6 illustrates a test design for incorporating measures, including the redensification and development of building stock, increased permeability and connection to surrounding neighbourhoods, changes in modes of transportation, unsealing, and creating qualified public spaces to enhance the climate-proofing of the area. However, "[i]n most parts…built on, it is much less dense than the development plan allows" (SenStadt, 2020, p. 63). Thus, new building projects should use the height potential for multi-storey buildings with small-scale areas for artisan or medium-sized production companies, while sustainable materials and green roofs or façades should be prioritised. Conversion and densification measures at the margins and entrances can contribute to the profiling and development of the entire area, with certain areas

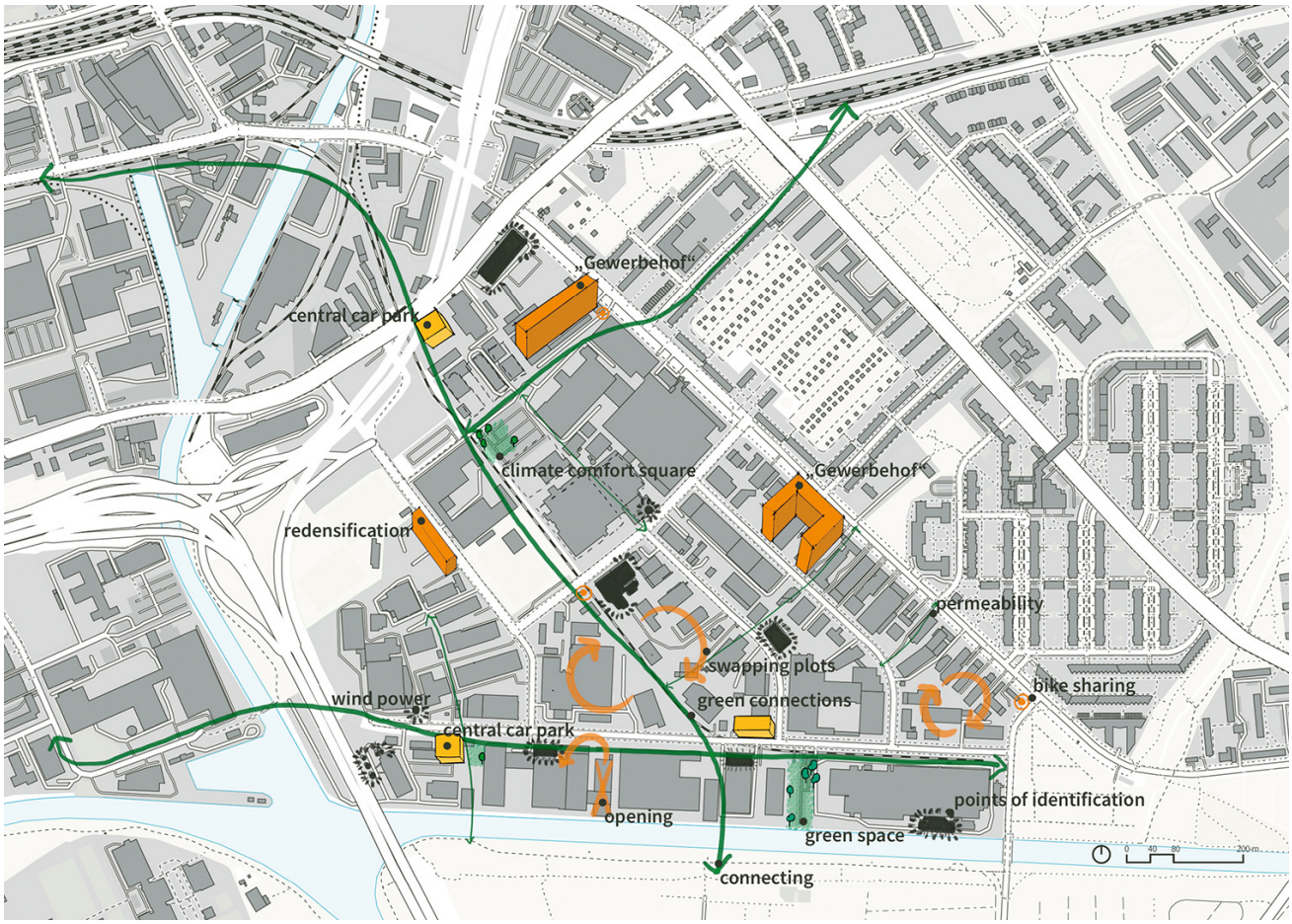

Figure 6. Test design for the Grenzallee industrial area.

preserved for less flexible businesses. Public spaces and access roads should be qualified, with attractive bicycle and pedestrian connections established. Central car parks (*Quartiersgaragen*) and car-sharing facilities can be promoted, while underutilised areas can be repurposed. Train tracks and waterways can be (re)activated for delivery logistics. Planting trees combined with infiltration trenches or roadside infiltration swales can improve water management and cooling. There should also be an upper limit on surface sealing for company properties or green spaces (*Klimakomfortplatz*; SenStadt, 2018).

The Grenzallee commercial and industrial area requires intensive renewal due to a large renovation backlog and the preservation of existing buildings. However, these circumstances also present opportunities for climate-proofing, including climate adaptation measures such as greening, unsealing, and traffic flow changes. Collaboration among businesses and the municipality can facilitate the implementation of small-scale climate adaptation interventions. Mixed-use developments and industrial diversity can prevent commercial gentrification and the displacement of existing businesses. Preserving a mix of industries and production areas is essential for the area's future (C. Mehner, personal communication, 9 September 2021), while balancing modernisation between exploiting trends of upgrading to improve climate adaptation and maintaining artisan and manufacturing industries.

3.6.2. Backcasting Analysis of the Funkerberg Suburban Area

If additional land consumption is justifiable at all, it must meet demands for climate adaptation, soil preservation, and emission-free transport. To this end, enforceable climate-proofing should be incorporated into (preparatory) land-use plans and funding incentives when awarding land. Large-scale businesses migrating from Berlin to suburban hinterlands contribute to high land consumption along Berlin's commuter belt even though there is still untapped potential in existing areas. This contradictory situation is known as the building land paradox (Davy, 1996), where suburban municipalities are pitted against each other. The test design highlights the importance of anchoring measures that promote space-saving density and profiling within the area. Only with this profiling and the spatial concentration of uses within a central spot in the area can a potential new business park serve as a flagship for climate-proof urban development and sustainable architecture. However, it must be ensured that climate-proofing one area is not used as a justification for further greenfield developments.

The backcasting analysis revealed that Funkerberg was the only viable location for commercial development in Königs Wusterhausen (J. Glase, personal communication, 26 January 2022), making it crucial to provide cornerstones for optimising the trade-off between land consumption and climate adaptation measures. To prevent further land consumption, an inter-municipal or regional land pool could be established. Enhancing the footprint of the area involves various architectural and land-use solutions to save open spaces as portrayed in Figure 7, such as concatenated industrial halls or multi-storey commercial buildings (*Gewerbehof*) with separate storage or shunting areas.

To support climate-proofing, an array of climate adaptation measures (e.g., emission-free traffic or a hydrogen filling station) should be installed, and a strategy for cycling infrastructure and stationary traffic is necessary. A central car park (*Quartiersgaragen*) with charging points for electric cars can be established, and parking spaces on company property can be reduced in size to promote effective use of the facility. The development should prioritise sustainable building materials, such as wood with PV systems on green roofs. The forest should be preserved by creating an appropriate protective strip between the new development sites and insect-friendly greenery with native and climate-adapted species should be planted throughout the area. To foster social cohesion and community building, a central site for social interaction with several services (e.g., cafeteria, event rooms, day care) could be established. Finally, properties should be transferred into a diverse ownership structure to ensure future municipal intervention capabilities.

3.6.3. Backcasting of the Peripheral Lauchhammer-Süd Area

To attract future-oriented industries, Lauchhammer needs an integrated vision with regard to climate-proofing and cost-benefit ratio. Its location between Berlin and Dresden, with a decent motorway connection and affordable land, could attract large-scale and automated production facilities, such as those in renewable energy and biotech sectors (Figure 5). Those facilities allow for economies of scale when implementing climate adaptation measures. To better manage the transition between industrial and residential areas in Lauchhammer-Süd, the allocation of land for small and medium-sized enterprises in the south and east of the area should be considered in order to prevent further encroachment of residential development (Roost et al., 2021). The existing railway lines in the south of the area could serve as transfer and access points for public and freight transport with potential to create a genuine commercial centre with a multi-storey utilisation. Lauchhammer-Süd currently relies heavily on car usage, but providing new infrastructure for electric vehicles, such as charging stations, could contribute to a shift in modes of mobility. Lauchhammer's economy is hindered by a lack of skilled workers and young people, which is partly due to a need for improvement in the quality of life in the municipality (Liepelt et al., 2021; Stadt Lauchhammer, 2015). To address this, green spaces in the land-use plan should be made accessible for recreation and used as a stepping stone for a bicycle and

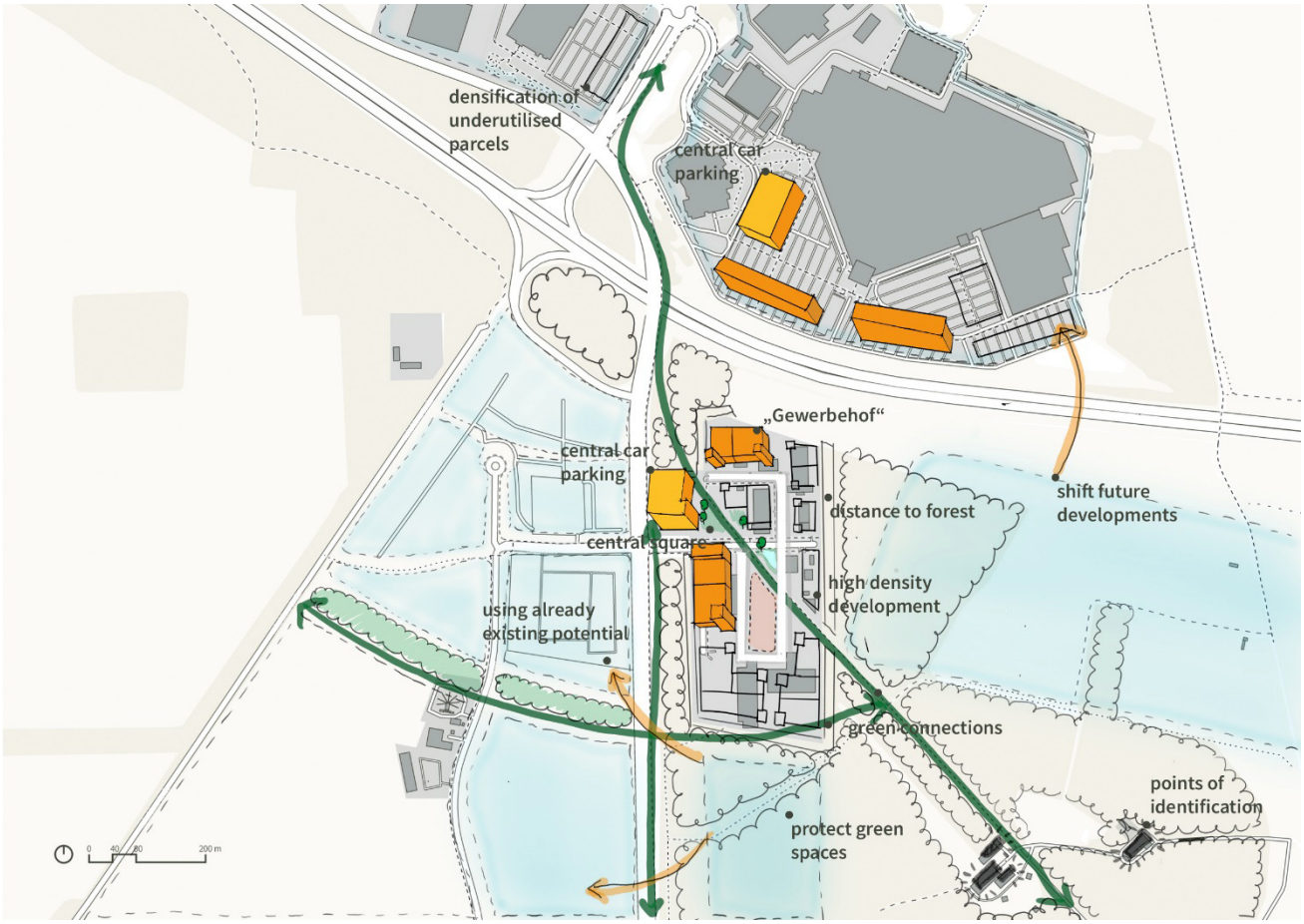

Figure 7. Test design for the Funkerberg industrial area.

foot connection between the different areas. Land in the north-eastern part of the area should be saved to address challenges in finding compensatory areas for new developments (A. Fischer, personal communication, 7 December 2021). A regional land pool or transregional partnership with another municipality along a transport life line with complementary needs (e.g., the Grenzallee area) could be set up to distribute commercial and compensatory land (Hardraht & Uhlig, 2019). In this model, vacant industrial areas could be offered as compensatory sites, either by receiving compensation payments or by allowing sites to be redeveloped in other suitable locations.

Lauchhammer-Süd's built-up area is scattered throughout the municipality due to past lignite mining as building on post-mining areas is generally not recommended (Liepelt et al., 2021; Stadt Lauchhammer, 2015). Notwithstanding, parts of the new commercial and industrial areas have been designated on adjacent greenfields, resulting in additional land consumption. In order to attract urgently needed skilled workers, the municipality's dispersed spatial structure should be upgraded and enhanced to improve quality of life, education, and leisure (Funk & Leuninger, 2014). Lauchhammer's leeway to enforce climate-proof governance is limited due to its economic situation. Currently, the success of future climate adaptation measures will largely depend on the willingness of prospective investors and businesses, as well as brave novel building laws (Roost et al., 2021). However, the municipality must not become a marginal site for commercial enterprises unwilling to transition to a climate-friendly economy, as conventional processes do not guarantee economic success. Potential solutions include attracting future-oriented companies to complement the value-chain with neighbouring sites such as Schwarzheide or regional partnerships with distant sites in agglomerations such as Grenzallee. The test design for Lauchhammer (Figure 8) shows that climate-proofing areas in need of revitalisation should focus on two domains: creating novel focal points in central areas and renaturing temporary vacant land during periods of low economic activity on the outskirts. Once new businesses are attracted, construction and climate adaptation measures should be established in a central location. This approach could promote sustainable development and improve the image of Lauchhammer-Süd.

4. Climate-Proofing Regional Plans to Adapt Industrial Areas to Climate Change

The objective of our next analysis step is to create a practical guide for place-based climate-proofing from a regional planning perspective by combining the climate adaptation measures developed inductively from case

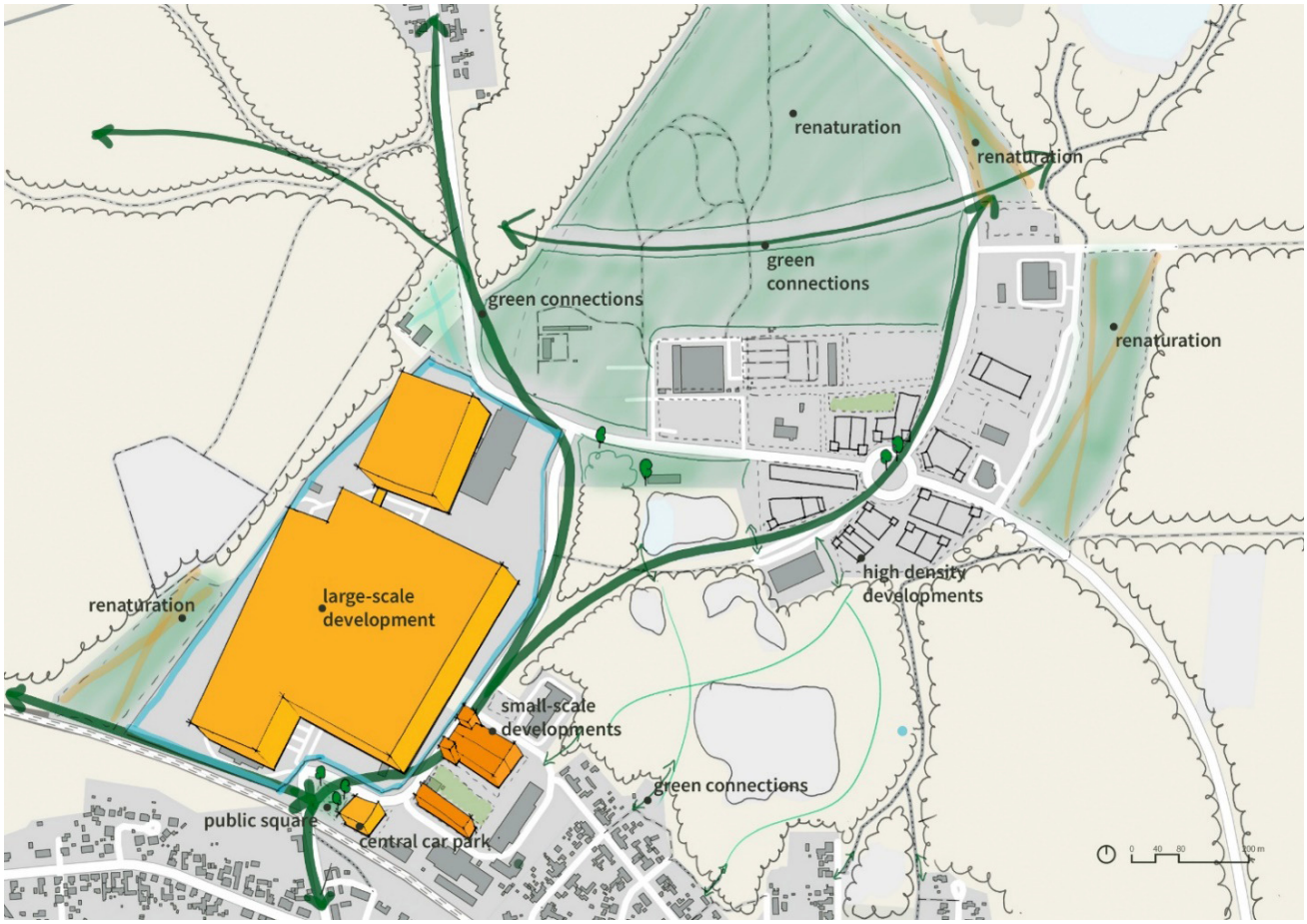

Figure 8. Spatial concept proposal for the Lauchhammer-Süd industrial area.

studies in Section 3 with general standards obtained deductively. The substantial integration of the two topics of climate adaptation and industrial land development is rarely addressed in regional planning practice (Birkmann & Fleischhauer, 2009; Breuer et al., 2020; Roost et al., 2021), despite being a guiding principle in German spatial planning law (*Raumordnungsgesetz*) since 2008. Climate adaptation should be included as a cornerstone in commercial development concepts rather than as a separate topic or plan (Osenberg et al., 2013).

To address the deficiency in implementing climate adaptation in commercial areas, better integration of the two topics is necessary. The concept of "climate-proofing" offers a solution by examining and adjusting plans and instruments to enhance resilience against current and future climate impacts (Birkmann & Fleischhauer, 2009). Unlike traditional environmental assessments, climate-proofing considers the project's vulnerability to the effects of climate change. This approach has already been successfully applied in infrastructure sectors like water and power supply (European Commission, 2021b). Originally intended for development cooperation, climate-proofing is now being discussed as a tool to integrate climate adaptation into urban and regional planning (Ahlhelm et al., 2020; Birkmann & Fleischhauer, 2009; Dosch et al., 2016; Fichter & Hintemann, 2012; Greiving et al., 2011).

Although possible in German planning law, controlling the spatial distribution of commercial and industrial areas through formal regional plans is rarely practiced (Schmitt, 2016; Wagner, 2021; Zaspel, 2012). Integrating climate adaptation measures into informal commercial development plans would provide a cost-effective approach that impacts other instruments such as formal regional plans (Veres-Homm et al., 2019). Hence, the objective in the last step of the backcasting method is to create a practical guide for climate-proofing existing regional plans with regard to industrial areas. The goal is to combine the standards obtained deductively from the literature with the inductive climate adaptation measures from the case studies. Below we outline an inventory of guidelines with differentiated place-based measures and general standards for climate adaptations in industrial areas to be integrated into regional planning.

The Berlin Climate Adaptation Concept of 2016 called for "making existing planning instruments climate-proof" (Reußwig et al., 2016, p. 5), but the instructions remain vague. At the same time, guidelines with differentiated place-based measures and general minimum standards for climate adaptation are necessary for effective climate-proof regional planning, reflecting the diversity and idiosyncrasy of regions.

To attract new investors, the Office for Economic Development in Lusatia currently observes that "central

to all investment enquiries are sustainability, climate neutrality [and] resource efficiency, in addition to the endorsing locational factors for settlements" (Niederlausitz Aktuell, 2022, para. 3). The objective of future regional commercial and industrial concepts for Berlin and Brandenburg must, therefore, include the climate adaptability of such areas as a reason for attracting new investors in addition to location-specific factors related to renewable energies. As a first step toward improving the deficit of climate adaptation in industrial areas in Berlin and Brandenburg, we propose identifying starting points within existing planning instruments into which climate adaptation measures can be integrated. In Berlin, commercial and industrial development and climate adaptation have been addressed in separate urban development plans to date (*Stadtentwicklungsplan Wirtschaft* and *Stadtentwicklungsplan Klima*) but are not fully developed yet, while there are currently no spatial plans for either topic in Brandenburg. The regional development concepts of the municipalities in Brandenburg (*Regionale Entwicklungskonzepte*) are compatible with Berlin's plans, but they would likely be overburdened if climate adaptation were to be included as a separate thematic field, as seen in the confusing diversity of climate mitigation concepts at this level in Brandenburg (Ministerium für Infrastruktur und Landesplanung des Landes, 2022).

4.1. Step 1: Defining Types of Commercial and Industrial Areas and Their Individual Development Goals

A solid database and the use of standardised and reliable GIS data are indispensable for making strategic decisions about commercial and industrial development. Both Berlin and Brandenburg are in the process of implementing such GIS systems (Berger et al., 2020; SenStadt, 2020). This should be used as an opportunity to accomplish two things: ensuring reciprocate compatibility and comparability of information in and between the states, and integrating climate adaptation and mitigation standards under the framework of climate-proofing.

4.2. Step 2: Place-Based Climate Adaptation Measures for the Three Types of Commercial and Industrial Areas

Climate adaptation must also be individually tailored to the different needs of the commercial and industrial areas in the respective region. Place-based measures have been brought to the fore by the inductive findings in our case studies, where specific links between climate adaptation and types of commercial and industrial areas (types 1–3) are found. However, this article shows that commercial and industrial areas benefit more from place-based climate adaptation measures according to their specific type and differentiated needs.

For *modernisation* and *preservation* (type 1) areas, small-scale and customised measures are favourable to increase climate adaptation, such as green roofs, unsealing of parking spaces, and redesigning overly wide streets (Figure 9):

- Full utilisation of existing planning legislation
- Densification through stacking of commercial areas
- Restructuring and better utilisation of land areas
- Exclusion of mixed use, multiple use, and multifunctionality to prevent displacement
- Many small greening measures for a cumulative effect
- Obligation to unseal surfaces on company premises
- Re-opening of fresh air corridors and integration to surrounding neighbourhoods
- Rental bicycles or car-sharing options

For the *new development* (type 2) area type, it has been shown that compact, dense facilities should be strengthened by climate-adaptation measures (cf. Figure 10). These areas should be designed around a nucleus in a land-saving manner:

- Space saving urban design (e.g., shared delivery and storage areas)

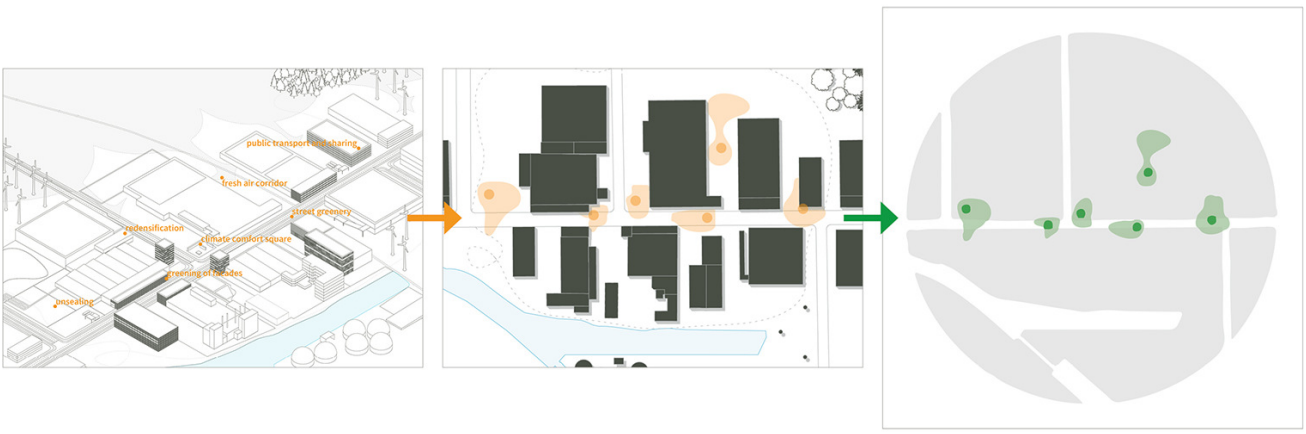

Figure 9. Spatial strategy for adapting *modernisation* and *preservation* (type 1) in commercial and industrial areas.

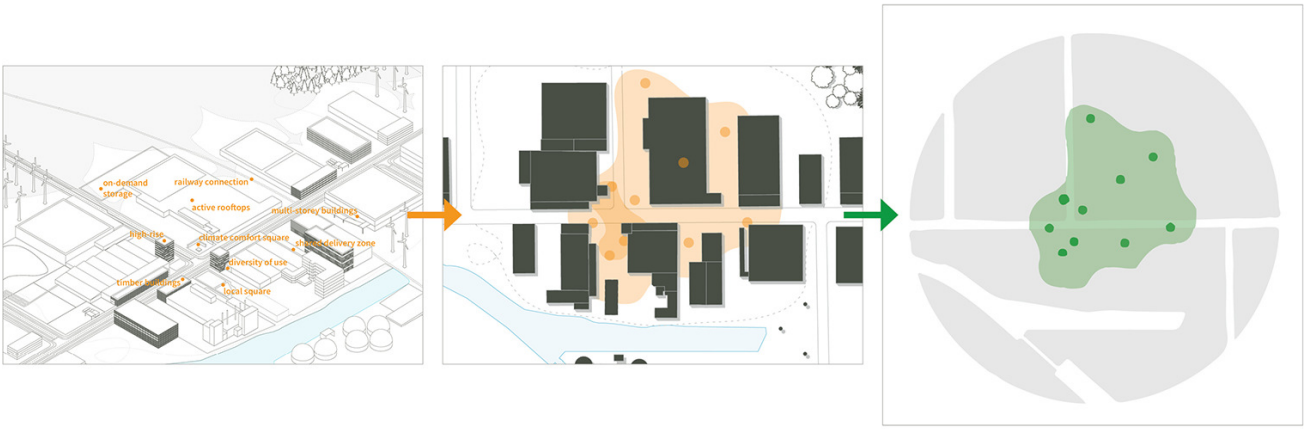

Figure 10. Spatial strategy for adapting *new development* (type 2) in commercial and industrial areas.

- Commitment to multi-storey construction (e.g., vertical logistic flows)
- Required multiple use and multifunctionality
- Funding guidelines should also incentivise climate adaptation
- Tailor-made planning regulations with a focus on climate adaptation
- Establishment of a sustainable ownership structure (mix of municipal ownership, leasehold, and private land)
- New developments only in connection with the establishment of inter-municipal industrial areas or pools
- Required train connections for new developments

For the *revitalisation* (type 3) area type, the spatial anchoring of climate adaptation measures is two-fold. On the one hand, at the margins of the area by means of renaturation or green connections with the surroundings (Figure 11); on the other hand, climate adaptation measures need to be conflated within a central point to attract desirable new economic activities. This promotes both the revitalisation and the improvement of climate adaptability in the areas:

- Mix of huge spaces and smaller structures
- Restructuring and better utilisation of land areas
- Multiple use and multifunctionality in a central location (an invigorating mix and critical mass is especially important for this type)
- Connected to the surroundings by landscape and urban design
- Measures for permanent and temporary greening and unsealing
- Prevention of forest fires by establishing green corridors
- Interregional cooperation with complementary urban commercial and industrial areas
- Profiling of future investors is crucial for the climate resilience of the site
- Restructuring towards a sustainable ownership structure (mixture of municipal ownership, heritable building rights, and private land)
- Modification of existing planning law to integrate more climate adaptation measures
- Establishment of (virtual) inter-municipal land pools to improve marketing and allocation of spaces

Figure 11. Spatial strategy for adapting *revitalisation* (type 3) in commercial and industrial areas.

4.3. Step 3: Climate Adaptation Standards for Commercial and Industrial Spaces in Berlin and Brandenburg

Although the above-mentioned measures are tailored to the individual needs of the three exemplary types of commercial and industrial areas in this study, the following requirements should apply universally to all industrial areas in Berlin and Brandenburg. The reason for implementing general standards for such areas stems from the results of the case studies, interviews, and test designs above. It was shown that although the three stylised types require place-based approaches, several overarching climate adaptation measures can be translated into standards. On this basis and in accordance with planning literature (see Section 2.4), the present study developed general standards for climate adaptation related to minimum requirements for four aspects: building quality, heat prevention in outdoor spaces, precautions against urban flooding, and transformation of transport.

Building quality:

- Obligation to use sustainable building materials (e.g., wood, clay, or recycled products)
- Application of building materials with high albedo value
- Specification of a percentage of green roofs or façades
- Percentage of self-produced energy from renewable sources
- Insurance of excellent building insulation and ban on air conditioning in social and office spaces

Heat prevention and promotion of biodiversity:

- Minimum size of evaporation or infiltration areas in relation to the total area
- Planting of continuous roadside greenery with trees on the main axes of the industrial areas
- Application of material in sealed open spaces with high albedo value
- Integration of small-scale neighbourhood greenery and creation of high-quality open space per sqm of industrial space or employee
- Selection of climate-resistant and native plant species

Prevention of urban flooding:

- Establishment of a maximum percentage of sealed surface area allowed on properties
- Continuous creation of infiltration swales along the greenery accompanying the main roads
- Use of porous surfaces or turf stones on manoeuvring and storage areas

Traffic:

- Obligation to install cycling lanes on the main roads/retrofitting of bike paths
- Obligation to install quality bicycle parking facilities on company property
- Creation/provision of high-quality footpaths
- Prohibition of ground-level parking spaces on company property as well as alongside roads
- Obligation to build and operate a neighbourhood car park
- Promotion of sector coupling in electromobility and hydrogen technology for commercial transport

5. Conclusion and Outlook

This article raises awareness, offers practical guides, and contributes to the advancement of existing regional planning instruments by integrating place-based climate adaptation measures and standards within commercial and industrial areas by utilising the concept of "climate-proofing." The process of climate-proofing results in the integration of (general) climate adaptation standards into planning governance at the regional level. The standards were derived from place-based climate adaptation measures at the local level. This multi-scalar and place-based perspective allows for relevant points of reference and widens operational ranges even for disadvantaged industrial areas. Integrating climate adaptation into strategic regional planning has the potential to define an entirely new guiding principle in practical planning and conforms with recently published political frameworks and practical guidelines (European Commission, 2021a; Schramm et al., 2023). New, robust structures and convincing images could entrench climate mitigation and adaptation as self-evident standards for planning under the roof of climate-proofing—just as fire safety guidelines were enshrined in German planning regulations a century ago.

Theoretically, the article connects and integrates the topics of climate adaptation, commercial and industrial areas, and regional planning by means of climate-proofing regional plans. In this regard, the concept of climate-proofing acts as an umbrella and unites both standards and measures for climate adaption (and even mitigation; Birkmann & Fleischhauer, 2009; European Commission, 2021a; Schmitt, 2016). The practical guide for climate-proof regional plans developed in Section 4 incorporates the empirical findings from our backcasting analysis, thus taking into account local considerations and generalising them into a comprehensive inventory of standards (Ministerium für Infrastruktur und Landesplanung des Landes, 2022). However, it also maintains the necessary flexibility to incorporate locally specific measures. Moreover, it takes into account the economic reality and fierce competition of such areas in global production networks (Beyer et al., 2020;

Hagemann & Beyer, 2020) and opts for inter-municipal and regional cooperation (Veres-Homm et al., 2019) in order to avoid a municipal race-to-the-bottom and left-behind places (Dierwechter, 2021; Pike et al., 2023).

The suggestion to systematically anchor climate adaptation as a basic principle in existing strategic planning instruments at the regional level not only enhances intra-regional cooperation but also allows for the more efficient utilisation of existing areas. This also creates the necessary unassailability assessment (*Abwägungsfestigkeit*) to successfully impact future projects in Germany (Diepes, 2018). With the increasing political significance of climate change, as well as the funds, measures, and regulations earmarked for it, it is crucial for spatial planning to define suitable standards, particularly for commercial and industrial areas. This is essential in terms of responding appropriately to the challenges and opportunities of climate adaptation. Regional planning is uniquely positioned to overcome sectoral thinking and implement the cross-cutting issue of climate adaptation.

Commercial and industrial areas can become sustainable role models for urban planning with renewable materials, green spaces, and innovative traffic solutions. Climate-proofing must be anchored in regional planning to achieve this vision. The days of voluntary action are gone, and the building and planning culture of tomorrow will emerge from creative design and governance responses to the main challenge of the future: climate change.

Conflict of Interests

The authors declare no conflict of interests.

Supplementary Material

Supplementary material for this article is available online in the format provided by the authors (unedited).

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