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URBAN PLANNING

Planning and Managing Climate and Energy Transitions in Ordinary Cities

Volume 9

2024

Open Access Journal

ISSN: 2183-7635

Edited by Agatino Rizzo, Aileen Aseron Espiritu, Jing Ma, Jannes Willems, and Daan Bossuyt

Urban Planning, 2024, Volume 9
Planning and Managing Climate and Energy Transitions in Ordinary Cities

Published by Cogitatio Press
Rua Fialho de Almeida 14, 2º Esq.,
1070–129 Lisbon
Portugal

Design by Typografia®
http://www.typografia.pt/en/

Cover image: © HemantMandot from iStock

Available online at: www.cogitatiopress.com/urbanplanning

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Urban Planning
2024 • Volume 9 • Article 8158
https://doi.org/10.17645/up.8158

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ARTICLE

Open Access Journal

From Social Barriers to Transformative Planning in Energy Transitions: Learning from Norwegian Planners' Perspectives

Bradley Loewen

Department of Interdisciplinary Studies of Culture, Norwegian University of Science and Technology, Norway

Correspondence: Bradley Loewen (bradley.loewen@ntnu.no)

Submitted: 30 January 2024 **Accepted:** 17 April 2024 **Published:** 29 May 2024

Issue: This article is part of the issue "Planning and Managing Climate and Energy Transitions in Ordinary Cities" edited by Agatino Rizzo (Luleå University of Technology), Aileen Aseron Espiritu (UiT The Arctic University of Norway), Jing Ma (Luleå University of Technology), Jannes Willems (University of Amsterdam), and Daan Bossuyt (Utrecht University), fully open access at https://doi.org/10.17645/up.i346

Abstract

This study investigates social barriers in Norwegian urban energy projects from the planner's perspective, bridging institutional and reflexive approaches in the field of planning. Compared to technological barriers encountered in the energy transition, social barriers have received relatively little attention. While the former implies a need for hard technological fixes, social barriers cross sectoral dimensions and can potentially be transformed through strategic action during the life of a project. When planning energy transitions under the popular guise of smart and sustainable cities, social barriers arise in the context of urban experimentation, which challenges institutional constructs, participatory planning principles, and knowledge. These aspects are addressed from the planner's perspective through analysis of planners' experiences in seven energy pilot and demonstration sites in Norway. The results identify categories of social barriers related to the understanding of a shared vision amongst stakeholders, lowered ambitions over the course of a project, lack of user involvement, and structural constraints to planning. A framework for a deeper understanding of social barriers is proposed, extending to the notion of planners' transformative agency to support sustainability transitions, which has the potential for future enrichment through the addition of cases and application in other fields of sustainability transitions.

Keywords

demonstration sites; energy transition; Norway; social barriers; sustainability transitions; transformative agency

1. Introduction

In recent years, the energy transition has become a crucial topic for sustainable urban planning and development, connecting discourses on smart cities (Balest et al., 2019; Mooses et al., 2022), green growth (Loewen, 2022), and citizen participation (Chilvers et al., 2021) in the era of climate change and global development goals. Following the 2015 Paris Climate Agreement and the adoption of the United Nations Agenda 2030 and Sustainable Development Goals (United Nations, 2015b, 2015a), planners have been tasked with translating complex goals, strategies, and targets from international and national levels to their local contexts. While planners have carried the mantle for sustainability in their communities since the 1980s, often privileging the knowledge, capacities, and experiences of high-profile metropolises (for example, C40 cities; see https://www.c40.org), the energy transition has the potential to funnel targeted actions for meeting sustainability challenges down to a "world of cities" (Robinson, 2005) including out-of-centre and small and medium-sized urban areas. At the same time, the localisation imperative has the potential to further stress the already limited capacities of ordinary cities and the roles and abilities of planners who find themselves charged with leading cities and their inhabitants towards sustainability.

Knowledge, participation, and consensus building have been recognised as continuous challenges in planning for environmental sustainability (Calderon et al., 2022; Plüschke-Altof et al., 2023; van den Hove, 2006). This is also the case in planning for the energy transition, as planners are confronted with the need to integrate highly technical and specialised knowledge while coordinating, educating, and convincing stakeholders with diverse and conflicting interests to collectively achieve a transformation of the built environment, all while adhering to democratic planning principles. Despite the opportunity for planners to integrate energy transition into sustainable urban development, aided by universal policy goals and technological availability, there is a shortage of studies linking planning with energy transition from a social rather than technological development perspective (cf. the "smart cities" literature). This article thus explores the urban energy transition in Norway, a country widely considered to be a leader in decarbonisation and use of renewables (International Energy Agency, 2022), despite critique as an oil and gas producer (Korsnes et al., 2023), by investigating the experiences of planners across a range of renewable and sustainable energy pilot project and demonstration sites.

Norway has benefitted from a strong legacy of technologically and, more recently, socially-oriented research and innovation programmes initiating energy transition projects since the 2000s, for example, through technology and social-science-oriented Centres for Environmentally Friendly Energy Research (FME) funded by the Research Council of Norway (RCN). While these programmes have primarily been driven by a need for technological development, tested through urban experimentation in pilot and demonstration sites, the current study shifts attention from planning technological to social aspects, in line with the priorities of recent research and innovation agendas (e.g., the European Green Deal and "human-centred city"; European Commission, 2019a, 2019b). Thus, the study aims to learn from the experiences of pilot and demonstration sites from the social perspective, specifically, by focusing on social barriers to implementation in urban energy projects.

In mature research environments like Norway, social barriers to sustainability transitions pose the key remaining challenges to socio-technical system transformation. Even so, social barriers have mainly received indirect attention in the literature, alongside enablers, and an indicative agenda for their investigation is

lacking. From a socio-technical system perspective, social barriers are highly contextual, and research approaches may depend on types of technological interventions (e.g., wind, solar, or hydropower installations) as well as researchers' focus on different types of stakeholders and communities. Understandably, the case-based literature tends to be eclectic, referring to the particular theoretical underpinnings or goals of particular projects rather than seeking to inform a theory or practice related to social barriers. This is apparent, for example, in the grey literature produced around zero emission neighbourhoods (ZENs) in Norway, which count various economic or political regulatory barriers and challenges of citizen participation among their findings (see Kauko et al., 2022; Vergerio & Knotten, 2024), yet do not intend for serious consideration of social barriers in themselves. Indeed, this has not been the primary objective of the mentioned research programmes. Nonetheless, the eclectic nature of the social barriers literature creates a challenge when seeking to unify learning across cases for feedback to theory. For this reason, social barriers are approached from the perspective of social innovation and planning sustainability transitions. The approach builds on the work of Baer et al. (2021) which analysed social innovation in Norwegian energy transition projects through the key social aspects of citizen involvement, stakeholder interaction, and capacity building, rooted in energy transition policy (SET Plan Temporary Working Group 3.2, 2018). To further work in this area, the article is exploratory in its aim of providing a useful starting point for the study of social barriers in planning, open to enrichment and theorisation from other cases and planning contexts, in support of planning urban energy transitions.

The analytical approach links planning with innovation and transition theories, placing the "urban" energy transition, referring here to the built environment also in suburban and rural areas, in the context of socio-technical system transformation. Building on a growing literature on transformative change in planning for sustainability (Castán Broto et al., 2019; Filion et al., 2015; Plüschke-Altof et al., 2023; Wolfram, 2016), the analysis considers the utility of theories around transformative agency and capacities for planning energy transitions, i.e., planners' reflexivity and institutionalism. In dealing with socio-technical systems and planning, it also adheres to an institutionalist view that acknowledges the structural constraints and agency of planners dealing with physical infrastructure (i.e., the built environment) and communities within local and/or national planning systems.

In the following section, the article backgrounds planning and barriers in socio-technical systems, considering distinctions to be made between technological and social barriers and drawing a connection to planning for transformative change. Section 3 presents the methodology and introductions to the case areas, and Section 4 presents the results of the inquiry into social barriers from the selected pilot and demonstration sites. Finally, a combined discussion and conclusions section considers the results in terms of themes derived from the barriers and their implications for planners and planning practice.

2. Planning for Energy Transitions

2.1. Urban Experimentation and Transformative Change

Planning for sustainability transitions has come to be associated with a culture of experimentation through real-world interventions, especially regarding flagship projects of strategic importance (Ehnert, 2023; Karvonen & van Heur, 2014; Witzell & Oldbury, 2023). Urban experimentation in smart and sustainable cities pilot projects aims to support transformative change in socio-technical systems (Isaksson et al., 2022;

Ryghaug & Skjølsvold, 2021). Yet, amidst the openness of experimentation, there is a degree of uncertainty over what is to be transformed and how it relates to the system. Evidence from the EU's Horizon 2020 (EU H2020) Smart Cities and Communities programme participants illustrates the difficulties of learning from urban experimentation, specifically a lack of process learning (Evans et al., 2021). This can be interpreted in part as a lack of synthetic knowledge, including knowledge of barriers and strategies to overcome them. Recently, scholars have highlighted the need for a critical alignment of goals and values, i.e., the what, how, and why (Isaksson et al., 2022), amongst public actors that can set a path of transformative change in motion beyond the lives of individual projects. By the very nature of urban experimentation, pilot projects have specific objectives, but the outcomes may be relatively open or unexpected. Thus, lacking a common approach to build upon lessons learned from experimentation, the momentum for transformative change can wane by the end of a project.

In order to learn from experimentation, a more structured approach for examining the barriers encountered at various stages of a pilot project is needed, through which researchers stand to benefit from more precise identification of challenges and strategies used to overcome them based on critical reflection of participants. Practically, this has value for the evaluation of demonstration and pilot projects, where barriers are often discussed ad hoc and ex post in terms of individual project findings but are rarely synthesised across projects or contribute to theorisation.

2.2. Social and Technological Barriers to Urban Energy Transitions

Accordingly, in urban experimentation, barriers may be discussed as findings in opposition to drivers or enablers of transition processes, but research rarely takes an interest in barriers as a starting point for inquiry. For socio-technical systems, barriers may be approached from the technological or social (non-technological) perspectives, from which discussions tend to privilege technological aspects that may be readily identifiable in terms of project outcomes that emphasise technological "fixes." Social factors, on the other hand, may influence or even stand alone from technological barriers hindering transitions. Social factors may therefore present more nuanced challenges to address from a social sciences perspective. For energy transitions, the initial interest and reliance on technological innovation has lent increasingly to social aspects of implementation and scalability, as seen through periodic updates to the EU's Strategic Energy Technology (SET) Plan (e.g., European Commission, 2023). In the case of urban energy transition projects—where urban planning meets technological experimentation, piloting, and demonstration in interaction with multiple stakeholders—a variety of social barriers are poised to appear from which planners and other stakeholders can learn.

Recent research on social as opposed to technological innovation can inform an approach to the study of social barriers in urban energy transitions. The theoretical distinction between technical and social innovation follows early understandings of material inventions (i.e., technological or mechanical changes) that could produce multiple social effects, which were to be distinguished from social inventions considered non-material even when enabled by technological change (Ogburn & Nimkoff, 1950). By this view, mechanical or technological elements were not deemed necessary for social inventions. In comparison today, social innovations are often understood as being social in their means (Hoppe & De Vries, 2019). They can also include technological solutions for socially defined needs, as in the case of digital social innovations for sustainability (Dionisio et al., 2024). In the search for an approach to analyse social barriers, it is not

necessary to exclude the technological, but rather, as in the case of urban energy transitions, it is relevant to focus on social aspects of technological development and deployment in a complex built environment filled with socially constructed subjectivities.

In Europe, urban energy transitions target the nexus of sustainable building stocks and transport, moving from the individual building to neighbourhood, district, and city scales. ZENs, and later positive energy districts (PEDs) which generate more renewable energy than they consume, are the key model concepts for integrated energy planning. The SET Plan, which aims to produce 100 PEDs, provides an example of intertwined streams of technological and social innovations (European Commission, 2023). Of these, three domains of social innovation are identified: stakeholder interaction, citizen participation, and capacity building (European Commission, 2018). Given the coordinated research agendas for ZEN and PED deployment in Europe, a valuable literature on experimentation has emerged that considers both technological and social aspects (Baer et al., 2021; Brozovsky et al., 2021; Derkenbaeva et al., 2022; Sareen et al., 2022).

Reviews of the PED literature have determined social aspects to be the least addressed (Brozovsky et al., 2021) and the most polarising among other types, including governance, market, context, incentive, process, and technological factors (Krangsås et al., 2021). Moreover, the consideration for social innovation in PED projects is suggested to increase with experience with PED development and implementation, supporting transformative change in the socio-technical system (Baer et al., 2021). These findings correspond with the growing field of social innovation as it relates to regional energy transitions (Suitner et al., 2022) and socio-technical energy transitions (Wittmayer et al., 2020).

2.3. Planning to Overcome Social Barriers in Energy Projects

Relatively few theoretical connections have been made between the planning and energy transitions literature to date, yet much can be learned to overcome social barriers from wider applications of planning for sustainability. Polarising and contested social aspects can be addressed through planning processes and practices with respect to institutional structures, requirements for public participation, the planner's role as a coordinator of competing interests, and the planner's role in leading toward urban sustainability. Institutional perspectives frame much of this literature. Filion et al. (2015) identified social obstacles to urban transformation from an institutionalist perspective, pointing to the importance of practical knowledge and professional values. Since then, learnings on social barriers can also be drawn from experiences of planning nature-based solutions, which identify structural, relational, and inner conflicts to be navigated by planners when fulfilling their expected roles (Dorst et al., 2022; Plüschke-Altof et al., 2023). Furthermore, research on PEDs suggests a clear role for the planner in mediating polarising social aspects (Krangsås et al., 2021) while being situated in their institutional context.

Whether planners recognise their mediating role in energy transitions and act upon it could potentially influence their own initiative to develop transformative agency in leading toward sustainable development. Related to transformative change, transformative agency describes the ability of actors to collectively transform an activity system, a process dependent on practitioners' knowledge and experience, in a way that redefines the object or outcome of the system (Virkkunen, 2006). In this way, the re-orientation of planning towards sustainability calls upon the exercise of transformative agency in planning, which has so far been

addressed in socio-ecological systems (Plüschke-Altof et al., 2023; Westley et al., 2013; Wolfram, 2016) but not in socio-technical systems (e.g., for energy transitions). Thus, there is an opportunity to develop conceptual linkages between the socio-technical system perspective and the potential for transformative agency, drawing on their common concern with context and agency.

Both socio-technical system and transformative agency theoretical approaches are used to relate strategic action to system change toward sustainability. Moreover, both are context-specific and dependent on relational and structural understandings of actors and systems. A conceptual difference can be seen, however, in the scale of action and change. Since the socio-technical system approach is primarily concerned with technologies in either a market dominance or challenger position, the scale of action accounting for change is often collective and generalised in such a way that makes tracing change down to individual actions difficult. The most commonly used socio-technical system frameworks for sustainability transitions, including the multi-level perspective and transition management (Markard et al., 2012), are particularly focused on the macro or meso levels and lack attention to individual agency. In contrast, the theory of transformative agency can usefully provide a link between individual action and institutional change, supporting a pathway to system-level change based on learning about the actions of specific (types of) actors. Of relevance for the current study, context and agency have been a topic in the socio-technical system context of community energy pilots, drawing attention to policies, culture, visions, and learning from multiple stakeholder perspectives (Ruggiero et al., 2021). The current study takes the first steps to address transformative agency in planning energy transitions, based on examples in Norway, going deeper into the experiences of planners in their shared institutional context.

3. Case Method and Approach

3.1. Case Summary

The study draws on learnings from seven Norwegian urban energy pilot and demonstration sites at various stages of planning and implementation (Table 1), funded by flagship programmes of the RCN, the EU, and Smart Innovation Norway. The selected projects primarily target urban energy transitions through the development of ZEN and PED projects but also include smart city initiatives involving, e.g., the installation of photo-voltaic panels, smart grids, and electric vehicle charging infrastructure. As such, those projects related to RCN and EU programmes have been monitored with respect to their technological ambitions, as reviewed in academic literature (e.g., Baer et al., 2021; Brozovsky et al., 2021) as well as research reports (e.g., Gjertsen et al., 2022; Kauko et al., 2022; Vergerio & Knotten, 2024). Shifting attention to social aspects, this study further contributes to the literature on smart cities, citizen participation, and competing discourses of planning for sustainability in Norway (Gohari et al., 2020; Haarstad, 2017; Oseland & Haarstad, 2022). More specifically, it builds upon the work by Baer et al. (2021) analysing 12 ZEN and PED projects for social innovation, which provided a detailed comparison of project ambitions, technological specifications, and methods for citizen participation.

The sites in focus include both small and large urban and semi-urban contexts across coastal and inland Norway but exclude sites in the capital and largest metropolitan area of Oslo (Figure 1). While this leaves geographical variation in the selection, the cases represent the breadth of an “ordinary” Norwegian planning context, and the focus of the study thereby avoids exceptional cases of globally recognised cities with

potentially outsized resources for transitions (Robinson, 2005). For further understanding of the national context, Norway has a relatively decentralised urban structure whereby nearly 83% of the population lives in urban settlements defined as continuous built-up areas, of which a large proportion comprises small- and medium-sized cities distributed along coastal areas from south to north. Only 10 of nearly 1,000 urban settlements in the country have more than 50,000 inhabitants, and six have more than 100,000 (Statistics Norway, 2023). Unlike pilot and demonstration sites in other European countries, the ones in Norway can be found throughout the country, from the most populated urban centres to comparatively rural and remote communities which still statistically qualify as urban settlements. Likewise, for the planning context, a similar range of stakeholders including planners, research institutes, state agencies, commercial partners, and local communities emerge for the facilitation of the ZEN and PED projects.

The exploratory nature of the study welcomes inherent variation amongst the cases, within the confines of an ordinary planning context in Norway. As such, it is not the intention to control for variation amongst the cases but, taking advantage of this, to gather and reflect on a breadth of planners' experiences around social barriers. Similarly, the potential variation of stakeholder constellations is not of particular concern in this study. Rather, the role of the planner incorporating energy transition into long-term planning and coordination—often

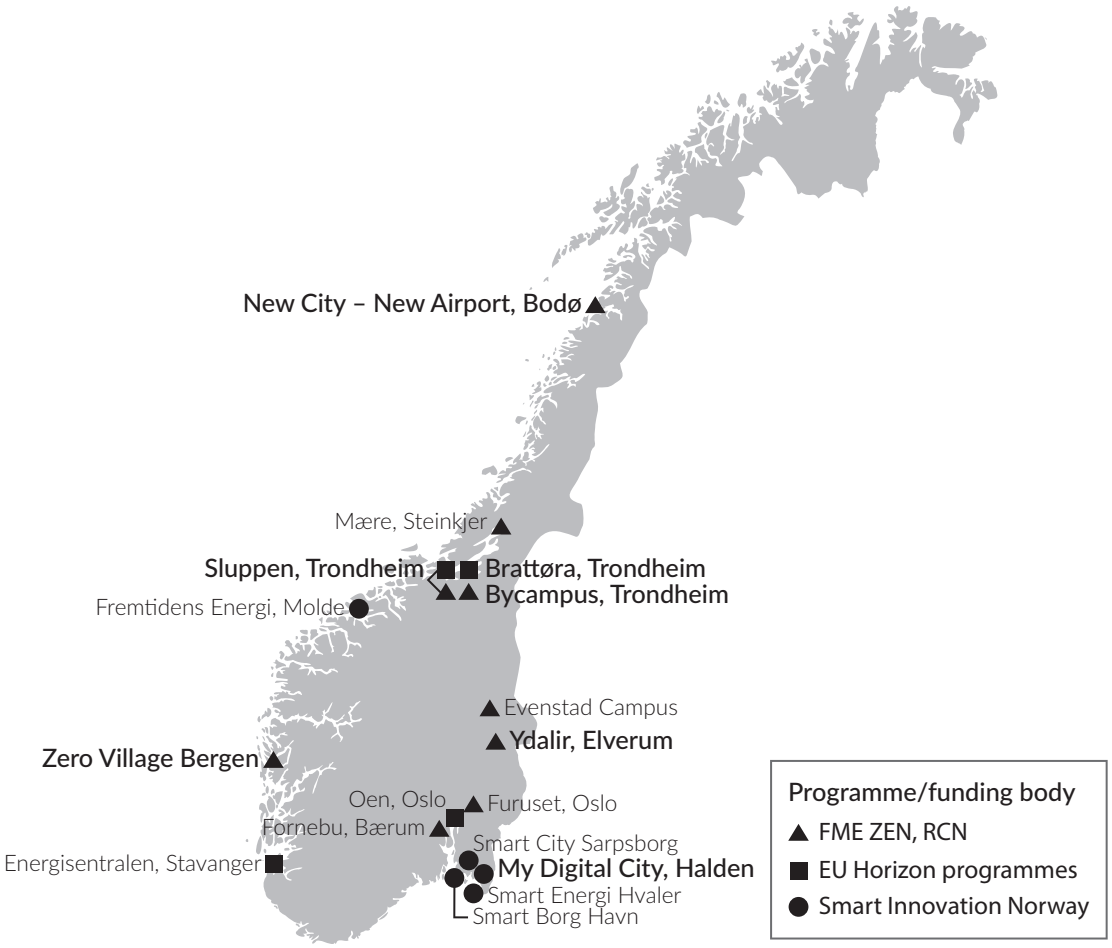

Figure 1. Geographical distribution of urban energy projects considered for the study, with selected sites emphasised in bold. Source: Author's work, adapted from Baer et al. (2021) with open map files from Kartverket.

trailblazing new sustainability initiatives within the bounds of the Planning and Building Act (Kommunal- og distriktsdepartementet, 2008) and the Energy Act (Energidepartementet, 2024)—is taken as a starting point for the inquiry.

3.2. Method

To pursue the aims of this study, the method joins 12 semi-structured interviews with planners and informants from planning adjacent roles, conducted under conditions of anonymity and confidentiality. For each potential case, the official contact persons of individual projects (pilot and demonstration sites) were approached to determine the most appropriate informant. While a municipal planner was usually identified, this sometimes led to a consultant or project manager primarily involved in the planning process, depending on the owner and type of project. This variation was acceptable for investigating the planning perspective, as it was jointly determined that the nominated individuals were the most knowledgeable as experts and first-hand informants for the interview topics.

While 15 potential projects were identified for inclusion from the relevant RCN, EU, and Smart Innovation Norway programmes, it follows that an informant could not be located from every eligible case. This was attributed to either the closure of a project and engagement of relevant informants in new activities, research fatigue at a particular site, or a lack of response from the official contact persons. Several cases additionally involved multiple informants, on the recommendation of the initial informant (i.e., snowballing), or when individual informants had experiences to report on multiple sites. These were the cases for informants in Bodø and Trondheim, respectively, where the projects followed long-term courses of development involving multiple stages of planning and implementation. The resulting set can therefore be seen as a purposeful sample of convenience, nonetheless representing the intended breadth of projects for the purposes of the study.

Even though social barriers were explicitly understood to be the topic of the study, the interviews were framed by the informants' professional roles and experiences in the cases. In this way, social barriers were addressed indirectly according to the timeframes and stages of the projects. The semi-structured interviews followed an interview guide designed to establish the informant's professional background and role as a planner, map stakeholder power and interests, discuss barriers encountered and strategies used to overcome them, and reflect on the planning process, stakeholder interactions (between public/state, private/market, and community sectors), and tools for participation. Due to the different stages of projects, strategies to overcome barriers, and tools for participation were not applicable for all cases. The informants as planners were positioned between the public (state) and community sectors due to their formal obligations, most often as state actors, alongside their professional interests in serving the public good. While public academic institutions and private research institutions form part of the stakeholder constellations, the author of this study had no prior formal or direct relations with the informants or projects under investigation.

Interviews of approximately one hour were conducted both physically and digitally, according to the informant's preference. The interviews were recorded, transcribed and analysed thematically with the aid of written interview notes, and specialist software for analysis was not required. The discussion of social barriers in each project reflected a learning and adaptation process, according to the timeframe and stage of the project, that deepened with accumulated national experience and increasing ambitions for energy

transition, stakeholder involvement, and societal transformation over time. Here forth, the analysis does not intend to be descriptive nor to unpack the cases themselves. Rather, a deeper discussion around understanding and working with social barriers when planning transitions is generated for the benefit of planning practice.

Table 1. Overview of selected projects.

Name of pilot and demonstration site(s), municipality	Project or programme, funding agency, years funded	Type of development	Geographical area, urban settlement size *	Interview
New City—New Airport and Master Plan for Port of Bodø, Bodø	FME ZEN, RCN, 2017–2024	Urban greenfield, airport redevelopment, port redevelopment	Northern coastal regional centre; 42,831 urban inhabitants (2023)	Interviews 10, 11, and 12
Brattøra, Trondheim	Positive City Exchange, EU H2020, 2018–2023	Urban brownfield, port redevelopment	Mid-Norway coastal regional centre; 196,948 urban inhabitants (2023)	Interviews 6, 7, and 8
Sluppen (part of "Knowledge Axis"), Trondheim	Positive City Exchange, EU H2020, 2018–2023 FME ZEN, RCN, 2017–2024	Urban brownfield, mixed-use development	Mid-Norway coastal regional centre; 196,948 urban inhabitants (2023)	Interviews 4, 6, 7, and 8
Bycampus (part of "Knowledge Axis"), Trondheim	FME ZEN, RCN, 2017–2024	Urban brownfield, university campus, and mixed-use development	Mid-Norway coastal regional centre; 196,948 urban inhabitants (2023)	Interviews 1 and 2
ZeroVillage Bergen, Bergen	FME ZEN, RCN, 2017–2024	Urban greenfield, residential district	Western Norway coastal regional centre; 269,548 urban inhabitants (2023)	Interview 9
My Digital City, Halden	Smart Cities and Communities, Smart Innovation Norway, 11 years ongoing	Urban brownfield, building retrofits, and mobility solutions	Southeastern Norway coastal small centre; 26,126 urban inhabitants (2023)	Interview 5
Byplan (Ydalir), Elverum	FME ZEN, RCN, 2017–2024	(Sub-)urban brownfield, residential district	Eastern Norway inland small centre; 15,632 urban inhabitants (2023)	Interview 3

Source: * Statistics Norway (2023).

4. Results

The interviews revealed several themes that can aid researchers and policymakers in understanding and addressing social barriers in energy transition projects. These emergent themes are elaborated below: (a) a lack of understanding or shared goal amongst stakeholders, (b) lowered ambitions over the course of a project than originally planned, (c) a lack of user involvement despite ambitions for a high degree of participation in the planning process, and (d) institutional and/or structural constraints upon the target of the project or planning practice.

The results communicate a range of opinions and experiences of planners involved in concrete energy pilot and demonstration sites in Norway, speaking of mid- to long-term funded projects in small- and medium-sized cities with similarly operating planning departments. Following the themes of the interview guide, it can be seen that the projects tended to engage with a similar range of stakeholders including national, regional, and local level actors from state, industry, and community sectors. Hence, as expected, there was a degree of homogeneity amongst planners in their professional roles, contexts, and activities in the energy transition projects, which can be accepted as reflective of an "ordinary" planning context in Norway.

4.1. Lack of Understanding (Knowledge) or Shared Goal

This first theme relates to a common challenge of both planning and sustainability transitions, that is, the vision of what is trying to be achieved. In urban energy transition projects, a lack of understanding and lack of knowledge about energy transitions amongst all relevant stakeholders, and more generally about the socio-technical implications of bridging urban and energy planning, poses a barrier to achieving the shared vision or goal. This can unfold in multiple ways according to ambition and ability. One informant stated, "Agreeing on the ambitions is very important…that you understand the consequences of it at an early stage" (Interview 4), while according to another, "We have the knowledge to do it, but it is hard to agree on the goal conflicts" (Interview 2). Yet, another was halted by ambition: "We have ambitions…but right now we don't really have a direction, and we don't really know what it involves other than being part of some networks" (Interview 11).

Related challenges for the planner are to navigate different interpretations of the vision by different stakeholders, to build consensus through a common understanding of the goal, and to match the goal to specific work programmes. To complicate this, as ambitions rise for energy transitions, strategies shift from project-specific towards paradigmatic change, which can put planners in an uncertain role leading an open-ended process of experimentation: "It's very easy to agree that you have high ambitions for things, but when you get to the practicalities, you're not quite aware that it meant you have to do things in a different way" (Interview 4).

Learning the implications of having high ambitions along the way forces a confrontation in the planner, as planning tools and processes present incompatibilities between ambitious goals and practical plans to be achieved through concrete investments. This is especially important for reconciling sectoral differences between urban planning and energy planning. According to one informant: "Planning and the energy sector need to understand each other better. But we also need to work at an early phase together to sort of plan how an area should look" (Interview 12). As another informant opined, a feasibility study does not

necessarily follow through to the detailed regulation (e.g., for a municipality) or to implementation through the cooperation of multiple stakeholders (e.g., for a real estate developer).

Furthermore, another informant reflected that as ambitions rise and spread with experience, the focus of attention shifts from convincing a core set of committed actors, to behavioural change amongst the general public to shift demand, which both need coordination to justify investments from commercial actors. While experience potentially improves the planner's ability to get things done, it can also lead to the next theme, which is an adjustment of the ambitions to suit the process.

4.2. Lowered Ambitions

Partly as a result of the former, planners' experiences indicate a lowering of ambitions to put plans into practice. In projects related to FME ZEN, for example, where multiple pilots are progressing towards similar ambitions, municipalities, and developers have the potential to generate competition and "show off" their achievements, but at the same time, practical success may depend on picking the "low hanging fruit" of technological solutions (Interview 9). Despite setting high ambitions for energy transition projects, the ambitions tend to be lowered when put into practice due to, for example, a lack of incentives for the involved stakeholders and a lack of regulatory conditions clarifying the way toward implementation. Informants from ZEN pilots, including some of the earliest examples in Norway, reflected on having few incentives to get private developers to relate to higher ambitions. On the system level, technological aspects controlled by private actors or monopolies have been resistant to change without political direction (Interview 8). On the local level, planners have been uncertain whether guidelines brought through planning processes would become voluntary for private developers (Interview 3). Working with relatively conventional processes, planners could initially use zoning and detailed regulations to achieve their energy ambitions in public buildings like schools and health centres, offering possibilities for energy exchange (Interview 4).

With growing knowledge and experience, there was a general belief that public actors such as public real estate companies could influence private actors to raise their ambitions, a notion confirmed by the growing commercialisation of ZEN and PED projects over time (Baer et al., 2021).

4.3. Lack of User Involvement

User involvement through participatory planning is a standard element of the planning process but continues to be seen as lacking. Traditional methods relying on planning tools have potential but mixed results, as they struggle to communicate complex challenges like energy transition. To overcome the resource limitations of planners, research institutes have a role as project participants to support planners by facilitating user involvement and communicating complex challenges. A range of strategies and planning tools are needed to reach different types of users according to the local conditions, and the scope of users targeted could be widened to cross sectors. The informants related testing a variety of methods for user involvement in the local context through urban experimentation, which requires the support of research institutes and commercial (technical) actors. Living labs were named as one possibility for municipalities to garner user interactions and involvement in the planning process. Used in the larger cities hosting multiple pilots, notably Trondheim, the digital and democratising activities aimed at user involvement could be seen as "planting seeds" for ideas around local energy (Interview 6).

There may be different challenges and strategies needed, however, for involving users in sites that are more remote and have fewer inhabitants to give input, or for involving users according to the functional social structure of an area, for example, instead of inhabitants, to involve employers and people who work and pass through those areas. Additionally, potentials and implications for user involvement may differ between greenfield and brownfield developments. For the former, there is a need to align planning processes (planners) with energy transition (energy experts) from the earliest stages, i.e., in setting the vision and master plan. While this requires detailed foresight to plan investments—both financial and technological—it was thought to be easier to plan ambitious goals in greenfield areas than to transform brownfield areas (Interviews 1, 10, and 12), partly due to the stakeholders involved.

From the smart cities perspective, user involvement can be a means of generating consensus around an ambitious vision through information sharing. One informant related their experiences with smart sensors to energy and mobility, believing that making information available to users on consumption and costs could impact behaviour (Interview 5). Nevertheless, the informant highlighted the uncertain regulatory restrictions on the uses of such data, requiring political attention.

4.4. Institutional and/or Organisational Structural Constraints

Despite intentions, planners face a range of structural limitations, for example, to go beyond basic regulatory requirements and the (public) resources afforded to them, with respect to their role within institutional and organisational constraints (financial, regulatory), the local culture around innovativeness and risk-taking, and the individual personalities in key roles who may be influential in setting local ambitions, navigating practical processes, and bridging networks. Of particular importance for planning, the Planning and Building Act as the most relevant regulation does not enable placing limitations on energy sustainability, for example, to require a zero-emission building or neighbourhood, which creates uncertainty for planners translating ambitious master plans to detailed local plans (Interview 10). Aside from public engagement through user involvement, there is a need for political engagement at the national level to develop the space for effective urban experimentation from both urban planning and energy planning perspectives (Interviews 6 and 12). While the designation of an area for urban experimentation has been successful in seeking project-specific dispensations, there is a need for national alignment in legislation that would set "parameters to follow" or "some equal treatment" for pilots to enable and streamline their possibilities to develop and test solutions (Interview 12). In detailing how one project attained the necessary dispensations to enable energy exchange between buildings, strategies of anchoring municipalities' positions, aligning positions on the county level, and building coalitions and partnerships to influence the national level were seen to be effective (Interview 8), in addition to direct channels to the national level (Interview 12). Thus, there has been an essential role of networking to navigate institutional and organisational constraints that operate on a system level.

Further to the structural constraints characterising the system, the informants relayed dependencies within institutions, as stakeholders, that vary in size and culture with respect to decision-making processes, affecting speed and agility, and with respect to risk aversion, affecting innovation and uncertainty. On an interpersonal level, they also relayed dependencies on the role of personalities affecting project ambition, initiative, cooperation, and networks. These were particularly important for dealing with regulatory constraints and re-ordering conventional workflows to account for longer horizons in planning investments and technical infrastructure (Interviews 6, 8, and 12).

5. Discussion and Conclusions

As potential categories of social barriers, the themes recall aspects of strategic planning, including visioning and participation, set amidst the challenging and often contentious context of planning for sustainability. Nevertheless, for energy transitions, the social barriers do not merely pose an inconvenience to the realisation of planning goals that could otherwise be pushed through a planning process, threatening legitimacy. Moreso, social barriers have the potential to cripple projects that are otherwise technically feasible, funded and have also gathered political support (on controversies around wind farm installations, see, e.g., Korsnes et al., 2023; Saglie et al., 2020), leading to potential cancellation and public backlash against further measures. Planning researchers, practitioners, and policymakers need a framework for the deeper and more reflective consideration of social barriers in practice.

The categories identified could be seen as a first step towards a way of working with social barriers, centred on the actor tasked to overcome them, when aiming for a planning practice that supports transformation. Going further, the next step is to consider a framework that puts the categories in relation to each other while being open to the addition of further categories over time. Given the inherent tension between the planner's inner role to serve the public good and the outer role structured by the institutional setting (Plüschke-Altof et al., 2023), it is proposed to orient the categories of social barriers on the planner and on the context in which the planner is situated and therefore practising.

Figure 2 demonstrates the categories on two axes to enable deeper reflection in relation to transformative agency: one representing the internal (i.e., personal) and external (i.e., public) arenas in which the barriers play out and the other relating to the formality or institutionalisation (i.e., formal or informal) of the social process associated with barriers.

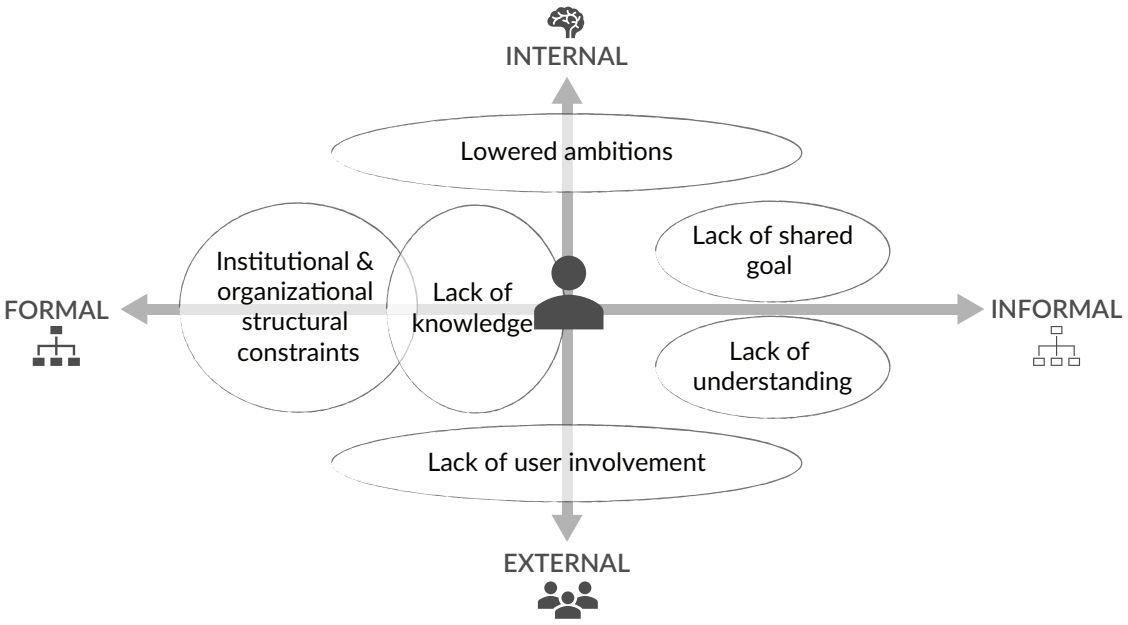

Figure 2. Towards a framework for analysing social barriers.

Through the use of the framework, the researcher would be able to orient challenges upon the inner and outer worlds of the planner and support a more structured approach to thinking about the strategies and specific measures that could be used to address social barriers in relation to "activity system transformation" (Virkkunen, 2006), from the planner to the field of planning. This is currently a theoretical and reflective exercise for the planner to strive toward a practice of transformative planning. For energy transitions, this supports a more active critical reflection on experimentation for transformative change (Isaksson et al., 2022). More practically, the potential transformative change can be traced through the actions and outcomes of the planner as they work through social barriers, requiring a more active role of the researcher in following the planning process. Accordingly, one direction for future research is the continued study of planners' strategies, activities, and outcomes to overcome the named barriers as they navigate the unfinished processes of transition in the examined cases. This study has provided a starting point for such investigation.

A limitation of the approach regards the size and depth of the cases studied, as the interviews represent snapshots in time of a limited number of ongoing projects and the partial perspectives of planners amidst a range of stakeholders. Although the current analysis is based solely on Norwegian planners' experiences of energy transition, the framework can be enriched with experiences from other planning contexts and applications to other fields of sustainability transitions. The recognised institutional aspect opens further potentials for enrichment through alignment with scales, as suggested by the importance of networks at local, regional, national, and international levels. The treatment of the institutional context has been limited in the current analysis to the immediate local but sometimes national contexts in which the planners situated themselves. This was not investigated in further detail here, but Lund et al. (2017) structure formal and informal enablers and barriers according to macro, meso, and micro levels, which could take the institutional aspect of future analyses further. The consideration of scales also points to potential connections with transition frameworks for the analysis of socio-technical systems, like the multi-level framework (Geels & Schot, 2007) or transition management (Kemp et al., 2007). This remains an area for future research.

Acknowledgments

I would like to thank the research participants for their valuable time and insights as well as FME NTRANS and FME ZEN partners, including Daniela Baer, for providing guidance and support.

Funding

The research leading to this article was performed under the Norwegian Centre for Energy Transition Strategies (FME NTRANS) funded by the Research Council of Norway (Project No. 296205) and the Research Centre on Zero Emission Neighbourhoods in Smart Cities (FME ZEN) funded by the Research Council of Norway (Project No. 257660).

Conflict of Interests

The author declares no conflict of interests.

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About the Author

Bradley Loewen is an associate professor in STS and sustainability transitions at the Department of Interdisciplinary Studies of Culture (KULT) of the Norwegian University of Science and Technology (NTNU). Trained as a planner and economic geographer, his current research joins socio-technical perspectives with planning for sustainability, focusing on urban and regional energy transitions, innovation, and planning in the Nordic-Baltic region.

Urban Planning
2024 • Volume 9 • Article 8253
https://doi.org/10.17645/up.8253

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ARTICLE

Open Access Journal

Contested Ecological Transition in Small and Medium-Sized Cities: The Case of Rochefort, France

Fabian Lévêque and Guillaume Faburel

School of Environment and Society, University of Lyon 2, France

Correspondence: Fabian Lévêque (f.leveque-carlet@univ-lyon2.fr)

Submitted: 10 February 2024 **Accepted:** 23 July 2024 **Published:** 29 August 2024

Issue: This article is part of the issue "Planning and Managing Climate and Energy Transitions in Ordinary Cities" edited by Agatino Rizzo (Luleå University of Technology), Aileen Aseron Espiritu (UiT The Arctic University of Norway), Jing Ma (Luleå University of Technology), Jannes Willems (University of Amsterdam), and Daan Bossuyt (Utrecht University), fully open access at https://doi.org/10.17645/up.i346

Abstract

In Europe, small and medium-sized cities (SMSCs) face significant challenges related to climate change and environmental degradation. In France, recent governmental measures have sought to accelerate the ecological transition (ET) across its national territory, aiming to meet carbon reduction targets and preserve biodiversity. Since the pandemic, SMSCs have been at the forefront of this ET policy, benefiting from support programmes designed to revitalise neglected city centres. However, several studies have already highlighted that, despite being "tailored" to the specificities of each beneficiary city, these programmes are largely inspired by metropolitan models focused on economic growth and territorial competitiveness. This article aims to highlight that the ET directives applied to SMSCs also derive from practices in larger cities, embodying an "institutionalised" conception of ecology as part of broader attractiveness strategies. An investigation conducted in 2021 in Rochefort (France) demonstrates that ET policies are often utilised as tools for enhancing territorial attractiveness, akin to promoting city tourism and industrial development. Using a mixed-method approach that includes semi-structured interviews and mapping workshops, we will analyse the representations and aspirations of inhabitants regarding the future of their living environment. This will help them envision an ecologically sustainable and socially viable trajectory for their city and ascertain whether it differs from ET policies. The objective of this research is to identify alternative action levers beyond national directives for SMSCs concerning ET, distinguishing them by their unique trajectories, thus revealing other comparative advantages, notably their size and scale as primary ecological indicators.

Keywords

bioregion; ecological transition; participatory mapping; small and medium-sized cities; urban ecology

1. Introduction

In Europe, small and medium-sized cities (SMSCs) are experiencing renewed interest (Servillo et al., 2014) and face challenges related to climate change and environmental degradation. However, there are few dedicated studies on these topics, aside from United Nations programs (OECD/UN-Habitat & United Nations Human Settlements Programme, 2022) or national research like in Germany (Häußler & Haupt, 2021). Nonetheless, the European Commission estimates that 21% of the population in Europe lives in towns with fewer than 50,000 inhabitants (Lecomte & Dijkstra, 2023). Urban research tends to focus on large cities and metropolitan areas (Bulkeley, 2010), without always considering the impact of size and their responsibility in such ecological crises (Wagner & Growe, 2021).

In France, government measures have been implemented in recent years to accelerate the ecological transition (ET) nationwide, aiming to meet carbon reduction and biodiversity preservation goals (e.g., the 2021 Climate and Resilience Law and the 2023 Law for the Recovery of Biodiversity, Nature, and Landscapes). Since the health crisis, SMSCs have been at the forefront of this ET, supported by economic funds and technical resources. However, due to the lack of research dedicated to SMSCs, the development model promoted by the state through specific national programmes detailed below is historically inspired by metropolitan planning policies (Fol, 2020).

In light of this context, is there then not a risk of importing practices into SMSC models that may not always be well-suited to meet the social demands for environmental quality, as expressed in France and elsewhere (i.e., Germany, Spain, the United States, etc.; see Descagerra & Moati, 2016)? While there has been a recent surge of interest in France regarding ecological issues applied to SMSCs by public institutions, this article aims to examine, at the intersection of political ecology and critical geography, how SMSCs are addressing climate and ecological issues. It critically analyses the measures implemented based on other representations of ecology, particularly those of the inhabitants, using the case of Rochefort as an example.

Section 2 introduces the theoretical framework of the research. Section 3 presents the case study and survey method. Section 4 discusses some of the results, particularly the residential trajectories of the respondents and the thoughts prompted by the sustained urbanization of the city. Section 5 then details the ecological aspirations of the residents interviewed and their outlooks for the future of their living environment. We conclude by proposing the bioregional approach, which emerges in the survey results as an alternative ecological trajectory for SMSCs.

2. The Ecological Conversion of SMSCs: An Opportunity to Question the Conception of Ecology at Stake

In France, SMSCs have recently gained the renewed attention of governmental authorities with the Action Cœur de Ville (Town Centre Action) programme, implemented in 2017 in 234 medium-sized towns with a total cost of 10 billion euros (CGET, 2017), and the Petites villes de demain (Small Towns of Tomorrow) programme, targeting 1,500 towns with fewer than 20,000 inhabitants with a budget of 3 billion euros. These programmes were initiated following warnings of their neglect (Razemon, 2019) and the Yellow Vest movement (Depraz, 2019). They involve contracts between the state and beneficiary cities aimed at revitalising neglected city centres (e.g., housing restructuring, commercial development, heritage enhancement, and access to public services). ET is

now considered a cross-cutting axis in these programmes (Warnant, 2020). It aims to accelerate energy-efficient building renovations, promote land conservation and achieve "net zero artificialization," contribute to low-carbon mobility, and renature public spaces in SMSCs (Bouvart et al., 2022).

SMSCs are presented as key players in ET policies through adaptation (i.e., resilience) and mitigation (i.e., carbon footprint reduction) policies. In the prevailing narrative, local authorities are encouraged to capitalise on the ET for economic development opportunities and territorial attractiveness levers (Calatayud, 2018). Applying this ecological model, SMSCs are expected to ensure their demographic growth—preferably by attracting well-off populations with an awareness of ecological issues—and their economic competitiveness —by securing investments and skilled jobs and increasing land and property rents. Thus, the conception of ecology embedded in ET is far from being politically and axiologically neutral. These ecological directives indicate a certain biased approach as they lead the SMSCs to adhere to official discourses and institutional policies of green growth and sustainable development, which are largely deconstructed by proponents of urban political ecology. As they remain limited by a lack of resources, SMSCs promptly implement state directives in the absence of other critical ecological narratives.

This hegemonic culture of ecology, which we describe as "institutionalized," has prevailed for the past four decades and is based on the idea that ecological and climate issues are consensual, reducing responses to managerial governance and technological solutionism (Swyngedouw, 2011). It is manifested through supposedly neutral mechanisms such as communication campaigns (e.g., environmental awareness), fiscal procedures (e.g., carbon tax, tax credits for renovation), and the promotion of technological innovation (e.g., digitalization, circular economy, geo-engineering) without questioning collective needs or lifestyles (Comby, 2019). Critical theories of political ecology have highlighted that in such a conception, existing political, economic, and epistemic power relations are thus concealed (Kalt, 2024).

In France, in particular, this conception of ecology has been primarily diffused through sustainable urban development and planning operations in metropolitan cities (Faburel, 2018). In this context, "metropolisation" corresponds to the increasing influence of large cities, particularly metropolises, and the neoliberal transformation of urbanisation into the dominant spatial and socio-economical reconfiguration of all territories, mainly through centralisation and competitiveness process (Hackworth, 2007). It has drawn on managerial imaginaries of the environment by preventing and concealing caused socio-ecological risks and hazards (Girault, 2019). This has then materialised, e.g., in standardised eco-district projects, promotion of the smart city concept for energy-efficient solutions, and the development of "green" and "blue" infrastructures, often at the cost of increasing property values and more marked gentrification (Anguelovski et al., 2022).

This institutionalized and urban conception of ecology fails to address the impact of metropolitan lifestyles (e.g., accelerated mobility, digitalization of daily life, consumption) on the degradation of both local and increasingly distant environments (e.g., logistics spaces, resource extraction, etc.) and the escalating climate change primarily affecting cities (Ernstson & Swyngedouw, 2018). Moreover, this ecology overlooks the limitations of metropolitan policies, such as the densification of built-up centralities, population concentration, activity polarization, and the artificialization of urban fringes. Research has increasingly highlighted their counter-productivity both in France (Bihouix et al., 2022) and in Europe (Meirelles et al., 2021). More broadly, the metropolitan imaginaries of greatness and artificiality are never directly challenged, despite their perpetuation of unlimited wealth accumulation and the idea of infinite urban growth (Faburel,

2023). This ecological model that is spread through double binds and things left unsaid neutralises any critique that is being duplicated in SMSCs through ET policies. By applying this conception that was originally intended for high-density areas, SMSCs risk reproducing the same socio-ecological effects on their environments (e.g., expansion, polarization, pollution, social exclusion) as observed in metropolitan areas in the short or medium term.

However, SMSCs have several comparative advantages to leverage owing to their territorial unit, in addition to their limited spatial footprint, reduced governance scales, and fewer environmental issues (Giffinger et al., 2007). French SMSCs also experienced a general slowdown in soil artificialization between 2012 and 2018, in the range of 1.1% compared to 5% in the 2000s. They even have proportionally half as much artificialized land as large cities, with 42% of land dedicated to agriculture (Villes de France, 2022). They are a desirable scale for living as a result of their low density by 43% of French people and are identified as the best places to "lead a lifestyle with the least possible impact on the environment and climate change" by 58% of the French population, especially the smallest ones (less than 20,000 inhabitants), compared to 8% for large cities (Gallard, 2021).

In their history, it was as if SMSCs have constituted "places of regulation" for national territorial dynamics (Santamaria, 2012, authors' translation). SMSCs have ultimately been assigned a subordinate role to national and metropolitan policies. As urban historian James J. Connolly wrote: "Smaller cities are merely on the receiving end of developments originating atop the urban hierarchy and that the experiences of people living with them warrant little consideration" (Connolly, 2008, p. 4). Urban geographer Wakefield (2022, p. 930) demonstrates that contemporary environmental challenges may involve rethinking established urban forms and metropolitan lifestyles that embrace new territorial organization:

> The 21st century's changing environments and technopolitical adaptive responses may well lead to the destruction of seemingly unquestionable spatial forms like the urban or globally networked urbanization, and birth new, previously unimagined geographies.

Given this, would it not be in their best interest to turn away from the dominant ET narratives preformatted by metropolises and instead conceptualise ecological trajectories that are truly their own and may then give rise to "unimagined geographies"? Some authors identified a "right to not catch up" territorial policies implemented from above (Demeterova et al., 2020). There may be a relation between density, territorial scale, and the type of ecological policies considered, as small towns consume less energy for instance. Could concretely defining the appropriate ecological size of cities be a relevant approach for rethinking the ecologically sustainable scale of places? If we considered their geographical reality and size, which unique ecological conceptions specific to SMSCs would truly incorporate principles of moderation, in step with the lives of those most concerned: the inhabitants?

3. Research Field and Methodology

3.1. Rochefort, the Development of a Small Medium-Sized City Applying Metropolitan Strategies

The survey was conducted in the city of Rochefort in 2021, a sub-prefecture of the Charente-Maritime department (see Figure 1).

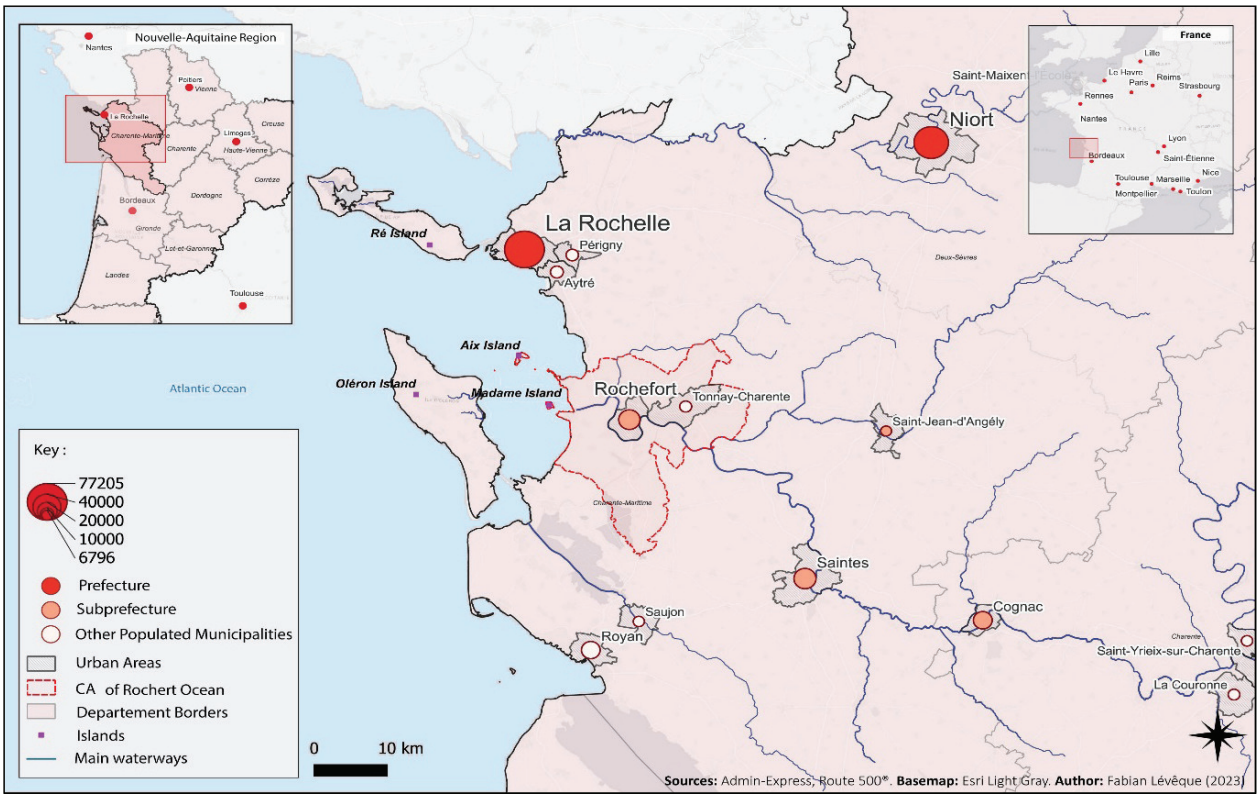

Figure 1. The situation map of Rochefort. The circles refer to the maximum and minimum inhabitants of each SMSC in the area. © UMR Triangle.

Rochefort is located near the Atlantic coast in southwest France, approximately twenty kilometres from La Rochelle. Founded in 1666 as a naval port, Rochefort thrived until the early 20th century (Renard, 1993). Gradually, between the 1930s and 1970s, various fertilizer, automobile, and aeronautics industries settled in, accommodating a large and unskilled local workforce. Deindustrialisation has been less severe in Rochefort compared to other SMSCs (Hamdouch et al., 2017), on account of proactive municipal policies. Nevertheless, the city has been slowly losing inhabitants. Its current population stands at 23,000, down from 36,000 at the beginning of the 20th century (Soumagne, 1982). The social composition of the city is notably shaped by this relatively sustained industrial presence (employees, 16%, workers, 13%). Retirees (34%) are the most strongly represented category, attracted by the oceanic climate that results in the city facing a significant aging population.

For these reasons, as indicated by the Plan Local d'Urbanisme (Ville de Rochefort, 2020), abbreviate below as PLU, the city suffers from a "major image deficit." For the past decade, Rochefort has implemented territorial marketing strategies to attract an additional 4,000 inhabitants by 2040. The municipality targets active young households, couples with children, and "higher socio-professional categories, those with purchasing power…and in recent years, the negative image of Rochefort has been fading" as the mayor argued in the local press (Charov, 2020). Rochefort particularly aims to attract professionals such as executives, self-employed professionals, and members of creative classes (Florida, 2004) bored by larger cities.

To achieve this, Rochefort focuses on tourism development, heritage rehabilitation, cultural and recreational activities (festivals, adventure parks), and the extension of the thermal spa facilities. The objective is to

attract both external flows and capital, especially as the city already has suitable infrastructure (hotels, tourist accommodations) to host more tourists. Rochefort's "place branding" strategy (Andersson, 2015) extends beyond its tourism and residential economy to include reindustrialisation efforts through the national programme Territoires d'industrie, addressing supply chain issues post-Covid-19 crisis and the war in Ukraine (Gros-Balthazard & Talandier, 2023). Thus, Rochefort aims to position itself as a city with a modern industry, driven by its rapidly booming local aeronautics sector.

Like most SMSCs, it is evident that ambitions of growth and expansion are a more desirable goal for Rochefort than a path of stagnation or even degrowth, which would be perceived as a failure (Bell & Jayne, 2006). However, Rochefort's urban growth objectives and economic strategies, although tailored to the size of its territory, are largely inspired by practices of metropolises over the past thirty years, such as employed heritage preservation and tourism promotion to act as primary attractiveness levers (Faburel, 2018). In its planning document, the Rochefort Ocean Agglomeration Community (CARO), which is a conurbation authority of 25 municipalities including Rochefort, aims to become a regional hub within a Central-Atlantic metropolitan network. This ambition aims to capture national flows and thus be able to host the sought-after "metropolitan economic functions" to enhance the competitiveness of Rochefort before other regional metropolises (e.g., Nantes, Bordeaux).

As in metropolises, growth ambitions are not contradicted by ET policies driven by the ACV programme. In 2021, the CARO signed a "CRTE," which refers to a contract usually aimed at facilitating economic recovery, ET, and territorial cohesion, to fund, in Rochefort, projects mainly supporting industrial sectors: the development of circular economy through the Circule'R association (i.e., recycling of industrial waste from industries) and thermal renovation of buildings. The CARO also promotes renewable energies with the deployment of rooftop photovoltaics and a solar power plant. The start-up VoltAero will soon establish production lines in Rochefort for hybrid aircraft, thereby supporting future air mobility solutions. In Rochefort, it includes the creation of an environmental awareness space, "green and blue corridors," and a flood prevention programme. The latter focuses on sustainable rainwater management by developing permeable parking spaces and "urban cool islands." Furthermore, a major project to redesign city green spaces is under study to ensure "ecological corridors," strengthen the existing "canopy," promote "soft mobility," and display the "connection to the river" (Ville de Rochefort, 2020).

This overview of Rochefort's environmental policies encapsulates the local adaptation of the metropolitan formula for "ET" and "climate resilience." Unlike metropolitan areas, action focuses here on industrial ecology and relies on state contracts and funds (i.e., ACV, CRTE, Territoires d'industrie, etc.). They do not prevent Rochefort from seeking to house new inhabitants: 2,700 housing units are expected to be built over the next 20 years. However, while these ecological developments may contribute to the embellishment of these cities and the well-being of its residents, they also run the risk of perpetuating the same socio-spatial inequalities, including green gentrification (Shackleton et al., 2018) if ET policies do not undergo a more critical approach. Notably, these environmental policies were implemented without involvement by the residents. What future do they envision in terms of ecology for Rochefort? What methods can be employed to bring their sensitivities and representations regarding adaptation trajectories into focus?

3.2. Investigation Protocol: Individual and Group Interviews

This research employed a mixed-method approach, including the analysis of planning and communication documents, semi-structured interviews (n = 30 residents), and two prospective workshops (n = 15 participants) to envision ecological trajectories for Rochefort. The qualitative method addressed the lack of comprehensive data on the social experiences and ecological aspirations of residents in SMSCs. Three city sectors were identified for interviews to target a diverse group of residents from typical urban contexts (i.e., urban centres, suburbs, and residential neighbourhoods) and for their varied urban operations in terms of density (i.e., from 30 to 200 housing units, individual or collective) and functions (i.e., residential, economic, or mixed-use). The investigated urban operations are "Pasteur," which is an urban renewal operation of a former hospital in the city centre; "Chemins Blancs," which refers to a densification project in place of collective gardens in the suburbs; and "Casse aux Prêtres," where an urban sprawl project for housing and economic activities is located on agricultural land. These sectors lose residents more slowly than other parts of the city due to their lower exposure to flood risks, thus attracting urban projects (see Figure 2).

The 30 interviewed residents were predominantly neighbours of these projects, directly impacted by changes in their living environment. The aim was to ascertain their awareness and opinions on the forthcoming changes. Ultimately, half of the interviews involved close neighbours, while the rest included broader neighbourhood residents. Some declined interviews, fearing repercussions from the municipality. Including other residents enabled a wider perspective on urban and economic dynamics beyond the immediate scope of the project.

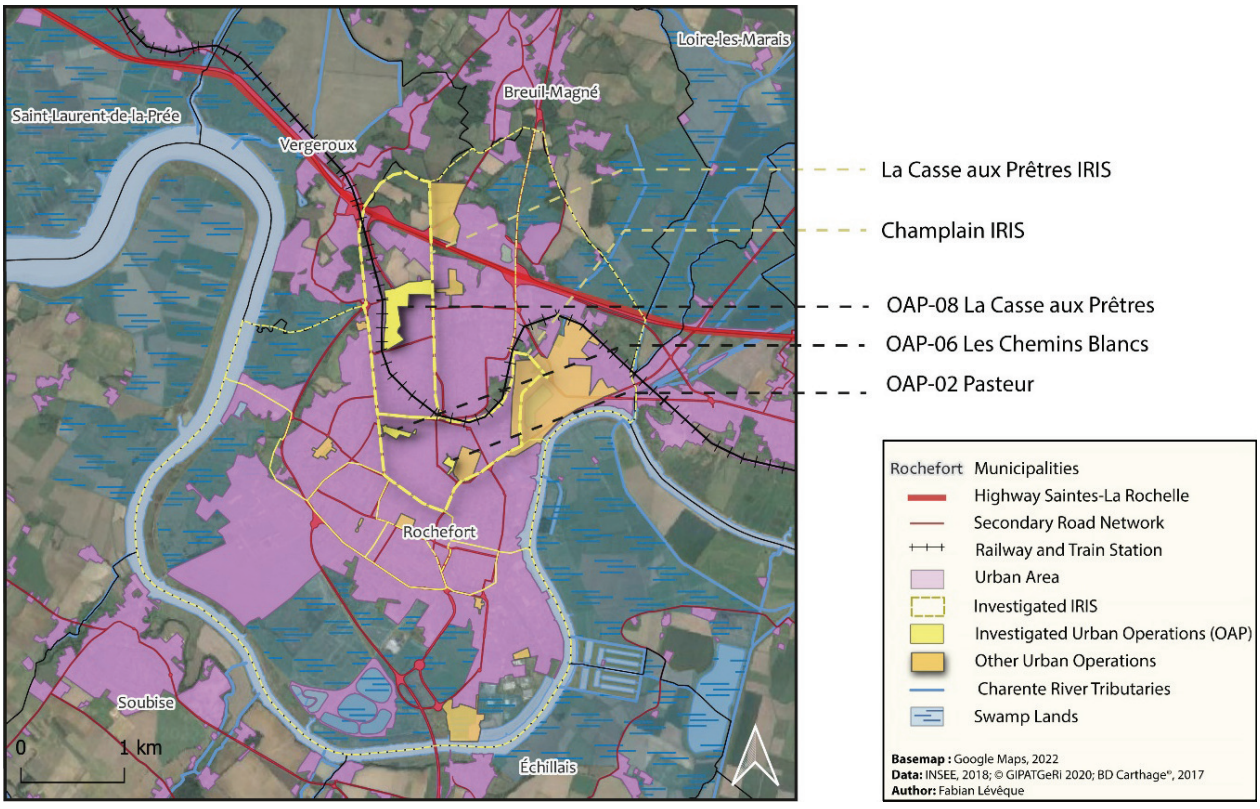

Figure 2. Location map of the selected urban operations. The numbers related to them on this map are those used in the PLU of Rochefort, among 15 others. © UMR Triangle.

The surveyed population was based on the RP2019 census data from the National Institute of Statistics and Economic Studies (INSEE), considered using the IRIS scale. In France, municipalities with at least 10,000 inhabitants are divided into sub-municipal statistical subdivisions of 2,000 inhabitants named "IRIS." This data guided the sampling process for the surveyed population (see Supplementary File, Table 1).

The surveyed population closely aligns with the target profiles outlined in the sampling framework, with some deviations. The 45–59 age group was overrepresented, which is justified by the increase of this particular group in Rochefort between 2013 and 2018. Socio-professional categories like "intermediate professions" and "executives and higher intellectual professions" had a slightly higher representation as these are the primary targets of urban and economic development. The pandemic context and curfew restrictions during interviews limited interactions with retirees aged 75 and over.

The two workshops aimed to broaden themes and issues broached in the interviews and foster collective debate. Participants were initially selected based on socioeconomic criteria, although mobilizing individuals from working-class backgrounds proved challenging (see Supplementary File, Table 2). Gender parity was achieved, and while "intermediate professions" were slightly overrepresented, each socio-professional category was represented at each workshop. The objective was to collectively debate and represent, by using digitally redrawn maps of the territory, two potential trajectories for the Rochefort area by 2040: one following the current direction and another reflecting ecological aspirations and requirements expressed during the interviews. These participatory mapping workshops served as mediation tools for open discussions about the future of their living environment, with the illustrative format capturing residents' emotional connections to the place they live.

4. A "Human-Scale" Town Altered by Urban Transformations and Economic Orientations

At the start of the interview, most residents expressed their affection for their city. They highlighted its heritage sites, a moderately dense urban layout, its pedestrian-friendly streets conducive to cycling, vibrant atmosphere, and residential sociability. They also appreciated the public services available (e.g., the post office, hospital) and cultural amenities (e.g., media library, cinema). Additionally, the natural surroundings, including the estuary and oceanic coast, provide direct experiences of nature and significantly contribute to the residents' quiescence. Natural environments are depicted as open and airy, where "our field of vision is never limited," according to Stéphane, a forty-something resident of the Casse aux Prêtres neighbourhood, or allowing to appreciate the "extraordinary starry skies at night," as described Odile, a translator living in the city centre. These observations align with what social psychology identifies as the revitalisation effects of distant vistas and panoramic viewpoints (Fleury & Fenoglio, 2022) and a mental calm from an ecosophic perspective (Guattari, 1989/2024). The small scale of the city thus allows it to be considered within its broader ecological environment.

These characteristics align with qualities long highlighted in SMSCs, often dismissed by French geographers as fantasies (Michel, 1977). Contrary to this, we believe that discussing them provides insights into the geographic and community living in Rochefort that residents describe positively. What emerges is a "human-scale" city, as many respondents expressed, indicating an interest in the size of liveable places, contrasting with unsustainable, oversized scales that have become standard. Far from being ashamed of living in a non-metropolitan area, residents expressed a sensitive attachment to a place

whose proportions are deemed ideal for a pleasant life, guiding the development of a different ecology from the SMSCs perspective.

However, the residents did not romanticise their living place or engage in the concealed promotion of their area to the researcher. Issues such as poverty, socio-spatial fragmentations, and healthcare inequalities were addressed in the interviews. Some respondents from modest backgrounds, predominantly residing in the residential neighbourhood of Casse aux Prêtres, expressed feelings of boredom and isolation, acknowledging successful urban developments but lamenting eroded social ties, disappearing non-commercial activities, and rising living costs of the city. Younger residents expressed their desire to leave Rochefort for larger cities to pursue their studies. Therefore, it is important to accept these social realities, common to most cities regardless of their size, due to urbanisation and population concentration.

Accordingly, some residents faced difficulties in accessing housing, both for renting and purchasing, drawing on their own residential experiences. The city's PLU aims to address this issue by building at least 133 new homes per year to stabilise its current population, but an average of 190 units per year is expected by 2041 to accommodate even more residents. The difficulties are due to increased secondary residences (up by 5% between 2006 and 2016) and vacant properties (up 2.13% for the same period). Rochefort, the sixth most visited thermal city in France, has many apartments that have been purchased in recent years and converted into vacation rentals for spa clients, limiting access for permanent residents. However, the municipality is aiming for 27,000 residents and plans to build new homes by densifying the existing urban fabric through the "Bimby" approach (i.e., "build in my backyard") and building renovations (derelict sites, vacant property).

Some respondents supported urban growth plans on the condition that the renovation of vacant properties and urban brownfields were prioritised before densifying inner city natural spaces or sprawling on agricultural lands. Therefore, the objections in the suburb and on the outskirts cannot, as the residents argued, be considered to be "nimbyist" (i.e., "not in my backyard"). Several testimonies highlighted the significant coastal urbanisation in recent years, that does not resolve permanent residents' housing issues. This perspective on limiting urban development was shared by residents who faced accommodation difficulties. Others pointed out the homogenising, undifferentiated, and highly dense contemporary urban fabric that could lead to neighbourhood incivilities or road congestion. Urban and human density is increasingly rejected, as reflected in opinion surveys showing a desire to move to much less dense areas (L'ObSoCo, 2023). Consequently, there are fears concerning new projects that would densify and develop new urban spaces, revealing visions that differ from aspirations for growth and territorial attractiveness expected by local authorities.

Another reason for rejecting dense and artificial urban forms lies in the residential trajectories of the respondents. Half of them have lived in a large city or a metropolis, describing experiences of suffocation due to confined, dense and verticalized spaces with accelerated, constant movement (Antonioli et al., 2019). "I led a breathless life," reminisces Véronique, a former Parisian now feeling better in an apartment in the city centre. Others remember long transit hours and noise disturbances from living nearby nocturnal businesses (e.g., bars and restaurants). Anne-Sophie worries about "facing the same issues we already experienced" in Lille, the Euro-metropolis in northern France, from where she moved out eight years ago to find "serenity" in a house in the suburbs.

Concerns regarding the homogenisation and denaturation of the area also lead to scrutiny around tourism development policies, seen as contributing to the same dynamics of standardisation and artificialisation as urban development. Rochefort aims to attract beach tourists and encourage them to stay in hotels in Rochefort. To this effect, a digital sound and light show named *Oceana Lumina* has been displayed every summer evening since 2021. This initiative aims to double tourist attendance by 2025, also banking on a maritime history-themed amusement park, a newly created electro-music festival in 2019, and a cinema festival in 2020. While some respondents view tourist influx positively for street activity, many criticise the substantial investment costs that total 25 million euros and argue these events overemphasise superficial aspects, promoting Rochefort as a hub of "entertainment" and consumption. Many projects have proven under-attended and unprofitable: Oceana Lumina attracted about 13,000 visitors in the summer of 2022, below the expected 40,000.

Several residents feel excluded from these tourist-focused initiatives, perceiving them as catering primarily to urban audiences, e.g., it was hoped that the renovation of the former "Quai aux Vivres" building would benefit the community, yet it instead became prestige apartments with a Michelin-starred restaurant on top and a luxury hotel. This urban project operates as a "flagship" due to tax incentives for attracting socially selected populations. Valerie, a fifty-year-old employee, finds it "pretty, what they've done, but it's reserved for a certain class of people" and feels marginalised. Consequently, most residents call for policies that are less focused on attractiveness and other wealthy external residents, and more focused on their social situation and environmental aspirations.

It is therefore unsurprising that many residents questioned the relentless pursuit of demographic growth, directly challenging the issue of Rochefort's size limit. In the early 20th century, the city welcomed an additional 13,000 inhabitants with a much smaller spatial footprint than today. At the time, the city extended only to the fringes of working-class suburbs. Moreover, these contained city block centres hosting food-producing gardens that have partially densified since that time. Nicolas, a self-employed gardener in his thirties residing in the suburbs, reflects: "When do we stop building, expanding our cities…? Maybe Rochefort has reached its maximum population because it has been losing residents for a long time." The issue of limiting the number of (new) residents seems relevant, resonating with some reviews (Paquot, 2020) and analyses on the appropriate ecological and democratic size of human settlements (Faburel, 2023). Growth objectives through attractiveness policies appear ineffective, as Rochefort continues to lose inhabitants, reaching historically low population levels in 2021.

These findings raise fundamental concerns about attractiveness policies that make the city reliant on external factors and question the territory's autonomy. What alternative vision of the city and its surroundings do residents then yearn for?

5. Going Back to Basics to Draw an Ecological Future for Small Cities

By first examining the motives of appreciation and residential trajectories of a small medium-sized city, this research has highlighted attempts to take a step back from metropolitan ways of life and urban development. Two-thirds of the respondents, including individuals who have spent their entire lives in Rochefort, find there to be a sense of "togetherness," an atmosphere of "peace and quiet," a "love of life," or a feeling of "great serenity." This desire to live in a relaxing environment, which could hastily be labelled as a withdrawal,

takes on a political character when observed as a desire to no longer contribute to the acceleration of the world's pace. However, this quest for tranquillity and deceleration would be made possible precisely due to the moderate size of Rochefort. This is exemplified by Benoît, a healthcare executive, who previously lived in a larger medium-sized city before moving to Rochefort in 2015. He was already aware of environmental issues, but added:

> Since we've moved to Rochefort, we've completely changed our way of life. We've transitioned to a lifestyle where we try to consume as little as possible…if we had been in a larger city, I'm pretty sure it would have been much more difficult.

As a family, they now prefer to go for a nature walk near the river rather than spend their free time shopping. This shift underscores the fact that living in a small town can influence the adoption of more ecological lifestyles and nurture sensitivities and values that differ from those dominant in metropolitan areas.

The pursuit of ecological limitation and voluntary sufficiency (Gorge et al., 2015) is evident among other social groups. For instance, a precarious worker and his wife strive to live simply: "We try to live in a simpler way, with less. We don't have much money, so we try to live with the bare minimum. No waste, no excessive consumption, we go to upcycled, second-hand shops. It's better this way." Their choice to reside in a small town with accessible shops and public services helps them cut unnecessary expenses. They may even own a small house with a garden and dream of living in a wooden house in the future. However, they currently live in a part of the city that is devalued due to its proximity to a chemical fertilizer company, accused of polluting the surrounding water and soil. This example and others underscore the environmental and health issues of the Rochefort region, including the management of industrial legacies and agricultural practices. The issues of land sealing and water pollution were addressed by Jean-Paul, a former welder, who lamented the degradation of local streams where he used to fish as a child: "Grasses used to float, we could see the bottom of the river, but now there's no life left." Chemical agriculture is thus called into question, along with its exportation abroad via the commercial port, once again raising the issue of dependency of the territory on globalized markets. The emergence of such topics during the interviews also reflects, far from any idealization, a genuine concern emphasizing the need for collective action to restore a healthier and lively environment for the whole population.

In this light, the quest for food autonomy emerges in the interviews as pivotal for fostering an ecologically sustainable and socially viable future. Gilles, in his fifties, earns a living cultivating a vegetable croft in the suburbs, initially driven by trade but also in an effort to be self-sufficient. He suggests that the municipality should acquire agricultural land to establish similar small farms like his, thus generating non-decentralizable jobs and serving the interest of the community. He envisions local agriculture that observes natural cycles to enhance local consumption. This aligns with Odile's concern about food security and ethical consumption. It would prevent "the poor living in Rochefort from eating things from Lidl, produced by slaves in poor countries," as she argued. Nonetheless, this direction hinges on sustaining current population levels to ensure their subsistence and cease attracting new residents. At the time of research, Rochefort's Territorial Food Strategy plan had not been implemented or even discussed. Despite its ambitious goal to achieve 30% of total food consumed to be locally produced for 2026, compared to 4% in 2020, it does not address the consumption of animal protein, for instance, which is a significant source of greenhouse gas emissions. Residents expressed a revival of local knowledge and popular techniques like hedge cultures and hand-crafted weaving, reflecting a broader "return to the roots" theme, spanning all social backgrounds.

These intentions are even more evident in the two cartography workshops involving two distinct groups of seven to nine participants respectively. While the first collective map depicted a densification of central and peripheral neighbourhoods in a uniform, grey landscape, with increased surveillance of tourist sites and new "theme parks" together with an eco-district and sporadic cycle paths. This "metropolized" vision of Rochefort was rejected by the participants who were quite aware of current attempts to greenwash the city, even if some participants would appreciate having more secure cycle paths. The second map (see Figure 3) immediately integrates well-documented risks of marine submersion and floods, like many coastal cities in the world that are home to 11% of the world's population (Glavovic et al., 2022). Participants foresee the climate challenges that will arise when the continued damming of the Charente River that today facilitates the city's expansion (although submerged areas, and thus non-buildable, are already delimited in PLU) becomes obsolete. Seawater would "naturally" penetrate inland and guide land management. The rise of the sea level was spontaneously depicted by both groups, as if its inevitable nature had already been internalised with quite marked apprehension.

Following this second projection, the central question attempts to answer how to ensure good living conditions for today's 23,000 inhabitants, rather than urbanizing the last available spaces to accommodate an additional 4,000 inhabitants by 2040 (i.e., 1st scenario discussed). The growth and expansion of the city would gradually yield to new paradigms and spatial configurations based on the satisfaction and relocalisation of fundamental needs to reduce dependencies and their socio-environmental impacts. Unlike

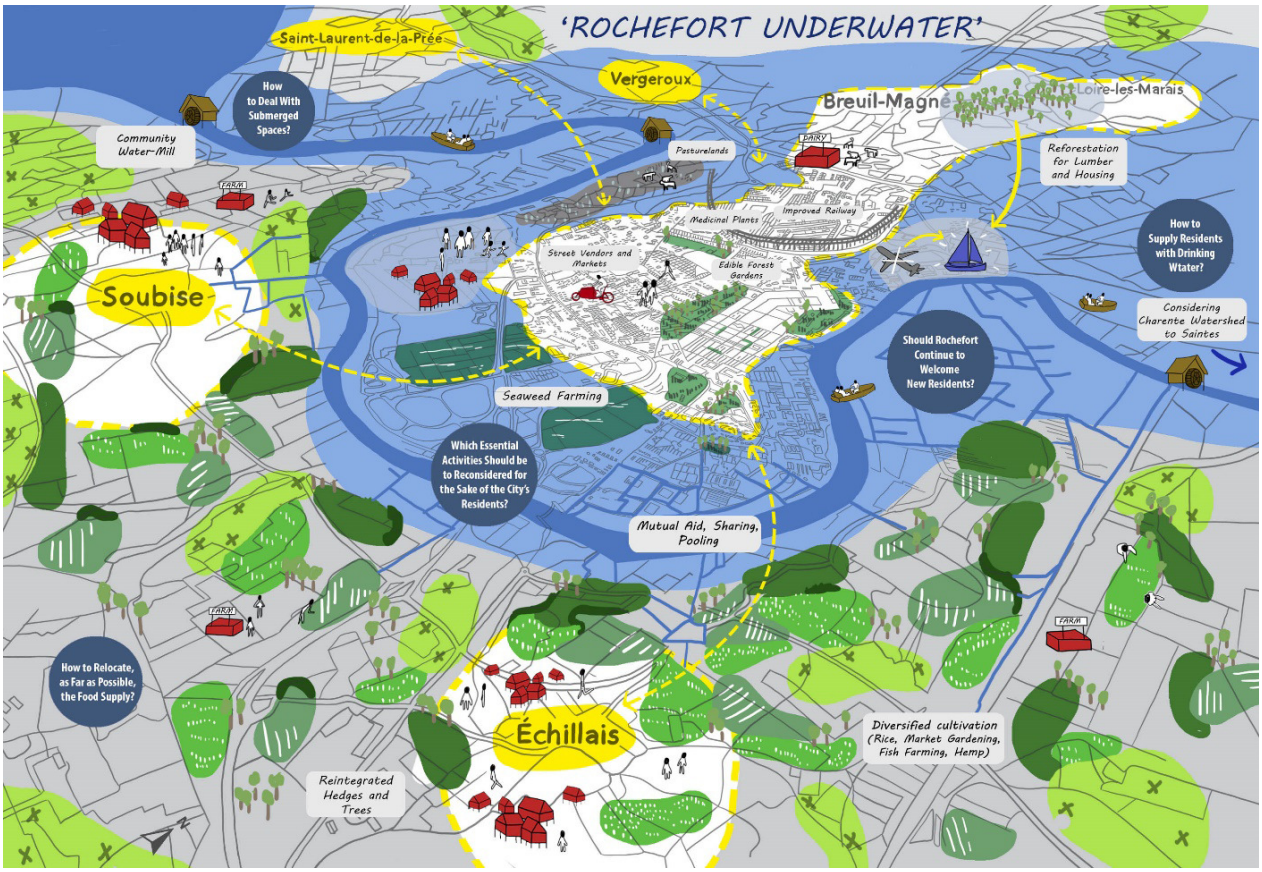

Figure 3. This digitally redesigned map summarises the participants' proposals for the second scenario, eventually named by them "Rochefort underwater." Drawn by Fanny Ehl, PhD student. © UMR Triangle.

large cities where urban agriculture is confined to the remnants of available spaces (e.g., gardens on brownfields, green roofs), the open territory of Rochefort, accessible to surrounding municipalities, is viewed as a fertile ground for achieving food autonomy. This includes cultivating a diverse array of crops directly in the soil and restoring historic forests on higher lands. Some emerged lands would be devoted to subsistence practices, while others would be dedicated to land-sea cultures adapted to the abundant presence of water. The envisioned agricultural landscape has been meticulously designed to enable a variety of purposes according to permaculture principles: food (e.g., vegetables, seaweed, fish farming), construction and heating (e.g., wood, hedges), clothing, material, and medicine (e.g., hemp). This relocalisation strategy resonates as it fosters a return to traditional forms of agriculture: "A few kilometres away, there were fortified farms to supply the arsenal with fresh produce," Jean-Paul mentioned in his interview. Among the survey respondents and participants, those who grew up in the countryside or others, such as people who have had cancer and other illnesses, expressed their desire to promote healthier agriculture. The green spaces in Rochefort's city centre would be transformed into nourishing gardens, and the historic mills along the Charente River could be renovated for grinding grains, crushing nuts, and producing paper, echoing their historical roles in the region.

Turning to housing, certain submerged areas would no longer be habitable. Consequently, residents would congregate in existing habitations and renovated vacant properties, reside in lightweight, transportable, or stilted dwellings, or relocate from the coast to inland areas. Participants also drew attention to the importance of mutual assistance and cooperation, primarily emphasizing the need to pool resources, symbolized by the groups of individuals depicted on both sides of the map. Displayed using arrows, interdependence would be reaffirmed among residents of different municipalities on the coastal plain, fostering a departure from polarizing and competitive dynamics at work today. Essential needs such as ways of living and relationships would thus be relocalised to foster closeness in order to rebuild a political community. This existence, however, is not perceived as a form of autarky, as the strategically elevated rail would continue to facilitate exchanges with surrounding areas, although participants shared the idea that long-distance transport would be reduced to strict necessity and is less conducive to permanent mobility.

However, this new spatial configuration does not claim to be exhaustive: For instance, it fails to detail the thought and political process needed to achieve it and partially represents the conflicting elements that were debated during the workshops regarding the future of industry in the area (e.g., should heavy aerospace productions be reconverted into small units for sail-powered river transport, or should the companies be dismantled to reclaim new land?), the necessity of maintaining economic attractiveness policies (e.g., what happens to the municipality's fiscal resources? How would this new reorganization be financed?), or the knowledge of urban planning (e.g., what should be done with the skills of urban planners in territorial planning? Should they be used to serve this second vision?). Throughout the workshops, participants were divided between enthusiasm for reinventing their living environment, concerns about imagining their future in a region directly affected by rising sea levels, and practical questions regarding ways of living that truly foster an ecological resilience.

The workshops provided an opportunity for participants to collectively think about the future of their living environment and to experience, in the process, what participation and even self-determination could entail, albeit with some unresolved issues including conserving sources of drinking water in the face of the progress of brackish waters. The workshops aimed to assert political positions, and present a "realistic

ideal" of environmentally-conscious lifestyles of inhabited places, thereby directly addressing the importance of maintaining a "human-scale" territory with attention to size and limit issues (Garcia, 2018) in an ecological perspective.

Understanding the ever-evolving limits of a revitalised place can therefore guide inhabitants towards sustainable forms of living, grounded in ecological knowledge of the surroundings. The bioregional perspective could epitomize this. As Berg (1978) put it:

> A society which practises living-in-place keeps a balance with its region of support through links between human lives, other living things, and the processes of the planet—seasons, weather, water cycles—as revealed by the place itself.…It involves becoming native to a place through becoming aware of the particular ecological relationships that operate within and around it.

Furthermore, the more moderate the concentration and polarization of inhabitants in a territory, the greater the likelihood that this ecological perspective could become a reality in a short while. The bioregional geography of the Charente River plain was spontaneously designed by workshop participants, albeit without explicitly using the term, foreshadowing alternative geographic frameworks aimed at preserving what still thrives in inhabited places, with responsible dimensions aligning with self-sustaining ecological environments and their socially cultivated capacities (i.e., the primary definition of any bioregion).

Size and scale thus emerge as primary indicators to address the socio-environmental ills prompted by urbanized societies and to imagine viable and vibrant rural bioregions, anchored in geographical settings that have historically fostered culture (e.g., valleys, uplands, islands, etc.) and that could ultimately reduce the ecological footprints of lifestyles driven by consumption and acceleration. In this perspective, small towns and inhabited areas with populations of less than 30,000, including rural villages down to hamlets, subdivided into even smaller communities for political organization and decision-making (e.g., villages, neighbourhoods), would prove to be a territorial framework prone to inspire a geography that is more attuned to the ecological exception of environments and the forms of life that could unfold therein (Giard et al., 2021).

6. Conclusion

Urban systems consume 70% of planetary resources and 80% of global energy. These figures are well-known, yet they often fail to differentiate the responsibility of cities based on size and scale issues. Reports like those from the IPCC frequently prompt critical examinations of metropolitan territorial organization as an accelerator of contemporary crises and barely assess prevailing environmental planning models like ET, spread across various urban contexts, from large cities to small and medium-sized towns, as a unified response to ecological crises. We hypothesise that these issues are interconnected and that it is essential to reconsider the role and trajectory of SMSCs by critically taking a step back from metropolitan policies and the associated spatial organisation rationale.

This expansive yet interconnected theoretical framework prompted our research in Rochefort, a "small medium-sized city" with 24,000 inhabitants. We investigated how residents perceive and interpret recent local urban-metropolitan development and their own ecological aspirations for their living place. Our

findings reveal a sense of dignity in living in a "human-sized" city characterised by lower density and a sparse population, fostering convivial human relationships and a consistent connection to natural spaces. This deliberate choice contrasts with increasingly unliveable metropolitan areas and unsustainable lifestyles. However, this feeling of satisfaction coexists with concerns for socio-economic difficulties (e.g., social precarity, spatial disparities) and environmental issues (e.g., urban sprawl, agricultural pollution). Ultimately, the size of the city and reduced density shape forms of life that emphasise aspirations for simplicity and sufficiency, manifested across many life trajectories. These principles could potentially inform local public policies.

Our research aimed to translate these ordinary experiences and affects associated with living in such a town into a new geography and community organization through participatory mapping. The most surprising aspect was that it revealed a vision of territorial planning that was diametrically opposed to the prevailing developmentalist urban approach and its ET policies. This vision highlights a shift towards prioritising simple and basic needs that could be local self-sufficiency implemented within the ecological limits of the area, thereby reducing the human impact on living environments and even promoting their restoration. This conception of ecology at stake, which we named "inhabiting ecology," testifies that ecology is a battlefield and needs to be repoliticised.

This mapping challenges conventional urban development paradigms of growth, competitiveness, and attractiveness, as well as ET policies that mainly aim to limit their environmental effects without fundamentally challenging them and proposing an alternative way of organising territories. The final mapping proposition does not correspond with any technological solutions usually put forward by the institutional conception of ecology, confirming the idea that residents spontaneously considered another direction when meeting as a group, and can conceive what is good for them and the place they live in terms of health and environmental issues. The proposition suggests starting with observing the collective needs and forms of life people want within the framework of biotic resources of places and their regeneration, understanding what they can sustain without being endangered, and planning organisation of the community accordingly. This entails reclaiming food production, thereby regaining material autonomy and democratic capacities for action.

These results suggest a different geographical trajectory for SMSCs on an environmental level, an "ecological bifurcation" that considers size and density issues. Evidently, it raises unsolved questions so far regarding the functioning of political governance, tax system, and even the real estate market. Yet, this research invites smaller SMSCs to break away from territorial organisation that places them at the bottom of the geographical hierarchy, dependent on larger cities and central authorities for leading their own socio-ecological and environmental policies. Due to their limited size and balanced density, SMSCs, alongside other scales of living such as rural towns, villages, and hamlets, represent more underappreciated asset territories to address the ecological crises than metropolises. This potential can be realised by slowing down, relocalising, and thoughtfully re-evaluating essential and ecological ways of living.

According to the conclusions of the TOWN project of the European Territorial Observatory Network, development scenarios around a network of small and medium-sized European towns (less than 50,000 inhabitants) would be particularly effective in terms of resilience and social cohesion compared to large urban agglomerations (Servillo et al., 2014). By embracing a bioregional perspective, SMSCs would lead the

way in seeking alternative planning models that harmonise human activities with inhabited and living environments and foster a fulfilling life.

Acknowledgments

The authors are deeply thankful to University Lyon 2 and the Triangle Laboratory for funding this research through multiple missions, as well as for covering the translation and publication fees of the article. The authors also express their gratitude to the anonymous reviewers for the constructiveness and accuracy of their comments throughout the revision process of this article, as well as the editors for their availability.

Conflict of Interests

The authors declare no conflict of interests.

Data Availability

The data quoted throughout this article are drawn either from the INSEE databases, presented in the urban planning documents of the city of Rochefort, or reported in the press.

Supplementary Material

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

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About the Authors

Fabian Lévêque is a PhD student in geography and urban studies at the University Lyon 2 and the Triangle Laboratory. His research focuses on the sensory experiences and ecological affects induced by the spatial, social, and environmental changes driven by metropolisation. His field studies span large metropolitan centres, suburban peripheries, and small cities. He seeks ecological ways of inhabiting places, using a protocol that combines qualitative methods, collective workshops, and audiovisual methods, including two research films produced for his thesis.

Guillaume Faburel is a geographer and a full professor at the University Lyon 2. He is researcher at the Triangle Laboratory and was an invited Research Fellow at the MIT in 2001–2002. His scientific works and lessons in urban studies mainly examine metropolitan phenomena and urban lifestyles, new forms of involvement and empowerments by ecological topics, and environmental justice stakes. He published in 2018 *Les métropoles barbares*, awarded by the Foundation for Political Ecology, and, in 2023, *Indécence urbaine. Pour un nouveau pacte avec le vivant*.

Urban Planning
2024 • Volume 9 • Article 8271
https://doi.org/10.17645/up.8271

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Open Access Journal

Ordinary vs. Extraordinary: An Urban Comparison in the Delta Po Area

Stefano Tornieri

Department of Civil, Environmental and Natural Resources, Luleå University of Technology, Sweden

Correspondence: Stefano Tornieri (stefano.tornieri@ltu.se)

Submitted: 14 February 2024 **Accepted:** 17 April 2024 **Published:** 27 June 2024

Issue: This article is part of the issue "Planning and Managing Climate and Energy Transitions in Ordinary Cities" edited by Agatino Rizzo (Luleå University of Technology), Aileen Aseron Espiritu (UiT The Arctic University of Norway), Jing Ma (Luleå University of Technology), Jannes Willems (University of Amsterdam), and Daan Bossuyt (Utrecht University), fully open access at https://doi.org/10.17645/up.i346

Abstract

In a time of pandemics and climate pressures, social sustainability has become a crucial issue within diverse sectors and disciplines. This article endeavors to enrich the discourse on social sustainability, particularly concerning community efforts, in contrast to large-scale private investments employed as catalysts for enhancing attraction and territorial development. This article critically examines the case of the Delta Po area along the Eastern Adriatic coast in Italy, where several "ordinary cities" are situated, featured in a similar urbanization pattern to the nearby Venetian Metropolitan areas, identified by B. Secchi as "*città diffusa*." To comprehend the significance of ordinary cities, this article delves into a comparative analysis between an ordinary setting, specifically the village of Massenzatica, and an extraordinary one, exemplified by the Porto Tolle power plant. These two contrasting approaches to utilizing the territory are assessed through a qualitative methodology in order to understand the factors that contribute to enhancing social and territorial sustainability.

Keywords

Delta Po; Italian countryside; ordinary cities; territorial sustainability; urban sprawl; wetlands

1. Introduction

In certain vulnerable and fertile territories, such as the margins of lagoons, coastlines, and river deltas, urban settlements are often unplanned and characterized by an urban morphology that arises from productive needs such as agricultural irrigation, access to water reservoirs, and logistical optimization for cultivation, or as consequences of high-impact industrialization impulses (Intergovernmental Panel on Climate Change,

2022). An exemplary illustration of this territorial organization is the Delta Po area, positioned between the Venetian Lagoon and the city of Ravenna on the west coast of the Adriatic Sea—a productive wetland forged over centuries through the collective efforts of its inhabitants and the utilization of reclamation techniques. Over the past half-century, from the great flood in 1966, the diminution of small villages in these territories has been evident, attributable to challenges encompassing demographic aging, escalating economic constraints, geographical remoteness from core infrastructure, and limited access to essential services (Simeoni & Corbau, 2009). However, in these areas, urban policies have predominantly concentrated on strategic industrialization initiatives designed to attract new residents, create employment opportunities, and facilitate the development of essential infrastructure. Technological transformations have been implemented to assist agriculture in addressing freshwater scarcity and mitigating the costs associated with safeguarding the territory from sea-level rise. The simultaneous presence of various urban and built structures, marked by significant differences in scale, functions, and architectural typologies, disrupts a social model based on the organization of small communities that have functioned for centuries (Tornieri, 2020). Current trends indicate a shift in favor of political initiatives that promote tourist attractions and new highly industrialized food production (Cencini, 1998). This trend poses a threat to the architectural and urban values of ordinary cities situated in these specific territories. The phenomenon needs to be studied by evaluating transformations in a systemic and integrated manner to assess the possible resilience of the ordinary in the face of the extraordinary.

1.1. Literature Review

Delta regions represent unique territories characterized by their rapid evolution throughout history. Given their position at or even below sea level, they are perpetually under threat. Defining a delta region is often a matter explored within the field of geology (Correggiari et al., 2005; Parrinello et al., 2021) but from the perspective of architecture and urban planning, a delta region is studied as an important and symbolic place where anthropology is intrinsically related to the shaping of the land (Mathur & Da Cunha, 2001). These regions are sparsely populated, often lacking large cities, as the land has historically been dedicated to agriculture and food production for other cities. An example of this is the Po River Delta and its relationship with the Venetian Republic (Tumiatti, 2005). After the fall of the Serenissima Empire in 1797, commercial exploitation between Venice and the surrounding productive territories, including the Delta Po, began to decrease and as a consequence, small communities and villages remained undeveloped. With a density of 71 inhabitants per km^2 and a surface of 683 km^2, Delta Po counts seven municipalities included in the UNESCO Man and the Biosphere heritage program and under the regulation of the Regional Park Area. The high productivity and heritage value of these regions make them integral to the theorization of the "ordinary city," as proposed by Robinson (2006). Robinson argues that to truly learn from different contexts, the focus of academic analysis and policy recommendations should not be limited to global cities or those in the developing world. Instead, attention should be directed towards what she terms "ordinary" cities, with all their complexity, diversity, and distinctiveness.

The literature on the landscape in the Po Delta area can be categorized into two main groups: studies focusing on territorial development and coastal modifications over centuries from a geographical perspective (Bertoncin, 2004; Bitelli et al., 2012; Nelson, 1970; Simeoni & Corbau, 2009), investigations delving into the cultural heritage values within an evolving landscape (Arillotta, 2022; Siebenhaar & Valtorta, 2017; Tornieri & Vanore, 2018; Tosi, 2013; Tosi et al., 2011; Vanore, 2010). More recently, it is important to

mention that many researchers are exploring various perspectives, not only focusing on the ability to describe a territory in its evolutions or heritage values but also integrating future scenarios for sustainable development (Magni et al., 2021; Marsico et al., 2017; Pungetti, 1993; Tornieri, 2017, 2019, 2020). This involves considering tourism as one of the main factors to achieve sustainability and counteract the effects of climate change.

In this specific sector of studies and especially with the urgent issues related to climate adaptation and mitigation, urban morphology and land use are rarely considered as critical factors in fostering social interaction that can generate alternatives to prevailing capitalist methods of exploiting the ground or profiting from a place.

1.2. Theoretical Problem

Even though the Delta del Po has never been consider as part of the Veneto Sprawl, it seems to have the character of the "*città diffusa*," which, in the idea of the Italian urbanist and theorist Bernardo Secchi, could be used as a synonym for sprawl or dispersion (Secchi, 1992, 2015). Dispersion is the result of a basic infrastructure of the territory that has developed over a very long period. This infrastructure consists of a dense network of canals, channels, and drains, partly intended for irrigation but mostly for draining poorly permeable lands. It is accompanied by a minor road network that mimics the forms and density of the canal network and an equally detailed division of fields and properties. In the 1990s, Francesco Indovina (1990), followed by Boeri and Lanzani (1992), described the changes in the structure and image of the Veneto region caused by intense phenomena of productive decentralization and the dispersion of activities and population that occurred in the two decades prior. Munarin and Tosi (2005) then analyzed in detail the history and characteristics of dispersion in Veneto, one of the Italian regions that, starting from the 1970s, has been at the forefront of studying the new features of urban phenomena.

Secchi (2005), starting with an understanding of the history of European cities and focusing on the social rationale behind the form of the city, argues that the descriptions of the city and the territory at the end of the century have brought to light the fragment, the specific, the local, the irreducible difference. This reveals that the space of dispersion is comprised of constellations of fragmentary materials, among which it becomes important to establish new relationships. Secchi (2005, para. 9) wrote: "[The] city is an image of an open society, where more and more is public, and seems to refuse enclosure and barrier, rigid functional subdivisions and role, imagining a fluid space traversing the dimensions of land and buildings."

As a contemporary revisitation of the influential theoretical framework developed by the Italian school of urbanism, Koolhaas's (2020) *Countryside* reimagines the concept of dispersed fragmentation as a characteristic pattern in the rural world. This notion is closely tied to the idea of a highly engineered territory, akin to the Dutch approach to reclaiming lands. According to Koolhaas, the historical heritage persists in shaping the present through the extensive network of greenhouses and large-scale hydro-engineering projects. This interpretation can also be applied to the coastal areas of the Veneto region or the northernmost part of the Emilia Romagna region, where the Po River Delta is situated. Although many studies address urban and architectural value in the Po Delta area and the value of the relationship between the heritage of the land and the heritage of water, as well as the landscape geometry produced by reclamation over centuries, researchers rarely provide a comparison of the sustainability of settlements,

even when considering different architectural scales and functions. In the 1990s, the same years as Secchi's theoretical work, the concept of the "ordinary city" emerged, developed by a group of geographers to critically challenge prevailing Western urban theory. This idea evolved to play an important role in the theoretical and methodological framework of post-colonial studies during the 2000s. Initially introduced by Amin and Graham (1997), the "ordinary city" concept aimed to highlight the significant shortcomings in the dominant urban theory of the 20th century. It critiqued the generalization of findings from a limited number of studies focused mainly on leading cities within the capitalist West. Over time, the perception that cities, as traditionally imagined and depicted, should no longer be the primary focus of urban studies has gained traction. This shift is attributed to the emergence of new urbanization theories viewing it as a global phenomenon, and recent epistemological developments have weakened the notion of urban areas being defined solely by agglomeration and high physical density. This evolution challenges well-known conceptual categories like center–periphery, urban–rural, and core–ring, especially as cities move beyond their classic local configurations to exhibit regional and global dimensions.

In the context of the Po Delta, the notion of the ordinary takes on an additional meaning related to conformity with what is natural and common. This interpretation aligns with the definition from *Treccani Enciclopedia* (Ordinary, n.d.), meaning regular, usual, common, and standard. In this semi-isolated territory, where food resources have been managed by year-round communities for centuries, the concept of the ordinary frequently appears in the "regular" maintenance of the land, the rural character of villages with similar urban and architectural setups, and in the simple life dictated by seasonality and weather conditions. Within this framework, the simplicity and ordinariness of villages and communities contrast with a few significant exceptions, such as large production facilities introduced to boost productivity and employment.

Within this theoretical interpretation, two primary questions emerge: What are the factors that contribute to the discourse on social sustainability, especially in the context of community initiatives in small and ordinary cities? What are the differences between the approach of an ordinary city and that of an extraordinary one concerning sustainability?

Understanding the community factors that enhance social sustainability can illuminate an alternative approach to utilizing and preserving the territory, one that is more closely tied to social empowerment rather than relying solely on tourism-driven economies. The research underscores the necessity of functional hybridization intended as the integration of multiple uses and functions within city spaces to enhance comfort, offer various ecosystem services, and foster areas that are self-organizing and encompass social, economic, recreational, and environmental dimensions (Krasilnikova & Klimov, 2020). This approach, combined with communal efforts in both typical cities and smaller locales, is considered critical for tackling present environmental issues, including saltwater intrusion, flood hazards, land subsidence, as well as social challenges peculiar to the Delta Po area like feelings of isolation, decreasing populations, challenges in accessing services, and economic viability (UNESCO, 2013). Such community-driven initiatives represent political engagement by the wider society, fostering urban resilience through collaborative management of shared spaces and resources, known as the urban commons (Foster, 2011). Additionally, it underscores the significance of developing urban and territorial projects capable of restructuring various components in a more adaptive and sustainable manner.

2. Methodology

A qualitative analysis method is employed to comprehend the urban and landscape quality, alongside fostering societal advancement and enhancing the well-being of the local residents. The primary focus of this article is to provide a description of the urban settlement, drawing a comparison between the village of Massenzatica, considered a typical village in terms of dimension and population in the Delta Po area, and the ambitious redevelopment project of the Porto Tolle power plant. This comparative analysis encompasses an assessment of both urban and landscape quality, utilizing explanatory schemas. Furthermore, the article evaluates the impact of the redevelopment project on the local populace, considering the number of people benefiting from it, the duration of these advantages, and the integration of the landscape into the project. Data collection for this study is facilitated through a collaborative effort between the municipality of Massenzatica and the documentation provided by Enel, the owner of the power plant. This collaboration involves accessing information related to both the construction phase of the power plant and Enel's plans for its future, particularly after the dismantling process. The comparison (Figure 1) has been conducted using three factors considered representative of the approach to using the territory as a sustainable resource or not: (a) territorial branding, defined as how the communication of territory has been employed to promote the attractiveness of a place; (b) the relationship with the surrounding environment, understood as the ability to initiate a virtuous process of inclusion; and (c) land use throughout the year (Table 1).

Figure 1. The location of the Delta Po area in Italy and the localization of Massenzatica and Polesine Camerini power plant.

Table 1. Data comparison between the two case studies.

	Massenzatica	Polesine Camerini
Land surface	353 ha	300 ha
Population	1,250 people (stable all year)	400 people (employees) 8,000 tourists per day (estimated)
Density	1.55 persons/ha	28 persons/ha (max)
Main services	Kindergarten and primary school Mail office Church Shops Sport facilities Agriculture products	Commercial activities Craft workshops Fish market Spa Sport facilities Restaurants
Cultural heritage sites	Protected natural area Fossils Dune	Power plant chimney
Tourism	Low	8,000 tourists per day (expected)

Source: Author's work based on data from Consorzio Uomini di Massenzatica (CUM, n.d.) and Enel (2019).

3. Results

3.1. Massenzatica

The Consorzio Uomini di Massenzatica (CUM), established in 1896, traces its origins back to an ancient collective property of medieval origin, for centuries settled in the territory that was difficult to manage due to the continuous change of boundaries between emerged and submerged lands generated by the cyclic processes of sedimentation and erosion that characterize the Po River Delta. It was the Abbot of Pomposa in 1182 who assigned the undivided patrimony to the community of Massenzatica when the use of the common lands took place through the collective use of pastures and woods by the inhabitants. It is from the end of the 19th century that a slow reclamation began, recounted over the years in poems and popular songs, stabilizing the river network, raising the banks, and making the marshes healthy. CUM is now recognized by the Italian Republic as a collective land management (Italian Republic, 2017). Six hundred families are members of CUM. The beneficiaries are all the heads of families—men or women—residing in the hamlet of Massenzatica, who can derive benefits from the common property in a direct way, through the allocation of shares of cultivable land granted to users at a subsidized rent (40% less than the market value) or through the possibility of working in the employ of the Consortium itself or of the companies to which the land is leased. Profits deriving from the management of collective land are directed partly to agricultural improvements and partly to the economic support of cultural, social, and welfare initiatives that take place in the area (Figure 2). The current 600 families have benefited from a particular legal form of ownership (neither private nor public) that has allowed a peculiar management method that has succeeded, especially in the last 20 years, in combining the income and employment of the Consortium members, with an entrepreneurial approach. In this sense, it takes the form of innovative management of an "internal community serving an external community," using part of the land to meet the objectives of the local community and giving a residual part of the land to private management. The land is currently suitable for any cultivation and is leased to Consortium and non-Consortium members with the obligation to manage it according to the best agricultural methods. The Consortium directly cultivates around 70 ha of the 353 it has at its disposal, of which one part is cultivated with maize and soya, another with tomatoes, industrial and

market potatoes (this is cultivated from year to year for variable crops with the intention of maximizing income and local employment), and another is occupied by a fixed green asparagus plantation. Approximately 160 ha of the Consortium's land are given under management through contracts with subsidized rents to direct cultivators or local professional farmers. Each rental contract assigns plots of about 5–8 ha each, and beneficiaries may include people who are already owners, on their own account, of other land (Figure 3).

Figure 2. Massenzatica workers in the past and today. Source: Courtesy of CUM.

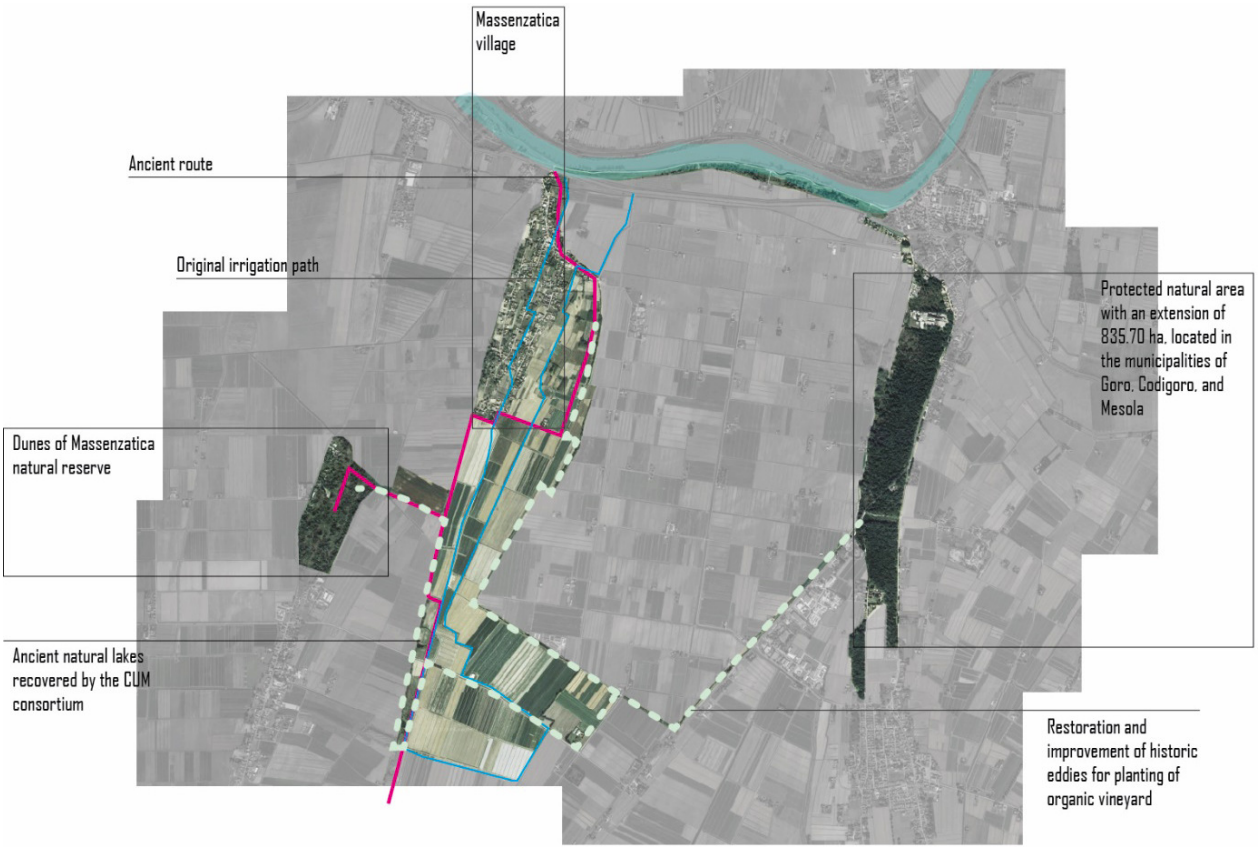

Figure 3. Massenzatica relations with the surrounding territory.

3.2. Porto Tolle Power Plant, the Project of Transformation

The thermoelectric power plant at Polesine Camerini, Porto Tolle, was one of the largest electricity production plants owned by Enel S.p.A, ranking among the largest in Europe, and is located in the southern part of the Veneto region. The plant, which stood in the area of the Delta Po, near the island of Polesine Camerini, about 4 km from the outlet into the sea, was extended over an area of 240 ha and operated from 1980 until July 2009. It produced 2,640 MW, or 10% of the national electricity output, with four units of 660 MW each, burning heavy fuel oil, amounting to three million tons per year. It was therefore equipped with a tank farm, consisting of seven tanks of 100,000 tons and two 50,000-ton tanks, as well as numerous boilers. Of absolute importance is the presence of the Delta Po, which constitutes one of the most important and vast wetlands in Europe and the Mediterranean, with an area covering 786 km^2, of which over 160 are valleys and lagoons of high naturalistic value and a UNESCO World Heritage Site. The distinctive value of this area is further attested by the introduction of various forms of protection, as described below:

- The Po Delta Regional Natural Park was established by Veneto Region Law of 8 September 1997 No. 36, with the declared aim of protecting, recovering, enhancing, and preserving the natural, historical, and cultural features of the Delta Po territory, as well as to ensure adequate promotion and protection of the economic activities typical of the area and contribute to the improvement of the quality of life of local communities.
- The site, designated as a Site of Community Importance (SCI IT3270017), borders the Enel thermoelectric power station on the perimeter area facing the sea. In accordance with the Habitats Directive 92/43CE, its main purpose is to protect the unique ecosystem of river branches and the various areas with sandbars, Bonelli, and "sacche" characteristic of the Delta Po.
- The Special Protection Area (SPA IT3270023), established in accordance with the Birds Directive 79/409CE, aims to protect the numerous bird species that reside in that type of habitat and which are particularly sensitive to alterations to the quality of the area, soil and water. Indeed, the area surrounding the thermoelectric plant, being of alluvial origin, is entirely flat, as is most of the province of Rovigo.

The tourist village project proposed by the Human Company group of Florence was presented in 2018 as the winner of the Futur-e tender promoted in 2016 by Enel to give new life to 23 disused power plants in Italy, including precisely that of Polesine Camerini. At the end of June 2019, the preliminary sale agreement between the energy giant and the tourism giant was signed. In January 2021, the actual dismantling began, while in November 2022 the municipality started the procedure of the Programme Agreement according to Art. 7 of Regional Law 11/2004 for the reconversion of the area of the former Enel power plant into the Po Delta agro-food sports tourism park: the Delta Farm. In the meantime, the administrative process is proceeding to arrive at the change from an industrial site to a tourist-receptive one, in order to then start with the construction of the village proper: 100 ha out of the 300 available, including a water park open to all. To build the tourist center, the Florentine Group will invest about 60 million euros, while Enel will contribute to the demolition work. Delta Farm will be built in the southern area of the former power plant, on an area of 110 ha, 20 of which are wooded, and will be able to host up to 8,000 tourists a day, with accommodation areas destined for different types of open-air hospitality, from pitches (2,000–2,200 caravans) to new mobile homes (Figure 4). Inside, there will be space for commercial activities, craft workshops, local entrepreneurs, fish markets, and markets dedicated to Polesine's agro-food excellence and

Figure 4. The old Polesine Camerini power plant and the future design of the area. Source: Human Company (n.d.).

floriculture. It is expected that 400 people will be employed directly. The project envisages, in particular, the construction of an open-air tourist village, a water sports center, a visitor center for the enhancement of environmental and landscape excellence, and one for the development of typical fish and agricultural production. Following the demolition of the four primary structures of the former power plant, a substantial area has been meticulously considered for the establishment of an expansive tourist resort. The overarching concept put forth by the victorious competition entrant involves the subdivision of the area into four distinct zones, each designated for specific activities. Adjacent to the landmark chimney, the project incorporates a sports center, featuring a diverse array of indoor and outdoor sports facilities such as tennis, soccer, and basketball. Positioned centrally within the designated area, a primary village is envisioned, comprising small cottages with gardens arranged in a systematic grid pattern. These dwellings are interlinked with an additional outdoor leisure pool, further enhancing the recreational offerings. Proceeding southward, the village layout maintains a consistent and orderly configuration, extending towards the southernmost region where an innovative experimental venture focused on fish-based tourism and gastronomy is envisaged. This specific area aims to celebrate and showcase local fish and produce, contributing to the overall appeal and uniqueness of the resort. Within the planned sequence of the new settlement, a narrative unfolds from north to south, characterized by new design elements. Notably, an exclusive access point to the beach has been incorporated for the village residents. Enhancing connectivity, a novel pedestrian bridge is slated for construction, facilitating a direct link between the village and a small beach situated along the west coast. In terms of access to the private area, the project retains the existing industrial harbor to the north, situated in proximity to the primary river arm. In contrast, to the south, a novel small-scale tourist harbor is envisioned. This newly proposed harbor will be seamlessly connected with an already established restaurant, creating a symbiotic relationship between tourism and culinary amenities (Figure 5).

4. Discussion

4.1. Territorial Branding

The Delta Po area exhibits one of the lowest population density grades in the entire Pianura Padana, ranging from 25 to 50 people per square mile. Despite being classified as an inner area, it holds significant landscape value, earning inclusion in the UNESCO Man and the Biosphere program, along with the regional Po Delta

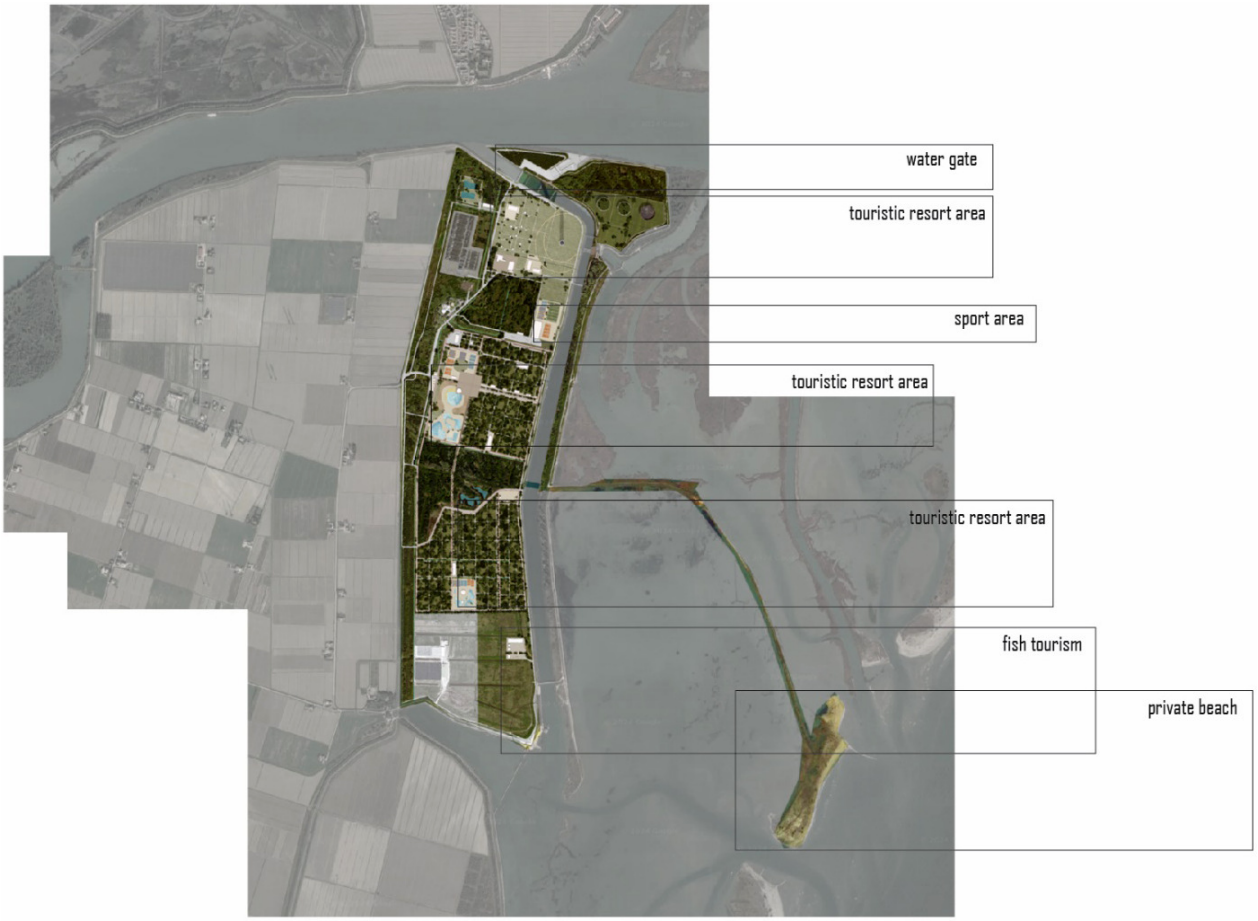

Figure 5. Polesine Camerini: Masterplan of the new resort.

Regional Natural Park. The presence within a UNESCO-designated area, encompassed by the Po Delta Regional Natural Park and Special Protection Area, appears to be a significant advantage, particularly in the context of the Delta Farm project. UNESCO and other territorial grants are conventionally utilized to allure individuals and tourism. The UNESCO Man and the Biosphere program, as implied by its name, seeks to enhance the relationship between human activities and the territory in which people reside. However, the Delta Farm project primarily leverages this designation as an attractive feature without substantially enhancing the quality of this relationship with the local populace. Conversely, in the case of the Massenzatica Cooperative, the residents view the land as a communal asset. Their objective, as written in the CUM foundation documentation (Giacoia, 2003) is to preserve the land's quality, cultivation practices, and the established landscape system that has endured for many years. Unlike the Delta Farm project, the Massenzatica Cooperative embodies a genuine commitment to the land as a shared resource, aiming to sustain not only the physical attributes of the landscape but also the intricate interplay between human existence and the environment over an extended period.

4.2. Relation With the Surrounding Environment

In terms of urban qualities, a notable disparity exists between the two entities. In the envisioned Delta Farm project, the concept revolves around establishing a sheltered, exclusive, and closely regulated village. Driven

by considerations of security and maintenance, the plan involves the implementation of a private perimeter, a fenced boundary of 9.7 km that delineates a secure enclave. While this configuration aims to create a "protected haven" within, it concurrently results in a restrictive enclosure with limited interaction with the external environment. Analogous to industrial areas mentioned earlier, this design features a non-porous fence, impeding meaningful connections with the surrounding landscape. As visible in Figure 5, the design proposal is readable as a sequence of delimited functions, conceived with an emphasis on security and containment. While safeguarding internal elements, the general functional plan contributes to a disconnected urban fabric, resembling the insularity often associated with industrial zones. In stark contrast, the Massenzatica Cooperative represents an open and inclusive structure where the community actively participates in preserving the high quality of the soil and ensuring the sustainable productivity and social well-being of the locale. The social aspect in Massenzatica indicates the view of a "new form of capitalism" (Gandini et al., 2007), where families have benefited from a particular legal form of ownership (neither private nor public) which has allowed a peculiar management method in the last 20 years. Distinguished by an absence of enclosed boundaries, this cooperative embraces an ethos that values the interconnectedness of the municipality's ecological assets. Unlike the Delta Farm project, which views the surrounding high-value ecological areas primarily as tourist attractions, Massenzatica perceives these areas as integral components of a complex ecosystem. Within this cooperative framework, the irrigation system, fields, residences, labor practices, and the intrinsic value of the landscape all contribute synergistically to a holistic, long-term sustainability strategy. By rejecting closed boundaries and adopting a community-centric approach, Massenzatica fosters a more integrated urban fabric, emphasizing the interdependence of human activities and the surrounding environment in the pursuit of enduring social and ecological sustainability.

4.3. Landscape Quality and Society

The Delta Po landscape is characterized by a distinctive system, documented in literature as a reclaimed land crafted, sustained, and governed by human intervention. It stands as an entirely artificial landscape, essentially a hydraulic mechanism whose survival hinges upon a delicate equilibrium maintained through ongoing land management (Figure 4). In the case of Massenzatica, residents form a community with direct ties to agricultural production, where agricultural fields serve as the primary means of supporting families. From 2000 to 2007, a total of 702,000 euros were spent, with 220,000 euros allocated for the purchase and renovation of the new headquarters of the Consortium (recorded in the years 2005, 2007, and 2008) and an additional 482,000 euros for various social activities, the most significant of which included (a) financial aid to individuals in need due to family hardships; (b) initiatives to support the spread and protection of green asparagus; (c) support for income and employment in agricultural labor through the planting of vegetable crops (asparagus, watermelon, cabbages, radicchio, pumpkins, etc.), which, despite causing economic losses to the Consortium, could ensure profitability, insurance, and pension protection for many members; (d) sponsorship and funding of expenses for publications aimed at cultural and tourist dissemination, among others (medicinal plants of the Massenzatica dune area, etc.; Gandini et al., 2007). The village, while seemingly unremarkable in its dimensions, holds a unique position within one of the most intriguing archaeological landscapes in the delta, the Massenzatica Dunes. Here, the landscape apparatus serves as a testament to the past, reinforcing a sense of community identity. The population residing in Massenzatica remains constant throughout the seasons, establishing a permanent and rooted presence, in stark contrast to the transient nature of the Delta Farm touristic resort. Delta Farm, with an anticipated daily tourist influx of around 8,000 visitors, presents a critical dissonance in its approach to inhabiting the territory. The Delta Po

region is characterized by low-density settlements and small and unassuming cities. The stark contrast in density introduced by Delta Farm is apparent and raises concerns about the harmony of coexistence within the landscape. Furthermore, the tourism-centric nature of Delta Farm, predominantly a summer activity in the Delta Po area, results in a significant population decline during the winter months, rendering the village nearly uninhabited. This discrepancy in living patterns creates a noticeable disjunction between the intended lifestyle of Delta Farm and the more enduring, community-oriented existence in Massenzatica.

5. Conclusion

Even if the resort, which is going to be built as part of the Porto Tolle power plant redevelopment, is still in the first phase of realization, some critical considerations are possible. These considerations can discuss the research questions and theoretical problems. The factors contributing to social sustainability in "extreme contexts" or delicate ecosystems, such as wetlands and deltas, are connected to the capacity to create new connections with the environment. It involves linking activity and land use to seasonality, the specificity of the landscape, and understanding its dynamic morphology, rather than merely using the landscape as a brand. The case of CUM demonstrates that in ordinary cities, a new organization is possible, and new ways of living in communities are achievable. It shows that the quality of the landscape should be considered a long-term attribute, not just as an attractor during the summer season. Moreover, interpreting the landscape as an "oasis" of beauty, as in the case of the resort, will surely evoke a sense of security but also create a separation from the "original" landscape. This approach goes in the opposite direction of a positive interpretation of sprawl, as proposed by Secchi (1992, 2005). The countryside, viewed as a new opportunity for the future in Koolhaas's (2020) research, finds in the Delta Po a remarkable example of a highly engineered landscape. Addressing safety from climate change consequences in such areas should involve connecting land use and territorial infrastructure, as demonstrated by CUM. The ordinary approach is grounded in a smooth and delicate intervention on the territory. It focuses on maintaining the original hydro system, restoring old cultivation, and reviving ancient routes with the aim of enhancing the sense of community and sustainability. In contrast, the "extraordinary" approach represents a significant economic investment that radically imposes a new urban structure, a novel challenge for the history of the place accompanied by a high degree of risk. In conclusion, it is important to highlight that Massenzatica serves as a model in alignment with the National Strategy of Inner Areas. This national place-based policy initiative has pioneered new multi-level local governance methods. These methods are designed to address demographic challenges and meet the needs of regions marked by significant geographic or demographic disadvantages through an integrated approach to local promotion and development. These fragile territories, which are often remote from major service centers and frequently neglected, actually comprise 60% of the national territory's surface area, encompassing 52% of its municipalities, and house 22% of its population. In Massenzatica, the stable population ensures ongoing and consistent maintenance of the area. This stability supports the regular functioning and needs of various public services (refer to Table 1), which are critical in combating depopulation, a key focus of the Inner Area National Strategy. Regarding the main connections with different levels of planning, it is important to mention the relevant program (Regional Law 11/2004) for the redevelopment of the former Enel power plant area. This involves a change to the territorial planning scheme, which requires the province's adherence and the approval of the agreement by the provincial president. It has been an exceptional accordance to permit the realization of a big private investment. On the opposite, the experience of Massenzatica represents a case of civil uses of community assets, intended to be enduring because they are legally inalienable. These are referred to as civic demesnes,

collective domains, or collective assets, equivalent terms that vary by geographic area within the country. These assets represent genuine forms of land ownership, exercised collectively by the community. Today, the civil uses of community assets are subject to a public regime and cannot be alienated. They are bound by specific legal purposes, as dictated by the Framework Law on the Reorganization of Civil Uses No. 1766 of June 16, 1927, which ensures controlled availability and dedication to the objectives specified by the law.

Conflict of Interests

The author declares no conflict of interests.

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About the Author

Stefano Tornieri holds a master's degree in architecture (2010) and a PhD in architectural composition (2015) from the University Iuav of Venice. From 2016 to 2023, he was a research fellow at IR.IDE (Infrastructure Research Integral Design Environment) at the University Iuav of Venice, and he is currently a senior lecturer at Luleå University of Technology in Sweden. He was the winner of the Lerici Foundation Grant in 2020 and the Canon Foundation Research Fellowship in 2023.

Urban Planning
2024 • Volume 9 • Article 8282
https://doi.org/10.17645/up.8282

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ARTICLE

Open Access Journal

Trans-Local Climate Politics in Ordinary Cities: From Local Agenda 21 to Transition Towns to Climate Emergency Declarations

Anton Brokow-Loga and Grischa Frederik Bertram

Institute for European Urban Studies, Bauhaus University Weimar, Germany

Correspondence: Anton Brokow-Loga (anton.brokow-loga@uni-weimar.de)

Submitted: 18 February 2024 **Accepted:** 1 August 2024 **Published:** 29 August 2024

Issue: This article is part of the issue "Planning and Managing Climate and Energy Transitions in Ordinary Cities" edited by Agatino Rizzo (Luleå University of Technology), Aileen Aseron Espiritu (UiT The Arctic University of Norway), Jing Ma (Luleå University of Technology), Jannes Willems (University of Amsterdam), and Daan Bossuyt (Utrecht University), fully open access at https://doi.org/10.17645/up.i346

Abstract

This article addresses the question of how ordinary cities, conceptualized here in a simplified way as peripheralized small and medium-sized cities, navigate (the complexities of) climate policy and planning. To do so, we elaborate on three temporal waves of trans-municipal environmental politics that have simultaneously shaped municipal climate politics in many places globally: (a) the Local Agenda 21, between 1992–2002; (b) the Transition Towns movement, between 2006 and 2015; and (c) recent climate emergency declarations, in place since 2016. Interestingly, the thousands of participating municipalities include not only the well-known frontrunners but also many small and medium-sized cities. Some have come into contact with climate and transformation issues for the first time, others have even been pioneers for much larger cities. However, the three waves also each have different characteristics in terms of underlying governance models, theory of change and scope of transition, role of planning and civil society, or output orientation. Through the combination of quantitative and qualitative methods, an overview of interlinkages between the three climate policy waves in German ordinary cities is compiled from publicly accessible databases. In addition, qualitative impressions allow for statements on the actors of this transformation processes, including municipal governments and councils, civil society organizations and social movements, various bridging agents, and trans-national municipal networks. This perspective on (referential and institutional) continuities is deepened in a case study on the medium-sized town of Marburg, Hesse. As participating cities in all three waves are predominantly located in the Global North, the article aims to also contribute to the application of the "ordinary city model" to regionally peripheralized cities in globally non-peripheral regions.

Keywords

climate emergency declarations; Germany; Local Agenda 21; municipal climate politics; ordinary cities; Transition Towns; urban policy mobility

1. Introduction

How can ordinary cities act in times of climate emergency? After activist intellectuals Spratt and Sutton (2008) published their book *Climate Code Red: The Case for Emergency Action*, in which they outline a strategy to move institutional responses to climate change beyond business-as-usual approaches, a rather small network of Australian activists coined the term "climate emergency" for mobilization, especially in small and medium-sized cities (SMCs; see CEDAMIA, 2024; Ruiz-Campillo et al., 2021). However, according to Chou (2021), the strategy of using municipal declarations to influence other municipalities ("sideways") or to call on higher levels to take action ("upwards") did not seem particularly successful at first. The declaration as a political tool needed a fertile environment to spread. Especially from mid-2018 on, scientific publications, popular interest, natural disasters, and last but not least, major global strikes and demonstrations pushed for climate emergency declarations (CEDs) worldwide. By April 2020, more than 1,000 actors had already joined under this banner (including nation-states, universities, and companies; see Ruiz-Campillo et al., 2021). By mid-2023, this figure stood at more than 2,200 authorities (Brokow-Loga & Krüger, 2023). With the first declaration in 2017, the ordinary city of Darebin, Australia, with its 150,000 inhabitants took the lead in this massive wave of CEDs around the globe. Two questions follow from this observation: What is the role of SMCs in driving forward a progressive climate policy agenda? And is this a new phenomenon?

The second question can be answered quickly: No, the phenomenon of small and insignificant municipalities that are active in climate policy is just as old as municipal sustainability and climate policy itself. Therefore, this article looks back and places CEDs in a historical context of precedent waves of local climate policy, in which there is an amplitude in ecologically motivated initiatives, decisions, and approaches to implementation in various towns and cities worldwide. Thus, in contrast to Castán Broto and Westman (2020), who define two different "waves" of climate- and city-related academic publications—urban optimism and urban pragmatism—this article defines waves based on trans-local circulation of these climate policies. We identify the three waves as follows: the Local Agenda 21 (LA21) with policies in the late 1990s and early 2000s; the Transition Town (TT) movement, with policies in the early 2010s; and climate emergency policies (based on CEDs) in the late 2010s. All contributed to a special momentum with local governments increasingly interested in climate and sustainability goals in their urban development, as well as in influencing other governmental and non-governmental actors both "sideways" and "upwards."

Rooted in the concepts of resilience and degrowth, TT is the most radical concept and seeks "the reinvigoration of communities so that they become more self-reliant, lower energy infrastructures and tools for rebuilding ecosystems and communities eroded by centuries of delocalized, expert-driven economic and political systems" (Escobar, 2015). The first TT took place in 2006 in Totnes, England, with a population of less than 8,000 at the time (Smith, 2011). The movement had a background in academia (Hopkins, 2011), but resulted in approximately 1,100 initiatives and citizens' groups in towns and cities worldwide (Feola, 2016, p. 2). In contrast, the idea of LA21 was a call to action at the local level by the nation-states following suggestions from city representatives at the 1992 Earth Summit in Rio de Janeiro (Coenen, 2009). LA21-inspired policies are rooted in the Summit's approach to sustainability to bridge environmental issues with the need for further development, especially in the Global South, but include aspects of localism and good governance (Freeman, 1996; Young, 1997). No individual city is known to have been the first to follow this path. The first phase of resolutions to draw up agendas began around 1995. In Germany, in addition to the major cities of Munich and Münster and the Berlin district of Köpenick, several SMCs are also part of the

first generation, such as Viernheim (Hesse; 33,000 inhabitants) and Landau (Rhineland-Palatinate; 47,000 inhabitants), the latter of which is also investigated in this article.

The primary aim of the article is to analyze the climate policy development paths of ordinary cities between the LA21 in the 1990s and the climate emergency at the end of the 2010s to shed light on often overlooked trans-temporal and local aspects of municipal climate policymaking. It is for this reason that the question of the specific roles of SMCs or ordinary cities in these climate policy waves, on the other hand, characterizes the argumentation of the article as a whole. In tracing the lines of innovative trans-municipal policy initiatives in the last three decades, we examine whether local path dependencies such as institutionalizations within the municipalities are an important context for present and future climate policy ambitions besides the global aspects mentioned above. Using Marburg as a case study, we specifically pursue the following research question: How are the municipal activities within the frameworks of the three climate policy waves—LA21, TTs, and CEDs—in German ordinary cities interlinked, and how do referential continuities affect the local actor constellation?

Although there are many individual case studies in the research field of urban climate policy, as well as summary evaluations of successes and failures, there is a notable lack of longitudinal studies. Whether EU Cities Mission or Resilient Cities, the focus is often on innovation and the prospect of finally acting now—yet scientific and political players run the risk of ignoring previous developments, barriers, experiences, and path dependencies. The importance of the historical developments of the 1970s and 1980s for contemporary urban climate policy is prominently mentioned by Angelo and Wachsmuth (2020, p. 2212), among others, who point out this shortcoming. Furthermore, in their article entitled "Cities and Climate Change: The Precedents and Why They Matter," Hebbert and Jankovic (2013) also emphasize that the close link between urban policy and planning and the consequences of anthropogenic global warming was anything but "unprecedented," as UN-HABITAT (2011, p. 1) has put it. However, while the authors search for traces well into the 1930s, in this article we limit ourselves to the period from the early 1990s to the present day.

We aim to close this gap by identifying seven similar cases through participation in all three waves and then using the city of Marburg, which is paradigmatic in several ways, to produce a more in-depth longitudinal case study that illustrates the conditions of emergence and (dis-)continuities of local climate policy. Above all, we are contributing to the debate with a historically informed view that at the same time consistently looks beyond the local horizon. The article presents original research using an explorative and innovative mixed-method design. To find appropriate cases, three different data sets were combined and internet searches conducted. This results in a rather broad comparison between seven cases primarily based on a qualitative analysis of policy and planning documents. The Marburg case study integrates findings from interviews that are part of an ongoing dissertation project by Anton Brokow-Loga.

Following this introductory section, we highlight a number of theories that are necessary to embed the empirical findings in the state of the art by adapting a systematic literature review. Section 3 makes our approach transparent, but also indicates its limitations. The case study research is twofold: First, we identify the (only) seven cases of those ordinary cities known to have participated in all three previously-mentioned waves to compare their ordinariness and specific climate governance as well as its trans-local and trans-temporal aspects. Second, we use a more in-depth case study of the city of Marburg to show these

aspects in greater detail. Finally, the concluding section classifies the study and identifies further practical and research potentials.

2. State of the Art

As this article covers an emerging debate that is situated in the wide and established field of research on cities and climate change at the intersection of urban planning, geography, and political science, the particular focus is on closing identified research gaps and problems. To operationalize the research question, ordinary cities and the various climate policy waves should be clearly outlined and defined. The central topics extracted from existing research and made manageable for empirical research include an examination of the *ordinariness* of climate politics and governance (2.1) and the characteristics of the temporal *waves* of trans-local climate politics (2.2). At the end of each section, we briefly present how this state of research informs the analysis grid: As an operationalization tool, this grid summarizes all the relevant theoretical categories relevant to the empirical research and can be found later in Table 3 as a general version that already encompasses parts of the research results.

2.1. Ordinary Cities and Climate Governance

As municipalities are often seen as strategic fields for climate change governance, as pioneers and networking agents, this article aims to investigate the research conducted around German ordinary cities in these contexts. Being officially recognized as sub-national actors in tackling climate change in the Paris Agreement of 2015, the role of cities and other municipalities has been subject to a widespread research landscape, but focus is mainly on larger cities (Bulkeley, 2010; Castán Broto, 2020; Kern & Bulkeley, 2009; van der Heijden et al., 2019b). Emphasis relevant to our research was placed on the diversity of agents at play (Castán Broto et al., 2020), the diversity of new governance arrangements (Haupt & Coppola, 2019), and the extensive engagement beyond national boundaries through trans-municipal networks (TMNs; see Lee, 2015). Among other aspects, this needs to be examined and embedded by discussing novel forms of agency within (trans-)local climate governance (van der Heijden et al., 2019a) as well as (trans-)temporal aspects of global sustainability thinking and policy (Angelo & Wachsmuth, 2020).

Ordinary cities have in general received little attention in research on local climate action thus far. Robinson (2002) refers to ordinary cities as cities "off the map"—in the context of municipal climate protection strategies. Given the importance of socio-ecological transformations in all municipalities, researching the (limited) strategies in "ordinary" places such as SMCs, especially if they are non-Anglophone, is probably much more relevant for a wider range of urban areas, especially when it comes to transferability questions. Although Robinson's (2013) analysis focuses primarily on peripheral cities in the Global South, we will continue to concentrate on the Global North, as a large proportion of greenhouse gas concentrations are caused by urban areas in the North leading to a higher transformation pressure (Hickel, 2021; Schmelzer et al., 2022).

If the response to human-induced climate change is the socio-ecological transformation of urban living spaces, it is unclear why research has thus far focused primarily on large metropolitan regions and pioneering cities. SMCs are significantly more numerous than these cities and therefore require greater attention in science and research transfer. SMCs are a gaping void in research on municipal climate policy and planning, and there are hardly any statements on urban policy mobility and participation in climate

policy TMNs (except Climate Alliance), with one exception being Haupt et al. (2021), who ask how German "ordinary" cities became climate pioneers. The research by Domorenok et al. (2020) on the effects of TMNs such as Covenant of Mayors also sheds light on transformation processes in larger cities, although Busch et al.'s (2018) assessment also includes smaller cities with more than 50,000 inhabitants. Haupt et al. (2021, p. 86) select Göttingen (120,000 inhabitants) and Remscheid (110,000 inhabitants) as ordinary cities gone climate pioneers. Research shows that Ordinary Cities have no fixed minimum or maximum limits in terms of population, density, or function in the system of central places. Although we follow this pragmatic classification by Haupt et al. (2021) of ordinary cities based on the number of inhabitants, we limit it to fewer than 100,000 inhabitants. This selection is in line with the official German classification of cities (BBSR, 2023). Due to a lack of very small municipalities participating in the three waves, there was no need to define a fixed minimum.

Based on the state of research on ordinary cities, we consider the limitation concerning the number of inhabitants—which is, however, contextualized in the specific spatial planning system and their location in a federal state—into the analysis grid. It is also necessary to consider the degree of peripheralization, which is why the administrative and economic function should also be included (see also Table 1). It also became clear that integration into TMNs can be an important influencing factor, especially for ordinary cities, which is considered in the analysis.

2.2. "Think Globally, Act Locally": Again and Again? Trans-Localism Over Time

Within the scholarly debate on CEDs, trans-localism is seen as an emerging mode of governance. The wider perspective taken in this article demonstrates that this mode has already emerged in LA21—most evident in the motto "think globally, act locally." Therefore, we also have to look at the trans-temporal cycles of this governance mode and the policies promoted. Municipalities or other local jurisdictions are increasingly recognized as strategic sites to tackle climate change (Castán Broto & Westman, 2020). However, urban policy mobility and the cycles of trans-local climate policies reflect not only the recognition of cities as important agents (van der Heijden et al., 2019a) that focus on local mitigation. A specific localism becomes visible here that can be rather described as a *trans*-localism in a notable way. As municipalities see their actions in connection with local-level activities around the world, other cities' experiences are mutually referenced and other levels of governmental action are specifically addressed or appealed to, a global—or better: trans-local—project seems to become visible.

Against the backdrop of existing research, it seems reasonable to first focus on this trans-boundary exchange. Which modes of polycentral governance with a focus on municipal agency are established in the absence of hierarchical authority relation (Gordon & Johnson, 2017, p. 699; cf. Ostrom, 2012, p. 425)? How exactly can central coordination and local collaboration be balanced (Dyson & Harvey-Scholes, 2022)? In addition, the specific governance must also become part of the investigations, especially when it comes to multi-scalar arrangements of very different actors: Not only municipal administrations, but also social movement initiatives, universities, companies, or the state are involved in novel forms of agency (van der Heijden et al., 2019a) and specific governance constellations implementing LA21, TT, and CED policies.

Although all the different actors in all three waves consider their actions not as contention but as initiatives and innovations toward the common good, at first glance, the intertemporal connections do have a striking

similarity to "cycles of contention" in movement theory (McAdam et al., 2001). Between LA21, TTs, and CEDs—and many cities even lacking the TT wave—there have been phases of latency (Melucci, 1984), but it seems a plausible assumption that there have been learning processes, individual and organizational continuities, and other connections over time (Tarrow, 2011). These wave crests and troughs will be used as empirical framework for the examination of the trans-temporal aspects.

We translate the following aspects from the state of research on trans-local political action and cycles of social movements into the analysis grid: The activities within the individual waves are just as much a part of this as the need to differentiate between firm municipal integration in a TMN or individuals in an activist network (see Table 3). Last but not least, the diversity of planning policy actors becomes clear, for which the analysis grid must remain open and flexible.

3. Research Strategy

After the identification of research gaps, we opted to approach the object of research in an explorative manner and with iterative loops. The methodological research approach consists of the following elements: Combination of databases; analyses of relevant documents and homepages; and guided expert interviews. We put the various elements together in an iterative process and sometimes faced the challenge of very poor data availability, especially with regard to the historical processes surrounding LA21 and TT initiatives. The triangulation with a detailed qualitative case study in Marburg is therefore intended to better contextualize the trends that were only vaguely documented in the other cities. Following the proposed research question, the operationalization in this section, therefore, focuses on defining and narrowing participating ordinary cities in Germany, the methodical identification of municipal activities, and interlinkages or references.

For all three waves, there is a clear preponderance of cities in Western democracies, and for TTs and LA21, there is a focus on Western Europe, which is largely due to the particular form of governance and planning systems. The Federal Republic of Germany, in which all three waves were relatively strongly represented, can provide a reasonably standardized frame of reference for the local activities. Pragmatic research reasons, namely language and access to specialist circles, also led to the research being geographically limited to Germany.

Within this geographical frame, we identified 106 municipalities with a CED (CEDAMIA, 2024), 66 of which qualify as ordinary cities of fewer than 100,000 inhabitants. With this data set, we were able to trace back the lines of previous TT and LA21 activities, basically relying on data sets conducted by movement actors (Agenda 21 Treffpunkt, n.d.; Transition Netzwerk DACH, n.d.; also partly based on government agencies) that contain 45 TT initiatives in ordinary cities and 2,335 ordinary cities that committed to LA21. We found 47 ordinary cities with CED and LA21 activities, but only seven with additional TT activities. However, none of the CED cities has engaged in TT but not LA21, while there are another 24 cities engaged in TT and LA21 but did not declare climate emergency for different reasons (Figure 1).

As we are particularly interested in the cities that went through all three waves, at the end of the selection process, seven cities were selected for more detailed analysis. It is worth noting that all seven cities are located in the former West Germany, whereas municipalities in the former German Democratic Republic (former East Germany) are underrepresented in all three waves.

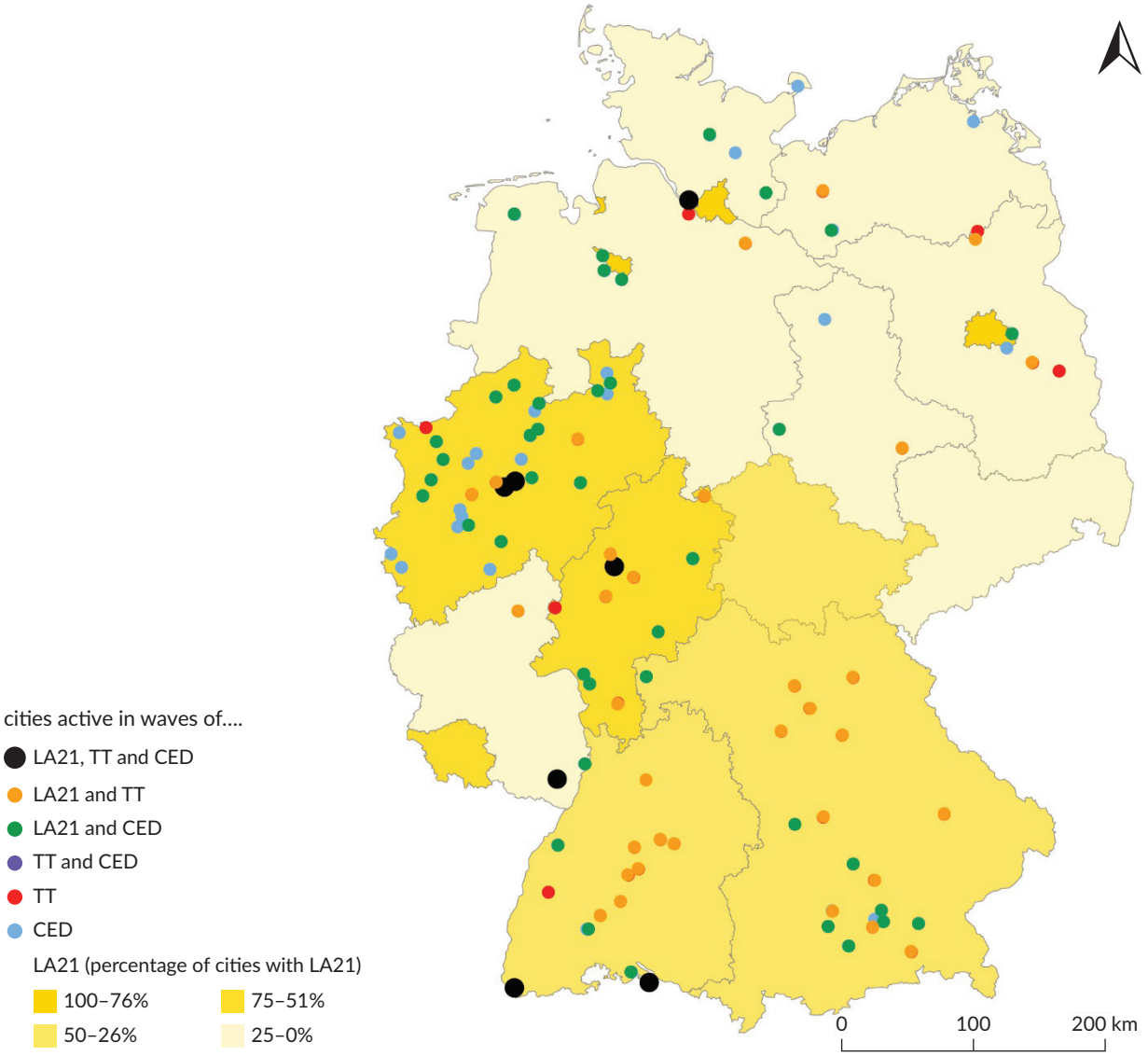

Figure 1. Map of German ordinary cities with CED, TT, and LA21 activities.

To investigate to what extent the selected cities qualify as ordinary, we revise whether cities are of higher importance despite their comparatively low size. The key data for the seven cities shows considerable differences with the number of inhabitants ranging from just under 23,000 in Herdecke to almost four times that number in Constance (over 87,000; Table 1). That the two largest cities are listed as higher-order centers in the central place system (Terfrüchte & Flex, 2018) despite having fewer than 100,000 inhabitants indicates the peripheral location of these ordinary cities: Their status exists due to the lack of major cities within easy reach. All other cities are middle-order centers within a metropolitan region. This role is often reflected in a lack of specialization, high commuter interdependencies, and subordinate public facilities. Only Lörrach and Landau function as the seat of the district administration in their surroundings or have independent city status.

The subordinate role of ordinary cities leads to significantly less attention within the multi-level system of spatial governance compared to metropolises. To evaluate the governance structure of climate politics, we

Table 1. Key data of German ordinary cities with CED, TT, and LA21 activities.

Municipality	State	Inhabitants (as of December 2022)	Centrality	Administrative function	Economic function
Herdecke	North Rhine-Westphalia	22,758	Middle-order center, part of Dortmund metropolitan region	Municipality	Mainly commuting, high income
Wedel	Schleswig-Holstein	34,538	Middle-order center, part of Hamburg metropolitan region	Municipality	Highly specialized production, commuting
Landau	Rhineland-Palatinate	47,610	Middle-order center, part of Rhine-Neckar metropolitan region	County-free city	Viticulture, broad economic base
Schwerte	North Rhine-Westphalia	46,658	Middle-order center, part of Dortmund metropolitan region	Municipality	Some production, public institutions, commuting
Lörrach	Baden-Württemberg	49,876	Middle-order center, part of Basel metropolitan region	County seat	Some production, public institutions, commuting
Marburg	Hesse	77,845	Peripheral higher-order city	County seat	University, specialized production and services (medicine)
Konstanz	Baden-Württemberg	87,355	Peripheral higher-order city	County seat	University, specialized production, public institutions

examine the role of local government, planning authorities, civil society, and citizens within the three waves. Unfortunately, very little data are available for the first wave. To measure trans-local connections of local climate politics, networks and the links to supra-local levels and other municipalities are examined in each case (Table 3).

On this basis, the case study Marburg was selected thanks to the particularly strong interlinkages, and it therefore represents the selection of a least likely case. By continuities/interlinkages, we refer to the references between the different waves in a city. The selection was not only concerned with the question of whether participation took place in each wave (on this basis, the seven cities were selected), but also whether a rhetorical or institutional connection between LA21, TT, and CED initiatives can be demonstrated. As will be shown, Marburg is the only city able to demonstrate this type of referential continuity, i.e., references between all three waves; thus, the city was selected for a more detailed analysis. A purposive sampling process was applied here to identify specific local actors from fields relevant to (climate) planning politics, such as representatives of civil society, municipal administration, press, and science), with whom structured interviews were conducted (Table 2). Extensive primary data were collected through eight guided interviews as part of Anton Brokow-Loga's dissertation project on the transformation processes of municipal climate governance in climate emergency municipalities and were analyzed in a secondary analysis for this

Table 2. List of interview partners.

Institution in the City of Marburg	Date of Interview	Code
Municipal administration	07.12.2023	MR1
Municipal administration	09.01.2024	MR2
Municipal politics	07.12.2023	MR3
Municipal politics	08.01.2024	MR4
Civil society	07.12.2023	MR5
Civil society	07.12.2023	MR6
Science	07.12.2023	MR7
Local press	11.12.2023	MR8

article. In addition, an analysis of Marburg urban policy and planning documents with thematic reference to LA21, TTs, and CEDs was carried out.

With regard to data analysis, the recorded interviews were anonymized, transcribed, and systematically coded using qualitative content analysis. Paraphrased or summarized statements are referenced in this article in anonymized form (e.g., MR1). Categories for evaluating interviews as well as results from document and website investigations were established, reviewed, and expanded both inductively and deductively. Thus, coding categories contained topics from the state of the art, such as institutional governance arrangements or the role of TMNs, as well as insights from the empirical material, such as personal continuities or coincidences. To reduce sampling and analysis bias, different researchers and assistants carried out the work separately, and the results were continuously triangulated and reflected upon.

The approach entails certain disadvantages and, thus, limitations. Data availability is a central problem in the exploratory studies on local references to other waves, especially due to the high reliance on internet sources, the scarcity of scientific studies, and the fact that some state-initialized databases have been scaled back. We were able to counter this problem with individual inquiries and triangulation with a more in-depth study. A second challenge is the desired comparability of historical processes: It quickly became apparent that TTs activated significantly different constellations of actors to the other two waves, which is also noticeable in the visibility of linkages. A third critical point is that only German cities could be analyzed here. The transferability of the research results is therefore limited.

4. Analysis of Interlinkages Between Climate Policy Waves in German Ordinary Cities

This first part of the analysis focuses intensively on the question of how the municipal activities within the frameworks of the three climate policy waves in German ordinary cities historically interlink with each other. However, these interlinkages are unevenly visible in the cities. After a look at the different temporal layers, at the end of this first analysis chapter, a type formation and the transition to the second analysis chapter and the correspondingly necessary case study take place. General information on the municipalities, trans-local networks, and references of local activities during the waves of LA21, TT, and CEDs can be found in Table 3.

Table 3. Analysis grid with trans-local networks and references of local activities during the three waves.

	LA21		TT			CED		
	Role of TMNs	References to trans-local activities	Role of NGO networks	Integration into trans-local structure	References to trans-local activities	Role of TMNs	Role of NGO networks	References to trans-local activities
Herdecke	Aalborg, ICLEI	X	X	X	X	Climate Alliance		X
Wedel	Aalborg, ICLEI	X	X					
Landau		X	X		X	Climate Alliance	Fridays for Future	X
Schwerte		X	X	X		Climate Alliance	Fridays for Future	X
Lörrach		X	X				Fridays for Future	
Marburg	ICLEI	X	X		X	Climate Alliance	Fridays for Future, Extinction Rebellion	X
Konstanz		X	X			Climate Alliance	Fridays for Future, Extinction Rebellion	X

4.1. Trans-Local Linkages

While the very use of the term LA21 refers to Agenda 21 as one of the final documents of the Earth Summit in Rio de Janeiro and this origin is usually also referred to in the documents, the network activities of ordinary cities are relatively limited. Memberships of the ICLEI and the signing of the *Charter of European Cities & Towns Towards Sustainability* (Aalborg Charter) were reviewed (European Conference on Sustainable Cities & Towns, 1994; ICLEI, 2023). Only the two smallest municipalities, Herdecke and Wedel, can provide evidence of both. The reverse is true for the TT initiatives, which all identify as part of an NGO network by being listed in the global directory of transition initiatives (Transition Netzwerk DACH, n.d.), but whose self-presentations rarely refer to this network or the origins of the TT movement. Again, exceptions are Herdecke and Marburg as well as Landau. The TT initiatives in Herdecke and Schwerte additionally resemble a special trans-local character as both have a twin structure acting as a common initiative with a larger, adjacent city (Witten, Dortmund), providing representation in two municipalities while using resources and capacities of one common group.

In CEDs, trans-local references are very present in resolutions and associated justifications. The Herdecke town council, for example, "calls on other municipalities, the federal states and the Federal Republic of Germany to follow the example of the towns of Constance, Kleve, Tönisvorst, Münster and Heidelberg" (Stadt Herdecke, 2019). Similar references to other municipalities and higher levels of government are made in all other cities surveyed. Even Constance's CED, which was the first in Germany, explicitly "calls on other

municipalities…to follow [its] example" (Stadt Konstanz, 2019). However, international trans-local references can only be found sporadically. Regarding integration into TMNs, the role of the Climate Alliance cannot be overlooked as it at an early stage self-determinedly disseminated, collected, and shared information, including templates for draft resolutions. It also supported participating municipalities in follow-up and implementation. In terms of embedding in social movement networks, a trans-locally networked local chapter of Fridays for Future or Extinction Rebellion usually triggered or pressured for action—a fact also mentioned by Satorras (2022) or Ruiz-Campillo et al. (2021). Noticeably, the larger the city, the more likely it is that local chapters of trans-locally networked social movements are involved in initiating the CED.

Taken together, we can observe a distinctive role of TMNs in the three waves. Thirty years ago, the LA21 was introduced by an intergovernmental global conference after it had been lobbied by a TMN (Coenen, 2009), but in the aftermath, municipalities in Germany were mostly left alone with the "call from Rio to the cities of the world" by the government (or governments as it was the competence of the Länder; Kissling, 1998). ICLEI itself had too few resources and was not visible enough as an advanced organization for the immense task, and other TMN activities such as the Aalborg Charter were formed later. Furthermore, the localist background of LA21 hindered a more extensive cooperation between municipalities (cf. Freeman, 1996; Young, 1997). This fundamentally changed in the next wave. Introduced as an academic and simultaneously grassroots project, TT never had the same aspirations as LA21 but was from the start equipped with a small-scale, yet visible TMN (Kenis & Mathijs, 2014; Maschkowski & Wanner, 2014). All TT initiatives we were able to identify in German municipalities were included in the TMN's dataset freely accessible online. However, TT with its narrower framework attracted many fewer members. With CEDs, there is a similar TMN at the core, but the organization is more virtual. Municipalities introducing a CED are not required to become members, but are seen as "soul mates" by the organizers and hence will be included into the database as soon as they know about the declaration via mass media and extensive and ongoing research. While TT initiatives are provided with a common overall concept, CEDs provides nothing more than a title or motto; other TMNs such as Climate Alliance and social movement organizations like Fridays for Future step in to facilitate information on enacting and implementing CED.

4.2. Trans-Temporal Linkages

Connections between the three waves of trans-municipal climate politics are much less widespread than between localities within one wave (Figure 2). Little continuity can be observed between LA21 and the TT movement, as Herdecke's TT initiative is the only one to mention the municipality's LA21. The local citizens' group appraises LA21 for "having been a promising start" but goes on to criticize the lack of implementation, "which is a pity" (Transition Town Witten, n.d., authors' translation). Still, the TT initiative also includes policies of sustainability from LA21. Landau's TT approach applies a concept of "wish production" originally used in many LA21 processes (Transition Town Landau, n.d., authors' translation).

Notwithstanding potential misinterpretation due to lacking data, we were able to identify three different trans-temporal trends:

- In the first type (Schwerte, Lörrach, Constance), participation in all three waves can be determined, but discontinuities can be observed.

- The second type shows a trans-temporal continuity or reference between LA21 and CEDs (Herdecke, Landau, Marburg). Presumably, the institutionalized capacities primarily led to the processing of the climate emergency tasks.
- The third type (Wedel, Marburg) shows links between TTs and CEDs. Here, temporally stable civil society cells provided the initial impetus for formative processes, including in administration.

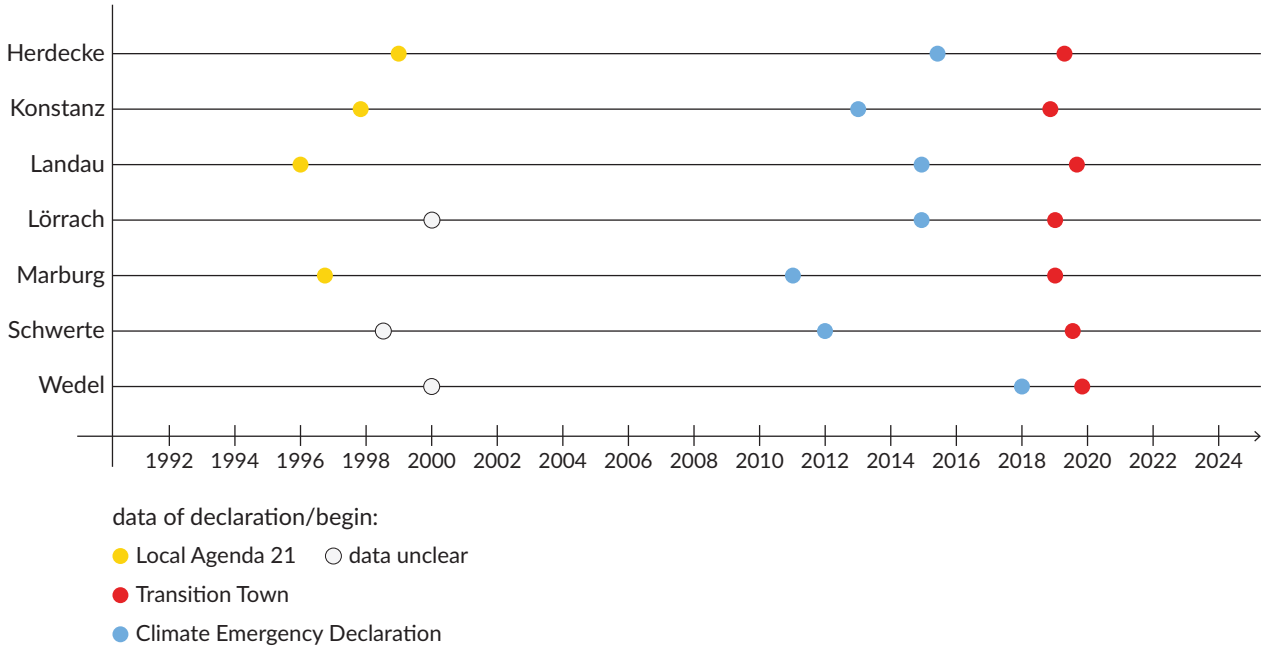

Figure 2. Trans-temporal climate politics in seven German cities.

As the city of Marburg has characteristics of both type 2 and type 3 and thus shows particular referential and institutional continuities, it will serve as a detailed case study to work out the features of trans-local climate policies.

5. Analysis of Referential Continuities and Actor Constellation in Marburg

In contrast to the predominant depiction in the literature (Freeman, 1996; Young, 1997), nearly all cities exhibit little activity by citizens and local civil society in the first wave (LA21). Instead, the municipality itself appears to have the organizing role with different departments such as the local planning authority being involved. Only in Schwerte was LA21 initiated by local civil society. The situation is quite different for the local TT initiatives, all of which are based on citizens' groups that at best have loose links to supra-local associations, local environmental associations, and existing citizens' initiatives, but relate to the basic concept of TT (s.a.). Local governments and planning authorities are only rarely named by TT initiatives and are regarded as addressees of demands or critique, but not cooperation. This is again in clear contrast to CEDs where it was always the city council passing the resolution, discussing measures, and initiating corresponding planning processes. Usually, a climate protection manager is entrusted with the process including local planning authorities. However, despite this high level of involvement, it was always civil society organizations that initiated the CED, while only in the three largest cities they also co-operated in the subsequent planning process. Yet even if a local citizens' initiative or civil society organization campaigns

for CED, the basic idea is that the municipality as a public entity declares the emergency and meanwhile acknowledges the need for action. The focus of further scientific research must therefore be on the concrete effects of (referential and institutional) continuities. Using Marburg as a detailed case study, how do referential continuities affect the local actor constellation in times of climate emergency?

The case of Marburg, a medium-sized city renowned mainly for one of the oldest universities in Germany, serves as an example of transformation processes with regard to trans-local and trans-temporal influences. All interviewees in Marburg mention a strong historical anchoring of environmental issues due to the university and politically active students (MR1, MR5, MR8). The LA21 process began in 1997 and intensified towards the end of that decade (MR6) with broad public involvement in eight thematic groups such as transport or economy (Lokale Agenda 21 Marburg, 2001) submitting concrete proposals for measures. However, in 2002/2003, the city council was unable to decide on these proposals and a year later would only "acknowledge" them. Despite this being a "participation trauma" to some participants (MR6), individual LA21 working groups still meet regularly voluntarily, receive support from the city administration, and continue to report to council committees, for more than twenty years now. In 2022, the LA21 working group on traffic referred to the CED and called for a halving of motorized private transport (Universitätsstadt Marburg, 2022). However, this position has since met with massive resistance from parts of the local population, including a successful referendum *against* the very same intention to halve car traffic (MR3, MR8). Not just as a side note: The implementation of democratically approved climate neutrality efforts is being turned completely on its head by referendums like this one.

After public protests in 2019 and 2020, the CED led to a climate action plan, an accelerated climate neutrality target for 2030, and a more comprehensive climate governance (Deutsch-Französisches Zukunftswerk & Stadt Marburg, 2021), which includes temporary citizens' councils and climate ambassadors (MR1, MR3, MR5). However, there are no explicit references to LA21 or the TT initiative, which was particularly active from 2011 to 2013, but like many other TT approaches was characterized by a low level of involvement in city administration and local politics. It also shared the loose networking structure and focus on bottom-up initiated projects such as Community Supported Agriculture, an annual education festival, or a cargo bike rental service (MR5). However, when the TT initiative faded to inexistence, in 2019 some members initiated the decisive participatory process leading to the local CED. In contrast to TT initiatives with little involvement, they took over the moderation of two events for the climate action plan and were funded by local authorities. This was done with explicit reference to Totnes, the TT's starting point:

> But what will this participation process look like? Who will shape it? In July, inspiration came from Totnes. There, Transition Town Totnes and many other partners organized an all-day event entitled "Totnes Declares a Climate Emergency—What's Next?" and expressly invited people to implement this concept in other cities. What if we did the same in Marburg? ("Bescherung," 2019, authors' translation)

While these experiences were passed on trans-locally to the now widely recognized process "Bonn4Future" (Irmisch et al., 2022, p. 34), these traces are lost in Marburg. The local TT initiatives name "Marburg in transition" has now become the title of the city council's sustainability brochure featuring second-hand stores, low-packaging shopping, and recycling. In Marburg, it is ultimately personnel continuity and informal relationships that ensure trans-temporal continuity. The person who coordinated LA21 in city administration became head of its environmental department, and shortly before retirement, initiated the decisive

steps for CED (MR6). Again, former TT members negotiated its participatory design ("Bescherung," 2019, authors' translation).

The case study shows that, in Marburg, successive cycles of environmental movement activities provided a current that was used by actors from local civil society groups to at least temporarily expand their influence on urban policy (MR6). These strategies were often the result of political circulation within very dynamic activist networks, which are facilitated in particular by the impact of the university—perhaps the least ordinary part of the ordinary city. This circulation is not unidirectional, but rather diffuse and multidimensional. However, the current was also used by the council to expand jobs or make them independent of funding (MR1), i.e., to ride the trans-local and trans-temporal waves for the often very ordinary perceived local good.

6. Conclusion

The empirical results of this article show that ordinary cities participate in trans-local and trans-temporal climate politics in very different ways. The case of Marburg in particular reveals how the three waves of municipal policy are omnipresent in urban policy practice and are strongly oriented towards the phases identified in this article. The theses of climate action politics that are mobile not only in trans-local (van der Heijden et al., 2019a), but also trans-temporal terms (Angelo & Wachsmuth, 2020) are clearly confirmed here. However, this cannot conceal that trans-local policy mobility to ordinary cities is lower than expected (Lee, 2015) at least within the German frame with its strong devolution of powers and little policy regulation from state and federal governments. The results should therefore be considered in context: There are 10,753 municipalities in Germany, of which 82 have more than 100,000 inhabitants. Given that there are 40 CEDs within the larger cities and only 66 among the ordinary cities and towns, the latter are clearly underrepresented. This is also because in our selection of seven case studies, TMNs are not the main source of policy mobility (for a broader picture cf. Busch et al., 2018; Domorenok et al., 2020). While five cities are members of Climate Alliance, networks in civil society and direct learning seem to be much stronger.

The first part of the research question is to be answered more explicitly here: How are the municipal activities within the frameworks of the three climate policy waves in German ordinary cities interlinked? With regard to the trans-local character of the resolutions and initiatives, the high degree of networking among the activists comes to the fore. The references to other cities in Germany are striking, although processes were also initiated by learning from other cities across national borders or urban policy networks (cf. Cook & Ward, 2011). Here, ordinary cities are not cities "off the map" (Robinson, 2002) but part of an ongoing debate among cities of different sizes and centrality. While ambivalent experiences of local failure can also lead to transformative successes elsewhere, local path dependency seems to be important. The trans-local activities during the initial and peak phases of the climate policy waves needed a fertile local ground so that continuous work was possible in the institutional structures of the new governance arrangements (Haupt & Coppola, 2019): environmental office, committees of the city council, deliberative panels. In the end, this continuity even in the "waves troughs" ensured that the municipal work went beyond concept development and resolutions, and included the important implementation work, too. The engagement in or collaboration with TMNs, which tends to be very strongly emphasized in research (Dyson & Harvey-Scholes, 2022; Lee, 2015), did not extend significantly beyond the initiating phase in any of the cases examined. This is contrary to the original assumption and puts this perspective in a different light for practice and research.

Although the trans-temporality of the three waves is clearly confirmed for the case studies, it is less substantiated elsewhere. As compared to 2,335 German ordinary cities committed to LA21, the waves of CEDs and especially TTs are comparatively low. While the CED criterium does by no means cover all cities with ambitious climate politics (Ruiz-Campillo et al., 2021), nor every trans-municipal activity, TT initiatives have not only been less successful in spreading trans-locally, but are also less connected trans-temporally. One reason is that TT is based on a radically different governance concept that does not allow for easy connections towards local politics and city administrations (Escobar, 2015). While there has been much reception to the concept in academia, local implementation is lagging behind. But even after a quarter of a century, today's CED activities rarely make direct reference to LA21. Given the importance and urgency of local climate politics today, the high continuity of these activities over the last decades proven by the Marburg case study is not necessarily relevant for local actors in their daily communication.

This makes some methodological notes necessary. The study has shown that the publicly available data is significantly less than expected, especially for the first two waves. This becomes particularly clear when analyzing ordinary cities. Only the in-depth investigation within the framework of qualitative case studies provides significant insights. The conceptual vagueness also makes qualitative analyses necessary. Despite the use of certain "labels," as LA21, TT, and CED ultimately all represent, and the associated support for trans-local ideas, this does not lead to standardized local policies but highly differentiated and sometimes contradicting approaches.

The iterative approach to the research for this article also brought to light a closer look at these references between the climate policy waves. The second part of the research question—how do referential continuities affect the local actor constellation, using Marburg as a case study?—is also to be answered more explicitly here. A closer look at the in-depth case study revealed the importance of personal aspects in local administration, politics, and civil society alike. These results from Marburg thus initially confirm earlier findings from planning research, particularly concerning the pre-decisive power of the administration and the role of informal networks in planning (Fox-Rogers & Murphy, 2014). Yet, the personal connections and even identities especially in the smaller cities researched do not necessarily lead to institutionalized involvement in municipal climate politics. The extent to which this is related to the size of the city is unclear, but it is noteworthy that civil society in ordinary cities may be too weak to participate in lengthy planning processes and the municipalities themselves have less capacity to enter into such collaborations. Like Haupt et al. (2021), however, this article refers to ordinary cities such as Konstanz and Marburg, which have a high proportion of their civil society actors recruited from the local university environment, which of course cannot exist everywhere. Informed by van der Heijden et al. (2019b), the article also highlights novel forms of agency and the engagement of social movement initiatives, companies, and education actors in multiple governance arrangements (Castán Broto et al., 2020; Haupt & Coppola, 2019). The specific role of these diverse actors as supporting pillars for urban climate policy might even become more urgent in the near future. In times of geostrategic tensions and a looming global economic and living cost crisis, new room for maneuver is not necessarily opening for chronically underfunded municipalities.

However, the most important intertemporal aspect of all three waves and the many individual local innovations to climate policy is something else: They are all directed to intergenerational justice (Brokow-Loga & Krüger, 2023). Therefore, and for the very different modes of governance at play, the three waves do not resemble "cycles of contention" (McAdam et al., 2001), but of cycle of *intention*. The very different actors, instruments,

and underlying concepts all contribute to a common idea, which also gave the title to the very first publication of the LA21 wave (cf. Fuhr et al., 2018): "Our Common Future."

Acknowledgments

The authors would like to thank Jette Schwormstede, Theresa Speh, and Marie Weber for their support in researching and evaluating the planning documents. The authors would also like to thank the interview partners in Marburg for their willingness to participate. Last but not least, we are grateful for the critical and constructive feedback from the two anonymous reviewers and the academic editors of this thematic issue.

Funding

Research for this article was partly funded by the Bauhaus University's seed funding entitled Wellen transkommunaler Klimapolitik—Demokratisierungseffekte und Wachstumskontinuitäten, from which the authors have benefited in 2023 and 2024.

Conflict of Interests

The authors declare no conflict of interests.

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About the Authors

Anton Brokow-Loga is a political scientist, transformative researcher, and fellow at the chair of Urban Studies and Social Sciences at Bauhaus University Weimar. There he is involved in the university education of architects and urban planners. His research focuses on degrowth-oriented planning, housing issues, and the interrelationship between democracy and climate policy in municipal transformation processes.

Grischa Frederik Bertram is an associate professor for spatial planning and research at the Bauhaus University Weimar. He was a senior researcher at the University of Kassel. His PhD on protest in local spatial planning in Berlin was published in 2019. He studied urban planning at the University of Kassel (Dipl.-Ing., 2004, 2006) and the Bartlett School of Planning, University College London. His main research areas include local governance, planning theory, and sustainable spatial development.

Urban Planning
2024 • Volume 9 • Article 8297
https://doi.org/10.17645/up.8297

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ARTICLE

Open Access Journal

An Urban Equalisation Strategy for Managing the Transition to Climate Resilience in an Ordinary Italian City

Riccardo Privitera

Department of Civil Engineering and Architecture, University of Catania, Italy

Correspondence: Riccardo Privitera (riccardo.privitera@unict.it)

Submitted: 21 February 2024 **Accepted:** 15 July 2024 **Published:** 22 August 2024

Issue: This article is part of the issue "Planning and Managing Climate and Energy Transitions in Ordinary Cities" edited by Agatino Rizzo (Luleå University of Technology), Aileen Aseron Espiritu (UiT The Arctic University of Norway), Jing Ma (Luleå University of Technology), Jannes Willems (University of Amsterdam), and Daan Bossuyt (Utrecht University), fully open access at https://doi.org/10.17645/up.i346

Abstract

Climate change poses complex challenges that require simple and viable responses, particularly for those small and ordinary cities that are traditionally lacking in financial and human resources. To effectively address climate change responses, adaptation and mitigation strategies imply the understanding of solutions as well as the inclusion of different actors in the decision-making process. Responses to climate change not only depend on the knowledge of the impacts of extreme weather events but also on the inclusion of comprehensive approaches that should consider the availability of areas for spatialising different solutions, the cooperation of stakeholders at different levels, and the disposal of financial resources and institutional capacities. Such approaches face several difficulties and limitations for their real development and management, especially in ordinary cities. This is mainly due to a general lack of areas belonging to municipalities to be used as public spaces for developing new adaptation and mitigation actions and, therefore, to their related economic viability. The implementation would require the public acquisition of private plots, which is often economically unsustainable for local administrations and faces resistance from private landowners. This study proposes an urban equalisation approach that is grounded in the principle of targeting a balanced sharing of benefits and liabilities among those private actors involved in adaptation and mitigation programmes. The case study of Ragalna, a small Italian town, is investigated in the framework of the recent Local Spatial Plan that carried out a tailored transfer of development rights strategy for building a new green infrastructure aimed at pursuing a climate-resilient scenario that can be adopted by other ordinary cities.

Keywords

climate resilience; green infrastructure; ordinary cities; transfer of development rights; urban equalisation

1. Introduction

1.1. Green Infrastructure for Climate-Resilient Strategies

The increasingly evident adverse effects of climate change on cities call for a profound rethinking of urban planning tools and their contents, especially with a view to defining new economic, social, and environmental sustainability objectives that allow for redesigning a more resilient, safer, and higher-quality urban environment. Reviewing spatial planning and management tools, through the introduction of innovation elements in urban policies and the research and adoption of new strategies, represents a fundamental step for re-designing and building settlements that can better adapt to climate change (Martinico et al., 2014). At the local level, cities face significant impacts from climate change because they are home to more than 50% of the world's population, are growing rapidly, and often concentrate economic activities, population, and infrastructure in high-risk locations (Araos et al., 2016). Urban climate change-related impacts include rising sea levels and storm floods, heat islands and heat stress, extreme precipitations, inland and coastal flooding, landslides, drought, increased aridity, water scarcity, and air pollution, with widespread negative impacts on people (and their health, livelihoods, and assets) and on local and national economies and ecosystems (Intergovernmental Panel on Climate Change, 2023). In these urban contexts, adaptation is about planning and building settlements that can adjust better to the consequences of all these changes. Predominantly, urban planning measures can help protect and enhance green spaces that have permeable and evapotranspiring features. This action is specifically related to adaptation, since urban green spaces can provide many relevant functions for coping with climate change. They provide essential ecosystem services such as stabilising the climate through carbon storage and sequestration and regulating the micro-climate features (in terms of air temperature and urban heat island reduction) through tree evapotranspiration processes and shading effects, which also contribute to building energy savings in the summertime (Palme et al., 2019; Privitera et al., 2021), controlling stormwater runoff through soil permeability (Elliot & Trowsdale, 2007), reducing noise through greenery canopy biomass, enhancing air and water quality through air pollutants removal, and providing compost biomass and soil protection (Henneberry et al., 2020; McHale et al., 2007). In addition, urban green spaces are relevant in physical planning since they provide a further layer of cultural ecosystem services such as increasing urban quality and creating more pedestrian-friendly, comfortable, and visually pleasing settlements and sense of place (Daily, 1997).

Accordingly, urban planning and management practices should be based around the multi-functional concept of green infrastructure (Handley et al., 2007), which can be envisioned as a new planning tool for effectively implementing adaptation and mitigation strategies. Nature as infrastructure has the potential to be a transformative concept for development. It goes beyond the idea of nature-based solutions, which are mostly understood as isolated and localised actions to mimic natural processes through green components. Nature-based solutions emphasise a problem-driven and solution-oriented approach that seeks to apply ecological wisdom to solve sustainability challenges (Eggermont et al., 2015) and to address societal challenges rather than just planning (Pauleit et al., 2017). Differently, the concept of green infrastructure is mainly referred to as a network of interlinked green areas, which can also include nature-based solutions. It has been introduced to upgrade urban green space systems, thus forming a coherent planning structure (Sandström, 2002). Indeed, green infrastructure can be made of different kinds of green spaces, connected as networks of multifunctional ecological systems within, around, and between urban areas, and at different

spatial scales (Mell, 2008). Green infrastructure comprises interconnected natural areas instead of separate parks, recreation sites, and any other nature-based solution scattered around the urban fabric. The concept of green infrastructure emphasises the quality as well as quantity of urban and peri-urban green spaces (Rudlin & Falk, 1999; Turner, 1996), their multifunctional role (Sandström, 2002), and the importance of interconnections between habitats (van der Ryn & Cowan, 1996). Green infrastructure maintains the integrity of habitat systems and provides the physical basis for ecological networks, which has been advocated as a way for alleviating the ecological impacts of habitat fragmentation, even in urban contexts (Bierwagen, 2007). This makes biodiversity conservation an integral part of sustainable landscapes (Opdam et al., 2006). Its design and management should also enhance the character and distinctiveness of an area with regard to existing habitats and landscape types. Green infrastructure also plays a key role in climate change adaptation and mitigation by improving the city's capacity to cope with rising temperatures and extreme weather events associated with climate change (Gill et al., 2008). Furthermore, the connection of urban green spaces increases the overall accessibility of these areas through the creation of cycling and walking paths. The term infrastructure implies a system that is vital to the functioning of a city, whereas green space may be regarded as something merely nice to have. Like other infrastructure typologies, such as transport, food/energy supplies, and water/waste management systems, green infrastructure can significantly contribute to the delivery of other forms of services to communities (Millennium Ecosystem Assessment, 2005). For all these reasons, green infrastructure should be seen as a primary consideration in planning, developing, and maintaining an eco-town. If it is proactively planned, developed, and maintained, it has the potential to guide urban development by providing a framework for economic growth and nature conservation (Schrijnen, 2000; van der Ryn & Cowan, 1996; Walmsley, 2006). Such a planned approach would offer many opportunities for integrating urban development, nature conservation, and public health promotion (Tzoulas et al., 2007).

1.2. Ordinary Cities Between Climate Crisis and Local Action

It is increasingly recognised that the delivery of climate policy ultimately happens through place-based initiatives at the local level (Galarraga et al., 2011; Howarth et al., 2021). It has also been widely argued that effective delivery of actions to promote low-carbon and climate-resilient development will require experiments with new governance arrangements (Bulkeley et al., 2019; Castán Broto, 2020; Jordan et al., 2018; Kivimaa et al., 2017). In particular, processes that engage and harness the combined energies of the public, private, and third sectors are required (Gouldson et al., 2016). The dominant literature traditionally focuses almost exclusively on cities that are represented as key command-and-control centres for globalised social, economic, cultural, and creative processes (Amin & Graham, 1997). Indeed, most academic studies have focused on large forerunner cities, often highlighting how their ambitious and innovative approaches aim to deliver carbon neutrality by 2050 or earlier. Such studies can usually provide positive and inspiring lessons because these places often benefit from favourable conditions, such as higher levels of financial resources, human capacity, and community support for action. Nevertheless, they only represent a small minority of the global population and an even smaller share of the world's cities. Indeed, the number of the world's ordinary cities is definitely higher than the leading ones. To raise awareness of innovative practices that such places might wish to adopt, more research into how lower-profile cities are seeking to tackle climate change is needed. This is because local governments need to address climate change, and, therefore, approaches have to be developed and shared in order to be applicable to a wide range of municipalities rather than just a handful of leaders (Haupt et al., 2022). In the context of local climate action, ordinary cities

can be understood as mostly mid-sized or smaller cities that are not high-profile progressive actors in climate governance (Haupt et al., 2022). Ordinary cities can be best defined by identifying what they may lack: They benefit from neither a particular power of attraction nor their extraordinary size or importance (Amin & Graham, 1997; Robinson, 2020). Robinson (2002, 2008) refers to them as cities off the map and argues that scholars should seek to study wealthy and innovative cities alongside poorer cities to identify and exploit the opportunities to learn from a wide array of diverse urban contexts. Thus, the term ordinary city has been used to deconstruct mainstream urban theory and to formulate a different methodological approach for more cosmopolitan urban research (Gemmiti, 2023). Indeed, given that the vast majority of cities have a much lower profile and are smaller in size than the handful of world cities around the globe, it can be seen how the experiences of such ordinary places are probably much more relevant for a wider range of urban areas. Therefore, if studies and practitioners focus predominantly on high-profile cities, they are probably neglecting the innovations adopted elsewhere that may be much easier to apply in other contexts.

For these ordinary cities, which can be subjected to a lack of financial and human resources, the complex challenges posed by climate adaptation and mitigation strategies may become untenable. The degree to which these strategies can be implemented alongside the cities greatly varies, as does the actual potential to generate public revenues or require government expenditures, which diverges according to the administrative scale at which they are applied (Intergovernmental Panel on Climate Change, 2023). Planning for adaptation and mitigation ultimately will not be effective if resources are lacking (Neufeldt et al., 2021), particularly after decades of austerity and associated chronic underinvestment in social and physical infrastructure (Hinkley & Weber, 2021). Placing green infrastructure at the centre of adaptation and mitigation projects, especially in similar contexts, entails the unpostponable task of exploring new and relevant financial mechanisms that ensure, on the one hand, the economic feasibility of the transformation scenarios and, on the other, guarantee the fair distribution, among public and private stakeholders, of burdens and benefits associated with transformation. Indeed, the first step towards developing the green infrastructure is to make the land available.

When local authorities have no land for specific purposes, they can basically operate through the expropriation of private land property. Even if considered an important tool for reducing the public burden of climate exposure (Dreyzin, 2018; Mach et al., 2019), expropriation may only be delivered for public goals or in the public interest, and economic compensation must be paid to landowners deprived of their own property. In countries with well-developed real estate markets and property rights institutions, land expropriation may be politically and economically unfeasible for local administrators (Eakin et al., 2022). Reversely, land-based taxes, including property and land-value taxes, are largely applied by the municipal authorities. Land-based taxes are often seen as an appropriate and relatively equitable mechanism for adaptation financing (Levy & Herst, 2018; Woodruff et al., 2020), given that adaptation is considered a public good and taxes are required proportionally with property values. However, linking adaptation funding to property-based revenue can result in a perverse incentive for urban development and soil sealing, which exacerbates climate change risks (Shi & Varuzzo, 2020). A large number of incentive-based policies have also been developed and implemented in recent decades, such as the development of impact fees, infill and redevelopment incentives, right-to-farm laws, and agricultural districts (Bengston et al., 2004).

More interestingly, other approaches have been developed to protect open spaces through the acquisition of development rights severed from land that is near urban areas and threatened by development. These

approaches include the transfer of development rights (TDR) and the purchase of development rights or conservation easements. They are based on the idea that ownership of land involves a bundle of rights, such as mineral rights, surface rights, air rights, and development rights, that can be separated (Wiebe et al., 1997). The TDR allows the sale of development rights from a specific parcel of land to other properties. Future use of the original parcel is then protected from development by a permanent conservation easement or deed restriction prohibiting development. A TDR programme defines an area to be protected from development (the sending area) and one where development will be allowed to occur (the receiving area). Landowners can transfer the rights to develop one parcel of land to another. As a consequence, the parcel from which the development rights are being transferred can no longer be developed or developed only in a limited way (Brabec & Smith, 2002). As a result, landowners are compensated for regulatory restrictions that reduce property values (Porter, 1997). TDR programmes allow more development than the one that might otherwise occur at the receiving site. The acquisition of the development rights is funded not by grants or taxes but by the developers of the receiving sites who acquire greater development potential, and therefore potential profit, by voluntarily using the TDR option. The sending sites are the areas that a community or municipal administration has identified as worthy of permanent preservation, and the receiving sites are the areas that are capable of accommodating additional development (Kaplowitz et al., 2008). TDR offers a planning policy that essentially redirects development rather than simply preventing it and thus recognises that there are areas where development must be allowed and even encouraged (Millward, 2006). These mechanisms have been described as promising for addressing sea level rise and flood exposure (McGuire & Goodman, 2020; Williams, 2014). To some extent, TDR programmes can be addressed as land value capture strategies, which refer to a suite of related mechanisms for the public sector to capture a share of the improved value of land that has been achieved in part through public and community contributions to development (Dunning & Lord, 2020). Instruments include betterment fees, district improvement financing, tax increment financing, developer contributions, and direct land sales (Levy & Herst, 2018). The land value capture approach allows for public revenues from high-value urban development and thus generates funds to finance infrastructure improvements and adaptations (Dunning & Lord, 2020).

In Italian cities, which are mostly characterised by a congenital deficit of public green spaces, local governance practices frequently fall short or are disregarded when it comes to addressing adaptation and mitigation methods, which are primarily distinguished by an inherent lack of public green areas (Molinaro, 2020; Serra et al., 2022). The reasons for this failure can be attributed to a lack of human resources and, more especially, to the scarcity of public land, which is necessary for the successful implementation of climate-resilient measures. On the other hand, acquiring land for putting into practice and spatialising new solutions via expropriation for public purposes implies public financial expenses and faces resistance from private landowners. That was often abandoned due to the reduced cash availability of most local authorities. Private investors also contributed to carrying out, within a real estate market devoid of significant economic investments, a very poor urban development in terms of public open spaces and green infrastructure. Moreover, since 1968, the Italian Ministerial Decree No. 1444/68 has enacted private developers to provide publicly accessible land and services (18 m^2 per inhabitant moving to the new residential area) in terms of green spaces, parking lots, schools, and other public facilities. However, as a result of this norm, thousands of small and unplanned fragments of land were randomly scattered around the urban peripheries of Italian cities. Consequently, these places are determined to be unfit for use as public green spaces and even unsuitable for conversion into new potential green infrastructure in the future.

The study aims at exploring and arguing about the urban equalisation approach and the TDR programmes as tools for managing the issue of the economic feasibility of adaptation and mitigation strategies in cities. This research objective is particularly conducted from the perspective of understanding how ordinary cities, which are characterised by insufficient financial and human resources, can plan and manage the climate and energy transition according to those tools. To achieve this aim, the article investigates the case study of Ragalna, an ordinary Italian city that implemented the new Local Spatial Plan according to urban equalisation and TDR principles. The proposed investigation method is structured into three parts: (a) a description of the case study; (b) urban equalisation and TDR principles; and (c) a presentation of the tailored urban equalisation method as delivered in Ragalna. Afterwards, opportunities and limitations are discussed in order to assess urban equalisation based on the TDR as an approach to be transferred to other ordinary cities for dealing with local climate action.

2. Materials and Method

2.1. Case Study

A recent urban planning practice in Ragalna (Southern Italy) stood out for its aim to project the new Local Spatial Plan around the idea of building a large green infrastructure for adaptation and mitigation strategies while protecting geomorphological specificities and exploiting local cultural identities. In 2015, according to Regional Act 71/1978, the Municipality of Ragalna started the process of drafting the Local Spatial Plan with the scientific support of the Department of Civil Engineering and Architecture, University of Catania (Italy). This Plan was aimed at exploring new economic feasibility for implementing green infrastructure through a tailored TDR programme. Ragalna is a very small town located between the south-west slope of Mount Etna and the large conurbation of the main city of Catania (Sicily, Italy). With approximately 4,000 residents and over 13,000 seasonal inhabitants, the municipality covers an area of around 39 km^2, and 2/3 falls within the Etna Regional Natural Park. The municipal land is characterised at the lowest altitudes by olive orchards and vineyards and gradually evolves into a high mountain environment, with slopes exceeding 10%, where large forest fragments are interspersed with pear and apple orchards and chestnut groves between volcanic cones and lava flow caves, which represent the icons of the Etna volcanic landscape. These semi-natural and agricultural lands represent the only economic sources for the local population. Moreover, the relevant natural Rosario Creek runs down through the urban centre of Ragalna from north to south, and due to its morphological and orographic features, it has resisted the processes of both agriculture and urban development, and today it represents the main natural distinctive constituent of the town (see Figure 1).

The urban fabric, which is divided into two halves by the stream, runs from 1,000 to 500 meters above sea level along the same path. It is a settlement made up of four urban clusters characterised by low-density residential fabrics closely located near small, widespread historical aggregates, agricultural areas, including abandoned ones, and isolated portions of the Etna Forest. Outside the urban centre, the agricultural land is covered by farmlands and rural buildings, as evidence of long-lasting anthropogenic processes.

2.2. Urban Equalisation

Preserving natural resources and implementing new public facilities and green spaces was a critical issue for Ragalna's local decision-makers because they had to deal with the land acquisition of open spaces and

Figure 1. The Rosario Creek, Ragalna (Sicily, Italy).

private plots that were definitely economically unsustainable, as well as facing resistance from private landowners. In the framework of the new Local Spatial Plan, a way for managing the issue of the economic feasibility of public intervention for putting on the ground adaptation and mitigation strategies has been addressed through an urban equalisation approach that is intended as a planning tool, usually integrated into the local spatial plans, which distributes development rights across the municipal land (Micelli, 2002; Scattoni & Falco, 2011). It is a form of agreement among private landowners and developers, the third sector, and public bodies (mainly municipalities), which focuses on equal treatment of private and public interests, somehow aimed at capturing land value to finance the public city (Gerber et al., 2018; Oppio et al., 2019). Urban equalisation is extremely complex, but the underlying principle of equalisation remains simple, which is to simultaneously burden the property with the benefit of buildability and the burden of contributing to the general elevation of the urban quality of the city (Fiale, 2003). These strategies, aimed at reducing the disparity in treatment between owners, are essentially based on the tool of granting development rights that can be spent in other areas of the municipal land through different methods (Urbani, 2010). Equalisation stands for an equity principle that supports a uniform and balanced recognition of private land tenure rights with key matters of public interest (Ave, 2018; Falco, 2016). In particular, urban equalisation allows to pursue, on the one hand, distributive justice of the benefits (among the landowners) deriving from urban transformations as envisaged by the Local Spatial Plan and, on the other hand, a fair distribution (between the landowners and the public actor) of the burdens when delivering public facilities and services. An urban equalisation approach is based on a TDR programme, which first defines areas to be protected from future development and others where development will be allowed to occur. The TDR programme assigns development rights to those private land parcels that local authorities plan to protect and exploit for future green public facilities. Development rights are assigned in response to a request for transferring the property of those parcels to the public realm in proportion to the development rights received. Development rights are understood as an equalisation ceiling and expressed in terms of the amount of development (building

volume) to be assigned to the land parcel (sending area) for being transferred to other parcels where urban development is allowed to occur (receiving area). As a consequence, the parcel from which the development rights are being transferred can no longer be developed and is transferred to public local property, and landowners are compensated with new development rights to be sold to future developers. The transfer of land property to the public realm can be understood as a planning obligation. Indeed, in order to make an urban transformation proposal acceptable in planning terms, the cost of any works to mitigate its impact, as defined in the associated planning obligation, had to be met by that proposal (Henneberry, 2016).

2.3. A Tailored Urban Equalisation Method

The method proposed for the Ragalna Local Spatial Plan was based on a three-step urban equalisation approach to allow public authority to acquire the land for green infrastructure with no economic expenses, as well as to target a balanced sharing of benefits and liabilities among those private actors involved in urban transformation: (a) The Rosario Creek was identified as the leading geomorphological component from which to build a larger green infrastructure through connecting the green ridge of the stream to all the most valuable green and open spaces; (b) the green infrastructure implementation included all the new foreseen public facilities; and (c) a targeted TDR programme was proposed in order to make the implementation of the green infrastructure viable.

The Ragalna Local Spatial Plan aimed at closely connecting the future development process to the new public facilities provision programme. The new green infrastructure was expected to include different public facilities such as urban and suburban parks, green spaces, small urban gardens, playgrounds, indoor and outdoor sports equipment, parking lots with high permeable pavements and tree cover, and cycling and pedestrian lanes. To this end, the primary objective was to transfer to the public realm at least the green areas strictly contiguous to the Rosario Creek for the development of a wider green infrastructure at the municipal scale around this green ridge. Secondly, other non-contiguous areas mostly characterised by abandoned or uncultivated agricultural fields, native vineyards, orchards, and shrubby vegetation could be converted to new forms of urban agriculture and connected to the green infrastructure through cycling and pedestrian paths across sprawled residential settlements. As a third phase, a tailored TDR programme was then developed for the Ragalna Local Spatial Plan and delivered in four steps:

1. Development rights are assigned both to the land parcels to be acquired (sending area) for implementing the green infrastructure (0.15 m^3 of building volume over a land parcel area unit of 1.00 m^2) and the land parcels (receiving areas) where the development will occur (0.35 m^3 of building volume over a land parcel area unit of 1.00 m^2).
2. Development rights take off from the sending area and land on the receiving area. These development rights are added to the rights generated by the same receiving area itself, allowing an increase of the building volume ratio (0.15 m^3/m^2 + 0.35 m^3/m^2 = 0.50 m^3/m^2) in the receiving area.
3. Private landowners of receiving areas buy and pay the economic value of the development rights to the private landowners of sending areas.
4. Property of sending areas is transferred to the public local authority property with no financial expenses from the public side.

Figure 2 shows how the Ragalna targeted TDR programme works.

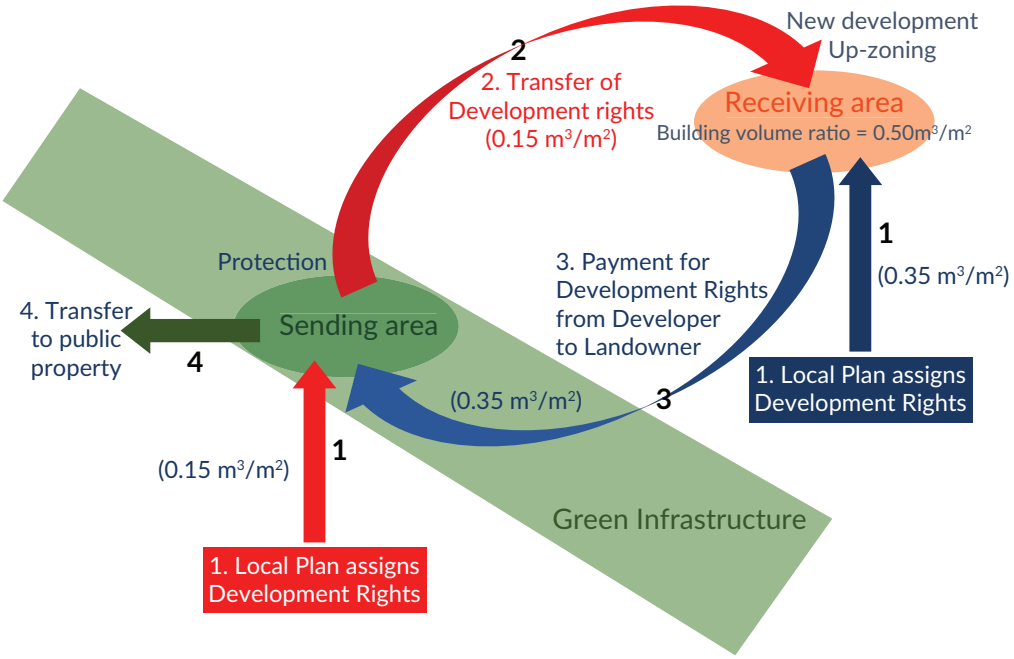

Figure 2. The TDR programme in the framework of the Ragalna Local Spatial Plan.

Such a programme implies that private landowners of receiving areas start the building process only after buying the development rights from the landowners of sending areas, who, in turn, get revenue from the buyers and leave their own land to the local public authority. Without those supplementary development rights, no urban development is allowed to occur in receiving areas. This mutual dependency allows to finally link private urban transformation with the public acquisition of land for future green infrastructure.

3. Results and Discussion

The Local Spatial Plan of Ragalna was officially approved by the Town Council in June 2023, and it came into effect at the beginning of 2024. The urban equalisation approach, as proposed by the Plan, will determine a gradual green infrastructure implementation through a parcel-by-parcel acquisition of land, which is strictly related to the private interventions in receiving land parcels. The land acquisition process will start with private land parcels nearby the Rosario Creek and will expand into other parcels mostly characterised by agricultural, abandoned, or uncultivated lands and spontaneous vegetation. These supplementary land parcels can be turned into suburban parks, equipped neighbourhood green areas, but also as parking lots with high permeable pavements and vegetation cover, which can sustain the future implementation of a wider green infrastructure around the Creek (see Figures 3 and 4, patches in green). In order to better manage the prioritisation of land parcels to be transferred to the public realm, a supplementary Green Infrastructure Priority Programme has been developed in the framework of the Spatial Plan to provide a clearer map of all parcels suitable to be part of the Green Infrastructure. Taking into account their size, land cover, and location (in terms of proximity to the city centre and public facilities), parcels have been labelled according to the three priority levels (P1, P2, P3—Figure 3).

On the other hand, urban development will only occur in those land parcels that are still undeveloped and are located within already urbanised areas (see Figure 4, patches in orange bounded by red dots). This approach

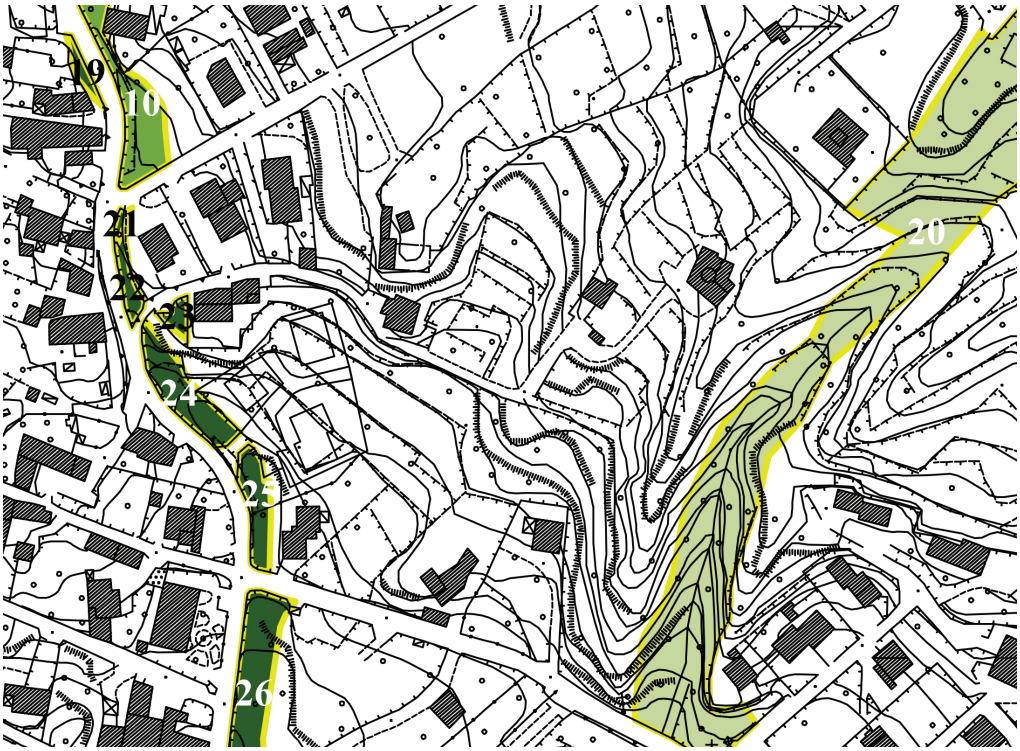

Figure 3. The Green Infrastructure Priority Programme. In dark green the highest priority level (P1); in intermediate green the medium level of priority (P2); in light green the lowest priority level (P3); number tags identify each sending area patch.

will allow to minimise land intake and preserve agricultural areas because only small vacant plots, surrounded by built-up areas, will be involved in the new development process. As a result of that, current urban fabrics will be up-zoned, compacted, and even shaped into more regular morphological structures. The resulting building volume ratio = 0.50 m^3/m^2 (as described in step 2 of the methodology; see Sub-Section 2.3) will permit the building of detached houses and/or semi-detached houses, and/or terraced houses within a 2,000 m^2 minimum plot area. Interestingly, the proposed urban equalisation approach has been aimed at balancing 1 m^2 of new built-up area (in terms of land parcel area) with 1 m^2 of new green area (in terms of land parcel area within the green infrastructure). In other terms, each new built-up land parcel (which includes the building and its open front and back yards) will be compensated by an equal-sized green area, and this will finally deliver, across the years, a public green infrastructure of over 50 hectares in size.

The prospected 50 hectares-wide green infrastructure will support the town of Ragalna in contrasting the negative effects of climate change over the next few years. Basically, the Rosario Creek and its basin zone will be totally moved to public property, and this will allow to mitigate the flood risk through implementing new interventions aimed at removing waste and other obstacles from the stream and restoring the permeability of embankments and floodplain areas. Other relevant green corridors will penetrate urban fabrics and, thanks to new tree plantations and increasing greenery strategies, will contribute to regulating micro-climate and reducing urban heat island effects through the shadow effect of tree canopies and the evapotranspiration potential of leaves and soil. Urban gardens and urban and suburban parks, as hubs of green infrastructure, will provide, through their biomass, other fundamental provisioning and regulating ecosystem services such as air and water purification, carbon storage and sequestration, water runoff, and

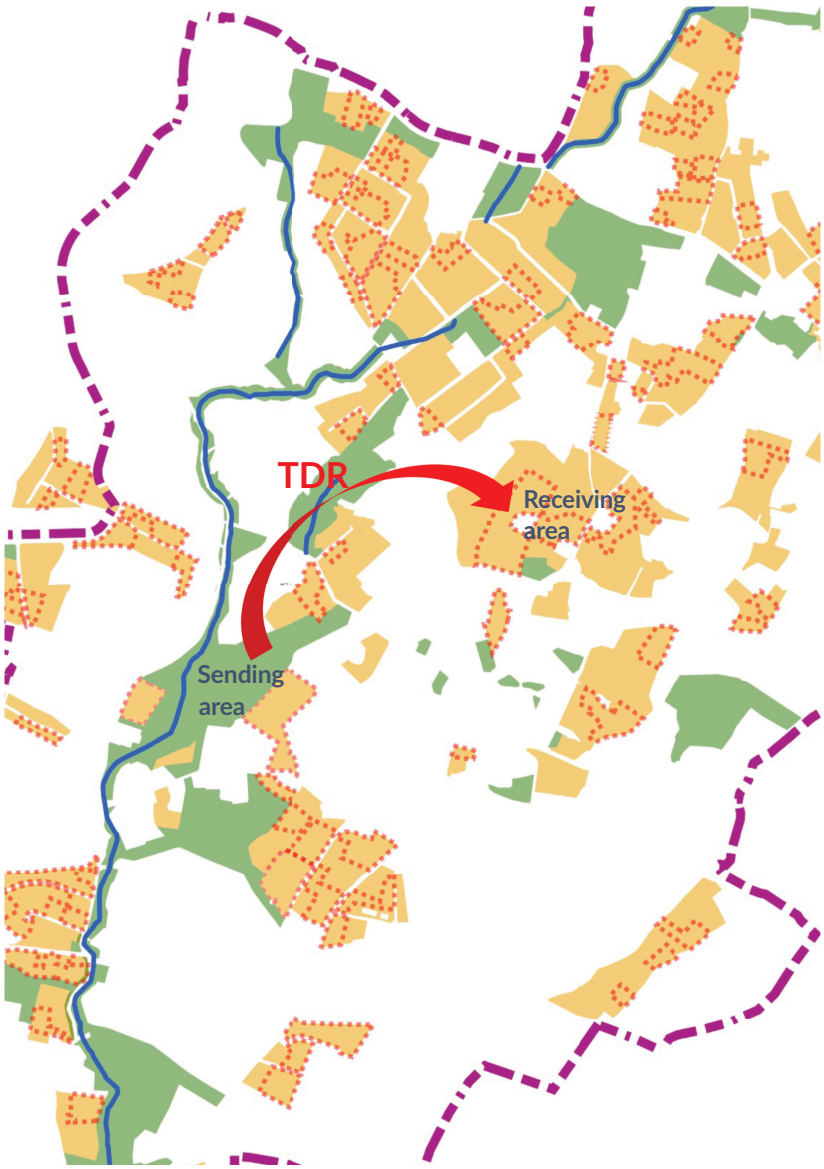

Figure 4. A frame of Ragalna's Local Spatial Plan: sending areas (in green), receiving areas (in orange bounded by red dots), densification areas (in orange), Rosario Creek (in blue), municipality boundaries (in violet).

noise reduction. At the same time, green infrastructure will increase accessibility to public green spaces, playgrounds, outdoor sports facilities, and public services through cycling and pedestrian routes, thus enhancing the overall well-being and health of residents and visitors. Even if promising, this implementation mechanism shows a noticeable limitation due to its strong dependency on the private initiative to undertake the urban transformation. Indeed, urban development processes could take a long time, consequently affecting and slowing down the implementation of green infrastructure. However, as an alternative option, the Ragalna Local Spatial Plan includes expropriation procedures for local public authorities to acquire private land parcels for implementing urgent and unpostponable green interventions for mitigating potential natural risks and securing built-up stock and residents.

Despite the significant expected benefits, the urban equalisation approach has provoked, since the very first proposal, some resistance from local residents, professionals (engineers and architects), and developers,

which emerged during participatory procedures and several community involvement events. Most of these local actors understood urban equalisation as a much more complicated and expensive mechanism for undertaking new urban development compared to the traditional one. The previous planning system was based on a traditional zoning strategy that identified urban development zones to be directly transformed by private landowners through applying the building volume ratio and public facilities and services zones to be managed through the public expropriation of private land parcels. Differently, the current equalisation approach implies a negotiation between landowners for selling or purchasing development rights from sending to receiving areas and then transferring the property of sending areas to the public realm. It must be said that this procedure represented a true novelty not only for this small town but also for the whole Catania metropolitan area, and it inevitably generated several objections. In order to overcome these uncertainties, the Town Council has recently implemented a further urban equalisation regulation to provide clearer and more flexible rules and procedures. This document also established a dedicated development rights inventory for monitoring the TDR and determining the market value of these rights for a more equitable management of the development process among private landowners and developers.

Ragalna's Local Spatial Plan has just started, and the local authority is aware of the challenges that will be posed by this innovative planning tool. To prevent potential critical issues, a monitoring programme has been set up for checking the efficiency and effectiveness of the urban equalisation model through controlling and adapting over time the priority levels as identified in the Green Infrastructure Priority Programme and the development rights market values as evaluated within the urban equalisation regulation. Both aspects will be subject to periodic reviews and updates to allow the municipal authority to adjust the land acquisition priorities according to the needs of any future project or external financing opportunity and to adapt the values of development rights to the local real estate market fluctuations.

4. Conclusion

To shorten the distance between private interests and public needs, current tools to finance the transition to climate resilience may need substantial revision to reprioritise the public and rebalance the needs of the different urban constituencies (Eakin et al., 2022). The urban equalisation approach as proposed by the Local Spatial Plan of Ragalna allowed to outline a scenario that envisaged the gradual construction of a public green infrastructure that grows through subsequent additions in relation to private urban transformation interventions in the expected receiving areas. This is an approach that pursues the right balance between the economic feasibility of private interventions and benefits for the community by permitting new urban development in specific already urbanised areas and developing a wide public green infrastructure alongside the Rosario Creek. Even though the relevant results were expected, the proposed approach inevitably clashed with the cultural resistance of an ordinary context not familiar with dealing with issues of environmental and economic sustainability in urban development. Indeed, the application of this approach in the framework of the Local Spatial Plan faces the challenge of undermining the traditional approach of local urban development practices, often characterised by a few limited rules between public and private actors. Reversely, more complex mechanisms can appear to be rather complicated, difficult to implement, and not yet sufficiently explored. Despite these difficulties, equalisation approaches in Italy have been gradually introduced in many regional acts aimed at regulating urban planning practices. Some Italian municipalities, such as Milano, Bologna, Padova, Arezzo, and Prato, have also started to deliver and experience the application of TDR programmes to manage the new sustainable urban transformations (Falco & Chiodelli, 2018).

Investigating the Local Spatial Plan of an ordinary city like Ragalna finally allowed to shed light on these urban equalisation approaches and TDR programmes, which resulted in viable tools for managing the issue of the economic feasibility of adaptation and mitigation strategies. For these reasons, the proposed urban equalisation approach can be understood as a promising strategy to be transferred to many other ordinary cities to help local authorities plan and manage the climate transition despite their insufficient financial and human resources. As shown by the Ragalna Local Spatial Plan, the transition to climate resilience can be possible for all ordinary cities just because the equalisation approach is based on the principle of relying only on one's own resources, which are made up of municipal land to be negotiated with the private sector.

Nevertheless, it is precisely the complexity of the implementation mechanisms that represents the great challenge of these innovative practices, which call for a profound renewal of the technical and management skills of companies in the construction sector to manage more complex urban transformation projects. And even more urgent is the need for public administrations to develop skills to govern the new market of development rights through the assignment of the economic market values of these rights and the establishment and management of a specific inventory for monitoring the take-off and landing of such rights. A strong public direction of urban transformation and effective policy instruments creating appropriate incentives for private support of climate transition (Bisaro & Hinkel, 2016; Tompkins & Eakin, 2012), if well designed, could help ordinary cities overturn a long-term trend: not involving urban developers to create high-value properties at the public expense, but attracting private investors to help cities transition into more equitable and liveable urban environments.

Acknowledgments

The author is grateful to the Municipality of Ragalna (Italy) and its mayor, Salvatore Chisari, for their fruitful support and cooperation in developing the urban equalisation approach within the Local Spatial Plan.

Funding

This research has been developed in the framework of the project NICHE "Nature In City for a Healthy Environment" funded by "2020/2022 PIACERI Plan – Line 3 Starting Grant," University of Catania (Italy).

Conflict of Interests

The author declares no conflict of interests.

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About the Author

Riccardo Privitera is associate professor of Urban and Spatial Planning at the Department of Civil Engineering and Architecture, University of Catania (Italy) and holds a PhD degree in Urban Planning. His scientific interests include climate change adaptation and mitigation strategies, urban green infrastructure, nature-based solutions, ecosystem services, urban morphology analysis, real estate development, and transfer of development rights. Based on these topics, he has more than 60 publications including scientific papers, chapters, books, edited books, and international journals special issues.

Urban Planning
2024 • Volume 9 • Article 8298
https://doi.org/10.17645/up.8298

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ARTICLE

Open Access Journal

"Arctic-tecture": Teaching Sustainable Urban Planning and Architecture for Ordinary Arctic Cities

Jing Ma and Agatino Rizzo

Department of Civil, Environmental and Natural Resources, Luleå University of Technology, Sweden

Correspondence: Jing Ma (jing.ma@ltu.se)

Submitted: 22 February 2024 **Accepted:** 1 August 2024 **Published:** 29 August 2024

Issue: This article is part of the issue "Planning and Managing Climate and Energy Transitions in Ordinary Cities" edited by Agatino Rizzo (Luleå University of Technology), Aileen Aseron Espiritu (UiT The Arctic University of Norway), Jing Ma (Luleå University of Technology), Jannes Willems (University of Amsterdam), and Daan Bossuyt (Utrecht University), fully open access at https://doi.org/10.17645/up.i346

Abstract

Arctic cities are often perceived as exceptional and uniquely challenged by extreme conditions, leading to their treatment as special cases in urban planning and development. However, this perception overlooks the reality that Arctic cities share similar issues common to many small and medium-sized urban centers globally, such as mobility, climate adaptation, and aging populations. By recognizing Arctic cities as ordinary cities, we can better address their needs and foster effective solutions. This article reflects on the results of a fourth-year Master-level course in Sustainable Urban Development, where students researched urban sustainability aspects (e.g., mobility, green infrastructure, energy, public spaces) in northern regions of Finland, Sweden, and Norway. It analyzes pedagogical approaches, highlighting challenges in integrating sustainability perspectives into architecture and planning curricula. Findings hold relevance for educators seeking to address similar challenges in the Arctic or other ordinary cities worldwide, contributing to more resilient and sustainable urban development across diverse environments.

Keywords

architecture education; Arctic cities; pedagogical approaches; sustainable urban development; urban planning

1. Introduction

Arctic cities face significant challenges due to their extreme weather conditions. Addressing these challenges requires innovative architectural and planning solutions, which are part of the education system (Antonini et al., 2021; Korobar & Siljanoska, 2016). However, treating Arctic cities as exceptional due to their extreme environment often results in overlooking these common urban challenges, thus hindering effective solutions

(Berman & Orttung, 2020; Heininen et al., 2020). Recognizing that Arctic cities face similar issues to other small and medium-sized ordinary cities globally—such as mobility, climate adaptation, and an aging population—allows for more inclusive and practical strategies. This perspective encourages the development of solutions, e.g., in urban planning education, that address the shared urban challenges of Arctic cities and other regions.

To address these issues, this research investigates the following question: How can pedagogical approaches effectively integrate Arctic sustainability perspectives into architecture education, particularly in urban planning? This article examines this question through a case study of a fourth-year course in the architectural engineering curriculum in Sweden. This course is in synergy with a research project funded by the Arctic Five, an alliance of five Nordic universities located in or near the Arctic region, focusing on implementing Sustainable Development Goals (SDGs) in Arctic cities. We nicknamed the project "Arctic-tecture," a playful merge between Arctic and architecture, to exemplify the challenges of adapting a well-established architecture curriculum to the fluid nature of environmental and social issues in the Arctic.

The course, Sustainable Urban Development, is offered as a part of the urban planning major at Luleå University of Technology. While it addresses a broad view of sustainable development, a unique aspect of this course is its focus on urban planning issues in the Arctic. Another main focus of this course is to teach students the challenges of implementing the global SDGs in smaller cities of the Arctic. Unlike other regions where urban challenges are similar to those in other parts of Europe (e.g., densification, mix-use development, heat islands, population increase, urban sprawl, etc.), Arctic municipalities face distinct challenges such as aging population, urban shrinkage, and transportation connectivity in sparsely populated areas. For instance, the population density in the Norrbotten region in the north of Sweden is three inhabitants per square kilometer compared to 376 in Stockholm. Additionally, between 2020 to 2023, the annual population change in Norrbotten decreased by 0.15% while in Stockholm it increased by 0.87% (SCB, 2023). In 2023, the average age in Stockholm region was 40.2 years, whereas in Norrbotten it was 44.6 years (SCB, 2023).

This article is structured as follows: In the next section we elaborate on the relevance of Arctic transformations for architecture and planning pedagogy. Section 3 outlines the chosen pedagogical framework and methodology. Section 4 delves into the Sustainable Urban Development course components and analyzes their effectiveness as a case study. Section 5 presents research findings, and Section 6 concludes with reflections on key challenges and future directions.

2. Transformations in the Arctic: Relevance for Architecture and Planning Pedagogy

The Arctic region, known for its extreme environment and rapid changes due to climate change, presents challenges and opportunities for architectural design. However, Arctic cities are often treated as exceptional cases, focusing excessively on their extremities and overlooking that they share many issues with other small and medium-sized cities globally. This perspective hinders the development of effective solutions to problems such as limited mobility, less concerns about climate adaptation, and aging populations. Integrating these considerations into architectural education will prepare students to design resilient, sustainable, and culturally sensitive structures that address both universal and region-specific urban challenges.

Within the past decade, the Swedish focus on the Arctic has intensified, coinciding with large-scale transformations in the Swedish resource sector under the "green transition" banner (Rizzo et al., 2024). This

transformation is marked by several significant milestones, including the ongoing relocation of Kiruna city (ongoing since 2004) to a new site due to land deformations caused by underground mining (Carrasco, 2020; Sjöholm, 2016). A similar process is underway in the nearby Malmberget district of Gällivare (Hidman, 2018). Additionally, the first large Facebook datacenter in Europe was established in the city of Luleå to benefit from the nearby green hydropower-generated electricity and cold temperature for cooling. Skellefteå, too, houses the largest battery factory in Europe (ongoing since 2018). Complementing these developments is the rising tide of international tourism in the Swedish Arctic.

However, this rapid change triggered by industrial transformation, climate change (evident in permafrost thaw, rising temperatures, and increased precipitation; Chapman, 2018; Robinson et al., 2006), and geopolitical shifts (e.g., the abandonment of the planned North-East Russian Passage in favor of Canada's North-West Passage due to the Ukraine conflict) presents a complex picture. While investment opportunities emerge for a shrinking local population, tensions resurface concerning the historical colonization and dispossession of the Indigenous Sápmi population (Normann, 2021). Further anxieties arise amongst the predominantly white society, fearing marginalization within the public and private sectors driven by the imperative to attract 100,000 new inhabitants to bolster the competitiveness and profitability of the Swedish resource sector. Climate activists, including Greta Thunberg and associated movements, also raise their voices amidst these transformations.

Sustainable development, a dynamic concept aiming to enhance quality of life, demands consideration of economic, social, and environmental aspects (Deakin et al., 2002; Dempsey et al., 2012; Hastrup, 2013; López Chao et al., 2020). Higher education increasingly links these dimensions in design and planning fields, emphasizing contextual relevance. This research specifically explores the pedagogical challenges of integrating Arctic sustainability perspectives into architecture and urban planning education. While architecture education boasts a long tradition of human-centered sustainability that is evident in early ecological studies (Bassas et al., 2020; McHarg, 1969), the climate crisis necessitates acknowledging a more intricate human–nature relationship. This compels collaboration between technical disciplines like architecture and scientific fields (biology, climatology) alongside humanistic ones (history and urban planning). The Arctic, considered the "urban frontier," exemplifies this complex entanglement. Here, human-induced impacts on nature are stark and rapid, with accelerated infrastructure degradation due to permafrost thaw (Hjort et al., 2022) exceeding the pace observed in temperate or tropical regions (Berteaux et al., 2004).

Teaching architecture and urban planning in the Arctic means incorporating elements of social and environmental justice in design disciplines (Park et al., 2022). From an urban ecology point of view, architect and educator Maria Kaika (2005) studies the interrelationship between water infrastructure policy and urbanization in Greece and England. In her research, water is treated as a fabricated resource rather than a natural one, that is inseparable from human intervention. This perspective is especially beneficial because it provides a clearer understanding of the role that urban infrastructures play in facilitating the commodification of natural resources. Kaika (2005, p. 33) argues that this fetishization of urban infrastructures aims at "being carriers of the modernist promise of participating in the phantasmagoric new world of technological advancement and progress; a world in which human freedom and emancipation resides in connecting to technology."

From a pedagogical point of view, there is the need to use methods and approaches that activate students' critical thinking in architecture and urban planning problem setting (Von Hauff & Nguyen, 2014). Particularly, it becomes central to localize (the concept of) sustainability in the Arctic. This involves understanding the peculiar characteristics of Arctic society and environment and critically situating sustainable architecture within this context. Moreover, there is a need to enable collaboration among students to co-define sustainability for the objectives of their course and to find suitable course tasks and deliverables. By treating Arctic cities as ordinary cities facing common urban challenges, educators can foster more effective and transferable solutions that benefit both Arctic and other regions with unique climate-related issues.

3. Pedagogical Framework

University curricula in urban-related fields should prioritize empowering students as independent learners, equipped with the knowledge and skills to address the complexities of urban development (Barth et al., 2007). Pedagogical principles are intended to form a foundation that stimulates continuous pedagogical growth and promotes active collaboration among university colleagues and across disciplines (Alejandro & David, 2018). In particular, this article focuses on three principles for effective learning in urban design and planning courses: active cognitive processing, assessment for learning, and knowledge-enhancing feedback (Gedda & Wikberg-Nilsson, 2013). These principles provide a framework (Figure 1) for understanding the pedagogical approaches utilized in architectural and urban planning education for sustainable urban development. They also align with the need for urban planners to synthesize knowledge from diverse fields, recall past concepts, and apply them to new complex scenarios.

Active cognitive processing emphasizes that students must deeply engage with course materials to achieve the fundamental abilities and knowledge to meet the learning outcomes. It requires that students integrate prior knowledge from various disciplines while adapting to the evolving challenges of urban development. While listening, reading, and note-taking are essential, active learning activities like collaborative projects, simulations, and discussions foster the critical thinking and adaptable problem-solving needed by urban

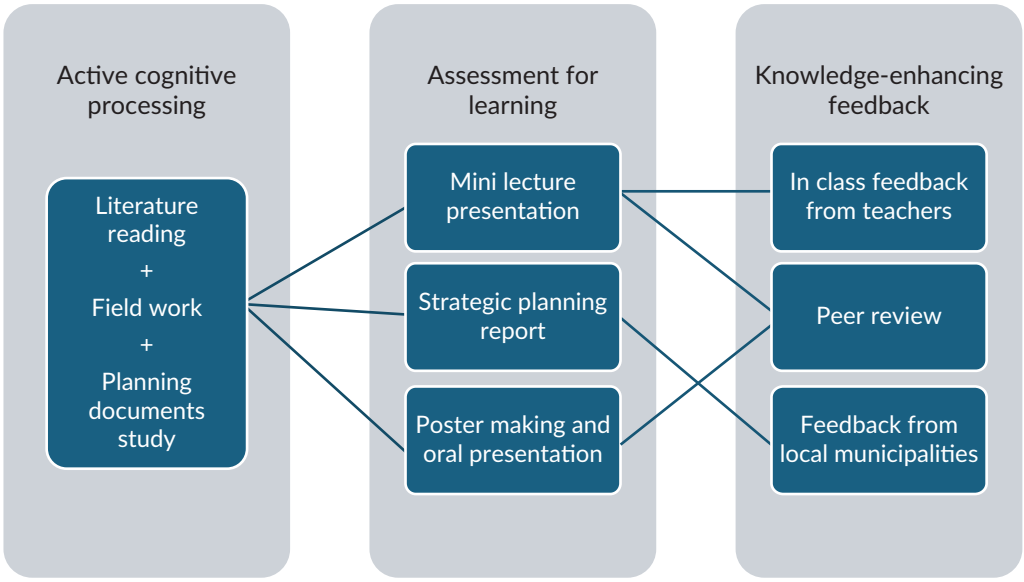


Figure 1. Pedagogical framework.

planners. To equip students with these essential skills, we employ active cognitive processing through a comprehensive array of elements, designed to provide opportunities for reflection and knowledge application across diverse contexts (Gedda & Wikberg-Nilsson, 2013). Within our teaching group, we have implemented several strategies in architectural education to foster such active cognitive processing (Table 1).

By integrating these actions and elements into our educational framework, we aim to create a dynamic and engaging learning environment that supports active cognitive processing. This approach not only enhances students' essential skills but also prepares them for professional success by fostering critical thinking, collaboration, and practical application of knowledge.

Among this active cognitive processing, assessment plays a crucial role in shaping student learning. By strategically selecting assessment methods, educators can guide students' efforts and focus their attention on essential skills and knowledge. Research on assessment's influence demonstrates that the form, frequency, and level of assessments significantly impact teaching practices and student learning outcomes (Rust, 2002). Additionally, types of assessment influence students' time management, their perception of the importance of the course material, and their capacity for self-evaluation (Gibbs, 2010). For example, Gratchev (2023) found that compared to a single in-depth final exam, multiple brief assignments with ongoing feedback promote student engagement and improve long-term knowledge retention.

University degrees serve as proof that students have acquired a specific body of knowledge and developed a specific set of skills. Assessments must be carefully designed to ensure validity in relation to both the intended learning outcomes of courses and broader program goals. We apply different forms of assessment to assure

Table 1. Actions consider the encouragement of active cognitive processing.

Elements	Actions
Collaboration for design activities	We organize the Teaching Progression Day to cultivate connections and collaborations across different courses and to refine course contents tailored for design activities.
Delivery forms	A variety of instructional methods are utilized, including written seminars, traditional lectures, and peer discussions. This multimodal approach ensures that students can absorb and interact with the material in multiple ways, catering to different learning styles and promoting a deeper understanding of the content.
Technical tools	The Canvas platform is used for organizing teaching activities, ensuring that all resources and assignments are easily accessible. For online guest lectures, we utilize Zoom and Microsoft Teams, allowing students to interact with industry professionals and gain insights from diverse perspectives, regardless of geographical constraints.
Course activities	Our curriculum includes a wide range of activities such as seminars, labs, studios, tutorials, debates, group discussions, role-plays, field trips, and oral presentations. These varied formats provide students with numerous opportunities to apply their knowledge practically, engage in critical thinking, and participate actively in their learning journey.
Forms of assessment	We employ diverse assessment methods to effectively evaluate student learning. These include written work (essays), quiz questions, posters, oral presentations, and report writing.

the quality in education, known as constructive alignment, calling for all tasks, activities, and assessments to support and build upon one another in a progression that aids students in achieving course goals. To ensure constructive alignment, our teaching and learning activities are carefully crafted to support the development of the knowledge and skills defined in the intended learning outcomes. The assessment plan is an integral part of each course and is designed to be accompanied by knowledge-enhancing feedback. For instance, we employ the portfolio method or workbooks, and in courses with a final exam, we incorporate smaller assignments or quizzes to gradually build and refine students' knowledge and understanding in preparation for the exam.

We create opportunities for students to demonstrate their knowledge through collaborative projects with stakeholders in the field, emphasizing the application of knowledge and skills to real-life situations. This approach not only enhances learning but also ensures that tasks cannot be easily copied or completed by someone other than the specific student being assessed, thereby maintaining academic integrity.

Another crucial element for cognitive processing and knowledge growth is the promotion of knowledge-enhancing feedback. This feedback encourages critical self-reflection, identifies knowledge gaps, and promotes continuous learning (Dochy et al., 1999; Evans, 2013; Yan & Carless, 2022). Throughout a course, opportunities should be provided for students to receive, apply, and provide feedback (Brown, 2020). Traditional end-of-course feedback in the form of grades and comments offers limited potential for students to implement new knowledge, potentially discouraging further engagement with the material. Timely and frequent provision of knowledge-enhancing feedback is essential for both students and educators to monitor progress and understanding. Tasks and activities should incorporate clear criteria for success and frameworks for constructive feedback to support this process.

Feedback in our teaching takes various forms, including automated responses to online assessments, teacher-to-student, teacher-to-group, and student-to-student interactions (Evans, 2013). Feedback yields the greatest impact when it is timely, personalized, specific, and perceived by students as encouraging and useful (Nicol et al., 2014). We, as educators, consider the most appropriate feedback type for specific learning activities and course stages. Additionally, cultivating students' ability to offer constructive criticism to their peers is a valuable skill throughout both their professional and academic careers. By actively incorporating student feedback, we can continuously refine teaching and learning activities to ensure alignment with intended learning outcomes.

While these pedagogical principles offer benefits across disciplines, they hold particular relevance within sustainability education. The complex and interconnected nature of sustainability challenges demands that students develop the capacity to navigate diverse knowledge domains, integrating ecological, economic, and social perspectives. Active cognitive processing, with its emphasis on prior knowledge application and adaptability, lays the groundwork for this holistic understanding. Sustainability problems are rarely static; thus, emphasizing reflection throughout the learning process mirrors the real-world need for continuous adaptation and course correction. Formative assessment, embedded with knowledge-enhancing feedback, allows students to iteratively improve their sustainability analysis and proposed solutions. Therefore, tertiary education with an active teaching and learning environment prioritizing these pedagogical principles nurtures the critical thinking and adaptability essential for tackling sustainability issues, especially within the rapidly evolving Arctic landscape.

Furthermore, sustainable development inherently prioritizes collaboration. Active collaboration in design and planning activities directly reflects real-world sustainability projects requiring input from diverse stakeholders, including scientists, policymakers, and local communities (Wheeler, 2013). The need to integrate multifaceted perspectives necessitates effective communication, negotiation, and an awareness of power dynamics. The Arctic region specifically demands a collaborative approach, balancing the push for resource-based economic development with the need for environmental responsibility and the rights of Indigenous communities. Consequently, the pedagogical principles discussed here become essential tools in empowering students to become effective contributors to multidisciplinary teams and facilitators of sustainable practices, particularly within the sensitive social and ecological context of the Arctic. We highlight these principles as the foundation for the specific study outcomes in our Architecture Engineering grogram. The case study we undertake is the Sustainable Urban Development course, cultivating the necessary skills for future sustainability researchers and planners.

4. Case Study

4.1. Sustainable Urban Development as a Key Program Course in North Sweden

The Swedish Arctic, characterized by its unique environment and rich natural resources, faces a complex nexus of sustainability challenges amplified by a rapidly changing climate. These changing conditions have been identified by the Nordic Council of Ministers (Rasmussen, 2011) which highlights the faster rate of Earth's global warming in the Arctic. Globalization is also one of the trends, especially the extractive industries and broader exploitation of natural resources like forests and ecosystem services for the travel and tourism sector (Flaquer, 2023; Rizzo & Petruccioli, 2023). This has led to significant changes, including permafrost thaw, altered precipitation patterns, shifts in vegetation zones, and the change of socio-demographic structure (Callaghan & Jonasson, 1995; Jungsberg et al., 2016). Another notable effect is that young people from northern areas move to larger towns and cities in the south to seek various educational and work opportunities. This leads to shrinking towns and villages, an older population, increased unemployment amongst young people, and a lack of entertainment and cultural identity (Corbett, 2007). These transformations, coupled with ongoing resource development pressures, create a complex landscape for sustainability planning. Despite these pressing challenges, the Swedish Arctic holds potential opportunities fueled by the worldwide push towards a green transition (Söderholm, 2020). It creates a uniquely demanding context for involving sustainability perspectives in higher education. These trends are similar in Finland and Norway (Khan et al., 2021; Lipiäinen et al., 2022).

In higher education, these challenges and opportunities must be addressed with the complexities of mitigating the detrimental impacts of climate change and historical resource exploitation while responsibly harnessing the potential of the green transition. This demands a pedagogical approach that fosters systems thinking, enabling students to analyze the interconnected ecological, economic, and social consequences of development actions. Most recently, architecture education in the north of Sweden is considering these challenges in the design and implementation of the energy transition in the Arctic region. While many are positive about the opportunities such an influx of investments can bring to a shrinking local population, others are concerned with the impacts of such a change on local identity (Fjellborg et al., 2022; Ojala & Nordin, 2015). In the Architectural Engineering program at Luleå University of Technology, the aim is to develop courses with unique perspectives into social and environmental sustainability, such as dealing with

climate mitigation and adaptation and urban attractivity. This approach is particularly reflected in the results of a fourth-year master course, Sustainable Urban Development.

4.2. Course Content and Structure

The United Nations' focus on Education for Sustainable Development highlights the urgency of embedding sustainability across all educational levels (Buckler & Creech, 2014). As stated in the influential World Commission on Environment and Development report, achieving sustainability demands that everyone takes "wider responsibility for the impacts of decisions" (Brundtland, 1987, p. 56). Higher education plays a crucial role in preparing future leaders to address these challenges (Fokdal et al., 2020). Therefore, universities are expanding their sustainable development curricula across disciplines, considering environmental, economic, and societal impacts, with particular emphasis on integrating sustainability into planning and design.

Our Sustainable Urban Development course focuses on these critical issues within the context of the rapidly changing Arctic region. Within a study period of eight weeks, students (both Swedish and international) explore the interplay of built structures, transportation networks (public, private, and active transport), green spaces, and their collective impact on sustainable living. Active learning and engagement with real-world Arctic planning challenges are prioritized (Fokdal et al., 2020), enabling students to develop holistic solutions. The course's overarching goal is to empower students to analyze and apply urban development theories in the Arctic, addressing complex social, ecological, and economic challenges posed by climate change and evolving resource development patterns.

This course examines the application of sustainability theories in urban planning, specifically within the context of the Nordic Arctic region (Figure 2). Students gain a foundational understanding of the Arctic's unique characteristics and the challenges of sustainable living in this context. Key course competencies

Figure 2. Nordic Arctic region. Source: Combeaux et al. (2022, p. 8).

include describing the concept of sustainability, analyzing relevant national and international agreements, defining objectives for sustainable urban development, and critically evaluating the social, ecological, and economic dimensions of urban projects in the Arctic.

The course structure blends theoretical foundations and practical application. Four core aspects are explored: green and blue infrastructure, urban areas, renewable energy, and sustainable mobility. Students collaborate in small groups to research and present mini lectures on these topics, supported by a curated reading list. This process fosters active learning and prepares students for in-depth discussions. Simultaneously, students engage in a project assignment grounded in real-world Arctic planning scenarios. This project emphasizes analysis, problem-solving, and the development of comprehensive proposals presented in various formats.

In the project assignment, students were divided into groups, focusing on writing a strategic planning proposal, based on the literature studies, analyzing how the case study area in the Arctic region functions today and proposing planning measures for future sustainable development. The proposal should address both short-term and long-term development phases, including housing, services, infrastructure, cultural and green structures, etc., and relate to the Agenda 2030 SDGs. The analysis addresses the case study area, regarding its urban structure, urban areas, renewable energy, and sustainable mobility.

5. Results

The investigation into Sustainable Urban Development within the Arctic regions of Norway, Sweden, and Finland underscores the critical importance of planning for sustainable communities underpinned by the principle of sustainable development. Sustainable development, which seeks to meet the current generation's needs without compromising future generations' ability, is pivotal in guiding municipal strategies across these regions. Our findings reveal that active cognitive processing, various assessments for learning, and knowledge-enhancing feedback—our three core pedagogical principles—were instrumental in achieving the course's learning outcomes.

The course divided 15 master-level students into three groups, each tasked with addressing sustainability in one of the Arctic regions. Through literature review, data collection, analysis, and field trips, students engaged deeply with the subject matter, embodying the principle of active cognitive processing. Each group conducted the research on a specific part of the Arctic region, namely Finnish Lapland (Finland), Troms og Finnmark (Norway), and Swedish Norrbotten (Sweden). Their objective was to understand the development goals of each region and how these goals connect with the global SDGs in Agenda 2030, comparing the similarities and differences among them. Their presentations to local stakeholders not only facilitated real-world engagement but also provided a platform for immediate, knowledge-enhancing feedback, further refining their understanding and proposals.

5.1. Active Cognitive Processing

Active cognitive processing, a fundamental principle of effective learning, encourages students to deeply engage with course materials and connect new information to their existing knowledge. In this course, students in each group conducted extensive research using provided literature, independent search for reports and municipality documents on Arctic development strategies and visions within Finland, Norway,

and Sweden. This pedagogical principle proved pivotal in empowering students to adeptly navigate the multifaceted and interlinked challenges endemic to these regions. Through this rigorous inquiry and understanding of the contextual dynamics, students were proficient in discerning the shared challenges inherent in the development strategies of each region. This was shown as visions in their strategic planning proposals for tailored strategies addressing both short-term and long-term development objectives (Figure 3).

In Finnish Lapland, students were confronted with the task of increasing population sustainability while leveraging renewable energy sources. They critically analyzed the region's unique environmental conditions, societal needs, and potential for green energy, leading to proposals that balanced ecological integrity with human development. This deep dive into the specifics of Lapland's context required students to synthesize diverse knowledge areas, from ecological science to social policy, demonstrating the principle's effectiveness in fostering a holistic understanding of sustainability. The strategic vision for Finnish Lapland involves expanding towards the larger cities in the northern region, beginning with Rovaniemi and extending to Inari and Muonio. Currently, Rovaniemi stands as the largest city in Finnish Lapland, boasting established connections to the southern parts of the country. Inari, situated amidst seven national parks and adjacent to a large lake, holds significant potential for attracting both tourists and new residents. The long-term plan, spanning the next 30 years, includes Muonio as a key focus for development. This selection is strategic due to Muonio's location on the Swedish border, its proximity to Norway, and its surrounding national parks. Additionally, the presence of undeveloped areas offers opportunities for the construction of wind farms, further enhancing the region's appeal and sustainability.

Norway's Troms og Finnmark presented a different set of challenges, characterized by dramatic topography and a sparse population. Here, students explored innovative solutions for sustainable mobility and community resilience, considering how to maintain the delicate balance between development and the preservation of natural landscapes. By engaging with this complex scenario, students developed proposals that were sensitive to the unique needs and opportunities of northern Norwegian communities, reflecting an advanced level of understanding and application of sustainability principles. They considered Troms og Finnmark a thriving region on the rise. Within its winding fjords and vast nature, they identified a strong network of tightly knit

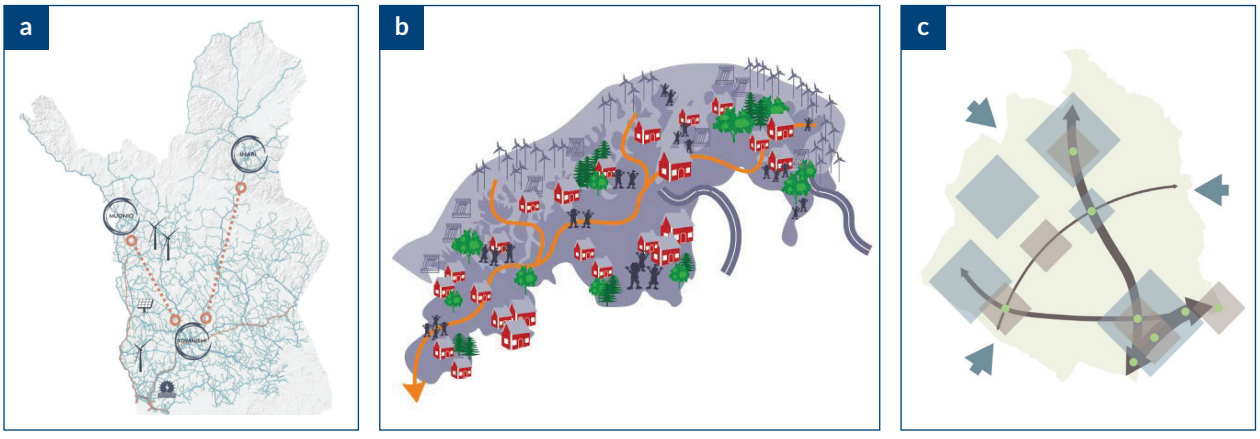


Figure 3. Visions of three countries in the Arctic region. Sources: a. Finland (Gideonsson et al., 2022, p. 11); b. Norway (Combeaux et al., 2022, p. 10); c. Sweden (Ravlic et al., 2022a, p. 4).

communities. The future for energy production should be greener than before, but within the capacity it has. The development of sustainable industries should support both nature and the people, standing side by side to ensure that Troms og Finnmark is a region connected to the Nordic Arctic.

In Sweden's Norrbotten, the emphasis on inclusivity and equity within the framework of sustainable urban development has prioritized the social dimensions of sustainability. This approach has explored how urban planning can enhance community cohesion and accessibility, particularly in regions characterized by significant geographic and demographic diversity. The investigation highlights the necessity of incorporating human factors into sustainability efforts. Norrbotten is seen as a hub of connectivity, collaboration, and innovation. The aim is to cultivate new ideas, improve resource utilization, and harness cleaner energy sources to overcome existing challenges. The vision includes creating novel spaces and working methods that challenge the status quo, striving for better internal connectivity within Norrbotten. Cities will remain green, contributing to micro-climatic environments that support the ecosystem. The nearby wilderness will continue to provide resources, inviting people to engage with nature, offering work, food, materials, health, and happiness.

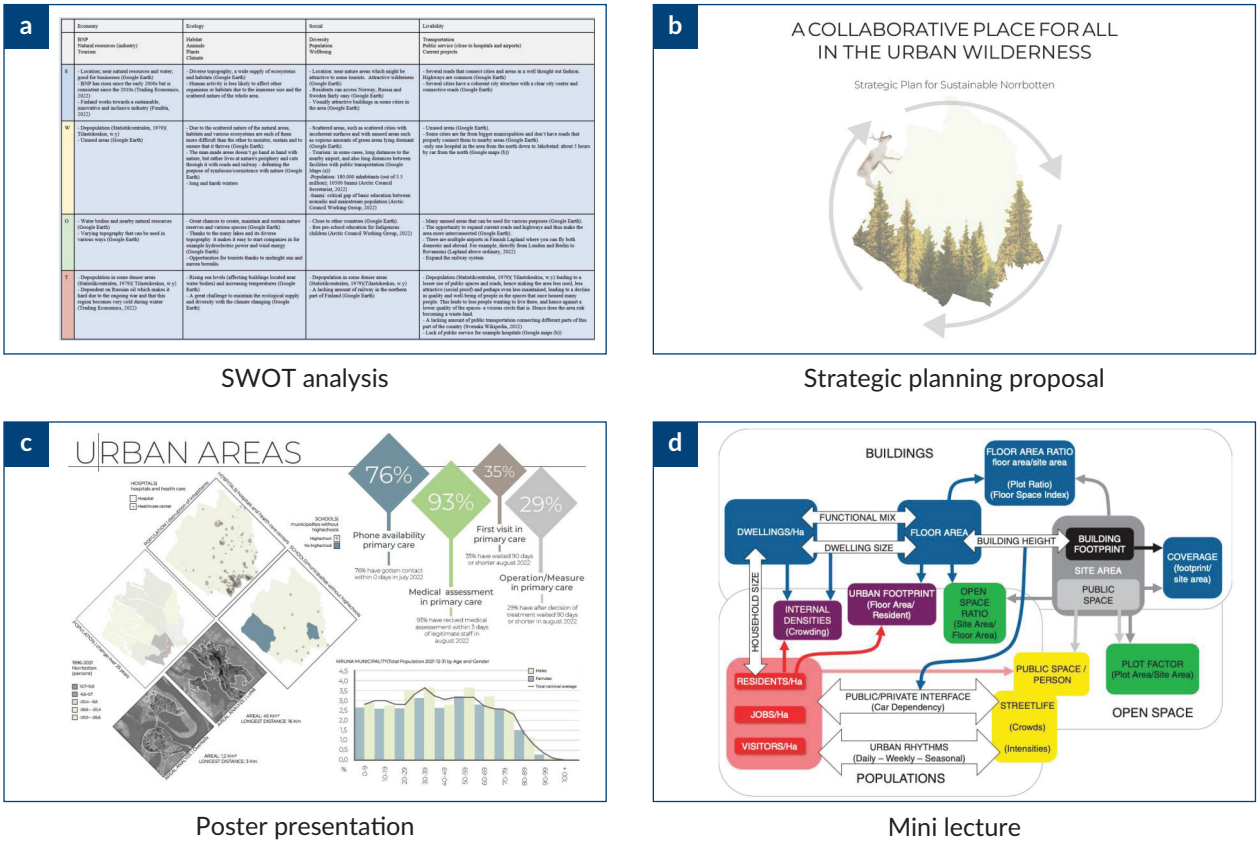
5.2. Various Assessments for Learning

The approach of assessment for learning, which prioritizes the use of assessment as a means to enhance learning rather than merely for evaluation, was instrumental in enriching students' comprehension of sustainability within the Arctic regions. The course applies this principle by integrating feedback mechanisms and reflective practices into the assessment framework, thereby ensuring that assessments serve as a continuous learning process.

A distinctive aspect of assessing students' learning outcomes involves group presentations on principal sustainability subjects. Recognizing the broad and general nature of the sustainability concept, the course narrowed its focus to specific areas such as mobility, green and blue infrastructure, energy, and public spaces. This focused approach helped to narrow down the scope of sustainable urban development, making the concept more tangible and manageable for students.

Various types of assessment have been applied in this course (Figure 4). The mini lecture presented by students were anchored in literature reviews of each topic, contextualized within the Arctic settings. This process significantly enhanced students' analytical capabilities and their ability to bridge theoretical concepts with practical applications. Additionally, the requirement for a planning proposal assessed students' proficiency in identifying and addressing problems. These proposals had to be articulated through formal writing, complemented by visual aids such as maps and diagrams to underscore key information.

Consequently, the synergy between oral presentations and written documents served not only to showcase students' written and verbal communication but also to test their in-depth understanding of the topics at hand. This combined assessment approach ensured that students were not merely evaluated but actively engaged in a learning process that reinforced their knowledge and skills in sustainable urban development within the Arctic context.



SWOT analysis | Strategic planning proposal

Poster presentation | Mini lecture

Figure 4. Various types of assessment. Sources: a. SWOT analysis (Gideonsson et al., 2022, p. 18); b. Strategic planning proposal (Ravlic et al., 2022b, p. 1); c. Poster presentation (Ravlic et al., 2022a, p. 1); d. Mini lecture (Dovey & Pafka, 2014, p. 70).

5.3. Knowledge-Enhancing Feedback

Knowledge-enhancing feedback, designed to bridge the gap between existing knowledge and the learning objectives yet to be achieved, played a crucial role in the educational experience of students. This principle fostered a dynamic educational environment, enabling students to actively incorporate feedback to refine their understanding and enhance their project proposals. Within this course framework, students were exposed to three distinct types of feedback, each serving to deepen their engagement with the subject matter and broaden their perspective on sustainability.

During course presentations, students encountered feedback from peers in opposing groups. This peer-to-peer interaction encouraged a critical exchange of ideas, wherein students from other groups posed questions and offered insights, thereby enriching the discourse on the presented topics. This form of feedback not only facilitated a deeper understanding of the subject but also introduced new perspectives and ideas into the conversation. They received immediate feedback from lecturers, drawing upon their extensive knowledge and experience in teaching and researching sustainability in Arctic contexts. Lecturers posed targeted questions to students with the aim of deepening their understanding and addressing any uncertainties. This immediate expert feedback was invaluable in clarifying complex concepts and guiding students towards a more nuanced comprehension of sustainability.

The most effective yet challenging one was the feedback students received from planners within local municipalities during field trips. In this course, students presented their research outcomes at both Haparanda and Tornio municipalities, Sweden. Practitioners, well-versed in local policies and the practical challenges of sustainable development, offered insights that bridged theoretical knowledge with real-world applications. Their feedback grounded students' understanding of sustainability in the tangible realities of regional planning, thereby enhancing their problem-solving and critical thinking skills.

This multilevel feedback system significantly enriched students' learning experiences, offering them a thorough understanding of sustainability that transcended textbook knowledge. By engaging with feedback from peers, academics, and practitioners, students were equipped to critically analyze and address the complex challenges of sustainable development in the Arctic regions, thereby fostering a more holistic and practical approach to learning.

The challenges and difficulties encountered in applying these pedagogical principles to higher education for learning sustainability address the complexity of teaching and learning in this domain. Each region presented unique challenges that required students to engage deeply with the material, critically assess their work, and incorporate feedback to enhance their understanding and proposals. The importance of these principles lies in their ability to foster a learning environment where students are active participants in their education, equipped with the skills and knowledge to address the pressing sustainability challenges of our time. Through this approach, sustainability education can move beyond theoretical knowledge, preparing students to contribute to sustainable development efforts in the Arctic and beyond.

6. Discussion and Conclusion

We started this article with the research question: How can pedagogical approaches effectively integrate Arctic sustainability perspectives into architecture and urban planning education? Addressing this involves navigating unique pedagogical challenges and seizing opportunities specific to the Arctic context. These include crafting curriculum content that is both engaging and relevant to the Arctic, overcoming students' preconceived notions about the Arctic, ensuring interdisciplinary collaboration, providing experiential learning in remote and harsh environments, and incorporating Indigenous knowledge and perspectives effectively into the curriculum. A significant pedagogical challenge is the tendency to view Arctic cities as exceptional or extreme cases. In reality, these cities face many of the same issues as other small and medium-sized urban areas, such as mobility, climate adaptation, and aging populations. Treating Arctic cities as exceptional can lead to inadequate solutions to their common urban problems.

However, these challenges also present opportunities. By exposing students to the real-world issues and diverse perspectives of Arctic environments, educational programs can foster a deeper understanding of sustainability. The Arctic context is ideal for developing innovative teaching methods that emphasize active learning, critical thinking, and problem-solving. For instance, students can engage directly with the unique ecological and social conditions of Arctic regions, which enhances their ability to address complex sustainability issues. The distinct environmental and social dynamics of the Arctic also offer a rich setting for interdisciplinary collaboration. This collaboration is crucial in tertiary education in urban planning, as it allows students to integrate knowledge from various fields such as engineering, environmental science, sociology, etc. For example, students working on projects that tackle the challenges of sustainable development in the

Arctic—like designing energy-efficient housing or improving transportation networks in sparsely populated areas—must draw on multiple disciplines to create effective solutions. This interdisciplinary approach not only broadens their knowledge base but also enhances their teamwork and communication skills.

Our course implementation highlighted several considerations necessary for successful sustainable development education. These include the emphasis of the need for contextual awareness of sustainability issues, well-structured learning environments, a wide range of reading resources, robust institutional support, and dynamic communication and feedback mechanisms with communities and public sectors. The broad and general nature of sustainability, encapsulated in the United Nations' 17 SDGs, poses educational challenges that require a comprehensive and context-specific approach.

A dual strategy was demonstrated to apply this approach: combining literature review and presentation to introduce broad theoretical dimensions of sustainability, and engaging students in real-world projects to apply these concepts in the Arctic context. This methodology facilitated direct observation, data collection, and reflective practice, enabling a deep understanding of sustainable urban development within urban planning. By engaging with stakeholders such as planners from local municipalities, students developed a nuanced understanding of sustainability that transcends traditional academic boundaries. This approach is critical for preparing future leaders in sustainable development, capable of addressing the complex challenges posed by climate change and societal shifts.

However, even when applying the aforementioned methods in the teaching and learning process, sustainability remains a vast concept that encompasses multiple aspects and involves various societal roles. Several challenges were encountered in our course. One significant challenge was the difficulty in maintaining ongoing engagement with local municipalities throughout the course. Often, municipality stakeholders have limited time and resources to commit to educational collaborations, which can hinder the depth of students' projects and their practical relevance. Additionally, the remote and sparsely populated nature of Arctic regions can make fieldwork and data collection logistically challenging and costly. Another challenge was balancing the broad theoretical dimensions of sustainability with the specific, localized issues of Arctic urban development. While the dual strategy of literature review and real-world projects aimed to bridge this gap, some students found it difficult to integrate these two aspects effectively within the limited duration of the course. Furthermore, the breadth of sustainability as a concept requires that students must engage in extensive literature reading and comprehend local context intricacies, which can be overwhelming.

A critical setback we realized in this course was the difficulty in conducting longitudinal studies to assess the long-term impacts of the course on students' careers and further studies. While immediate feedback through evaluation surveys of the course provides some insights, a detailed approach to tracking and analyzing students' outcomes over time is lacking. To truly understand and improve the educational impact of sustainability courses, a more thorough approach to tracking and analyzing students' outcomes is needed. This includes not only immediate feedback but also longitudinal studies to assess how specific courses influence career paths and lifestyle choices over time.

In conclusion, teaching sustainability-related topics in urban planning is crucial and challenging. Arctic sustainability provides a valuable lens through which students could explore and understand the complexities of sustainable development. Recognizing that Arctic cities face similar issues to other

small and medium-sized urban areas helps shift the focus from their perceived extremities to their common urban challenges. The application of active cognitive processing, assessment for learning, and knowledge-enhancing feedback within this context not only enhances students' learning experiences but also prepares them to contribute to the global sustainability discourse. As the world continues to face the pressing challenges of climate change and sustainable development, educational approaches like those employed in this course will be crucial for equipping future generations with the necessary knowledge, skills, and perspectives. It is essential to recognize and address the challenges and setbacks encountered to continually improve and adapt pedagogical approaches for better outcomes.

Acknowledgments

This research was supported by the Arctic Five Chair program. The authors extend their gratitude to the four anonymous reviewers for their constructive comments on the drafts.

Conflict of Interests

The authors declare no conflict of interests.

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About the Authors

Jing Ma is an associate senior lecturer in architecture at Luleå University of Technology (LTU). Her work primarily revolves around the spatial analysis of public open spaces to improve human health and well-being. Currently, her research focuses on sustainable urban development in Arctic regions, addressing unique challenges and opportunities in these environments. Her contributions to the field are geared towards fostering healthier and more sustainable communities.

Agatino Rizzo is the chaired professor of architecture at Luleå University of Technology (LTU) in Sweden. In this university he leads a research group of 25 people focusing on the climate transition in cities, urban living labs, and climate-sensitive design/planning. His research has been funded by, among others, Qatar QNRF, EU Horizon, Swedish Energy Agency, Formas, and Vinnova.

Social Inclusion
2024 • Volume 12 • Article 8302
https://doi.org/10.17645/up.8302

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Open Access Journal

Infrastructure Transitions in Southern Cities: Organising Urban Service Delivery for Climate and Development

Lucy Oates [1] and **Andrew Sudmant** [2]

[1] Faculty of Architecture and the Built Environment, Delft University of Technology, The Netherlands
[2] Edinburgh Climate Change Institute, University of Edinburgh, UK

Correspondence: Lucy Oates (l.e.oates@tudelft.nl)

Submitted: 22 February 2024 **Accepted:** 22 July 2024 **Published:** 29 August 2024

Issue: This article is part of the issue "Planning and Managing Climate and Energy Transitions in Ordinary Cities" edited by Agatino Rizzo (Luleå University of Technology), Aileen Aseron Espiritu (UiT The Arctic University of Norway), Jing Ma (Luleå University of Technology), Jannes Willems (University of Amsterdam), and Daan Bossuyt (Utrecht University), fully open access at https://doi.org/10.17645/up.i346

Abstract

Rapidly growing cities in the Global South are characterised by high levels of vulnerability and informality and are expected to bear a disproportionate share of the costs of a changing climate. The confluence of climate change impacts, inequitable urbanisation processes, and under-development emphasise the need for accelerated urban transitions in Southern cities, yet mainstream theories of urban sustainability transitions have been shown to be insufficient for such contexts. This is particularly relevant with regard to urban infrastructure: While mainstream urban theory tends to regard infrastructure as static, centralised, and heavily engineered, infrastructure configurations in cities of the Global South are often heterogeneous, comprising multiple dynamic social and material flows. Drawing on theory from Southern Urbanism and empirical data of unorthodox infrastructures from 14 cities, this article assesses the potential challenges posed by applying a key transitions framework—namely the Multi-Level Perspective—in Southern contexts. The article closes by suggesting a set of theoretical propositions for future conceptual and empirical research that could advance transitions literature more broadly, and highlights the need for all cities to pursue inclusive service delivery models that are responsive to the complex and shifting landscape of climate impacts.

Keywords

climate change; Global South; multi-level perspective; poverty; Southern urbanism; urban infrastructure

1. Introduction

The confluence of urbanisation and climate change presents an unprecedented challenge to conventional theories of how to bring about sustainability transitions in the built environment and its associated institutional structures. Urban infrastructures are directly or indirectly responsible for a significant proportion of greenhouse gas emissions, yet their efficacy is also key in building the resilience of urban areas to climate change and enabling citizens to adapt and respond to environmental shocks. As a result, urban infrastructures and the services they deliver both configure, and increasingly are configured by, urban responses to climate change (Bulkeley et al., 2014).

Whether carbon-intensive or not, inadequate or outdated physical infrastructures and inefficient or inequitable access to the associated services provided by those infrastructures can have dramatic effects on human wellbeing, the economy, and the environment (Floater et al., 2014). This is most acutely felt in the cities of the so-called Global South, where 90 percent of all population growth until 2050 will take place (United Nations Department of Economic and Social Affairs, 2019) and where more than a billion people already live in informal settlements. Informal settlements are especially ill-prepared for the risks of climate change, many of them being located in high-risk areas. Access to basic public services that help to build citizens' adaptive capacity to shocks is often inadequate or non-existent.

Cities in high-income countries face different yet related infrastructure challenges in the context of environmental change. Nowadays, many cities in the North are dealing with carbon lock-in arising from having constructed long-lived, energy-intensive infrastructures that generate emissions either directly (for example, buildings and factories which burn fossil fuels for energy) or indirectly (for example, urban sprawl and cultural preferences that encourage a dependence on private cars; Erickson & Tempest, 2015). Developed cities also face the capital-, labour-, and time-intensive challenge of updating and maintaining vast, centralised systems, as well as uncertainties around future demand, which is likely to grow.

Accordingly, urban actors worldwide are seeking alternatives to the "modern infrastructure ideal" (Graham & Marvin, 2001) of large-scale, centralised, and top-down networks. The majority of residents in Southern cities access or augment their access to urban infrastructure and the services it provides via decentralised and often informal channels, where a host of initiatives of varying degrees of formality and with varying levels of state support have evolved to fill service delivery gaps (Hodson et al., 2012). These infrastructures are often provided either for or by (or both for *and* by) the very citizens who are otherwise excluded from formal service delivery models, offering lessons for urban inclusion. They are often inherently flexible and adapted to local circumstances, offering lessons for resilience-building in the face of climate uncertainty.

This article argues that reframing this "unorthodox" infrastructure development in the context of climate uncertainty may lead to new insights for alternative pathways towards more inclusive and resilient cities. Central to this reframing is an understanding of the dynamics and characteristics particular to urban infrastructure development in the Global South. Drawing on 13 case studies of unorthodox infrastructure provision from the Global South, the article extracts principles for alternative imaginaries of urban service delivery that may be both more inclusive and better positioned to respond to a future defined by climate uncertainty. It explores how the nexus of climate change and development challenges in Southern cities necessitates a re-evaluation of the way in which sustainability transitions more broadly are conceptualised, challenging the hegemony of Northern urban theory and praxis.

The rest of the article is structured as follows. The remainder of this section resolves some definitional matters. The following section briefly reviews two key areas of literature—namely sustainability transitions and Southern Urbanism—upon which the analytical framework used for this article is built. The methods section follows, briefly outlining the empirical data collection approach for the case studies and explaining the application of the analytical framework to conduct a meta-analysis of these cases. Headline results from the meta-analysis, illustrated by vignettes of the case studies, are presented in Section 4. Section 5 discusses the implications of these findings for the theory and praxis of sustainability transitions. The article concludes with a reflection on the need—and the opportunity—to envision a more inclusive urban future that will be defined by continuous adaptation of the built environment in the face of climate uncertainty.

In framing this work, three terms are used that require further elaboration, though it is outside the scope of this article to engage in the detailed discussion they deserve. Firstly, the term "Global South," though contested, is used. It is understood not as a geographical construct but rather as a way to conceptualize a de-territorialised political economy of the uneven processes of economic development generated by capitalism and colonialism (Mahler, 2018). Secondly, the term "unorthodox" is used to describe service delivery models that may only be categorised this way when assessed by Western standards, and may be conventional within urban contexts in the Global South. It is thus employed to reflect the divergence of these models from mainstream theoretical perspectives rather than to suggest that they deviate from the norm in the contexts within which they exist. Third, the term "climate uncertainty" is used to reference the inherent unpredictability in the extent, timing, and impacts of climate change resulting from complex interactions between natural processes and human activities. More broadly, efforts to respond to that uncertainty can themselves have unpredictable results, which in turn poses significant challenges for planning and implementing effective adaptation and mitigation strategies. This is particularly the case in urban environments where both the variability and intensity of climate-related events, and the implementation of projects in the name of climate action, can have profound social, economic, and environmental consequences.

2. The Analytical Framework

Initial attempts to better connect transitions studies to Southern contexts emphasise the need to engage with local dynamics, where context and specificity plays a key role, calling for more knowledge-intensive urbanist approaches that draw on understandings of how people organise locally (Swilling & Annecke, 2012). This is particularly relevant for—and at the same time offers opportunity to learn from—service delivery in Southern cities, which is variously described as unorthodox, alternative, informal, non-conformist, or unconventional. Conceptualising everyday infrastructure practices as such reinforces the centrality of hegemonic Northern planning customs in both theory and practice (Lawhon et al., 2023)—a shortcoming to which Southern Urbanism seeks to respond.

2.1. Sustainability Transitions in Urban Service Delivery

Environmentally sustainable and socially inclusive alternatives to prevailing forms of urban service delivery are urgently required in the face of the climate emergency and related global crises. It is widely agreed that standalone interventions will not be sufficient to address these challenges at the scale which is needed. Accordingly, theory and practice are increasingly focused on sustainability transitions—that is, the evolution of both social and technological institutions towards sustainability (Köhler et al., 2019).

Sociotechnical systems—including for example energy supply, water supply, transportation networks, and telecommunications networks—can be understood as networks of actors, institutions, material artefacts and knowledge which interact to deliver specific services to society (Markard et al., 2012). A transition is a fundamental shift in the way sociotechnical systems are organised, which necessarily involves substantial technical, institutional, organisational, political, economic, and cultural changes (Geels & Schot, 2010). A sustainability transition, therefore, is the transformation process through which established sociotechnical systems attain more sustainable configurations.

2.1.1. A Multi-Level Perspective on Urban Service Delivery

The Multi-Level Perspective (MLP) is the key analytical framework upon which transitions theory is based, and was developed to assess the role of multi-actor processes in transitions (Geels, 2012). It posits that various dynamics influencing a sociotechnical transition occur simultaneously across three different, interacting levels (see Table 1): The landscape level involves macro-level exogenous factors such as economic, political, and environmental trends; a regime is an established set of rules, norms, and technologies embedded in entrenched institutions and infrastructures; and niches are sites of radical innovation that, if successfully diffused, might destabilise, alter, or even replace incumbent regimes. The analytical constructs, concepts, and principles of the MLP that are most relevant for this research are expanded upon in the Supplementary Material.

Though nowadays a well-established evolutionary perspective, the (use of the) MLP has also been subject to criticism. Notably, transitions research in general has keenly favoured Northern European case studies, perhaps reflecting the provenance of the most cited authors (Markard et al., 2012). In contrast, studies on the transition processes of countries in the Global South, though growing in number, are relatively rare (Köhler et al., 2019; Wieczorek, 2018). The theoretical and conceptual foundations of transitions studies have therefore neither been adequately applied in such contexts, nor developed with those contexts in mind. These geographical limitations are not restricted to transitions theory but are prevalent in urban theory more generally. Partly as a result of its origins in contexts where ecological modernisation has been a common response to sustainability challenges in the built environment, the MLP tends towards the suggestion of applying technical solutions to environmental and societal problems (Savaget et al., 2019). This narrow view on sustainability emphasises technical fixes at the expense of more participatory processes (Lawrence &

Table 1. Analytical constructs of the MLP (Geels, 2002, 2012).

Construct	Definition
Niche	• Protected spaces that support emerging innovations; • Novel innovations are intended to be used in or even replace the dominant regime.
Regime	• A semi-coherent set of deep-structural rules that coordinate and guide an actor's perceptions and actions; • Stabilised by many lock-in mechanisms.
Landscape	• A set of deep structural trends; • The external structure and context within which niche and regime interactions take place; • Commonly includes factors such as economic growth, wars, broad political trends, major environmental challenges, *and* cultural and normative values.

Haasnoot, 2017; Lin et al., 2017) and in place of social or political reorganisation (Hegger et al., 2007). Studies using the MLP have typically centred around discrete technologies and innovations, while conceptual blind spots remain with regard to the role that power imbalances and politics play in defining and enabling (or hindering) transitions processes (van Welie & Romijn, 2018). The MLP is considered especially insufficient for isolating the significance of geopolitical dynamics in shaping transitions pathways (Meadowcroft, 2011; Swilling & Annecke, 2012). It thus provides relatively little insight into how the developments of certain infrastructures are a product of a global process resulting from the interplay of decisions made across the political, socio-technical, and technological realms (Derwort et al., 2022).

Despite the aforementioned limitations—and in an effort to address these—a growing number of scholars are recognising the value of using sociotechnical theory to study sustainability transitions in the Global South (Ghosh et al., 2021; Hansen et al., 2018; Jayaweera et al., 2023; van Welie & Romijn, 2018; Wieczorek, 2018). In addition to noting the potential utility of the MLP as an analytical lens in this setting, most authors also observe that the MLP would benefit from input that serves to make it more sensitive to contexts outside of its origins (Murphy, 2015), helps it move beyond technological determinism (Savaget et al., 2019), contributes to broadening its geographical basis (Wieczorek, 2018), and offers further insight into integrating issues related to power and politics (Gillard et al., 2016; Köhler et al., 2019).

2.2. Southern Urbanism

Existing research finds that examining Southern contexts through a *modified* transitions lens can constructively highlight the interplay between niche service delivery models and wider landscape pressures such as poverty and inequality (Oates, 2021; Ramos-Mejía et al., 2018). Indeed, for transitions theory—as for theory and practice more generally—it is of vital importance to engage with empirical work that comes from contexts where conventional urban theories hold little relevance (Parnell & Pieterse, 2016; Robinson, 2006) but where the overwhelming majority of urban growth between now and 2050 will occur.

A rich and growing body of work that broadly falls under the heading "Southern Urbanism" responds to the shortcomings highlighted by critiques of modern urban theory, many of which are consistent with the shortcomings identified in sustainability transitions theory. Southern Urbanism is unambiguously based on empirical and conceptual contributions from the Global South. This is in contrast both with dominant urban theory—which is biased towards the urban condition in the Global North—and with attempts to describe a universal form of the "global condition" of urbanisation (Brenner & Schmid, 2014, p. 747)—which implies that the majority of cities experience largely the same problems and thus can employ the same solutions (Roy & Ong, 2011; Schindler, 2017).

That said, a set of broad, common characteristics that are in general applicable for Southern cities can be identified in the Southern Urbanism literature (Table 2; these characteristics are also elaborated upon in the Supplementary Material). Amongst other things, this set of features places issues of politics and power (imbalances) centre-stage, critically questioning development interventions by exploring for and by whom the development and greening of urban infrastructure takes place (Hodson et al., 2012; Holgersen, 2020). It directly addresses the fact that institutions, especially state institutions, often have limited human, financial, and technical capacity. It therefore emphasises the significance of the actions and responsibilities of a wider range of actors, including small and medium local enterprises, NGOs, community-based

Table 2. Key characteristics of Southern Urbanism identified through a systematic literature review by Parida and Agrawal (2023).

Characteristic	Description
Persistence of long expansion and continuous transitions have colonial roots and are dominated by post-colonial elite politics	Urban spaces are often characterized by a hybrid spatial culture, mostly driven by discourses on social identity traceable to a longstanding legacy of colonialism and elite politics
Territorial change is a governance priority	Governance regimes are inclined more towards the transformation of land (through infrastructure and real estate development) compared to industrial production
Informality is a dominant process as well as the context in which everyday urban processes manifest	Urban processes are evolving within a wider context where both state and non-state actors and institutions practice different forms of informality. At the same time, in the various urban processes, the formal and informal actors/institutions constantly shape each other
City spaces and resident groups are characterized by high vulnerability	Cities that are characterized by a large part of the population being vulnerable to socio-economic, cultural, as well as emerging environmental (and climate) risks
Everyday urban processes are driven by uncertainty, surprises, and creative livelihood techniques	Waves of change can have their origins anywhere—through middle-class activism as well as through subaltern assertiveness on land through legal or "rogue" means; livelihood techniques of residents of informal settlements are highly unique and adaptive based on the degree of vulnerability as well as closeness to political circles
Conflicting rationalities persist between and within groups	There is a persistent clash of rationalities between techno-managerial planning and governance systems and marginalized urban populations in the city (predominantly seen in informal settlements)
A disconnect between capital and labour	Southern cities have been accumulating a huge workforce, yet the formal economy is unable to absorb most of the labour force

organisations, and individuals. It stresses that many of the often creative livelihood and survival strategies undertaken by such actors are undertaken either in the context of and/or as a direct response to chronic vulnerability, which can be understood as the persistent and long-term susceptibility of certain populations or areas to adverse conditions and shocks. This arises from a combination of systemic factors, such as inadequate infrastructure, limited access to essential services, socio-economic inequalities, and (disproportionate) exposure to environmental risks, and is often deeply rooted in historical, political, and economic structures.

3. Methodology

3.1. Case Selection and Data Collection

This article is based on case studies of 13 service delivery initiatives from across 14 Southern cities, carried out during the course of a multiyear, multistakeholder international research project funded by a global knowledge coalition. Cases were selected in collaboration with the coalition members based upon the following criteria.

They must: (a) be an initiative closely related to the provision of a basic urban service; (b) intend to deliver some form of climate action, whether mitigation or adaptation; (c) intend to deliver some form of human development benefit; and (d) demonstrate organisational arrangements that might be considered "unorthodox" according to mainstream urban theory. The justification for case selection on a case-by-case basis can be found in the Supplementary Material.

The empirical data was collected during multiple phases of fieldwork in 14 cities across six countries between May 2018 and July 2023 (see Table 3). Methods included semi-structured interviews, site visits, multistakeholder workshops, focus groups, and the extensive consultation of policy documentation and other literature (see the Supplementary Material for a full overview and breakdown of methods per case study).

3.2. Data Analysis

The initial analysis of each case involved the inductive coding of case-specific data to produce an extensive account of each initiative including the policy context, its organisational arrangements, its climate and development impacts, key successes and challenges, and recommendations for scaling up the benefits. For the purposes of this article, a secondary meta-analysis was then conducted, which involved using an analytical framework combining the MLP with Southern Urbanism (developed in Section 2 and clarified in the Supplementary Material) to interpret the (analysed) results of each case study. This abstraction allowed for a comparative meta-analysis across cases in order to extract broader implications for both sustainability transitions theory and for the governance of urban service delivery more generally. The cross-case nature of

Table 3. Overview of case studies [(i)].

	Case study	Country	City	Sector [(ii)]
1	Dockless bicycle-sharing scheme	China	Shanghai	Transport
2	Sponge cities programme		Wuhan	Water
3	Waste picker cooperative	India	Ahmedabad	Waste
4	Community-led participatory housing		Kochi and Trivandrum	Housing
5	Residential rooftop solar		Delhi	Energy
6	Participatory slum upgrading	Kenya	Nairobi	Housing
7	Energy efficient affordable housing	Mexico	Hermosillo	Housing
8	Bicycle-sharing scheme		Mexico City and Guadalajara	Transport
9	Locally-led adaptation plan		Xalapa	Water
10	Land registration programme	Tanzania	Dar Es Salaam	Housing
11	Community-led participatory housing		Dar Es Salaam	Housing
12	Solar-powered streetlights	Uganda	Jinja	Energy
13	Local waste-to-briquettes enterprise		Kampala	Waste

Notes: (i) Previously published policy-focused work on these cases is available at https://urbantransitions.global/publications/?select-publication-series%5b%5d=frontrunners; (ii) Each case is assigned to the sector to which it primarily relates, though in many cases there is direct or indirect overlap with other sectors.

this evaluation ensures that the conclusions drawn, though inherently subjective, are as verifiable, transferable, reliable, rigorous, and robust as possible.

4. Headline Results From Meta-Analysis of Case Studies

This section briefly highlights some of the most salient findings from the meta-analysis in relation to the shortcomings of transitions theory, and in the context of inequitable access to urban infrastructure services that is compounded by the impacts of climate change. It presents vignettes from specific cases to illustrate these results.

The cases demonstrate the diverse ways in which non-state actors are asserting their influence on urban service delivery through self-organising initiatives, in response to conventional state-led mechanisms that are struggling to meet the demands of growing urban populations in an environmentally sustainable manner. In doing so, many of the infrastructure projects studied are contributing to building urban resilience to climate change through a combination of improving ecological and social security. In the cities of Kochi and Trivandrum, in the Southern Indian state of Kerala, community-based organisation Kudumbashree was mandated to oversee the implementation of a nationwide slum upgrading programme (Basic Services for the Urban Poor; case 4). In partnership with the municipal government and a local architecture firm, they developed cost-effective low-carbon neighbourhoods that have the highest occupancy rates among the settlements involved in the Basic Services for the Urban Poor programme. In Jinja, Uganda, efforts undertaken by an organisation of slum dwellers resulted in a joint project with the municipality to erect 20 solar-powered streetlights in an informal settlement (case 12). Initially a one-off infrastructure investment, the project has led to continued collaboration on urban planning priorities. In Ahmedabad, India, a group of women waste pickers formed a cooperative under the Self Employed Women's Association and entered into a contract with a district authority to collect and segregate waste from around 45,000 households between 2004 and 2009 (case 3). This resulted in an increase in the amount and security of the women's earnings as well as the collection and recycling of an estimated 70 percent of household waste. In the Bosco neighbourhood of Hermosillo, Mexico (case 8), a local architect designed a sustainable living community using green building techniques without increasing the upfront cost of investment compared to "business as usual" development. This cost-effectiveness was partly achieved by gaining authorisation to build at higher than usual density, resulting in the use of less land without having to compromise on housing quality. A similar approach was taken by the Chamazi housing cooperative in Dar Es Salaam, Tanzania, which applied for and was granted permission to develop incremental housing on plots of half the legally ordained minimum plot size (case 11). Though their application was submitted in response to the forced resettlement of the low-income community who were looking for a way to develop housing that suited their own needs and resources, it has wider implications for resilience too in terms of flexible building standards and increasing liveable density.

At the same time, however, a contradictory narrative emerges. Despite isolated successes, there are often barriers to the wider scaling up or out of these initiatives, which are rarely integrated into wider spatial planning processes. For example, the land purchased by the Chamazi housing cooperative has since been surrounded by informal settlements, preventing the expansion of trunk infrastructure and effectively cutting off the community from the city centre and its abundance of income-generating opportunities. In Wuhan, China, 389 sponge projects covering almost 40 square kilometres have been developed to showcase the

protective qualities of nature by expanding parkland, vegetation, green buildings, and permeable pavements (case 2). Yet the sponge cities programme has been critiqued as a series of technical interventions—most of which are located outside of the built-up urban areas where they are most needed, since land is cheaper and construction is more straightforward—that promote land-based urban growth and property speculation. Similarly, Tanzania's 20,000 Plots Project was widely praised for being the country's largest national land delivery scheme in decades but has since been shown to have increased urban sprawl and land speculation (case 10).

These (in)coherences can be in part attributed to the extent to which initiatives are integrated into wider institutional arrangements. In Nairobi's Special Planning Areas, participatory slum upgrading has been legally mandated, giving greater voice to communities (case 5), while Shanghai's bicycle sharing scheme is being rolled out alongside complementary efforts designed to offer comprehensive non-motorised transport options for its residents, including an expanded public mass transport system, restrictions on vehicle ownership, and investments in pedestrian and cyclist safety (case 1). In contrast, in Ahmedabad, the contract between the district council and the women waste pickers was terminated after the district was absorbed into the wider city's jurisdiction, meaning the waste pickers were suddenly obliged to meet the requirements of a tender process that demanded the use of high-tech machinery—a condition they were unable to satisfy. In Hermosillo, while the Bosco neighbourhood inspires the imagination of a greener housing sector, it is seen as a one-off example rather than a replicable model. These examples indicate that the perceived benefits from technocentric interventions—such as those designed around the construction of trunk infrastructure, land registration and titling, or waste incineration—are not automatic, and can even have an adverse effect on climate and development goals when contextual conditions and equity concerns are not explicitly addressed in the project design and the accompanying policy strategies.

5. Situating Southern Urban Service Delivery in Transitions Studies

Section 2 highlighted a set of established limitations of transitions theory for understanding service delivery in Southern cities. The case studies show how these limitations are particularly salient when climate and development goals are taken as key contextual elements shaping the purpose, structure, and governance of infrastructure services. Climate change is well established as a factor exacerbating the social, economic, and environmental challenges of infrastructure provision, both in the Global North (Corvellec et al., 2013) and South (Dodman et al., 2023). Similarly, development challenges are regularly coupled to discussions around access to basic services (Lawhon et al., 2023). However, juxtaposing climate risk with development needs in the context of urban service delivery systems calls into question dominant understandings of infrastructure resilience. Beyond the capacity of the physical engineered networks to withstand or recover from climate-related shocks, the cases highlight the importance of embedding adaptive capacities into governance structures as well as building the resilience of all populations by ensuring their basic needs are met. Several of the cases highlight how failing to integrate successful service delivery mechanisms into wider multi-level governance structures and decision-making strategies can minimise or even reverse climate and development gains. This may lead to the further exclusion of vulnerable groups who participate in or benefit from the provision of a service, as in the case of the women waste pickers in Ahmedabad who lost their job security due to stringent regulations, for example. Inflexible planning rules could also be blamed for the underperformance of sponge city projects, which are implemented based on the same set of technical guidelines in each pilot city despite vastly differing meteorological and hydrological conditions

across China. Conversely, the examples from Jinja, Kerala, and (to an extent) Nairobi show how changing the rules and structures of infrastructure governance to account for heterogeneity—in these examples by institutionalising meaningful participation in equitable low-carbon infrastructure provision—can generate ongoing co-benefits. Though the institutional settings differ greatly across cases, a common need to encompass the socio-political dimensions of sustainability in urban service provision—for example through fostering institutional flexibility, community empowerment, and equitable access to resources—is clearly identifiable, and is supported in existing literature (Lawhon et al., 2023; Wamuchiru, 2017).

The importance of attending to power imbalances in transitions processes is especially essential since the global response to climate change has ushered in new forms of intervention in the built environment of Southern cities by actors from the Global North (for example, through development finance or private sector investment), often reproducing patterns of imposition that mirror colonial infrastructural and governance practices. The evidence from the case studies underscores the need for transitions theory to critically examine these patterns—for example, in India, the replacement of the effective recycling activities of the Self Employed Women's Association with technically-versed private operators, set against the backdrop of a national preference for "smart" solutions such as waste incineration plants; similarly, the ongoing privatisation of Uganda's waste sector that diverts scarce resources away from local enterprises and towards externally financed mega-projects; and the formalisation of land under Tanzania's 20,000 Plots Project without adequate regard for local ownership structures and livelihood strategies. In practice, this manifests in spatial policy designed primarily around wealth-generating (or wealth-extracting) infrastructure projects and real estate investments. Where a techno-managerial lens might lead to the conclusion that factors preventing niche activities from generating meaningful and lasting regime change are related to internal shortcomings (such as their failure to become commercially viable at scale) or external factors (such as restrictive spatial policy and a stringent regulatory environment), interrogating the underlying governance and power relations paints a more nuanced picture in which climate and development goals are superseded by—or are even used as rhetoric to justify—the pursuit of deeply embedded financial and geopolitical interests through infrastructure investment. Transitions theory, if it is to realise its transformative ambitions, must account for and resist neo-imperial tendencies that overlook local contexts and knowledge systems. Instead, it should advocate for participatory approaches that prioritize voices from and the needs of the Global South, recognizing the diversity of experiences and expertise that these communities bring to the table in addressing climate change.

In this context, incremental infrastructures need to be considered as the norm, and not the exception, in post-colonial cities (Silver, 2014), affecting both the way that niches can be conceptualised and, accordingly, the strategies that are put in place to protect and manage innovations. From a conventional transitions perspective, many of the cases studied here would likely be conceptualised as niches, because they operate (at least partially) outside of formal institutions, have frequently emerged at the local level in response to place-specific needs, or are not considered commercially viable when measured in conventional economic terms. Ultimately, they rarely fit the Western neoliberal model of urban service delivery upon which transitions theory has been generated. However, in most cities of the Global South, such activities are arguably in fact an integral part of the regime: For example, an estimated 1 percent of the urban population in developing countries—equal to almost 20 million people worldwide—is engaged in informal waste picking activities (International Labour Organization & Women in Informal Employment: Globalizing and Organizing, 2017), while the urban poor are most often responsible for the upgrading of their own homes (Bredenoord &

van Lindert, 2010). This is in line with previous research that has indicated the distinction between niche and regime is increasingly difficult to ascertain in Southern contexts (Ghosh & Schot, 2019; van Welie, 2019).

A key tenet of Southern Urbanism is that empirical differences between cities should be studied not independently but rather alongside a critique of existing knowledge production and processes (Lawhon et al., 2020). Uncritically applying the MLP framework in settings of informality, with its emphasis on niche innovations and grassroots initiatives, may both overlook context-specific aspects of existing regimes and neglect the systemic barriers and power imbalances that commonly hinder sustainable development efforts in the Global South. Similarly, its focus on niche development may not fully accommodate the urgent need for transformative change, the environmental case for which is amplified by the presence of persistent poverty and inequity.

Problematising the service delivery models commonly seen in transitions studies creates space to interrogate a far broader range of options in urban service delivery (Lawhon et al., 2018), and for this the MLP serves as a valuable analytical entry point. At the same time, its applicability in Southern contexts requires critical examination and adaptation to ensure its relevance in fostering socially inclusive as well as ecologically sustainable development. While the imperative for sustainability transitions in urban service delivery has never been more urgent, the case studies illustrate that an evolving climate crisis necessitates a re-evaluation of what is meant by "transition": Who defines the future state towards which a transition is needed in the context of unprecedented uncertainty, and who can participate in the process of getting there? Traditionally, transitions theory has focused on these pathways and end-states, often conceptualized as shifts from one stable regime to another. However, the dynamic and unpredictable nature of climate change compels us to reconsider this. Rather than a linear or teleological process, transitions in the context of climate change must be viewed as iterative, adaptive, and continuous. This reorientation recognizes that the "end-state" of the transition is in fact a moving target, where adaptation and transformation are constant requirements in response to the changing climate landscape. This calls for a conceptual shift away from orthodox considerations of infrastructure as top-down, stable, replicable, and wealth-generating (Lawhon et al., 2023), towards understanding both infrastructure and the associated services it provides as a set of evolving and dynamic interconnected systems with multiple and overlapping social, economic, and environmental objectives.

6. Propositions for Sustainability Transitions Theory

The analysis and discussion presented above can be synthesised into a set of theoretical propositions for the further development of the MLP framework and transitions studies more generally. Though tailored to the research presented in this article, the propositions are generally aligned with existing and acknowledged critiques of the MLP (Geels, 2011) and the research agenda for the field of sustainability transitions studies (Köhler et al., 2019).

Further develop understandings of niche organisational arrangements: Managerial, fiscal, and legislative interventions related to making discrete technologies competitive remain dominant in transitions literatures (Oates et al., 2023; Smith & Raven, 2012; van Welie & Romijn, 2018). The findings presented here, however, demonstrate that niches are not just spaces for technical innovation but are also critical for fostering more socially and environmentally sustainable organisational forms (Fransen et al., 2023; Patnaik & Bhowmick,

2020; Wolfram, 2018). Allowing these organisational forms to develop will depend on innovations in governance structures rather than technologies (Bosomworth et al., 2017) and necessitates new metrics for evaluation that go beyond traditional financial and economic metrics.

Recognise the existence of multiple, overlapping, and in some cases unorthodox, systems within regimes: While unorthodox infrastructure initiatives may not address all drivers of social injustice or climate change (and nor should they necessarily be responsible for doing so), they do provide a valuable complement to conventional, centralised, or formal systems. Many of the unorthodox delivery models studied in this research—and the vast array of similar and emerging initiatives through which the majority of urban residents, not least the urban poor, access services in Southern cities—are thus arguably integral components of existing infrastructure regimes (Ghosh & Schot, 2019). They may exist alongside more conventional state-provided service delivery systems or there may be no alternative, yet still their degree of informality has so far largely prevented such models from being taken seriously in infrastructure planning. On the contrary, conditions such as informality, and communal organisation should be foregrounded as majority conditions to which development agendas must meaningfully respond. This is increasingly crucial in light of the enormity of the sustainability challenges society faces today, and the sustained and joint contribution of all actors that will be necessary in making the huge changes required to achieve transitions.

Interrogate the distinction between the concepts of niche and regime: Connected to the previous proposition, this research highlights how unclear the division between niche and regime can be in the context of urban infrastructure in Southern cities, where the boundaries between niches and regimes can be more fluid. Unorthodox service providers such as community-based enterprises often operate in a grey area, simultaneously challenging and integrating with existing regimes. This is particularly salient where urban service delivery mechanisms operate across a spectrum of formal and informal, top-down and bottom-up, and centralised and communal approaches. This hybridity suggests that what mainstream transitions theory might classify as niches are not always isolated pockets of innovation but can be deeply embedded within and continuously interact with the regimes in which transformation is sought. Similarly, it is not easy to delimit the regime in such contexts because the technological, regulatory, and infrastructural frameworks as defined by certain (Northern) standards may not adequately capture the complexity of more hybrid systems. It might therefore be valuable to reconsider the prevailing duality through which niche and regime are currently viewed and instead move towards a more mutable classification of the concepts.

Embed climate in all conceptualisations of niche, regime, landscape, and transition: Climate change is commonly understood as a landscape factor within the MLP framework, a backdrop in which environmental change is exerting pressure on infrastructure systems to adapt and evolve over time. The case studies here, however, demonstrate this conventional perspective to be inadequate. Climate change is not just an external pressure; it continuously interacts with and shapes the socio-technical nature of niches, regimes, and transitions. It is a multifaceted phenomenon that both influences and is influenced by the very fabric of socio-economic structures, calling for a more prominent integration into the MLP. The immediacy and pervasive nature of the climate crisis necessitates that niches prioritise resilience and sustainability. The scale of the climate challenge forces regimes to restructure and shift resources to climate-related priorities. Moreover, the uncertainty associated with both the impacts of and responses to climate change demands a continuously evolving and iterative conceptualisation of transitions. This requires the holistic mainstreaming of climate change into understandings of sustainability transitions, ensuring that niche

innovations, regime transformations, and landscape dynamics are all aligned with overarching climate resilience and sustainability goals.

7. Conclusions

Drawing on critiques from Southern Urbanism and extensive empirical data from 14 Southern cities across three continents, this article highlights potential shortcomings in current transitions theory. It stresses the need for a paradigm shift away from hegemonic theory and practice that currently imposes a predominantly Northern perspective on infrastructural change. Situating climate change and development as ongoing challenges that are central to understanding service delivery in Southern cities, the research suggests that some of these limitations can be overcome by embracing the diversity and dynamism of infrastructural landscapes that might be considered "unorthodox" when viewed through certain theoretical lenses.

The findings from diverse case studies illustrate how non-state actors are catalysing innovative, self-organising service delivery initiatives to address gaps left by more conventionally endorsed centralised infrastructure. These initiatives are pivotal in enhancing urban resilience to climate change, especially but not exclusively for vulnerable populations, and often do so while improving ecological and social security. However, alongside these successes, the findings show that systemic barriers can hinder the scaling and integration of such initiatives into broader urban planning frameworks. Common challenges include regulatory constraints, a lack of institutional support, and spatial inequities that are in turn exacerbated by climate impacts.

For practice, these insights underscore the critical role of adaptive governance structures and inclusive decision-making processes in fostering resilient and equitable urban development. A more theoretically motivated synthesis of the results suggests several key directions for advancing understandings of transitions studies, centred around a critical engagement with the key analytical constructs of niche, regime, and landscape. Applying these concepts to infrastructure service delivery in Southern cities highlights the need for greater flexibility in the way in which they are commonly delimited, which until now has been largely according to Northern standards. Further, embedding climate considerations into all facets of niche, regime, landscape, and transition analyses more broadly—rather than treating climate change simply as a contextual factor—is crucial. The propositions introduced above thus collectively advocate for a more inclusive, adaptive, and context-sensitive approach to transitions theory, which is particularly urgent for addressing global sustainability challenges in diverse Southern urban contexts and is relevant globally too. Although research presented in this article has focused on the Global South, the limitations of large-scale, centralised systems in addressing the diverse and dynamic realities of infrastructural change in the context of climate uncertainty also deserve greater consideration in the Global North. These findings emphasise the defining role that so-called unorthodox infrastructures could play in building inclusive and resilient cities in any city concerned with more socially just and ecologically sustainable futures.

Acknowledgments

The authors would like to thank all those involved in the case study research, as well as Andy Gouldson, Sarah Colenbrander, Ellen van Bueren, and Aksel Ersoy for their guidance and collaboration. Sincere thanks also to the editors and three anonymous reviewers for their comments on an earlier version of this manuscript.

Funding

The case study research was supported by the UK Department for International Development [Grant/Award Number: 113550] and the TU Delft Global Initiative.

Conflict of Interests

The authors declare no conflict of interests.

Data Availability

Metadata and background information relevant to this article, including the case study coding and analysis, is available at the following DOI: https://doi.org/10.4121/c8a2a8aa-6a1a-4ba4-9d9d-c264fd1894f3.

Supplementary Material

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

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About the Authors

Lucy Oates has extensive experience coordinating and conducting research related to international development and climate change. She has worked in several countries across multiple continents. She is currently completing her PhD on the sustainable governance of urban service delivery in cities of the so-called Global South. Lucy also has experience working in local and national government in the UK and the Netherlands.

Andrew Sudmant has worked in academia and consultancy for the last 11 years, conducting research on and providing advice to local and national governments, public organisations, and the private sector regarding achieving net zero emissions. Andrew's areas of research include economic modelling of local and regional climate actions and the science of urban sustainability. Andrew has taught at the undergraduate and postgraduate levels on the economics of climate action, carbon accounting, and urban climate economics.

Urban Planning
2024 • Volume 9 • Article 8349
https://doi.org/10.17645/up.8349

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Open Access Journal

Urban Sustainability in Arctic Cities: Challenges and Opportunities of Implementing the Sustainable Development Goals

Ava Soroudi, Agatino Rizzo, and Jing Ma

Department of Civil, Environmental and Natural Resources, Luleå University of Technology, Sweden

Correspondence: Ava Soroudi (ava.soroudi@ltu.se)

Submitted: 8 March 2024 **Accepted:** 2 July 2024 **Published:** 16 August 2024

Issue: This article is part of the issue "Planning and Managing Climate and Energy Transitions in Ordinary Cities" edited by Agatino Rizzo (Luleå University of Technology), Aileen Aseron Espiritu (UiT The Arctic University of Norway), Jing Ma (Luleå University of Technology), Jannes Willems (University of Amsterdam), and Daan Bossuyt (Utrecht University), fully open access at https://doi.org/10.17645/up.i346

Abstract

Arctic cities are at the forefront of climate change, experiencing distinctive obstacles in their endeavors to pursue green transitions and attain sustainability objectives. These cities are marked by high energy consumption, primarily driven by activities related to resource extraction and the demanding climate. Moreover, they rely heavily on natural resources for growth, have limited infrastructure, and experience significant external and internal remoteness. This article presents a comprehensive analysis of urban sustainability in Arctic cities, focusing on key themes, trends, and challenges. Through a systematic review of extant literature, this study examines current research on urban sustainability in the Arctic and identifies crucial gaps, delineating a path to sustainability. Using VOSviewer software, six thematic clusters were identified: climate change and environmental adaptation, SDGs and smart urban planning, sustainable development and urban governance, sustainable economic development, social sustainability, and green energy transition. These clusters provide valuable insights into the dominant themes and evolving discourse in Arctic sustainability research. The findings show that the literature focuses predominantly on Russian Arctic cities, signaling an imperative for a more inclusive strategy encompassing a broader spectrum of Arctic cities. Additionally, sustainability is inherently site-specific and necessitates a nuanced understanding that incorporates different stakeholders' perspectives and considers particular regional traits to create a more effective and meaningful approach to measuring and achieving sustainability in Arctic cities. This article contributes to the ongoing discourse on sustainability in Arctic cities by advocating for a comprehensive framework that accommodates unique challenges and opportunities of Arctic urban environments.

Keywords

Arctic cities; green transition; SDGs; sustainable development; urban sustainability

1. Introduction

Climate change is altering the way policymakers and planners intervene in urban areas. The Paris Agreement and the Sustainable Development Goals (SDGs) have established a set of indicators and targets that promise to transform our cities, making them more sustainable and adaptable to climate events. One area of the globe most affected by climate change is the Arctic (Chapman et al., 2018). According to various scenarios (Swedish Meteorological and Hydrological Institute, 2024), the Arctic is experiencing consistent temperature anomalies, increased precipitation, and melting ice, which are already impacting urban infrastructures built in the previous century. Arctic sustainability has become a growing concern both within the region and among stakeholders worldwide, given the ongoing transformation and development occurring in the polar region (Petrov et al., 2016; Rizzo & Sordi, 2020). Monitoring sustainability, which involves analyzing data on environmental, social, and economic factors, is crucial to combat the far-reaching impacts of climate change. It helps to understand the current sustainability status by providing real-time data and trends that direct future sustainability initiatives. This imperative evaluation helps in shaping strategies to achieve sustainability, identifying challenges, and implementing the necessary actions toward a more sustainable future. Arctic sustainability research is expanding as a significant contributor to global sustainability knowledge by examining unique environmental conditions and human–environment interactions in the Arctic (Petrov et al., 2016; Tornieri et al., 2024).

Arctic cities encounter specific challenges in achieving sustainability, including extreme climate, fragile ecosystems, and distinct social dynamics. To navigate this complex terrain, it is essential to scrutinize and adapt the global SDGs to align with the Arctic cities' specific needs and aspirations. Some efforts have been made to create a tailored monitoring framework for Arctic cities. For instance, Berman and Orttung (2020) conducted a thorough evaluation of the applicability of the ISO 37120 index for the Arctic urban context. They highlighted the unique challenges in the Arctic, arising from factors such as geographical remoteness, harsh climates, and reliance on resource-based economies, emphasizing the essential requirement for supplementary indicators that account for regional contexts and the presence of Indigenous populations (Berman & Orttung, 2020). Nilsson and Larsen (2020) examined the need for region-specific SDGs and indicators in the Arctic context, focusing on demographic factors, Indigenous rights, Arctic-specific economic measures, and local engagement, to ensure that sustainable development aligns with the unique challenges of the region. However, despite these insightful efforts, a crucial gap remains in the literature concerning a comprehensive measurement of sustainability tailored to the specific characteristics and challenges faced by Arctic cities.

This study seeks to review and assess the current state of knowledge about sustainability in Arctic cities by conducting a comprehensive systematic literature review. The main research questions are: (a) What are the emerging trends, patterns, and key themes within the literature? (b) What are the challenges and opportunities of implementing the SDGs in Arctic cities? This study highlights the key areas of focus for urban sustainability in the Arctic, allowing for the development of more accurate and relevant indicators tailored to the unique challenges and priorities of the region. The article begins by presenting the research methodology and data collection process (Section 2). Following this, Section 3 explores the literature by investigating how keywords appear together to understand connections and thematic clusters, track changes over time, and visualize thematic concentrations across the datasets. In Section 4, we analyze each key thematic cluster to elucidate the challenges and opportunities Arctic cities encounter in implementing

SDGs. We answer the research questions and discuss the results in the final section, highlighting existing gaps in the literature and identifying potential areas for future studies.

2. Material and Methods

A systematic literature review was conducted to achieve the article's objectives. According to Snyder (2019), adherence to rigorous steps is imperative to make the review credible and trustworthy. This methodology, renowned for its clarity in objectives, rigorous and reproducible procedures, and thorough search strategy, is effective in minimizing potential bias (Liberati et al., 2009). This article adheres to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) as outlined by Moher et al. (2009).

The search query employed for this study is as follows:

> ("SDG*" OR "sustainable development goal*" OR "agenda 2030" OR "global goal*" OR "ISO 37120" OR "energy transition" OR "green transition" OR "urban sustainability" OR "Arctic sustainability" OR "sustainable urban development" OR "sustainability strategies*" OR "GHG emission*" OR "greenhouse gas*" OR "smart cit*") AND ("Arctic" OR "circumpolar" OR "Nordic" OR "Northern cit*")

The search query was strategically split into two main parts. The first part encompasses a spectrum of integrated sustainability concepts, including SDGs and urban sustainability, while the second part narrows the focus to the distinctive geographical context of the Arctic region. We filtered existing literature specifically relevant to urban dimensions of sustainability in the Arctic (excluding sub-Arctic), concentrating on its unique challenges and opportunities to reach sustainable development goals. This dual-part approach ensures a comprehensive understanding of urban sustainability concepts in the specific context of Arctic cities. Two major academic databases, Scopus and Web of Science (WOS), were selected to find relevant articles due to their extensive coverage of peer-reviewed and interdisciplinary journals. WOS was used to find publications published between 2002 and 2023, and Scopus was used to find articles published between 2000 and 2023. However, the first relevant paper was not published until 2014 (Figure 1).

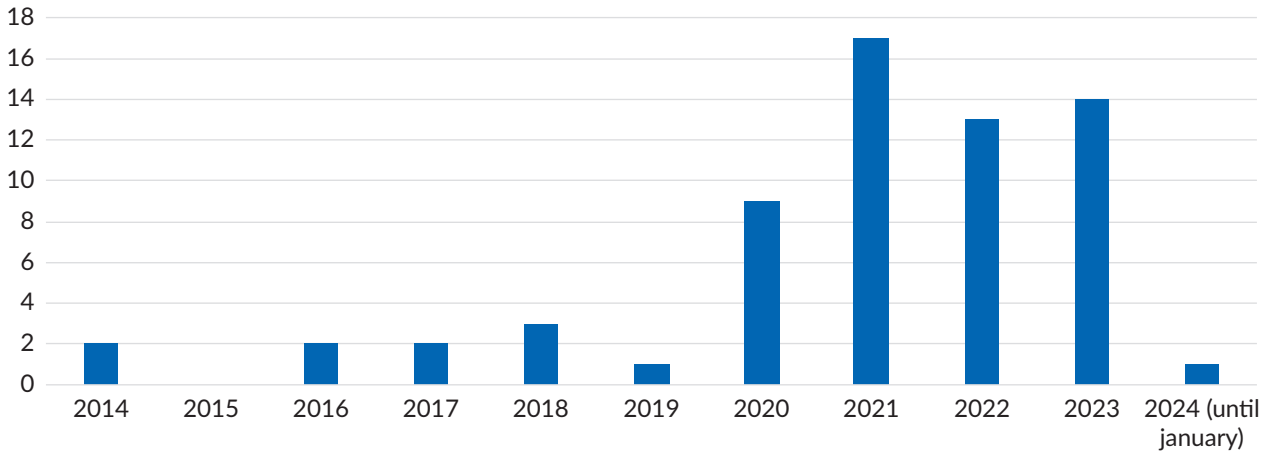

Figure 1. Number of relevant articles per year from Scopus and WOS.

For practical reasons, we limited our queries to English-language journal papers. Figure 2 illustrates the procedures employed for source selection. The initial search was conducted on December 20, 2023. After removing duplicate records, our dataset comprised 337 articles. Subsequent screening of titles and abstracts led to the exclusion of 187 records unrelated to sustainability in the Arctic, resulting in a selection of 150 articles for thorough examination. We further refined our selection by excluding articles focusing on different geographical regions or unrelated subjects concerning urban sustainability, SDGs, and energy transition in the Arctic. Ultimately, this process yielded a final set of 64 relevant articles for comprehensive analysis in our study.

A mixed-methods approach was used to analyze thematic content within the dataset. Initially, thematic clusters were identified using VOSviewer, a bibliometric analysis tool which facilitates the extraction of dominant themes based on co-occurrence patterns of words. Subsequently, a deductive analysis approach (Casula et al., 2021) was employed to extract and analyze text segments in the datasets corresponding to the identified themes.

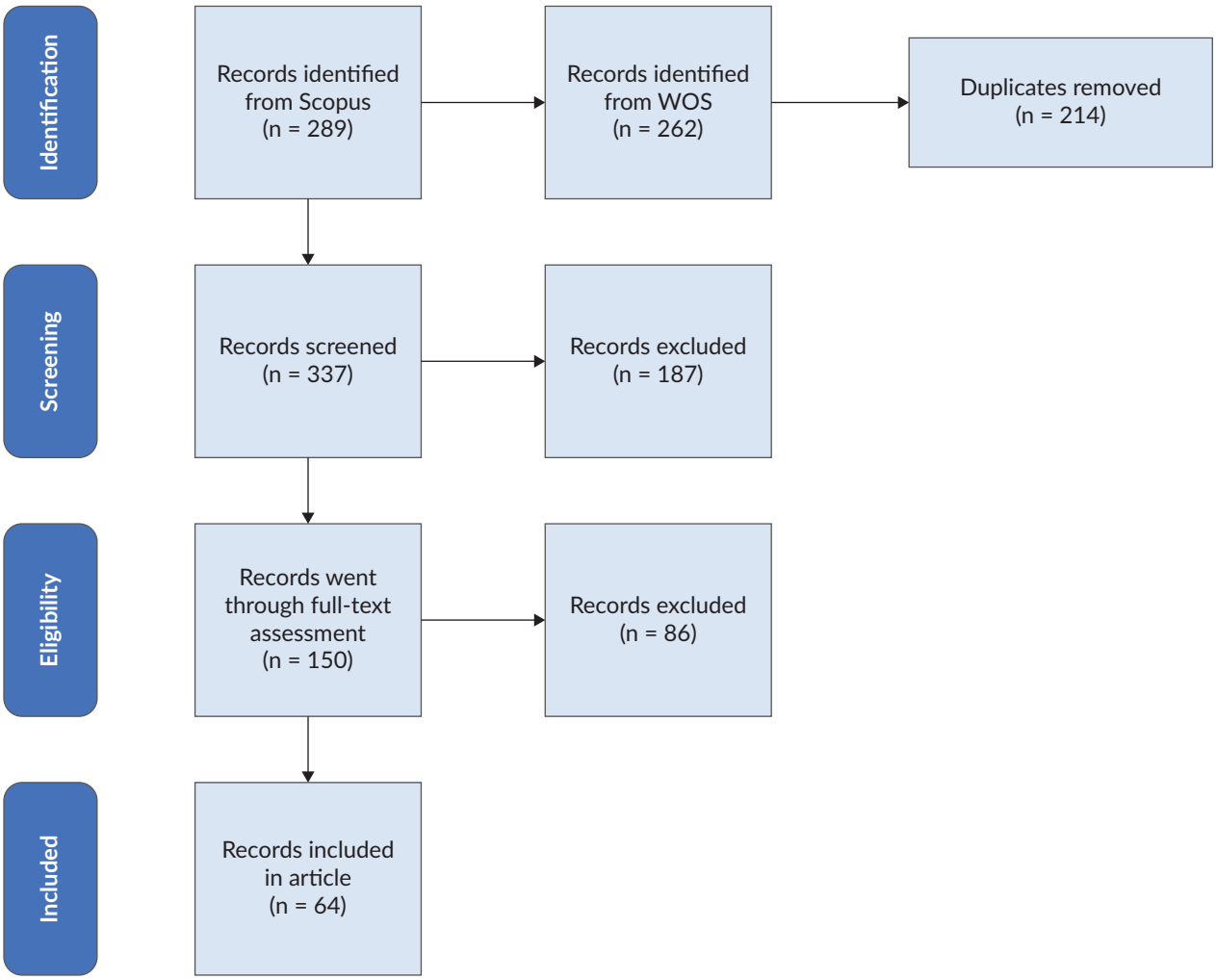

Figure 2. PRISMA flow diagram illustrating the selection of literature (Moher et al., 2009; Page et al., 2021).

3. Bibliographic Analysis

In this section, we conduct a comprehensive bibliographic analysis by examining the co-occurrence of keywords. We begin by identifying the interconnectedness of the keywords and the thematic clusters within the dataset. Then, we evaluate keyword co-occurrence over time to reveal shifting trends and emerging topics. Subsequently, we employ density visualization to understand thematic concentrations and dispersion across the dataset.

3.1. Analysis of Keywords Co-Occurrence

Keyword co-occurrence was analyzed using VOSviewer to identify prominent thematic clusters within the included papers. We applied an occurrence threshold of three instances per keyword to identify significant keyword associations in this study. This means that keywords appearing at least three times were considered. Additionally, we incorporated a manually created thesaurus file to merge keywords that were duplicates or closely related in meaning, ensuring greater consistency and avoiding redundancy. As a result, 27 keywords were identified. In VOSviewer, six main clusters emerged (Figure 3), each distinguished by a unique color and representing a sub-field of urban sustainability in the Arctic. We labeled these clusters by examining relevant datasets to understand their primary themes and focus. The clusters include Cluster 1: climate change

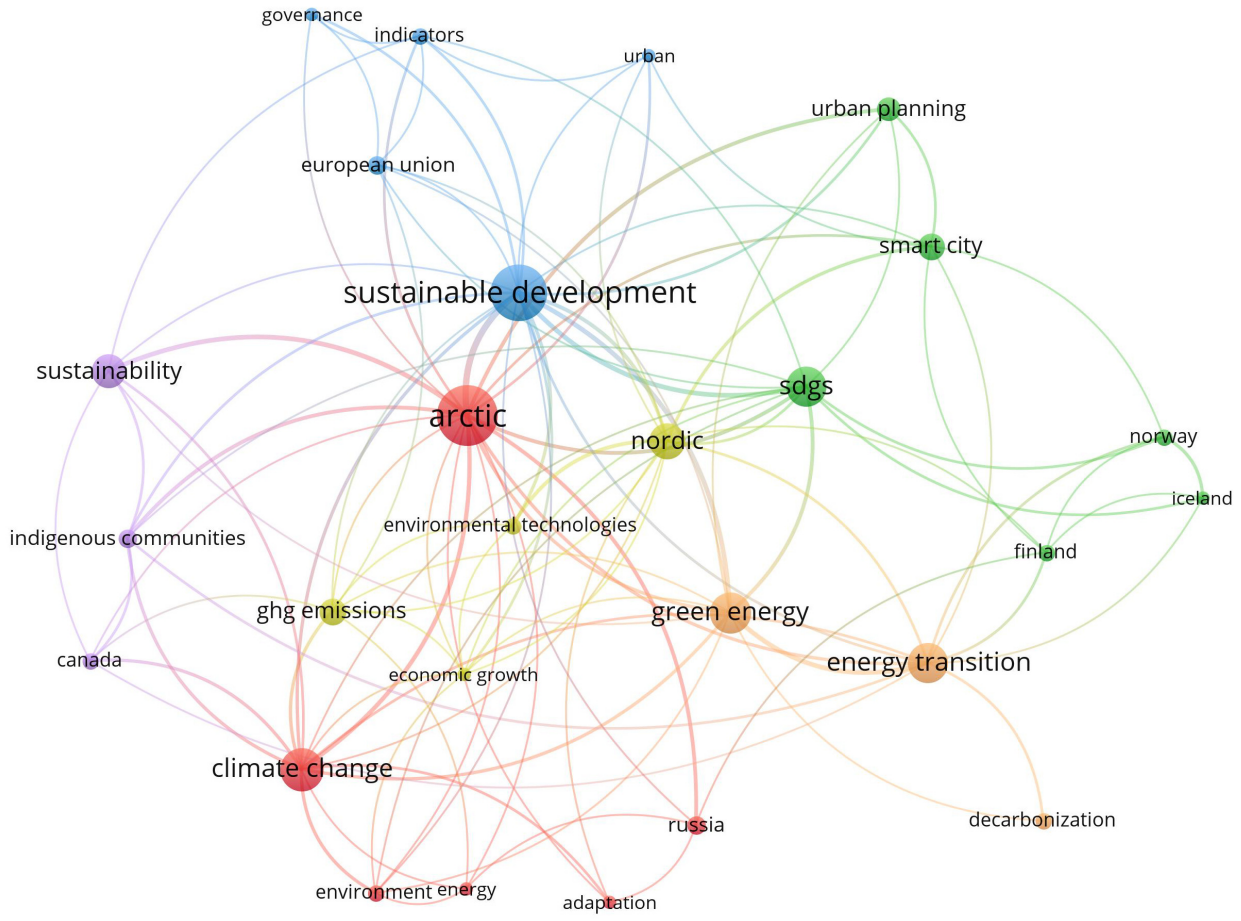

Figure 3. Co-occurrence keywords network map.

and environmental adaptation (red), Cluster 2: SDGs and smart urban planning (green), Cluster 3: sustainable development and urban governance (blue), Cluster 4: sustainable economic development (yellow), Cluster 5: social sustainability (purple), and Cluster 6: green energy transition (orange). The cluster map consists of texts, nodes, and lines, where the size of the texts and nodes corresponds to their weights, with larger sizes indicating higher weights (Jan van Eck & Waltman, 2017). Additionally, the lines denote the common co-occurrence of one keyword with another. The strength of the association between two items is represented by the thickness of the connecting line, with thicker lines indicating a stronger link (Jan van Eck & Waltman, 2017).

The keyword "Arctic" was connected and co-occurred with 19 other keywords, with the most frequent associations being with sustainable development (11), sustainability (6), climate change (5), SDGs (4), Indigenous communities (4), urban planning (4), and Russia (4). The total link strength, however, shows how frequently a specific keyword co-occurs with other keywords (Guo et al., 2019). Table 1 shows the keywords corresponding to each cluster. For instance, the total link strength of "Arctic" is 57, indicating that this keyword was associated with or occurred together with other keywords in a total of 57 publications within the dataset. The top six keywords with the highest total link strength and occurrence include Arctic, sustainable development, climate change, green energy, SDGs, and energy transition.

Table 1. Keyword metrics in clusters.

Ranking order	Keyword	Occurrences	Total link strength	Cluster number
1	Arctic	34	57	1
2	Sustainable development	30	52	3
3	Climate change	19	33	1
4	Green energy	18	29	6
5	SDGs	17	27	2
6	Energy transition	17	26	6
7	Nordic	14	22	4
8	Sustainability	13	14	5
9	GHG emissions	9	12	4
10	Smart city	9	12	2
11	Urban planning	7	10	2
12	European Union	5	7	3
13	Russia	5	8	1
14	Indigenous communities	5	16	5
15	Environment	4	9	1
16	Environmental technologies	4	9	4
17	Finland	4	7	2
18	Indicators	4	9	3
19	Norway	4	9	2
20	Canada	4	9	5
21	Decarbonization	4	3	6
22	Economic growth	3	10	4
23	Energy	3	5	1
24	Adaptation	3	5	1
25	Urban	3	6	3
26	Governance	3	5	3
27	Iceland	3	7	2

3.2. The Temporal Evaluation of Keyword Co-Occurrence

Figure 4 visualizes how the keywords have appeared together over time. The color of each circle in the map corresponds to the average publication year of the respective keyword (Zhang et al., 2021). For instance, "Arctic" was dominantly associated with other keywords in 2020, indicating its significant presence and frequent co-occurrence with other keywords in articles published during that year. This chronological map reveals a thematic evolution surrounding the keyword "Arctic" and its associations with various topics over time. The initial emphasis in Arctic-related discussions was on "governance" and "indicators." Then, the focus appears to shift towards "climate change," "environment," and "adaptation," emphasizing the environmental challenges and adaptive measures in the Arctic region. In 2021, the associations with "Arctic" extended to include keywords like "energy transition" and "sustainability," implying a growing consideration of energy-related aspects of sustainability. Moving from 2021, the connections diversified, encompassing broader sustainability themes with associations to "green energy," "urban planning," "Indigenous communities," "GHG emissions," and "sustainable development." This expansion suggests a nuanced investigation of environmental concerns and social and sustainable development aspects related to the Arctic. By 2022, "Arctic" formed associations with "smart city," "economic growth," and "SDGs." This shift indicates a more recent focus on technological advancements, economic considerations, and commitment to global sustainability goals in the Arctic. Based on our observations, by 2023, the themes broadened to include youth perspectives, justice, and stakeholder-driven solutions, indicating deeper attention to inclusivity and participatory methods in Arctic sustainable development.

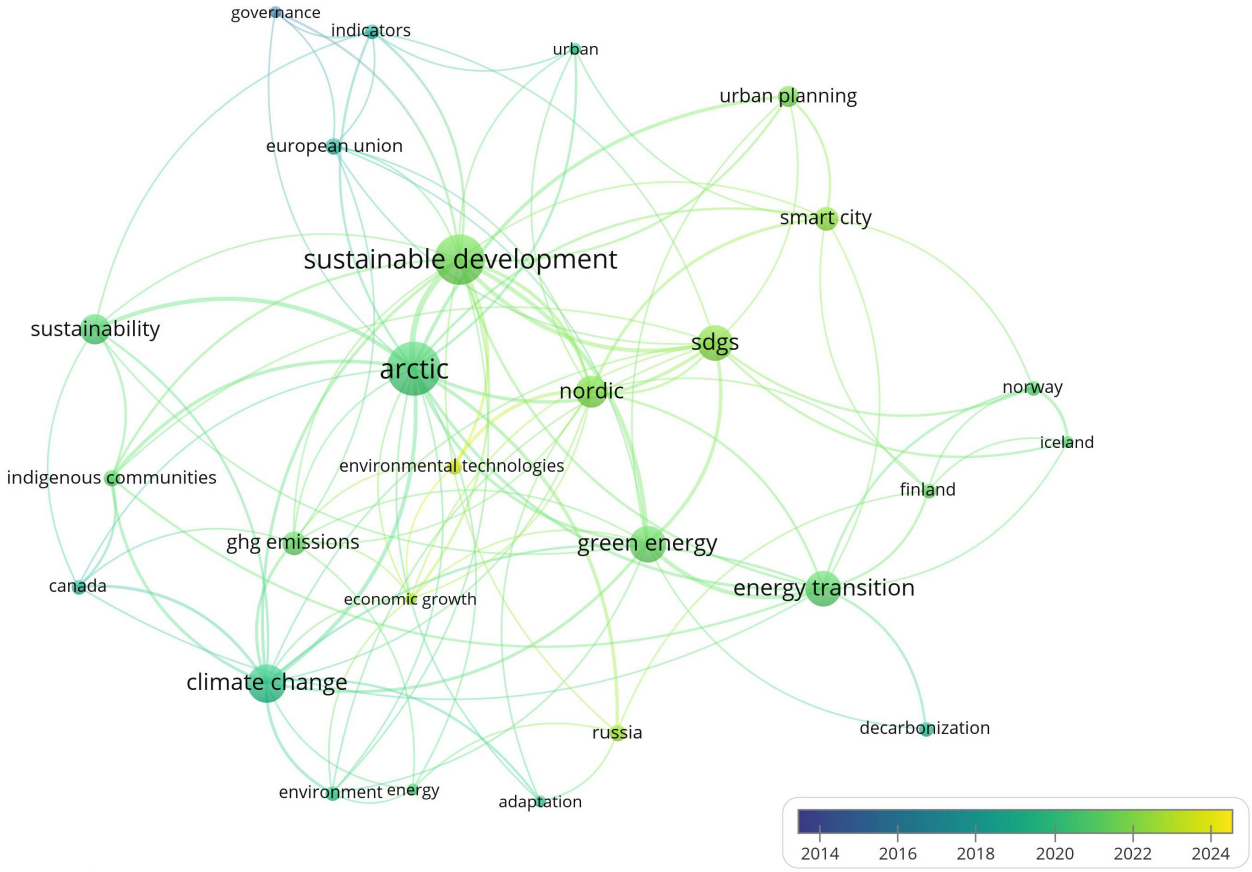

Figure 4. The temporal evaluation of keyword co-occurrence.

3.3. Density Visualization of Keywords Co-Occurrence

Based on color indications, we identified concentrated and dispersed topics in the dataset by showing item density visualization of keyword co-occurrence (Figure 5). Each point on the map corresponds to a keyword, and the color of each indicates the density of the related items. Points with higher item numbers and greater neighboring item weights appear closer to yellow, while those with fewer items and lower neighboring weights tend to lean toward blue (Jan van Eck & Waltman, 2017). Hotspot topics relevant to the Arctic are "sustainable development," "SDGs," "energy transition," "green energy," "sustainability," and "climate change," each demonstrating a high concentration of articles around these central themes.

3.4. Geographical Spread

A notable portion of scholarly articles within the dataset (23) focus on the Arctic region without specifying particular countries or cities (Figure 6). Following this, most case studies are in Russia (18), Canada (12), Norway (11), Greenland (9), and the USA (8). Fewer studies are dedicated to Finland (7), Iceland (6), and Sweden (6). The disparity between the total number of articles and the total number of case studies arises because some articles include more than one case study.

Most of the studies were conducted by authors from the USA (19), Russia (11), Finland (7), and Canada (6), indicating their prominent role in urban Arctic sustainability research (Figure 7). However, the country of

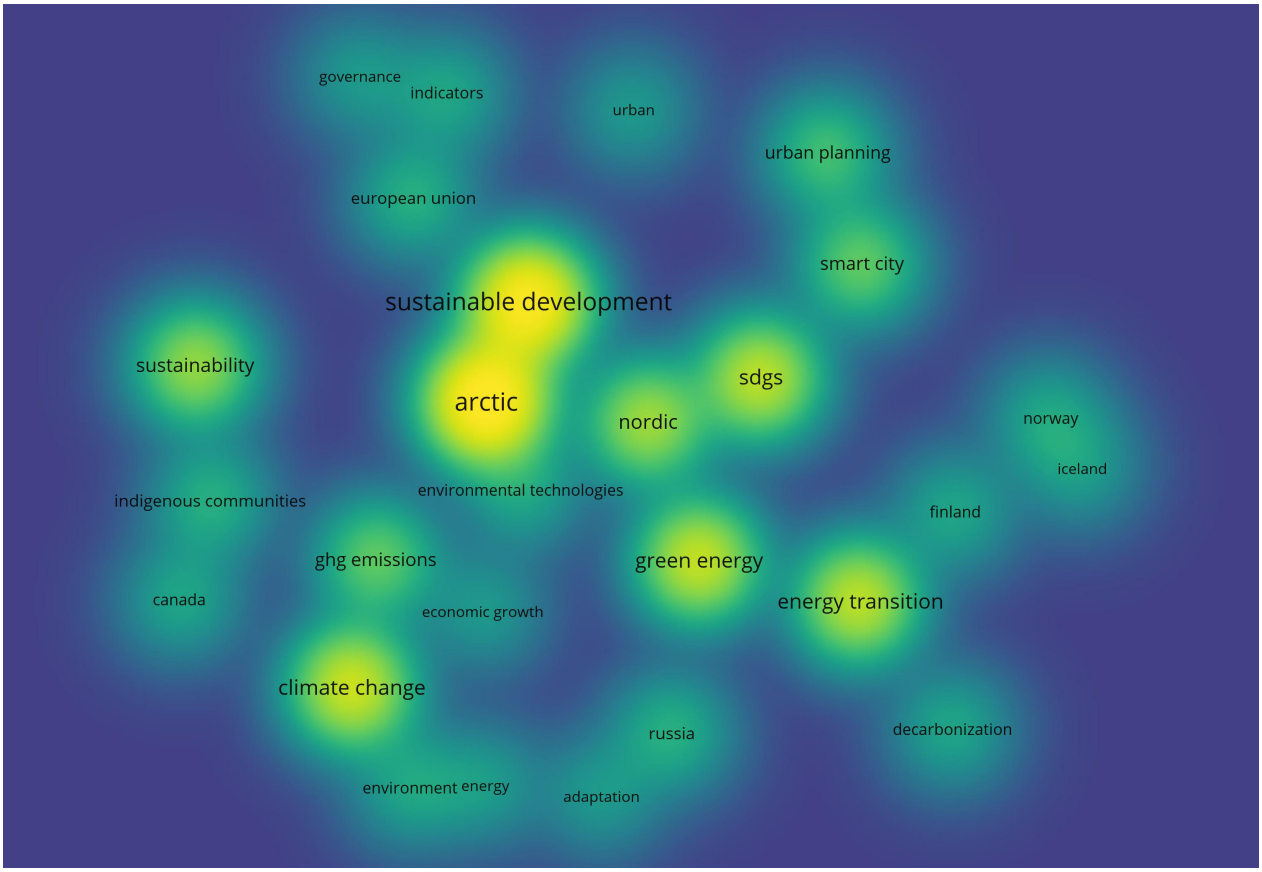

Figure 5. Density visualization of keywords co-occurrence.

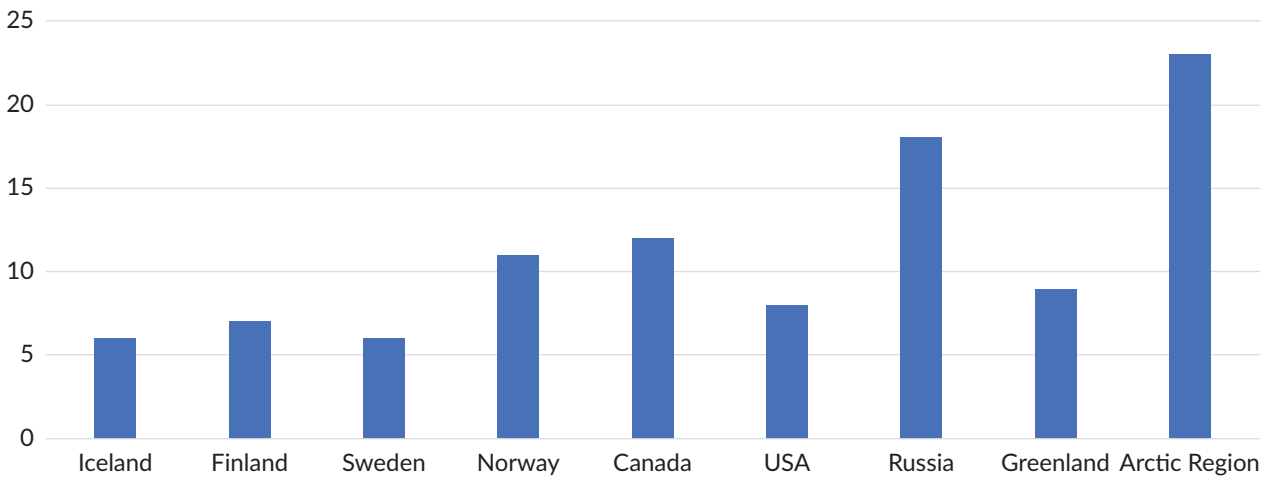

Figure 6. Case studies of the selected articles.

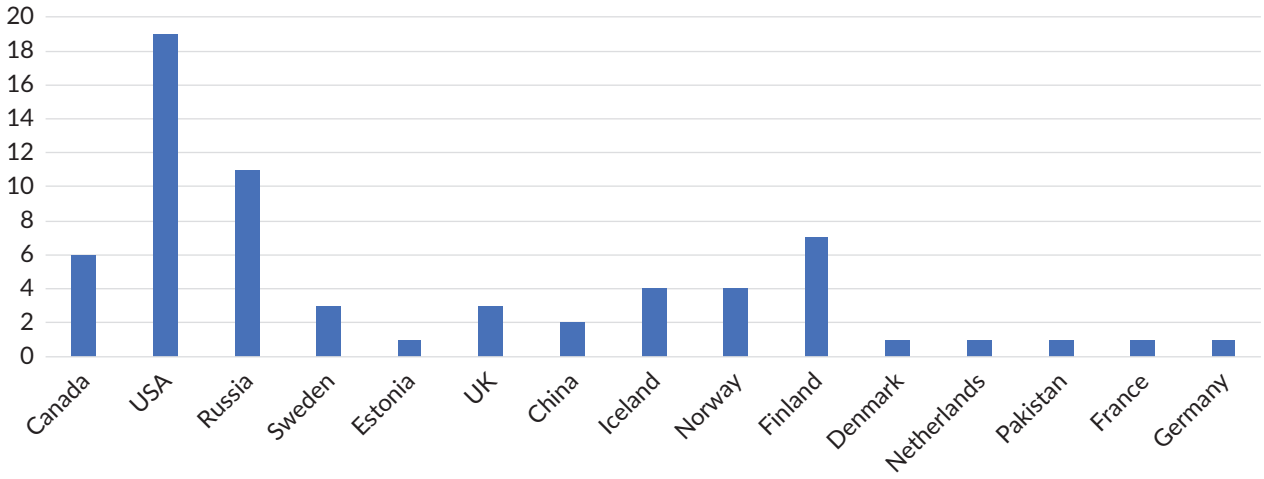

Figure 7. Country of the corresponding authors.

the main author and their case studies do not always align, indicating a broader international engagement with Arctic-related research beyond the geographical confines of the authors' home countries. Corresponding authors from smaller Arctic countries mostly had case studies within their home countries, while those from larger Arctic countries or outside the region tended to focus on the entire Arctic region.

Analyzing all contributing authors (Figure 8) shows that the USA (59), Russia (51), Finland (28), and Canada (23) constitute the primary sources of scholarly contributions. In the dataset, when a case study focuses on a specific country, there is always at least one author whose home country matches the case study.

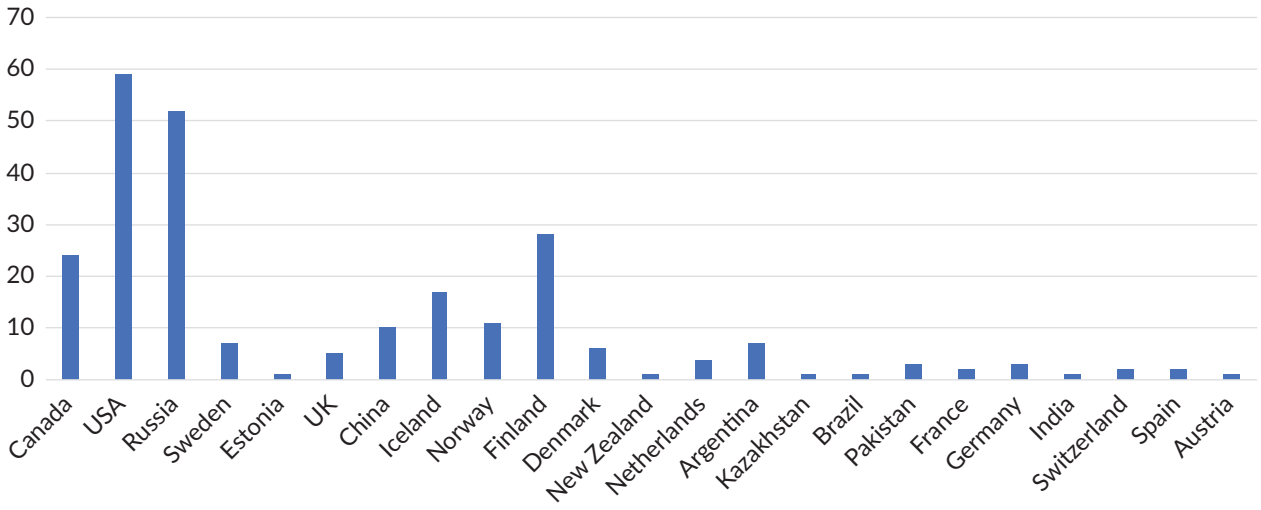

Figure 8. Country of all authors.

4. Text and Thematic Analysis

Arctic cities share some distinctive characteristics, although each one is unique in its own way (Nilsson & Larsen, 2020). Challenges in maintaining energy sustainability, coping with high transportation expenses, and grappling with constraints in infrastructure development are inherent to these relatively recently established cities (Berman & Orttung, 2020). In this section, we comprehensively examine each thematic cluster identified in this study to clarify Arctic cities' challenges and opportunities in reaching sustainability goals.

4.1. Climate Change and Adaptation

The Arctic regions are experiencing the most rapid increase in temperatures, causing profound and substantial changes in both the natural environment and the socio-economic dimensions within Arctic communities (Noe et al., 2022). This accelerated transformation highlights the urgent need for adaptation strategies. Fourteen articles within the dataset delve into specific topics spanning from waste management to climate adaptation policies and justice framework. These articles comprehensively explore various challenges and opportunities posed by climate change in the Arctic region, emphasizing collaboration efforts to mitigate impacts and promote sustainability and resilience (Baijnath-Rodino et al., 2021; Bressler & Hennessy, 2018; Cirkovic, 2021; Hansen-Magnusson & Gehrke, 2023; Kuokkanen, 2023; McCauley et al., 2022; Moe et al., 2023; Natali et al., 2022; Nicu & Fatorić, 2023; Orttung & Reisser, 2014; Salonen, 2021; Sebastian & Louis, 2021; Stephen, 2018; Tiller et al., 2022). Given the crucial influence of the Arctic regions on global climate change and their role in shaping worldwide environmental dynamics (Noe et al., 2022), addressing these challenges is imperative for broader climate resilience efforts.

4.2. SDGs and Smart Urban Planning

Fostering global governance is essential to align the diverse perspectives and interests of Arctic communities and people from other regions, emphasizing the need for the SDGs to establish a framework that encourages inclusive decision-making for sustainability (Noe et al., 2022). The SDGs framework is designed like a pyramid, starting with a wide range of data, scientific knowledge, and empirical evidence (Noe et al.,

2022). Moving up toward the top of the pyramid, this vast data is narrowed down and structured, eventually leading to the formation of specific indicators and the defined 17 SDGs (Noe et al., 2022). The SDGs represent a holistic vision for sustainable development, addressing economic, social, and environmental aspects (Noe et al., 2022). However, Nilsson and Larsen (2020) highlight that the notion of sustainability varies across different contexts and geographical locations, making it challenging yet essential to customize the SDGs to fit the particular features of the Arctic, thereby addressing the region's distinct needs more effectively. Eighteen articles within our dataset underscore the need for region-specific indicators and approaches tailored to the unique environmental, social, and economic conditions of the Arctic (Berman & Orttung, 2020; Bie et al., 2023; Bohlmann & Koller, 2020; Brazovskaia et al., 2021; Bressler & Hennessy, 2018; Burns et al., 2021; Degai et al., 2021; Degai & Petrov, 2021; DiNapoli & Jull, 2020; Dmitrieva & Romasheva, 2020; Hansen-Magnusson & Gehrke, 2023; Kuklina et al., 2021; Nilsson & Larsen, 2020; Noe et al., 2022; Raspotnik et al., 2020; Rizzo et al., 2023; Shijin et al., 2023; Tiller et al., 2022). These studies use various methodologies, such as remote sensing, statistical analysis, and stakeholder engagement, to assess sustainability metrics and progress toward the SDGs. Indeed, region-specific adaptations are crucial for effectively addressing the distinct characteristics of the Arctic. According to Degai and Petrov (2021), to enhance the quality of life in Arctic communities, it is crucial to incorporate new goals into the SDGs that accurately capture the region's unique needs, while also reflecting the insights and desires of Indigenous people for sustainable progress. To achieve this, they introduced five additional goals to the SDGs, focusing on (a) recognizing and safeguarding Indigenous rights for sustainable governance; (b) preserving cultural heritage, enhancing community resilience, and maintaining traditional practices and livelihood; (c) monitoring changes in sea ice patterns and permafrost conditions through Indigenous knowledge; (d) ensuring that the community members benefit equitably from natural resources; and (e) preserving Indigenous culture, knowledge, and heritage among the younger generation (Degai & Petrov, 2021). Incorporating Indigenous perspectives and values into the SDGs in the Arctic region can make these goals more relevant, representative, and impactful (Degai & Petrov, 2021), ensuring sustainable development strategies are culturally sensitive and effective for Arctic communities. Degai and Petrov (2021) suggest that the Arctic Council, consisting of representatives from Arctic states and Indigenous and local communities, could serve as a key platform for developing a sustainable development framework specifically tailored to the Arctic's unique needs and challenges.

Alongside this, data availability is a major concern for future work on Arctic SDGs, emphasizing the critical need for improved data across the Arctic (Nilsson & Larsen, 2020). In pursuit of this objective, Noe et al. (2022) argue that the ICUPE (Integrative and Comprehensive Understanding on Polar Environments) project developed over 20 datasets during its lifetime by employing a combination of on-site (ground-based) and remote sensing observations (from space). This project demonstrates how the integration of different Arctic datasets can be effectively used for sustainable development (Noe et al., 2022). These datasets encompass a broad array of subjects, covering the anthropogenic influences on the Arctic environment and the natural processes and dynamics in the region (Noe et al., 2022). To organize the datasets and link each of them to SDGs, they were categorized based on where the essential variables are observed (Noe et al., 2022). Then, "data teasers" were created, which are concise summaries of each dataset to identify prospective beneficiaries (Noe et al., 2022). Finally, scientists initiated discussions with stakeholders, including local communities, organizations, and policymakers, enabling a deep understanding of their needs and concerns, and ensuring that the created datasets meet real-world requirements (Noe et al., 2022). Therefore, incorporating comprehensive datasets is crucial for enhancing the effectiveness of Arctic SDGs, as they

provide a robust foundation for sustainable development initiatives and policies tailored to the region's unique environmental and socioeconomic dynamics. Degai et al. (2021) also argue that the lack of comprehensive data in Russian Arctic cities poses challenges in accurately evaluating the effectiveness of initiatives, potentially resulting in a bureaucratic focus on meeting numerical targets rather than fully achieving sustainability objectives, especially when these targets are determined externally.

4.3. Sustainable Development and Urban Governance

Implementing SDGs necessitates actions at the local level, where municipalities play a crucial role. Establishing sustainability programs within municipalities not only helps to downscale SDGs to address local challenges but also ensures that initiatives are aligned with the specific needs and priorities of each municipality. Seventeen articles within our dataset explore Arctic sustainability and provide insights into addressing the challenges faced by the region through interdisciplinary collaboration, policy interventions, and community engagement (Burkhart et al., 2017; Cirkovic, 2021; Degai et al., 2021; Dmitrieva & Romasheva, 2020; Esau et al., 2021; Huhmarniemi & Jokela, 2020; Kapsar et al., 2022; Laruelle & Hohmann, 2017; Orttung & Reisser, 2014; Paquette, 2020; Perrin et al., 2021; Petrov et al., 2016; Raheem et al., 2022; Speca, 2023; Stammler et al., 2023; Trump et al., 2018; Vlasova & Volkov, 2016). In their study, Degai et al. (2021) investigate the execution of sustainable urban development in the Russian Arctic by scrutinizing the sustainability plans of two Russian cities. Through a comparative analysis of these plans, they gain valuable insights regarding the prioritized and commonly adapted strategies, enabling a comprehensive understanding of sustainable development efforts across the entire Russian Arctic region (Degai et al., 2021). The plans were crafted to address different aspects of sustainability, although they did not directly mention any sustainability framework (Degai et al., 2021). They encompass a wide range of initiatives aimed at protecting natural resources, improving quality of life, enhancing transportation systems, fostering economic diversity, promoting energy efficiency, fostering community engagement, ensuring public health and safety, addressing social equity concerns, supporting cultural heritage, and investing in education and human capital development (Degai et al., 2021). Even though these initiatives indirectly consider some aspects of SDGs, they lack explicit alignment with these goals, leading to inefficiencies in addressing key sustainability challenges (Degai et al., 2021). For instance, they predominantly concentrate on enhancing the effectiveness of road and bus systems to facilitate accessibility, overlooking targeted approaches for reducing CO2 emissions (Degai et al., 2021). The trade-offs between SDGs highlight the need for developing balanced strategies that can achieve multiple goals simultaneously. Besides, most of the plans operated in a top-down manner, with a predominant focus on addressing economic issues while giving relatively less consideration to social and environmental sustainability (Degai et al., 2021). The lack of explicit direction for adapting sustainable development principles to local contexts, coupled with limited opportunities for community involvement, leads to the fragmentation and ineffectiveness of these plans (Degai et al., 2021). By integrating these initiatives with SDGs, each city can formulate comprehensive strategies for sustainable urban development.

4.4. Sustainable Economic Development

Arctic regions are facing a critical challenge, necessitating a shift from a boom-bust cyclical pattern dependent on natural resources to more stable, diverse, and sustainable economies (Berman & Orttung, 2020; Petrov et al., 2016). This transition aims to move away from economic fluctuations and build resilience

by diversifying economic activities beyond resource extraction. However, to effectively gauge economic success in the Arctic, economic indicators must be formulated and tailored to the unique context of the region (Nilsson & Larsen, 2020). The existing SDGs lack considerations for the specificities of Arctic economies, including subsistence activities and resource economics (Nilsson & Larsen, 2020). To address this gap, it is essential to generate indicators that consider factors such as the sustainability of extraction-based economies, fair wealth distribution, and gender-related aspects of local economic activities (Nilsson & Larsen, 2020). This holistic approach goes beyond relying solely on metrics such as Gross Regional Product or per capita household income and captures the diverse and unique economic dynamics of the Arctic region (Nilsson & Larsen, 2020). Eight articles within our dataset seek to understand and address economic sustainability within the unique context of the Arctic region (Bohlmann & Koller, 2020; Garbis et al., 2023; Orttung & Reisser, 2014; Raheem et al., 2022; Tiller et al., 2022; Tishkov et al., 2022; Trump et al., 2018; Usman et al., 2022). Based on the study by Garbis et al. (2023), in northern Sweden, industrial actors and governments prioritize economic growth and consumption over environmental sustainability. Meanwhile, Sámi reindeer herders, youth climate advocates, and conservationists prioritize maintaining the natural environment and traditional ways of life (Garbis et al., 2023).

4.5. Social Sustainability

Considering social capital and institutions is crucial amid the Arctic region's rapid transformations (Nilsson & Larsen, 2020). Social dynamics play a pivotal role in the Arctic's sustainable development, as the existing SDGs inadequately address demographic trends, such as out-migration (Nilsson & Larsen, 2020) and the growing urbanization witnessed in the region (Berman & Orttung, 2020), including the movement of populations toward larger cities (Koffi et al., 2021). Urbanization is reshaping the Arctic as people migrate from smaller to larger settlements for better opportunities, potentially leading to population decline in smaller communities (Heleniak, 2020). This urbanization trend, accentuated by increased population concentration, is further increased by the emergence of "climigration," caused by climate-related factors, adding a unique dimension to these demographic shifts (Larsen & Fondahl, 2015). Seventeen articles within our dataset emphasize the importance of understanding local contexts, Indigenous perspectives, and community engagement for improving sustainability in the Arctic (Bogdanova et al., 2022; Degai & Petrov, 2021; Holdmann et al., 2022; Middleton, 2023; Naylor & Hunt, 2021; Noe et al., 2022; Orttung & Reisser, 2014; Paquette, 2020; Perrin et al., 2021; Rozanova-Smith, 2021; Schwoerer et al., 2020; Stephen, 2018; Stoyanov & Sakharova, 2023; Svartdal & Kristoffersen, 2023; Tiller et al., 2022; Tishkov et al., 2022; Vlasova & Volkov, 2016). Noe et al. (2022) suggested a mobile web application pilot service aimed at supporting the reindeer herding community in the Scandinavian Arctic. This initiative integrates scientific data sources with Indigenous knowledge to provide practical information for sustainable reindeer herding practices in the region (Noe et al., 2022). The incorporation of user feedback from the community, including traditional knowledge and experiences, not only enhances the service's relevance but also improves the capability to track progress towards the SDGs using relevant indicators (Noe et al., 2022). According to Noe et al. (2022), actively involving the insights and experiences of Indigenous communities in structuring observation systems ensures the accuracy and relevance of the collected data, making the services more effective and inclusive. Emphasizing the importance of grassroots involvement, Nilsson and Larsen (2020) underscore the necessity for initiatives that can facilitate bottom-up processes. These initiatives should enable local actors to identify indicators that align with their specific visions of sustainability, directly addressing the unique challenges and perspectives of the Arctic region (Nilsson & Larsen, 2020). Achieving SDGs in the Arctic

requires an inclusive dialogue with global and Arctic stakeholders (Degai & Petrov, 2021). Degai and Petrov (2021) acknowledge the importance of Indigenous knowledge in tailoring the goals to the region's distinctive needs. Thus, active and equitable participation of Indigenous people in decision-making processes is essential to achieve meaningful and effective outcomes (Degai & Petrov, 2021). Involving local communities and respecting their perspectives is imperative, as external entities have historically imposed their preferences and visions for the desired future of the region (Nilsson & Larsen, 2020). Such an approach actively engages Indigenous peoples, local communities, and citizens, thereby gathering their knowledge and perspectives (Nilsson & Larsen, 2020). This cohesive and contextually relevant framework appropriately reflects the subtleties of sustainable development in the Arctic, ensured by this cooperative and locally focused approach. Nilsson and Larsen (2020) highlight the significance of empowering Arctic residents and subnational decision-making processes to actively contribute to determining the future of their communities. Developing benchmarks to specifically address the economic challenges and assess economic success is necessary for a comprehensive approach to Arctic sustainability (Nilsson & Larsen, 2020).

4.6. Green Energy Transition

Transitioning from fossil fuels to renewable resources is highlighted by the urgent need to mitigate climate change effects, particularly in the Arctic, where accelerated warming and heavy dependence on oil exacerbate susceptibility to environmental impact and price fluctuations (Galimova et al., 2024). Confronting the trade-offs between protecting the environment, promoting economic growth, ensuring social fairness, and finding a balance among these factors is crucial for achieving sustainability (Garbis et al., 2023). Twenty-one articles within our dataset centered around energy transition and sustainable resources in the Arctic (Brazovskaia et al., 2021; Das & Canizares, 2019; de Witt et al., 2021a, 2021b, 2022; Dmitrieva & Solovyova, 2023; Galimova et al., 2024; Garbis et al., 2023; Holdmann et al., 2022; Kuokkanen, 2023; McCauley et al., 2022; Middleton, 2023; Morgunova, 2021; Pantaleo et al., 2022; Salonen, 2021; Schwoerer et al., 2020; Shafiei et al., 2014; Sovacool et al., 2022; Tishkov et al., 2022; Usman et al., 2022; Zhukovskiy et al., 2021). Although transitioning to clean energy sources brings undeniable benefits, it poses challenges such as biodiversity loss, disruption to the reindeer herding of Indigenous communities, and urban development pressures (Garbis et al., 2023). According to Tishkov et al. (2022), Arctic residents may have insufficient knowledge and abilities to adjust their behaviors for transitioning towards sustainable energy practices, necessitating effective energy policies to incorporate public awareness campaigns aimed at educating and involving citizens.

5. Discussion and Conclusion

Through a systematic literature review and bibliographic analysis, we identified six main thematic clusters: climate change and adaptation, SDGs and smart urban planning, sustainable development and urban governance, sustainable economic development, social sustainability, and green energy transition. This highlights the multidimensional nature of sustainability challenges in the Arctic. Most studies concentrated on the Arctic region holistically, without specific focus on individual countries or cities within it (Figure 9). SDG implementation is closely linked to smart urban planning (see Figure 3), emphasizing the integration of sustainable practices into urban development. According to the published literature (Figure 9), Arctic sustainability research is stronger in the areas of "SDGs and smart urban planning" and "green energy transition," which have been widely studied across various Arctic countries, especially Russia. However, a

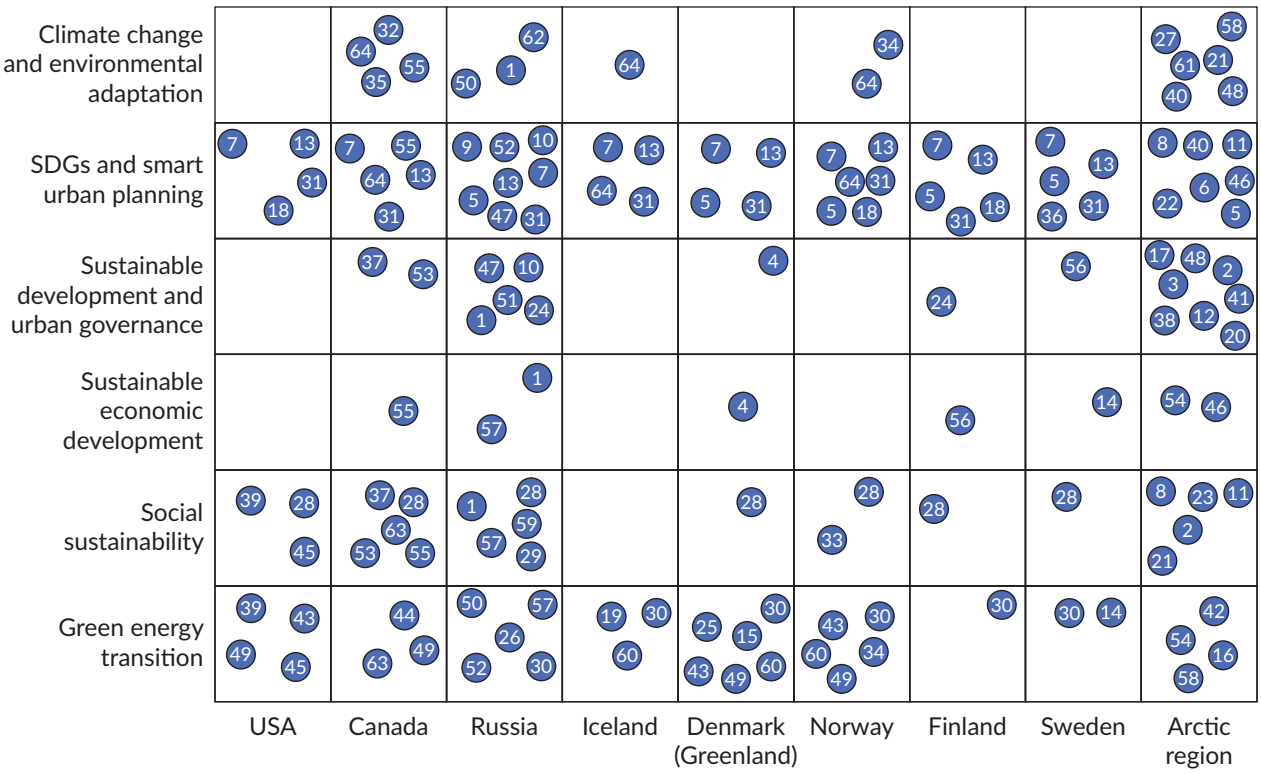

Figure 9. Article distribution based on recognized themes and geographical regions in the Arctic.

lack of research on the sustainability of Arctic cities in Nordic countries is evident, particularly concerning environmental adaptation, and social, economic, and governance sustainability.

Specific features in Arctic cities, such as limited population, geographical remoteness, intense seasonal fluctuations, and frigid weather, differentiate the sustainability measures from those in urban areas elsewhere (Berman & Orttung, 2020). It is imperative to identify SDGs tailored to the Arctic cities for monitoring progress and ensuring initiatives are suited to their distinctive conditions. This is supported by existing literature, such as Degai and Petrov (2021), which argues that to enhance the well-being of Arctic communities, redefining the SDGs is essential to establish additional objectives specifically for the Arctic. Efforts have been made to refine existing frameworks, such as SDGs or ISO 37120, for the Arctic context; however, these initiatives are limited to just a few studies. To improve a comprehensive framework tailored for Arctic cities, relevant indicators from the six identified clusters must be generated to accurately track progress toward sustainability goals, identify areas for improvement, and develop strategies. Arctic-specific indicators will also facilitate comparative analysis between different Arctic clusters. On the other hand, as the lack of data in the Arctic poses significant challenges in generating relevant indicators and targets, incorporating citizens in gathering data can address this problem to some extent.

We acknowledge that the decision to limit the search to English, peer-reviewed journal articles, and search engines in Scopus and WOS, might have excluded technical reports, books, and book chapters in English and other languages. Additionally, our broad search query, while synthesizing existing knowledge, may have generalized the findings and overlooked specific characteristics and disparities among different Arctic cities. Future research should investigate specific themes and contexts within the Arctic. Alongside this,

incorporating studies published in local languages will provide a richer understanding of urban sustainability in these areas.

To develop more holistic and culturally sensitive approaches in Arctic research, close collaboration with a wide range of stakeholders—including local people, Indigenous communities, and government agencies—and the incorporation of traditional knowledge held by local communities is necessary. Research should continuously focus on Indigenous communities; it is equally important to broaden the scope to include non-Indigenous people. This would ensure that a variety of perspectives, knowledge, and interests are considered, leading to more effective strategies that align better with the needs and values of Arctic residents. We conclude that a holistic approach is needed to consider diverse perspectives, subjective opinions, experiences, and contributions of both Indigenous and non-Indigenous populations to ensure inclusive and effective decision-making processes and policies.

Acknowledgments

The authors gratefully acknowledge funding from Arctic Five through the Arctic Chair in Architecture and Planning at Luleå University of Technology (2022–2024) and Region Norrbotten research project for the visualisation of SDGs indicators for regional planning.

Funding

Arctic Five Chairs.

Conflict of Interests

The authors declare no conflict of interests.

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About the Authors

Ava Soroudi is a PhD student in architecture at Luleå University of Technology (LTU) in Sweden. Her research focuses on green transition and implementing sustainable development goals (SDGs) in Arctic cities and towns. She explores the potential challenges and opportunities that Arctic municipalities may face when adopting green energy solutions and sustainable development practices. She aims to develop strategies to address these challenges, contributing to the creation of resilient and sustainable Arctic communities.

Agatino Rizzo is the chaired professor of architecture at Luleå University of Technology (LTU) in Sweden. In this university he leads a research group of 25 people focusing on the climate transition in cities, urban living labs, and climate-sensitive design/planning. His research has been funded by, among others, Qatar QNRF, EU Horizon, Swedish Energy Agency, Formas, and Vinnova.

Jing Ma (PhD) is an associate senior lecturer in architecture at Luleå University of Technology (LTU). Her work primarily revolves around the spatial analysis of public open spaces to improve human health and well-being. Currently, her research focuses on sustainable urban development in Arctic regions, addressing unique challenges and opportunities in these environments. Her contributions to the field are geared toward fostering healthier and more sustainable communities.

Urban Planning
2024 • Volume 9 • Article 8350
https://doi.org/10.17645/up.8350

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ARTICLE

Open Access Journal

Urban Microclimate Impact on Vertical Building-Integrated Photovoltaic Panels

Max Spett, Kevin Lau, and Agatino Rizzo

Architecture Research Group, Luleå University of Technology, Sweden

Correspondence: Max Spett (max.spett@ltu.se)

Submitted: 8 March 2024 **Accepted:** 2 July 2024 **Published:** 29 August 2024

Issue: This article is part of the issue "Planning and Managing Climate and Energy Transitions in Ordinary Cities" edited by Agatino Rizzo (Luleå University of Technology), Aileen Aseron Espiritu (UiT The Arctic University of Norway), Jing Ma (Luleå University of Technology), Jannes Willems (University of Amsterdam), and Daan Bossuyt (Utrecht University), fully open access at https://doi.org/10.17645/up.i346

Abstract

The ongoing climate crisis and turbulence on the world stage has highlighted the need for sustainability and resilience in the development and maintenance of urban areas regarding climate comfort and energy access. Local production of green energy increases both the sustainability and resilience of an area. Traditionally, photovoltaic (PV) panels are deployed wherever the amount of sunlight is highest but lowering costs for PV panels makes them cost-effective even in colder climates. Within the broader umbrella of positive energy districts, façade mounted building-integrated PV panels in urban areas additionally present unique opportunities and challenges, as factors such as wind, solar irradiance, or nearby obstructions can have either a positive or negative effect on the performance of the PV panels. In this article, we aimed to answer the question: What factors inform the optimization of vertical PV panels? To answer this, we developed a method for the optimization of placement of PV panels. By building upon readily available weather data, local panel conditions were examined, and field-driven aggregation algorithm used to guide panel placement. Performance of the resulting panel configurations were then compared to a baseline case. Results indicate that our developed method helped mitigate negative impacts of the aforementioned factors, and often improved performance over baseline.

Keywords

building envelope; building-integrated photovoltaic panels; field-driven aggregation; form finding; positive energy districts

1. Introduction

The decarbonization of the economy, as a response to climate change, poses significant challenges to the housing sector. Research estimates suggest that the housing sector alone contributes a substantial amount of CO^2 emissions annually, accounting for approximately 30% of total global greenhouse gas (GHG) emissions (Swedish Energy Agency, 2020). This places it alongside industry and transportation as the principal sources of environmental impact (Nejat et al., 2015). These figures highlight the urgent need for targeted policies and innovations in these sectors to mitigate their environmental footprint. In response to the pressing need for sustainable development, the United Nations introduced the Sustainable Development Goals (SDGs) and facilitated the Paris Agreement in 2015. These initiatives represent a global commitment to transforming economic activities by significantly reducing GHG emissions. The SDGs and the Paris Agreement underscore the collective acknowledgement of climate change's threats and the imperative for immediate and coordinated actions to ensure a sustainable future (United Nations, 2023).

This pursuit is critical for maintaining Sweden's status as an advanced industrialized economy, which historically has relied on cheap and reliable energy sources, including hydro power, nuclear, and various non-renewable options. However, the global push towards sustainable development, spearheaded by the SDGs and the Paris Agreement, has accelerated Sweden's shift towards greener energy sources. By 2022, Sweden had already made significant progress, with 66% of its energy consumption coming from renewable sources, a stark contrast to the European Union average of 23%, according to Eurostat (2023). This transition is increasingly characterized by investments in wind energy, photovoltaics (PVs), and hydrogen for energy storage, marking a pivotal shift from its historical energy mix towards a future powered by renewable energy, setting a commendable example for nations worldwide. At the urban scale, since 2018 the EU has directed working groups and funding to transform existing urban areas into positive energy districts (Joint Research Center, 2018), that is, neighborhoods that produce more energy that they need over a calendar year.

One of the important factors to achieve this target is to localize PV energy production by integrating it within urban and building contexts. Urban environments, characterized by their density and fragmented nature, present a stark contrast to the expansive openness of typical solar parks, necessitating innovative approaches for PV panel integration across diverse urban scenarios (Kalogirou, 2013; Savvides et al., 2024; Vassiliades et al., 2023). Particularly in high-latitude countries, the potential for vertical façades to harness solar energy has been recognized (O'Hegarty et al., 2016). However, both in practice and scholarly research, examples of PV panel integration in building façades remain scarce. This highlights a critical need for the development of new methodologies that not only optimize the technical performance of PV panel technologies but also consider their aesthetic integration within urban landscapes.

In this article, we explore the critical role of building-integrated PV (BIPV) panels within the broader framework of urban climate mitigation strategies, particularly emphasizing its importance in reducing GHG emissions in the housing sector. We do so by having as a case study an ordinary middle size city in Sweden, Luleå. 65% of the total population in Sweden lives in middle and small cities (Rizzo et al., 2020). At the same time, these cities have the least amount of (both human and capital) resources to achieve Sweden national target of 100% electricity generated by renewable energy sources by 2040. By tracing the evolution and development of BIPV panels, we underscore their potential as a key element in achieving energy sustainability and climate resilience. Our investigation specifically focuses on the application of BIPV panels

in façades, an area of significant relevance in high-latitude regions where solar radiation can be captured both in vertical and horizontal planes. Central to our analysis is the need for optimizing the configuration of BIPV panels in these systems to enhance their efficiency and aesthetic integration into urban architecture. This article aims to provide a comprehensive examination of the technical and environmental aspects of BIPV panel integration, advocating for optimized configurations as essential to leveraging the full potential of BIPV panel façades in contributing to the reduction of GHG emissions and the promotion of a green transition in urban environments.

Differences in temperatures, sun paths, and urban morphology mean that conditions for BIPV panel systems differ in different locations, and strategies need to account for local conditions to achieve optimal performance. Freitas et al. (2020) assessed BIPV panel performance in Brasilia, Brazil. They found that surrounding geometry presented noticeable shadowing on neighboring buildings and found that BIPV panel roof applications outperformed BIPV panels applied on façades. They also emphasized the need for panel cooling in warmer climates. Shekar et al. (2023) assessed the impact of tilt angle on the performance of PV panels in the subarctic city of Oulu in Northern Finland. They found that their vertical PV panel setup performed better than their rooftop panels during autumn and winter. The vertical PV panels were also unaffected by snow, unlike the rooftop inclined panels. Numerous methods to optimize PV panel deployment for local conditions have been proposed. Several studies have focused on methods for the optimization of building surfaces for PV panels, often focusing on building envelope morphology. Shirazi et al. (2019) optimized PV panel placement on roofs and façades in Tehran, Iran, from a cost/benefit point of view. They considered the impact of PV panel angle and placement density, although the panels were arranged in a more traditional, rectangular grid. Vulkan et al. (2018) assessed the solar potential of façades in Rishon LeZion, Israel, when accounting for the impact of shadows. They found that while low-rise buildings had high total solar exposure on both roofs and south-facing façades, high-rises solar exposure was mostly concentrated on their façades, due to the high façade area and low roof area. While the study took buildings' façade features such as windows into account, this was expressed as a ratio of total façade area, rather than actual positioning of individual elements. Bomfim and Tavares (2019) used meteorological data to optimize façade construction for PV deployment. They compared the angles between points on the façade and solar angles, optimizing the façade angles for use as a substrate for PV panels. Several methods deployed evolutionary and genetic algorithms to optimize solar gain. Esfahani et al. (2021) optimized residential building roof shapes for high solar gain potential. They deployed an evolutionary algorithm to find optimal roof tilt, shape, azimuth, and building aspect ratios for sun exposure. Walker et al. (2019) utilized genetic algorithms to optimize placement of thin-film copper-indium-gallium-selenide cells on a parametric, non-planar roof, focusing both on panel placement and interconnection.

By contrast, our method focused on optimizing placement of panels on existing building façades. We have developed a method for using differences in temperatures, shade, and urban morphology present in a subarctic city in Northern Sweden as a generator for finding optimized, non-gridded, panel placements. While aspects of our area of interest have been explored, as in the aforementioned studies, to the authors' knowledge combinations as in our specific case remain relatively unexplored. Specifically, we set out to answer the following question: What factors inform the optimization of vertical PV panels in a typical middle size city urban configuration in Sweden? We were also interested in exploring how microclimate conditions affect the performance of vertical PV panels and whether the morphology of cities affect how PV panel configurations perform.

In this article, we introduced a novel method crafted to optimize the placement of vertical PV panels across various usage scenarios in Section 2. The approach leveraged an algorithm developed within the Grasshopper platform, tailored to assess and enhance the performance of BIPV panel systems. In Section 3, the algorithm was applied to examine and contrast different scenarios, considering usage patterns and local environmental conditions. Section 4 delved into a discussion where we synthesized our findings from Section 3 to directly address our central research question. Here, we articulated the role and influence of the investigated factors on façade optimization and BIPV panel efficiency. We have concluded with a summary of our findings, outlining their implications for future research in sustainable urban design and renewable energy integration.

2. Methods

2.1. Site and Weather Data

The methodology was evaluated in Luleå, a city situated in Sweden's northern region (Figure 1). As of the end of 2020, Luleå had a population of 49,123 (SCB, 2021) and serves as the administrative center of Norrbotten County. Characterized by its subarctic climate, Luleå falls within the Köppen Dfc climate zone. For this study's purpose, two multi-story residential buildings in the city were chosen as test sites, both presumed to be constructed in the latter part of the 20th century. The first building, located in the Örnäset suburb, stands at six stories. The selected testing surface on its façade faces 127° southeast and is partially covered by windows. While the façade covers an estimated 187m^2 on the selected building side, the planar subset used covers 102m^2 and the largest subsection without windows 45m^2. The surrounding area exhibits medium density housing, predominantly three-story buildings. The second building is situated in Luleå's central district, rising four stories high. Its testing façade faces 166° south and, similar to the Örnäset site,

Figure 1. Map of central Luleå. The respective host buildings are highlighted in red. The city center location is situated to the west and Örnäset to the east.

features partial window obstructions. The façade covers an estimated 108m^2. The largest subsection without windows covers 45m^2. The central area is denser, with narrower streets and a greater variety of building heights.

For weather data, we utilized the Typical Meteorological Year (TMY) dataset from the Climate.Onebuilding.org project, presented in the EnergyPlus Weather (EPW) file format. The primary data collection point was Luleå-Kallax Airport, located at latitude 65.5430 and longitude 22.1240. The airport is located 4.9 km southwest from Örnäset test site and 4.2 km from the city center test site. The two sites are located 2.2 km apart.

2.2. Model Construction

Our methodology primarily utilizes the Rhinoceros 3D CAD modeling software and Grasshopper, a visual programming language and environment tailored for Rhinoceros. Renowned for its robust geometric modeling capabilities, Grasshopper is extensively employed by architects, engineers, and urban planners. It benefits from a vast ecosystem of third-party plugins, including a variety of energy simulation tools that are particularly relevant to our study. Additionally, for data processing and final evaluation, we employed Pandas, a comprehensive data analysis library, and pvlib, a PV performance assessment toolbox, in Python. This combination of tools enables a sophisticated approach to modeling, simulation, and analysis, facilitating the optimization of vertical PV panel placement within building façades.

Our methodology unfolds through a structured series of steps designed to construct and analyze our model comprehensively:

1. *Model Construction*: Initially, we create detailed models of buildings and their surrounding neighborhoods. This process leverages open mapping data verified by field observation to ensure accuracy of the geometry. Alongside, we acquire TMY data to simulate local weather conditions accurately.
2. *Local Conditions Synthesis*: Utilizing the foundational data from the first step, we conduct simulations and calculations to encapsulate the local environmental conditions comprehensively. This step is crucial for understanding the specific context in which the PV installations will operate.
3. *PV Placement Optimization*: The insights gained from the synthesis of local conditions are then applied to optimize the placement of tiled PV panels. This optimization process uses a field-driven aggregation approach, guided by a set of weights, to determine the most effective arrangement for energy generation.
4. *Performance Evaluation*: Finally, we assess the energy performance of the PV panels in their optimized arrangement. This evaluation involves comparing the optimized setup against a baseline scenario, where standard panels are used instead. Through this comparative analysis, we aim to quantify the benefits of our optimized placement strategy in terms of increased energy efficiency and potential for renewable energy generation.

2.2.1. Construction of Building Neighborhood

Building outline data was obtained through manual download from the crowd-sourced open mapping platform OpenStreetMap (2017), subsequently processed using the Elk plugin for data parsing.

OpenStreetMap provides building data as a collection of points that delineate the building's two-dimensional footprint in the WGS 84 standard, accompanied by various metadata elements. This metadata may include details on the building's height, number of floors, or in some cases, neither. To transition from two-dimensional footprints to three-dimensional models, we employed the provided height data directly when available. In instances where only the number of floors was specified, we calculated height estimates by multiplying the number of floors by 2.7 m. For buildings lacking both height and floor count information, a default single-story height of 2.7 m or multi-story height of 8.1 m was assumed, depending on how high the average building in the neighborhood was determined to be. These procedures enabled the extrusion of building footprints to their corresponding heights, resulting in a comprehensive set of three-dimensional building volumes.

Following the automated generation of the neighborhood's building models, structures in proximity to the designated area for PV panel installation underwent manual verification and adjustment. This process involved comparing the generated building models to photographs captured during site visits. Discrepancies, such as a single modeled outline inaccurately representing adjacent buildings or significant deviations between the model and the actual building's appearance, prompted corrections. These adjustments were meticulously carried out using the modeling capabilities of Rhinoceros, ensuring that the digital representations closely matched the real-world conditions.

2.2.2. Construction of Analytical Model

The building designated for PV panel integration received a higher level of detail in its modeling compared to the surrounding structures. This detailed modeling was achieved through manual techniques within Rhinoceros. We focused on accurately modeling a typical storey, under the assumption that each subsequent storey would mirror this template, except for significant deviations. The standard height for each storey was set at 2.7 m. Estimations for window positions and configurations were derived from photographic evidence, while the layout and dimensions of the apartments were also approximated. This typical story model was then replicated for each floor, culminating in the construction of the building to its full intended height.

To precisely control the placement of PV panels and ensure they are confined to specific sections of the façade, a particular surface area of the façade was chosen to act as the base for panel installation. This chosen area, referred to as the "crawling surface," was extracted from the vertical sections of the building's model. It spanned from the ground level to the building's roof, incorporating openings where windows are located to exclude these sections. Utilizing this surface, we then engaged the Wasp plugin (Rossi, 2021) to generate a "Wasp Field" along with a corresponding point grid. This grid was strategically positioned 20 cm from the façade, with grid points spaced 25 cm apart, effectively enveloping the designated surface area for PV panel application.

2.2.3. Derived Values

The Wasp plugin serves as a sophisticated combinatorial toolkit designed for crafting complex geometric configurations. By defining a series of geometries alongside rules for their combination—specifying permissible connections between parts—Wasp orchestrates the assembly of these geometries into cohesive

aggregations. These assemblies can be generated through stochastic processes or be directed by specific fields, also incorporating collision detection to prevent geometric overlaps. In our approach, we chose to guide the aggregation of PV panels using a method influenced by fields. To this end, we established three fields to steer the placement process effectively. An occupancy grid field was designed to ensure that panels do not obstruct windows and doors, maintaining clearances. Another field was derived from the shadow patterns on the building, advising the algorithm to avoid areas that receive less sunlight. Finally, a wind strength field based on computational fluid dynamics (CFD) was constructed to inform the algorithm about local wind conditions. We limited the aggregation to a two-dimensional plane close to the building walls to maintain coherence with the architectural structure. This algorithm evaluates points within the field, favoring locations with higher value assignments for panel placement, thus optimizing their positioning.

To aid in this optimization, we developed a building occupancy grid (BOG) based on the crawling surface. Each point in the point grid was evaluated in relation to the façade. Points directly in front of where PV panels could be placed were assigned a value of 1, indicating optimal placement zones, whereas points coinciding with non-panel areas, such as those in front of windows, were assigned a value of 0, signaling exclusion from panel placement.

2.3. Microclimate Simulation

The Ladybug plugin suite was employed to trace the sun's path across the sky for the given location over the course of a year, enabling us to simulate the impact of shadowing from surrounding buildings on the building façade. This simulation produced a mesh overlaying the building façade, each mesh point representing the cumulative hours of direct sunlight received annually. Points within our established point grid were then mapped to the nearest mesh point values, assimilating the sunlight exposure data. These values were subsequently normalized by dividing them by the total annual sun-over-horizon hours, which amounted to 4,556 hours in our study area. This normalization process yielded sun exposure ratios (SER) for each grid point, quantitatively expressing the relative solar exposure across the façade.

A CFD analysis was conducted to assess local wind patterns around the building and its immediate surroundings, utilizing the building models without incorporating ground mesh or vegetation in the simulation setup. This study utilized the Eddy 3D plugin (Kastner & Dogan, 2021), which employs the 2017 version of BlueCFD, a distribution of OpenFOAM, for its simulations. The simulation domain was configured as a cylinder, with an inner rectangular area measuring 200 m on each side and the outer cylinder dimensions set at a diameter of 450 m and a height of 113 m, with a uniform block size of 3 m throughout. The meshing process was executed using a snappy mesh technique, assigning a meshing precision of 3 for the buildings and their edges, while the planar ground surface received a precision level of 2, and the bounding box was set at 0. Utilizing the Shear Stress Transport k-ω model for turbulence, along with finely tuned relaxation factors and control settings for the solution and algorithm, the wind conditions were simulated across eight directions, corresponding to the cardinal and intercardinal points, at a reference height of 10 m and with a surface roughness assumption of 1 m. Each of the eight simulations ran for 1,024 iterations, reaching a loosely convergent state with residuals for all wind velocity components (Ux, Uy, Uz) falling below 10^{-4} for all directions, except for a slightly higher residual of 1.01556×10^{-4} observed in the eastern wind simulation for the city center case.

Wind velocity data derived from the CFD simulations were analyzed at each point within the grid to calculate their annual wind factor. This calculation was facilitated by the Wind Factors component within Eddy3D. The process involves matching each hourly wind data point from the EPW file to the nearest wind direction simulated and adjusting the data to align with the simulated wind velocities. This approach allows for the generation of an estimated wind factor for each grid point for every hour of the year. The compiled data forms a comprehensive matrix indicating the hourly estimated wind factors for each test point throughout the year. To synthesize this data, the annual average was computed across the matrix, producing a condensed matrix that presents the yearly mean wind factors (YMWF) for each grid point, offering a streamlined overview of wind exposure at each location over the course of the year.

The resulting BOG, SER, and YMWF were each weighted, i.e., multiplied by a weight between 0 and 1, and then summed together for each point. This combined field was then used to inform the aggregator for where to place tiles in the following step.

For both locations, base cases were constructed. The base cases consisted of 14 regular PV panels, placed in grids on the windowless portion of the façades. The panels were modelled as rectangles and would later serve as a reference to compare panel performance against. For our method, the panels were modelled as polygonal shapes. For simplicity, regular pentagons, each ¼th the area of a base case panel, were selected as the aggregating shape. While shapes other than pentagons can be used, we selected pentagons as they do not tile the plane, which combined with our selected aggregation method create diverse designs and avoid obstructing windows. For both locations, a total of 57 panels were placed and the total as to closely match the total area of the base case. Starting points for the aggregations were determined experimentally, with each starting in the upper part of the windowless area. An initial pentagon was placed, after which the pentagons were set to aggregate over the selected surface, guided by the field. The aggregation was performed by the field-driven aggregation component provided by the Wasp plugin. The aggregator placed panels edge-to-edge, sampling the grid, and placing the panel at the most beneficial location. This was repeated until all 57 panels were placed. By varying the weighting given to the BOG, SER, and YMWF, varying placements of panels can be achieved. To test different configurations, three different sets of weightings were tested. In all cases, the BOG weighting was set to 0.5, while in Test Case 1 SER was set to 0.0 and YMWF to 1.0, in Test Case 3 the opposite, with SER set to 1.0 and YMWF to 0.0. For each location, a case which balanced the traits between the extremes were created and named Test Case 2. For Örnäset, SER was set to 0.95 and YMWF to 0.05, while for the city center, SER was set to 0.6 and YMWF to 0.4 (see Table 1). The weightings were derived experimentally. In total, 8 panel arrangements were constructed, i.e., 4 per site, each consisting of 1 base case and 3 test cases using our method.

To facilitate comparison between panel arrangements, the panels in the test cases were substituted with panels identical to the ones used in the base case. Positions for these impostor panels were determined by clustering. The centroids of the source panels were divided into 14 clusters using k-means clustering, as

Table 1. Weightings of panel generation test cases.

	Test Case 1	Test Case 2: City Center	Test Case 2: Örnäset	Test Case 3
BOG	0.5	0.5	0.5	0.5
SER	0.0	0.6	0.95	1.0
YMWF	1.0	0.4	0.05	0.0

implemented by the NGon plugin suite for Grasshopper (Vestartas & Rad, 2021). At each respective center, impostor panels were placed and evaluated. The wind simulations performed at both locations were again sampled at the panels' center points and the annual wind factors were calculated, although the results were not averaged at this point. The amount of sun exposure for each panel was calculated, with data for whether the panel was considered in sunlight or shaded by neighboring buildings being recorded for each hour throughout the year (Figures 2 and 3).

The performance of test panels was evaluated against a reference case using the Python programming language using Pandas and pvlib. pvlib is a toolbox providing various tools for assessing PV energy systems (Holmgren et al., 2018, 2023). pvlib has been validated against real-world measurements by Deville et al. (2024), in which all models performed well, the authors finding the average normalized mean bias error to be within ±2.3% of the real-world measurements. It makes available databases of both Sandia PV panel modules and CEC inverters. A modern and dimensionally suitable panel was selected from the Sandia database, U300 Black from Silevo Triex. The inverter was selected by filtering the CEC Inverter database.

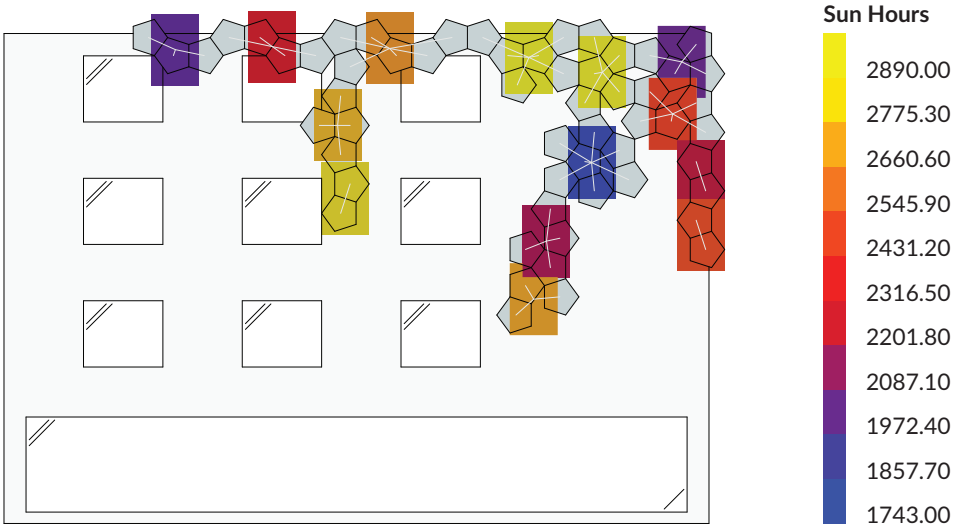

Figure 2. Sun exposure by panel and diagrammatic drawing of façade and panel aggregation, as well as the k-means clustering. While the panels overlap, they are separate in the simulation. City Center Test Case 2.

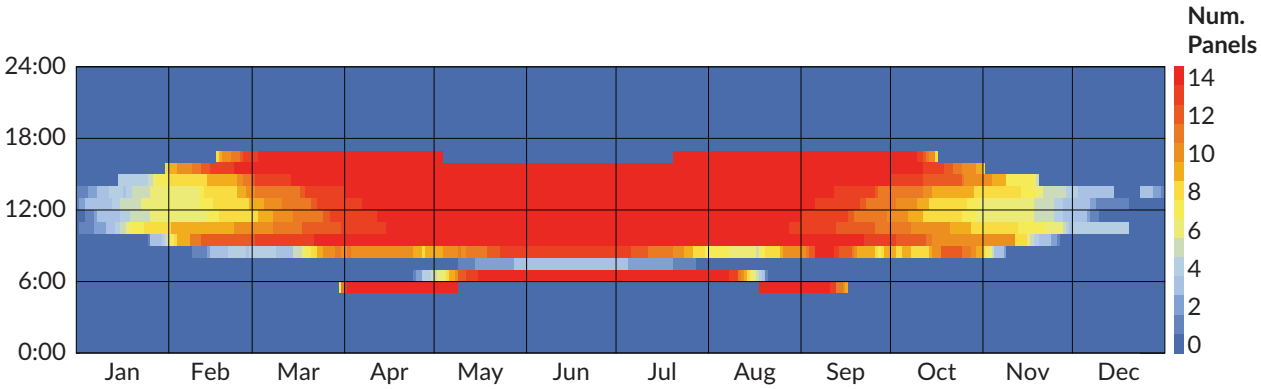

Figure 3. Number of panels with direct exposure to the sun throughout the year. Notably, the panels do not receive direct sunlight between 08:00 and 09:00 for a large portion of the year due to a nearby multi-storey building blocking the sun. City Center Test Case 2.

Inverters with an AC output of 240 V was selected, then further filtered by selecting inverters where the AC output was achieved with a voltage either matching or exceeding (by a maximum of 25 V) the peak voltage output of the panel. Finally, the inverter with the lowest DC power requirement before outputting AC power was selected, the Sunteams 1500 from Beijing Kinglong New Energy Technology. The inverter also has a low night tare, which is important in the dark winter months. The vertical PV panel were assumed to be freestanding, and both the reference and test panels were set up with one inverter per panel. The altitude of the panels was set to their height in the model, plus 8 m. Using air temperature, direct normal irradiance, global horizontal irradiance, and diffuse horizontal irradiance values for the whole TMY from the EPW data, the panels were set up for evaluation in pvlib. A dedicated weather profile was constructed for each panel. DNI, GHI, and DHI values were modulated by whether the particular panel was considered to be shaded for a given hour, with values being set to 0 if panels were in shade. The air temperature and albedo data were applied verbatim while the calculated annual wind factors were used as wind speed. The TMY performance of each panel was then simulated in turn, and the results aggregated.

3. Results

To facilitate comparison, the hottest, coldest, stalest (least windy), windiest, and sunniest weeks in the typical mean year data were identified. As the TMY data is an amalgamation of several years' data, the year was assumed to start on a Monday, as was the definition of "week." The mean of each week's weather was used as a basis for the criteria, and the 31st of December was ignored in terms of week selection in order to only analyze full weeks. Wind chill effect was not considered, i.e., only air temperature was considered for the warmest and coldest weeks. The coldest week was week 4 between the 22nd and 28th of February. Temperatures ranged between −26 and 0 °C, the mean wind speed was 3.63 m/s, and the mean of the sum of solar irradiance values was 30.86 Wh/m^2. The hottest week was week 30 in the middle of summer, between the 23rd and 29th of July. Temperatures varied between +10 and +24 °C, mean wind speed was 3.08 m/s, and solar irradiance 651.21 Wh/m^2. The windiest week was in spring, week 43 between the 22nd and 28th of October. Temperatures varied between −8 and +3 °C, mean wind speed was 5.77 m/s, and mean irradiance 53.06 Wh/m^2. The stalest week was week 9, between the 26th of February and 4th of March. Temperatures varied between −22 and −1 °C, mean wind speed was 2.13 m/s, and mean irradiance 143.47 Wh/m^2. The sunniest week was week 22 in early summer, between the 28th of May and the 3rd of June. Despite being the week with the largest amount of sun radiation, temperatures were still relatively low, ranging between +2 and +15 °C. The mean wind speed was also relatively high, at 5.41 m/s. The mean irradiance was 68.52 Wh/m^2. The weather is summarized in Table 2 and Figure 4.

Table 2. Representative weather weeks from the TMY.

Week Type	Week Range	Temperature Range (°C)	Mean Wind Speed (m/s)	Mean Irradiance (Wh/m^2)
Coldest Week	Week 04: Jan 22–Jan 28	−26–0	3.63	30.86
Hottest Week	Week 30: Jul 23–Jul 29	+10–+24	3.08	612.90
Windiest Week	Week 43: Oct 22–Oct 28	−8–+3	5.77	53.06
Stalest Week	Week 09: Feb 26–Mar 04	−22–−1	2.13	143.47
Sunniest Week	Week 22: May 28–Jun 03	+2–+15	5.41	768.52
Whole Year	Jan 01–Dec 31	−28–+26	3.57	292.97

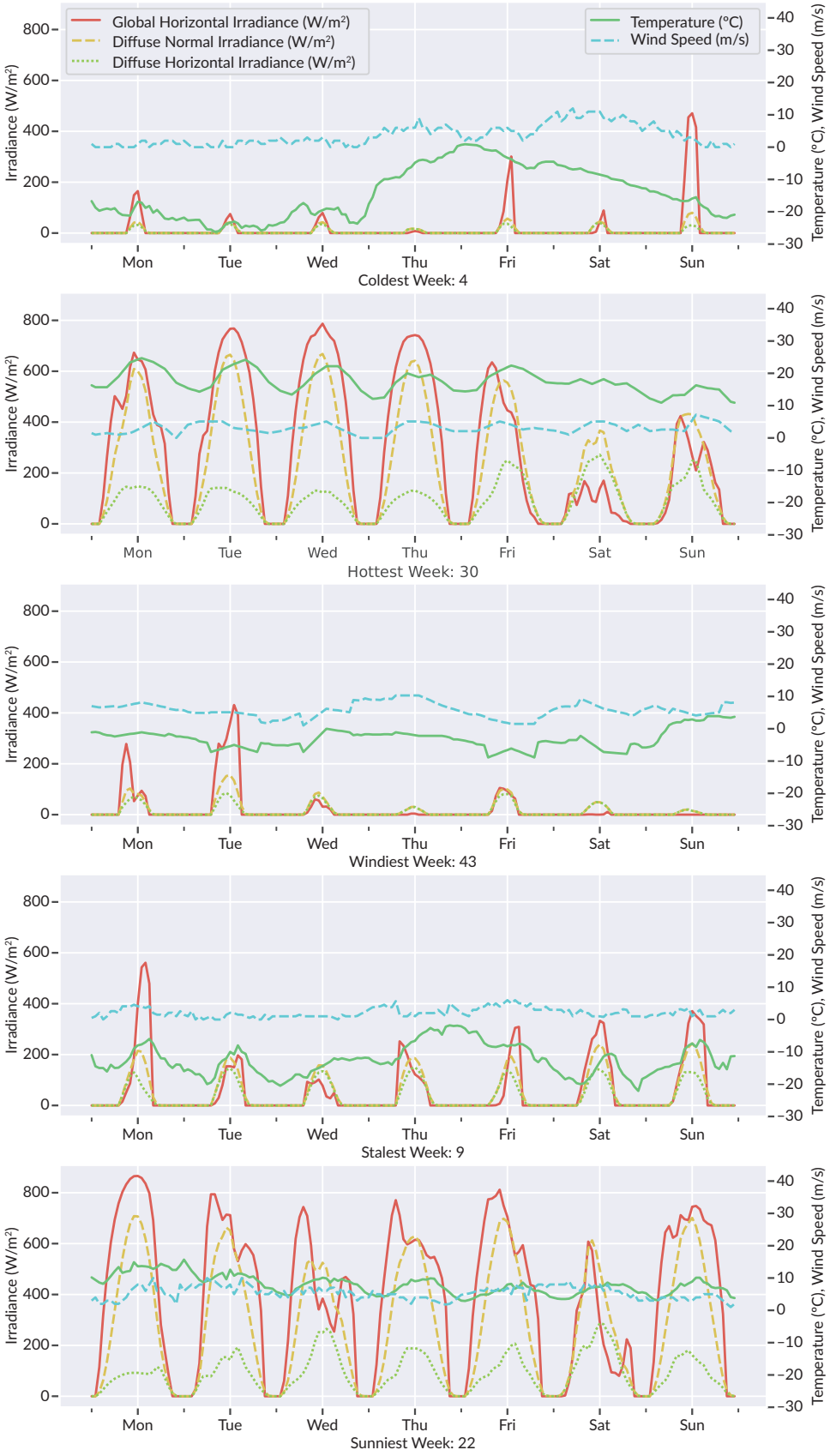

Figure 4. Weather during the representative weeks.

The climate conditions affected the performance of all panel configurations, but not in a uniform manner. The sunniest week, week 22 between May and June, was the most productive period for all panel configurations, followed by the hottest week, week 30 in July. Compared to the sunniest and hottest weeks, the week with the lowest mean wind speed, week 9 in February, performed less well, with all panel configurations underperforming. The coldest and windiest weeks of the year were week 4 in January and 43 in October, where no panel performed particularly well. The vertical PV panels in Örnäset generally performed better than their counterparts in the city center, with the exceptions of test panel 3 in the city center outperforming Örnäset during the coldest week, test panel configurations 2 and 3 performing better than the Örnäset panels during the windiest and stalest weeks, and the reference panels performing better during the stalest week. The different test panel configurations showed minimal deviation in performance and temperature from the reference panels in Örnäset, indicating little variance during all testing periods. In contrast, the panel configurations in the city center demonstrated significant performance variability, with notable differences across all test periods. Throughout the year, the panels in Örnäset consistently performed better, except for test panel configuration 3 in the city center, which exhibited the best annual performance. PV cell temperatures exhibited less variations than the panel performance. For Örnäset, temperatures remained consistent across all panel configurations. Cell temperatures somewhat varied more in the city center, with test panel configuration 1 consistently being the coolest and configuration 3 being the warmest. The panel configurations are summarized in Table 3. Figure 5 shows the performance of the city center panels configurations for each week and Figure 6 shows the equivalent performance for Örnäset.

Table 3. PV panel performance.

		Week Type	Coldest	Hottest	Windiest	Stalest	Sunniest	Year
Aggr. AC Output (kWh)	Örnäset	Reference Panels	−0.46	78.50	5.72	24.90	104.27	2,259.20
		Test Panels 1	−0.51	78.54	5.55	24.71	104.30	2,258.31
		Test Panels 2	−0.45	78.50	5.72	24.97	104.27	2,259.75
		Test Panels 3	−0.45	78.50	5.72	24.97	104.29	2,260.39
	City Center	Reference Panels	−0.80	66.68	4.29	26.43	81.58	2,060.62
		Test Panels 1	−0.88	65.29	3.23	17.51	81.33	1,821.35
		Test Panels 2	−0.53	68.44	6.58	31.62	83.54	2,169.02
		Test Panels 3	−0.17	71.48	9.40	43.40	85.42	2,343.69
Mean Cell Temp (°C)	Örnäset	Reference Panels	−13.76	22.74	−2.47	−10.52	14.39	5.32
		Test Panels 1	−13.81	22.71	−2.50	−10.56	14.37	5.29
		Test Panels 2	−13.75	22.74	−2.44	−10.51	14.39	5.31
		Test Panels 3	−13.75	22.73	−2.44	−10.51	14.37	5.30
	City Center	Reference Panels	−14.26	22.20	−2.60	−10.69	13.21	5.05
		Test Panels 1	−14.19	22.05	−2.73	−11.24	13.14	4.75
		Test Panels 2	−13.96	22.27	−2.44	−10.37	13.32	5.19
		Test Panels 3	−13.74	22.49	−2.22	−9.68	13.43	5.41

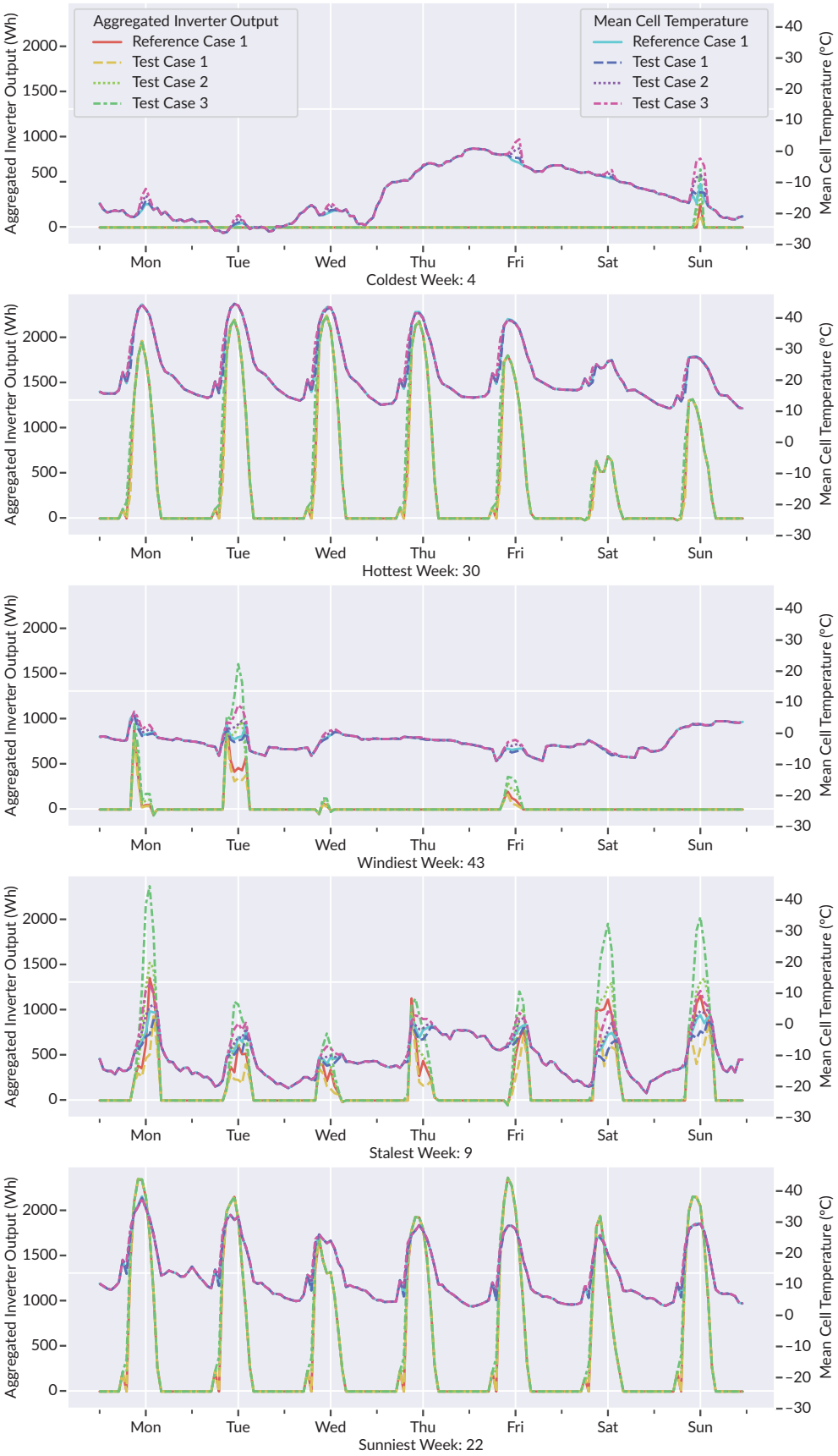

Figure 5. City center PV panel configuration performance.

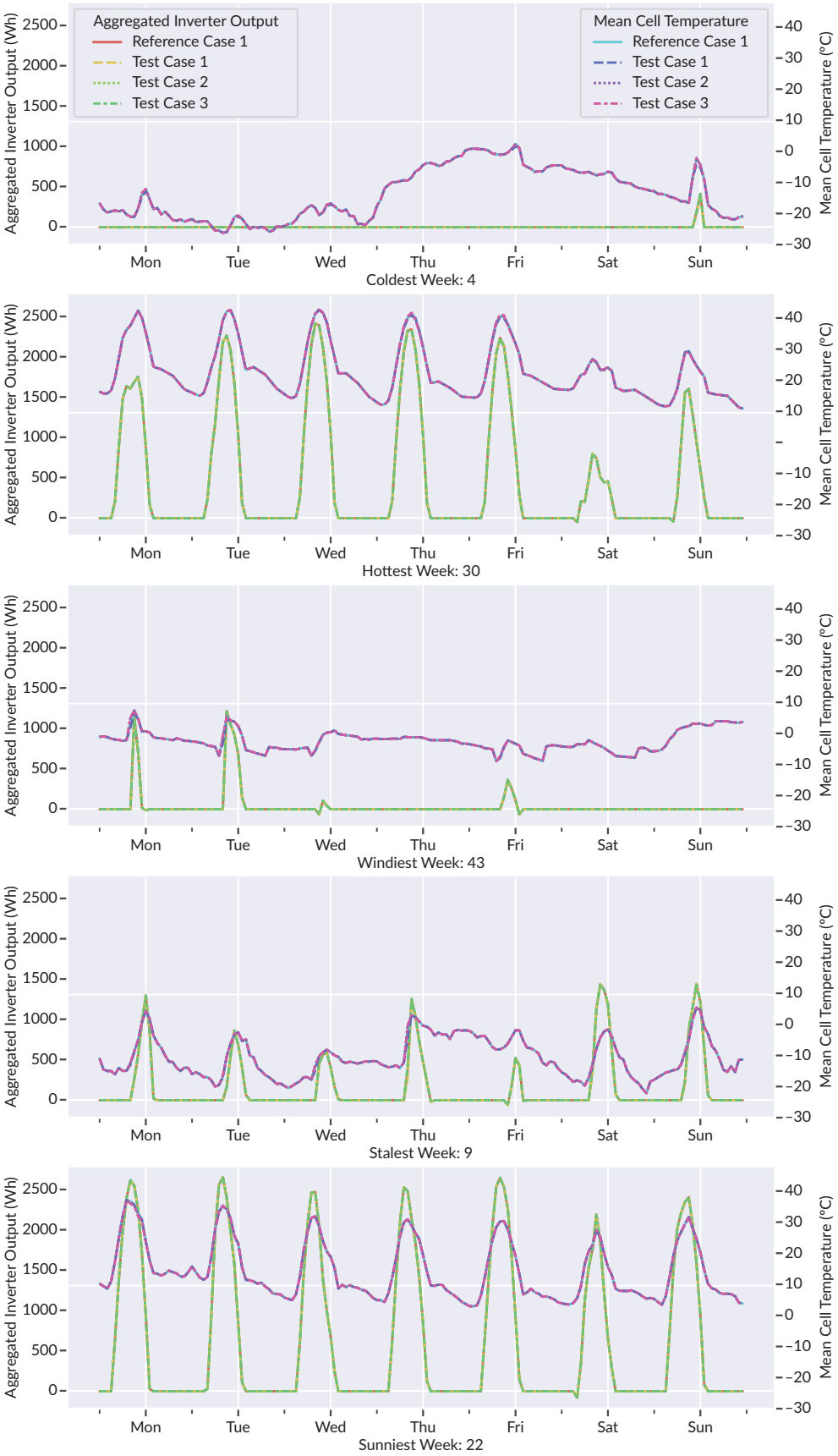

Figure 6. Örnäset PV panel configuration performance.

4. Discussion and Conclusions

In this article, we introduced a novel method for the optimization of the positioning of PV panels on building façades. In order to transform existing urban areas into positive energy districts there is a need to use all the available building surface for the installation of PV panels. In Nordic countries, this means to use façades as well as the solar azimuth is quite low. However, not all of the possible usable surface can generate appreciable amount of energy as well as there are important construction and architectural implications to consider when upscaling PV coverage in urban areas. Using publicly available cartographic and weather data, models for two urban scenarios in the subarctic city of Luleå, Sweden, were constructed. Microclimate simulation of wind, coupled with and façade obstruction provided three-dimensional fields representing each factor. The factors were then weighted to create three scenarios. Guided by these three fields, the panels were aggregated into three configurations, which in turn were clustered into a set of impostor panels for the sake of comparison. The performance of the panels was evaluated and compared to a typical, gridded configuration. We found that the configuration of the panels had an impact on their performance, with some configurations performing above the typical gridded configuration, and others below.

Our initial question was: What factors inform the optimization of vertical PV panels in a typical middle size city urban configuration in Sweden? Based on our simulation models we suggest that local conditions such as microclimate and city morphology do seem to have an effect on how different configurations of BIPV panels perform, although the complexities of the results suggest that there is no one optimal solution. The results indicate that alternative configurations of PV panels could yield energy gains in the right conditions. It also showed that evaluation is of importance, as not every design was an improvement over the base case. In the city center, test panel configurations 2 and 3 outperformed the reference case in all scenarios, as well as throughout the year. Configuration 3 also had the best yearly performance of any panel, irrespective of location. By contrast, test panel configuration 1 underperformed in all cases. As Test Case 1 prioritized panel aggregation towards areas with high mean wind factor to the detriment to areas with high sun exposure, this could indicate that the sun exposure factor is a better indicator for PV panel performance, especially since test panel configuration 3, which prioritized sun exposure, performed better than both the reference and other test panel configurations.

The morphology of the surrounding area seems to play a large role in the performance of the panel arrangements. The relatively minor differences in performance between well-performing test cases in Örnäset and the larger differences between panel performance in the city center indicates that panel arrangement optimization is potentially more beneficial in morphologically more difficult urban settings. That the third test arrangement in the otherwise less performant city center had the most efficient yearly performance is promising, indicating that the application of our methods could lead to more efficient panel arrangements, even in already optimal cases. The flexibility of our method allows it to be used by designers and decision makers to explore design spaces and develop informed understandings for the viability of panel configurations. The novel approach towards shapes lets designers reevaluate how PV panels can look. Future studies would benefit from an evaluation of panel aesthetics. In a survey by Bao et al. (2017), participants indicated that they were willing to pay more for aesthetically pleasing panels. The survey also showed that more aesthetically pleasing panels are preferred by testing groups, especially when seen in context to the building they are installed to, although the study showed that less visually intrusive panels were preferred.

While PV panel shapes were limited to one in this study, future research could expand upon the range of selected shapes, as well as the use of multiple shapes. For our study, we chose to use pentagons. As pentagons do not tile the plane, their manufacture would likely be less efficient than tilable shapes such as triangles and especially rectangles. Another main limitation is due to the lack of empirical testing of our model. We plan to conduct future experiments in the following steps of our ongoing projects. Although currently an involved process, our method has the potential to be highly automated. Future research could streamline the presentation and user experience, enabling our method to be used by decision makers and non-researchers to inform urban planning and architectural developments.

Furthermore, Ricci et al. (2020) compared the accuracy of turbulence models in the CFD software Gambit in comparison to a 1:300 scale wind tunnel model of Quartie La Venezia, Livorno, Italy. While the authors found the majority of models, including the Shear Stress Transport k-□model used in this article, to have a similar qualitative wind flows in the urban canopy layer, they found that all models had issues with flows around and downstream obstructions such as buildings. Therefore, future studies could benefit from local verification of wind conditions to ensure accuracy. Additionally, as our method presented in this article is novel, future research could benefit from verifying PV panel performance in real test cases.

Acknowledgments

Map data copyrighted OpenStreetMap contributors and available from https://www.openstreetmap.org. The ChatGPT-based LLM Consensus was used for finding literature relevant to the topic: https://chatgpt.com/g/g-bo0FiWLY7-consensus.

Funding

This project was supported by Formas funding (grant #2018–01267) for the project titled “Eco-district” and the Swedish Energy Agency funding (46355–1) for the project titled “Solar Districts.”

Conflict of Interests

The authors declare no conflict of interests.

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About the Authors

Max Spett is a PhD candidate at the Architecture group at Luleå University of Technology, Sweden. He holds a Master of Architecture degree from the Royal Institute of Technology, Stockholm. Max's research lies at the intersection between energy efficiency, digitality, and history. He has researched automation strategies for microclimate model generation and is currently investigating the role of aesthetics in automated timber component manufacturing processes.

Kevin Lau, an urban climatologist with 15 years of experience, specializes in climate-sensitive urban planning and design. His research focuses on the relationship between the built environment and urban climate, particularly human thermal comfort outdoors. He explores the interplay between the built environment, climate, and health. Kevin has led interdisciplinary projects for government, NGOs, and private sectors, and is a member of the WMO Expert Network on various commissions.

Agatino Rizzo is the chaired professor of architecture at Luleå University of Technology (LTU) in Sweden. In this university he leads a research group of 25 people focusing on the climate transition in cities, urban living labs, and climate-sensitive design/planning. His research has been funded by, among others, Qatar QNRF, EU Horizon, Swedish Energy Agency, Formas, and Vinnova.

URBAN PLANNING
ISSN: 2183-7635

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