

**NATURE-BASED SOLUTIONS FOR
“SPONGETOWN” CHRISTIANIA**
SUSTAINABILITY PATHWAYS OF A
COUNTERCULTURAL URBAN LIVING LAB

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abstract

Christiania, a countercultural anarchist urban niche in the Danish capital offers insights from decades of decentralised, community-driven sustainability experiments. The “Freetown”'s pionner engagement with Nature-Based Solutions (NbS) is a grassroots initiative challenging conventional urban governance (Coppola & Vanolo, 2014). Our study explores Christiania's relationships with Copenhagen's urban systems and climate-adaptation strategies, leveraging Transition Management (TM) and Strategic Niche Management (SNM) to address interconnected sustainability challenges (Jørgensen, 2022) within the framework of Planetary Boundaries (PBs) and Sustainable Development Goals (SDGs).

We employ a grounded theory approach to bridge Actor-Network Theory (ANT), the Multilevel Perspective (MLP) on Transitions, TM, and SNM (Stiles, 2020). This connects socio-technical ideas with bio-inspired and socio-ecological NbS approaches (McPhearson et al., 2022) towards a Multi-Criteria Decision Analysis (MCDA) process. We prospect the socio-technical, institutional, and socio-ecological domains of urban sustainability practice, focusing on empowering Christiania's NbS and the transition processes of Copenhagen and international institutions. Our research includes literature reviews, interviews, participatory observations, and urban analysis based on Resilient, Circular, Symbiotic, and Regenerative (RCSR) paradigms (Horn & Proksch, 2022), exploring how TM and SNM guide multi-level interactions away from grey-centralized systems (Agaton & Giulia, 2023; Vymazal, 2022) towards a Sponge City Copenhagen agenda.

Christiania's exceptionalism could facilitate ecosystem services (ES) valuation pathways in Copenhagen and globally. As an informal Urban Living Lab (ULL) (Florez-Ayala et al., 2022), Christiania can significantly advance Copenhagen's Sponge City ambitions. We identify key actors, drivers, barriers, and scenarios for expanding Christiania's niches to advance Green-Blue Infrastructure (GBI) and integrated urban water management (IUWM) systems (Liu et al., 2019). A novel IUCN-DGNB strategy for sustainable urban development is proposed for Christiania's Local Plan.

“Spongetown” Christiania envisions design options for promoting NbS and GBI for IUWM. Integrating RCSR paradigms into a shared NbS agenda formalizes community-led innovations within municipal strategies. Future pathways suggest merging sociotechnical, techno-economic, socioecological, and neo-institutional approaches towards ES integration in lifecycle assessment and urban sustainability certification processes. Christiania is poised to become a pilot project for these efforts, as our collaborative research demonstrates.

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A short word of appreciation for the fascinating World we cohabit and a word of hope for finding a common future towards its stewardship. May we find resilient, circular, symbiotic, and regenerative ways of creating a meaningful, just, and beautiful life for all.

Thank you All,
Lina and Manuel

acronym list

ANT - Actor-Network Theory
BI - Blue Infrastructure
CE - Circular Economy
CW - Constructed Wetlands
C2C - Cradle-to-Cradle
DFUD - Doughnut For Urban Development
DGNB - sustainability certification system (Deutsche Gesellschaft für Nachhaltiges Bauen)
ES - Ecosystem Services
GI - Green Infrastructure
GBI - Green-Blue Infrastructure
IUCN - International Union for the Conservation of Nature
IUWM - Integrated Urban Water Management
LCA - Lifecycle Assessment
MCDA - Multi Criteria Decision Analysis
MLP - Multi-Level Perspective
NbS - Nature-Based Solutions
PESTEL - Political, Economic, Social, Technological, Environment and Legal
RCSR - Regenerative Circular Symbiotic and Regenerative (Sustainability)
PBs - Planetary Boundaries
RBS - Reed Bed Systems
SCC - Sponge City Concept
SDGs - Sustainable Development Goals
STES - Socio-Technical-Ecological Systems
SES - Socioecological Systems
SNM - Strategic Niche Management
STIs - Sociotechnical Imaginaries
STS - Sociotechnical Systems
SUDS - Sustainable Urban Drainage Systems
SWOT - Strengths, Weaknesses, Opportunities and Threats
TP - Transition Pathway
ULLs - Urban Living Labs
WEFE - Water-Energy-Food-Ecosystems Nexus
WSUD - Water-Sensitive Urban Design
WoO - Windows of Opportunity

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1. Introduction

In this thesis, we introduce our unique case study of Freetown Christiania, where we applied sustainability indicators derived from a grounding on state-of-the-art sustainability paradigms to inform our methodology on how to conduct an urban analysis of the area. Through this methodology, we focused on the current and future barriers and drivers for Christiania to become an integral component of Copenhagen's urban transition agenda, while maintaining its own critical autonomy. Based on these findings, we are pleased to present our Spongetown Christiania project—an urban plan designed to address Christiania's sustainability needs, protect its freedom, and safety while aligning its course with the broader agenda of Greater Copenhagen.

Ever since the Brundtland Commission [1] defined Sustainability as a normative concept to describe healthy human development in co-evolution with our biospheric environment at a planetary level, a myriad of further attempts at defining the concept's characteristics, domains and related qualities sprouted in numerous disciplines, theories and ideological fields in Philosophy [2]. In order to better understand urban sustainability transitions and to inquire their relevance for a given community with a legacy as Christiania, one has to understand why it could be considered countercultural from a perspective on the conceptualisation of sustainability itself.

In our thesis we will inquire how these Sustainability Paradigms [3–5] - namely the four most prevalent ones related with the concepts of Resilience [6], Circularity [7], Symbiosis [8,9] and Regeneration [10,11] (hereinafter referred to as RCSR for short) – are present in urban planning for Sustainability Transitions (STs) [12–14] in the Danish Capital of Copenhagen [15,16], in a rather unique neighbourhood - Freetown Christiania.

RCSR paradigms have been previously identified across the literature in numerous works, as one can see from the usage of these concepts in the Global Status Report for Buildings and Construction from United Nations Environmental Program (UNEP) earlier this year of 2024 [17] or in the Building Materials and Climate report of 2023 [18].

RCSR paradigms translate differently to Green Building Councils (GBCs) worldwide along with certification and assessment methodologies established in institutions followed AEC organisations worldwide [19]. Methodological systems, like DGNB, LEED, and BREEAM, are being globally and locally translated to ensure that sustainability claims obey standardised prerequisites and benchmarks. These can be audited and classified regarding their compliance with the above-mentioned systems, whose auditors report on their impacts by providing EPD-certified data on the operations spanning the product or service lifecycle [20].

Our thesis aims to test these paradigms' relevance (and the methodologies they have sprouted) in steering the urban transformation of our case-study of Christiania. Freetown Christiania is an internationally known informal settlement in the heart of Copenhagen, capital of one of the leading Nordic countries in STs, Denmark – famous for its countercultural takes on urban development, governance, community culture, environmental ethos and sustainability [21–24].

STs are framed by Science and Technology scholars [25,26] that adhere to the Multi-Level Perspective (MLP) [27–30] as trajectories of change in sociotechnical systems that lead towards sustainable outcomes. These change trajectories take place in multi-level selection

environments where alternative systems (niches) sprout in the micro-level before they become widely adopted as a new regime at the meso-level. Incumbent (existing) regimes are populated by organisations which often have unsustainable agendas, giving rise to the niches of opportunity that alternative systems are developed to address. Regimes and niches alike have to contend with external pressures which configure within MLP the selection environment for the alternative sociotechnical systems to adapt and survive or wither and become extinct – we call this environment in MLP the landscape – or the macro level. Since our work is linked with urban and landscape design, we will often adopt the expression “selection environment” instead of the term landscape to refer to this macro-level, to enhance the clarity in our discourse [30–33]. MLP was born from an evolutionary and systemic change perspective that has institutionalist/functionalist underpinnings, but as a mid-range theory often overlaps with phenomenological and more subjective approaches such as ANT [34,35] sociotechnical field of study. In our work we tapped this overlap to diagnose perceptions on evolutionary trajectories in sociotechnical and socioecological systems within Urban Transitions, in Copenhagen and Christiania as we will explore in Chapter 2, pertaining to the Literature Review.

Our Spongetown Christiania project and RCSR sustainability concept were first conceptualised from our own research and networking along the full scope of studies that precedes this thesis time frame. We ended up creating a manuscript that focused on a thorough review of different landscape pressures and regime and niche pathways impacting Copenhagen and Christiania’s shared trajectory towards a Sponge City concept (SCC) [36–39] a concept proposed by the Chinese European Water Partnership (CEWP) for Green-Blue Infrastructure (GBI). Our findings led us to the hypothesis being tested in this thesis: Christiania can become an experimental neighbourhood for the SCC by nurturing and expanding its Nature-based Solutions (NbS), by further shielding its proto-regime [36] as an Urban Living Lab (ULL) [40–45] in Copenhagen.

Christiania as a community and place is a fertile ground for the CEWP agenda to take root in [36]; since they share with most coastal urban communities worldwide these matters of concern and because they have been pioneering NbS for the past four decades since the early 80s. Christiania sits in the vanguard of coastal urban communities in Denmark and Copenhagen that lie few meters (or even centimetres!) away from rising sea-levels. The risk that these communities are currently inhabiting places that will soon become more suitable for estuary wetlands than conventional human urban territories is palpable and has become painfully empirically observed recently in 2011 when the city was hit by a cloudburst event, energising urban transitions in this regard. In this work we will test our hypothesis of using NbS for RCSR Urban Planning in the context of Christiania. To steer multi-level management of Christiania and the Danish AEC Sector, we analyse the leading Sustainability Certification System for Urbanism in Denmark: DGNB-DK, along with its most recent assessment framework which includes Planetary Boundaries and Doughnut Economics alongside SDGs: DGNB-DK Planet [15].

Our selection of Freetown Christiania as our case study is linked to this informal community’s famed countercultural approaches to Sustainability and its uncanny independent and semi-autonomous presence within Copenhagen. With this work we analyse Christiania and DGNB matters of concern and propose a revised tailored assessment method for Christiania that we believe could be used to advance DGNB towards a closer link with NbS and Sponge City agendas for WEF (Water, Energy, Food and Ecosystems) and Urban systems transitions worldwide.

By adopting the IUCN Global Standard [46,47] for NbS as a complementary framework to DGNB, we intend to showcase the courses of action that the Doughnut for Urban Development (DFUD) [15,16], in Denmark, and UNEP at an international level are chartering towards the

decarbonisation of the Global AEC sector. Furthermore, we present an alternative or complementary course of action to DGNB-DK, By og Havn, Copenhagen's municipality and other key actors in the city with our Spongetown Christiania project, including several Danish ministries, namely from the Environmental, Transportation and Mobility sectors. These organisations and the institutions they promote have been championing a worldwide famous project named Lynetteholm, which promises to solve at once three of the greatest problems of Copenhagen: urbanisation demand, sea-level rise and storm surges.



1 - Christiania's Origins Collage (source: Slots og Kulturstyrrelsen Udviklingsplan (2006))

Christiania as an anarchist consensus democracy community with a post-growth and post-capital stance on numerous issues, has been left out of the picture within this regime trajectory that is linked with the bet on Lynetteholm to solve Copenhagen's environmental risks such as flooding, sea-level rise and storm surges. As we hinted in our previous research, the path dependency that arose from the ideological conflict between a) Copenhagen's mix of economic institutionalism and exposure to global neo-liberal markets and business-as-usual sustainability trends [48]; and b) Christiania countercultural degrowth agenda [49,50]; has locked a trajectory for this part of the city and its community away from the broader urban policy context of Copenhagen.



2 - Christiania's Origins Collage (source: Slots og Kulturstyrrelsen Udviklingsplan (2006))

The promotion of NbS and GBI for Copenhagen and Christiania alike are key, but they can be used and strategised in numerous manners which are linked with the broader socio-technical-ecological [51,52] and institutional environments [30,53] in which they take place. Our work intends not only to give concrete answers to the present moment, but also to acknowledge the path dependency [54] alternative systems face when contending with regime forces, in order to design feasible solutions for the present moment.

For example, we cannot ignore that most likely Lynetteholm in one way or another will most likely be built [55,56], even if the project faced expressive public backlash [57], or even if other alternatives could exist [58,59]. We therefore felt a responsibility to try to mend the information and strategic gap between Lynetteholm's design and the urban planning for the community of Christiania — bridging the relationships between this community and the municipality and state that watch over it [60] and that is — to a limit — entrusted to protect its interest.



3 - Christiania's Origins Collage (source: Bevar Christiania Facebook page, Alis Skateshop Webpage and Atlas Obscura website)

Spongetown Christiania envisions the urban masterplan of Christiania as a key interessement device and boundary object that could bind all of these common matters of concern [61] together and present what is at stake for Christiania to make informed decisions in its forthcoming urban negotiations with the municipality [62]. A new urban agenda for Christiania [63,64] could defy both the current regime of Copenhagen and the Christiania niche to set aside their differences in finding novel common ground on which to build foundations for RCSR sustainability transition pathways – by reconnecting Christiania to the city's agenda and strategic direction, recognising and acknowledging its contributions, and learning from 40 years of NbS experiments and pioneer projects [36]. As discussed in Chapter 3, we propose Christiania and Copenhagen to use the EU as an external mediator and financing device that we believe could bridge these two parties into a newfound common sustainable agenda for Sponge City Copenhagen and Nature-based Christiania.

2. Research Context, Theoretical Framework and Literature Review

Echoing the constant need of reinventing its cause and rejuvenating its relevance and standpoints, Christiania has in the month of April 2024 overcome one of its most radical political and economic stances, alongside pressing social threats and stigmatising weaknesses: organised crime linked with the recreational drugs black trade which was tolerated in its main square and street – two places often raided by the police and where murders took place due to gang disputes [65]. In the process, some might argue, ironically, Christiania has lost some of the most liberal niches that they occupied with their quasi-monopoly on recreational cannabinoid sales in Copenhagen [66].

In Pusher Square and Pusher Street in Christiania, cannabis and its derivative products - which could, if you entertain the idea, be framed as NbS that became a big problem for human societies – have been banned for the first time with true local support from the open street markets of Christiania. Cannabinoid and derivatives sales and the connected market and cultural scene were, however, an indisputable component of the attractiveness of the community to a wide audience of consumers who will now either change their habits or resort to organised crime elsewhere while seeking this product within Danish boundaries [67] – and most certainly a factor that made Christiania one of the most visited attraction in the city of Copenhagen until recently, with up to a million visitors reported by news-sources like The Guardian [68].

As these prohibitionist measures take place in Denmark, quite the opposite takes place in the neighbouring Germany – where legalisation was the pursued at the national level course of action for the entire sector of recreational cannabinoid use. Christiania has grown a reputation to support the German policy since its early days, decades before countries like Canada, Georgia, Luxembourg, Malta, Mexico, South Africa, Thailand, Uruguay and certain USA states and the capital region of Australia took the step to eliminating the cannabis black markets through legalisation and market regulations instead of prohibition and law enforcement [67,69].

Both measures (enforcing prohibition or legalising) could be framed as sustainable transitions depending on political and cultural inclinations, because sustainability is not subject merely to matters of fact, but to an amalgamation of matters of concern which are composed by subjective, political, and cultural valuation and scientific fact alike. Indeed, the radical liberal stance on drug use (and abuse) in Christiania that made this place's inhabiting community stand in defiance of Danish law (and to create their own internal ones too) was slowly but surely forgotten and discarded as people began being killed in the gangster territories of Pusher Street and Pusher Square. Christianites sought then intervention from the Danish state to enforce the uprooting of pusher culture in its public core. The transition agenda affirming Christiania as a weed-positive place that supports the legalisation policy risks slowly being forgotten as the community now intends to overcome the social stigma it once faced in Denmark through normalising this cultural aspect.

Our poster survey posters stood there as this thesis was written, inviting people's opinions on the future of this community and place, precisely under the tent that occupies what was recently the worldwide renowned as the Green Light District of Copenhagen, in the places that previously went by the names of Pusher Square and Pusher Street (Fig 1. – Conceptual Map about how Christiania is perceived by Copenhagengers).

When one thinks of NbS and Christiania (Fig. 4), weed and hash are a recurrent part of the local sociotechnical and socio-ecological imaginaries, being often expressed in our survey either as problems or even as part of the place and community's identity. Moreover, they were an integral part of its economy – at least in an indirect sense for the high touristic affluence of the place, internationally renowned for the trade of these products. However, these traits could also be attributed to highly developed artistic organisations of Christiania and their events, or the synergies between these venues and events, and the availability of recreational drugs.

We acknowledge that these herbs (along with many species of flora and fauna) might come to play a role once more in the future of this community once more, as trends towards legalisation seem to be outflanking internationally the Danish stance on the issue. Meanwhile, Christiania might have been a pioneer in the fair treatment of recreational substance and their users even before an international agenda rose in the landscape. However, the municipality's semi-

tolerance of the unique status of the place as a market niche for cannabis, did not stop the enforcement of constant police raiding of the original hippie markets in the span of a single decade became a marginalised - but tolerated and feared black market - where only organised crime is equipped to compete.

Our point with this introductory narrative is to point out that despite the importance of cannabis and the legalisation politics that have shrewd Christiania in stigma, NbS and their potential in Christiania do go far beyond cannabinoids and their derivatives. Green Roofs, Green Walls, Permeable Pavements, Urban Farming, Composting Toilets, Constructed Wetlands, Swales, and many other measures that we increasingly consider best practices in the design of urban, rural and peri-urban built environments have found their place in Christiania, way before the terms NbS and Bio-based Materials became so mainstreamed [17,40,70]. This community agenda has kept Christiania a respected place within environmentalists and radical sustainability niches, through organisations like biodiversity protecting Frie Natur or its Gardeners Association, despite people being much less aware of their presence in Christiania – which is far better renowned for cannabis than other forms of social, economic and even environmental innovative policies. All of this anecdotal evidence brings forth the narrative of Christiania as a countercultural and experimental place in Copenhagen.

what 3 words or ideas come to mind when you think of Christiania?



4 – answers on “what 3 words or ideas come to mind when you think of Christiania?” (source: our survey, appendix B)

In this work we will review how Christiania’s alternative systems, organisations and institutions constitute, in our opinion, Christiania’s NbS proto-regime in Copenhagen - discussed thoroughly in our publication submission for the NbS journal. Before our deep dive into this project scope, we will first frame how more conventional takes in Urban Sustainability in Copenhagen, Denmark, Europe and internationally are taking place globally and could be translated locally to Christiania. We will then utilise this analysis to propose adjustments to DGNB to align with RCSR sustainability paradigms through the adoption of the IUCN Global Standard for NbS, as well as a Masterplan for Christiania’s Urban Transition towards RCSR Sustainability.

Before we take a deep dive into this research context, a spatio-temporal orientation is of paramount importance. On Fig 1. we provide a timeline and map that pinpoint chronologically and geographically Christiania's urban matters of concern in relationship with Copenhagen and the Danish state, along with the AEC sector. The items revolve around the scope of our work within NbS, Sponge City and Urban Transitions towards Sustainability and how these are related to Copenhagen and Christiania.

A wave breaking seawall is still being built slowly but surely far out in the Øresund shore, despite public crackdowns against it, as the ones behind its design intend to protect Copenhagen from rising sea-levels and storm surges, which will, in combination with increased pluviosity, threaten the city with persistent flooding. The reason why these city walls keep expanding may now be portrayed as environmental, and designed to meet those criteria, but another key reason for their adoption is rapid urban growth and demand for land near cities and the appeal for investments to be made boosting economic growth, as argued in By og Havn reports on the projects' strategy and scenarios.

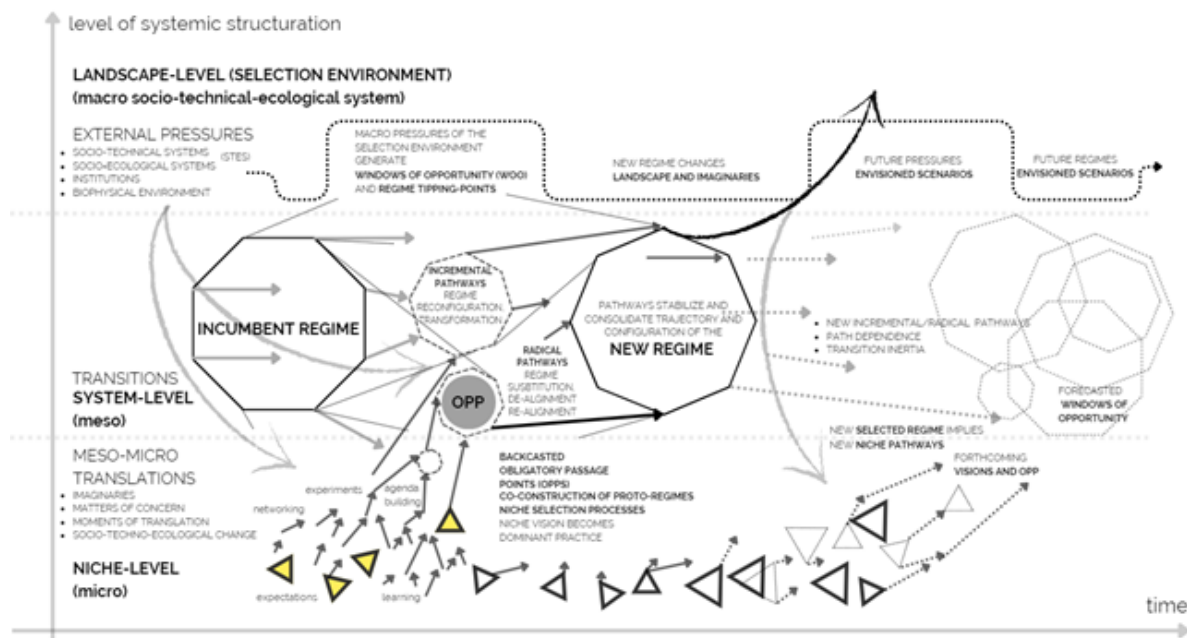
The threat this seawall poses to marine life and its already dwindling biodiversity is strongly perceived as a negative trade-off that should be avoided [71,72], coupled with the inherent risks of gentrification that another neighbourhood could bring to the city [73,74], despite the efforts to create public housing in Lynetteholm. If such a wall or sea-break is not erected though, Copenhagen will have to prepare for becoming a wetland-rich landscape on which only houseboats could survive. Green seawalls, bio-retention and infiltration GBI are therefore the strategic shoreline defence measure that Sponge Cities like Copenhagen endorse [75,76] as a NbS alternative system to the grey-infrastructure regime that is now substantially contested due to its ineffectiveness for climate change adaptation [77,78]

In this work, these urban scenarios and different trade-offs will be compared and considered in alignment with our Master-plan Proposal for Christiania, considering different ways in which Copenhagen can pursue its Sponge City agenda, and how those strategies can be translated to Christiania's forthcoming masterplan. We believe this research to be timely and fundamental to understand the crossroads in which Christiania and Copenhagen stand: a crossfire of opportunities, threats and related matters of concern across all dimensions of sustainability. The future of this community and place, does not look so far away in a time when the call for profound reinvention and re-imagination arrives at the doorstep of the most informal of Copenhagen's neighbourhoods and communities. Multiple Urban Challenges (UC) lie in Christiania and Copenhagen's horizon, especially related with Climate Adaptation and other PB connected issues, but also of the Social and Economic kind, like the risk of Normalisation and Gentrification, which we will also discuss as part of our Urban Transitions Management framework for Christiania.

2.1 A Multi-Level Perspective of Christiania in the Urban Sustainability Transitions Landscape

As previously introduced, this thesis builds upon the work conducted during the first two project modules of the Sustainable Design Engineering MSc in Aalborg University. In the first semester

module, named Design for Sustainability, we started an investigation on the regenerative potential of a specific NbS we found in Christiania — its Constructed Wetlands (CWs) and Reed-bed Systems (RbS) (see interviews: A.7, A.11). In this program's scope we inquired the role of Biomimicry and Bio-inspired approaches to the Design of CWs, and how they could be integrated in a regenerative design program for Christiania's future urban imaginaries.



5 - Our MLP-ANT-TM-SNM-STI integration framework (Morgado et al., forthcoming) draws on Geels & Schot's structure (2007) to understand translations and transition pathways of SNM, (Raven & Geels, 2006) and TM (author, date). ANT contributes to the multi-level translations through MoT (Callon, 1986) which interact with STI concepts (Sovacool et al., 2020)

On the second semester project module, named Design for Sustainable Change, we broadened our Christiania network's problematisation scope towards transitions in Christiania's and Copenhagen's built environment, and we arrived at our first inquiries regarding Spongetown Christiania concept for its urban development. Earlier this year we submitted both semesters' works to the NbS Journal as a manuscript which is currently under peer review.

In the first section of the introduction chapter, we will present the main theoretical structure developed in this manuscript which compiles our main theoretical framework, methods and preliminary results on which this thesis builds further upon. The manuscript, named "Spongetown" Christiania as an Urban Living Lab: NbS for Resilient, Circular, Symbiotic, and Regenerative Transitions in Urban Waters" [36] is a propositional work in the theoretical and practical sense (Fig.5 for the theoretical framework, see Fig.7 for contextual application). Since this thesis elaborates further on the full scope of that research paper, we have attached it to this submission, in Appendix A, and will continuously refer to its framework, concepts, structure and findings along this document.

In the theory sphere, our previous work mobilises numerous – and often antagonistic - schools of thought related to the design of transitions from the socio-technical systems and socio-ecological systems standpoints. By embracing a socio-technical-ecological systems hybrid framework (STES) we amalgamated an understanding of urban transitions that tries to consolidate major theoretical frameworks on the issue of sustainability transitions and their design [25,51,52]. MLP on was chosen as the core framework to frame our Transition Analysis

and Design work – it proved its value as an umbrella mid-range theory where we made use of our previous Actor-Network Theory (ANT) [30,79–81] empirical work on CWs in Christiania to delve deeper into the micro-meso-macro interactions discussed in Strategic Niche Management (SNM)[63,82–85] and Transition Management (TM) [86–88] design schools of thought. SNM and TM converge with MLP in forecasting, back casting, designing, engineering and managing STs and their inherent visions and scenarios across a multi-level understanding of reality. We used concepts from the Moments of Translation (MoTs) [62,89–93] understanding ANT constructivist-empiricist theoretical standpoint to do so, such as problematisation, interessement, enrolment and mobilising that we found to be useful in diagnosing agendas, expectations and to enable learning processes that are considered key for steering systemic change in sociotechnical studies towards obligatory passage points (OPPs) that bind the actors of organisations to commitments through boundary objects like urban plans

We are not alone in this diagnosis that there is value in theoretical cross-fertilisation between systemic, evolutionary as well as constructivist and structuralist understandings of sociotechnical change – hints given by Geels, the leading and founding author on MLP [30,94]. Benjamin Sovacool - whose work was instrumental along with Frank Geels' in sprouting our theoretical curiosity [25,26,95] – didn't shy away from reaching out to the Sociotechnical Imaginaries (STI) school of thought along with the ones we just mentioned. We used his inventory of concepts such as cues, ideographs, visions, and imaginaries to ground our full understanding of changing values, norms, beliefs, lifestyles and, of course, institutions. Indeed, our work goes even further towards the Socio-Ecological Systems field of studies, departing from the sociotechnical turf altogether, while expanding it, as Ahlborg, McPhearson and other authors also endorse.

Our first publication applies this agnostic theoretical grounding (Fig 2.) practice to Christiania and Copenhagen (Fig.3) as the focus of its research. Christiania as a place and ecosystem (socio-ecological system, or SES) and community or organisation (socio-technical system, or STS) is empirically identifiable as an urban niche and experimentally planned community. It is renowned for radically alternative takes regarding sustainability across all the three dimensions and constitutes a refuge for many misfits and stigmatised minorities in all forms of societal change taking place in Copenhagen. The alternative systems that materialise this alternative place and community have a highly relevant conflict-order dimension to their relationship with the municipality's and the state's. Sovereignty over Christiania as a contested territory where public utilities and heritage are present, within the revolutionary neighbourhoods' boundaries; is a disputed political matter of concern.

Furthermore, Christianites are not entirely self-sufficient, and they have a shared identity that spans Christiania, Denmark and international radical sustainability and political grass-roots movements. As the dichotomies between insiders and outsiders of Christiania surface and dilute, so does the regime-niche dynamic become more apparent, but also more diffuse - pathways for regime and niche transition revolving around the synthesis of common agendas. All these realities have forced Christianites to negotiate their autonomy more often than they would perhaps care to admit or acknowledge as a positive transition pathway for their community.

Our findings led us to assume our initial hypothesis of Christiania being an urban niche to be objective and empirically observable. However, the claim on the community's sustainability was found to be contested regarding their overall potential contribution without adequately defined analysis criteria. Echoing numerous other research findings on the same urban case-study and topic, however, we also diagnose Christiania as a rather unique, special and experimental place

[96–100]. We find that characterisation to be truly applicable in the social, the environmental, the economic and even in the institutional sense in Freetown – which led us to study it as an urban niche [64,101]. In this thesis we will prospect how as an urban niche Christiania can steer the regime towards RCSR sustainability.

There is no such thing as a singular, optimisable, or objective better pathway for STs, whether we are talking about Christiania, Copenhagen, Denmark, Europe or the World – but a myriad of potential scenarios, visions and imaginaries [95,102,103] that stem from trade-offs and common agendas between sustainability paradigms interactions with social, political and cultural underpinnings of concepts of development and progress. In this work, we will navigate the ideological field on Sustainability and make a proposition for Christiania in terms of Sponge City Master-planning for NbS [104,105]– an agenda that we believe to be valuable for the global society and local community to pursue and to be adopted by the Danish GBC.

Introducing our work on Urban STs, we have here to explain why we are not only interested in a pure Multi-Level Perspective of Sustainability Transitions and why we are compelled to move forward and along with other theoretical frameworks.

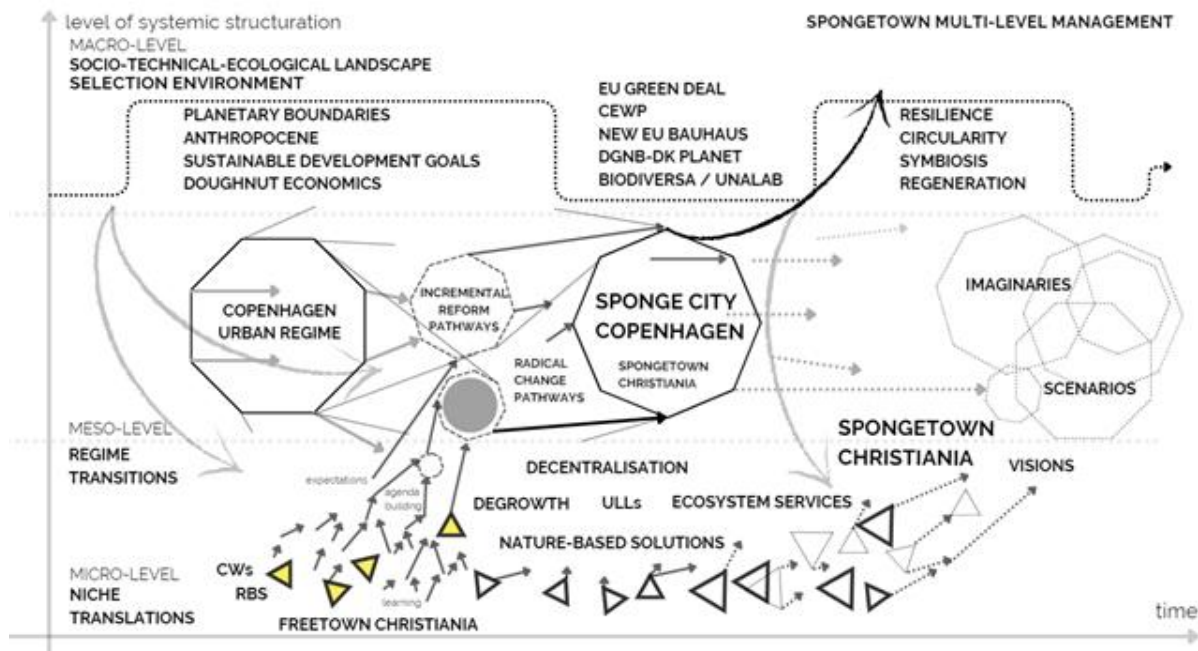
The reasoning behind this approach is that we believe other schools of thought concerned with tactical aspects of social change to be heuristically relevant to Transition Design. Steering can be better understood through the Translations of Actor-Networks, which tend to be experienced phenomenologically and empirically rather than systemically understood, despite the actors' perceptions. We believe that ANT can empower niche-led radical pathways (empowerment of grass-roots alternative systems) and regime-led incremental pathways (incumbent systems reform, adaptation or overhaul) alike – which resulted in our combined Multi-Level Transition and participatory approach developed in our first manuscript, and our division between Incremental and Radical Transition Pathways.

We mapped key players that Christiania can (and most likely must!) ally within order to pursue our proposed project ideas (Fig.6). Multiple regime players and landscape forces are relevant for the multi-level understanding and steering of the transitions we have envisioned collaboratively with key actors in the Christiania community. We engaged residents, workers, allies, visitors, tourists and fellow researchers in our moments of translation, achieving a diffuse but palpable momentum as problematisations, interessements, enrolments and mobilisations aligned along with agendas and expectations. Participating in the development of Christiania's masterplan with novel research seemed to us the right and timely thing to do then – a heuristic necessity.

Our previous findings led us to understand the current process of Master-planning Christiania as a Window of Opportunity (WoO) and an OPP for our Spongetown Christiania proposition. That proposition, on its turn, could perhaps even function as a tipping point for the trajectory of transition pathways (TPs) of Copenhagen towards NbS. Both shared understandings between us and our partners in this project generated the perfect excuse to engage in masterplanning for one of the most peculiar communities in this city as our master thesis – and we took it.

Danish and Municipal
Government Authorities

6 - Danish AEC Regime and Niche Timeline Framework

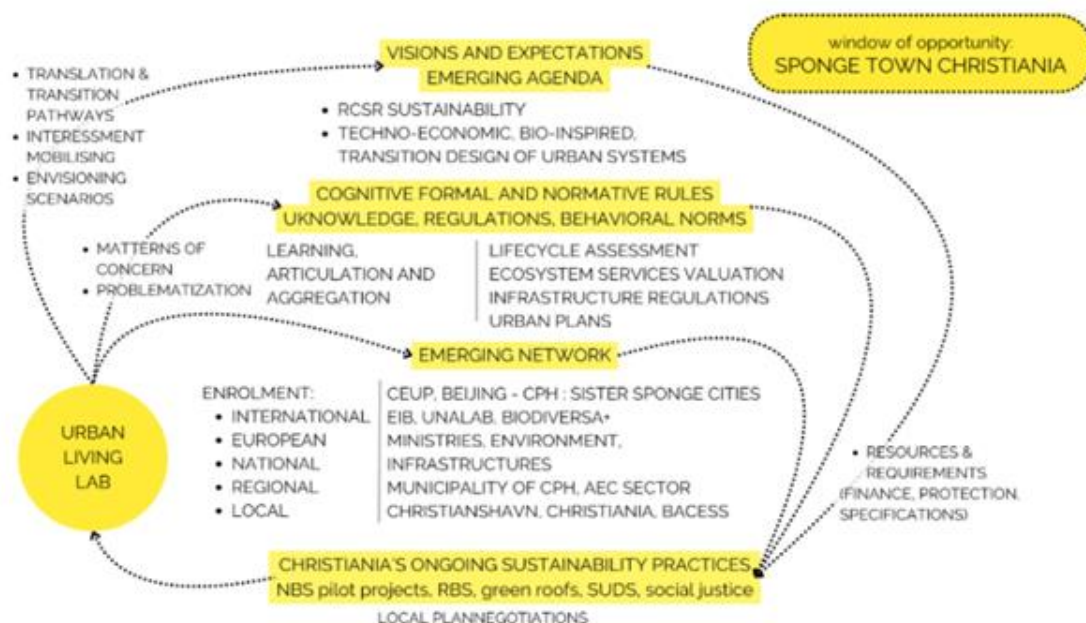


7 - Our MLP-ANT-TM-SNM-STI application to the Spongetown Christiania project (Morgado et al., forthcoming).

As a cautionary tale, we were told by our local partners that even successful architecture firms with vanguard sustainability approaches such as Vandkunsten have failed to keep Christiania as a client. The firm defied the community for having built a conventional residential building in the direct immediacy of the Fristaden (Freetown, short for Fristaden Christiania, the full name of the community and the place it inhabits) that the local inhabitants considered not up to its own standards of sustainability, progress and development.

The building was, despite the backlash, erected on the site of a wetland which was until then cherished by the community. Christiania kept in memory the wetlands that were lost, and Vandkunsten lost also a community project that gathered a lot of qualities and which we ended up endorsing as valuable insight for our own master-plan here presented. Their story was also a warning – beware of master planning sustainability Christiania, for community and public support can be suddenly lost when the wrong moves are taken.

MULTI-LEVEL MANAGEMENT OF SPONGETOWN CHRISTIANIA TRANSLATION



8 - Multi-level framing of three niche processes identified by SNM scholars (expectations, networking, and learning), adapted to Spongetown Christiania, integrating ANT, TM and STI concepts, based on Geels & Raven, 2006 (Morgado et al., forthcoming)



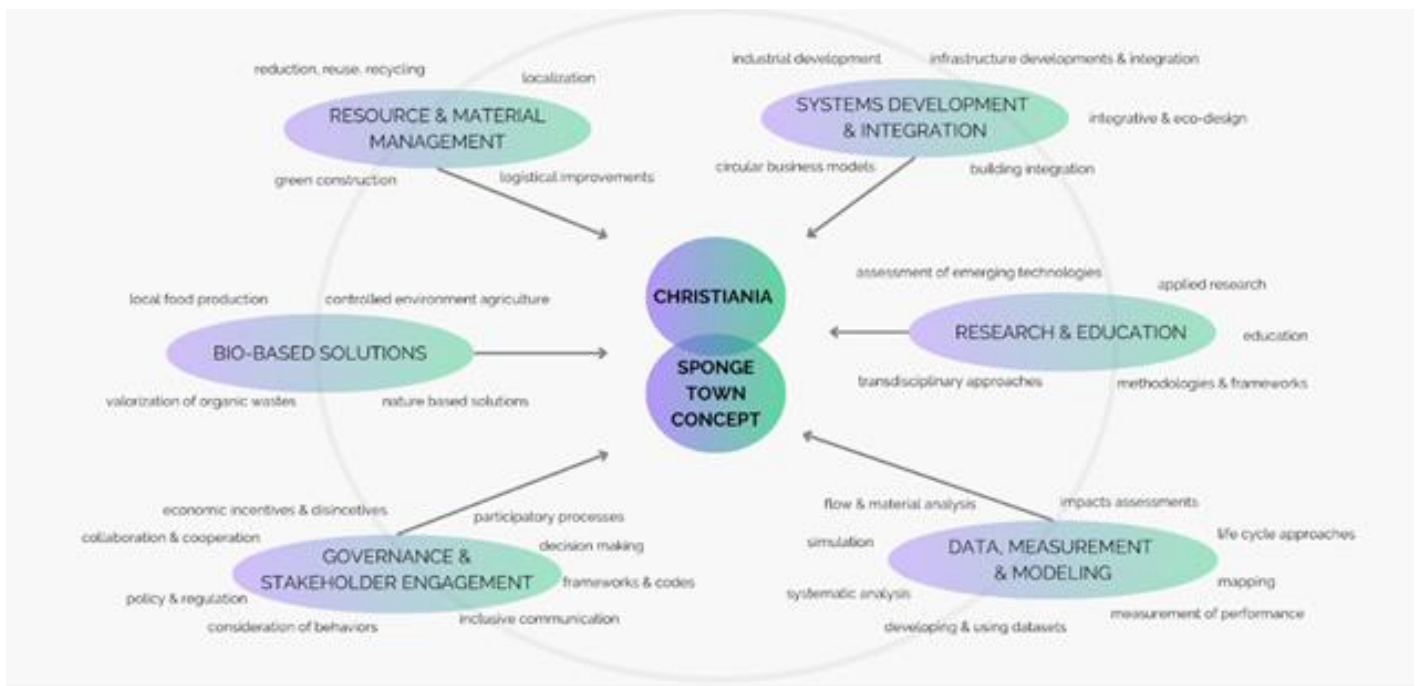
9 – photographs of the meetings we had during our research (source: our own, appendix B)

Regarding the specific scope of sustainability, how exactly Christiania exists as a niche for sustainable urban living, we have developed previous research on the potential of its NbS to address local, regional and global urban challenges.

We assert our participatory findings (see Fig. 9 for a quick glimpse of the process) that Christiania may yet prove to become an invaluable laboratory for NbS and the Copenhagen city's goal of becoming a Sponge City, and we intend to demonstrate in this thesis what a conceptual vision could look like from an Urban master-planning process and organisational perspective, as described in Fig. 8. Christiania can experiment with pathways that the Danish-Chinese-European dreams of translating the Sponge City concept in many of its cities threatened by water, food, energy and ecosystem change and connected management issues of all sorts – it has this vocation and offers alternative systems from some of the most ambitious NbS and Sponge City agendas and visions, like urban degrowth and decentralisation (see interviews annexed interviews A.3; A.4; A.8; A.12; A.14).

To truly become an NbS ULL to help Copenhagen in its wider Sponge City transition, Christiania must take steps to keep its identity in the process and to not succumb to gentrification and full-scale normalisation. It intends to remain an institutionally diverse place, and relevant arguments have been brought forth by us to endorse the relevance of preserving Christiania and its cultural uniqueness in both the sense of its community as in the sense of the place that expresses its identity – key matters of concern in connection to the translation of the concept are mapped in Fig. 10.

Ideals like RCSR are no strangers to Christiania, a vanguard community in many senses that is eager to experiment with alternatives that find higher resistance elsewhere, as long as they believe in them – however, Christiania's ideas are becoming less radical, as they have expressed to share a high affinity with the transition that the Danish AEC regime is now embracing, and a sense of trust in the European project, which was first discarded by the community. In this introduction in Chapter, in the following section 2 we will review the state of the Regime within the landscape transitions that we have diagnosed, and in section 3 we will focus on Christiania's uniqueness as a study object on the design and engineering of urban sustainability transitions.



10 - RCSR Sustainability problematisation of Spongetown Christiania - based on Horn & Proksch, 2022 (Morgado et al., forthcoming).

2.2 Within the Doughnut: Chartering the Built Environment Sustainability Trajectory

Urban systems and science of the built environment are fields of work devoted to the design and planning of land assets' transformation [6,106–108], towards the creation of artificial habitats for human dwellers and management of the Earth's space for societal usage and resource extraction or generation [109]. Urban landscapes establish territorial systems and infrastructure as networks connecting people to buildings, places and landscapes [110–115]. Urban systems' infrastructure has been classified in numerous ways, along with their types, composing subsystems and specific qualities that distinguish them from other systems.

Urban Systems have nuanced overlaps with other territorial and land-use bound design scopes such as Agronomy, Ecosystem Management, Industrial and Infrastructural Design, that dispute with Urban Systems the ownership, usage and governance of human territories and their built environments.

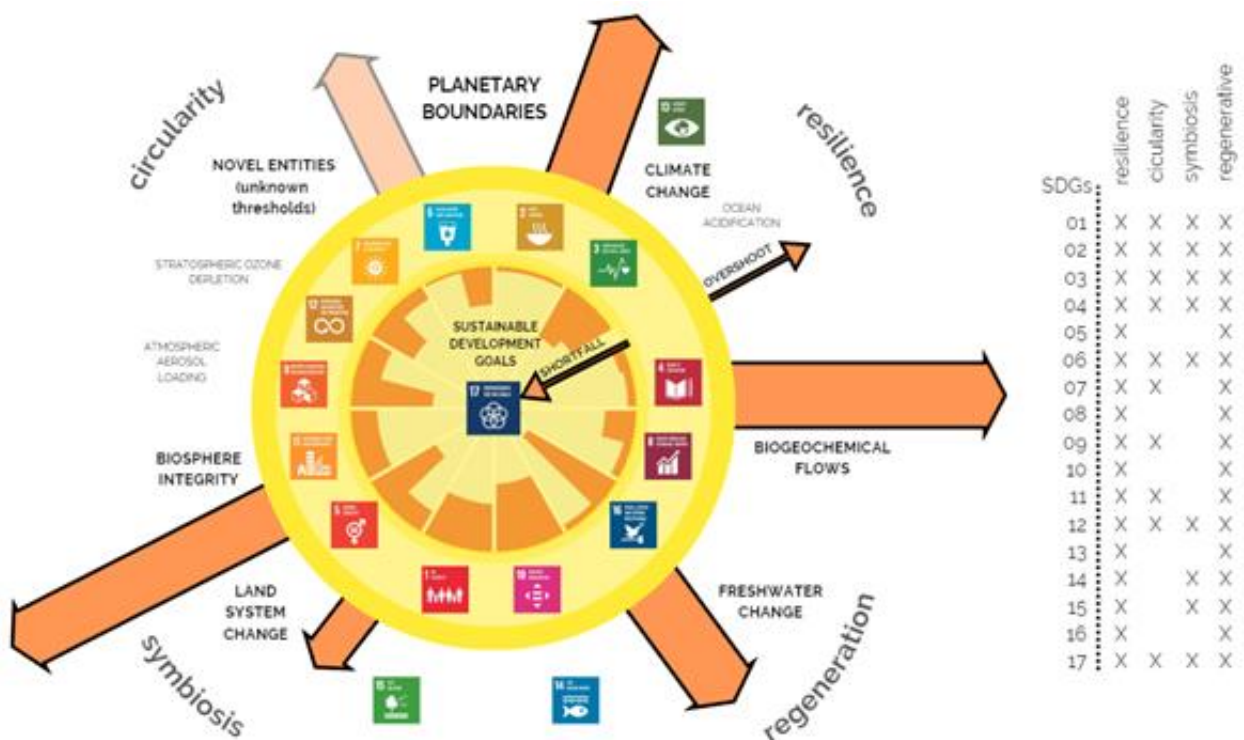
Nevertheless, territorial and spatial design of infrastructure and land-use have often been the focus and turf of landscape architects, architects and engineers, who must address matters of concern from society at large in the pursuit of the common good, incorporating in their designs the plurality of interests of a plethora of economic sectors, environmental factors, social aspects and institutional norms.

Christiania is a particularly unique place when it comes to sustainability - even in a vanguard country in this transition such as Denmark. In the heart of the Danish capital, Christiania is an anarchist intentional community that governs with semi-autonomy a place where individual property rights over land do not exist and where governance takes place through direct consensus democracy. Being famed for its Marxist anti-capitalist inheritance, Christiania is an

extremely sceptical place of contested agendas in academic circles such as Green Growth [49,50,116,117].

Its stories tell us a narrative of a place and community where sustainability is allowed to exist, if it can be understandable by the laypeople who inhabit it, but where it comes to wither if it must materialise through advanced and indecipherable technology. Christiania is a revolutionary and reactionary place simultaneously – kept alive by its contradictions, compromises and the curiosity for novelty it sparks in Copenhagen’s citizens, and even internationally as a rebel flag during the European and Danish hegemony.

Not underestimating how different Christiania is from other places and communities in Copenhagen and the world, in our previous work with Christiania, we analysed different conceptualisations of Sustainability and compared them with the Doughnut Economics teleology, prospecting the present of those concepts in key Sustainability frameworks underlying DE, such as Planetary Boundaries (PBs) [15,16,109,118] and the UN Sustainable Development Goals (SDGs) [119]. We identified 4 non-redundant and highly recurring sustainability paradigms in this work, which we will introduce here, along with their history. See figure 11 for a diagram merging these frameworks and our conceptualisation of RCSR sustainability paradigms.



11- Doughnut for the Anthropocene (Raworth, 2017) Framework for framing Sustainability teleology (Morgado et al., forthcoming), according to two criteria: Planetary Boundaries (Richardsen, et al ,2023) and Societal Foundations. (defined by the SDGs (UN, 2015)). Between PBs and SGGs lies the safe and just space for Humanity - and the realm for Planetary Stewardship (Steffen, 2011)

In order to not underestimate how different Christiania is from other places and communities in Copenhagen and the world, in our previous work with Christiania, we analysed different conceptualisations of Sustainability and compared them with the Doughnut Economics teleology, prospecting the present of those concepts in key Sustainability frameworks underlying DE, such as Planetary Boundaries (PBs)[15,16,109,118] and the UN Sustainable Development

Goals (SDGs)[119]. We identified 4 non-redundant and highly recurring sustainability paradigms in this work, which we will introduce here, along with their history:

A. Resilience: Adapting to Environmental Change

Resilience in urban design underscores the capacity of urban systems to withstand, adapt to, and recover from environmental stresses and changes. Resilience is often characterized by its focus on the capacity to recover from shocks and stresses. This concept has evolved to not only include the ability to bounce back but also to adapt and transform in response to changing conditions. The emphasis is increasingly on proactive and preventive approaches to building long-term resilience, rather than just reactive measures.

- John Ruskin, in *The Seven Lamps of Architecture* (1849) [120], laid the early philosophical groundwork, advocating for the integration of natural aesthetics in construction, hinting at resilience against industrial disregard for the environment.
- Patrick Geddes expanded these ideas in *Cities in Evolution* (1915) [121], proposing that urban planning should organically integrate social, economic, and environmental factors, which were foundational for his early evolutionary perspectives on urban systems and for multi scalar thinking between global and local dimensions of urban planning.
- Lewis Mumford in *The City in History* (1961) built on Patrick Geddes' working principles [122], promoting designs aligned with natural processes and anticipating cities that adapt and recover from environmental stresses.
- C.S. Holling, a Canadian ecologist, is credited with formulating the ecological resilience theory. His seminal work, *Resilience and Stability of Ecological Systems* (1973) [123], introduced resilience as the capacity of ecosystems to absorb disturbances and still maintain their basic function and structure.
- Judith Rodin has become influential in applying resilience thinking to contemporary urban planning and disaster preparedness. Her book, *"The Resilience Dividend: Being Strong in a World Where Things Go Wrong"* (2014) [124], discusses resilience in the context of global challenges and is pivotal for modern resilience strategies in urban environments.

B. Circularity: Resource Efficiency and Waste Elimination

Circularity involves maximizing resource efficiency and eliminating waste through the reuse and recycling of materials in a closed-loop system. The concepts' focus is on minimizing waste and efficiently using resources by creating closed-loop systems that promote recycling and reuse. This paradigm is growing in focus as cities and businesses look to create more sustainable practices that reduce their environmental footprint and promote sustainability not just in terms of resource use but also in economic models.

- Kenneth E. Boulding's essay *"The Economics of the Coming Spaceship Earth"* (1966) [125] is foundational in conceptualizing what would later be known as the circular economy. Boulding presented the idea of the Earth as a closed system where sustainability depends on recycling resources and minimizing waste.

- Buckminster Fuller and Jaime Snyder emphasized and promoted comprehensive global resource efficiency management in *Operating Manual for Spaceship Earth* (1969) [126], advocating for a design philosophy that minimizes inefficient resource usage and waste.
- Hassan Fathy demonstrated practical and down-to-earth applications of circularity in *Architecture for the Poor* (1973) [127], using traditional materials and techniques for modern constructions that minimize waste and maximize resource efficiency in sync with natural systems and human needs.
- William McDonough and Michael Braungart advanced these concepts in *Cradle to Cradle: Remaking the Way We Make Things* (2002) [128], proposing designs that allow for continuous reuse and the elimination of waste.

C. Symbiosis: Bio-inspired, Collaborative Design

Symbiosis in sustainability involves designs that exist in a mutually beneficial relationship with the natural world. It is related to design schools such as Biomimicry, Bio-inspired Design and more recently with the concept of NbS.

- Ian McHarg's *Design with Nature* (1969) [129] explicitly incorporated environmental factors into urban planning, promoting a harmonious relationship between human settlements and natural settings as a form of symbiotic relationship.
- John Todd in *From Eco-Cities to Living Machines* (1994) [130] discussed architectural and urban systems integrating with biological processes, transcending their existence as artifacts towards artificial living systems.
- Janine Benyus' "*Biomimicry: Innovation Inspired by Nature*" (1997) [131]: Benyus popularized the idea of designing solutions based on biological processes, emphasizing learning and mimicking behaviours from living beings and systems, along with the patterns and processes inherent from their evolution to the environments we share.

The term symbiosis traditionally comes from biology and was first used to describe the living together of differently named organisms, but it has been applied to industrial and environmental systems by thinkers like Lester Brown in his work *Eco-Economy: Building an Economy for the Earth* (2001) [132], where industries and environments operate interactively, much like ecosystems.

Symbiosis in sustainability draws from its biological roots to promote cooperative interactions between different elements of a system. In environmental and industrial contexts, this often means designing processes where waste materials from one process serve as input for another, thereby creating systems that mimic natural ecosystems in their efficiency and balance. Moreover, Symbiosis refers to anti-anthropocentrism in sustainability discourse and to an ontological relationship of stewardship for Earth System's evolutionary success in maintaining resilient, circular and regenerative properties. Symbiosis seeks to leverage bio-inspiration processes to learn with Earth System's Science how to emulate these properties towards sustainability.

D. Regeneration: Net-positive Impact Design and Co-evolution

Regeneration involves creating designs that actively improve their environments, having a net-positive impact on people and the planet. Regeneration of human systems draws from resilience, circularity, and symbiosis paradigms to emulate living systems' capacity to not only withstand environmental impacts but to actively regenerate the conditions where life can thrive.

Permaculture, Organic Agriculture and Regenerative Underpinnings of Reimagining Settlements

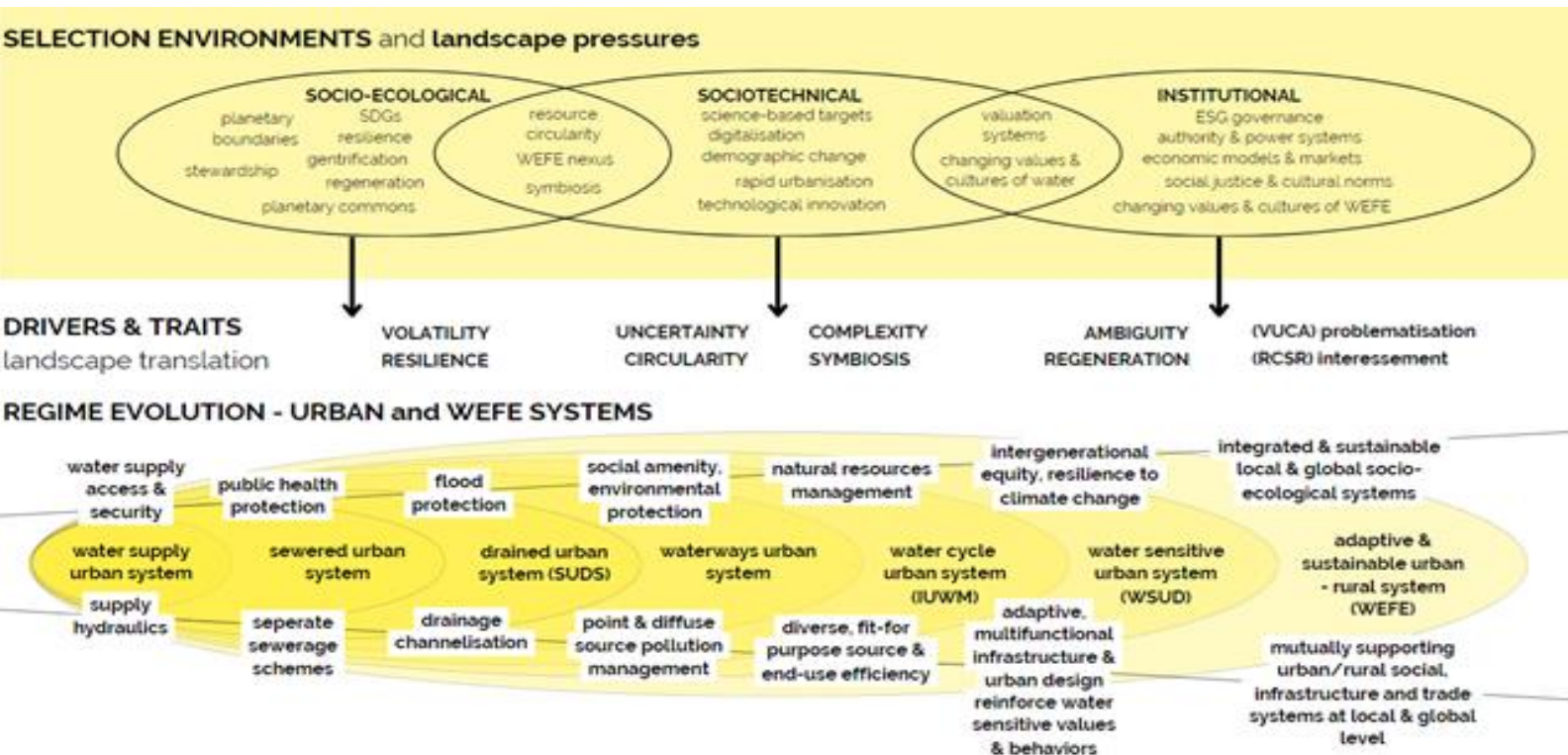
- Regenerative principles are deeply rooted in traditional agricultural practices and human habitat management, which have been employed by indigenous cultures for thousands of years before contemporary industrial production practices. Permaculture, agroecology, and agroforestry emphasize the interdependence and respect for natural systems and try to bring these traditional methods into contemporary sustainable food production. These methods are based on the principles of diversity, resilience, and sustainability that are intrinsic to natural ecosystems. Bill Mollison and David Holmgren were pivotal in conceptualising the permaculture movement in the 1970s. Their seminal work, *Permaculture One: A Perennial Agriculture for Human Settlements* (1978) [133], established a design system for sustainable living and land use that mimics the patterns and relationships found in natural ecosystems and bring them into urban settlement management for the development of permanent cultures of stewards of nature dedicated to regenerating ecosystems.
- Paolo Soleri introduced the concept of "arcology" in the 1970s. His experimental town, Arcosanti, initiated in 1970, focuses on creating self-sustaining habitats that minimize ecological impact while maximizing human interaction, illustrating a regenerative approach. Soleri's key work includes *Arcology: The City in the Image of Man* (1969) [134].
- Christopher Alexander's *A Pattern Language* (1977) [135] and *The Timeless Way of Building* (1979) [136] emphasize designs that are sensitive to their context, promoting a harmonious balance between human structures and their environments. His later work, *The Nature of Order* (2003-2004) [137], further explores these ideas, emphasizing the importance of creating living, healthy, whole environments.
- Robert Rodale coined the term "regenerative organic agriculture" in the early 1980s. His work emphasized promoting soil health and ecosystem restoration, aiming to create agricultural systems that are self-sustaining and improving over time. Key publications include his contributions to the Rodale Institute and *The Organic Manifesto* (2010) [138] written by his daughter Maria Rodale.

Emergence of Regenerative Design for Sustainable Development

- John Tillman Lyle's work in regenerative design provided a foundation for creating environments that restore and renew the resources they consume. His influential book, *Regenerative Design for Sustainable Development* (1994) [139], laid out principles for designing systems that actively contribute to ecological health, it was also the first work to explicitly relate the concept of regeneration to the one of sustainability.
- In 1995, the term "regenerative development" was formalized by the Regenesys Group. Building on Lyle's work, the Regenesys Group, including key figures like Bill Reed and Pamela Mang, and Ben Haggard introduced a framework for development that interweaves indissociably environmental, economic and social aspects on sustainability. Their most recent works include *The Regenerative Practitioner* (2016) by Reed and *Regenerative Development and Design: A Framework for Evolving Sustainability* (2017) by Mang and Reed. Continuing their influential work with the

Regenes Group, the authors contributed to the development of regenerative design principles and practices. Their works and educational efforts have been crucial in spreading regenerative ideas within the architecture and planning communities.

- Peter Calthorpe's *The Next American Metropolis: Ecology, Community, and the American Dream* (1993) and Sim Van der Ryn's *Ecological Design* (1996) advocate for urban designs that renew and revitalize their own energy and material sources, contributing to the concept of urban regeneration, the latter making explicit reference to the term regenerative development echoing Regenes Group concepts.
- Regenerative development has become a widespread concept breaching into sustainability regimes worldwide, as expressed in the publication *Doughnut for Urban Development* (DFUD) to change the Danish AEC sector's DGNB regime [15].



12 - Main Drivers and Traits to be Selected from Regime Evolution pathways, within the selection environment. The Regime Evolution of WEFE systems is documented in the work of Daniell et al., (2015), which we used (Morgado et al., forthcoming) to frame our conceptualisation of WEFE transitions, pathways, strategic scenarios, and visions.

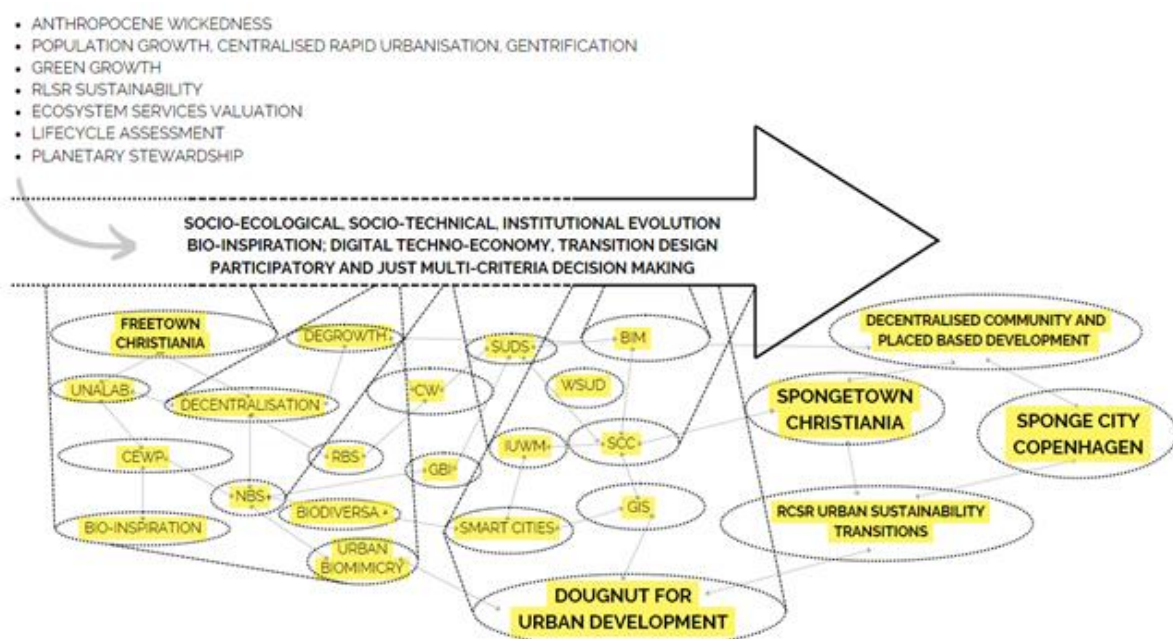
Sustainability paradigms, regardless of how they are framed, have been charting the trajectory of the discourse on the conceptualisation of sustainability and our understanding of connected phenomena (see Fig. 12) – they refer to a diversity of approaches to solve a problem which is understood through multifaceted lenses. Indeed, this diversity of perceptions can even be useful for green-washing – when one claims to be symbiotic, but failing at being circular, per instance, defeating the purpose.

Avoiding false flags in sustainability – colloquially known as green-washing - can be extremely challenging, especially when demagoguery and charlatanism are as abundant in the industry as errors due to ignorance or ill-founded problematisations leading to incomplete, faulty or even irrelevant solutions that only perpetuate systemic issues.

It might be difficult or even impossible to discern between those two drivers – but that does not imply that subjectiveness defeats any attempts at objective analysis of sustainability. Certification and standardisation demand therefore grows in the pathways for transition, as minimum pre-requisites for Sustainability-relevant gain momentum in planning within an ever-expanding and changing number of environmental, ecological, social, economic and institutional parameters, criteria and indicators across industries.

Places like Christiania and people like Christianites, who do not find themselves amused by the exclusionary technocracy of sustainability science, might find some solace in the fact that they are far from alone in this challenge. This is all the truer in the built environment sector. When we refer to AEC and Real Estate economic activities – we are referring to the constellations of human habitats in the Biosphere and connected ecological niches, all laymen are experts, and all experts are laymen in the holistic sense of this field that concerns one of the most universal experiences of human condition: inhabiting.

From all our infrastructure, none has a cumulatively crystallised locked-in path dependency preventing sudden changes of courses of action as the institutions that enshrine the power that be – independence in this sense is one of Christiania's main opportunities for bold investors who are interested in experimenting with different approaches to societal development, organisational change and institutional experimentation. Emotional attachments, norms, values, beliefs, property rights, regulations, high investment thresholds, among many other factors create a plethora Political, Economic, Social, Technological, Environmental, and Legal (PESTEL) barriers and drivers disabling or enabling our current capacity for achieving meaningful change in our ongoing trajectory deeper into the Anthropocene. Changing our urban systems regulatory, governance and valuation systems might be the most important tipping point for a multi-sectorial sustainability transition – since even other Land Use intensive sectors such as WEFE and Transportation, Mobility and Communication Systems are all inexorably interwoven and enmeshed with Urban Built Environment Systems and the AEC and Real-Estate sectors in general; along with the market and governance decision-making centres that command them.



13 - Pathways and Trajectories Stabilization in Spongetown Christiania, adapted from Geels & Raven, 2006. We analyse the relationships between this teleology and the translation of RCSR paradigms (Morgado et al., forthcoming).

The vast Urban Challenges (UC) posed by the imminent, ongoing and growing transgression of PBs is foreseen to only augment the scale of wickedness (volatility, uncertainty, complexity and ambiguity) of the Sustainability problem and related Anthropocene issues (we attempt to describe this complex multi-level phenomenon in Fig. 13.). PESTEL systems influence Urban Systems and function as key factors of the selection environment under which Sustainability Solutions are created, including NbS. The UN 17 SDGs create the most thorough worldwide agenda commitment to enact the necessary changes towards transition – with clear targets for 2030, which we seem to be about to transgress, according to the United Nations Environmental Program report, as we will elaborate in the following section.

Earlier this year, the UNEP published the Global Status Report for Buildings and Construction, titled *“Beyond foundations – Mainstreaming sustainable solutions to cut emissions from the building sector”*. The report’s press release states the following:

“The 2022 update of the Global Buildings Climate Tracker (GBCT) paints a concerning picture: the gap between the current state and the desired decarbonization path is significant. To align with the 2030 milestone, an annual increase of ten decarbonization points is now required, a substantial jump from the six points anticipated per year starting in 2015.”

The press release enumerates 7 key takeaways from the report for the transition in the AEC sector that is needed for the envisioned decarbonisation transition:

- establishing Zero-Emissions Building (ZEB) Energy Codes internationally – only 3 countries had them as of 2022.
- increasing the rate and impact of Retrofitting the Existing Buildings for energy efficiency – from the mere 1% to 5-10% per year until 2030.
- Passive Energy Design measures for all new buildings
- Mainstreaming Building Passports and other relevant data collecting tools
- Financial incentives for greater investment in Decarbonising the AEC and Real-Estate sectors – shifting towards Reuse, Circularity, Natural/Bio-based materials, Green Mortgages offered by banks – however, investment is estimated to fall across 2023 as households and businesses face higher borrowing costs and buildings face higher costs in construction, labour and materials.
- Develop a sound understanding of the AEC and Real-Estate sectors social impacts, by incorporating equity and diversity standards in their work.
- NGOs can raise awareness of buildings’ role in climate change towards inclusive and sustainable design approaches

But why is the built environment struggling so much in decarbonising, currently actually increasing its gargantuan emissions? According to the report, only 6% of the energy used in buildings in 2022 came from renewable sources; however, the energy intensity of the sector dropped by 3.5% - so why are emissions not dropping, but rather augmenting?

The ideological trend for decreasing the environmental load of the sector does not manifest in carbon emissions empirical reality, which instead reports an ever-growing carbon intensive sector. The likely culprits are rapid carbon-intensive construction technologies and materials backing ever growing urbanisation – as the UNEP 2024 report states quotes the World Business Council for Sustainable Development and ARUP report of 2023 “embodied carbon emissions of materials used in buildings construction are an important area for action due to their being around 50 per cent of the overall carbon emissions in new buildings”.

The superficiality in addressing data on embodied carbon emissions is quite concerning, if one does not want to sound too revolutionary or apocalyptic. The UNEP report states also that *“it is important to consider the role of embodied carbon emissions in the building sector [-un]fortunately, these are not being currently included in the GBCT due to the lack of a data set covering this portion of the emissions in the sector worldwide and through the timespan of the tracker.”* It is hard for one to fathom what is preventing the industry from mitigating this evidently extremely serious externality [140] without coming across as conspiracy-theory prone – most certainly the lack of data can be blamed, but so can the lack of willingness to acquire it.



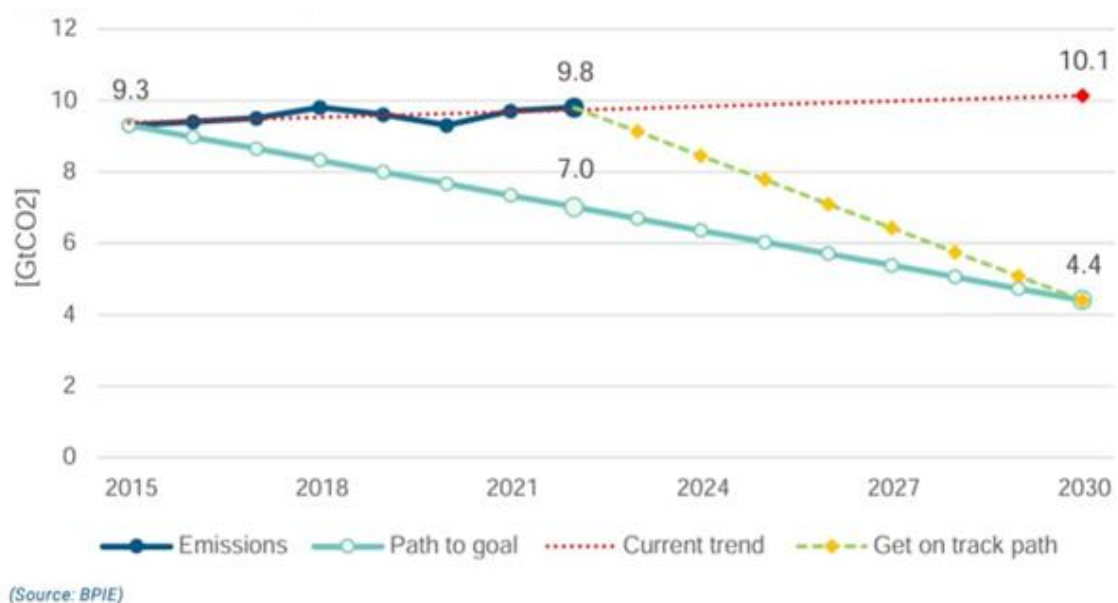
14 - UNEP 2024 | Building Sector Energy Intensity and Path to get on track to Agenda 2030

The Global Alliance for Building and Construction (GlobalABC) Roadmap states 4 key scopes of strategic action: (1) Embodied Carbon; (2) Operational Carbon Reduction; (3) Adaptation, and (4) Well-Being and Inclusion to Align with the Paris Agreement and Climate Action Pathways.

“Half of the buildings that will exist by 2050 have not yet been built. This is a major opportunity for the sector to reimagine the buildings of the future – buildings that prioritise resilience, renovation and reuse, renewable energy generation and low carbon construction, all while addressing social inequalities. Now is the time for governments and industries to follow up on COP28 promises and deliver real-word emission reductions through a true buildings' breakthrough.”

In other words, the magnitude of the human-built environments is expected to double – and, without embodied carbon changes to the AEC sector, 50% of the issue can be dealt through use of renewables in building operation and construction – where the greatest progress has been achieved regarding the carbon accounting of the industry. *“While energy efficiency measures are a high priority, they must be combined with material efficiency strategies. Embodied carbon emissions still represent more than a quarter of the sector’s emissions and are set to grow. The challenges of a changing climate also need to be taken on board – retrofitting existing buildings and designing new ones with climate extremes in mind is essential.”*

For one to understand the magnitude of the issue, it could suffice to say that cement is the second most used material globally after water. Cement is used in concrete, which, on par with steel, represents the global standard for building structures, along with the hybrid reinforced concrete. Honourable exceptions can be made as we see some recent development in structural alternatives such as structural engineered wood materials, earth, stone and other ceramic alternatives to concrete, bamboo, among other interesting niches. Decreasing embodied emissions means contending with the market supremacy in structural design and construction of steel and concrete.



15 - Observations of the CO2 emission of the global building stock’s operation and Path to get on track to Agenda 2030.

This empire, however, has only recent historical precedent in our AEC sector’s industrial technological and material culture. The relatively new hegemony of cement and steel as an incumbent regime might have sent temporarily traditional and local material-based construction techniques that occupied that podium for millennia back to the micro-level of heritage renovation projects and some maverick sustainability-prone communities. Not so long ago, however, as many buildings around the world which stand for centuries testify to, cement and steel were mainly structural reinforcement materials, and not the bulk of our structures in themselves. Per instance, it was claimed in the early 2000s that up to 30% of the human population worldwide still lived in buildings constructed through raw earth building technologies, the figure rising to up to 50% in developing countries – nowadays, recent reports account for 8-10% in developed countries and up to 20-25% in the developing ones [141].

Returning to our local context within this global scenario and selection environment for construction technologies, we will focus in our thesis on Christiania's role in changing design, engineering and construction cultures towards Bio-inspired and even Bio-based Urban Planning, tackling the combined issues of WEFE and Urban systems. We leverage RCSR paradigms of Sustainability and their inherent perceptions of the Sustainability challenges that encompass our common concerns regarding Urban Development in the Anthropocene. The previous research highlights the thought process we applied to our urban planning approach through a set of lenses that follows RCSR concepts in its teleology, ideology, ontology and epistemology and that was crucial to sprout the research questions we will introduce in the next chapter and that we devoted this thesis to illuminate with answers and a project that conveys a conceptual solution.

In our previous work, RCSR paradigms and a MLP on Urban Transitions led us to arrive at a somewhat novel definition of sustainability that we distilled from our past collaborative investigations with Christiania and the relevant literature illuminating these multi-level trajectories. It feels adequate at this stage to present our sustainability concept as a kickstarting point for our current investigation interests and masterplan proposal for Spongetown Christiania.

Sustainability: the Brundtland Commission's report, "Our Common Future," published in 1987, famously defined sustainable development as: "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [1]. Since then, the discourse spanned virtually every single discipline, and at least hundreds of attempts have been made at new definitions of the concept [2] and thousands of linked concepts emerged during the last four decades. Our propositional concept towards a new theoretical grounding of the concept of sustainability [142] understands its scope as a science [143–145] but transcends it as a set of inter-related transdisciplinary theories on different aspects or branches of philosophy, such as metaphysics, ethics, aesthetics and epistemology [146].

Within this work's context, Sustainability is an ideological field connected with multiple theoretical models in philosophy. Its ideas manifest the value, visions and methodologies of the RCSR paradigmatic principles, which are grounded by generating transition processes through holistic and heuristic approaches to practice in the pursuit of its goals.

The order of our proposed acronym RCSR stems from a matter of principle prioritization: first, protection against/adaptability towards environmental change - Resilience; second, environmental harm mitigation and cyclical resource management - Circularity; third, post-anthropocentrism and biological/ecological synergies - Symbiosis; fourth, net-positive impacts and systemic co-evolution - Regeneration.

As a set of goals or teleology [147,148], it means ensuring a harmonious balance between ecological integrity, social equity, and economic viability, enabling human societies and lifeforms to survive the Anthropocene and to thrive within the Earth's carrying capacity by establishing global agreements and commitments (SDGs) [16].

As a holistic approach, it addresses the overshoot of Earth's planetary boundaries [149,150] and strives to protect and nurture the Holocene's environmental and biospheric foundations for all humanity, acknowledging the value of the natural world's planetary commons [109] and the interconnectedness of life's entities and systems [151].

As a set of principles for justice and resilience [152,153], it recognizes the problematic need for revolutionary changes [154,155] in socio-cultural [156–158]); socio-economic [159], ecological

[160], techno-institutional [30,154] dimensions of anthropogenic, living and environmental systems [161].

As a methodology, it aims to organise human systems through poly-epistemological heuristics [162] to ensure the resilience of the Earth's living systems' circular [128] and regenerative [10] capacities and to foster transitions [163,164] through participatory, symbiotic, and co-evolutionary relationships [165] between humans, other living beings, and our common environments [166].

As a process or practice, it translates these changes through transitions [14,79,101] towards adequate ([167,168], adaptive [169,170], effective [14,29,43] and efficient [171] systemic solutions that can respond to volatile, uncertain, complex, ambiguous [172,173] wicked problems [174] across local-global levels and relevant timeframes [175].

As an ideology [176] it transcends practice and policy, weaving our values, norms and beliefs into the fabric of its ecocentric, more-than-human, community-oriented aesthetics, ethics and metaphysics [177]. As a vision, it perceives non-human, personal and collective agency, well-being and fulfilment as not being at odds with the health of our planet and human societies, but as quintessential pillars for biospheric stewardship and the co-evolution of human naturecultures and the ecology of their environments [109,178,179].

As a set of values, It advocates and strives for a world in which all individual and collective actions are informed by a deep awareness of their common role on the environment and society, fostering an ontology where Sustainability is not just a necessity in preventing the Earth from becoming uninhabitable [180–182]- but a better path to a meaningful and beautiful human life [183] in prosperous harmony with all beings [184].”

2.3 Regime Change and the Agenda 2030 Vision: Copenhagen as a Nature-based Sponge City

Drawing still from our previous work manuscript, we will in this section introduce the main drivers for profound change in the Danish DGNB-DK Regime [185] that NbS and Sponge Cities may come to represent for this built environment certification system [55,186,187]. For studying these potential transition trajectories, it is first and foremost necessary to present a meaningful and connected definition of Sustainability Transitions (STs):

Sustainability Transitions: transitions are "non-linear shifts from one dynamic equilibrium to another" and are studied by many different scientific fields. Transitions towards Sustainability underscore planet-wide systemic changes and their volatility, uncertainty, complexity and ambiguity (VUCA) traits or wickedness [113,172,173]- in connection with a) backcasting/forecasting past, ongoing, incoming and potential forthcoming changes; and b) the need of transforming anthropogenic and planetary systems towards sustainable futures (normative scenarios) [103,188].

The discussion surrounding possible conceptualizations of this term spans numerous and diverse schools of thought in philosophy, like idealist/cultural, institutionalist/political. It is also

present in technological innovation focused studies, alongside different system research types (socio-technical, socio-institutional, socio-ecological) and change processes investigations (socio-technical transitions, socio-ecological systems, sustainability pathways and inherent paradigms).

Critiques of socio-technical systems (STS) transitions research focus on its technology-centric view, limited engagement with socio-ecological and economic (distribution) systems, and a primary orientation towards the study change processes without adequately tracking sustainability outcomes, their safety and justice [29]. Socio-ecological systems (SES) approaches are, on the other hand, often accused of overly focusing on ecological and cultural/societal transformation, disregarding technological factors [51]. Ongoing research directions [189] the multi-dimensional and transdisciplinary nature of sustainability transitions and "commonalities can be characterized in notions such as path dependencies, regimes, niches, experiments, and governance" [175] (for a detailed exploration, see also [33], and cited authors in those works.

In the context of our thesis, we understand transitions as non-linear changes in Socio-Technical-Ecological Systems (STES) [51]. STES (or SETS) transitions are critical for the translation of the Sustainability concept and connected transitions in Anthropogenic systems relationships with [150] the planetary-level Earth System [109].

A case could also be made about the relevance of institutional systems for this framework, gathering realms such as Political, Legal and Economic dimensions of PESTEL, but the clear boundaries between these domains and Social Systems are not easily definable, if they even exist. However, Institutions do play a role in mediating Technological, Ecological and Social systems, and potentially exist as systems in their own terms or as a meta-system that binds them together. This definition of sustainability transitions underscores the mediator aspect of technological systems [32,51] in bridging human relationships with the socio-ecological and wider planetary environmental contexts - the whole/living/universal system. In the Glossary of our thesis, you can find the definitions we have collected on transition phenomena from these different authors and school of thought on STs.

We will now explore the latest development of the Danish AEC and Real-Estate sectors in enacting RCSR transitions. Sustainability involves a process that is commonly studied today as transitions, which – it is argued - can be engineerable and designable which is in the base of our novel field of studies in Sustainable Design Engineering.

When talking about Sustainability in the context of AEC design and engineering, one has to address the World Green Building Council (WGBC) [190]. They are the self-proclaimed authority in local-regional-global action network accelerating sustainability in the built environment”, composed by “70+ Green Building Councils, driving systemic changes”, with a tripartioned transition teleology:

- a. To decarbonise the built environment and deliver integrated sustainability solutions that: Address whole life carbon emissions of existing and new buildings.
- b. Enable resilient, healthy, equitable and inclusive places.
- c. regenerative, resource efficient and waste-free infrastructure.

The Danish Green Building Council spearheads this movement [191]. Their DGNB-DK Planet certification scheme (the most ambitious of them all, along with Diamond level) is the only framework for sustainability in the Built Environment thus far that conceptualises and aims to directly tackle all the Planetary Boundaries acknowledged by interdisciplinary experts of Earth's System Science. [15]

DGNB-DK

ORIGIN AND HISTORY

In 2010, The **Danish Green Building Council** was founded to promote the **sustainable development** of the Danish building sector.

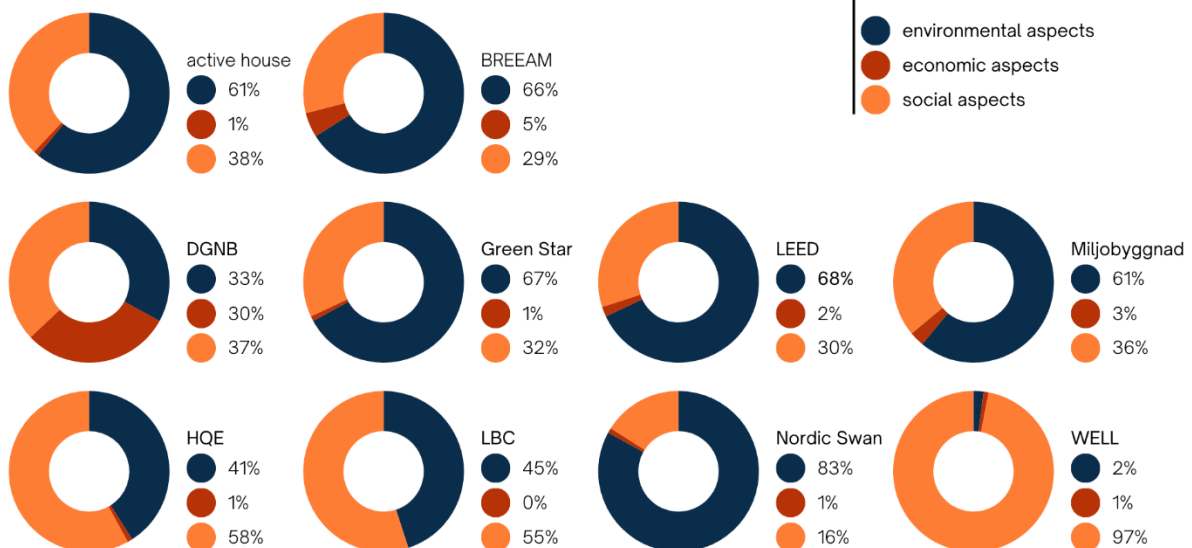
A consortium of experts from the building industry set up a **comparison of the four leading sustainability certification systems (BREEAM, LEED, HQE and DGNB)**.

In 2012, DGNB was chosen due to its **holistic and near-equal division of environmental, social and economic aspects**. The greater focus on economic indicators compared to the three other respective certification systems makes DGNB a more balanced certification system.



16 - DGNB-DK Origin and History – based on 3XN/GXN Guide to Sustainability Certifications.

DGNB-DK RELEVANCE

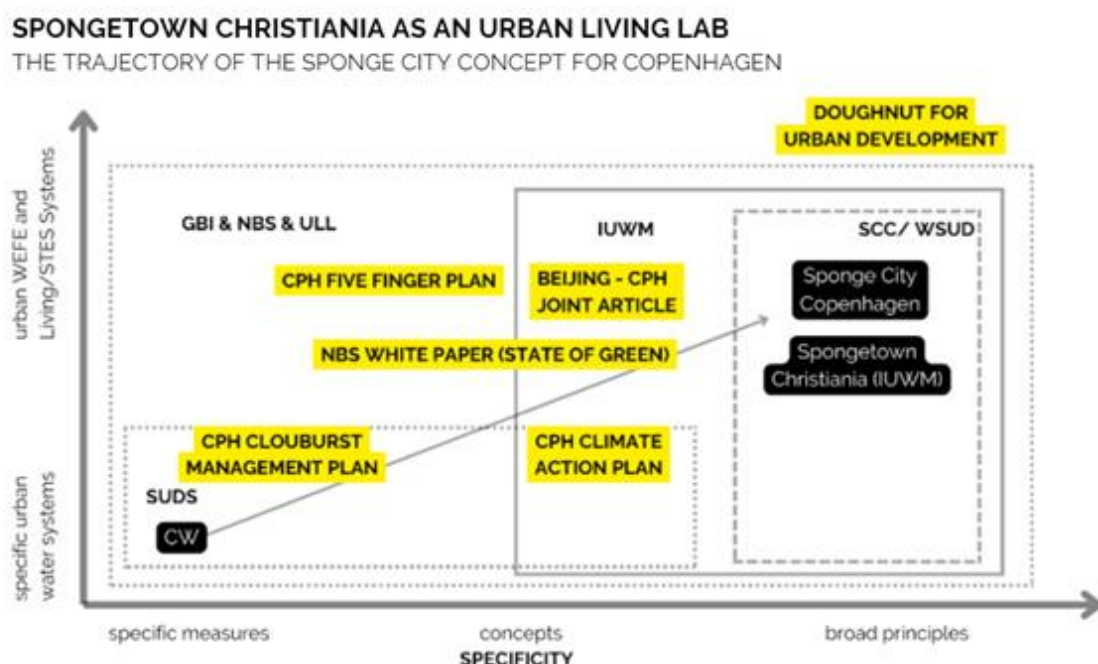


17 - DGNB-DK – Relevance for the AEC Sector Sustainability Regime based on 3XN/GXN Guide to Sustainability Certifications.

DGNB, the German Green Building Council scheme for sustainability certification was chosen by the Danish authorities due to its inclusion of Economic indicators and the relative 30% of weighing assigned to these aspects that are championed by Lifecycle Costing (see Figs. 16 and 17). Lifecycle Costing differs from conventional Cost-Benefit Analysis (CBA) by prospecting the full scope of value of assets, considering their economic life from a demand-side standpoint, extending towards the maintenance of the asset during operational lifetime and end-of-life scenarios. LCC is disregarded by most certification schemes available at an international level for built environment sustainability, which lead DGNB to be preferred by the Danish Green Building Council over LEED, BREEAM and other market leading schemes at an international level [19].

At a regional level, Copenhagen as the main city in the Hovedstaden and the Danish capital, has engaged in numerous activities echoing the leadership of its AEC regime. As analysed in our first publication, the 2011 Cloudburst Event made very notorious the cost of inaction regarding climate-change preparation and resilience strategies at the urban level in the Danish Capital [192]. Flooding damaged numerous assets and disturbed the Danish Capital thriving economic activities and made the ineffable impacts of a distant climate change very tangible all too quickly [36].

Following the significant 2011 Cloudburst Event, Copenhagen's proactive measures in its Architectural, Engineering, and Construction (AEC) regime demonstrate a concerted effort to incorporate NbS (NBS) and transition the Finger Plan towards a Sponge City urban plan. In our manuscript we outline several critical strategies and collaborations, synthesised in Fig. 18 regarding their scope of principles and level of systemic approach. The only major update in this current document is the inclusion of Lynetteholmen plans, which we have decided to include considering recent developments and documentation provided by the Copenhagen's portuary and coastal management real-estate organisation and urban development agency By og Havn.



18 - Systemic Focus and Specificity of WEFEE concepts, framework adapted from Zevenbergen et al. (2018) and adapted to our work in order to map measures undertaken at the regime level towards urban WEFEE transition in Copenhagen (Morgado et al., forthcoming).

1. Strategic Frameworks and Plans:

- **Climate Adaptation Plan:** Shortly after the 2011 event, Copenhagen implemented a comprehensive Climate Adaptation Plan [75] focused on improving the city's resilience to similar future events. This plan includes specifics on infrastructure upgrades to handle extreme weather conditions.
- **Cloudburst Management Plan:** Developed to specifically handle sudden, heavy rainfalls and mitigate flooding impacts by implementing green roofs, permeable surfaces, and other NbS and GBI projects [192].
- **The Finger Plan:** The city's historical and leading urban planning strategy and concept that promotes green corridors throughout the city, facilitating both environmental sustainability and urban expansion without compromising the ecological balance [193].
- **Lynetteholm Plan [58,60]** is a significant urban development and coastal defense project undertaken by the City of Copenhagen. This ambitious initiative aims to address multiple future challenges, including climate change, urban expansion, and environmental sustainability. The project involves creating a new peninsula in Copenhagen Harbor between Nordhavn and Refshaleøen, serving as both a residential and commercial area and a crucial part of the city's storm surge protection system.

2. Key Regulations:

- **Green Roof Mandate:**
 - Requiring new buildings to incorporate green roofs to enhance biodiversity and improving stormwater and urban heat island effect (UHIE) resilience. Over 40 green roofs have been designed and built since the mandate was first introduced in 2010, since green roofs have been made mandatory on most new buildings with a roof slope of less than 30 degrees. Green roofs are a key component of Copenhagen's strategy to achieve carbon neutrality by 2025. The policy is part of broader efforts to enhance urban green spaces and integrate sustainable practices into urban planning. The city calculates that these mandates will result in 200,000 square meters of new green roofs being installed as NbS for new buildings. [194]
- **Sustainability Certification Scheme and Danish Building Regulations (BR-18):**
 - The requirement to calculate the building's climate impact applies to the construction of buildings which must also comply with the rules on the energy framework according to the building regulations. In addition, buildings with a heated floor area of more than 1,000 square meters must comply with a limit value of 12.0 kg CO₂ equivalents per m² per year.
 - Certain types of buildings, which have a justified greater need for materials and thus a greater climate impact, e.g. laboratories, sports halls and industrial buildings with a need for a heavy foundation, are covered by a special exception when calculating the limit value.

- Special conditions result from the building's location, function or similar conditions. Examples of special conditions are special soil conditions or high cleanliness requirements.
- The LCA calculation rules for buildings with special conditions can be found in Annex 2, Table 9 of BR-18[195].

3. Partnerships and Collaborations:

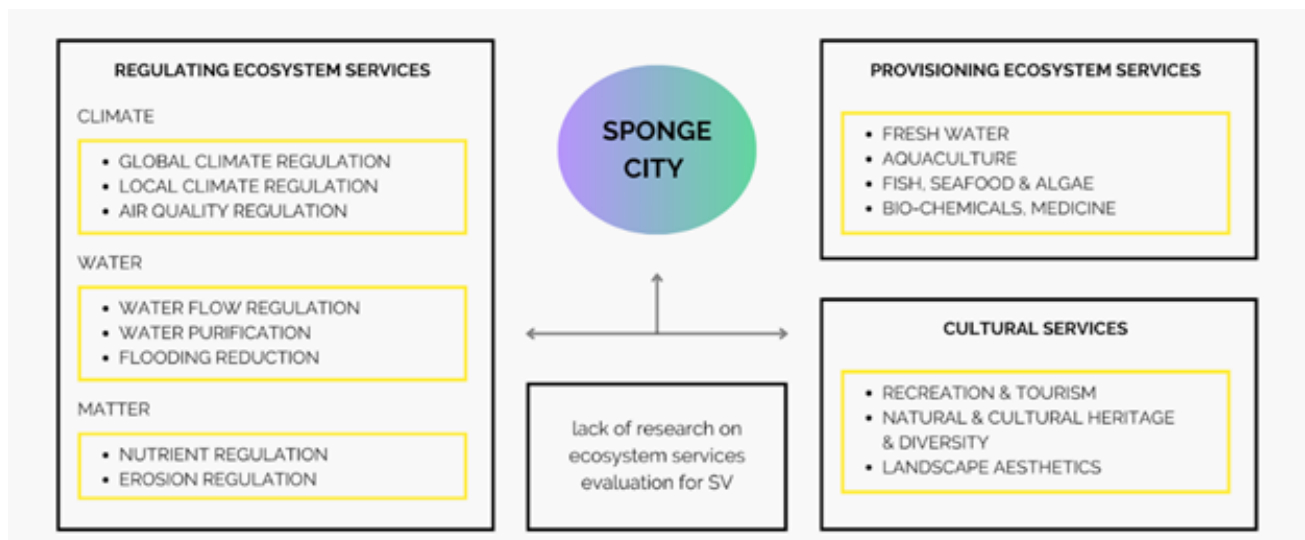
- EU Horizon Projects: Ramboll in Copenhagen was until 2022 a participant in the UNALAB consortium, focusing on urban innovation through NbS to enhance resilience. UNALAB and Biodiversa+ projects fostered international Urban Living Lab partnerships projects at a European level oriented towards NbS by promoting ULL pilot projects.
- CEWP: The Chin European Water Platform under these initiatives helped Copenhagen integrate international best practices and innovations in water management and biodiversity conservation. A key vehicle for intercontinental research on Urban Water, NbS, Green-Blue Infrastructure and Sponge Cities as announced by State of Green, a leading AEC non-profit organisation in the Danish regime [196].
- Copenhagen-Beijing Partnership: This bilateral collaboration of the Sister Cities towards becoming Sponge Cities is aimed at exchanging knowledge and strategies related to urban water management and sustainable urban development. [187,197]
- NbS in the Nordic Region: International organisations like the UNEA, IPBES and IPCC have identified NbS as a major pathway to solve biodiversity and climate crises. The newest report Working with NbS (2023) [198] from the Nordic Council of Ministers reviews 54 Nordic NbS and shows how more could be done in the Nordic countries. In Denmark, in State of Green's NbS White Paper (2002) [199], a key document outlining the practices and benefits of NBS, serving as a guideline and promotional tool to advocate for green solutions in urban environments.

The DGBN certification scheme is an adaptive assessment framework that was designed to adapt to an ever evolving cross-disciplinary framework for sustainability assessment of the Built Environment. In this work we will take a deep look at a major research gap underlying one of the strongest traits of DGBN – its Lifecycle Assessment (LCA) accountability system for the Built Environment, and its overlook on Ecosystem Services (ES), Natural Capital Assessment (NCA), and other components of the IUCN Global Standard for NbS, on chapter 4.

Despite the growing momentum of NbSs gaining traction in the sustainability agenda of Copenhagen towards a Sponge City transition, the explicit reference to ES that can bring net-positive regenerative impacts is nowhere to be seen. Carbon sequestration, a key ecosystem service, is not accounted for by the DGBN system, which strikes us as odd, considering the claims to measure sustainability at a territorial, geographical level typical of urban and architectural planning. These omissions in the assessment process obscure the capacity for accurate understanding of the sustainability of the built environments we are designing, whether

under DGNB or any of the other GBC sustainability assessment systems worldwide, to the best of our knowledge.

There are trade-offs to be pursued in the climate cycle of a building and accounting exclusively for negative impacts should not be our sole priority — even if accounting embodied carbon and GHG in general — and establishing hard limits is indeed a crucial aspect of the transition taking place. In this work, we focus also on the net-positive potential of urban transformation, which is the second reason behind our choice of Christiania for such purposes, as we will explore in the next section of the introduction.



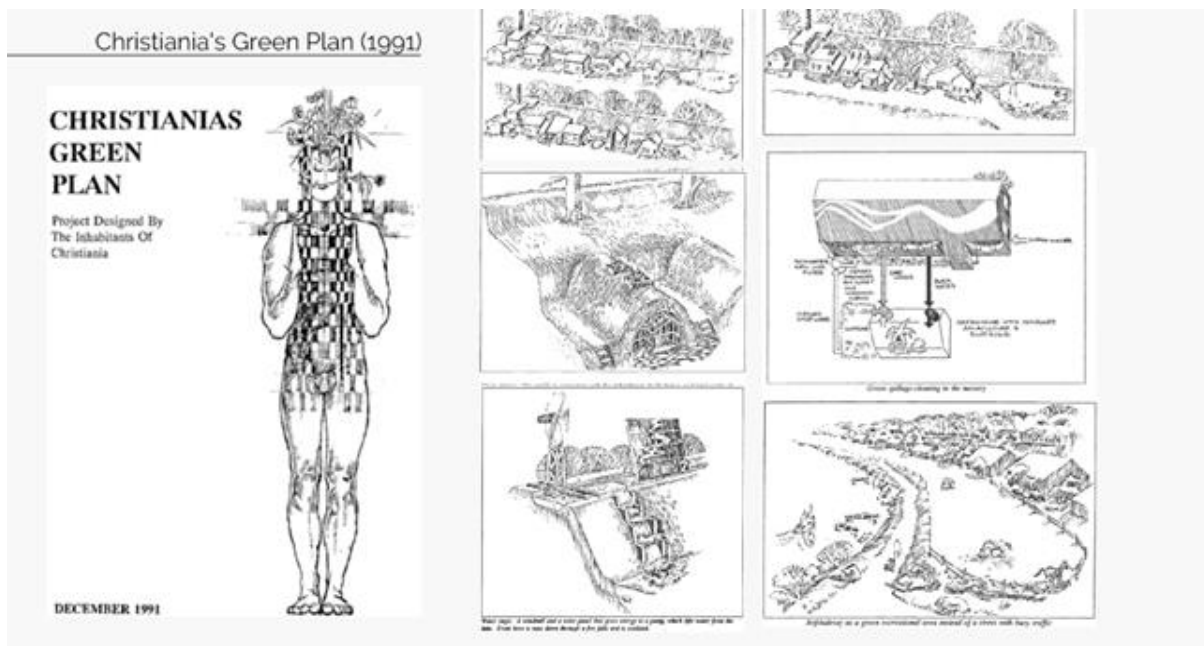
19 - Ecosystem Services of Sponge Cities, Knowledge Gaps and Barriers (Morgado et al., forthcoming)

2.4 Christiania's role in NbS for Copenhagen's Urban WEF E Transitions

In 1991, Christiania issued its very own ambitious local Green Plan – A Project Designed by the Inhabitants of Christiania [200]. The plan would easily appeal to John Ruskin's ideological inclinations towards place and community identity based restorative planning. A truly reactionary low-tech, bottom-up approach to construction by laypeople - coupled with a revivalism of the architectonic culture of the Nordic vernacular construction traditions

The intentions to repurpose the military fortifications and constructions went as far in their ambitions as to propose the creation of local micro-generation infrastructure for renewable energy. We had the privilege of talking directly to one of the authors of the Green Plan during our collaborative research with Christiania, in Appendix B.

The high hopes and dreams of the Green Plan would meet a short-lived ambition, as the Agency for Culture and Castles from the Culture Ministry, along with the Ministry of Defence would prohibit the alteration of the fortification ramparts where housing and the micro-generation system had been planned, using a combination of solar, wind and hydro power generation systems.



20 - Christiania's Green Plan of 1991



21 - Christiania's Lokalplan (2007) mapped the main territorial boundaries deemed relevant for Spongetown Christiania's management area as an ULL and urban planning device.

Christiania would not surrender the full scope of its sustainability ambitions. In 2007, the Lokalplan for Christiania (see Fig.21) presented a strategy of transforming the autonomous community and its place into a laboratory for alternative sustainable lifestyles in the city. Its adoption lagged and the plan would meet its obsolescence as the agreements for constructing a total amount of 30.000 square meters of new construction quickly became contested by the community who until this day strives for minimum development.

The current agreement in place is of 15.000 sqm for new construction and plans for the demolition of the housing and infrastructure projects that currently occupy the illegal areas near the bastions of the fortifications and the lakes of Christiania.

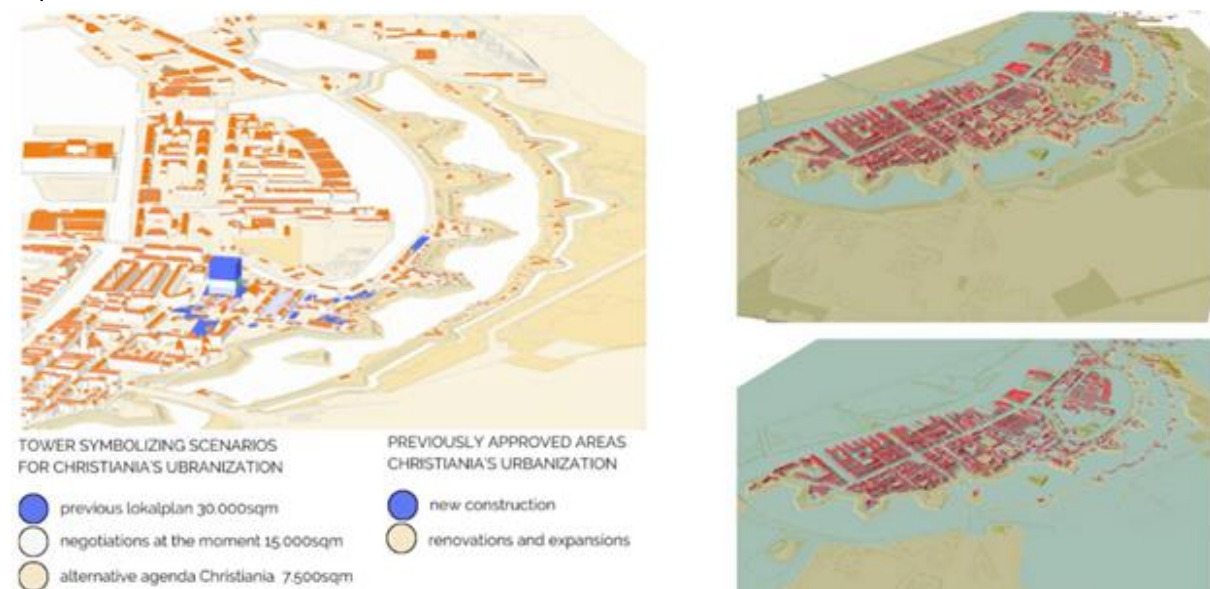
However, when Vandkunsten was at the helm of the project, in plans that can still be accessed through their website, a much more vocal ambition of interwoven Christiania's urban living

lifestyle with a proximity to the public interest territories (the fortifications and the lakes) was expressed by the community (see Fig.22). As Jørgen Løgstrup eloquently puts in our interview: “The city must decide if the ancient military history of the base that once existed in Christiania is more relevant than the current community and that inhabits it and the vision that it has for this place. If we are protecting heritage, which heritage is that? Which holds more value? The heritage of old military history or the recent heritage and history that brought this place back to life 50 years ago?”



22 - Vandkunsten's Response to Christiania's Lokalplan (2005)

As in most diplomatic missions, a way towards peaceful compromise potentially exists as a middle-way between the conflicting interests in this story. When looking at NbS, one can extend the canvas of territorial design away from the boundaries that confine urban development to the center of Christiania surrounding the ruins of what are now “ex-Pusher Street” and “ex-Pusher Square”.



24 - Key negotiation factors in Urban Development - urban density proposals from different enrolled actors in Spongetown Christiania (Morgado et al., forthcoming).

23 - Based on data from Climate Adaptation Plan, which predicts a sea-level rise of 226 cm. A high-water event of this level will statistically occur every 20 years in 2110, according to the DVR90 model used for the simulation (Morgado et al., forthcoming).

Taking place in a time of reinvention for the community, which we followed closely, along with the main developments in the sustainability discourse surrounding the built environment, our project addresses the major scenarios for STES change in Christiania, highlighted in Figs. 23 and 24 – 1) rapid urbanisation, and 2) flooding in connection to sea-level rise, excessive rainfall and storm surges.

The next chapter will introduce our work's methodology and prolong the literature review a little further — articulating this introduction with our previous manuscript which encompasses both this chapter as the following one. The methodology section will critically review DGNB now as the leading agenda for Sustainability in the Danish AEC regime transformation in combination with landscape drivers, which could be defined as a proto-regime or the birth of a new institution in the sector through its different scheme's role as boundary objects for legal compliance with sustainability standards [185]. DGNB is a Problem Structuring Methodology (PSM) [201] which defines what Urban Sustainability is in Denmark. In the next two chapters we will review this assessment methodology and the underlying design planning tools it suggests as what they implicitly are: a Multi-Criteria Decision Making (MCDA) framework based on an expert-led consensus [202,203].

In the methodology chapter coming next, we review and deconstruct the Sustainability PSM that underlies DGNB's MCDA, and we will inquire into its shortcomings in representing the RCSR Agenda for Christiania that we believe to be the most valuable for its Urban Development: a Spongetown Urban Living Lab for the pursuit of Ecosystem Services through NbS within the boundaries of Doughnut Economics.

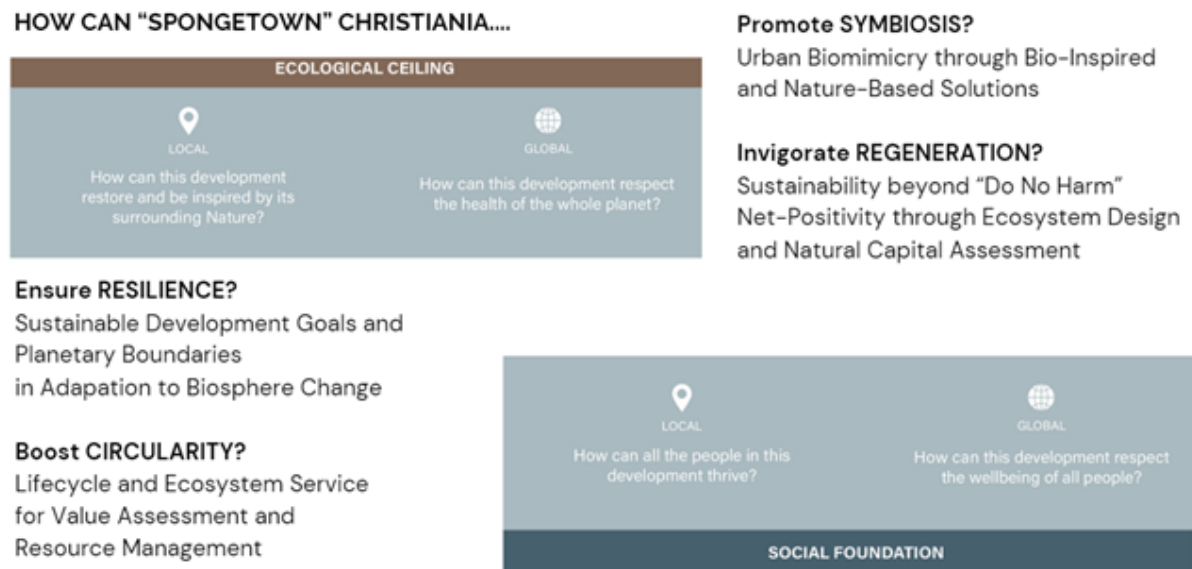
3. Research Design and Methodology

3.1 Research Questions

Our methodology structure discussed in this chapter lays out our Analysis, Discussion and Design chapters foundation and concludes the problematisation, by directing the context towards our specific project focus, introduced in the previous chapter. Keeping a broad focus on Urban WEFEE transitions [204–208] and a STES lens for the framing of these sustainability issues, we will in this section review the link between theoretical exploration and practical application of our work – starting by the broadest research questions that inspired our Research Design approach.

Starting at the highest landscape level of inquiry, the sections in this chapter inquire the relevance and methodology of translating RCSR sustainability paradigms and akin concepts that have been applied in our participatory approaches to Urban Niche Analysis work through a collection of project interviews and two surveys, one directed at the larger public who interacts with Christiania and Copenhagen, and a more focused one directed at locals and residents.

The following research questions (Fig.25) are structured and directed towards prospecting Christiania's role as an Urban Living Lab in advancing the RCSR, Sponge City and NbS agendas in Copenhagen, and lay the foundation for the follow-up Analysis, Discussion and Design chapters.



25 - Research Questions and the RCSR link to the Doughnut for Urban Development

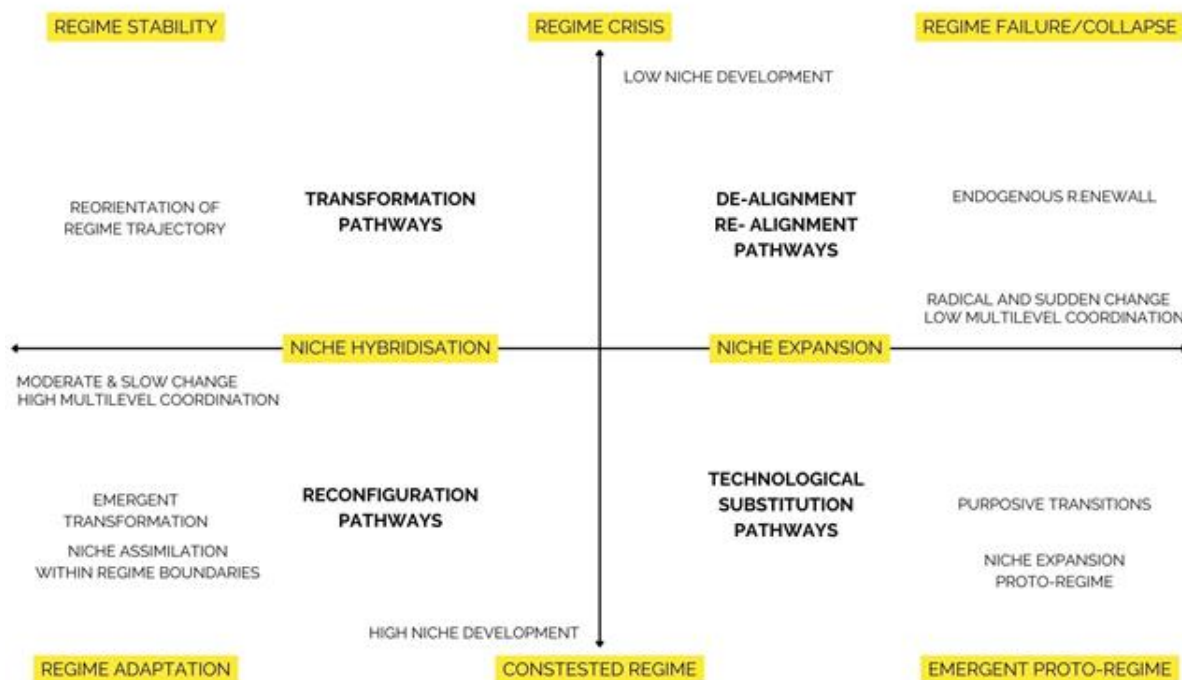
In the coming chapter 4, we will develop our Regime Analysis, in which we deconstruct the fundamental problematisation structures underlying the conceptualisation of DGNB, as an MCDA system applying SDG and PBs. Chapter 4 decodes, from a PSM standpoint, how the leading RCSR paradigms manifest in DGNB, and suggests a Transition Pathway for Christiania's Urban Planning that builds on and goes beyond DGNB criteria, while respecting its structure, quality levels and overall transition agenda – for a clarification on Transition Pathways typologies, see Fig. 26.

Preceding the next chapter, in our last section of the methodology, we also introduce the relationships between DGNB's PSMs and the main research gap identified within the scope of this research: the link between Ecosystem Services Assessment and Lifecycle Assessment (ESA-LCA). This link has been recognised as a valuable gap that could build consensus, if addressed, namely by the ISO, towards what has been framed as Natural Capital Assessment (NCA [209]), which we would prefer to rebrand as Whole or Total Value Assessment (WCA), as proposed by ECO 1.1 in DGNB-DK, instead of the original Lifecycle Costs German designation for the criterion. In chapter 5, we conduct this proposed Assessment to the Urban and Site Analysis of Copenhagen and Christiania, with a focus on NbS, Sponge City, DGNB, and ESA-LCA indicators.

While some of these acronyms might seem novel to many non-academic readers or laymen in these design and management fields akin to Urban Planning, these concepts all draw from growing fields of theory and practice which have given valuable contributions to sustainability practice. Our work decodes Sustainability Paradigms inherent to DGNB criteria, assessing their sufficiency in a practical urban design case-study.

Sustainability criteria is instrumental in articulating techno-economic, socio-ecological, socio-technical, institutional and bio-inspired design approaches to the Design of Urban WEFE STs. As we will seek to illustrate, by grounding these approaches in a specific case study, we endorse these design approaches to be fundamental for Urban WEFE Sustainability Transitions. Our Spongetown Christiania Urban Living Lab project and connected Masterplan proposal and Nature-based Urban Design Projects steer the paradigmatic change towards a complete RCSR PSM that could be embraced by GBCs such as DGNB in their TPs towards including NbS and the IUCN Global Standard in their assessment – an early demonstration of our urban strategy concept that followed our manuscript submission can be seen on Fig. 27.

In the following section (3.1.) We will first review the relevant literature on the state-of-the-art MCDA processes for Sustainability Urban WEFE STs and connected research progress and gaps (3.2.). We will then review this processes' different synergies with several PSM in the literature and their relationship to ESA-LCA and DGNB (3.3.). In the following section, we then use 3 PSM that we found relevant to charter our way between DGNB and Christiania's problematisations of Sustainability: SWOT, PESTEL and Scenario Planning.



26 - Types of Transition Pathways, Regime-Led/Incremental and Niche-led/Radical Types

In the following section (3.2) we will first review the relevant literature on the state-of-the-art Sustainability Urban WEFE STs and connected research progress and gaps. We will then review this processes' different synergies with several PSM in the literature and their relationship to ESA-LCA and DGNB (3.3.). In the following sections and chapters, we explore three PSM that we found relevant to charter our way between DGNB and Christiania's problematisations of Sustainability: SWOT, PESTEL and Scenario Planning.

We found in our theoretical grounding research now focused on MCDAA and PSM considerable overlap between SWOT, MLP SNM, and TM; and even between PESTEL and STES system frameworks, which we will address in the coming sections. Parallels were also found between Scenario Planning, ANT's MoT, STI, TM and SNM, and integrated into our MLP framework.

We will then anchor this scope of work on Urban Design Decision Making with our initial inquiries on the Multi-level Management broader spectrum of STs and STES (2.5). In the last section, we will review how Urban Master-planning can function as an OPP for Niche and Regime change, following the rising trend of change towards Whole Capital Assessment (WCA) of Built Environment Sustainability, which we believe that best materialises the RCSR paradigms previously discussed. To conclude this process, we will then discuss the core research gap addressed by our work in this research: Urban Ecosystem Service Assessment in Christiania as a key driver for NbS and the Sponge City and Doughnut agendas in Copenhagen's AEC regime.



27 - Spongetown as an emerging common agenda after the 2011 Cloudburst Concerns. Geels & Raven, 2006)

3.2 Mediating Multi-Level Urban Transitions between Christiania and Copenhagen

Regarding adoption of certification systems within the Built Environment's landscape, the World GBC, and different National GBCs worldwide have advanced numerous certification systems that have from their genesis tried to offer sustainability as an optional premium in the absence of formal legal frameworks for sustainability transitions in the built environment. In our previous manuscript we did a thorough review of landscapes, regimes and niches connecting RCSR paradigms, the SCC, NbS, ULL, and connected agendas.

The DGNB is the most consensual and effective form of regime agenda convergence in Denmark, functioning as an incumbent boundary object and interessement device promoted by the Danish GBC due to the particular focus it places in Economic Quality. We will now fully introduce this

certification system in function of diagnosed vectors for landscape and regime change. niches present in Christiania and Copenhagen alike that can help us steer, manage, plan and design relevant boundary objects as translations that can influence this envisioned transition's tipping points.

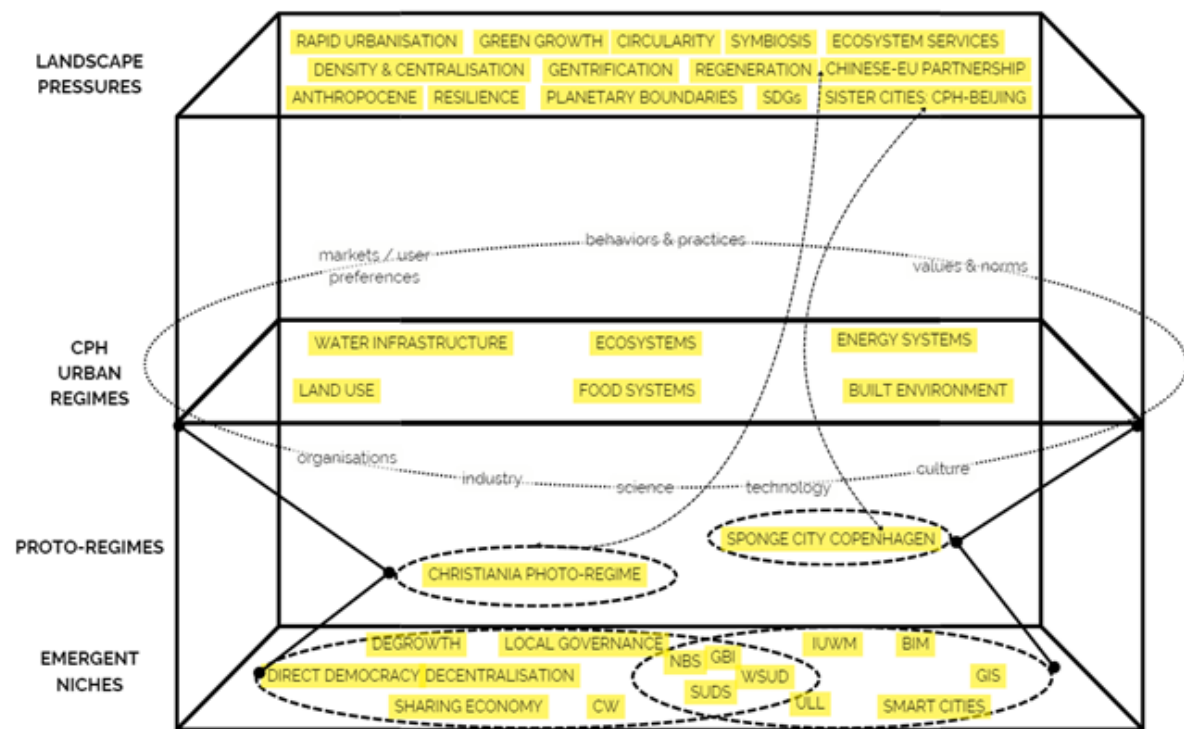
In Denmark, as reported by 3XN/GXN (as previously showed in Figs. 16 and 17), an internationally acclaimed architecture studio located across the canal that delineates Christiania's Northwestern shore, in their Guide to Sustainable Building Certification, claim that the most widely used systems are the Nordic Swan system together with the German DGNB system. Other international systems such as LEED and BREEAM the company states, are also present in the Danish market. However, DGNB has been outranking all of those recently being adopted in the most ambitious urban developments in Copenhagen for which the DGNB Gold and Platinum projects of Nordhavn and Sydhavn Copenhagen neighbours testify to, both certified Districts with numerous certified buildings.

In our previous work we have framed the multi-level dynamics of Urban WEFE transitions in Christiania. We have diagnosed their pioneering adoption of NbS, treating them as alternative viable solutions in comparison to their urban context in the city of Copenhagen during the end of the past century. Promoting their continued development, we will on chapter 5 diagnose scenarios, visions and analyse plans for future sustainability transitions (STs) that Christiania's ongoing Lokalplan negotiations holds in store for this rather unique neighbourhood in the city.

We resorted to semi-structured interviews, analysis of urban planning and infrastructure regulation documents and research articles to frame the relevance of multiple design approaches and nature-based urban solutions for participatory and sustainable development. Regarding urban development, in our collaborative work with local inhabitants and community-led organisations in the real-life setting of Freetown Christiania, we explored potential infrastructure systems innovations present in this radical community, famous for its alternative sustainability agenda in Copenhagen – and we attempted to prospect those through an internally conducted survey to broaden our scope of insight and diminish the bias of talking directly with NbS project planners, practitioners and Christiania's organisational leadership in environmental and sustainability projects.

We applied a non-dogmatic assembly of concepts from multiple schools of sociotechnical thought that comprise the STES framework, spanning the Multi-Level Perspective on Sustainability Transitions (MLP), Transition Management (TM), Strategic Niche Management (SNM), Socio-technical Imaginaries (STI) and Actor-Network Theory's (ANT) Moments of Translation (MoT).

MLP was crucial to conceptualise Christiania's standpoint as an alternative socio-technical-ecological system (a niche) in Copenhagen (which stands under this understanding as an incumbent regime). Governance shifts, AEC market adaptations and academic research reinforce the relevance of Christiania's early experiments, but global STES impact and transition trajectory is not well assessed or decided, despite how notorious the community has become in academic circles, especially in Urban Studies. We attempted to translate these multi-level dynamics in Fig. 28.



28 - Describing multi-level interactions bottom-up and top-down pressures exerting influence over the Copenhagen's Regime, adapted from Geels 2020.

Lack of data, research and development may sabotage Christiania's claim in ongoing urban planning negotiations with the municipality and other relevant ministerial and private stakeholders. The broader regime organisational constellation may also unknowingly fail to recognise the potential of NbS in Christiania, for lack of documentation, risking a scenario where local solutions are assumed to be worthless or altogether ignored, and a pathway that fails to tap the inherent NbS potential ignored altogether. This research is directed to fill that strategic agenda alignment gap with solution pathways that create simultaneously venues for compromise and innovation.

Initiating the mitigation of this problem and knowledge gap with the people of Freetown Christiania, in our previous work we collaboratively documented multiple NbS (NbS) implemented in their grounds and adopted by the inhabitants over the last four decades. We concluded that Christiania not only gathers unique conditions for being an Urban Living Lab (ULL), but also that it has been pioneering the behaviour of one, before even this urban and territorial ST experiments terminology existed in academic, private and governmental circles.

Christiania is a beacon of NbS in Copenhagen, with technologies that are seldom found in the capital, such as its Reed-bed Systems (RBS) that function as Constructed Wetlands (CWs) [210] for wastewater treatment, on pair with composting toilets, green roofs, urban agriculture, biodiversity projects, soil management. Outside NbS, Christiania has a Recycling Center promoting resource circularity, and institutional agreements towards sharing markets, access policies over property rights, among other pioneering urban experiments that profoundly impact its social and economic reality, which is echoed by the public perception of the Freetown, as we will see in our survey analysis later in Chapter 5 pertaining to Christiania's urban analysis.

However, its decentralised nature and technocentric-development aversion standpoint have prevented adoption of highly sophisticated ICT synergies for NbS impact and performance monitoring. The case-study offered a nuanced perspective on the technological development trajectory of NbS, where the community advocates for a slow-technology (see interviews A.4, A.11, A.15, A.17) approach to NbS. Beyond conventional technical and valuation barriers, Christiania embodies a protective space that dismantles some of the institutional barriers to systemic innovations for sustainability, where radical sustainability paradigms sought refuge in their early days in Copenhagen, such as degrowth, decentralisation, and even nature-based agendas.

Our work binds these STS and SES methodologies as structural components of our RCSR paradigm for a conceptual design of Christiania as a Spongetown. Understanding STES systems evolutionary, dialectic, cyclical and teleological motors of change as a novel theoretical framework to decode Sustainability, as we have defended in the manuscript in Appendix A.

The RCSR sustainability paradigms for STES change to be a compatible vision with Raworth's Doughnut Economics and the broader cultural and institutional change drivers that stem from the adoption of Planetary Stewardship and Sustainable Development Goals (SDGs) within Earth System's boundaries. RCSR paradigms translate into development agendas the following needs and/or desires:

- the need/desire to achieve anthropic and biophysical/ecological resilience to broader environmental change, or **Resilience**.
- the need/desire for wise, just and cyclical resource management, or **Circularity**.
- the need/desire for a post-anthropocentric focus on systemic synergies of anthropic and ecological systems, or **Symbiosis**.
- the need/desire for net-positive socio-technical-ecological systemic development in accordance with environmental co-evolution, or **Regeneration**.

3.3 Multi-Criteria Decision Making and Problem Structuring Methodology

RCSR sustainability paradigms and the philosophical inquiries underpinning them may yet lead to the development of further indicators, criteria and perhaps even paradigms for sustainability transitions. As we have documented, a crossfire of diverse schools of thought has been populating the field with an ever-changing vocabulary of terminologies and a plethora of methodologies and theoretical underpinnings, leading to an ever-changing framework.

Life Cycle Assessment (LCA) of the built environment and Urban Ecosystem Services Assessment (ESA) [211–213] stand out as the main scientific analytical frameworks for application in the field of sustainable territorial design spanning WEFE and urban systems.

Indeed, these methodologies exist at the root of multiple certification systems within the AEC sector and governance agendas for urban sustainability transitions worldwide. There is a tendency to include more and more indicators to inform assessment tools in sustainable design,

and weighing methodologies are diverse in the assessment of the built environment sustainability.

In this realm, through international GBCs in the private sphere, along with multiple Public-Private-Partnerships (PPPs) [214] extending also to non-governmental and non-profit organisations, MCDA is a growing field of studies in connection with the leading practices to find heuristic compromises between disciplines and common agendas for strategic definition and goal setting – key aspects of SNM and TM navigating the problematic wickedness of STs.

Wickedness hinders decision-making through VUCA factors, which is why Specific, Measurable, Actionable, Relevant, and Time-Bound (SMART) mechanisms have often been deployed for the control of Science-based Targets (SbTs) [147] and their variables – defining them and establishing them as key point indicators (KPIs), therefore trying to predict change, to assure certainty, to simplify complexity and to define non-ambiguous terms and strategies with clear boundaries, processes and goals. Such endeavours intend to produce well-formulated understandings of the problem, as a base for adequate, adaptable, effective and efficient solutions. DGNB applies this process to its multiple schemes – defining minimum KPI pre-requisites for quality in strategic criteria in its agenda.

However, MCDA is riddled with a plethora of different methodologies for context analysis and strategic definition [201] which are at odds with trade-offs between, on one side, always trying to broaden the scope to make the decision process as comprehensive and integrative as possible; and, on the other, limiting the VUCA factors of the decision-making process towards a reasonable capacity of time-bound heuristics typical of Agile and SMART project management practices [215,216].

The VUCA of inter-systemic domains of human development and transdisciplinary fields of design and engineering studies is in our work understandable in terms of systemic wickedness by opposition to dynamic equilibrium or system predictability, alluding to the elusiveness of sustainability problem-solving.

SMART teleology has been applied within urban planning strategic practices in order to materialize with decisiveness the often fuzzily diagnosed Strengths, Weaknesses, Opportunities and Threats (SWOT) across Political, Economic, Socio-Cultural, Technological, Environmental and Legal (PESTEL) dimensions [217]. SMART, SWOT and PESTEL assessments of design contexts under wicked conditions do not avoid ill-structured, mono-disciplinary, supply-sided, top-down problematisations – and they share this problem and interest in common with MCDA [201].

MCDA methods for weighing of factors impacting the decisions over what sustainability of urban designs should look like, follow a wide range of strategic and analytical structures for problematisation. Contemporary science-based problematisations and assessment are tendentiously infused with LCA and ESA and Participatory PSM and MCDA to activate NbS through Urban Living Labs in Territorial Management, Urban Design and Infrastructure Planning.

Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) [203,217–219] are the most often used outlooks developed to weigh stakeholders' perceptions in MCDA of urban potential. These expert recurring methodologies are often criticised for lack of stakeholder involvement and analysis. PSM are often used to ground MCDA on participatory understandings - frameworks like SWOT, PESTEL, Scenario Planning, and Stakeholder Analysis are often used to structure relevant criteria and relative weighing in the decision-making process. Our work does

not have the scope to discuss the different nuances on how these different approaches can influence participatory criteria weighing and defining, but we merge these different approaches in a loose-ended intuitive manner due to the variety of approaches we used in our project in relationship to STS and SES fields of study. We explain the broad methodological inquiry underlying our MCDA revision of IUCN and DGNB in Chapter 4, in Fig. 29 and Fig. 30. In Fig. 31 we explain the timeline of activities we followed this semester in connection with this methodology.

METHODOLOGICAL SUMMARY

MULTI-CRITERIA DECISION MAKING

- DGNB PLANET CRITERIA BASIS FOR ANALYSIS
- URBAN TRANSITIONS DESIGN SCOPE
- WATER, ENERGY, FOOD AND ECOSYSTEMS (WEFE)
- ECOSYSTEM SERVICES AND LCA RESEARCH GAP
- CO2 EMISSIONS (LCA) AND SEQUESTRATION (ESA)
- NATURE-BASED URBAN LIVING LAB OPP PROPOSAL
- NICHE FOR SPONGE CITY COPENHAGEN EXPERIMENTS

PROJECT DELIVERABLES

- URBAN AND SITE ANALYSIS
- DGNB PLANET MCDM ANALYSIS
- NATURE-BASED SOLUTIONS POTENTIAL
- URBAN LIVING LAB SCENARIOS AND VISIONS
- MASTERPLAN PROPOSAL



29 - Methodological Summary and Illustration articulating imaginaries and insights from key stakeholders in our previous interviews regarding urban development possibilities and desires for Christiania's urban future with Nature-based Solutions

Regarding our sociotechnical Multi-Level ANT approach [80,220], Scenario Modelling (SM) [102,103] and Cognitive Mapping,[201] echo parallels with sociotechnical approaches such as STI and ANT respectively, focusing on (1) imaginaries, visions, scenarios, and (2) the cognitive processes underlying actor-network's MoTs. Agile management (curiously sprouted from the architects Christopher Alexander's work [135,137] approaches echo the iterative learning, experimental process and trajectory-recalibrating agenda alignment of adaptive management advocated by TM, SNM and ULL participation principles. Furthermore, SWOT, by framing internal (Strengths and Weaknesses) and external (Opportunities and Threats), endorses an ontology like MLP regarding how systems behave and relate to each other's selection environments. Despite the diversity of nuance between all these methodologies', we believe them to be heuristically relevant in navigating the wickedness that MLP leads us to perceive in the domains of systemic transitions and evolution.

URBAN TRANSITION FRAMEWORK AND APPROACH

"SPONGETOWN" CHRISTIANIA AS AN URBAN LIVING LAB

EVOLVING THE CHRISTIANIA NICHE:

Nature-Based Solutions for a Sponge Neighborhood in CPH

DOUGHNUT ECONOMICS: A RISING URBAN REGIME

Sustainable Development Goals and Planetary Boundaries

BEYOND ENVIRONMENTAL DAMAGE MITIGATION:

Resilient, Circular, Symbiotic and Regenerative Paradigms

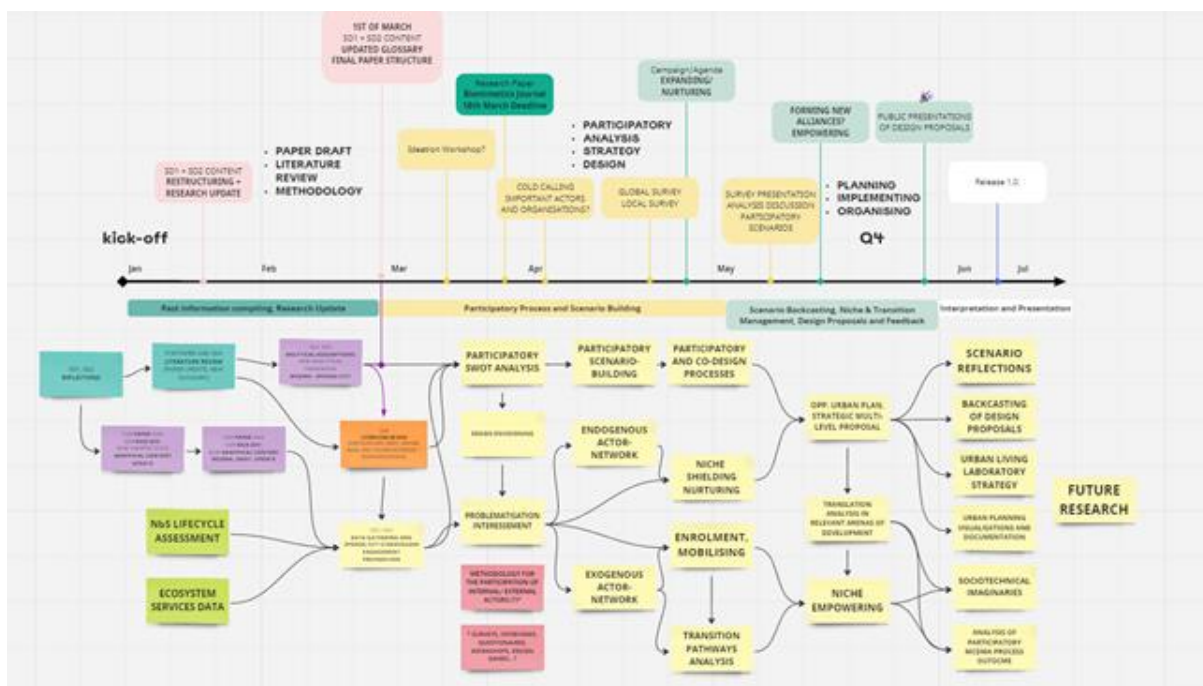
NATURE-BASED SOLUTIONS FOR NATURAL CAPITAL:

Life Cycle and Ecosystem Services Assessment Integration

Boundary Object for Urban Living Lab:
Certification with **DGNB-DK PLANET**



30 - RCSR Urban Transitions Framework and the Doughnut for Urban Development



31 - Project Calendar and Tasks

3.4 Multi-Level MCDA through SWOT, PESTEL and Scenario Planning

DGNB itself underscores the usage of hybrid problematisations that are measures through different criteria across its quality levels. Cost-Benefit Analysis (CBA), SM, LCA, among others are integral components of its structure. PESTEL – apart from Political and Legal domains – integrates the frameworks quality levels; SWOT could be used to navigate trade-offs in the system – and made more objective through the objective KPIs of the criteria in the different assessed qualities.

We integrate these methods (SWOT, PESTEL and Scenario Mapping) in the assessment of the pathways for trajectory of change both in DGNB and Christiania's strategy – using the Masterplan as a boundary object [221] but also as an interessement device [222] towards promoting RCSR sustainability paradigms on both the niche and the regime sides of the equation. We will seek to inquire the usefulness of ESA-LCA as a relevant economic valuation argument for Christiania's urban planning. ESA is assumed to be able to cope with many of the current externalities of Christiania within a DGNB problematisation scope. Including ESA and LCA might be a common procedural channel for IUCN and DGNB merger as we will see in the next chapter. We believe that such a process cross-pollination can be the deal-breaker for an RCSR transition tipping point [32], by integrating ESA and LCA in DGNB's Economic Assessment [209,211,213].

3.5 Multi-Level STES Management of Transition Pathways, Translations and Imaginaries

Regarding the selected tactics and methods applied to the analysis and design process in this thesis, introduced, and now explored in detail, in Chapters 1 and 2, respectively, we have continued our previous learning strategy of our first manuscript. We focused on keeping a networking and agenda-defining processes, which were documented qualitatively and ethnographically through observant-participation in our previous publication, and in our Appendix B to this thesis.

We kept these methods for our stakeholder engagement process collected from events organised for project development, where we sought to empower the community's agency and mobilise a newfound sense of collective ownership of the agenda that underlies our design experiment for Spongetown Christiania. In this thesis we now expand towards quantitative STES data collection through surveys directed to different types of stakeholders – local inhabitants, local neighbours, citizens of Copenhagen, Danes in general, and overall users and visitors of Christiania. The survey focused on key aspects of our work described before such as the SCC, NbS, ULL and Integrated Urban Water Management (IUWM) within RCSR transitions for STs impacting Copenhagen's WEFE Nexus.

The results of our survey were used for a preliminary agenda-steering meeting with local inhabitants and key decision-making actors such as Christiania's Building Office and Secretary – and they were key to structure the findings of our following Chapter 4, about IUCN and DGNB. We presented the collected data from surveys and public documentation and accessible databases to further refine the weighing of factors in our MCDA into a strategy that reflects

Copenhagen's and local Freetown interests, by consulting with a broader network of stakeholders. After this phase, we designed our own visions and scenarios for Christiania urban planning, attempting to reflect the community's needs, desires and their strategic understanding of common matters of concern, translating these into indicators and weighing criteria. We held a second meeting to wrap up the process with our proposed solutions for the masterplan. We analyse this process and the obtained results for our masterplan proposals in Chapter 5. Fig. 32 highlights the Survey posters we used to collect said information.



32 – the survey posters that we put around Christiania and online, for more information see Appendix B

In Chapter 3 we document our STES masterplan guidelines and proposals for Christiania's built environment and landscape design by analysing IUCN and DGNB. We apply the terms and methods reviewed and defined in our first 2 Chapters for RCSR urban experiments in the design of STs to structure our problem-solving approach in that chapter. We then use the participatory process described in Chapters 4 and 5 to apply criteria to weigh different indicators for Christiania's urban sustainability disclosed in the conclusion of Chapter 3. In Section 4.1, we discuss different envisioned trajectories, scenarios, imaginaries and translations underlying the weighing of indicators such as ES and LCA in our urban design and organisational management proposal. In Section 4.2, we discuss how translation of matters of concern was converted to weighing of indicators, through collective problematisation and interestment, towards enrolment and mobilisation. In Section 4.3, we propose masterplan scenarios, design solutions and recommendations for the obligatory passage point (OPP) that the Localplan for Christiania represents for Spongetown Christiania's ULL experiments.

In Section 4.4 we discuss envisioned scenarios for trajectory change, steering transition pathways and further recommendations for the management of our proposed urban experiment.

3.6 Urban Masterplanning as an Obligatory Passage Point for Nature-based Transition Pathways: the case for Ecosystem Service and Lifecycle Assessment integration (ESA-LCA)

In the integration of NbS and ES in Planning to address Urban Challenges, the causality links between the former these three aspects (specific technologies and services they provide) has been substantially qualified, but still lacks tangible quantification of numerous aspects and potential (see Fig. 33 for examples). The nexus shared between these two socio-ecological realms and specific Urban Challenges (UCs) (including institutional and sociotechnical aspects) is still in its infancy [223]. Sustainability Indicators for the Urban Environment and the Socio-Ecological Systems that support them often require extensive knowledge resources and sophisticated cross-disciplinary methods for weighing the relevant criteria for decision-making.

Land Use in urban planning is a key factor for NbS uptake in urban systems [108,223,224]. Urban Planning typically dictates what economic activities can be conducted, by assuming social, environmental and economic impacts in urban and wider geographical and territorial systems – Land Use is also a PB, making it a boundary object for the planning of NbS and ES.

Rapid and centralised urbanisation, once linked with a rural exodus propelled by the promises of the centralised progress experienced in urban life, is now understood as both a key driver and symptom of the imbalances underlying the sustainability crisis that affect Humanity's relationships with Earth's Systems [225,226]. Could wetlands, forests and other crucial ecosystems compete against the pressure of urbanisation pressure in the urban economy? Within the current externality ridden valuation process of land assets in urban territories, most likely that is not the case – but methodologies like ESA of NbS promise to reverse this situation through economic regulation frameworks like the EU-ETS.

CHRISTIANIA AS AN URBAN LIVING LAB SUSTAINABILITY BEYOND DGNB CERTIFICATION

SWOT-PESTEL ANALYSIS of

Current Problems and Matters of Concern:
through Perception of Strengths, Weaknesses, Opportunities and Threats (SWOT) in Political, Economic, Social, Technological, Environmental, and Legal (PESTEL) Factors of Urban and Ecological Systemic Relationships between Copenhagen and Christiania

- **URBAN CHALLENGES (UC)**
- **URBAN VALUE AND NATURAL CAPITAL**
- **NATURE-BASED SOLUTIONS (NBS)**
- **ECOSYSTEM SERVICES (ES)**
- **LIFECYCLE OF BUILT ENVIRONMENT**
- **PLANETARY BOUNDARIES**
- **SUSTAINABLE DEVELOPMENT GOALS**

Types of Perception and Assumptions to test:

- 1) UC cannot be mitigated by, ES, and therefore NBS



- 2) UC cannot be mitigated by, ES, but influences NBS



- 3) UC might be mitigated depending on NBS implementation



- 4) UC can be mitigated by ES, and therefore by NBS



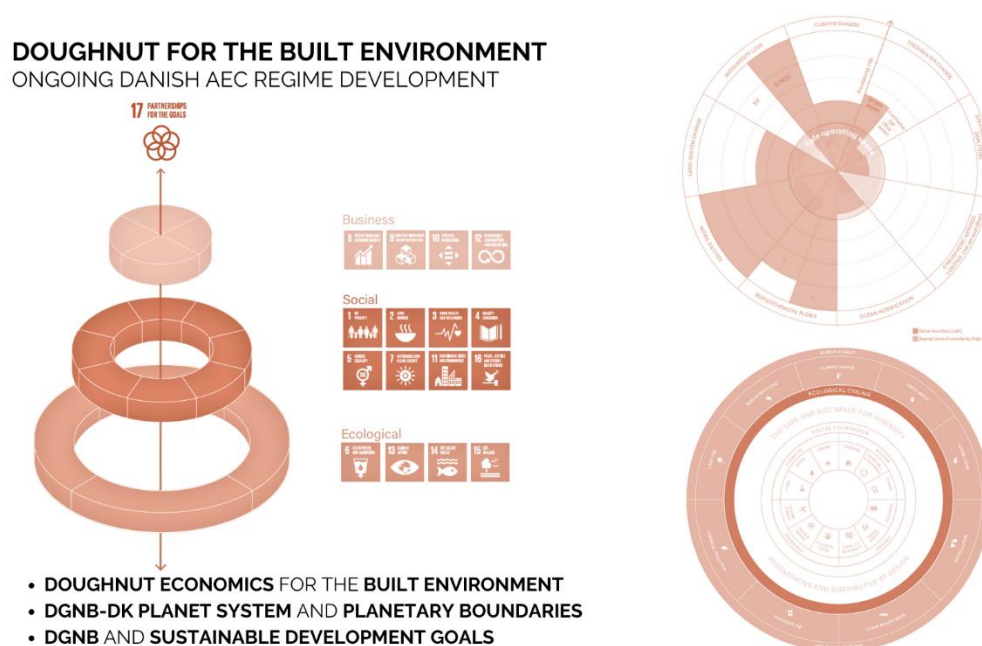
Land Use-related UCs are also linked with problems of Social Equity in fair access to space, just distribution of rights and duties in developing and exploiting ES – problems that socio-ecological systems and their ES have little solutions for, since they are diagnosed as anthropic issues. For how could NbS prevent gentrification or never-ending urban growth on their own?

The socio-ecological links of causality between cultural ES (recreation, education, aesthetic value, place meaningfulness, community identity) and UCs remains the most unclear, despite being rather profound and potentially a key driver for mainstreaming NbS as a competitive force in the Real-Estate market competition for Land Use.

Within the context of RCSR paradigms for Urban STs of our research, we intend to leverage the Doughnut Economics framing of PBs and SDGs [15,16]. These sustainability standards in the Danish AEC market are already present in DGNB. In this section we will now review how specific political agendas in the market sector such as DFUD and the Danish Reduction Roadmap for GHG emissions in the AEC sector may influence the trajectory of certification systems adoption or the transition towards mandatory sustainability assessment, foreshadowed by the recent BR LCA threshold inclusions [195].

We will do so by analysing the quality of these efforts in materializing RCSR paradigms, by assessing what indicators they prioritize in their processes, between ESA and LCA, and how those reflect locally the global agenda of NbS for the Built Environment's Doughnut Economics.

Architect SDE (Sustainable Design Engineer) Dani Hill-Hilsen, a student from the same Masters' course this thesis was written in, has been spearheading numerous initiatives that have been proving structural for the adaptation of the AEC regime in Denmark. She is one of the leading figures behind the DFUD and the DGNB-Planet certification that connects to it, making the case for the capacity of further adapting DGNB's MCDA process in reflecting state-of-the art STs problematisations – and a leadership figure in EFFEKT Architects. She actively works for the inclusion of PBs, ES and NbS in the DFUD framework, as explained in Fig.34.



NbS shows great promise especially to build Regenerative and Symbiotic properties in the ecosystemic value potential of urban systems, as acknowledged by the UNEP and GlobalABC. NbS integrates in Urban Planning a framework for valuing urban ES such as habitat creation, biodiversity promotion, purified water, clean air, soil fertility, coastal erosion protection and the mitigation of the urban heat island effect (UHIE), among others), that are already key matters of concern diagnosed through interviews in Christiania. The construction of these systems, however, entails a wide range of potential impacts.

The energy-hungry and emission-ridden AEC industry has favoured and preferred construction technologies and building materials (especially, steel, cement, and reinforced concrete, as discussed before) that are largely depending on fossil sources and non-renewable energy sources. This situation could be changed in the future by mitigating the environmental harm of these industries.

Fossil sources are also linked with the production of key polymers (and their embodied carbon emissions) for making the built environment impervious to water and for the thermal insulation of buildings, along with additives for concrete and other structural applications.

NbS proponents have therefore, when using the industry standard materials and construction processes, to address the need to assess the embodied environmental impacts of their lifecycles and circularity potential. This consideration is methodologically understood as a trade-off: between potentially provided services (and disservices) to local and global ecosystems; and the environmental impacts of the full lifecycle of their design, manufacturing, implementation, operation, maintenance, and end-of-life scenarios.

However, as bio-based polymers and policies towards the usage of local materials and implementation of carbon limits to the industry loom in the horizon, a case could be made that we are about to witness if not the phasing out of the construction industry structural hegemony of cement and steel, perhaps the opening windows of opportunity to the technologies that governed the built environment before the industrial revolutions. Of course, this would never imply the return to such building standards or architectonic styles of so-called vernacular architecture (by opposition to non-erudite, architecture by people, not architects, and akin anti-expert design ideologies) - but could very well mean that the critical regionalism movement in Architecture, championed by John Ruskin, Hasan Fathy, Christopher Alexander and others, was correct in their prophecies.

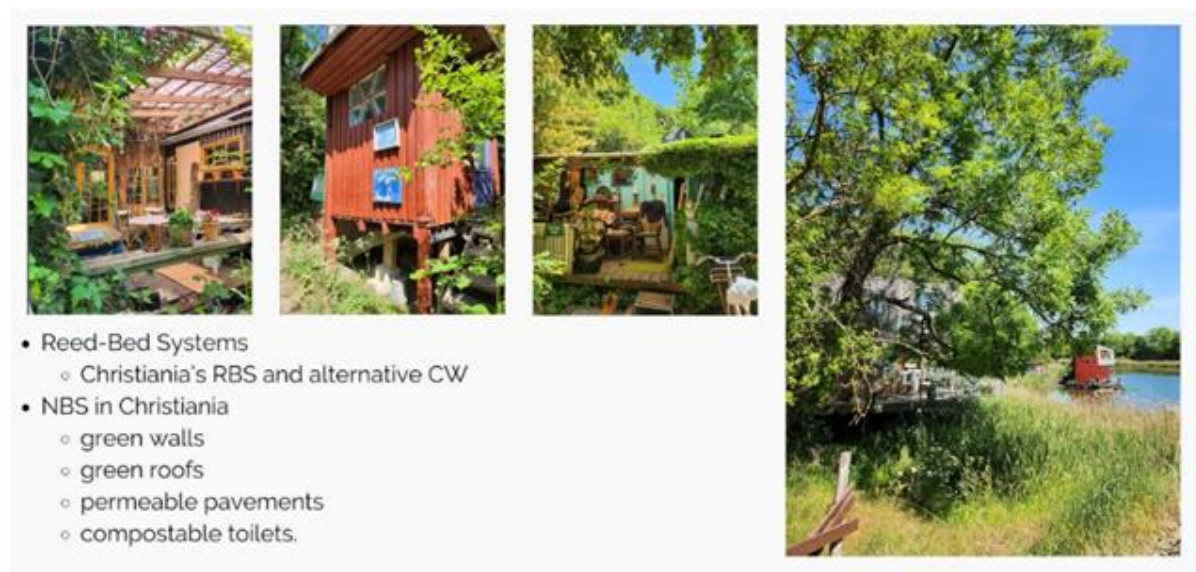
It took us many carbon parts per million in the atmosphere for bioregionalist arguments and ideas to take root in our local-based approach to Sustainability. Critical regionalism in Architecture might be today outdated – at least their scope was not sufficiently interwoven with the articulation of their agenda traditional and local construction technology agenda with the need for nature-based and ecosystemic design. Their message was however not forgotten there is value in understanding the history of the construction and architectonic history of places and regions – for we most likely should not be building everything out of concrete and steel or applying other universal design and construction processes, regardless of their availability and the technical capacity to do so. The 13th of May 2024 gathering at the Danish Architecture Center to enforce a Reduction Roadmap on Carbon by over 600 companies of the Danish AEC makes the case for the fact that such scenarios might not be as far from us as it has been before – especially

as the industry tries to decouple as much as possible from construction processes and materials ridden with an unacceptable level of GHG embodied emissions.

ESA-LCA trade-offs are essential to frame the net-positivity of NbS regarding Biodiversity, as stated by the IUCN Global Standard – but the same argument could easily be made regarding the other 8 PBs. PBs and SDGs state the benchmarks for this teleology, and we will, in the scope of this work, frame DGNB's contribution and shortcomings for the current assessment of these traits and for the future adaptability of the system itself. In Chapter 4, we conduct this regime analysis, proposing hybridization pathways for new shared indicators between AEC and NbS agendas and how they are present in DGNB-DK certification system. This framework will then be applied in Chapter 6 to the Urban Analysis of Christiania preceding our Masterplan in Chapter 7.

In isolation, net-positive regenerative impact in a single ES does not necessarily mean that projects are sustainable, as the combined impact of multiple net-positive specific ES provided by NbS could still amount to crossing the safe and just thresholds of specific PBs and SDGs in a specific project if taken in isolation. Per instance, a zoo could increase local biodiversity locally and ecological awareness and education, but its global resource consumption lifecycle and ecosystem services depletion potential have a much trickier framing for such a project to become remotely sustainable.

NATURE-BASED SOLUTIONS IN AN URBAN NICHE



35 - Nature-based Solutions in Christiania Collage (own photos).

ES empowers the argument for the need for a deeper and strong paradigm of sustainability in urban planning – expressed by the full scope of RCSR sustainability paradigms and connected transitions as a whole. We assert that enshrining the link between Ecosystem Design through IUCN and Urban Design in institutions such as DGNB to be a key WoO for a very relevant partnership between sectors that often keep to their own turfs such as territorial-level energy and water infrastructure, nature conservation, food systems, urbanism, architecture and construction – or, in other words, a key translation of the Urban WEFE systems link in the built environment industries.

The Anthropocene creates unknowable challenges for the future of Earth Systems' synergies with anthropic systems and pathways for more ambitious sustainability paradigms. What other non-

Holocene scenarios can frame a “safe and just operating space for Humanity”? And how can we design not only urban systems, but the ecosystems (and planetary commons) through Planetary Stewardship? How does Stewardship envision the design processes for ecosystems and enmeshed urban systems?

Moreover, how can we make sure that NbS constitute incremental and/or radical RCSR transitions towards addressing the VUCA factors that the Anthropocene holds in store for the future of urban systems? How can we ensure that we deal with volatility, uncertainty, complexity and ambiguity despite our limited cognition of the Earth’s Systems and key local factors impacting the global agenda of sustainability and the multiple visions and scenarios for its realisation as new civilizational paradigm in alternative to the problematic modern urban centralised progress? We will strive to answer these questions in our DGNB analysis in Chapter 4., by proposing an indicator set that expresses NbS’ capacity to bring DGNB into an RCSR sustainability paradigm by incorporating the IUCN Global Standard in its assessment criteria.

A pragmatic answer to these questions is that the solution of these global issues must trickle down to the local level towards visions of climate adaptation that envisions global change of the ecosystems, and the local translation of urban, peri-urban, rural and natural systems transitions under expected but VUCA scenarios of biophysical change. This solution is, however, short-sighted, as the full systemic relevance of local solutions would have to be globally and locally managed in an iterative and adaptive manner to a constantly evolving system and its dynamic equilibrium and disruption events and complying with the criteria of the IUCN Global Standard for NbS (Fig. 36).

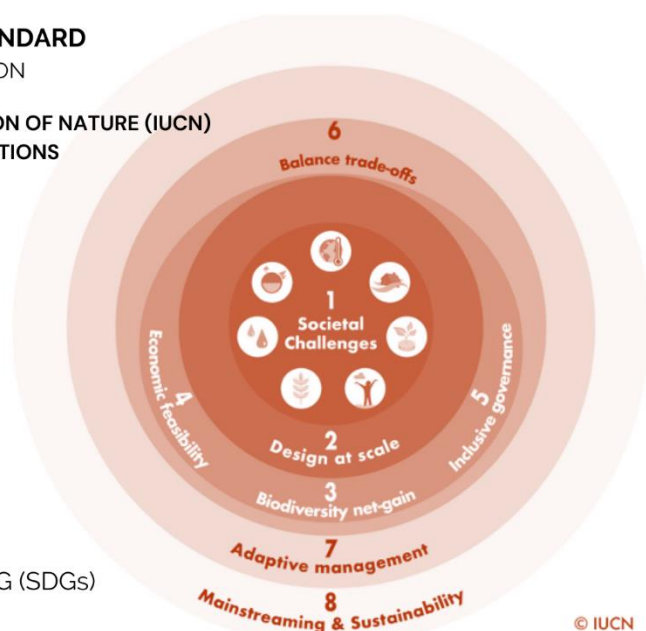
NbS ASSESSMENT | IUCN GLOBAL STANDARD

SUSTAINABILITY BEYOND DGNB CERTIFICATION

INTERNATIONAL UNION FOR THE CONSERVATION OF NATURE (IUCN)
GLOBAL STANDARD FOR NATURE-BASED SOLUTIONS

CRITERIA GROUPS:

- 1) SOCIETAL CHALLENGES
- 2) DESIGN AT SCALE
- 3) BIODIVERSITY NET-GAIN
- 4) ECONOMIC FEASIBILITY
- 5) INCLUSIVE GOVERNANCE
- 6) TRADE-OFF BALANCES
- 7) ADAPTIVE MANAGEMENT
- 8) SUSTAINABILITY MAINSTREAMING (SDGs)



36 - Global Standard for Nature-based Solutions | IUCN Criteria Summary

NbS have the capacity to integrate existing functioning ecosystems and promote their resilience and circularity. They may also help to regenerate symbiotically depleted existing ecosystems. NbS can even integrate the design of novel ecosystems, functioning as components of a newly

envisioned ecological whole. This diversity has led NbS to be defined [223] as an umbrella concept consisting of 3 typologies:

Type 1 “solutions that permit not only a better use, but also a better management (i.e. non-physical modifications) of existing natural or naturalistic ecosystems”

Type 2 “solutions and procedures to restore ecosystems, (...) further differentiated into reclamation and restoration categories”

Type 3 “solutions that involve creating novel ecosystem (...) [including] solutions that involve the extensive (i.e. a large percentage of area) and intensive (i.e. high degree) modifications of existing ecosystems.

Assuming the local preponderance over the global provides heuristic shortcuts for action, in detriment of inaction due to management incapacity of control for VUCA factors trickling down from the infancy of tangible global commitments like SDGs materialisation into concrete inter-governance agendas and market regulations, along with strategies on Sustainability through policy and accountability systems. The focus on “doing no harm” in DGNB-DK in the environmental sense speaks to the widespread adoption of LCA as an emission-control standard by GBCs worldwide [DGNB PLANET ref]. ESA, which is expressed in less local and more regional and global terms, lacks adoption due to the difficult pathways towards the economic valuation of these assets that are often perceived as externalities, unless directly linked with economic activities.

Per instance, soil quality is not fully considered in DGNB-DK, which assumes these ecological services and disservices to be acceptable externalities in their interventions in the built environment. Even if the link between fertile soil and Biodiversity and Land Use is an undeniable ecological impact of the AEC sector, and tacitly acknowledged by the full focus of DGNB’s indicators, projects that augment soil quality and fertility are not rewarded by these stunts in the current framework of urban sustainability analysis, not even in the PB adherent DGNB Planet.

The focus on weak sustainability paradigms linked with harm reduction and damage mitigation (prevalent in DGNB-DK structure) is widely recognised in the literature to be insufficient, yet seldom explicit and quantifiable net-positive criteria exist as requirements in Urban Planning for the development of ES. To the best of our knowledge, no single Built Environment Certification system accurately reports for the full scope of ES [209]– another reason for DGNB and GBCs worldwide to ally with the IUCN NbS standards to promote the rise of nature-based ULLs worldwide.

Conservation of ecosystems (linked with NbS Type 1 and 2, championed by the leading NbS organisation, IUCN, may also fall short as the agenda shifts to embrace the now probably inevitable profound climate adaptation linked UCs and related WEFE scenarios. As the awareness improves about the ongoing anthropogenic changes in Earth Systems, simultaneously the time-horizons to prevent irreversibility further decreases the WoOs to stop this inevitability, as PB overshoot keeps rising in 6 of the 9 already crossed boundaries.

Still biodiversity protection agenda in the built environment seems concerned primarily with conservative approaches through the increment of area allocated to native species as primary (and sole) indicators in certification systems such as DGNB, disregarding the need for climate-adaptive ecosystem design (linked with Type 3 NbS).

The certification systems for renovated built environments also make concessions immediately to the achievable quality levels of renovation approaches to districts and buildings. DGNB proponents assume that a new construction will always outperform an older one, offering little leeway for the pursued renovation approach to change this strategic assessment through novel tactics and institutional change drivers such as NbS and ULLs.

Despite this internally diagnosed and assumed transition inertia of the currently inherited built environments, renovations are still deemed to be very relevant for sustainability, as they mitigate some impacts of new construction, particularly embodied energy and GHG emissions.

Urban regeneration through renovation might require a deeper translation of alternative economic agendas at the institutional, governance and economic institutional levels, documented in our Appendix A manuscript, such as Degrowth, among others, to effectively mobilise international AEC sectors and connected industries away from cement, steel and other high-impact technologies, and towards the decentralised valuation and innovation of so called nature-based and vernacular materials and building technologies such as natural stone and minerals, raw earth techniques, wood and natural tensile materials, along with fibres and biopolymers – which represent the alternative local and decentralised degrowth paradigm in the built environment transformation, by opposition to the green growth of ecological reinforced concrete and steel structures, couples with continued urban growth and centralisation.

The next Chapter, where we begin our Analysis of DGNB's transition trajectory, landscape pressures and possible transition pathways aims to shed some light on how Christiania can make use of DGNB to pursue our Nature-based Spongetown vision. It documents DGNB's accomplishments and shortcomings in framing key matters of concern expressed by Christiania to us both through their official communications and documentation, as well as interviews, workshops and surveys we have conducted with this community. For a full understanding of that participatory process, we refer to both our manuscript and participatory process chapters of our Appendix A and B, respectively.

The following chapter 4 is still a key component of our methodology. In its contents we will reviewing in detail this key boundary object in Sustainability for the Danish Built Environment – DGNB-DK Planet, that we believe to accurately synthesise the characterisation of the present Urban Sustainability regime in Copenhagen. That analysis will be then our departure point towards an ESA-LCA Urban Analysis of Christiania, on Chapter 4 – which we will use to discuss NbS present in Christiania on Chapter 5.

4. The Danish “DGNB Regime”: A certification system designed to adapt to an evolving Landscape

4.1 Landscape Evolution and Regime Pathways: RCSR Sustainability Paradigms in DGNB Trajectory

Towards mobilisation of our Spongetown Agenda for Christiania, in this section we will dig deeper into the techno-procedural aspects of urban Design which are diagnosed in academic, market and governance realms as structural for the further interessement, specific enrolment and mobilisation of our local translation of the NbS, Sponge City and the DFUD concepts.

Techno-procedural aspects of Sustainability are directly qualified by the DGNB-DK built environment certification system recommended by the Danish Green Building Council [227]. Bio-inspiration in DGNB is omitted from the certification system, which seems to disregard valuable contributions of research fields in Urban Sustainability, such as Biomimicry [228–230]. Ecosystem Design through NbS and Urban Biomimicry through ESA-inspired methods show great promise for better design methodologies regarding Environmental Quality net-positivity.

The DGNB system accounts for the “triple bottom line” (source) of Social (People), Economic (Profit), and Environmental (Planet) of sustainability in an even handed manner, while the Procedural and Technical Qualities assess the cooperation or synergy between development targets - or in the case of DGNB, built environment design criteria - that affect all of the three sustainability domains (in a manner similar to the role SDG 17 plays in the SDG sustainability framework).

The DFUD proposal for DGNB has an assessment pillar on the boundary of Biodiversity, assessing the impacts of Construction through habitat occupation, destruction, remediation and regeneration through construction activities. The DFUD makes explicit reference to known ES, without any of the systems directly mentioning this concept and overall framework at all. This could be because ESA is very dependent on the local context, which should provide the baseline for specific assessment of broader ES in relationship to PBs and SDGs, as showcased in Fig.39.

Despite the lack of PB-ESA links in DGNB – as we can see in the full criteria sets of DGNB schemes for Districts, New Buildings and Renovations (Fig. 37) the certification system rewards

DGNB-DK | DISTRICTS CERTIFICATION SCHEME

QUALITY CRITERIA, INDICATOR CODES AND DESIGNATIONS

 ENVIRONMENTAL QUALITY 20% of total score	(ENV) Environmental Quality (ENV1.1) Life cycle assessment (ENV1.5) Urban climate (ENV1.6) Natural disasters (ENV2.2) Water cycle (ENV2.3) Land use (ENV2.4) Biodiversity	 PROCESS QUALITY 20% of total score	(PRO) Process Quality (PRO1.2) Integrated planning (PRO1.7) Involvement (PRO1.8) Project management (PRO1.9) Commitment of the parties (PRO2.1) Building Site and Construction Process (PRO2.4) Monitoring and retention
 SOCIOCULTURAL AND FUNCTIONAL QUALITY 20% of total score	(SOC) Social/Cultural Quality (SOC1.6) Outdoor areas (SOC3.1) Urban integration and identity (SOC3.2) Culture and aesthetics (SOC3.4) Social and commercial facilities (SOC1.9) Noise, light, and air pollution (SOC1.7) City life and security (SOC2.1) Accessibility (SOC1.1) Microclimate and comfort (SOC3.3) Robustness through diversity	 TECHNICAL QUALITY 20% of total score	(TEC) Technical Quality (TEC2.1) Energy supply (TEC2.2) Resource circuit (TEC3.1) Mobility planning (TEC3.2) Public Transportation and Motorways (TEC3.3) Cyclable and Pedestrian Mobility (TEC2.4) Smart-City infrastructure
 ECONOMIC QUALITY 20% of total score	(ECO) Economic Quality (ECO1.1) Lifecycle Costs (LCC) (ECO1.2) Financial effects in the municipality (ECO2.1) Adaptability and Robustness (ECO2.3) Land Use (ECO2.4) Local economic stability		

DGNB-DK | NEW BUILDINGS AND RENOVATIONS [2023]

QUALITY CRITERIA, INDICATOR CODES AND DESIGNATIONS

 ENVIRONMENTAL QUALITY 22.5% of total score	(ENV) Environmental Quality (ENV1.1) Lifecycle Assessment (LCA) (ENV1.2) Environmentally Hazardous Substances (ENV1.3) Responsible Resource Extraction (ENV2.2) Water and Wastewater Management (ENV2.3) Land Use (ENV2.4) Biodiversity	 PROCESS QUALITY 12.5% of total score	(PRO) Process Quality (PRO1.1) Quality in Project Preparation (PRO1.4) Contract Tendering for Sustainability (PRO1.5) Maintenance and Operation Guidance (PRO1.6) Architectural Design Procedural Quality (PRO2.1) Building Site and Construction Process (PRO2.2) Documentation of Execution Quality (PRO2.2) Commissioning (PRO2.4) User Communication
 SOCIOCULTURAL AND FUNCTIONAL QUALITY 22.5% of total score	(SOC) Social/Cultural Quality (SOC1.6) Thermal Comfort (SOC3.1) Indoor Air Quality (SOC3.2) Indoor Acoustics (SOC3.4) Visual Comfort (SOC1.9) Quality of Outdoor Areas (SOC1.7) Universal Design (SOC2.1) Building Integrated Art (SOC3.3) Plan Disposition	 TECHNICAL QUALITY 15% of total score	(TEC) Technical Quality (TEC1.1) Fire Protection and Safety (TEC1.3) Quality of the Building Envelope (TEC1.4) Adaptability of the Technical Systems (TEC1.5) Design for Maintenance and Cleaning (TEC1.6) Disassembly and Recycling (TEC1.8) Environmental Product Declarations (EPDs) (TEC3.1) Mobility Infrastructure
 ECONOMIC QUALITY 22.5% of total score	(ECO) Economic Quality (ECO1.1) Total Economy (ECO2.1) Flexibility and Adaptability (ECO2.2) Robustness	 SITE QUALITY 5% of total score	(SITE) Site Quality (SITE1.1) Local Environment (SITE1.2) Influence of the District (SITE1.3) Traffic Connections (SITE1.4) Access to Local Facilities

37 - DGNB-DK | Districts and New Buildings [2023]

practices that allow for the creation of habitat for native species, water drainage and management techniques (ENV 2.3; ENV. 2.4 – which are fully explored at the districts level regarding their indicators in Fig. 38) – all relevant provisioning, maintaining and regulating ES. DGNB even mentions the Sponge City concept as a good practice for Water Quality, however, does not make even a single explicit reference to the broader ES framing of Sponge Cities, which have, in China, already established this important ESA-LCA link in some evaluation structures and design planning methodologies.

In our Spongetown ULL we intend to bypass the current shortcomings of this framing, by displaying it through a specific boundary object such as Christiania's Urban Plan and potential DGNB Planet certification pathway, the transition strategy of current certification systems and ULL design towards NbS-ES-UC framing of PBs and SDGs at the local level.

4.2 DGNB as a Regime Boundary Object: Analysing the Incumbent Danish System Criteria

The DFUD acknowledges the broad PB framing underlying Doughnut Economics along with the relevance of NbS to address some of those problems, but then takes a rather selective dive in PBs towards Biodiversity and Climate Change indicators as key quantifiers for the Regeneration capacity of the assessed construction.

Once more, even if most of the indicators for regeneration are deeply intelocked with Type 3 NbS and the capacity for the novel construction to create habitat and generate or protect biodiversity, this provisional ES as well as an explicit grounding of the work on a broader ES-PB framework is nowhere to be found, most likely due to the lack of integration with LCA through a viable ISO. However, the absence of references to IUCN and other leading NbS organisations' standards is hard to understand. The UNEP 2024 Report we discussed during the introduction, also declares for future work that our research scope of NbS and ESA integration in DGNB to be of utter relevance, with the following statement:

“NbS approaches aim to create a harmonious, symbiotic relationship between the built environment and the natural world. They have been defined as “actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits” (International Union for Conservation of Nature (IUCN) 2024). NbS are inspired by nature and use the intricate workings of natural ecosystems to offer a range of services, from indoor climate conditioning and water purification to carbon sequestration and bio-diverse habitat provision. NbS can improve air and water quality, mitigate biodiversity loss, sequester carbon and reduce urban heat island effects (Matthews et al. 2022; Marvin et al. 2023). Underpinned by a holistic understanding of ecosystems, NbS recognise the complexity and the interconnections between different natural and built systems and see nature as a resource. At present, this resource is being heavily depleted. Total investments in NbS have been estimated at US\$200 billion per year, which is less than three per cent of the US\$7 trillion in finance flows that have been assessed to have a direct negative impact on nature in a recent UNEP report (Birch et al. 2023).”

Despite current trends to praise the utility of IUCN's Global Standard for NbS and ES, an ISO for ES is suggested in the literature as a necessary barrier to overcome transition inertia to its adoption and for the adoption of WCA. Nevertheless, the DFUD is represented in the DGNB-DK system - where 7 of the 9 boundaries are represented, with the exclusion of Stratospheric Ozone and Atmospheric Aerosol Loading. These absences are most likely justified - the first probably for the low relevance it holds for current STs, and the second due to the unknown threshold status that stems from the absence of Key Point Indicators (KPIs) for its assessment.

Other commonalities between DGNB and the DFUD exist as shared matters of concern. LCA and Lifecycle Costing (LCC) distinguish the DGNB system capacity of dealing closely with Economic indicators' integration in the Whole Lifecycle of the Built Environment, making it one of the most transdisciplinary systems for sustainability quality certification in the AEC sector and a market leader, especially in Northern Europe[19]. LCA methodology is also present in the criteria DFUD and is the key assessment feature of the Reduction Roadmap on which the former builds upon. The DFUD then uses data from the LCA to estimate global biodiversity impact assessing the trade-offs with local impact mitigation and regeneration capacity of specific building operations

Despite the link between urban environment LCA and ESA being addressed explicitly by some methodological studies on Sustainability Assessment of Sponge Cities [39,186,231] and NbS [41,211,232–234], these methodologies still seldom make explicit or replicable the sets of indicators and standardised weighing procedures through their Multi-Criteria Decision-Making processes. The variation in these foundational analytical sustainability assessment indicators and defined approaches for their weighing within decision-making criteria sets is a widely acknowledged issue within MCDA literature on sustainability problem-solving.

As many authors call for the standardisation and establishment of best practices within LCA and ESA alike, it seems to us disheartening to find still so few articles and especially market certification systems tackling head-on the need to integrate the full scope of LCA-ESA frameworks for a PB-SDG STES nexus in Urban Planning sustainability that can help us make sense of Sponge Cities as a key translation of Doughnut Economics for the Built Environment. To the best of our knowledge, no certification system has a standard for this assessment – but the UNEP and GlobalABC seem optimistic about the pathways towards its mainstreaming through the IUCN conventions for NbS and ES.

DGNB-DK | DISTRICTS

ENVIRONMENTAL QUALITY CRITERIA AND KPIS



**ENVIRONMENTAL
QUALITY**
20% of total score

(ENV1.1)	Lifecycle Assessment (LCA) 1) Early integration in the Planning Process 2) Iterative LCA Planning Process 3) SDG Goals Bonus: Climate-Neutrality	(ENV2.2)	Water Cycle 1) Reduction of Drinking Water Demand 2) Urban Area Water Balance (Precipitation Runoff) 3) Impervious Area Proportion
(ENV1.5)	Urban Climate 1) Urban Area Climate Analysis 2) Urban Thermal Comfort and Ventilation 3) Urban Biofactor (Green Infrastructure Area)	(ENV 2.3)	Land Use 1) Brownfield Area Proportion 2) Integration in Urban Development Area 3) Excavation and Soil Management 4) Water Structure (Blue Infrastructure Types)
(ENV1.6)	Natural Disasters 3 most relevant Environmental Risks from: 1) Storms, 2) Floods, 3) Cloudbursts, 4) Landslides and Subsidence, 5) Storm Surges	(ENV2.4)	Biodiversity 1) Preservation of Existing Habitats 2) Strategy for Biodiversity 3) Design of Quality Habitats 4) Special Local Fauna Measures 5) Functional & Ecological Habitat Connectivity 6) Vegetation Control Measures 7) Dissemination, Mediation and User Involvement

DGNB-DK | DISTRICTS

SOCIOCULTURAL AND FUNCTIONAL QUALITY CRITERIA AND KPIS



**SOCIOCULTURAL AND
FUNCTIONAL QUALITY**
20% of total score

(SOC1.1)	Microclimate and Comfort 1) Micro-Climate, Sun Exposure and Shading 2) Wind Exposure and Comfort 3) SDG Bonus: Health and Thermal Comfort	(SOC 2.1)	Accessibility 1) Design for Universal Inclusivity and Accessibility 2) Accessible Housing, Transportation and Stores 3) Urban Accessibility Planning and Execution
(SOC1.6)	Outdoor Areas 1) Public Outdoor Area Factor in District Project 2) Private Outdoor Area Factor in District Project 3) Public Outdoor Areas near District	(SOC3.1)	Urban Integration and Identity 1) Urban Cityscape and Mobility Integration 2) Identity Creation and Heritage Conservation
(SOC 1.7)	City Life and Security 1) Design for Safe Public Mobility 2) Mixed-Use and Public-Private Urban Functions 3) Interior-Exterior Visual Connectivity 4) Lighting Concept	(SOC 3.2)	Culture and Aesthetics 1) Quantity and Quality of Artistic Projects 2) Architectural and Infrastructural Guidelines 3) Design Vision, Detailing and Implementation
(SOC 1.9)	Air, Light and Noise Pollution 1) Measures to Improve Air Quality 2) Measures to Reduce Light Pollution 3) Measures to Control Noise Levels SDG Bonus: Health and Night Noise Reduction	(SOC 3.3)	Resilience through Diversity 1) Functional and Social Integration 2) Urban and Spatial Structures for Social Diversity 3) Local Economy Concept and Land Use Shares
		(SOC 3.4)	Social and Commercial Facilities 1) Social Infrastructure 2) Commercial Infrastructure 3) Public Offer Synergies 4) Circularity Bonus: Sustainable Daily Life Offers

DGNB-DK | DISTRICTS

ECONOMIC QUALITY CRITERIA AND KPIS



(ECO1.1)	Lifecycle Costs (LCC) 1) Total Economic Analysis in Planning 2) LCC Calculation	(ECO2.3)	Land Utilisation 1) Urbanisation Proportion of Available Area 2) Urban Density and Occupancy Rate 3) Roof Surfaces Utilisation Rate
(ECO1.2)	Financial Effects in the Municipality 1) Financial Balance of the Municipality 2) Sensitivity Analysis of Economic Impact	(ECO2.4)	Local Economic Stability 1) Diversification, Cohesion and Ownership 2) Workplaces and Job Creation 3) Unemployment 4) Project Awards
(PRO1.8)	Adaptability and Robustness (Resilience) 1) Climate Adaptation and Water Management 2) Water, Energy, Food and Transportation Supply 3) Mixed-Use Urban Design and Building Planning 4) Circularity Bonus: Building BIM Model Passport 5) Circularity Bonus: Design for Disassembly		

DGNB-DK | DISTRICTS

PROCESS QUALITY CRITERIA AND KPIS



(ECO1.1)	Integrated Planning 1) Professional Interdisciplinary Representation 2) DGNB Criteria Integration in Design Process 3) Urban Scenarios and Master Plan Quality	(PRO1.9)	Commitment of the Parties 1) Active Ownership and Community-Building 2) Municipal Commitment 3) Municipal Start-up Projects
(PRO1.7)	Involvement 1) Vision, Approach, Development and Application 2) Participant's Influence on the Process and Result 3) Focus of participant-involving on Sustainability	(PRO2.1)	Building Site 1) Logistics Concept and Impact Minimising 2) Circularity Bonus: Construction Residual Waste 3) Innovation Bonus: Noise and Vibrations 4) Innovation Bonus: Dust 5) Innovation Bonus: Environment Impact
(PRO1.8)	Project Management 1) Assignment of Project Manager 2) Project Risk Management Milestones 3) Quality Assurance on Sustainability Criteria 4) Time Management and Scheduling 5) Project Economics and CBA Optimisation	(PRO2.4)	Monitoring and Detection 1) Sustainability Manager for Operational Phases 2) Energy Monitoring 3) Design Guidelines 4) Coordinated Digital Model (GIS, CIM, BIM)

DGNB-DK | DISTRICTS

TECHINICAL QUALITY CRITERIA AND KPIS

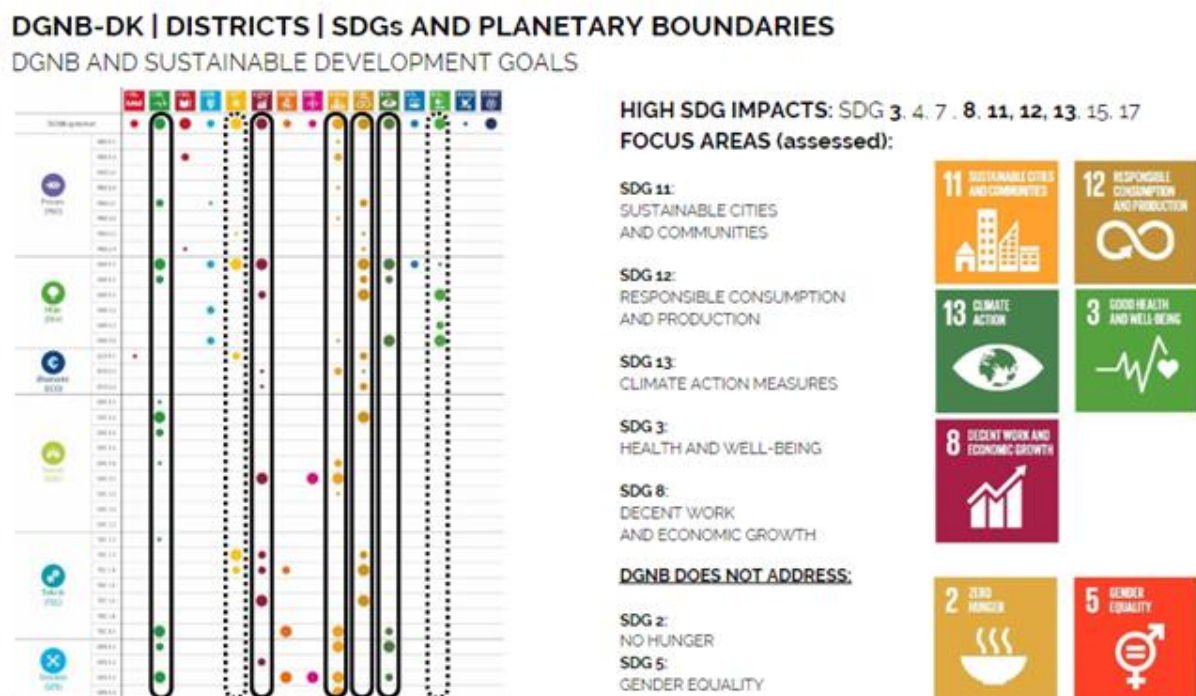


(TEC2.1)	Energy Supply 1) Integrated Energy and Heating Supply Concept 2) Coherent Energy Supply Structure 3) Energy Systems Synergy Possibility	(TEC3.1)	Mobility Planning 1) Mobility Plan and Traffic Model 2) Public Transport Plan 3) Parking 4) Heavy Traffic Plan 5) Special Overall Mobility Measures
(TEC2.2)	Resource Cycle 1) Resource Cycle Concept 2) Waste Reduction and Prevention Measures 3) Upcycling and Sharing Economy 4) Circularity Bonus: Sorting and Recycling 5) Innovation Bonus: Technology and Logistics	(TEC3.2)	Public Transportation and Motorways 1) Infrastructure Design for Public Transport 2) Automobile Infrastructure and Road Safety 3) Car Parking Visual Impact 4) Special Measures 5) SDG Bonus: Fossil-free Transportation Systems
(TEC2.4)	Smart City 1) Planning of Smart City Solutions 2) Planning the Digital Network 3) Data Handling and Storage 4) Internet of Things 5) Person-related Internet 6) Data Collection	(TEC3.3)	Soft Mobility and Pedestrian Infrastructure 1) Infrastructure for Cyclists 2) Bicycle Parking 3) Infrastructure for Pedestrians 4) Innovative Cycling and Pedestrian Measures

38 - DGNB-DK | Districts – Full Criteria and KPI Summary

Endeavours exploring the Nexus between Urban Challenges, Ecosystem Services and NbS echo the needs for a better systematisation of global and local impacts of the AEC sector in the Built Environment and Earth Systems alike. In the next section we will attempt to collect the state-of-the-art indicators that could be relevant for our analysis of Christiania, considering the previously mentioned Problem Structuring Methodologies of Sustainability Assessments (ESA and LCA).

The reviewed methodologies spanning ULLs, NbS, Sponge Cities, along with hybrid approaches between them, often include tacitly or even explicitly other PSMs which often find their way into the criteria defining and weighing processes. We found such as Scenario Planning, Stakeholder Management, SWOT, known PSM to support MCDA approaches to be present in DGNB. However, the criteria weighing process in DGNB seems to have been oriented in an AHP or ANP manner of PSM; as often reiterated by its methodology, which often requires further expert knowledge to be gathered for a proper assessment.



39 - DGNB-DK | Sustainable Development Goals Integration Summary

Here we can assume that our sociotechnical mixed ANT-MLP-TM-SNM-STI framing of Socio-Ecological and Techno-Procedural design aspects can be sufficient for the conceptualisation of urban STs. These approaches, in our opinion, encompass, operationalise and transcend Stakeholder Management, Scenario Planning and SWOT analysis, along with other PSM that usually support AHP, ANP and other expert-lead decision-making processes within MCDA, which still represent almost a third of the research on NbS for Green and Blue Infrastructure Systems.

DGNB itself acknowledges the need to evolve along with the transitions taking place in the global AEC sector, and often introduces the criteria that are subject to future changes in its assessment orientation documents which fully explained the indicators addressed in our research scope. The DGNB however does not explain how it envisions the transitions it expects for its future development in its documentation – we believe that absence of transition trajectory framing to be of strategic importance and hope our analysis to be enlightening for how DGNB could incorporate the transition pathways we mentioned in its assessment.

As we have documented, ensuring urban adaptability, adequacy, efficiency and effectiveness, while simultaneously seeking net-positive co-evolutionary synergies with ecosystems and the environment as a whole is the development vision of RCSR paradigms in nature-based urban planning. These align with the Reduction Roadmap, Sponge City, NbS and Doughnut agendas, materialised in the new 2025 Pilot for DGNB (Fig. 42 and 43.) and its latest predecessor including

a PB and EU Taxonomy framework in connection with DGNB Planet (as displayed in Figs. 40 and 42).

DGNB-DK | NEW BUILDINGS AND RENOVATIONS 2025 PILOT

ENVIRONMENTAL QUALITY CRITERIA AND KPIS

(ENV 1)	Global Warming Certification Requirement: C1) BR Requirements for Climate Impact 1) LCA Calculation (BR standards) 2) Scope of Calculation and Data Transparency DGNB Planet: Higher Requirements for LCA.
(ENV 2)	Hazardous and Harmful Substances ENV Quality Minimum Requirement: 1) Pre-requisites on Harmful Substances 2) Protection of the Construction Site DGNB Planet: Higher Requirements for 1) and 2). DGNB Heart: Synergy with 1)

(ENV 3)	Resources ENV Quality Minimum Requirement: LCA of Demolition and Resources for Renovations 1) Origin of Resources and Reduction of Raw Material 2) Design for Disassembly and Recycling 3) Waste Prevention 4) Water DGNB Planet: Higher Requirements for LCA.
(ENV 4)	Biodiversity ENV Quality Minimum Requirement: Documentation of Natural Land and Old Trees 1) Biodiversity on Site 2) Biodiversity off-Site DGNB Planet: Higher Requirements for LCA on terms of GHG, Eutrophication and Acidification

DGNB-DK | NEW BUILDINGS AND RENOVATIONS 2025 PILOT

SOCIOCULTURAL AND FUNCTIONAL QUALITY CRITERIA AND KPIS

(SOC 1)	Air Certification Requirements: C2) Volatile Organic Compounds (VOC) C3) PCB (for Renovations pre-1986) C4) Radon Measurements 1) Thermal Comfort 2) Ventilation 3) User Control of Indoor Climate 4) Indoor Climate Resilience 5) Indoor Air Pollution
(SOC 2)	Sound 1) Acoustic Quality and Reverberation 2) Sound Insulation and Noise DGNB Heart: Synergy with all indicators
(SOC 3)	Light 1) Lighting Strategy 2) Daylight 3) Sunlight 4) Electric Lighting DGNB Heart: Synergy with all indicators

(SOC 4)	User Focus and Universal Design Certification Requirements: c5) BR Requirements for Accessibility 1) Universal Design Social Objectives 2) Ongoing Involvement of the User Perspective
(SOC 5)	Architectural and Building Quality DGNB Diamond Requirement: D1) Appraisal in Architecture Competition 1) Architectural Valuation through SAVE method 2) Resilience and Flexibility to Use Change 3) Social Contributions of the Building Bonus: Integrated Art in the Building DGNB Heart: Synergy with all indicators
(SOC 6)	Landscape Quality 1) Recreational and Health Landscape Benefits 2) Relationship with the Landscape/District 3) Social Contributions of the Landscape/District Bonus: Visible Recycled Materials DGNB Heart: Green and Blue Landscape Features

DGNB-DK | NEW BUILDINGS AND RENOVATIONS 2025 PILOT

ECONOMIC QUALITY CRITERIA, AND KPIS

(ECO 1)	Total Economy (Circularity) 1) Operation and Maintenance 2) Building-related Lifecycle Costs (LCC) 3) Investment in Environmental Optimisation Bonus: LCC and LCA Scenario Comparison
(ECO 2)	Robustness (Resilience) 1) Building Envelope Construction Technology 2) Air Tightness, Moisture and Mold Prevention 3) Risk Analysis and Climate Adaptation
(ECO 3)	Mobility 1) Public Transport and Micro-Mobility Planning 2) Measures that Promote Micro-Mobility 3) Local and Regional Service Analysis

(ECO 4)	Construction for Operation ECO Quality Minimum Requirements: M1) BR Requirements for Function Tests M2) Commissioning, Planning and Operations 1) Commissioning Process 2) Process Progress and Meeting Documents 3) User Training and Information Availability Bonus: BIM Model Availability
(ECO 5)	Responsible Procurement 1) Community Building and Work Environment 2) Minimisation of Dust and Noise 3) Responsible Procurement (Wood and Stone)

40 - DGNB-DK | 2025 Pilot for New Buildings and Renovations

ESA-LCA is an endeavour to undertake with long-term investment return horizons which would require shared knowledge creation, property and resource management practices and most likely new institutions and organisations for their valuation between local private parties and central global/national/regional management depending on the project scale and jurisdiction.

The authors believe that the Degrowth focus on place and community-based development through local resources is closely linked with the socio-ecological agenda to promote provisional, supporting, regulatory and cultural ES for planetary stewardship and steering Anthropocene's transitions. Our survey findings also underscore public sympathy for Christiania's role in Copenhagen as a bastion for such sustainable development models.

A shared economy and open-source ES and LCA knowledge are however antagonistic to a market populated by private property rights protection, which impacts NbS. From intellectual property to prioritising the freedom of privatised land-use, such structural aspects of our current political market economy and the institutions which are widely acknowledged as legitimate to govern our lives, despite the hindrances they place towards the acceleration of the pursuit for the common good by the general population. To all that complexity creating transition inertia, the knowledge gaps regarding scientific knowledge necessary to accurately and effectively control NbS VUCA factors piles up as an additional barrier – however, momentum seems to be growing through the endorsement of UNEP, Global ABC, GBCs shaping the AEC landscape worldwide, and many niche agendas which we have framed before and that enrich our perspective of the landscape changes we have observed. Some of these niches are places like Christiania, where this nascent proto regime can be iterated and experimented with.

4.3 Forthcoming Systemic Changes: Ecosystem Services and Natural Capital, Degrowth and Decentralisation, NbS and Urban Living Labs Indicators

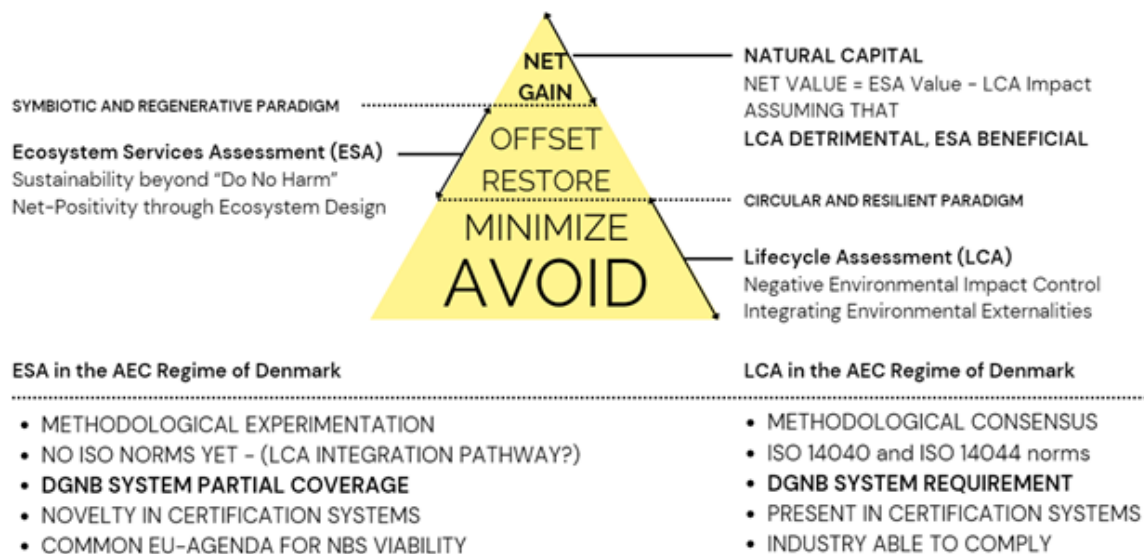
A particular paper on NCA echoes findings regarding methodologies of valuation that curiously echo the propositions of Bio-inspiration studies in NbS application – both studies present the relevance of ESA-LCA methodological integration for taming the wicked externalities that socio-ecological systems represent in the economy [209] and the aesthetic experience [232]. This established bridge between these conceptualisations of extra-human “natural” agency and capital highlights important symbiotic pathways in our envisioned RCSR transitions. Rugani et al. (2023) define Natural Capital in the following manner, described in Fig.41:

«the Natural Capital (NC), on which the life cycle of goods and services depend upon, is the heritage of ecological assets that encompasses all renewable and non-renewable, abiotic, and biotic resources existing on Earth, as well as the processes and functions that take place within and across ecosystems at different spatial and temporal scales. Those assets can be inventoried as environmental intervention flows, used by the activities in the life cycle of the production system in the form of intermediate or final ecosystem services, after their extraction from depletable or not depletable ecosystem stocks (above- or below-ground) has taken place.»

Reviewing the literature on ESA-LCA methodologies, the authoring proponents of the NCA integrative methodology, claim that ES provide offsetting and restorative benefits that can further mitigate the biophysical impacts of products and services that LCA methodologies strive to avoid and minimize.

CHRISTIANIA AS AN URBAN LIVING LAB

URBAN NATURE-BASED SOLUTIONS VALUATION PROCESSES



41 - Nature-based Solutions and Natural Capital Assessment – based on Rugani et al. (2023)

This broader circular and evolutionary model of STES change drivers can frame detrimental and beneficial impacts between ecological and anthropic systems with a focus on resource consumption and generation. NCA hypothesises and seeks Net-Gains relationships that can benefit both systems in an integrated way of framing the living systems' regeneration potential of human activity output. Ecosystem Services Assessment promises to offer ways of Offsetting and Restoring Lifecycle Impacts, while simultaneously integrating efforts towards the resilience of valuable systems by avoiding and minimizing negative impacts.

The authors however alert for the need of expert consensus reaching endeavours for the coming years towards the inclusion of biological, ecological, socio-ecological expert knowledge for the valuation of ES. LCA and ESA are extremely sophisticated processes for decision-making, offer parametrised by components prone to objective analysis, and strategised towards practices of decision-making fuelled by science-based but still subjective visions on transition trajectories.

LCA-ESA methodologies that are framed by PB-SDGs pre-requisites are still lacking consensus and a formal integration. This methodology represents however the state of the Art in Sustainability Assessment for the Built Environment, sometimes named Territorial LCA, which is the primary Problem Structuring Methodology that can contribute for a MCDA process for urban development.

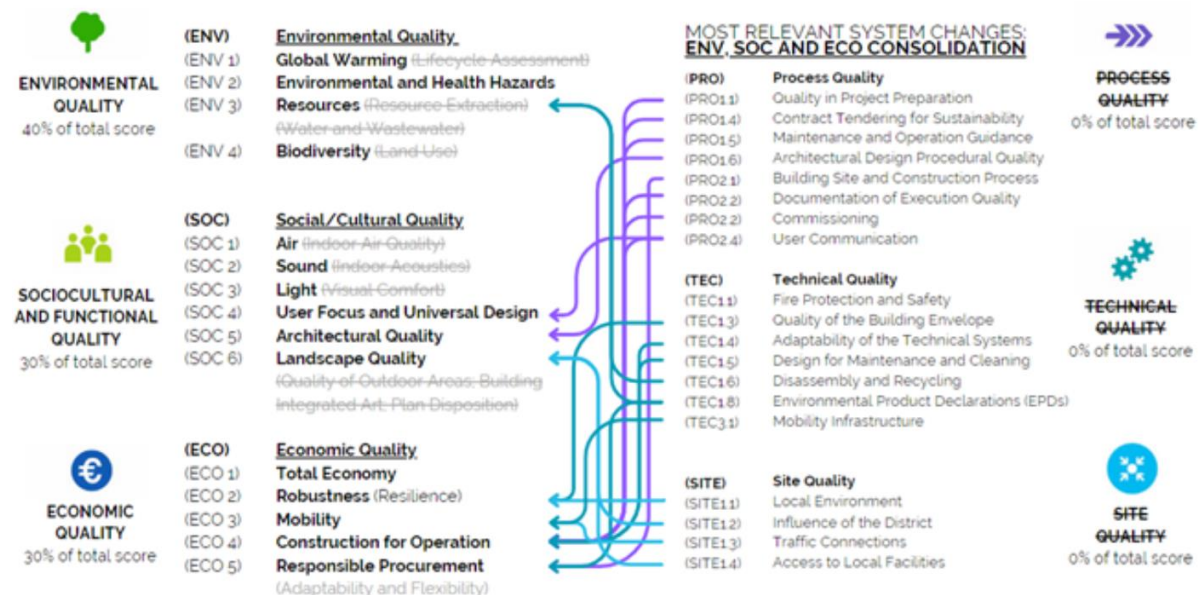
MCDA review processes often reiterate the need for a better inclusion process of stakeholders in the decision-making process of indicator selection, weighing, scenario mapping, stakeholder identification, and so-on. However, this might also be a necessary political assertion due to the need to reach a type of consensus which is not yet available in the scientific community, but that markets and governance must find ways to address these problems heuristically.

LCA became, through its normalisation via the International Standardisation Organisation (ISO), a commonplace for objective comparison of sustainability performance of different options for products and services. ESA lacks a comparable specific regulatory framework or standardisation within the international organisation for standardisation (ISO) akin to what exists for Life Cycle

Assessment (LCA). LCA is well-established in the ISO framework, particularly through ISO 14040 and ISO 14044, which provide guidelines on the principles, framework, and methodology for conducting LCA studies. These standards are widely recognized and used globally to assess the environmental aspects and potential impacts throughout a product's life cycle [209].

DGNB-DK | NEW BUILDINGS AND RENOVATIONS [2025 PILOT SCHEME]

QUALITY CRITERIA AND INDICATORS COMPARISON WITH 2023 VERSION



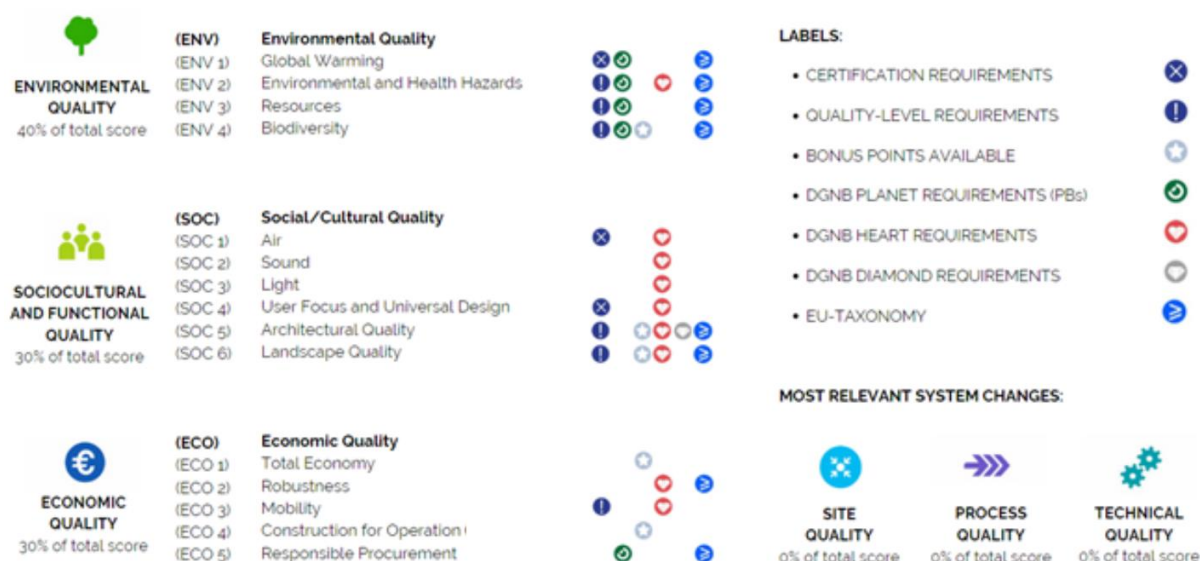
42 - DGNB-DK | Quality Criteria Indicators Simplification | 2025 Pilot Version

The closest ISO standards that relate to ecosystem services without explicitly naming them might be those under the ISO 14000 family, which addresses various aspects of environmental management. These include standards for environmental management systems (ISO 14001), environmental labelling in connection to market certifications (ISO 14020 series), and greenhouse gas quantification and reporting (ISO 14064 series), among others. These standards indirectly support the conservation and sustainable use of ES by promoting environmental management and sustainability, but do not account for their full scope.

Furthermore, the availability of data for conducting a thorough ESA-LCA methodology under the context of urban planning and masterplan design is most often incomplete at best - non-existing at worst, especially if we consider countries not as industrialised and informatised as Denmark [235]. Territorial LCA [236,237] approaches are quite novel but promise ways of looking closer into global and local aspects of lifecycles and framing ES spatio-temporal interactions in them. All of this problem wickedness may be perceived as a valid criterion to exclude the enrolment of laypeople in decision-making, discarding their perceptions in indicator identification and valuation in MCDA processes on sustainability as science-based criteria render the decision making indecipherable for laypeople. The objectively defined aspects of standardised LCA create barriers to the subjective assessment of environmental science-based data, and creating an ISO-backed ESA standard might allow not only for the integration, but for the decrease in subjective analysis of LCA and to attend the criticisms on the shortcomings of the methodology which is a key structure of the EU-ETS system.

DGNB-DK | NEW BUILDINGS AND RENOVATIONS [2025 PILOT SCHEME]

QUALITY CRITERIA, INDICATOR CODES AND DESIGNATIONS



43 - DGNB-DK | Quality Criteria, DGNB Planet, PBs and EU-Taxonomy

The advocates for slow, local technology for Sustainability will be disheartened to realise that ESA will most likely make LCA even more complex, and expert-knowledge ridden. This reality might indicate that laypeople will be excluded even further from integrative NCA processes, especially at the environmental-ecological and economic levels and before the institutionalisation of these perceptions of value into scientific key point indicators, and sufficient statistics such as pricing, taxes, and other market mechanics translate the understanding of their social value [140,238].

Expert knowledge is, however, not necessarily a barrier to adoption. Many highly sophisticated technologies are enjoyed by the public even without a true user understanding of the philosophical underpinning underlying their design. This is due not only to lack of education and capacity for interpretation or critical thinking, but also to the lack of access to information which is all too often subject to intellectual property rights claims to trade secrets – fundamental principles for a competition-based market.

Furthermore, the often-experienced unavailability of thorough data for the incredible number of considerable indicators to perform a full ESA-LCA framing of STES could lead to embracing this VUCA problem setting once more through participatory MCDA for the political motive of consensus reaching when decision-makers are faced with excessive problem wickedness. Sceptics on the value of participatory decision-making may find that the need for social ideas of inclusion, justice and fairness in that process may lead to ecological and technical inefficiencies and inefficacies, where the uninformed masses democratically impede the knowledgeable authority of experts in decision-making. However, the necessity for fine-tuning social indicators may pave the way to include subjectivity in an ESA-LCA that accounts for the whole/living systems through a STES approach to capital valuation.

MCDA scholars often hypothesise that enrolling non-experts in such decision-making processes may lead to a broader diagnosing of matters of concern that can be translated to indicators [201,202,215]. This is considerably disheartening for experts to endorse the participation of laymen, who often already deal with sufficient complexity in their own expert-defined terms –

which leads to the high adoption of ANP and AHP for criteria weighing and decision making. Mobilising society for a quicker problematisation and interessement towards a common agenda surrounding Planetary Stewardship, may only be possible through such processes of decision-making enrolling – those moments themselves functioning as important formative stages in the developing of shared understandings, problematisations and interests.

The need for fail-safe processes that acknowledge the necessary input of laypeople and experts in sustainability problematisations has been thoroughly documented in past literature reviews and is a key pillar of community resilience and regeneration in socio-ecological literature. Our past work on Sustainability Transitions in Christiania strived to nurture and empower an urban niche and minoritarian communities that inhabit it in Copenhagen. The Fristaden niche has had success in pioneering sustainability approaches that remain relevant and popular to this day, in contrast to expert decision-makers in centralised powers, which often intended to normalise their space.

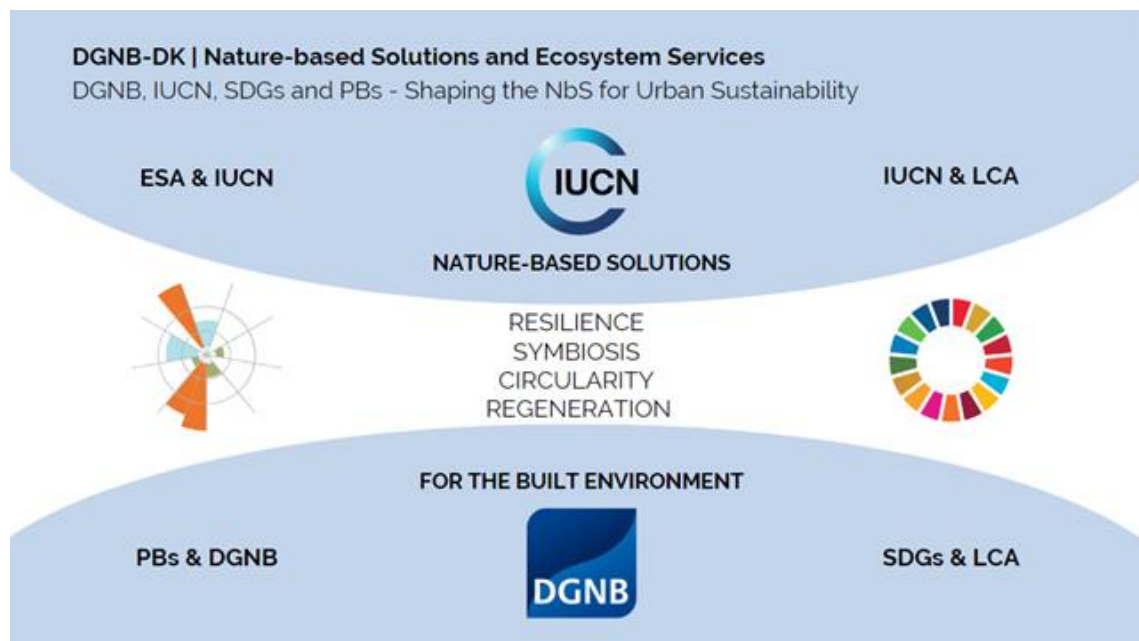
Our observant-participatory strategic ethnographic study documented in our Appendix lays out Christiania's community narrative of oppression resistance, revolution inspiring, normality disruptive ethos and sticking-it-to-the-man anarchic and countercultural bio-inspired ethics and aesthetics. We illustrated a canvas in which this forward-thinking urban community functioned as a niche for institutional change and novel STES experimentation in the Danish capital's regime. Christiania's decision-makers however, faced with the diagnosed Urban Challenges (UC) and their global origins in our previous work, pointed out the need for collaboration with the Danish Estate, Copenhagen Municipality and their direct neighbours in Christianshavn and diagnosed an assumption of incapacity of locally addressing sufficiently the global and regional aspects of the issue and the local impacts of forthcoming macro-level changes in biophysical and social.

Willingness to compromise might indicate how the critical and revolutionary steam might be blowing off in Christiania or, alternatively, how the need for reconciliation over a shared agenda for Sustainability Transitions in Copenhagen and Christiania is beginning to emerge, despite many conflict sources in the nuanced relationships between the community and the larger power structures that encompass numerous aspects of the existence of this urban niche.

As an alternative niche for decentralisation of STES and the quest for the integration of LCA and ESA, Christiania could become a candidate for a rather unique exploration in urban development in Copenhagen – an Urban Living Lab in radical sustainability agendas that seldom encounter ways of taking root in cities pressed by rapid urbanisation, gentrification and other systemic drivers for ecosystemic stressing.

In the following section we will draw from the literature a collection of indicators to be studied in Christiania's Lokalplan decision-making process for the pursuit of these traits within the assessment, planning and management of forthcoming urban transition experiments.

4.4 Structuring the Problem: DGNB and the IUCN Global Standard for NbS as RCSR Interessement Devices for Christiania's Urban Planning Trajectory Steering



44 - SDGs, PBs, ESA, LCA, IUCN and DGNB Integration for Spongetown NbS ULL

We believe that NCA is the only valid format for the analysis of Christiania's value as an urban niche for sustainability – or any other territory, for that matter. There is a documented lack of consensus on ESA-LCA methodologies for full RCSR translation in the regime. For the establishment of indicators in our work, we select a broad collection from DGNB for Districts, which we expand by inquiring PBs and SDGs framing capacity of this certification system – that we propose in Figs. 44, 45 and 46. Attempting to keep urban development within a safe space in the Earth's carrying capacity and just space framed by human rights and societal foundations at a planetary level, we attempt to translate locally regime change agendas. Building on the transition direction set by regime agendas such as DFUD, we will investigate the community's willingness to go even further and in a more specified manner, by prospecting the UC-ES-NbS Nexus and the ESA-LCA indicator framing for NCA of its current situation and the scenarios of its conversion to a Spongetown, aligned with the Sponge City agenda of Copenhagen and multiple cities worldwide.

As described in the previous section, wicked challenges of the sustainability crisis are linked with urban, territorial and biophysical systems, which are framed conventionally by Environmental, Social, Economic, and more recently, Institutional Dimensions – these dimensions collect internally criteria and KPIs. The DGNB certification system, per instance, adds Technical and Procedural dimensions to the three conventional ones, attempting to translate the institutional focus on transparent collaborations and partnerships with early-on goal setting for the pursuit of said targets. This focus on institutional change is also linked with SDG 17, showcasing the growing acknowledgment of the relevance of institutional change in STs.

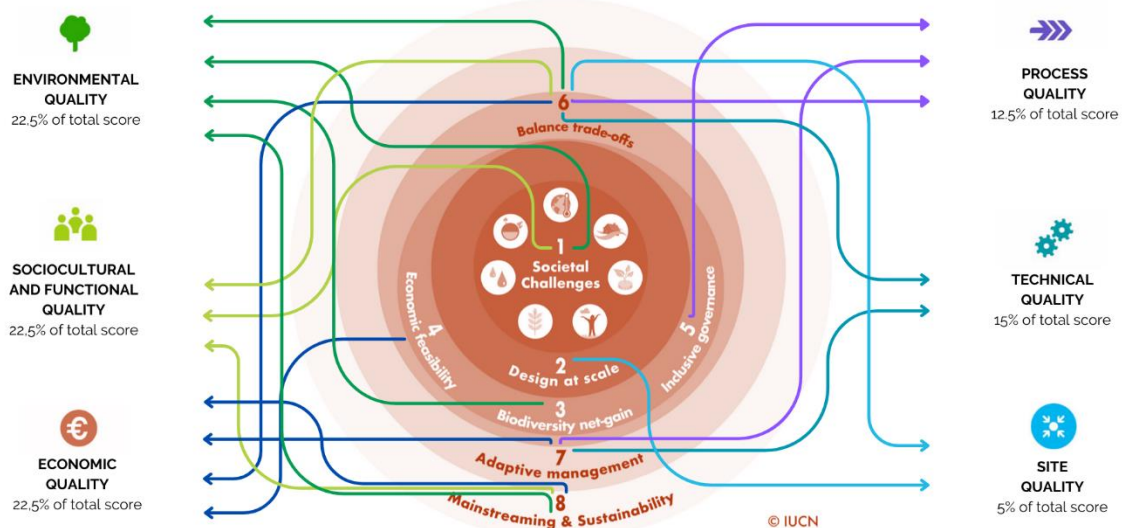
We identified through interviews main areas of concern in Christiania locally linked with globally overshoot PBs 1) Climate Change; 2) Biosphere Integrity; 3) Biogeochemical Flows; 4) Freshwater Change and 5) Land System Change, which expresses community awareness of local manifestation of these key global sustainability issues. It also manifests how these issues are already impacting quality of life locally. Per instance, interviewees pointed out the following PB-linked matters of concern:

1. Climate Change adaptation already manifests its urgency through issues like Baltic Sea-level rise and Copenhagen's coastal protection, Flood-risk and Rising Temperatures;

2. Biosphere Integrity translates as an agenda in Christiania - Biodiversity is prized and protected by local organisations, which point out multiple stressors to local ecosystems and local measures.
3. Nitrogen loads already impact locally the eutrophication levels of the Christianhavns Vold – the main water body traversing Christiania's territory; sewage leaks in neighbouring grey infrastructure has been pointed out as the likely culprit for excess nitrogen levels and algae blooms that took place after relatively recent construction and infrastructure works in the neighbouring area.
4. Land System Change is to this day a key aspect for Christiania's development. Dealing with the industrial effects of the military operations and connected industrial infrastructure that were present in its grounds during WWII, before the squat project claimed the abandoned military site. Soil toxicity, particularly through the presence of heavy metals like mercury (Hg) and lead (Pb), which prevents widespread adoption of Urban Farming for edible purposes – but didn't prevent the community from pursuing reforestation and re-naturalisation agendas to restore previous land system conditions;
5. Freshwater Change is a key matter of concern in the community, which is worried by the threat salinization poses to Christianhavns Vold and its ecosystems. This description of key issues surrounding Christiania's Green-Blue infrastructure (GBI), showcases how global PBs are interwoven even at local level issues. This description, focused on the value of local GBI also showcases how the notion of planetary commons can trickle down to place, local, regional and national commons – as the biospheric elements through which infrastructure for ES could be accounted for.

DGNB-DK | Nature-based Solutions and Ecosystem Services

IUCN NbS Global Standard Integration Pathways in DGNB

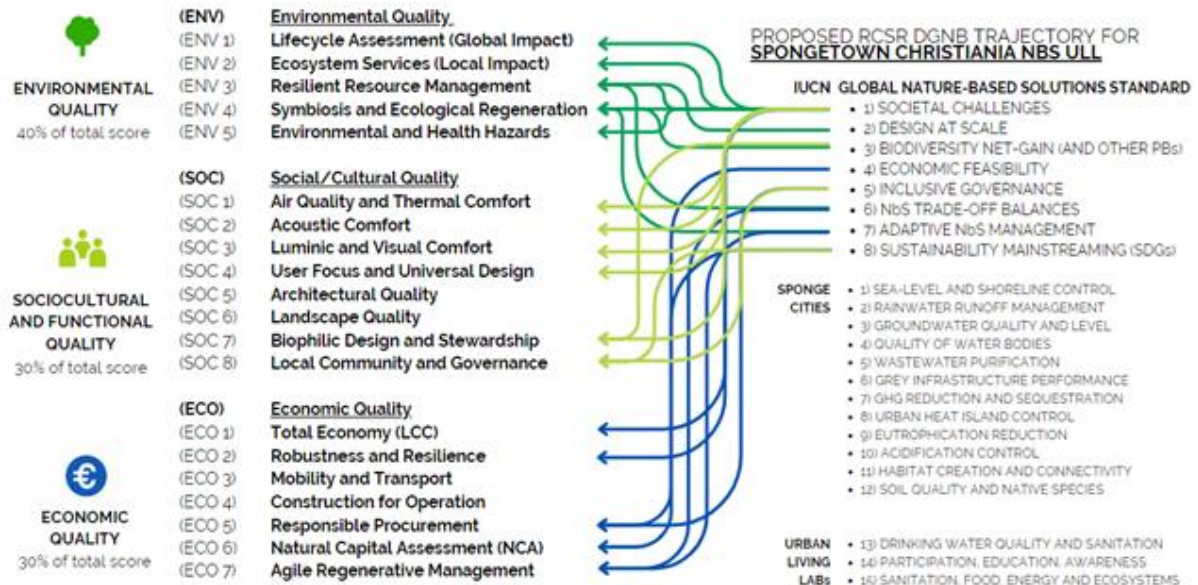


45 - IUCN Global Standard Integration Pathways in DGNB Quality Structure

Despite the valuable local awareness that Christiania's community manifests on key sustainability issues and potential solutions, accounting for the concrete value of its NbS and GBI is very limited. This is due not only to the lack of international consensus and standards, but also to the need for highly sophisticated systems for the accounting of local Natural Capital and the contributions of the community's NbS for STES transitions towards sustainability. (Appendix B)

DGNB-DK | RESEARCH GAP AND FUTURE REGIME TRAJECTORY

Full Criteria Set for an RCSR DGNB-based Spongetown Project in Christiania



46 - IUCN Global Standard Integration Pathways in DGNB Criteria and Indicators

The following criteria and indicator set for Christiania's Sustainability Pathways in a potential Urban Planning for an RCSR sustainability paradigm has been proposed to Christiania's Building Office and Secretariat, as a complementary set to DGNB Planet – which should be the minimum target of future Urban and WEFE systems planning for the community. The proposed criteria (documented in Figs. 46 and applied to the Urban Analysis of Christiania in the following Chapter) along with indicators (Fig. 47) follow the recommendations for NbS of IUCN's Global Standard, as well as more specific indicators connected with the SCC literature. We believe these to be crucial to formalize an NbS "Spongetown" for Christiania that can comply with SDGs and PBs.

INDICATOR SET FOR SPONGETOWN CHRISTIANIA AS A NBS ULL ENVIRONMENTAL QUALITY CRITERIA AND KPIS



(ENV 1) Global Warming [GLOBAL LIFECYCLE IMPACT] DGNB Certification Requirement: C1) BR Requirements for Climate Impact 1) LCA Calculation (BR standards) 2) Scope of Calculation and Data Transparency 3) LCA Calculation in Relationship to Full Scope of PBs [?]	(ENV 4) Biodiversity [SYMBIOSIS AND ECOLOGICAL REGENERATION] ENV Quality Minimum Requirement: Documentation of Natural Land and Old Trees 1) Ecosystem Design Plan and Evolution Scenarios 2) Biodiversity and Ecosystemic Integrity 3) Land System Change and Land Use 4) Freshwater Change 5) Local Nutrient Cycle and Soil Quality 6) Resilience to Climate Change
(ENV 2) [ECOSYSTEM SERVICES ON SITE] 1) Local Ecosystem Services Assessment 2) Detrimental Effects on Local Ecosystem Services 3) Beneficial Effects on Local Ecosystem Services	
(ENV 3) Resources [RESILIENT RESOURCE MANAGEMENT] DGNB ENV Quality Minimum Requirement: LCA of Demolition and Resources for Renovations 1) Origin of Resources and Reduction of Raw Material 2) Design for Disassembly and Recycling 3) Waste Prevention 4) Water 5) Ecosystem Services and Lifecycle Trade-Offs	(ENV 5) Environmental and Health Hazards ENV Quality Minimum Requirement: 1) Harmful Substances Usage Mitigation 2) Protection of the Construction Site 3) Protection of Existing Ecosystems

INDICATOR SET FOR SPONGETOWN CHRISTIANIA AS A NBS ULL SOCIOCULTURAL AND FUNCTIONAL QUALITY CRITERIA AND KPIS



(SOC 1) Air Quality and Thermal Comfort Certification Requirements: VOC, PCB, Radon, and other Health Hazards 1) Thermal Comfort 2) Ventilation 3) User Control of Indoor Climate 4) Indoor Climate Resilience 5) Indoor Air Pollution	(SOC 5) Architectural and Building Quality DGNB Diamond Requirement: D1) Appraisal in Architecture Competition 1) Architectural Valuation through SAVE method 2) Resilience and Flexibility to Use Change 3) Social Contributions of the Building Bonus: Integrated Art in the Building DGNB Heart: Synergy with all Indicators
(SOC 2) Acoustic Comfort 1) Acoustic Quality and Reverberation 2) Sound Insulation and Noise	
(SOC 3) Luminic and Visual Comfort 1) Lighting Strategy 2) Daylight 3) Sunlight 4) Electric Lighting	(SOC 6) Landscape Quality 1) Recreational and Health Landscape Benefits 2) Relationship with the Landscape/District 3) Social Contributions of the Landscape/District Bonus: Visible Recycled Materials DGNB Heart: Green and Blue Landscape Features
(SOC 4) User Focus and Universal Design Certification Requirements: c5) BR Requirements for Accessibility 1) Universal Design Social Objectives 2) Ongoing Involvement of the User Perspective	(SOC 7) [Biophilic Design and Stewardship] 1) Information, Education and Awareness 2) Ecosystemic Integration of Infrastructures (SOC 8) Local Community and Governance 1) Environmental and Economic Fairness 2) Local Empowerment and Management 3) Sharing Economy and Decentralisation

INDICATOR SET FOR SPONGETOWN CHRISTIANIA AS A NBS ULL ECONOMIC QUALITY CRITERIA, AND KPIS



(ECO 1) Total Economy (Circularity) 1) Operation and Maintenance 2) Building-related Lifecycle Costs (LCC) 3) Investment in Environmental Optimisation Bonus: LCC and LCA Scenario Comparison	(ECO 5) Responsible Procurement 1) Community Building and Work Environment 2) Minimisation of Dust and Noise 3) Responsible Procurement (Wood and Stone)
(ECO 2) Robustness (Resilience) 1) Building Envelope Construction Technology 2) Air Tightness, Moisture and Mold Prevention 3) Risk Analysis and Climate Adaptation	(ECO 6) [NATURAL CAPITAL ASSESSMENT] 1) ESA-LCA and LCC Trade-off Scenarios 2) Value Creation and Tracking Scope 3) Cost-Benefits-Risks Analysis Integration
(ECO 3) Mobility and Transport 1) Public Transport and Micro-Mobility Planning 2) Measures that Promote Micro-Mobility 3) Local and Regional Service Analysis	(ECO 7) [AGILE REGENERATIVE MANAGEMENT] 1) Planning for Change 2) Measures for Adjustments during Use Phase 3) Optimisation of Operation 4) Iterative Learning and Scenario Update
(ECO 4) Construction for Operation ECO Quality Minimum Requirements: M1) BR Requirements for Function Tests M2) Commissioning, Planning and Operations 1) Commissioning Process 2) Process Progress and Meeting Documents 3) User Training and Information Availability Bonus: BIM Model Availability	

4.5 Navigating the RCSR Landscape by Steering the DGNB-DK Regime towards NbS ULL

European projects and programs are actively promoting NbS and ULLs through a variety of mechanisms, including funding, co-creation processes, and innovative financing models. In this section we present an overview of how these initiatives specifically support NBS and ULLs, as discussed with our project network in interviews (A.12, A.14, A.15, A.17), as part of our organisational recommendations for the project of Spongetown Christiania:

- *European Investment Bank (EIB)*

The EIB plays a significant role in financing NBS through various instruments. The Natural Capital Financing Facility (NCFF), a joint initiative between the EIB and the European Commission, supports projects that promote biodiversity and climate adaptation.

“The EIB supports scaling up nature-positive investments by mainstreaming biodiversity across policies, investments, and operations. We provide a range of financial products, including loans, grants, and investment guarantees, tailored to early-stage projects and those with diverse risk profiles” (EIB, 2023) (EIB) (EIB).

The EIB emphasizes the importance of combining public and private sector efforts to fund and implement NBS. Their report, “Investing in NbS,” highlights the need for regulatory reforms and a more flexible spectrum of financial instruments to incentivize investment in NBS (EIB, 2023) (EIB) (Climate ADAPT).

- *Horizon Europe*

Horizon Europe is a key funding program supporting research and innovation projects related to NBS and ULLs. Cluster 6 of Horizon Europe focuses on food, bioeconomy, natural resources, agriculture, and environment, explicitly mentioning NBS.

“Horizon Europe Cluster 6 aims to address biodiversity loss, climate change mitigation and adaptation, environmental sustainability, and ecosystems services, including NbS” (European Commission, 2021) (EU CAP Network).

- *LIFE Programme*

The LIFE Programme is dedicated to environmental and climate action projects, including NBS.

“LIFE funds nature conservation projects, particularly in the fields of biodiversity, habitat restoration, and NbS” (LIFE Programme, 2023) (EIB).

- *URBACT*

URBACT supports cities in developing sustainable urban solutions through networking and knowledge exchange. It facilitates the integration of NBS into urban planning frameworks.

“URBACT enables cities to work together to develop sustainable solutions to major urban challenges, through networking, knowledge-sharing, and identifying innovative urban practices, including urban living labs and NbS” (URBACT, 2023) (EU CAP Network).

➤ CLEVER Cities and proGReg Projects

These Horizon 2020 projects are prime examples of initiatives that focus on implementing NBS through ULLs.

CLEVER Cities: “Implements NbS in urban living labs in cities like London, Milan, and Hamburg, focusing on co-creation processes with local communities to enhance urban resilience and ecological connectivity” (CLEVER Cities, 2023) (Clever Cities).

proGReg: “Develops, tests, and implements NbS in living labs in cities such as Dortmund, Turin, Zagreb, and Ningbo, promoting green infrastructure for post-industrial urban regeneration” (proGReg, 2023) (ProGReg).

These projects demonstrate the EU’s commitment to fostering sustainable urban environments by integrating nature into city planning, thereby addressing critical environmental, social, and economic challenges. This EU focus on NbS and ULLs promises potential for future changes as AEC regimes worldwide catch up to an RCSR paradigm of Sustainability, such as the Danish version of DGNB.

At a national and regional level, within the scope of Christiania’s project, many other organisations can be relevant to further materialise allegiances towards different RCSR configurations. These organisations have been documented in our manuscript in Appendix. A.

We believe these unengaged stakeholders to hold a lot of promise for Christiania and DGNB alike, which is why we prepared a relevant interview with their Secretariat and Planning Offices, to promote our general RCSR vision for Spongetown Christiania, and to inquire openness to pursue EU funding and DGNB certification simultaneously towards NbS preservation and development. Even though they mostly belong to the “landscape” or “higher regime” framing of our MLP, they could become crucial actors for Christiania’s niche, provided that the future allegiances we envisioned collectively in this project can be pursued.

Scenarios, and the related visions that the strategies to address them give rise to are fundamental to translate our MLP in relevant project management approaches to an Urban Design such as Christiania. In the next chapter, we will conduct a more managerial and urban analysis approach to PESTEL dimensions through DGNB indicators related with the reviewed criteria. This analysis was conducted bearing in mind that Political and Legal dimensions are dismissed largely by DGNB, unless directly related with building and urban regulations.

Since Christiania’s identity and community is diagnosed to be in peril due to urban phenomena such as gentrification (which is not assessed by DGNB); and to the fact that land use and private property do not share the economic link of conventional societies; we gathered a specific set of indicators related with our proposed criteria set in SOC 7, and SOC 8.

In the next chapter we will conduct an Urban Analysis of Christiania to build different Scenarios through a SWOT-PESTEL analysis of different Transition Pathways for the forthcoming Localplan,

considering IUCN and DGNB criteria established in this chapter. We will factor in the pursuit of different potential allegiances that Christiania may establish with the constellation of networked organisations that we have been documenting thus far; and how those are related with the foreseen scenarios for Christiania’s Urban Planning towards an RCSR sustainability paradigm.

5. Christiania’s “Nature-based Niche” in the Evolution of Copenhagen’s Urban WEFE System

MLP’s framing of aspirational niches contending with incumbent regimes becomes very literal when we are analysing an alternative community and place such as Christiania - occupying an abandoned military base that became obsolete as a component of the Danish military regime in 1971. The base, with a long history going back to at least the XVII century, had long been progressively deactivated, all the way to its final obsolescence as a contaminated industrial site in the heart of Copenhagen to be taken by an organised community of local squatters.

The military base, fortifications, lakes and trenches, ramparts and heritage buildings that belong to the complex are protected by the Danish Ministry of Culture’s Agency for Palaces and Property and other ministerial departments of the Danish government. The Environmental Protection Agency, the, which shares the jurisdiction over the land and its assets with the community of Christiania, the municipality of Copenhagen and other key Danish Ministries such as the Environmental Protection Agency.



48 - Survey Results – Outsiders: Perceptions on Christiania’s Urban Value

After the pathways towards Christiania’s integration in Danish society as an autonomous niche society were accepted by Danish governance, negotiations ensued for the urban future of the community. Persuaded to make multiple concessions to the city regarding the conditions and

types of land uses to be pursued, urban density targets and what buildings and infrastructure, including the landscape itself in the ecological sense, should be deemed worthy of conservation.

This strategy, enshrined in documents like “Udviklingsplan Christianiaområdet voldanlæg” of September 2006, by the Palaces and Property Agency and the equally important NIRAS Report relating to the Soil, Groundwater Quality and Hazardous Pollutants; would pave the way to a municipal strategy of urban renewal in close proximity with the local community, paving the way for the acceptance and integration of the community in the regional and national state apparatus, as documented in the following timeline:

To provide context on the current matters of concern encompassing the urban and heritage renewal of the place nowadays known as Christiania, we will in this analysis, first introduce the history of this place and of how it came to be used by a civilian countercultural community after its military use.

5.1. Before Christiania: From fortified new landscape to military base

The history of the place known nowadays and for the past five decades as Christiania begins in the early 17th century, intertwined with the broader military and urban development strategies of Copenhagen in the Late Modern Period. The Danish King Christian IV founded Christianshavn in 1617, envisioning it as a fortified town that would bolster the city’s defences against invasions and sieges through naval warfare, especially against Sweden. This strategic city defence and expansion plan involved transforming low-lying beaches and islets between Copenhagen and Amager into a network of fortifications, reflecting the advanced dutch fortification military architectural techniques of the period, in connection with gunpowder-based artillery (Wikipedia) (Gupea).

➤ Construction of the Ramparts

The fortifications of Christianshavn, constructed between 1682 and 1692, formed a critical component of Copenhagen's defensive strategy. The design and construction were overseen by the fortress engineer Gottfried Hoffmann, following Dutch military architectural principles. This involved building extensive ramparts, bastions, and a complex system of moats. The primary purpose of these fortifications was to protect Copenhagen from potential naval and ground invasions, particularly from the south and east (Wikipedia).

➤ Expansion and Military Utilization

Throughout the 18th and 19th centuries, the fortifications were continually upgraded to meet the evolving needs of military defence. The area included the Bådsmandsstræde Barracks, housing various military units such as the royal artillery regiment. These barracks were integral to the area’s military function, providing storage for ammunition and other essential military supplies. The site also included numerous powder magazines and other buildings necessary for military operations.

➤ Decline of Military Importance

By the late 19th century, advancements in military technology rendered traditional fortifications less critical. This period marked the beginning of a significant shift, as the strategic importance of the fortifications diminished. In 1909, the Danish military decommissioned the fortress as a defensive structure. Subsequently, many parts of the fortifications were repurposed for urban development, while others fell into disuse and disrepair. This process of decommissioning allowed the city of Copenhagen to expand beyond its historic defences, transforming previously restricted military zones into public spaces and parks.

➤ Military Obsolescence and Transition to Civilian Use

Following World War II, the military's presence in the area continued to wane. By the 1950s, the barracks were largely abandoned, leaving behind a collection of dilapidated buildings and unused spaces. The once vibrant military area was now a quiet, neglected part of the city, with the Danish military having little need for the old fortifications. This abandonment created a unique opportunity for transformation.

➤ The Birth of Christiania

In September 1971, a group of activists and residents from nearby neighbourhoods broke into the abandoned military base, initiating the occupation that led to the establishment of Christiania. This occupation was driven by a severe housing shortage in Copenhagen and a desire to create a new kind of community based on communal living and self-governance. The group declared the area a "Freetown," and it quickly became a hub for countercultural movements.

Jacob Ludvigsen, a journalist and activist, played a pivotal role in publicizing the occupation. In his magazine, he declared the establishment of Christiania, which attracted people from across Denmark and beyond, all eager to participate in this social experiment. The residents of Christiania repurposed the abandoned military buildings, using recycled materials to create homes, workshops, and communal spaces. This marked the beginning of Christiania as a unique, self-sustaining community within the heart of Copenhagen.

➤ Bridging the Gaps: Christiania and the Memory of the City

Despite numerous legal challenges from the Danish government, Christiania has maintained its autonomous status. The area's historical military structures have been preserved, but also adulterated and integrated into the fabric of the community, blending the past with the present in a way that highlights the resilience and adaptability not only of the historic built environment but also of its current community of residents. The old fortifications, ramparts, and military buildings continue to serve as a reminder of the area's historical significance while providing a backdrop for Christiania's ongoing experiment in alternative urban living.

The Charlotte Amalie's Bastion, constructed between 1685 and 1692, played a pivotal role in Copenhagen's defense. Named after Queen Charlotte Amalie, it was strategically designed to house artillery, providing robust defense against sea and land attacks. As military threats subsided in the early 20th century, the bastion's role shifted from defense to accommodating various military operations and storage. Today, Charlotte Amalie's Bastion stands as a historical landmark within Christiania, blending its past with modern recreational and residential uses.

Similarly, Carl's and Frederiks Bastions were integral to the city's military infrastructure. Built during the same period, these bastions housed crucial powder magazines for storing

ammunition. Throughout the 19th century, these areas expanded their industrial capabilities, reflecting the military's shift towards production and storage. By the late 19th century, as the military presence waned, these bastions began integrating with the surrounding civilian areas. Presently, Carl's and Frederiks Bastions are significant parts of Christiania, their historical buildings repurposed for residential and communal activities.

The Erdkehlgraven and the Factory Area further illustrate Christiania's military-industrial evolution. Originally serving as a defensive moat, Erdkehlgraven added an extra layer of protection. Adjacent to this moat, the Factory Area was pivotal for military production, particularly ammunition manufacturing. This industrial activity peaked in the 19th century with large-scale production facilities and storage bunkers. As the defensive importance diminished, the area continued to be used for industrial purposes, gradually integrating with civilian infrastructure. Today, it hosts various community workshops and artistic spaces, maintaining its industrial heritage while serving new creative purposes.

Sofie Hedevig's Bastion also transitioned from a defensive stronghold to a more civilian-oriented space. Initially constructed as part of the city's fortifications, it housed military barracks and storage facilities. With the decline in military necessity during the 20th century, the bastion and its buildings were repurposed for residential and artistic uses. Now, Sofie Hedevig's Bastion serves as a historical and cultural site, merging its past with modern communal living.

Ulrik's Bastion followed a similar path. Built for defensive purposes, it later accommodated various military operations and storage facilities. By the early to mid-20th century, as military functions decreased, the bastion began to be used for industrial storage and community activities. Currently, it houses various community projects and residential spaces, reflecting the adaptive reuse of historical structures.

The Envelope and its five Redans were constructed in the 18th century as part of an advanced defensive line. These structures facilitated troop movement and protected key positions, with the redans housing gunpowder magazines and other supplies. As the military importance of these structures declined in the 19th and 20th centuries, the area transitioned to more civilian uses. Today, the Envelope features gardens and communal spaces, blending historical military architecture with green spaces and community projects.

The Nyartillerikaserne (New Artillery Barracks), built in the 1830s on newly infilled land, marked a significant expansion of the military-industrial complex. Serving as a key site for artillery production and training, the barracks' importance waned by the late 19th century, allowing for gradual integration with civilian areas. Now part of the Christiania community, the former military buildings are repurposed for residential and cultural activities.

Laboratories and workshops established in the 19th century supported the production of ammunition and other military supplies. These facilities played a crucial role in the area's industrial activities. As military operations decreased in the early 20th century, these workshops continued to be used for industrial purposes but gradually incorporated more civilian-oriented activities. They now serve as community workshops and creative spaces, preserving the area's industrial past while supporting modern community needs.

Refshalevej, developed in the late 19th century, provided crucial access to Christiania, facilitating military and industrial activities. As military operations reduced, the road became vital for integrating the area with the broader urban fabric of Copenhagen. Today, Refshalevej

remains a vital access point, linking various parts of Christiania and supporting its modern infrastructure.

The Bådsmandsstræde Barracks were among the first to transition from military use. By the late 1960s and early 1970s, these barracks were settled by new residents, marking the beginning of Christiania's transformation. Initially used for military housing and operations, these buildings were repurposed for residential and communal uses by the new occupants. Today, they form a central part of Christiania's community, symbolizing the area's adaptive reuse.

Kommandørhuset and the Gunpowder House are significant structures within Christiania. The Kommandørhuset, originally used for military command purposes, and the Gunpowder House, used for storing gunpowder, were pivotal in the area's military history. In the post-military era, these buildings were among the first to be adapted for civilian use, reflecting a blend of historical preservation and new functional needs. They now serve various residential and community purposes, maintaining their historical significance.

The Dyssebroen bridge connects different parts of Christiania, enhancing accessibility and linking various historical and functional areas. The bridge represents the integration of the old military infrastructure with new community needs, facilitating movement and connectivity within Christiania.

Stadsgraven, a significant water feature, originally served as a defensive moat surrounding Christiania's fortifications. Over time, as the military significance of the area diminished, Stadsgraven became an integral part of the recreational and natural landscape of Christiania. The transformation of this water feature highlights the adaptive reuse of military infrastructure for peaceful and communal purposes.

Fredens Eng and the Bear Path (Bærmestien) are key green spaces within Christiania. These areas, initially part of the military fortifications and later naturalized, provide important recreational spaces for residents and visitors. The Bear Path has evolved into a nature trail, reflecting Christiania's commitment to preserving green spaces and promoting environmental sustainability.

Christiania's transformation from a fortified military zone to a diverse urban community is a testament to its rich historical heritage and adaptive reuse. Each bastion, workshop, and industrial site reflects a layer of history, contributing to the unique cultural landscape of modern Christiania. The evolution of land use and activities in these areas showcases the dynamic changes that have shaped Christiania's development over the centuries. From a military defence legacy to the birth of anti-war vibrant community, Christiania is a tale of urban, but also societal and historic transitions.

5.2. DGNB Assessment: Environmental, Economic, Sociocultural and Functional Qualities

5.2.1 Environmental Quality Criteria

In Copenhagen and broader Denmark, the legal framework for the built environment has increasingly integrated Life Cycle Assessment (LCA) as a mandatory tool for ensuring sustainability. The Danish Building Regulations now require LCA for all new constructions over a certain size threshold, specifically those exceeding 1,000 square meters. These regulations emphasize the importance of assessing environmental impacts throughout a building's entire lifecycle, from material extraction to end-of-life disposal.

5.2.1.1 Lifecycle Assessment (LCA)

➤ Mandatory LCA Requirements

Starting from 2023, Denmark has implemented stringent LCA requirements for new construction projects. For buildings larger than 1,000 square meters, an LCA must demonstrate that the embodied carbon emissions do not exceed 12 kg CO₂-eq/m²/year. For smaller buildings, while an LCA is still required, there are no specific carbon thresholds that must be met, but the process must still account for the total environmental impact of the construction materials and methods used.

➤ Environmental Product Declarations (EPDs)

LCA in Denmark is facilitated using Environmental Product Declarations (EPDs), which provide standardized information on the environmental impacts of construction products. EPDs ensure that materials used in construction meet specific sustainability criteria and help in the accurate calculation of a building's overall environmental footprint. This standardization allows for more straightforward compliance and comparison across projects, making LCA a more accessible tool for achieving sustainability targets.

➤ Relationship with DGNB-DK

The DGNB (German Sustainable Building Council) certification in Denmark, known as DGNB-DK, incorporates LCA as a core component of its sustainability assessment. DGNB-DK uses LCA to evaluate the environmental performance of buildings, aligning with the legal requirements set forth by Danish regulations. This integration ensures that buildings seeking DGNB certification not only comply with legal mandates but also meet higher standards of sustainability performance.

➤ Challenges and Opportunities

Despite the clear regulatory framework, there are challenges associated with implementing LCA, particularly for smaller projects or those with limited budgets that cannot afford certification or to collaborate with EPD compliant partners and using LCA assessed products and services. Unlike standardized LCA processes facilitated by EPDs, assessing ES, in connection with this issue for smaller projects offers even a higher gap regarding the entry level. This barrier is linked with the fact that ESA lacks a standardized approach, making it difficult for low-investment projects to achieve comprehensive sustainability assessments that can provide relevant cost-risk-benefit analysis as pointed out in the IUCN Global Standard. This gap highlights the need for further development of methodologies that can accurately account for the economic and environmental benefits of ecosystem services within the LCA framework.

Christiania, as a cluster of smaller organisations, may be able to organise its community towards in-house LCA accounting, but the lack of internal capacity for assessment is thus far pointed out as the main culprit for the non-adoption of the procedure in its urban planning, even if other partners can comply partially with relevant information for DGNB certification. LCA is applied, per instance, in Hofo projects for geothermal passive systems in Christiania which will soon be adopted, according to internal accounts shared with us in Interview X, in appendix Y.

5.1.1.2 Ecosystem Services Assessment (ESA)



49 - Urban Analysis of Green Blue Infrastructure

Biodiversity

Christiania's biodiversity is one of its most valuable assets and a foundational Ecosystem Service related with a majorly overshoot PB (Biospheric Integrity). The Blue Green Infrastructure present in the area creates a range of biotopes that are to be preserved and their resilience increased, as mapped in Fig. 49.

Biotopes

Christiania's biotopes are varied and include both terrestrial and aquatic habitats that are essential for the survival of many species. The development plan includes measures to enhance these biotopes, making them more suitable for wildlife and more resilient to environmental changes.

Aquatic Biotopes

- **Storage Ponds:** Located at Carl's Bastion (Den Blå Karamel) and Frederik's Bastion (Bjørnekloen), these ponds are crucial for amphibians and aquatic plants. The plan proposes cleaning and expanding these ponds to improve water quality and habitat conditions, which will benefit species such as the common frog and smooth newt.
- **Stadsgraven (City Moat):** This large water body is maintained to support waterfowl and aquatic life. The reed beds along its banks provide nesting sites and shelter for species like the mallard (*Anas platyrhynchos*) and mute swan (*Cygnus olor*).

Terrestrial Biotopes

- **Dense Scrub:** Areas with dense scrub are preserved to provide nesting and foraging habitats for small birds and mammals. The maintenance of native shrubs like hawthorn and elderberry is crucial for this biotope.
- **Mature Woodlands:** Mature trees, particularly oak and beech, are preserved for their ecological value. These woodlands support a variety of birds, insects, and mammals.
- **Open Grasslands:** These areas are maintained to support herbaceous plants and provide foraging grounds for insects and birds.

Encompassing a wide range of species from birds and amphibians to various plant species, the diversity of habitats within Christiania includes dense scrub, mature woodlands, open grasslands, and wetland areas, supporting a cornucopia of species. The Urban Planning report on Christiania by the Property and Palaces Agency of the Danish Culture Ministry reports the following species of interest, and ecological integrity measures to be taken in consortium with public heritage restoration and preservation of the heritage site, its buildings and military fortification systems.

Bird Species

- **Great Tit (*Parus major*):** This common but important species thrives in wooded areas and benefits from the presence of mature trees and nesting sites.
- **Blue Tit (*Cyanistes caeruleus*):** Another widespread species that relies on tree cavities for nesting.
- **European Robin (*Erithacus rubecula*):** Prefers dense undergrowth for nesting and foraging.
- **Blackbird (*Turdus merula*):** Common in both urban and woodland areas, relies on dense scrub and trees for nesting.
- **Woodpecker Species:** Including the great spotted woodpecker (*Dendrocopos major*), which relies on dead trees and branches for nesting and foraging.

Amphibians can be found in the freshwater biotopes surrounding the old gunpowder storage buildings in the two northernmost bastions of the fortification complex. Both biotopes are components of the Natura 2000 network. The Oresund Environmental School of the municipality takes place in this area of Christiania as it has been granted to the city for said purpose.

- Common Frog (*Rana temporaria*): Found in wetland areas and ponds, benefits from clean, undisturbed water bodies
- Newt (*Lissotriton vulgaris*): Prefers ponds and slow-moving waters with abundant aquatic vegetation.
- Plant Species abound in Christiania, the following deserving special mention in the Culture Ministry urban planning report on Christiania:
- Oak (*Quercus robur*): A keystone species in many European woodlands, providing habitat and food for numerous species.
- Beech (*Fagus sylvatica*): Another dominant tree species that supports a diverse range of wildlife.
- Hawthorn (*Crataegus monogyna*): Important for its berries, which are a crucial food source for many bird species.
- Elderberry (*Sambucus nigra*): Provides both food and habitat for birds and insects.

Ecological Integrity Measures

The development plan for Christiania includes several measures aimed at maintaining and enhancing the ecological integrity of the area. These measures focus on habitat preservation, species protection, and the creation of new biotopes.

- Habitat Preservation
 - Old Tree Retention: Preserving old trees that provide nesting cavities and support insect populations is a priority. This is particularly important for cavity-nesting birds like woodpeckers and owls.
- Dense Scrub Maintenance: Areas with dense scrub are carefully managed to prevent overgrowth while ensuring they provide adequate shelter and nesting sites for wildlife.
- Food-Bearing Vegetation: Trees and shrubs that produce berries, such as hawthorn, are preserved and planted to provide a reliable food source for birds, especially during winter.
- Species Protection
 - Endangered and Protected Species: Efforts are made to protect species that are endangered or have special conservation status. This includes ensuring their habitats are not disturbed and that they have access to adequate food and shelter.
- Invasive Species Control: Managing and controlling invasive plant species to prevent them from outcompeting native flora and disrupting local ecosystems.
- Creation and Enhancement of Biotopes
 - Pond Cleaning and Expansion: Proposals to clean and expand storage ponds aim to create better habitats for amphibians and aquatic plants. This includes removing sediment and overgrown vegetation, which can improve water quality and habitat diversity.
 - Water Quality Improvement: Measures to ensure the quality of water bodies like Stadsgraven, such as maintaining reed beds and monitoring pollution levels, are crucial for supporting aquatic life.
 - Planting Native Species: New plantings focus on native species that support local wildlife and enhance biodiversity. This includes trees like oak and beech, as well as shrubs like hawthorn and elderberry.

- Restoration of Historical Landforms: Recreating the original profiles of ramparts and embankments through careful vegetation management helps preserve the historical landscape while enhancing its ecological value.
- Community Involvement and Education
 - Engaging the Community: Involving the Christiania community in conservation efforts through educational programs and volunteer opportunities fosters a sense of stewardship and ensures sustainable practices are followed.
 - Awareness Campaigns: Raising awareness about the importance of biodiversity and ecological integrity helps garner support for conservation measures and encourages responsible behaviour among residents and visitors.

Maintaining the ecological integrity of Christiania involves a multifaceted approach focused on preserving natural habitats, promoting biodiversity, and enhancing biotopes. By protecting old trees, dense scrub, and food-bearing vegetation, and by improving water bodies and other habitats, the development plan aims to support a rich variety of bird species and other wildlife. These efforts are crucial for sustaining the area's unique ecological character and ensuring a healthy, vibrant environment for future generations.

5.2.1.3 Resource Management

The valuation of NbS (NbS) and Ecosystem Services (ES) is integral to urban and WEFE systems, lifecycle processes, and resilient resource management. Accurately valuing ES ensures that urban planning and development are aligned with sustainability goals, promoting long-term environmental health and community well-being beyond global environmental impact mitigation through LCA. Integrating these values into certification schemes and urban planning frameworks can drive the mainstream adoption of NbS, facilitating sustainable development in cities like Copenhagen.

Valuation of NbS and Ecosystem Services

Denmark's AEC sector is pioneering efforts to integrate the valuation of NbS and ecosystem services into urban planning. This involves developing robust methodologies to assess the economic and environmental benefits provided by green and blue infrastructure. For example, constructed wetlands offer valuable services such as wastewater treatment, stormwater management, and habitat creation. The valuation methods used include contingent valuation, cost-benefit analysis, and benefits transfer, which help quantify these benefits comprehensively.

Integrating NbS and GBI with Certification Systems

DGNB Certification includes comprehensive sustainability assessments, evaluating buildings and their inherent design process based on environmental, economic, social, technical and procedural qualities and criteria. DGNB-DK's integration of NbS criteria can ensure that buildings not only meet environmental standards but also contribute to ecosystem resilience and urban biodiversity.

IUCN Standards: The IUCN's Global Standard for NbS provides a framework for assessing the holistic benefits of NbS, including biodiversity support, climate resilience, and socio-economic advantages. Incorporating these standards into Danish urban planning can bridge gaps in current certification schemes, ensuring that the full range of ecosystem services is recognized and valued.

Benefits of RCSR Resource Management Adoption in Christiania

Green and Blue Infrastructure (GBI): Christiania's extensive use of GBI, such as green roofs, urban forests, and constructed wetlands, provides multiple ecosystem services. For instance, constructed wetlands treat wastewater, manage stormwater, and create habitats for wildlife. By integrating ESA into the certification process, the full value of these services can be recognized and quantified.

Urban WEFEE Systems

The Water-Energy-Food-Ecosystems (WEFEE) nexus in Christiania is strengthened through NbS that support water purification, energy savings, food production, and ecosystem health. Green roofs and urban gardens enhance food security and biodiversity, while sustainable drainage systems improve water management – all increase the community's self-reliance and independence – traits deeply cherished in Christiania. These initiatives demonstrate how integrating NbS into urban planning can pave RCSR pathways.

Economic Valuation

Using cost-benefit-risks analysis promoted by the IUCN standard, the economic value of Christiania's NbS can be quantified. For example, the cost savings from reduced wastewater treatment needs and the increased property values from enhanced green spaces can be included in urban sustainability assessments – even if the latter may be slightly irrelevant for Christianites, it is a factor for investors and taxation purposes. This economic valuation supports investment in NbS by demonstrating their tangible benefits, boosting transparency in decision-making.

Promoting Certification Schemes

Integrating NbS criteria into green certification schemes for buildings and infrastructure can significantly promote their mainstreaming. Certification schemes like DGNB, LEED, and BREEAM play influential roles in the urban development sector, demonstrating the multiple benefits of NbS. These schemes are goal- and target-oriented, providing clear indicators and monitoring tools for sustainability progress. By including NbS in these schemes, investments in sustainable urban development can be incentivized, leading to increased adoption of NbS.

To ensure that territorial sustainability can be discussed without significant environmental externalities or the oversight of relevant threats and opportunities, it is crucial to integrate a true Water-Energy-Food-Ecosystems (WEFEE) valuation of green-blue infrastructure (GBI) and NbS within urban sustainability assessments. By combining Ecosystem Services Assessment (ESA) and LCA, Copenhagen can advance its sustainability goals through robust valuation frameworks that fully capture the benefits of NbS.

5.2.1.4 Symbiosis and Ecological Regeneration

Christiania plays a unique role in the city's biodiversity strategy due to its historical significance, diverse habitats, and active community involvement. We will now focus on the biodiversity analysis of Christiania drawing from Copenhagen's Biodiversity Strategy 2022-2050 and its analysis of current ecological status in the city. It outlines the major goals, specific measures, strategies, and detailed data to enhance biodiversity in this area.

Major Goals and Objectives for 2050 in Copenhagen

Reversing Species Decline

- By 2050, Copenhagen aims to reverse the decline in species and ensure that all residents have access to nature and biodiversity experiences.
- The city plans to create resilient ecosystems that are protected and integrated into urban planning and development.

Enhancing Biodiversity

- Increase the area of freshwater habitats by 10% through the opening of piped streams and creation of new water bodies.
- Connect and expand green and blue areas to form a coherent network of habitats and corridors for wildlife.

Community Involvement and Education

- Engage 50% of Copenhageners in activities that enhance biodiversity.
- Integrate biodiversity into educational programs and local community projects.

Specific Measures for Christianshavn and Christiania

- Preservation and Improvement of Existing Biodiversity
 - Green and Blue Infrastructure: Preserve and enhance existing green spaces and waterways. For Christiania, this includes the protection of woody vegetation and the conservation of water bodies
 - Habitat Connectivity: Ensure that green areas are connected to form continuous habitats. This involves creating green corridors that link Christiania's natural areas with larger urban parks and waterways.
- Creation of New Biodiversity
 - Urban Greening Projects: Implement projects to introduce new green spaces and improve existing ones. This includes creating more green roofs, facades, and urban gardens.
 - Water Bodies: Develop new waterholes and open up piped streams to increase aquatic habitats in Christiania.
 - NbS for Urban Greening Green Roofs, Green Facades, Constructed Wetlands, Rain Gardens and many other GBI features can contribute to the creation of new ecosystems and create habitat for new and existing species.
 - Riparian Transitions and Ecological Connectivity

- Designing green and blue NbS for GBI interconnectivity can help turn the fragmented mosaic of green spaces and water bodies into thriving urban ecosystems, augmenting biodiversity resilience to urban and environmental stressors and regenerating the urban ecosystems of Copenhagen.
- Education and Awareness
 - Community Engagement: Promotion biodiversity through local initiatives and community involvement. Christiania's unique social structure can be leveraged to foster community-led biodiversity projects.
 - Educational Programs: Integration of biodiversity into school curriculums and public awareness campaigns. This includes nature walks, workshops, and interactive learning experiences focused on local species and ecosystems. The Oresund Environmental school is a great example of the shared agendas between Christiania and Copenhagen.
- Strategic Focus Areas in Christiania
 - Stadsgraven and Canals: Focus on maintaining and enhancing the biodiversity of these water bodies, which are crucial for local wildlife and contribute to the area's ecological balance.
 - Green Spaces and Parks: Improve the biodiversity in Christiania's green spaces by planting native species, creating diverse habitats, and managing these areas for both ecological and recreational use.

Numeric Data and Key Indicators

- Protected Areas and Species
 - Protected Areas: Christiania and Christianshavn include several protected areas under §3 of the Danish Nature Protection Act. These areas host a variety of species that are crucial for maintaining biodiversity.
 - Key Species: Efforts are being made to monitor and support populations of particular fauna species and favouring habitat restoration processes. In Christiania, this is especially relevant due to the existence of multiple types of habitats and its role in the city as a key ecological corridor.
 - Plant Species: Native plant species such as the European beech, oak, and various wildflowers are prioritized to support local biodiversity.
- Green and Blue Area Expansion
 - Green Areas: the city strategy bets on increasing the green area coverage in Copenhagen by at least 30%, with 10% of these areas being protected. For Christiania, this means not only preserving its existing green spaces but also enhancing them to support a wider range of species and biotopes.
 - Water Bodies: The strategy aims to increase freshwater habitats by 10% through the creation of new water bodies and the restoration of existing ones in Christiania.
- Community Participation
 - Engagement Target: The strategy aims to engage over 50% of the local community in biodiversity-enhancing activities, including participation in planting events, habitat restoration projects, and educational programs, these targets may prove especially easy to achieve in a community of proud environmental stewards such as Christiania.

- Educational Initiatives: Schools in Christianshavn are integrating biodiversity into their curriculums, with outdoor classrooms and nature-based learning activities becoming more common. Environmental education is a type of curriculum that is fostered by the community in Christiania, with many local programs directly related to it with key organisations for local biodiversity.

Strategies and Design Features

- Integrated Urban Planning
 - Biodiversity in Urban Planning: Incorporate biodiversity goals into all aspects of urban planning and development. This includes ensuring new constructions and renovations consider biodiversity impacts and opportunities.
 - Green Infrastructure: Utilize green infrastructure such as permeable surfaces, green roofs, and vertical gardens to enhance urban biodiversity.
- NbS
 - Flood Management: Echoing the city strategy, Christianites have implement NbS to address urban challenges such as stormwater management and the urban heat island effects. This includes using green spaces and water bodies to mitigate flooding and provide cooling effects.
 - Native Species: Promote the use of native species in landscaping to support local biodiversity and create resilient urban ecosystems.

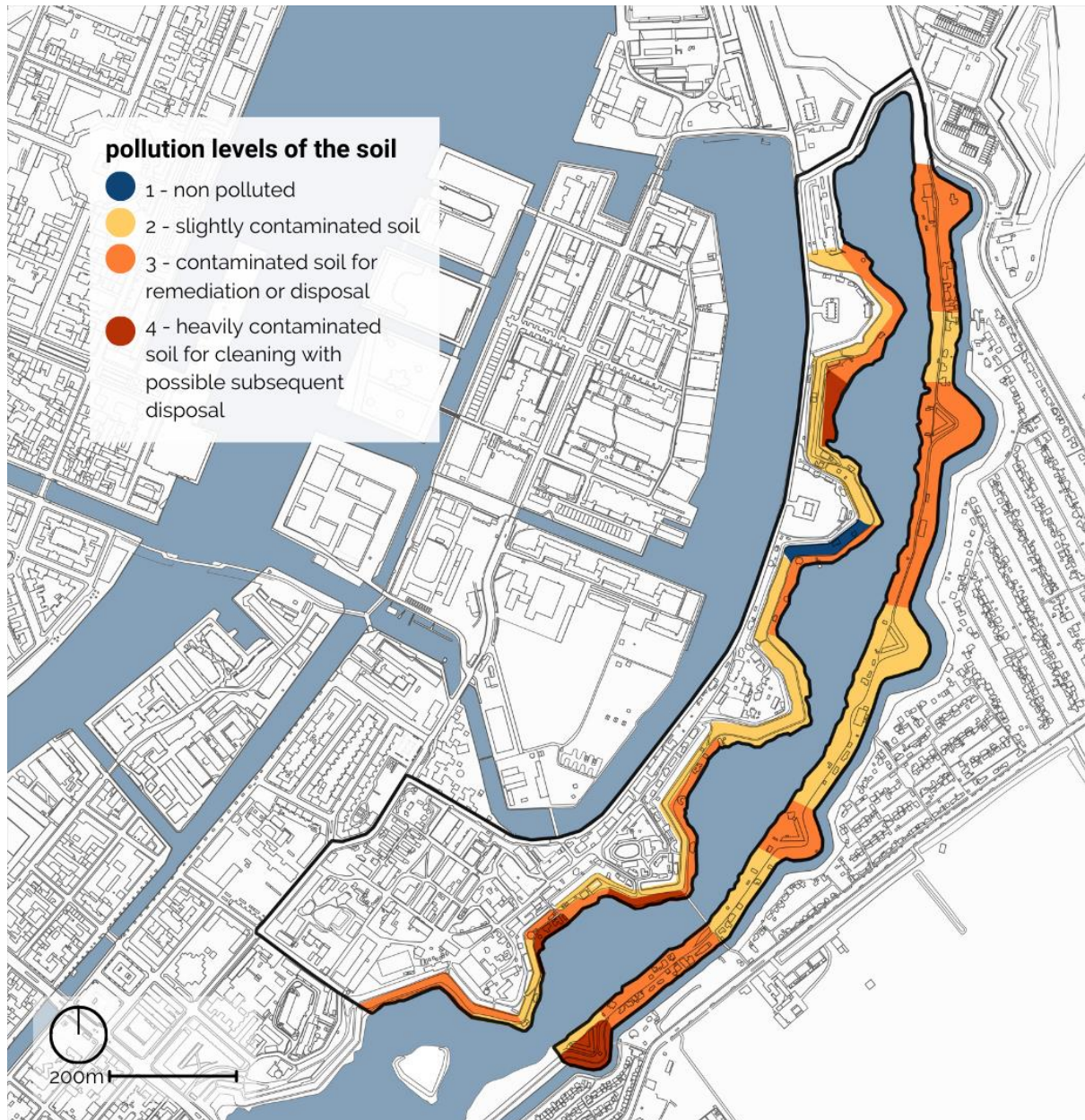
Monitoring and Evaluation

- Regular Assessments: Copenhagen intends to establish a robust monitoring system to track progress towards biodiversity goals, including regular assessments of species populations, habitat quality, and community engagement. Empowering Christianites to develop a standardised reporting system and to collaborate more strictly with the municipality requires investment, but Copenhagen has the resources to endorse these endeavours.
- Adaptive Management: Use data from these assessments to inform future actions and ensure continuous improvement in biodiversity management. Installing an IoT infrastructure in connection with local NbS in Christiania seems to be a no-brainer option, but adaptation to the community's needs is crucial for information sharing and learning processes which are required in connection with technological adoption.

The biodiversity strategy for Christiania and Christianshavn is an integral part of Copenhagen's broader effort to create a sustainable and resilient urban environment. By preserving existing natural areas, creating new habitats, and engaging the community, Christiania can serve as a model for urban biodiversity enhancement. This comprehensive approach will help ensure that Christiania remains a vibrant, biodiverse area within the heart of Copenhagen.

5.2.1.5 Environmental and Health Hazards

Analysis of Pollutants, Health, and Environmental Hazards in Christiania



50 - Urban Analysis of Pollutants in Christiania Soil

Soil Contamination

The soil in various areas of Christiania is heavily contaminated with a range of pollutants, primarily due to its historical industrial and military activities, as mapped in Fig.50. The soil samples across different locations have shown elevated levels of heavy metals such as lead, mercury, cadmium, and copper, as well as organic pollutants like benz(a)pyrene and other polycyclic aromatic hydrocarbons (PAHs). The NIRAS report on which the Culture Ministry built its urban planning recommendations reports the following critical areas and pollutants:

- North Area 228-232: Severe soil contamination was found, including mercury levels ranging from 4.4 to 110 mg/kg and lead levels between 100 and 300 mg/kg, significantly exceeding the soil quality criteria. Cadmium and benz(a)pyrene also exceeded safety limits. The sources of these contaminants are unknown, but they likely stem from past military and industrial operations.
- Area West of Sølyst: This area showed heavy contamination with lead (up to 8500 mg/kg) and mercury (up to 11 mg/kg). Additional pollutants included copper, nickel, and zinc, all exceeding the cut-off criteria, indicating extensive contamination likely due to historical military activities and use of shooting range embankments.
- Mælkebøtten/Omeletten Area: Near-ground soil samples showed high levels of lead (870 mg/kg) and benz(a)pyrene (3.0 mg/kg), along with mercury and hydrocarbons. The presence of these contaminants is linked to former laboratory activities and possibly other industrial processes.
- Krudthuset (The Powder House): Soil contamination around this former gunpowder magazine included lead, cadmium, nickel, zinc, and mercury. Benz(a)pyrene concentrations also exceeded the cut-off criteria, suggesting that the pollutants originated from the fill material used in the moat surrounding the magazine.
- Grønsagen Restaurant: Soil and air contamination near this former machine workshop showed high levels of trichlorethylene (TCE), a chlorinated solvent used for degreasing metal parts. Soil contamination included lead, mercury, and hydrocarbons, indicating extensive industrial pollution.

Groundwater Contamination

Groundwater contamination in Christiania is significant, particularly with trichlorethylene (TCE), which has been detected in several areas. This solvent is commonly used in metal degreasing and has severe health implications due to its volatile nature.

- Fabrikken/Byens Lys (The Factory/City Lights): Groundwater samples revealed TCE concentrations up to 16 µg/l, exceeding by 1600% the groundwater quality criterion of 1 µg/l. This suggests historical pollution from metal foundry activities.

Health and Environmental Hazards

The pollutants identified in Christiania's soil and groundwater pose numerous health risks. Prolonged exposure to these contaminants can lead to severe health issues, including:

- Lead: Affects the brain and nervous system, particularly harmful to children, causing cognitive impairments, hearing loss, and behavioral problems.
- Mercury: Accumulates in the body, affecting the nervous system and leading to neurological and developmental disorders.
- Cadmium: Accumulates in the liver and kidneys, causing kidney failure, osteoporosis, lung changes, and cancer.
- Copper: Toxic to aquatic organisms, can cause gastrointestinal distress in humans, and poses risks during pregnancy.
- Benz(a)pyrene and PAHs: Carcinogenic, causing skin irritation, rashes, and hypersensitivity.
- Trichlorethylene (TCE): A chlorinated solvent that can cause liver and kidney damage, and is a probable human carcinogen.

Mitigation and Recommendations

The contamination in Christiania requires extensive mitigation efforts to protect human health and the environment. Recommendations include:

- **Soil Remediation:** Removing or isolating contaminated soil, particularly in residential and recreational areas. Utilizing NbS for bioextraction through hyperaccumulating species.
- **Water Quality Monitoring:** Regular testing of groundwater and surface water bodies to assess contamination levels and implement necessary purification measures.
- **Health Risk Assessment:** Conducting detailed health risk assessments for residents and providing guidelines to minimize exposure, such as washing hands after soil contact and avoiding direct contact with contaminated areas.
- **Indoor Air Quality Control:** Implementing measures to ensure that volatile contaminants like TCE do not affect indoor air quality, including installing vapor barriers and conducting air quality tests in affected buildings.

The extensive contamination in Christiania presents significant health and environmental challenges. Addressing these issues requires a comprehensive approach involving soil remediation, water quality monitoring, health risk assessments, and ongoing environmental management to ensure the safety and well-being of the community.

5.2.2 Sociocultural and Functional Quality Criteria

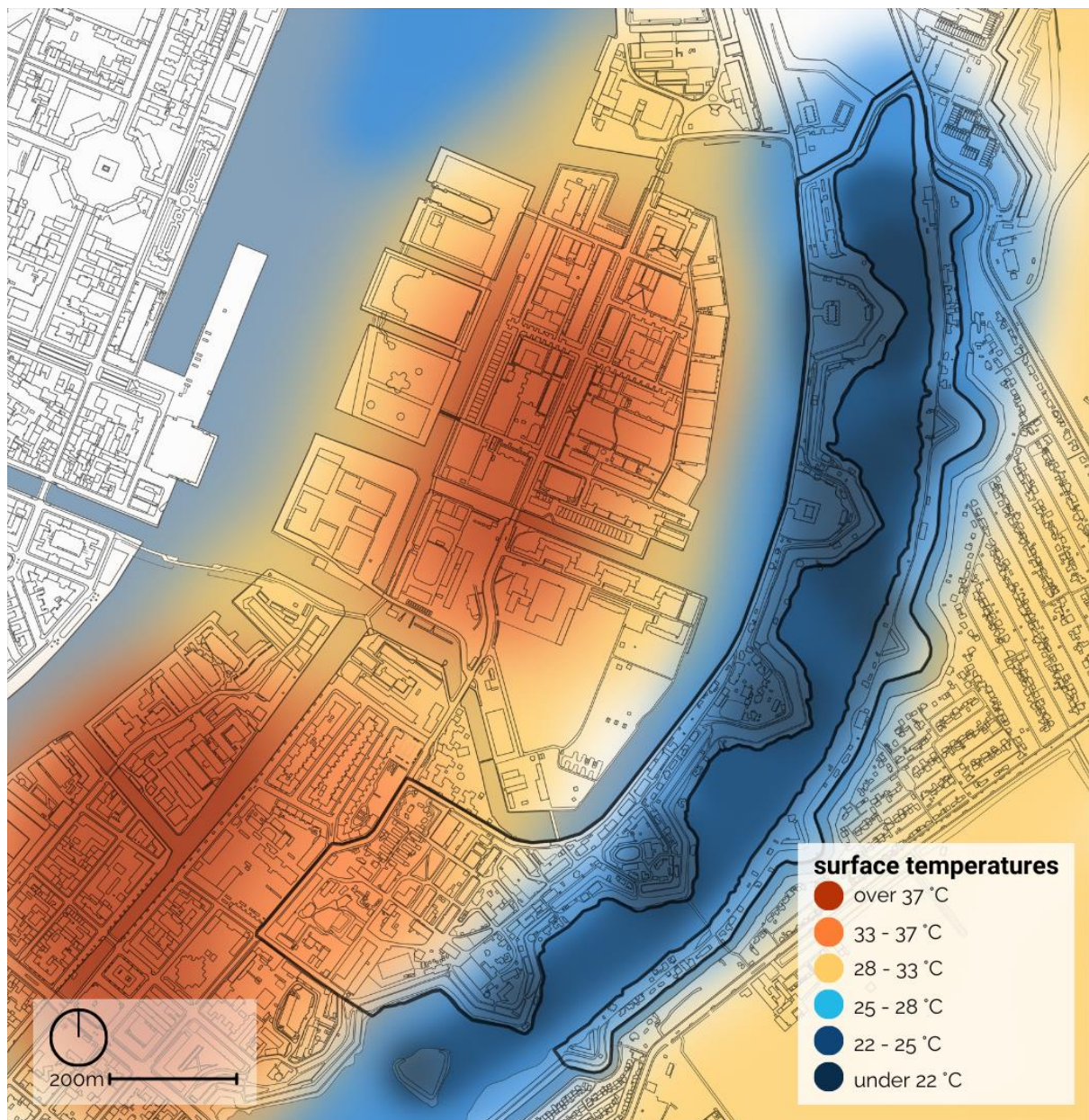
5.2.2.1 Air Quality and Bioclimatic Comfort

Air Quality and Bioclimatic comfort are key drivers for human health, energy performance and other sustainability matters of concern. Fig 51. represent the mitigation of the UHIE around the city moat adjacent to the Christiania's fortifications and protected landscape due to the presence of the previously referred GBI

The air quality in Copenhagen, particularly in areas such as Indre By, Christianshavn, and Christiania, is of critical importance due to its impact on public health and the environment. This report presents an analysis of air quality based on the 2022 air quality monitoring data, focusing on key pollutants, their sources, and the strategies implemented to manage and improve air quality.

Measurement Locations and Parameters:

- Five measuring stations were set up in Copenhagen: Krügersgade, Søtorvet, Folehaven, Hillerødsgade, and Backersvej.
- Key pollutants measured included Nitrogen Dioxide (NO₂), Particulate Matter (PM_{2.5}), and Black Carbon (BC).



51- Urban Analysis of Maximum Surface Temperatures and Urban Heat Island Effect

Pollution Levels:

- Nitrogen Dioxide (NO₂): The highest annual average NO₂ levels were found at Hillerødgade and Folehaven, both recording 19 µg/m³. These levels were significantly influenced by local traffic intensity.
- Particulate Matter (PM_{2.5}): Annual average PM_{2.5} levels were consistent across all stations, around 8-9 µg/m³. This uniformity suggests that long-distance transport is a major contributor to PM_{2.5} levels rather than local sources.
- Black Carbon (BC): Higher BC levels were observed at Folehaven, attributed to greater traffic intensity.

Compliance with Standards:

- All EU limit values for NO₂ and PM_{2.5} were met at the measuring stations.

- WHO guidelines for annual average NO₂ and PM_{2.5} were exceeded at most stations, except for NO₂ at Backersvej.

Specific Data for Indre By, Christianshavn, and Christiania

Indre By

- NO₂ Levels: The annual average NO₂ level at Søtorvet was 14 µg/m³, with the 99.8 percentile for hourly averages reaching 75 µg/m³.
- PM_{2.5} Levels: Annual average PM_{2.5} levels were around 8-9 µg/m³, with daily averages frequently exceeding WHO guidelines.

Christianshavn

- NO₂ Levels: Christianshavn, monitored indirectly via surrounding stations, showed similar NO₂ trends influenced by traffic and urban activities.
- PM_{2.5} Levels: Like other urban areas, PM_{2.5} levels were around 8-9 µg/m³ annually.

Christiania

- NO₂ Levels: Christiania, although not directly monitored by the fixed stations, is expected to have lower NO₂ levels compared to high-traffic areas like Folehaven.
- PM_{2.5} Levels: Likely similar to Christianshavn, influenced by both local activities and long-distance transport.

Strategies for Air Quality Improvement

Traffic Management:

- Implementation of speed limits and promotion of public transportation to reduce vehicular emissions.
- Expansion of pedestrian zones and cycling infrastructure to decrease traffic density.

Regulatory Measures:

- Enforcement of stricter emission standards for vehicles, especially older diesel engines.
- Regular monitoring and reporting of air quality data to ensure compliance with EU and WHO guidelines.

Public Awareness and Engagement:

- Educational campaigns to inform residents about the sources and impacts of air pollution.
- Encouragement of community involvement in air quality monitoring and reporting.

Urban Planning and Green Infrastructure:

- Integration of green spaces and green roofs to improve air quality and provide natural barriers against pollution.
- Promotion of urban designs that facilitate better air circulation and reduce pollution hotspots.

Technological Innovations:

- Adoption of advanced air filtration systems in public buildings and transportation.
- Use of real-time air quality monitoring technology to provide immediate data and feedback for policy adjustments.

The air quality in Copenhagen, especially in densely populated and trafficked areas such as Indre By, Christianshavn, and Christiania, poses significant challenges – Christiania is a green lung for this part of the city but stands climate adaptation threats. By implementing a combination of traffic management, regulatory measures, public engagement, urban planning, and technological innovations, Copenhagen aims to improve air quality and ensure a healthier environment for its residents. Continuous monitoring and adherence to both EU and WHO guidelines will be crucial in achieving these goals.

5.2.2.2 Acoustic Comfort and Sound

Noise pollution from road traffic is a significant environmental issue in Copenhagen, posing health risks such as stress, sleep disturbances, and cardiovascular diseases. This report is based on the comprehensive noise management plan for 2018-2023, focusing specifically on the Christianshavn area, including Christiania.

Key Facts and Figures

Current Noise Levels

- As of 2017, approximately 45% of all residences in Copenhagen are exposed to noise levels above 58 dB, with 7% experiencing noise levels above 68 dB.
- In Christianshavn, noise levels are particularly high due to the dense urban environment and significant traffic volume.

Health Impacts

- Traffic noise is linked to increased stress, sleep disturbances, and a higher risk of heart disease and stroke.
- The World Health Organization (WHO) indicates that exposure to high noise levels can reduce quality of life and cause chronic health conditions.

Reduction Targets

- The goal is to halve the number of residences exposed to noise levels above 68 dB by 2025, reducing from 35,000 to 17,500 homes.

Major Strategies for Noise Reduction

Reduction of Vehicle Traffic

- Electric Vehicles: Promoting the use of electric and low-emission vehicles to reduce noise pollution from engines.
- Road Pricing and Environmental Zones: Implementing stricter emission standards and potential road pricing to decrease the number of high-emission vehicles.

Speed Reduction

- Reducing speed limits on major roads to 40 km/h and residential roads to 30 km/h can lower noise levels by approximately 1.5 to 3 dB.

Noise-Reducing Pavements

- Using noise-reducing asphalt on 20 km of roads annually, aiming to cover 100 km by the end of the plan period. This can reduce noise by 1-3 dB.

Quiet Tires for Municipal Vehicles

- Equipping all municipal vehicles with low-noise tires that comply with EU regulations, potentially reducing noise by up to 4 dB.

Traffic Management

- Optimizing traffic signals to reduce stop-and-go situations, which can lower noise from vehicle acceleration and braking.

Community and Building Measures

- Noise Barriers: Installing noise barriers along major roads to protect residential areas.
- Soundproofing: Enhancing soundproofing in buildings, particularly those near high-traffic areas, using innovative window solutions that can reduce noise by up to 15 dB.
- Urban Planning: Ensuring that new developments include noise mitigation measures and that buildings are designed to shield outdoor recreational areas from traffic noise.

Christianshavn-Specific Initiatives

Local Planning

- Evaluating and updating local plans to address noise pollution effectively, focusing on the most affected areas within Christianshavn.
- Encouraging the development of noise-free outdoor areas through strategic urban planning and green space integration.

Community Involvement

- Engaging residents in noise reduction initiatives, including educational campaigns about the impacts of noise pollution and the benefits of quieter urban environments.

Bicycle and Pedestrian Infrastructure

- Expanding and improving infrastructure for bicycles and pedestrians to encourage a shift from motor vehicles to quieter, sustainable transportation modes.

Green Spaces and Noise Reduction

- Leveraging green spaces in Christianshavn, including Christiania, to act as noise buffers. This includes planting trees and creating green walls that can absorb sound and improve the overall acoustic environment.

Copenhagen's comprehensive noise management plan aims to significantly reduce road traffic noise by 2023 through a combination of vehicle regulation, infrastructure improvements, and urban planning strategies. In Christianshavn and Christiania, specific measures include promoting electric vehicles, reducing speed limits, installing noise-reducing pavements, and enhancing soundproofing in buildings. These initiatives are critical for improving the quality of life and health of residents in these densely populated areas.

Christiania enjoys a particularly favourable acoustic environment, with a lot of natural buffers and physical barriers that prevent the vehicle noise from the outside coming deep into its urban fabric and landscape. The main acoustic entry points of vehicle noise pollution come from the South limit of the lakes, where some of the main motorways of the city intersect.

The absence of cars and personal motorised vehicles in Christiania creates an overall high quality acoustic environment in Christiania. However, the large social activity that customarily takes place in this neighbourhood coupled with events such as music festivals, often compromise the tranquillity of the neighbourhood - even if only for a few hours in specific days and nights, this still happens quite regularly. These events make the villae and apartments that linger closer to Christiania's downtown centre (close to what was previously Pusher Street and Square) more vulnerable to these noise emissions and susceptible for higher soundproofing requirement.

5.2.2.3 Visual Comfort and Lighting

Here we report on the urban lighting conditions in Copenhagen, particularly in Christiania (Christianshavn), based on the findings from the Copenhagen Lighting Master Plan. The master plan aims to enhance the city's lighting infrastructure to improve safety, energy efficiency, and urban aesthetics while respecting historical contexts and environmental considerations.

Overview of Urban Lighting in Copenhagen

Lighting Master Plan Goals

- The Lighting Master Plan for Copenhagen was developed to modernize the city's street lighting, ensuring better safety, security, and comfort. It includes replacing approximately 20,000 street lamps with new LED technology to achieve a 57% energy saving by 2025, significantly reducing CO2 emissions and supporting the goal of becoming a carbon-neutral capital.
- The plan emphasizes creating a cohesive lighting image for Copenhagen, integrating modern technology with the city's historical and cultural identity.

Key Areas and Focus Points

- The master plan outlines specific guidelines and concepts for new lighting, focusing on enhancing the city's atmosphere, safety, and functionality. Key areas include historical districts, residential areas, green spaces, and major roads.
- Lighting strategies are tailored to the unique characteristics of each district, ensuring that the lighting supports local urban life and cultural heritage.

Lighting Conditions in Christianshavn and Christiania

Historical and Cultural Context

- Christianshavn, including Christiania, is characterized by its historical buildings, canals, and vibrant cultural life. The lighting strategy in this area aims to highlight these features while ensuring safety and comfort for residents and visitors.
- Key landmarks and public spaces such as Nyhavn and the canals in Christiania are focal points for lighting enhancements.

Current Challenges and Objectives

- Safety and Security: Improving lighting in dark areas, particularly along pedestrian and cyclist pathways, is crucial to enhancing safety and security. The plan includes upgrading lighting in areas perceived as unsafe or poorly lit.
- Energy Efficiency: Transitioning to LED lighting across Christianshavn to reduce energy consumption and maintenance costs while providing better illumination.
- Aesthetic Enhancement: Using warm white light in residential areas and neutral white light on major roads to create a pleasant and secure environment. Decorative fixtures are proposed for historical and cultural landmarks to enhance their visibility and attractiveness at night.

Specific Lighting Conditions and Strategies in Christiania

Dark Areas and Safety Improvements

- Selected Darkness: Areas such as Stadsgraven and the canals in Christiania are identified as vulnerable to light pollution due to their biodiversity. The strategy includes preserving these dark areas while ensuring safety with carefully placed lighting that does not disrupt the natural environment.
- Pedestrian and Cyclist Safety: Enhancing lighting on pathways and roads to ensure safe movement for pedestrians and cyclists, particularly in areas like Refsale Road and Torvegade.

Urban and Architectural Lighting

- Historical Buildings: Utilizing fixtures that blend antique and modern styles to illuminate historical buildings and public spaces, maintaining the cultural heritage while providing modern lighting benefits.
- Public Spaces: Lighting public assembly spaces and amenities such as benches and outdoor dining areas to encourage social interaction and improve the overall urban experience.

Environmental Considerations

- **Biodiversity Protection:** Ensuring that lighting in green and blue infrastructure areas, such as parks and waterways, minimizes light pollution and supports local wildlife.
- **Energy-Efficient Solutions:** Implementing LED lighting throughout Christiania to reduce energy use and enhance the sustainability of urban lighting infrastructure.

The comprehensive urban lighting strategy for Copenhagen, including Christiania in Christianshavn, focuses on improving safety, energy efficiency, and urban aesthetics while respecting historical and environmental contexts. By upgrading to modern LED technology and tailoring lighting strategies to the unique needs of each area, the plan aims to create a cohesive and sustainable lighting environment that enhances the quality of life for residents and visitors.

5.2.2.4 User Focus and Universal Design

Here we will focus the analysis on the principles of user focus and universal design within Christiania, highlighting how these principles are applied to create an accessible, equitable, and user-friendly environment for all residents and visitors.

Key Principles of User Focus and Universal Design

Inclusivity and Accessibility

- Ensuring that all public spaces, buildings, and amenities are accessible to everyone, regardless of physical abilities, age, or socioeconomic status.
- Designing environments that promote social inclusion and participation, fostering a sense of community and belonging.

Human-Centered Design

- Focusing on the needs and experiences of users in the design process, ensuring that spaces are intuitive, safe, and comfortable.
- Involving residents in the planning and design process to reflect their preferences and needs.

Flexibility and Adaptability

- Creating spaces that can adapt to changing needs and uses over time.
- Designing multi-functional areas that serve various purposes and can be easily modified.

Applications in Christiania

Inclusive Public Spaces

- **Shared Spaces:** Christiania features numerous shared spaces designed to be accessible and welcoming to all. These areas include communal gardens, playgrounds, and public squares where residents can gather, interact, and participate in community activities.

- **Seating and Rest Areas:** Public spaces are equipped with ample seating and rest areas to accommodate people of all ages and physical abilities. These areas are strategically placed to provide rest points along pathways and in communal gathering spots.

Accessible Pathways and Mobility

- **Pedestrian Pathways:** Pathways in Christiania are designed to be wide, flat, and free of obstacles, ensuring easy access for individuals with mobility challenges, including those using wheelchairs or strollers.
- **Cycling Infrastructure:** Given the high prevalence of cycling in Copenhagen, Christiania includes well-maintained cycling paths that connect to the broader city's network, promoting sustainable and accessible transportation options.

Universal Design in Buildings

- **Entrance and Accessibility Features:** Buildings in Christiania are equipped with ramps, wide doorways, and accessible entrances to accommodate people with disabilities. This ensures that everyone can access public buildings, shops, and community centers.
- **Restroom Facilities:** Public and community buildings feature accessible restroom facilities designed to meet the needs of all users, including those with disabilities.

User-Centered Community Initiatives

- **Participatory Planning:** Christiania's governance model emphasizes participatory planning, involving residents in the decision-making process. This approach ensures that the community's needs and preferences are reflected in urban planning and development projects.
- **Community Workshops and Events:** Regular workshops and events are held to educate residents about universal design and gather feedback on how to improve accessibility and usability in the neighborhood.

Specific Initiatives and Projects

The Green Plan

- **Christiania's Green Plan** outlines strategies for creating inclusive and accessible green spaces. This includes the development of wheelchair-accessible paths in parks and the installation of benches and rest areas that cater to people with varying mobility levels.
- The plan also promotes the use of native plants and sustainable landscaping practices, enhancing the aesthetic and environmental quality of public spaces.

Urban Gardening and Community Spaces

- **Community Gardens:** Christiania's community gardens are designed to be accessible to all residents. Raised garden beds are used to accommodate people with physical disabilities, allowing them to participate in gardening activities.
- **Public Art Installations:** Public art projects in Christiania often incorporate elements of universal design, ensuring that art is accessible and engaging for all. This includes tactile sculptures and interactive installations that can be enjoyed by people with visual impairments.

Sustainable and Inclusive Housing

- Co-Housing Projects: Christiania features several co-housing projects designed with universal design principles. These projects prioritize accessibility, with features such as ground-floor units, accessible kitchens and bathrooms, and communal living spaces that encourage social interaction.
- Retrofit and Renovation Programs: Ongoing retrofit and renovation programs aim to update older buildings to meet modern accessibility standards. This includes installing elevators, widening doorways, and enhancing overall building accessibility.

Challenges and Future Directions

Balancing Historical Preservation and Modern Accessibility

- •Christiania's historical buildings and unique architectural styles present challenges in implementing modern accessibility features. The community is committed to finding innovative solutions that preserve historical integrity while enhancing accessibility.

Engaging the Broader Community

- While Christiania has made significant strides in user-focused design, ongoing efforts are needed to engage the broader Copenhagen community in these initiatives. Collaborative projects and partnerships with local organizations can enhance these efforts.

Adapting to Changing Needs

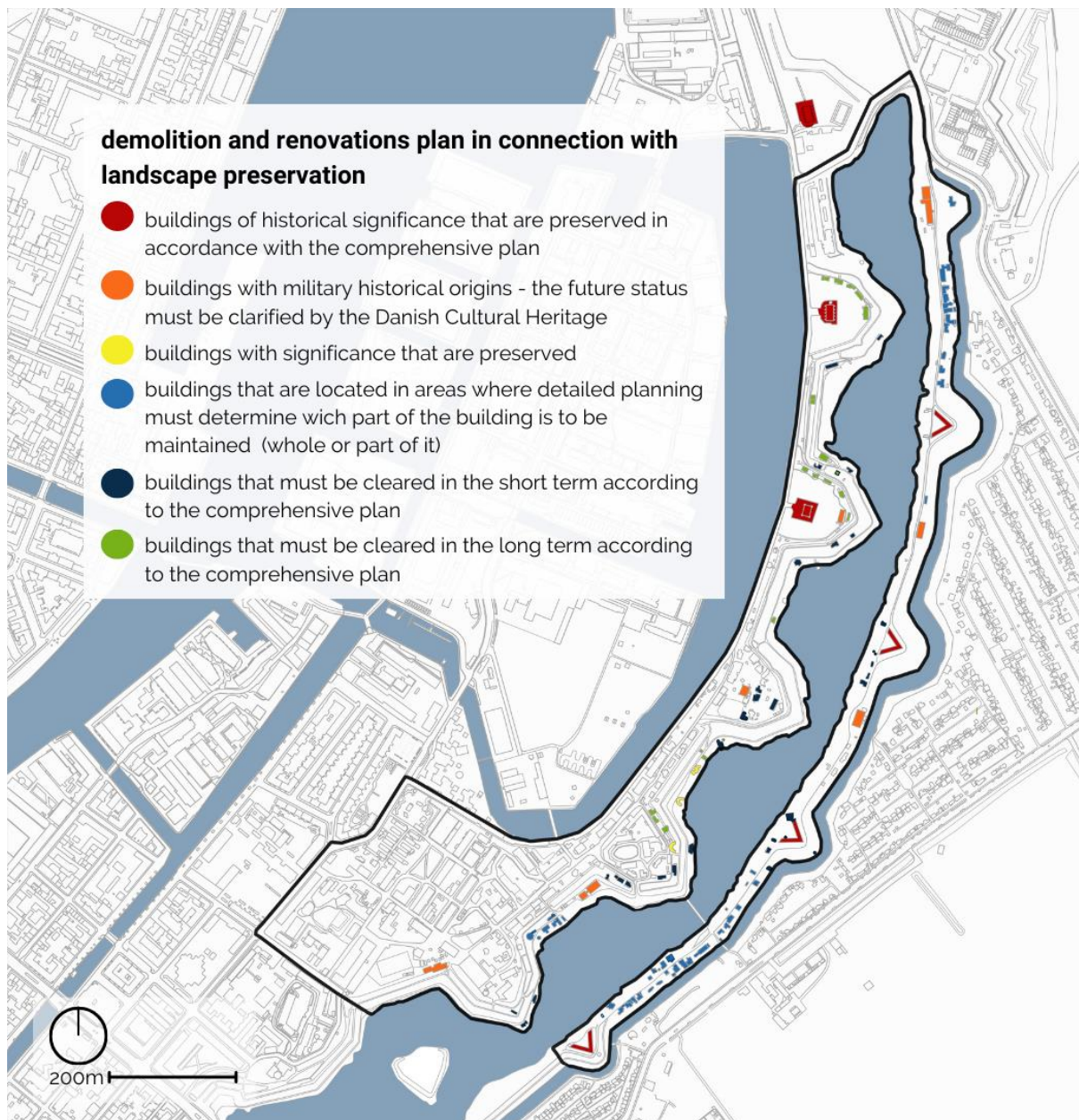
- As the population of Christiania evolves, so too do its needs. The community must remain flexible and adaptable, continuously updating and improving its urban design to meet the diverse and changing needs of its residents.

Christiania exemplifies the principles of user focus and universal design through its inclusive, community-driven approach to urban planning. By prioritizing accessibility, flexibility, and human-centered design, Christiania creates a welcoming environment for all residents and visitors. The community's commitment to continuous improvement and adaptation ensures that it remains a model of inclusive urban living within Copenhagen.

5.2.2.5 Architectural Quality

Community Governed Land Use and Construction Practices

Christiania encompasses a variety of land uses, reflecting its diverse functions and community-driven development. The primary land use types include residential areas, cultural spaces, commercial enterprises, and green spaces. However, land use, especially irregular land use taking place around the lakes and on top of the military fortifications and heritage buildings, poses a significant matter of concern. The city planned the demolitions and renovation projects on the map annexed in Fig. 52.



52 - Urban Analysis of Demolitions, Renovations and New Construction

Residential Areas

- Bådsmandsstræde Barracks: These former military barracks have been repurposed into collective housing. Multiple families share facilities and household responsibilities, fostering a sense of community.
- Self-Built Homes: Christiania is home to 221 self-built houses, each uniquely designed by its residents using local and recycled materials. Notable examples include:
 - Banana House
 - Pagoden
 - Sixth Sense
 - The Dome
- Fredens Ark: A large communal living structure known for its alternative lifestyle and collective governance.
- Glass House: A striking example of creative architecture using recycled materials.

Cultural Spaces

- Music and Performance Venues:
 - The Opera: A major venue for music and theatrical performances, hosting a wide range of events.
 - Den Grå Hal (The Grey Hall): A large, versatile space used for concerts, festivals, and other large gatherings.
 - Loppen: A famous music venue known for its eclectic programming, from rock to electronic music.
 - Nemoland: An open-air venue popular for its summer concerts and social events.
- Art Spaces:
 - Stadens Museum for Kunst: A museum dedicated to self-made art, reflecting the community's creative spirit.
 - Gallopperiet: An art gallery that hosts exhibitions and events, showcasing both local and international artists.
 - Grønsagen: An area rich in murals, graffiti, and outdoor sculptures, highlighting the vibrant street art culture.

Commercial Enterprises

- Workshops and Markets:
 - Snedkeriet: A woodworking shop known for its craftsmanship and custom furniture.
 - Kvindesmedien: A blacksmith shop operated by women, producing a range of metal goods.
 - Christiania Bike Factory: Famous for its production of the iconic Christiania cargo bikes.
- Cafes and Restaurants:
 - Månefiskeren: A cozy cafe popular with locals and visitors alike.
 - Morgenstedet: A vegetarian restaurant known for its healthy and organic meals.
 - Spiseloppen: A restaurant offering a diverse menu, set in a former factory building.

Green Spaces

- Community Gardens: Various plots where residents grow vegetables, herbs, and flowers, contributing to the area's sustainability.
- Fredens Eng: A large open field used for recreation, community gatherings, and events.
- Green Hall: An indoor space for growing plants and holding workshops on sustainable living.

Urban Fabric

The urban fabric of Christiania is characterized by its organic and porous composition, contrasting with the rigid grid structure of its military origins. This unique layout facilitates free movement and fosters a sense of openness and community.

- Porosity and Accessibility
 - Christiania is noted for its numerous openings and informal pathways that invite exploration and movement. Pathways like Dysebroen bridge connect different parts of the area, enhancing accessibility and encouraging social interaction.

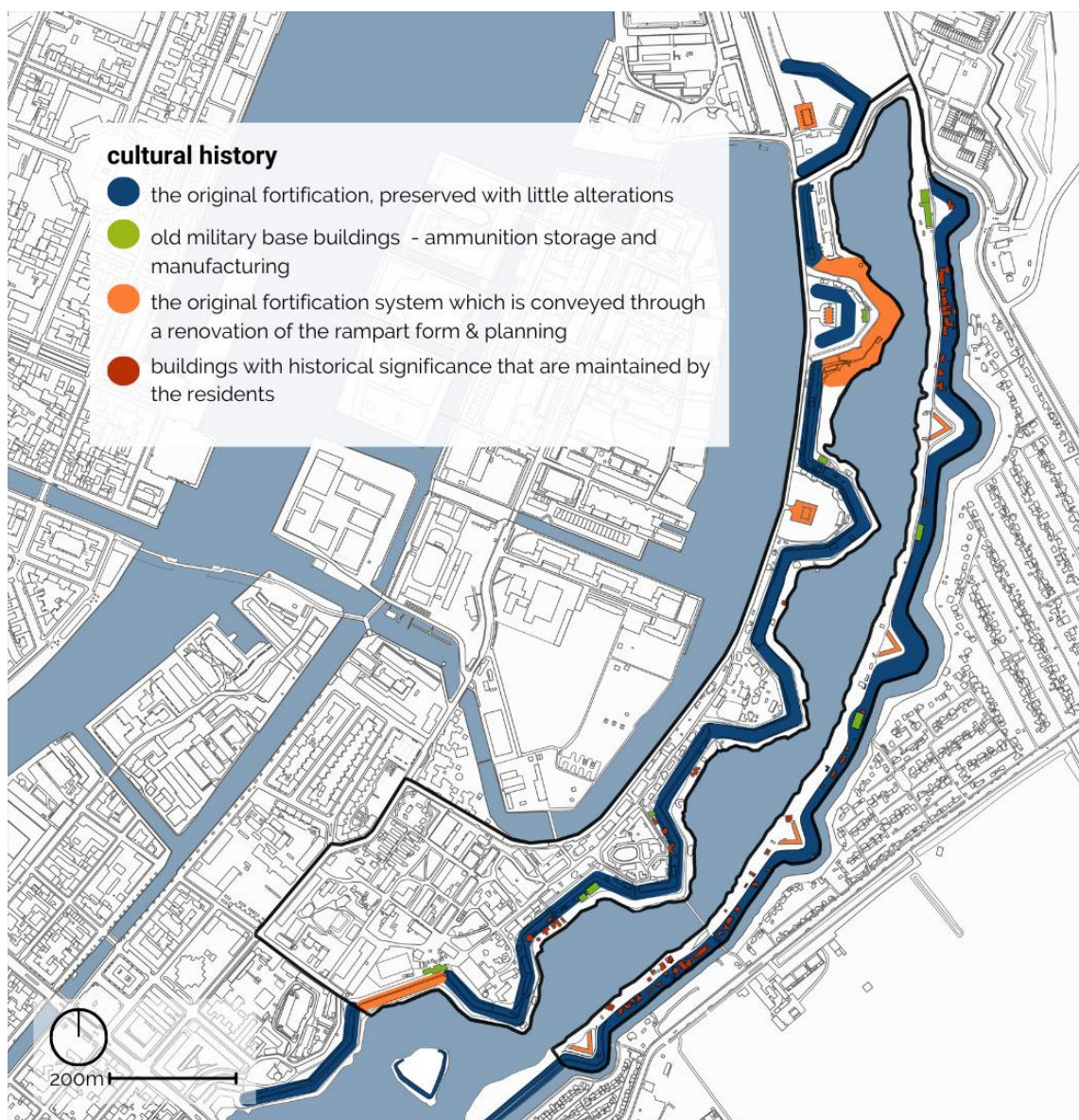
Public and Private Spaces

- The distinction between public and private spaces in Christiania is fluid. Areas like Fredens Ark and The Dome serve as communal living spaces, while also allowing for personal privacy within their collective housing setups.

Building Plots and Densification

- Development policies allow for future densification within designated areas, particularly within the ancient monument protection line. This potential for growth must balance the community's desire for preservation and the need for additional housing and facilities.

5.1.2.6 Landscape Quality



Ecological Aspects of Christiania: Landscape Design and Trees

➤ Landscape Design

The landscape design of Christiania is intricately linked to its historical and ecological significance. The development plan of Slots-og-Ejendomsstyrelsen emphasizes the preservation and enhancement of the area's unique landscape features, which include historic ramparts, embankments, and green spaces. These features are vital not only for their historical value but also for their ecological benefits, and the city strategy for these is illustrated in Fig 53.

➤ Historic Ramparts and Embankments

Christiania's ramparts and embankments were originally constructed for defence purposes. These earthworks, built between the late 17th and early 18th centuries, have since evolved into significant landscape elements that contribute to the area's character and biodiversity. The development plan proposes maintaining the original profiles of these ramparts, ensuring that their historical shapes are preserved. This involves careful management of vegetation to prevent overgrowth that could obscure the landforms.

➤ Recreation of Historical Profiles

One of the key strategies in landscape design is the recreation of the original rampart profiles. In areas such as Fredens Eng and Frederiks Bastion, the plan suggests re-establishing the original shapes of the embankments. This includes thinning out dense vegetation and replanting with species that are historically and ecologically appropriate. The goal is to create a landscape that reflects its historical origins while providing ecological benefits.

➤ Pathways and Access

The development plan also emphasizes the importance of pathways and access points throughout Christiania. The pathways are designed to improve accessibility while preserving the integrity of the landscape. Historical paths are to be restored, and new routes are proposed to highlight the area's natural and historical features. These paths will be carefully integrated into the landscape to minimize ecological disruption and enhance the visitor experience.

➤ Trees

Trees play a crucial role in the landscape design of Christiania, providing ecological benefits such as habitat for wildlife, stabilization of soil, and enhancement of air quality. The development plan focuses on both the preservation of existing trees and the planting of new ones to maintain and enhance the area's biodiversity.

➤ Preservation of Existing Trees

The existing trees on the ramparts and embankments are to be preserved wherever possible. These trees include a mix of native species that are important for maintaining the ecological balance. Specific trees of historical significance, such as those planted along the city ditch in Dyssen, are highlighted for preservation. These trees not only contribute to the area's aesthetic but also provide critical habitat for bird species and other wildlife.

➤ Tree Rows and Historical Planting Patterns

One of the significant aspects of landscape design is the restoration of historical planting patterns. This includes replanting tree rows that were originally part of the defense structures. In

areas like Dyssen, where the original row of trees along the city ditch is to be replanted, the aim is to recreate the historical landscape while supporting ecological functions. These tree rows historically included species such as oak (*Quercus robur*) and beech (*Fagus sylvatica*), which are native to Denmark and support a wide range of biodiversity.

➤ Selective Thinning and Canopy Management

To maintain the visibility of the ramparts and embankments, the development plan proposes selective thinning of large trees on the slopes. This process involves removing certain trees to ensure that the original landforms and canopy trees are more recognizable. Thinning is to be done carefully to avoid ecological disruption and to enhance the aesthetic and historical value of the landscape. The canopy management will focus on preserving older trees that provide significant ecological benefits while removing invasive species or trees that pose a risk to the structural integrity of the ramparts.

➤ Species Selection and New Plantings

New plantings are an essential part of landscape design, aimed at enhancing biodiversity and restoring historical planting patterns. The selection of tree species will prioritize native varieties that are historically appropriate and ecologically beneficial. For example, hawthorn (*Crataegus monogyna*) is emphasized due to its importance for birdlife, providing food and nesting sites. Other species likely to be included in new plantings are ash (*Fraxinus excelsior*), lime (*Tilia cordata*), and elm (*Ulmus glabra*), which are all native to the region and support a diverse range of wildlife.

➤ Managing Tree Health and Sustainability

Maintaining the health and sustainability of the trees is a key focus of the development plan. This includes regular monitoring and maintenance to ensure that the trees remain healthy and do not pose a risk to the structures or the public. Sustainable practices such as mulching, proper irrigation, and pest management will be employed to support tree health. Additionally, the plan includes provisions for replacing trees that die or become hazardous, ensuring that the landscape remains vibrant and ecologically functional.

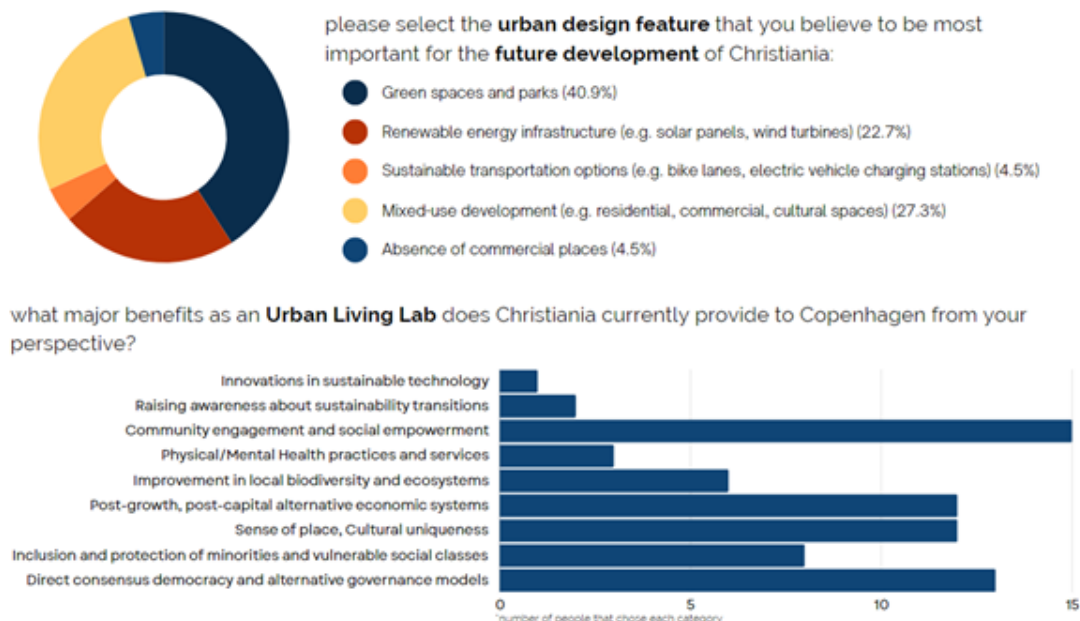
➤ Balancing Conservation with Community Needs

The landscape design and tree management strategies aim to balance conservation efforts with the needs of the Christiania community. This includes creating spaces that are not only ecologically sustainable but also accessible and enjoyable for residents and visitors. The integration of green spaces, recreational areas, and historical elements aims to create a harmonious environment that respects the past while looking towards a sustainable future.

Landscape design and tree management proposals for Christiania are comprehensive strategies that aim to preserve the area's historical and ecological integrity. By focusing on the preservation and enhancement of historic ramparts, the careful management of existing trees, and the thoughtful selection of new plantings, the development plan seeks to create a sustainable and vibrant landscape that honors Christiania's unique heritage and supports its diverse ecosystem.

5.2.2.7 Biophilic Design and Stewardship

Christiania, known for its unique socio-political and environmental landscape, integrates biophilic design principles and stewardship in its urban planning and community management. This section explores the specific aspects of biophilic design and stewardship in Christiania, drawing from the comprehensive document on its development and planning.



54 - Urban Land Use Types in Christiania

Historical Context and Development

Christiania's inception in 1971 was driven by a vision of creating a self-sustaining, ecologically responsible community. This vision has been central to its evolution, emphasizing the integration of natural elements and environmental stewardship. Environmental stewardship has been identified as one of the prized aspects of Christiania in our survey results displayed in Fig. 54.

Biophilic Design in Christiania

Integration of Natural Elements

- **Green Spaces:** Christiania features extensive green spaces, including community gardens, parks, and green roofs. These areas serve as essential components of the urban ecosystem, providing habitats for various species and recreational spaces for residents.
- **Water Features:** The presence of water bodies, including canals and ponds, enhances the natural aesthetic and supports biodiversity. These water features are integral to the community's approach to sustainable water management.

Architectural Harmony with Nature

- **Building Design:** The architecture in Christiania reflects a deep connection with nature. Buildings are often constructed using natural materials and are designed to blend seamlessly with the surrounding environment. The use of wood, stone, and other locally sourced materials is prevalent.
- **Green Roofs and Walls:** Many structures feature green roofs and walls, which not only contribute to the aesthetic appeal but also improve air quality, reduce urban heat island effects, and support local biodiversity.

Community Spaces and Interaction with Nature

- **Public Spaces:** Christiania's public spaces are designed to encourage interaction with nature. The community prioritizes the creation of outdoor communal areas where residents can gather, relax, and engage in recreational activities.
- **Educational Gardens:** The community maintains educational gardens where residents and visitors can learn about local flora and sustainable gardening practices. These spaces serve as living classrooms that promote environmental awareness and stewardship.

Stewardship in Christiania

Environmental Management

- **Waste Management:** Christiania has implemented comprehensive waste management practices, including recycling and composting. The community emphasizes the reduction of waste and the reuse of materials whenever possible, one of the main Local Recycling Centers of Christianshavn is placed in downtown Christiania, in close quarters to the iconic indoor 24/7 skatepark "Wonderland".
- **Water Conservation:** Efforts to conserve water include rainwater harvesting and the use of greywater systems. These initiatives reduce the community's reliance on external water sources and promote sustainable water use.

Biodiversity Conservation

- **Habitat Preservation:** The community is committed to preserving and enhancing local habitats. This includes protecting native plant species, creating wildlife corridors, and maintaining green spaces that support diverse ecosystems.
- **Species Monitoring:** Regular monitoring of local species, both flora, and fauna, ensures that the biodiversity of Christiania is maintained and enhanced. This data is used to inform conservation strategies and actions.

Community Engagement and Education

- **Participatory Governance:** Christiania's governance model emphasizes community participation in decision-making processes. This approach ensures that environmental stewardship is a collective responsibility, with residents actively involved in managing and protecting their natural surroundings.
- **Environmental Education:** The community prioritizes environmental education, offering workshops, courses, and events focused on sustainability and conservation. These educational efforts foster a culture of stewardship and empower residents to take action in their daily lives.

Specific Initiatives and Projects

The Green Plan

- The Green Plan, developed in the early 1990s, outlines Christiania's approach to environmental management and sustainability. It includes detailed strategies for waste reduction, energy efficiency, and the preservation of green spaces.
- The plan emphasizes the importance of community involvement and outlines specific actions for residents to take in promoting environmental stewardship.

Community-Led Projects

- Urban Farming: Christiania has several urban farming projects that provide fresh produce to the community and serve as educational tools. These projects promote sustainable agriculture practices and enhance food security.
- Renewable Energy: The community has invested in renewable energy sources, including solar panels and wind turbines, to reduce its carbon footprint and promote energy independence.

Challenges and Future Directions

Balancing Growth and Sustainability

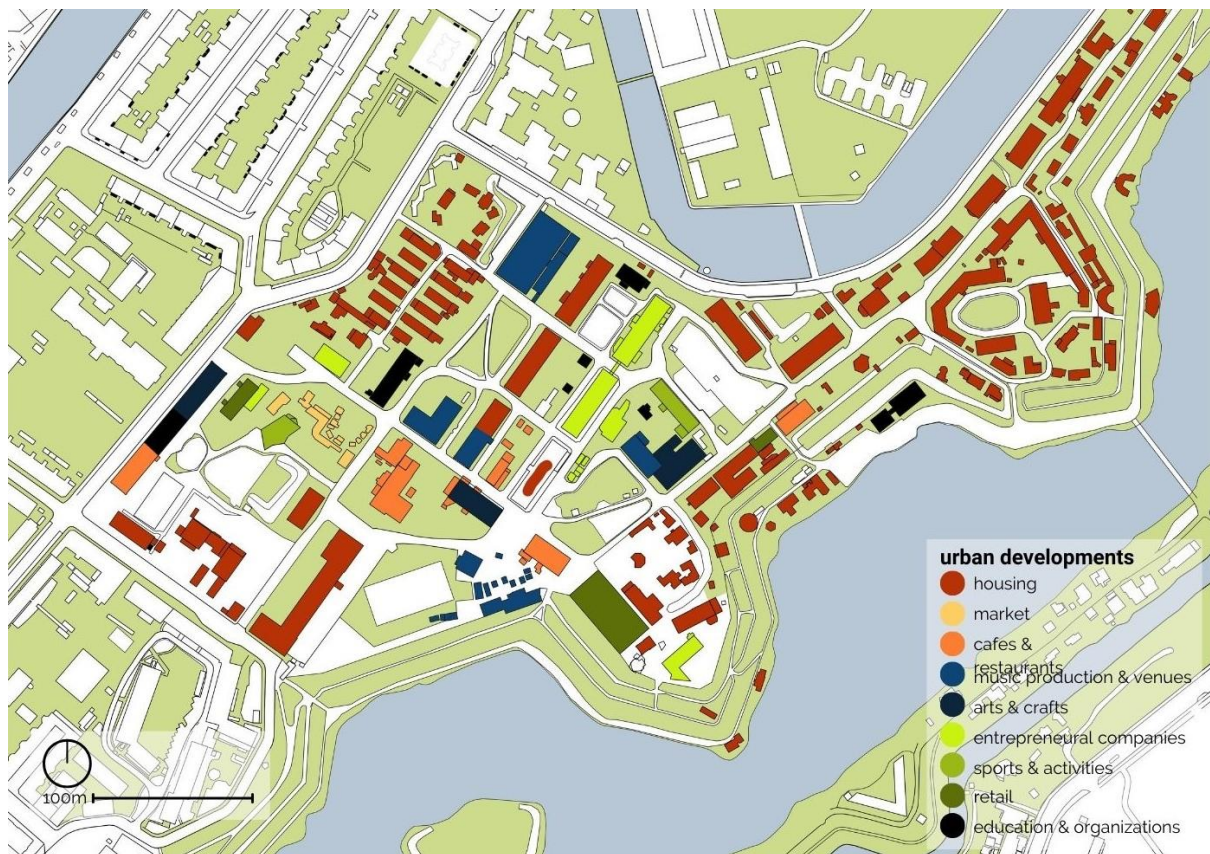
- As Christiania continues to evolve, balancing growth with sustainability remains a key challenge. The community must navigate the pressures of urban development while maintaining its commitment to environmental stewardship.
- Future plans include expanding green infrastructure, enhancing biodiversity corridors, and continuing to promote sustainable living practices among residents.

Engaging the Broader Community

- Engaging the broader Copenhagen community in Christiania's environmental initiatives is crucial for broader impact. Collaborative projects and partnerships with local organizations and government agencies can enhance these efforts.
- Increasing awareness and participation in environmental stewardship activities can help build a more resilient and sustainable urban environment for all.

Christiania's approach to biophilic design and stewardship exemplifies a holistic and community-driven model of urban sustainability. By integrating natural elements into its urban fabric and fostering a culture of environmental responsibility, Christiania not only enhances the quality of life for its residents but also contributes to the broader goals of sustainability and resilience in Copenhagen.

5.2.2.8 Local Community and Governance



55 - Urban Land Use Types in Christiania

Christiania, a self-proclaimed autonomous neighborhood in Copenhagen, presents a unique case study in urban development, community dynamics, and alternative living arrangements. Its evolution from a military base to a vibrant, self-organized community illustrates a blend of sociocultural and functional elements that contribute to its distinct urban fabric.

Sociocultural Aspects

The sociocultural dynamics of Christiania are central to its identity as a community. These aspects are deeply intertwined with its historical context, governance, and daily practices. Land use reflects the diversity of Christiania's organisations – a key aspect of the community's resilience and an asset to be tapped for the future urban strategy to negotiate with the municipality, as we can see from Fig. 55.

Collective Identity

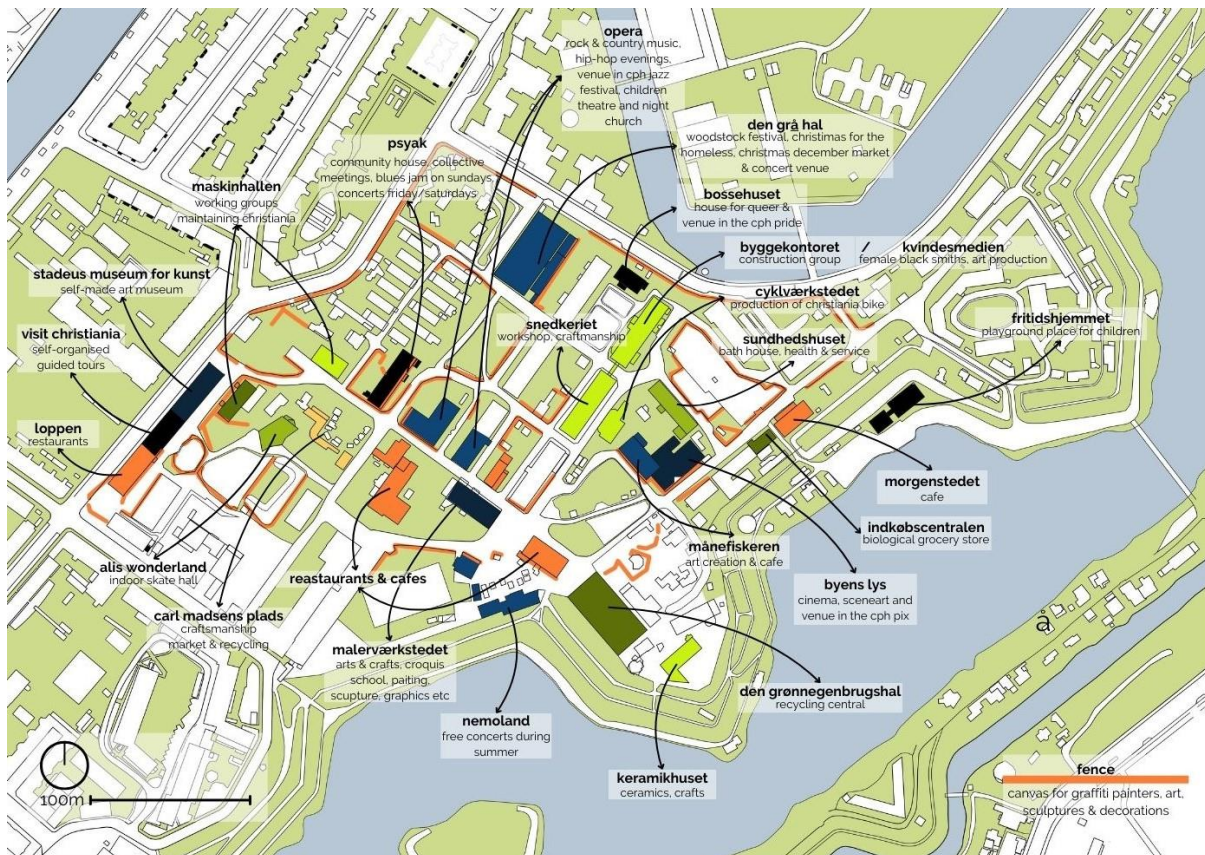
- Christiania's collective identity is built on principles of self-governance, cultural production, and ecological sustainability. The community's rules, such as prohibitions on cars, violence, weapons, and hard drugs, are collectively enforced and reflect shared values.

Cultural and Social Activities

- The community hosts a wide range of cultural and social activities, including music festivals, art exhibitions, and communal gatherings. Events like the Christiania Christmas Market and Lysfest (Festival of Lights) are key cultural touchstones that reinforce community bonds and cultural identity.

Self-Governance and Maintenance

- Governance in Christiania is based on consensus democracy, with decisions made through monthly collective meetings. The Fællesmødet (Common Meeting) is the primary decision-making body, ensuring that all voices are heard. Residents also participate in self-organized maintenance groups, ensuring that both the physical and social infrastructure is cared for.



56 – Organizations and Activities in Christiania

Functional Aspects

Christiania functions as a multifaceted urban system, where various activities and uses coexist harmoniously. This functional diversity supports the community's sustainability and resilience.

Housing and Collective Living

- Housing is a mix of repurposed military buildings and self-built homes. This variety accommodates different living arrangements, from collective housing to individual family homes, reflecting the community's flexibility and inclusiveness.

Economic Enterprises

- The local economy is supported by a range of small businesses and workshops. These enterprises not only provide goods and services but also create jobs and foster economic self-sufficiency. Organizations like Christiania Business Council help coordinate and support these enterprises.

Social Services

- Christiania offers various social services, such as the Sundhedshuset bathhouse and health service, addressing the well-being of its residents. The Children's House (Børnehuset) provides childcare and educational activities, supporting families within the community.

Relationship to Social Activity and Community Identity

The spatial and functional characteristics of Christiania are closely related to its social activity and community identity. The unique urban fabric and land use patterns support a lifestyle that values creativity, community, and sustainability.

Community Engagement

- The design and organization of spaces in Christiania encourages active participation and engagement from residents. The communal gardens, cultural venues, and public spaces are all sites of social interaction and collective activity. Events like the weekly Common Dinner and communal workdays foster a strong sense of community.

Cultural Expression

- The emphasis on cultural spaces and artistic expression reinforces Christiania's identity as a haven for creativity and alternative living. The prevalence of art and music in daily life contributes to a strong sense of community and shared purpose. The presence of artist collectives and workshops, such as Art Factory (Kunstfabrikken), highlights the community's commitment to cultural production.

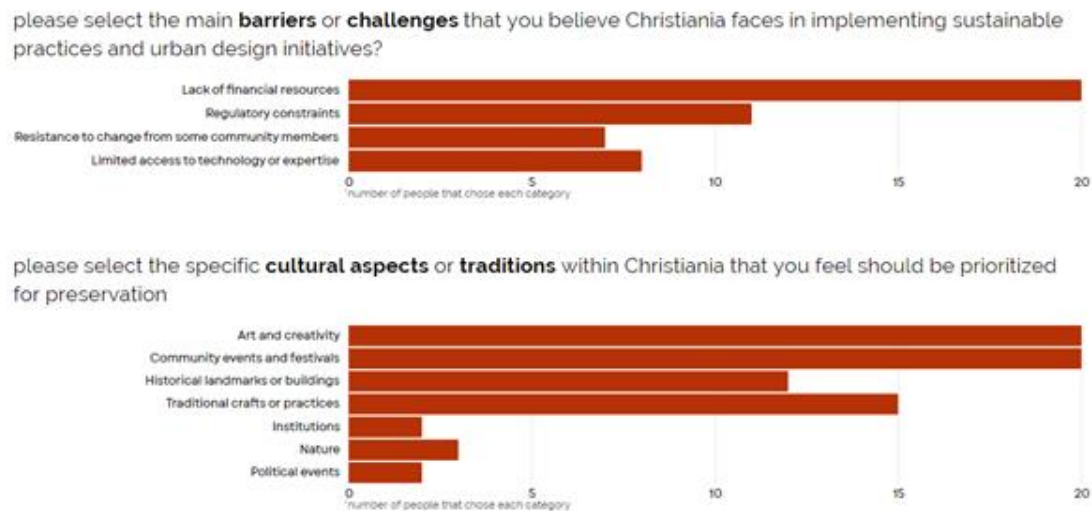
Ecological and Social Sustainability

- The integration of green spaces and sustainable practices into the urban fabric supports both ecological and social sustainability. Community gardens, recycling programs, and eco-friendly building practices are all part of this holistic approach. Organisations like the Green Hall, Frie Natur, and the Gardeners Group promote environmental education and sustainable living practices.

5.2.3 Economic Quality Criteria

The economic quality criteria comprehend factors related to land use, lifecycle costs, ecosystem services and infrastructural circularity and economic development synergies. Our framework reflects the rich transition between land use types and economic activities in connection with

the multi-purpose land use strategy for Christiania and Christianshavn proposed in our project which aims to include and strategise according to the city's strategy for urban renewal and expansion in connection with coastal risk and resource management and climatic adaptation.



57 – results on specific questions of our survey (for more information see Appendix B)

5.2.3.1 Lifecycle Costs (Total Economy)

This DGNB criterion emphasizes the economic sustainability of buildings by evaluating costs incurred throughout their entire lifecycle, from construction to demolition. It is also a common assessment framework in NbS projects, endorsed by the IUCN in the Global Standard. With increased urban development endeavours investing strongly in the direct neighborhood of Christiania, land asset value is expected to rise rampantly, as it will soon occupy the intersection of highly coveted city neighbourhoods, while keeping a central location and privileged access to many pivotal areas of interest in the cultural and business core of the city, as mapped in Fig. 58.

Key Indicators

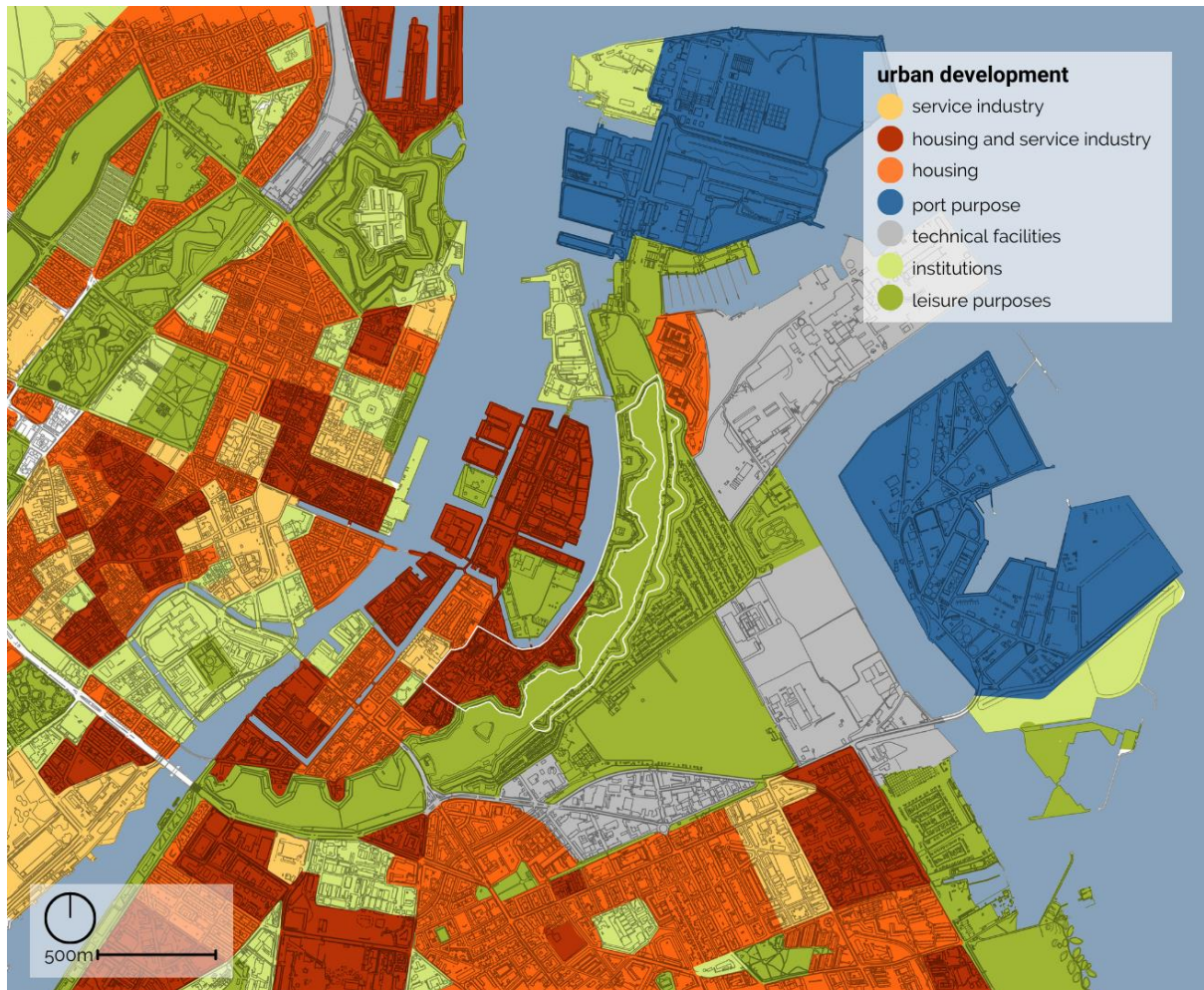
Initial Investment Costs

- Construction Costs: Expenses related to building materials, labor, and initial setup.
- Design and Planning: Costs for architectural design, engineering, and project management.

Operational Costs

- Energy Consumption: Costs related to heating, cooling, lighting, and other energy uses.

- Maintenance and Repairs: Routine and unexpected maintenance, repair costs, and system upgrades.
- Water and Waste Management: Costs associated with water supply, sewage, and waste disposal.



58 – Urban Land Use in Copenhagen area

Maintenance and Refurbishment Costs

- Scheduled Maintenance: Regular upkeep to prevent major failures.
- Refurbishment: Costs for updating building components to meet current standards or user needs.

End-of-Life Costs

- Demolition: Expenses for dismantling structures.
- Disposal and Recycling: Costs for disposing of or recycling building materials.

Financial Incentives and Grants

- Government Grants: Availability of subsidies or grants for sustainable building practices.
- Tax Incentives: Benefits or deductions for implementing energy-efficient solutions.

Relevance to Christiania's Urban Development

- **Sustainable Financial Planning** Long-Term Cost Efficiency: Ensures that Christiania's projects are financially sustainable over their entire lifespan, reducing the risk of unforeseen expenses.
- **Budget Allocation:** Helps in effective budgeting and allocation of resources for maintenance and upgrades.

Community Engagement

- **Participatory Budgeting:** Engages the community in financial decision-making, ensuring that investments align with residents' needs and priorities.

Environmental Benefits

- **Energy Efficiency:** Lower operational costs due to reduced energy consumption promote environmental sustainability.
- **Resource Management:** Effective waste and water management reduce operational costs and environmental impact.

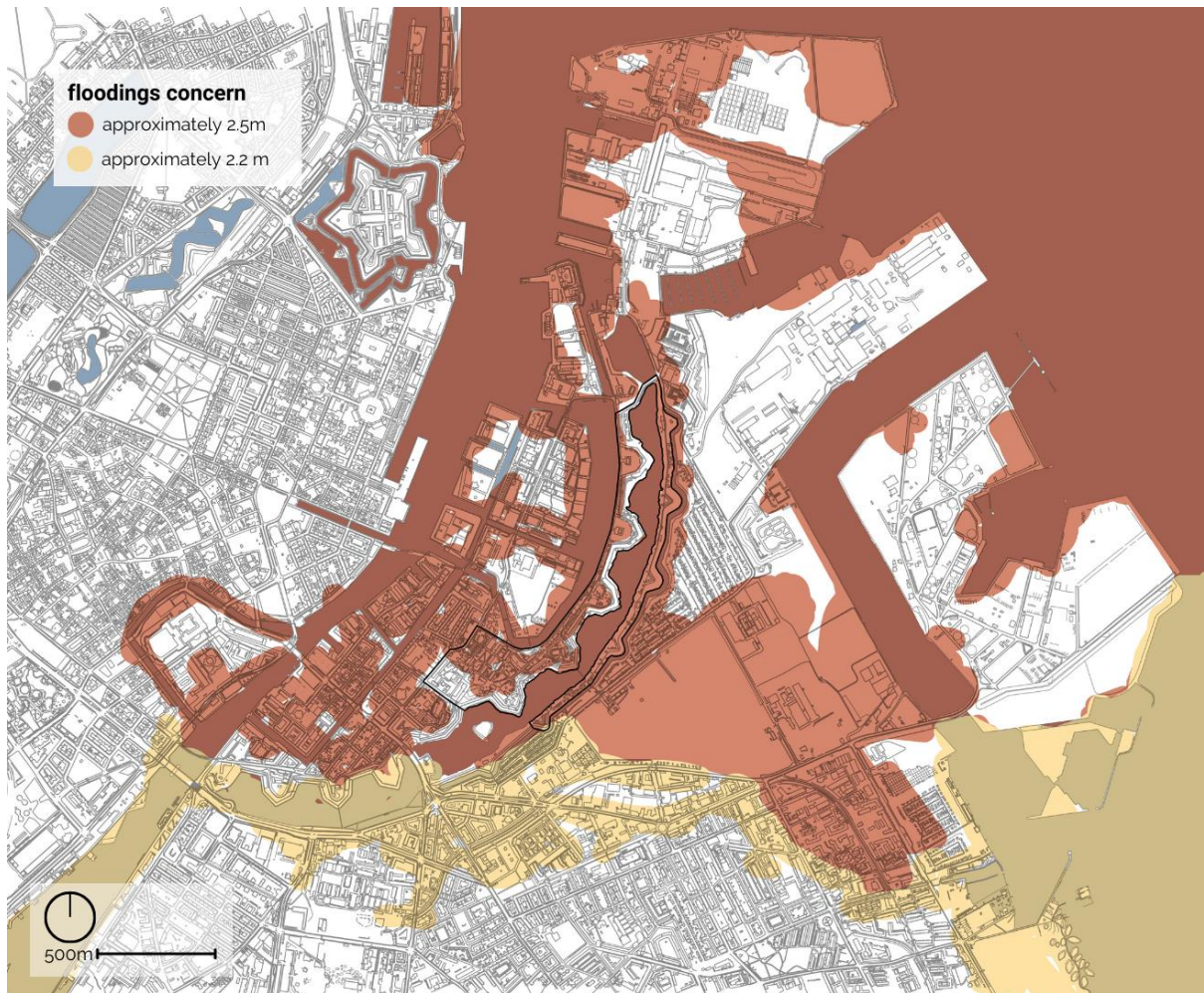
Social and Economic Impact

- **Affordable Housing:** Ensures that housing remains affordable by minimizing operational and maintenance costs.
- **Local Economy Support:** Encourages the use of local materials and labour, supporting the local economy.

The "Total Economy" criterion within the DGNB framework, focusing on Lifecycle Costs, is crucial for ensuring the financial sustainability of urban development projects. The name may be slightly misleading, to say the least, due to the high absence of ESA in the proposed framework for urban economics. Despite DGNB's LCC shortcomings for the full scope of Christiania's matters of concern regarding the community's urbanisation agenda, integrating these principles can enhance long-term economic viability, environmental sustainability, and community well-being, ensuring that development aligns with the community's unique socio-economic context and drive towards ecosystem services valuation.

5.2.3.2 Robustness (Resilience)

Christiania, situated in a low-lying area of Copenhagen, faces significant risks from storm surges exacerbated by climate change. The 2024 report on Storm Surges in Copenhagen outlines the urban planning strategies, relevant dimensions, and design features necessary to enhance Christiania's resilience based on Copenhagen's strategic storm surge adaptation document. On top of the already overwhelming sea-level rise expected for 2125 (oscillating between 2.5 and 2.2m above current levels – as mapped on Fig. 59, storm surges can bring this level up even higher on specific events of high pluviosity, wind orientation and wave formation. These extraordinary events might reach a maximum of 7.4 meters on extremely wavy scenarios – in which 3-meter waves will ride on top of a total expected sea-level rise of 4.4 m).



59 - Urban Flooding Levels in Copenhagen

Major Facts Related to Storm Surges, Sea-level Rise and Extreme Rainwater Events

Geographical Context and Vulnerability

- Christiania's low elevation and proximity to water bodies make it highly susceptible to flooding during storm surges.
- Historical fortifications provide some existing protection but require modern enhancements to handle current and future risks.

Historical Storm Surge Events

- The area has experienced several significant storm surge events, with notable historical floods in 1872, which reached a water level of 2.86 meters in Køge Bay.
- Recent models project design water levels for extreme events, with a potential reach of up to 3.79 meters in the Køge Bay area in 50 years' time.

Climate Change Impact

- The report emphasizes the impact of climate change, predicting increased frequency and severity of storm surges due to rising sea levels.

- Rising sea levels and increased storm surge frequency are significant threats. By 2075, design water levels are expected to reach 3.8 meters, rising to 4.4 meters by 2125 under the SSP3-7.0 emission scenario.
- Maximum Wave Heights: Studies indicate that significant wave heights during extreme storm surge events can reach up to 2-3 meters above the normal water level. Which means that waves can reach 5.8m to 6.8m above the current sea-level in 2075, and 6.4m to 7.4m in 2125, within the assessed scenario by the city's report.

Main Figures and Numeric Data

A. Design Water Levels and Protection

- Projected design water levels:
- 2075: 3.79 meters DVR90
- 2125: 4.4 meters DVR90
- Required protection levels account for wave impacts, adding a wave allowance to the design water levels for enhanced safety.

B. Storm Surge Barriers and Dykes

- Primary and secondary coastal defence systems include robust dykes and high water walls designed to withstand projected water levels and wave impacts.
- The implementation of storm surge barriers provides additional protection.

Urban Planning Strategies and Design Features

Integrated Coastal Defence Systems

- Primary Protection Line: Reinforcing and elevating existing dykes around Christiania to provide a robust first line of defence. These dykes must be designed to handle both the current and projected future water levels and wave impacts.
- Secondary Protection Line: Establishing secondary barriers inland to provide additional layers of protection, slowing down and managing overflow if the primary defences are breached.
- NbS and Sponge City Concept: These techniques promoting infiltration and bio-retention can help slow down the water flow and make it more manageable by both green-blue and grey infrastructure alike, diminishing the impacts of combined impacts of extreme pluviosity, sea-level rise and storm surges.

Green Infrastructure and NbS

- Wetlands and Mangroves: Utilizing natural barriers such as wetlands and mangroves to attenuate waves and absorb floodwaters. These natural solutions also provide ecological benefits, enhancing biodiversity and water quality.
- Permeable Surfaces: Implementing permeable pavements and green roofs to reduce surface runoff and increase water absorption during storm surges.

Adaptive Urban Design

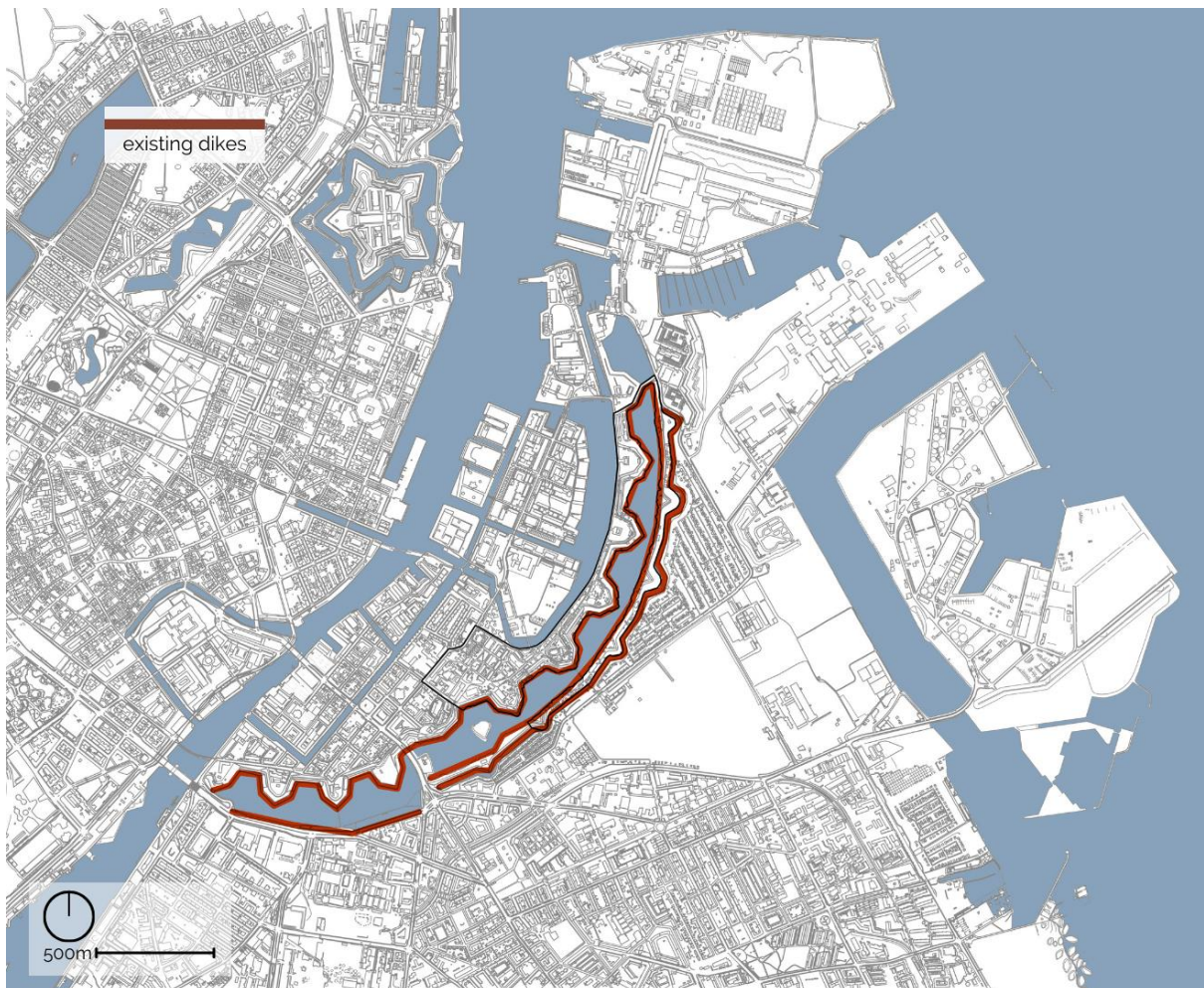
- **Elevated Structures:** Designing buildings and infrastructure with elevated foundations to reduce flood damage. This includes raising critical facilities and residential buildings above projected flood levels.
- **Floating Structures:** Exploring innovative solutions such as floating homes and platforms that can rise with water levels, ensuring that residential and commercial areas remain functional during floods.

Urban Water Management

- **Rainwater Harvesting:** Integrating systems to collect and store rainwater, reducing the burden on drainage systems during heavy rains and storm surges.
- **Retention Basins:** Creating retention basins and ponds within Christiania to temporarily hold excess stormwater, preventing immediate flooding of residential areas.

Emergency Response Infrastructure

- **Evacuation Routes:** Designing clear and accessible evacuation routes, ensuring that all residents can quickly and safely move to higher ground during storm surges.
- **Early Warning Systems:** Implementing advanced early warning systems to provide real-time information on impending storm surges, allowing timely evacuation and preparation.



60 - Urban Analysis of existing Storm Surge Barriers and Dykes

Stakeholder Engagement and Community Involvement

- **Participatory Planning:** Involving residents in the planning and decision-making process to ensure that adaptation strategies meet the community's needs and preferences.
- **Public Awareness Campaigns:** Conducting regular public awareness campaigns to educate residents on storm surge risks and the importance of preparedness measures.

Enhancing Christiania's resilience to storm surges requires a multifaceted approach that combines robust engineering solutions with nature-based strategies and adaptive urban design. By implementing integrated coastal defenses, promoting green infrastructure, and ensuring community involvement, Christiania can effectively mitigate the risks associated with storm surges and create a safer, more sustainable urban environment. The strategic document on storm surge adaptation for Copenhagen provides a comprehensive framework that can be tailored to address the unique challenges faced by Christiania. The report by the working group on storm surge safety issued the following elements of Christiania's landscape as strategic importance, as described in Fig. 60.

There is some relevance for the Lynetteholmen project to address the expected flooding, however the specific measures undertaken and their effectiveness in addressing Christiania's problem (especially from the Northwestern front of the Oresund in connection with its lakes remains to be seen. Also, international, national and local backlash regarding multiple impacts of the project leaves room to speculate on the feasibility of the solution and the relevance of focusing on the creation of a new area in detriment of prioritising other local adaptation measures in connection with the Sponge City transition.

5.2.3.3 Mobility and Transport

Mobility Strategy for Christiania, Christianshavn, and Copenhagen

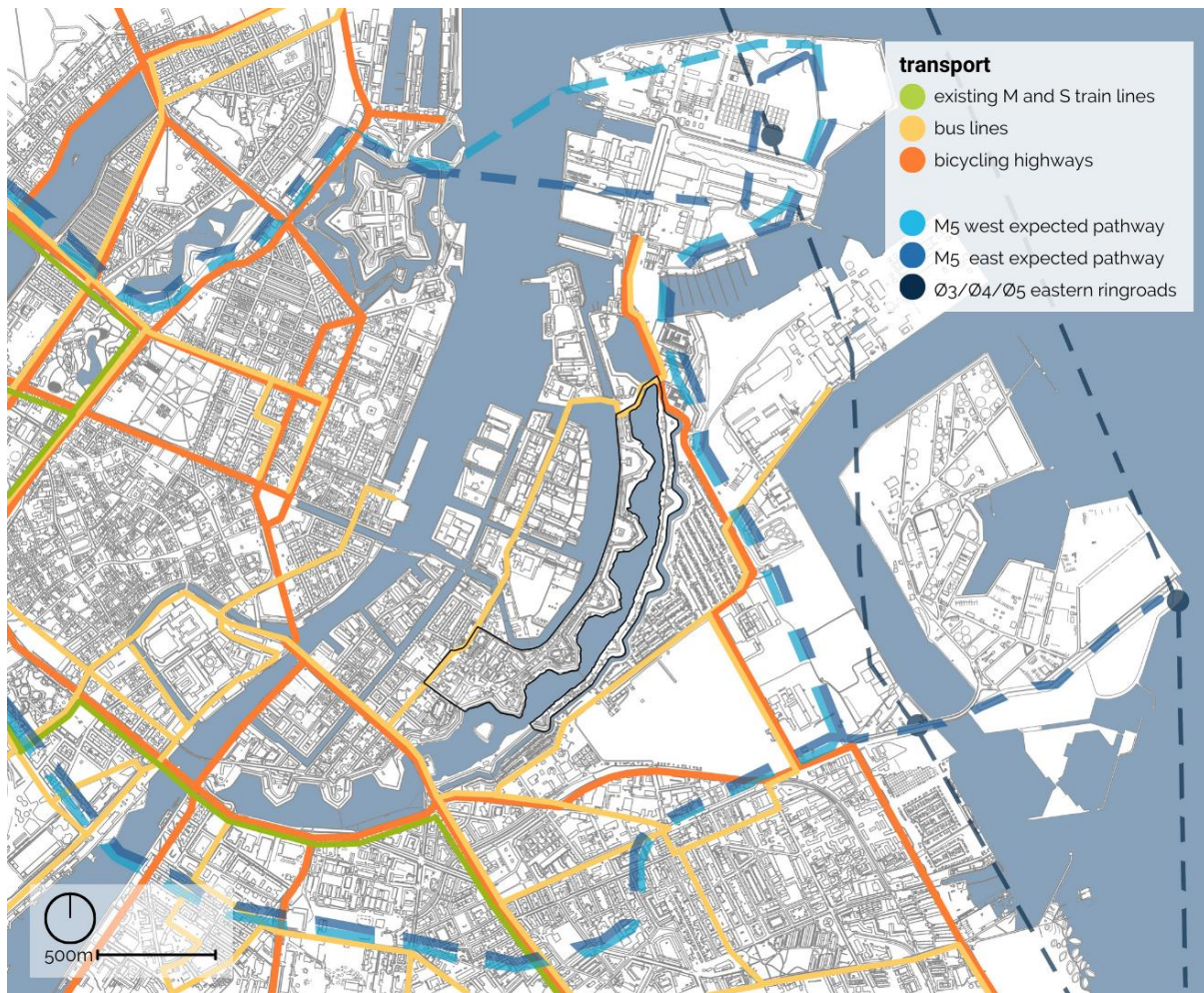
Copenhagen has developed a comprehensive mobility strategy focusing on sustainable urban transport, emphasizing cycling, public transport, and reducing car usage. The recent changes on the territorial and coastal adaptation of the city have highly impacted its mobility strategy, which now seems to be slightly deviating from the Finger Plan concept. Our Fig. 61 highlights these potential trajectories for mobility and transportation infrastructure with a specific focus on Christiania and Christianshavn, incorporating insights from the broader Copenhagen mobility plans and the impact of significant infrastructure projects like Lynetteholm.

Key Components of Copenhagen's Mobility Strategy

Cycling Infrastructure

- **Supercykelstier (Cycle Superhighways):** Copenhagen's network of cycle superhighways aims to make cycling a viable and attractive option for longer commutes. These routes provide direct, fast, and safe paths for cyclists, integrating seamlessly with public transport hubs.

- **Cycle Tracks and Green Routes:** Extensive cycle tracks and green routes ensure that cyclists can navigate the city efficiently and safely. By 2025, Copenhagen aims to have a 50% increase in cycling trips (Copenhagen Urban Development).



61 - Public Transport and Mobility Infrastructure Development Plans (Lynetteholmen)

Public Transport Enhancements

- **Metro Expansion:** The M3 City Ring, opened in 2019, significantly improved public transport accessibility. Future expansions aim to further enhance connectivity between different parts of the city, including Christiania and Christianshavn (Copenhagen Urban Development).
- **Integration with Bicycles:** Initiatives such as City Bikes, extensive bicycle parking at stations, and the ability to carry bikes on trains and buses support multimodal transport (Copenhagen Urban Development).

Electric and Sustainable Transport

- **Electric Vehicles (EVs):** Copenhagen promotes the use of electric vehicles by providing incentives like free parking and developing extensive charging infrastructure (BID Blog).
- **Zero-Emission Zones:** The city is working towards establishing zero-emission zones, particularly in areas with high pedestrian traffic and historical significance (Copenhagen Urban Development).

Traffic Management

- **Speed Reduction:** Implementing speed limits of 30 km/h in residential areas to enhance safety and reduce noise pollution.
- **Car-Free Zones:** Expanding car-free zones, particularly in the inner city, to prioritize pedestrians, cyclists, and public transport (Copenhagen Urban Development).

Impact on Christiania and Christianshavn

Integration with Lynetteholm Project

- **Enhanced Connectivity:** The Lynetteholm project, a large artificial island, includes plans for improved transport links that will benefit Christiania and Christianshavn. This includes new metro lines and better cycling routes including a bridge over the main canal of Copenhagen linking Refshaløen with Indre By over the Øresund (Copenhagen Urban Development).
- **Sustainable Urban Development:** Lynetteholm aims to incorporate green infrastructure and sustainable transport options, aligning with the goals of reducing car dependency and enhancing public transport and cycling networks (Copenhagen Urban Development).

Current and Future Mobility Infrastructure

- **Metro Lines:** Existing and planned metro lines improve connectivity to Christiania and Christianshavn. The City Ring (M3) and future expansions ensure these areas are well-served by efficient public transport (Copenhagen Urban Development).
- **Cycling Superhighways:** Supercykelstier passing through Christianshavn and leading to Christiania provide safe and direct routes for cyclists, encouraging more residents and visitors to opt for cycling (Copenhagen Urban Development).

Local Initiatives in Christiania

- **Car-Free Zones:** Christiania is predominantly a car-free area, promoting walking and cycling within the community. This aligns with Copenhagen's broader goals of reducing car usage (Copenhagen Urban Development).
- **Community Engagement:** Christiania's unique governance model facilitates active community involvement in planning and implementing sustainable mobility initiatives. This grassroots approach ensures that mobility solutions meet local needs and preferences (Copenhagen Urban Development).

Copenhagen's mobility strategy focuses on sustainable transport solutions, enhancing cycling infrastructure, expanding public transport, and reducing car dependency. For Christiania and Christianshavn, these initiatives mean better connectivity, safer and more efficient transport options, and a cleaner environment. The integration with major projects like Lynetteholm further supports these goals, ensuring that these areas benefit from the city's holistic approach to mobility and urban planning.

5.2.3.4 Construction for Operation

The Danish variant of the DGNB certification includes specific criteria under the economic quality category, one of which is "Construction for Operation." This criterion focuses on ensuring that buildings are designed and constructed with long-term operational efficiency and sustainability in mind.

Definition and Objectives

"Construction for Operation" refers to the processes and practices involved in constructing buildings that are efficient, cost-effective, and sustainable throughout their operational life. This criterion aims to optimize the performance of buildings over their entire lifecycle, considering factors such as energy efficiency, maintenance costs, and overall durability.

Key Indicators

The indicators for the "Construction for Operation" criterion in the Danish DGNB certification scheme typically include:

Lifecycle Costs (LCC)

- Initial Investment: Cost of construction and materials.
- Operational Costs: Energy consumption, water usage, and other utilities.
- Maintenance Costs: Regular upkeep, repairs, and replacements.
- End-of-Life Costs: Demolition, recycling, and disposal of materials.

Energy Efficiency

- Energy Performance: Adherence to energy efficiency standards and regulations of LCA ISO norms and BR-18.
- Renewable Energy Integration: Use of renewable energy sources such as solar panels or wind turbines.
- Energy Management Systems: Implementation of systems to monitor and optimize energy use.

Resource Efficiency

- Material Selection: Use of sustainable, durable, and low-maintenance materials.
- Waste Management: Strategies for minimizing waste during construction and operation.
- Water Efficiency: Systems for reducing water consumption and recycling greywater.

Operational Performance

- Building Automation: Use of smart technologies to enhance operational efficiency.
- Indoor Environmental Quality: Ensuring optimal indoor air quality, lighting, and thermal comfort.
- User Experience: Design elements that improve the usability and functionality of the building for occupants.

Relevance to Copenhagen's Construction Processes

Copenhagen's approach to urban development emphasizes sustainability, energy efficiency, and long-term economic viability. The city's construction processes align with the principles of the DGNB "Construction for Operation" criterion in several ways:

1 Sustainable Building Practices

- **Energy-Efficient Buildings:** Copenhagen has stringent building codes that require high energy performance standards, encouraging the integration of renewable energy sources and advanced insulation techniques (Copenhagen Urban Development).
- **Green Building Materials:** Preference for materials that have a lower environmental impact and require minimal maintenance.

Lifecycle Cost Analysis

- **Cost Optimization:** Projects in Copenhagen often include detailed lifecycle cost analysis to ensure that buildings are not only cost-effective at the point of construction but also economical to operate over time (Copenhagen Urban Development).

Technological Integration

- **Smart Building Technologies:** Use of smart systems for energy management, which helps in monitoring and optimizing the energy consumption of buildings (Copenhagen Urban Development).
- **Sustainable Design:** Incorporation of design features that enhance user comfort and reduce operational costs.

Application in Christiania

Community-Driven Sustainability

- **Participatory Planning and Community-based Implementation:** Involving residents in the planning and design process to ensure that buildings meet community needs while being in continuous improvement through planned reporting, monitoring and collective decision-making on future planning adaptations to evolving scenarios and unfolding new drivers of the urban context.

Energy and Resource Efficiency

- **Renewable Energy Projects:** Implementing community solar projects or wind energy to reduce operational energy costs.
- **Water Management:** Utilizing rainwater harvesting and greywater recycling systems to enhance water efficiency (see Appendix B).

Long-Term Economic Viability

- **Maintenance and Durability:** Selecting materials and construction methods that reduce long-term maintenance costs, thereby ensuring the financial sustainability of community projects.

- **Smart Technologies:** Integrating smart technologies to optimize energy use and improve the operational performance of buildings. The ageing population of Christiania may pose resistance to highly sophisticated methods due to ideological resistance to conceding local decision-making to expert knowledge and tools.

"Construction for Operation" emphasizes creating buildings that are sustainable, cost-effective, and efficient throughout their lifecycle. Copenhagen's construction processes align well with these principles, focusing on energy efficiency, resource management, and long-term operational performance. In Christiania, adopting these strategies can enhance sustainability, community engagement, and economic viability, ensuring a resilient and environmentally responsible urban environment.

5.2.3.5 Responsible Procurement

Responsible Procurement refers to the process of acquiring goods and services in a manner that considers the long-term economic, environmental, and social impacts. The aim is to promote sustainable practices throughout the supply chain, from the extraction of raw materials to the final construction and operation of buildings.

Key Indicators

The indicators for the "Responsible Procurement" criterion in the Danish DGNB certification scheme typically include:

Sustainable Materials

- **Environmental Product Declarations (EPDs):** Use of materials with certified EPDs that provide information on the environmental impact of products throughout their lifecycle.
- **Recycled and Renewable Materials:** Preference for materials that are recycled, renewable, or have a low environmental impact.

Ethical Sourcing

- **Fair Labor Practices:** Ensuring that materials and services are sourced from suppliers that adhere to fair labor practices, including fair wages, safe working conditions, and prohibition of child labor.
- **Transparency and Traceability:** Maintaining transparency in the supply chain and ensuring traceability of materials from source to site.

Local Procurement

- **Supporting Local Economy:** Prioritizing the procurement of materials and services from local suppliers to support the local economy and reduce transportation emissions.
- **Community Engagement:** Involving local communities in the procurement process to ensure that their needs and concerns are addressed.

Life Cycle Costing (LCC)

- **Cost Efficiency:** Evaluating the long-term costs associated with materials and services, including maintenance, operation, and end-of-life disposal.
- **Value for Money:** Ensuring that procurement decisions provide the best value for money over the lifecycle of the project.

Waste Management

- **Minimizing Waste:** Implementing strategies to minimize waste generated during procurement and construction. **Circular Economy:** Promoting the use of materials that can be reused or recycled at the end of their life.

Relevance to Copenhagen's Construction Processes

Copenhagen's construction processes align with the principles of the DGNB "Responsible Procurement" criterion in several ways:

Sustainable Construction Practices

- **Green Building Materials:** Copenhagen prioritizes the use of sustainable building materials with low environmental impact and certified EPDs.
- **Local Sourcing:** There is a strong emphasis on sourcing materials locally to support the local economy and reduce transportation-related emissions (Copenhagen Urban Development) (Copenhagen Urban Development).

Ethical and Transparent Supply Chains

- **Supplier Code of Conduct:** The city enforces a code of conduct for suppliers to ensure ethical labor practices and transparency in sourcing.
- **Sustainable Procurement Policies:** Policies are in place to ensure that all procurement activities adhere to sustainable and ethical standards (Copenhagen Urban Development) (Copenhagen Urban Development).

Economic and Environmental Efficiency

Lifecycle Cost Analysis: Projects in Copenhagen include detailed lifecycle cost analysis to ensure that procurement decisions are economically and environmentally efficient over the long term (Copenhagen Urban Development) (Copenhagen Urban Development).

Application in Christiania's Urban Analysis

Christiania can benefit from adopting the principles of the DGNB "Responsible Procurement" criterion in several ways:

Sustainable and Ethical Sourcing

- **Local and Ethical Materials:** Emphasizing the use of locally sourced, sustainable, and ethically produced materials can support the community's economic and environmental goals.

- Transparency: Maintaining transparency in procurement processes to ensure accountability and trust within the community.

Community Involvement

- Participatory Procurement: Engaging residents in the procurement process to ensure that decisions reflect community values and priorities.
- Education and Awareness: Educating the community about the benefits of responsible procurement and encouraging participation in sustainable practices.

Long-Term Economic Viability

- Lifecycle Costing: Applying lifecycle cost analysis to procurement decisions to ensure that materials and services are cost-effective over the long term.
- Waste Reduction: Implementing waste management strategies to minimize construction waste and promote circular economy practices.

5.2.3.6 *Natural Capital Assessment*

Danish Green GDP and Its Relation to LCA, ESA, and NCA

The Danish Green GDP initiative integrates environmental and economic accounting to provide a holistic view of the nation's economic activities and their impacts on natural capital. This approach is closely related to Life Cycle Assessment (LCA), Ecosystem Services Assessment (ESA), and Natural Capital Accounting (NCA).

Key Aspects of Danish Green GDP

Holistic Economic Measurement

- The Green GDP includes the value of environmental and natural services and accounts for pollution, greenhouse gas emissions, and natural capital depletion.
- This measure helps assess whether economic growth occurs at the expense of the environment.

Green REFORM Model

- This model simulates environmental and economic outcomes, aiding policymakers in evaluating the impact of various environmental policies and economic activities.
- It integrates data from multiple sectors, such as energy, agriculture, and transport, to predict environmental footprints and policy impacts.

Monetary Valuation of Nature

- Environmental and natural assets are given economic value through public surveys, which determine how much citizens are willing to pay for environmental improvements.
- This evaluation provides a comprehensive picture of environmental damages and helps prioritize policy actions.

Relation to LCA, ESA, and NCA

Life Cycle Assessment (LCA)

- LCA evaluates the environmental impacts of products and services from cradle to grave.
- The Green GDP incorporates LCA data to quantify the environmental costs associated with economic activities, ensuring a comprehensive assessment of their lifecycle impacts.

Ecosystem Services Assessment (ESA)

- ESA identifies and values the benefits provided by ecosystems, such as clean water, air, and biodiversity.
- The Green GDP uses ESA to integrate the value of these services into economic accounting, highlighting the importance of ecosystems in supporting economic activities.

Natural Capital Accounting (NCA)

- NCA systematically measures and reports on natural assets, including forests, water bodies, and mineral resources.
- The Green GDP incorporates NCA to track changes in natural capital, ensuring that economic growth does not deplete these critical resources.

Application to Urban Analysis in Copenhagen and Christiania

Copenhagen's Urban Planning

- The integration of Green GDP principles helps Copenhagen prioritize sustainable urban development projects.
- It ensures that infrastructure projects, such as the Lynetteholm development, consider their long-term environmental impacts and contributions to natural capital.

Christiania's Urban Sustainability

- Christiania can apply LCA, ESA, and NCA to enhance its sustainable practices, ensuring that community projects are environmentally and economically viable.
- These frameworks support community-led initiatives that balance growth with environmental stewardship, maintaining Christiania's unique socio-environmental character.

The Danish Green GDP framework provides a robust mechanism for integrating environmental considerations into economic decision-making. By incorporating LCA, ESA, and NCA, it ensures that economic activities support sustainable development. This holistic approach can significantly enhance urban planning and sustainability efforts in Copenhagen and Christiania, promoting long-term ecological and economic resilience. The assumption that Green GDP must be at the service of Economic Growth approaches is prevalent in anti-capitalist ideology but also environmental scopes of economic understanding, such as the famous Limits to Growth report of the Club of Rome ominously pointed out in 1972. Inclusion of LCA and ESA framework in Green

GDP can create pathways for NCA in Denmark, that would be very useful for a project such as Spongetown Christiania and other ULLs for NbS and RCSR sustainability to be fully developed and enacted.

5.2.3.7 Adaptive RCSR Management

An NbS ULL framed by IUCN and DGNB scopes of problematisation and systemic boundaries leads us to once more contend with wickedness in this project's capacity to assess the sustainability of a community and place such as Freetown Christiania.

To plan urban strategies, one has to contend with different scenarios, such as required by DGNB and IUCN alike. Scenario Mapping, Building and Assessing in this project will be framed by a PESTEL-SWOT scope of analysis where we will map criteria of our Spongetown set. Adaptive RCSR Management focuses on Resilience, Circularity, Symbiosis and Regeneration trade-offs through a Cost-Risks-Benefits analysis as highlighted by the IUCN Global Standard for NbS and DGNB alike.

First and foremost, one must acknowledge that there is unavailability of thorough information and science-based procedures even to conduct at this moment an LCA-ESA urban analysis process in Christiania that can be internationally recognised. Enrolling the full scope of interdisciplinary actors that will bring forth the new Lokalplan for Christiania, either by BR and Municipal laws and requirements, or by EU and DGNB partnerships towards Christiania's mobilisation to become the ULL for NbS that we have envisioned is the only way to break the transition inertia of a project such as Spongetown Christiania, as we will develop in our PESTEL analysis of the DGNB-IUCN analysis of Christiania which we have now finalised within the conceptual boundaries of this study, which does not intend to formalise the proposal in quantifiable terms, due to lack of key data in multiple aspects of a true Cost-Risk-Benefits analytical framework to decipher the best pathways within the scenarios we diagnosed, as we will see. Furthermore, even if a full set of relevant data was present, still the subjective valuation of different criteria, its weighing and relative importance or relevance would have to be assessed within an inter-stakeholder framework that our academic project scope could not effectively tackle in a capable manner representing the Christiania's community Council.

By determining factors (criteria) and assessing the presence of relevant indicators and information to assess them accurately according to standards; and questioning the relevance of these indicators; we did our first conceptualisation of trajectories for DGNB change and Christiania's adoption of the certification system within its NbS agenda. In this section, contending with Known Knowns, Known Unknowns, Unknown Knowns and Unknown Unknowns we will pursue this common framework of scenario planning within PESTEL domains of analysis.

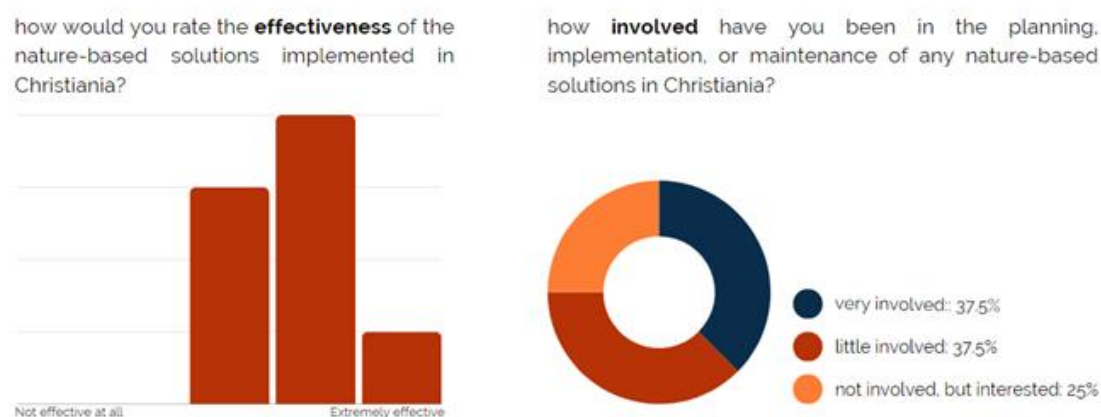
Furthermore, the level of awareness on general phenomena affecting sustainability in STES, can be linked and qualified with the inherent Volatility, Uncertainty, Complexity, and Ambiguity of said knowledge fields – we will, in this section, address those concerns within our own understanding – regarding how we problematised, were interested/promoted interest on, and

even how we enrolled and mobilised available knowledge within the inherent biases of the organisational constellation we navigated with this project.

Scenarios are also very linked with Imaginaries, such as utopian and dystopian thought processes, which tend to be normative and ideologically charged. Avoiding contaminating scenario building through a very biased lens is therefore necessary to the task at hand - even if the bias of Sustainability tends to be portrayed as inherently good, what sustainability means in specific is subject to plenty of diversity. These options led us to discard the pathway of defining sustainability criteria with Christiania's community alone, despite their famed reputation in the pursuit of countercultural niche successful alternatives to dominant regimes.

Framing the problem through a lens that is both niche and regime oriented with a set of indicators that echoes matters of concern present as drivers and barriers for AEC and WEFE systems change and NbS adoption seemed to be the best path to ensure a thorough review of potential RCSR translation of strategies. Combining common matters of concern as the frameworks of analysis was pursued to render a research document that relates to and addresses the capacity for future actors to steer the transition pathways with a broad understanding of the full scope of options for Christiania's urban planning considering the strategy of Copenhagen following envisioned scenarios for the pursuit of future multi-level interactions in connection with this Spongetown Project and the future Urban Plan of Christiania that we devote our analysis and conceptual masterplan to.

In the following section, we will inquire how the diagnosed set of matters of concern of DGNB and IUCN and the indicators we reviewed can be assessed properly in our Scenario Building process, by first deciphering through a VUCA framework how exactly knowledge (or lack of thereof) was processed in our project's system boundaries definition and scenario navigation for the creation of an imaginary through a conceptual master-plan for Spongetown Christiania. We found a very optimistic result regarding public perception of Christiania's current state of NbS, which encourages us further to promote these technologies to take centre stage in future urban negotiations for the neighbourhood, as we display in Fig.62.



62 - Survey Results – Perception and Public Participation on NbS present in Christiania

5.3 Going beyond DGNB: System Boundaries, Urban Challenges and Scenario Planning in Christiania

5.3.1 Political Scenarios

CHRISTIANIA AS AN URBAN LIVING LAB SWOT-PESTEL ANALYSIS | POLITICAL DIMENSION

<u>internal factors</u>	<u>positive</u> STRENGTHS • ALIGNMENT WITH REGIONAL AND INTERNATIONAL SUSTAINABILITY AGENDAS • COMMUNITY DRIVEN GOVERNANCE AND ECONOMIC AUTONOMY	<u>negative</u> WEAKNESSES • REGULATORY CONSTRAINTS AND LACK OF URBAN POLICY COORDINATION WITH CHRISTIANIA • DEPENDENCY ON EXTERNAL ACTORS AND FRAMEWORKS
<u>external factors</u>	OPPORTUNITIES • INNOVATIVE GOVERNANCE MODELS • LEVERAGING EUROPEAN INVESTMENTS IN URBAN NEGOTIATIONS • DECENTRALISATION AND DEGROWTH	THREATS • CONFLICTS WITH BROADER LEGAL FRAMEWORKS • INCONSISTENCIES AND EXCLUSION OF BROADER URBAN DEVELOPMENT POLICY AGENDAS

63 - SWOT-PESTEL Analysis of Spongetown NbS ULL | Political Dimension

Christiania's urban development can be framed within different political scenarios (Fig.63), focusing on sustainability planning and governance. One potential scenario is the collaboration with regional, Danish, and international sustainability agendas. This involves aligning Christiania's development with frameworks such as the IUCN and DGNB sustainability measures. An alternative scenario is maintaining independence in establishing its sustainability criteria, allowing Christiania to tailor its initiatives to the community's unique needs. A hybrid approach could combine both strategies, integrating external sustainability frameworks with locally defined criteria.

Governance and economic systems can also vary, ranging from alternative post-capitalist models to economic institutionalism and neoliberalism, or a hybrid of these approaches. Christiania can be positioned as a niche institution within Copenhagen, emphasizing consensus democracy and community ownership policies. Alternatively, it can adopt a hybrid governance model, balancing decentralization with formal regulatory frameworks (see Appendix B). Main strategies may include normalizing Christiania's institutions and promoting alternative, decentralised post-growth development.

5.3.2 Environmental Scenarios

CHRISTIANIA AS AN URBAN LIVING LAB SWOT-PESTEL ANALYSIS | ENVIRONMENTAL DIMENSION

<u>internal factors</u>	<u>positive</u> STRENGTHS • NATURE-BASED SOLUTIONS PIONEERING ADOPTION IN CHRISTIANIA'S URBAN EXPERIMENTS • COMMUNITY ENGAGEMENT LEVELS IN SUSTAINABILITY POLICY • SUBSTANTIAL ECOSYSTEM SERVICES PROVISIONING TO COPENHAGEN	<u>negative</u> WEAKNESSES • ENVIRONMENTAL DATA GAPS AND LACK OF INTERNATIONAL STANDARDISATION • REGULATORY CONSTRAINTS ON ENVIRONMENTAL INNOVATION PROJECTS
<u>external factors</u>	OPPORTUNITIES • HYBRID INFRASTRUCTURE MODELS • INTEGRATION WITH REGIONAL AND LOCAL CLIMATE ADAPTATION STRATEGIES	THREATS • CLIMATE CHANGE IMPACTS ON LOCAL BIOTOPES AND BIODIVERSITY • LACK OF COORDINATION WITH BROADER URBAN DEVELOPMENT AND GBI STRATEGY

64 - SWOT-PESTEL Analysis of Spongetown NbS ULL | Environmental Dimension

Coastal Protection, Sea-level Rise and Flooding (REGIME/NICHE/HYBRID)

- Lynetteholm Seawall and Sea-Breaking Structures

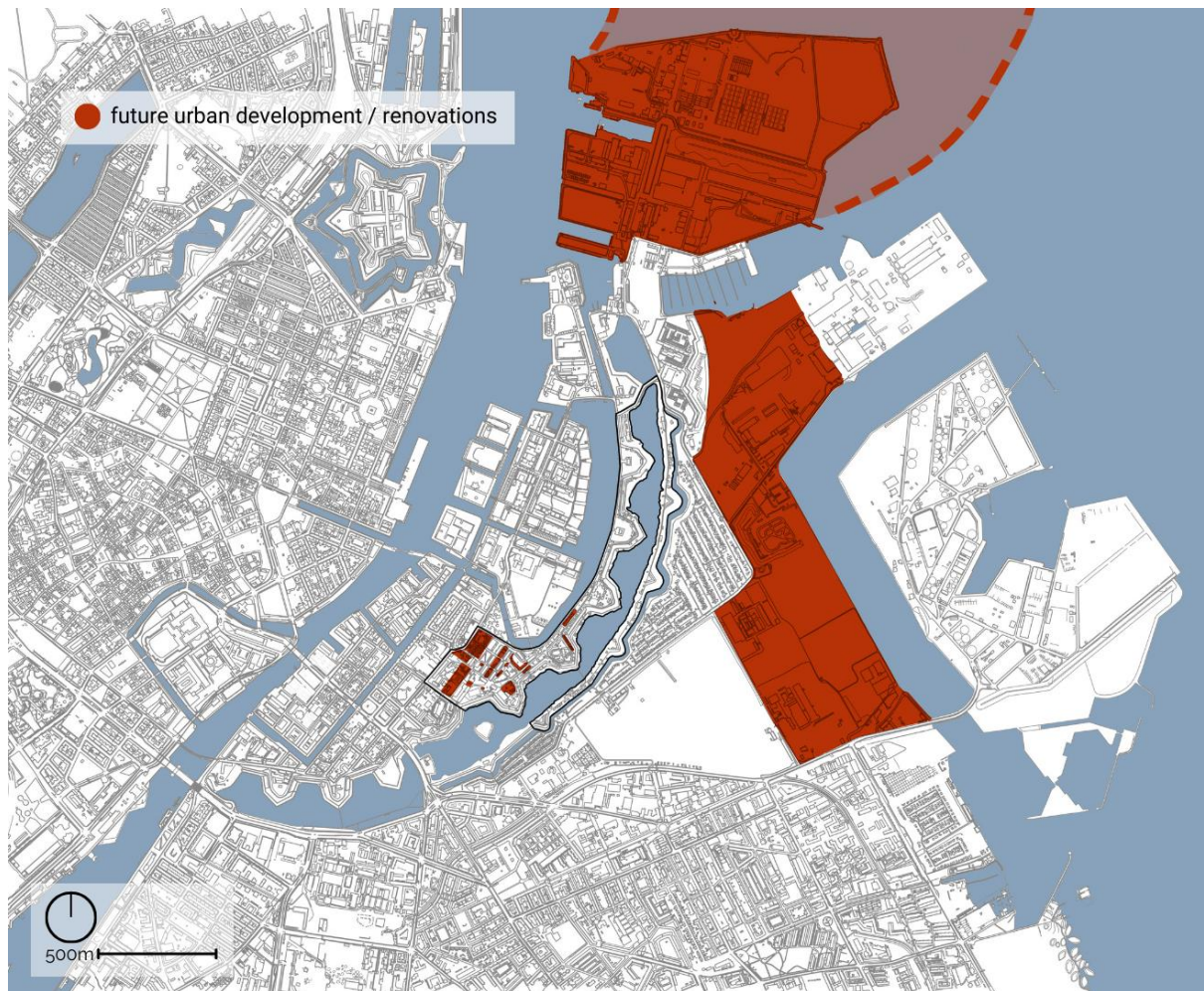
One primary environmental adaptation scenario (for a complete outlook see Fig. 64) regarding urban negotiations and integration of Christiania in the city agenda involves integrating and adapting to the Lynetteholm project (expansion area documented in Fig. 65.), which includes the construction of seawalls and other sea-breaking structures such as dykes and dams. These structures are designed to protect Copenhagen from storm surges and rising sea levels, which are also relevant to Christiania. The planned sea defences can mitigate flooding risks, particularly from storm surges predicted to impact the area severely – Christiania's defence systems can be externalised regarding storm surges and potentially sea-level rise, but the local community feels unease in waiting for the completion of these projects, considering their relatively higher vulnerability comparing to some neighbourhoods in the city.

In our survey, flooding management was not considered to be at a personal level an ecosystem service that was very much prized, however it always ranked high in the priorities of the respondents regarding Christiania's role in Copenhagen, as we can see on Fig. 66.

- Sponge City Design

Another approach is adopting a sponge city design, which uses green, grey, and blue infrastructure to enhance water infiltration and bio-retention. This design incorporates features like permeable pavements, rain gardens, green roofs, and wetlands (see Appendix B) to manage

stormwater and reduce flood risks. Implementing such infrastructure in Christiania can significantly enhance its resilience to heavy rainfall and rising sea levels.



65 - Urban Analysis of Local Expected Urban Expansion and Renewal Areas

Land System Change and Land Use

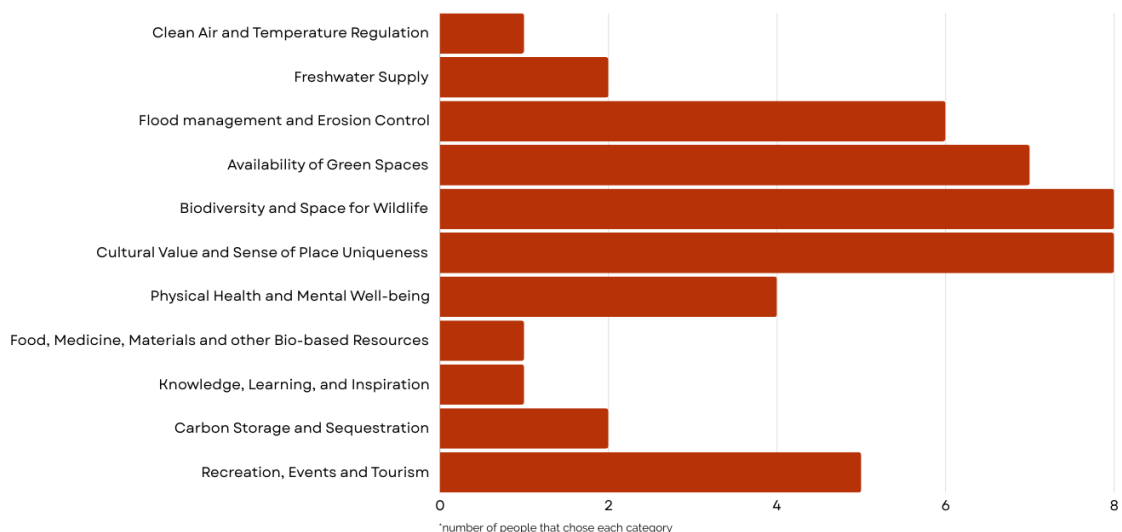
- Dense Urban Growth

One scenario focuses on dense urban growth, concentrating 15,000 sqm of new construction and renovations within Christiania's urban core. This strategy maximizes land use efficiency and minimizes the impact on surrounding natural areas. It involves building multi-use structures that combine residential, commercial, and community spaces, reducing the overall footprint while increasing capacity.

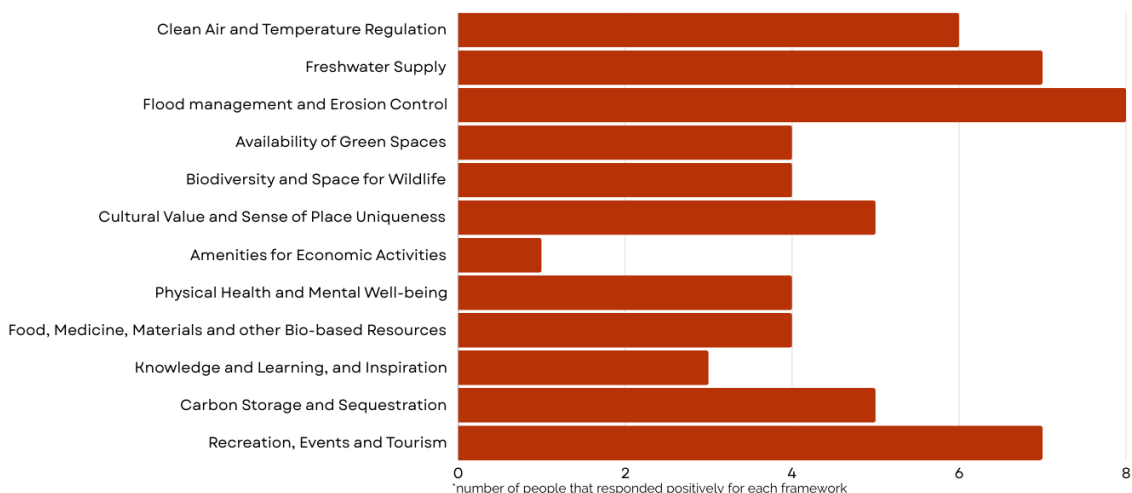
- Disperse Urban Growth

Alternatively, a more dispersed urban growth model distributes the new 15,000 sqm of construction across the urban core and around fortifications, heritage sites, and lakes. This approach balances development with the preservation of historical and natural sites, fostering a harmonious integration of new and old structures.

the following ecosystems services in Christiania provide important benefits for Copenhagen.
please select the ones that are important to you.



the following **ecosystems services** in Christiania provide important **benefits** for Copenhagen. Choose the ones that are important to you.



66 - Survey Results – Perception on Personal and City relevance of Christiania’s Ecosystem Services

○ Floating Urbanisation

Given the flooding risks, especially in the lakes, floating urbanisation presents an innovative solution. New guidelines can be developed for floating buildings that rise with the water level, providing a resilient housing option. These structures can be placed on the lakes and the canal on the eastern margin of Refshalevej, ensuring that homes and facilities remain functional even during extreme weather events.

○ Freshwater Change

Changes in freshwater systems are critical, especially concerning the salinity and pH levels in Christiania’s lakes. Potential scenarios include flooding of the lakes with seawater due to

excessive rain and storm surges, impacting local ecosystems. Addressing these challenges requires effective stormwater management and resilience strategies to maintain ecological balance, that the Lynetteholm project intends to solve city-wide along with other Sponge City and seawall measures for coastal resilience.

Local measures that can be taken are being taken in multiple neighbourhoods and districts of Copenhagen. Lynetteholm increases the resilience and redundancy to the city's defence systems against seawater flooding, but specific impacts on sea-level rise in the city's main water channel separating Amager from Sjælland are still not available, as the project itself faces backlash from biodiversity protection and anti-growth advocates who believe that urban expansion should be avoided and that coastal defence and flooding prevention measures along with urban renewal, infrastructure overhaul and landscape projects should be pursued in its stead.

Biodiversity Change

- Biophysical Changes to the Lakes, Blue-Infrastructure, and Surrounding Green-Infrastructure

The biophysical environment of Christiania, including its lakes, blue-infrastructure, and green spaces, faces potential changes due to urban development and climate impacts. These changes can alter the habitat conditions for local flora and fauna, necessitating careful planning to maintain biodiversity. Efforts should include enhancing the connectivity between green and blue spaces to support wildlife movement and reduce habitat fragmentation.

- Freshwater Change to Seawater and Connected Ecosystem Changes

Christiania's lakes may experience changes in salinity and pH levels due to the intrusion of seawater, especially during flooding events or storm surges. These changes can significantly affect the aquatic ecosystems, requiring adaptive measures to protect freshwater species and manage the transition to brackish water conditions. Implementing salinity-tolerant vegetation and creating buffer zones can help mitigate these impacts.

- Lifecycle Impact, Damage Mitigation, and Harm Reduction Approaches to Urban Resilience and Ecosystem Protection and Restoration

A comprehensive approach to managing the lifecycle impacts of urban development involves integrating damage mitigation and harm reduction strategies. Utilizing the DGNB standards for urban resilience, Christiania can focus on protecting existing ecosystems while restoring degraded habitats. This includes measures like controlled land use, sustainable construction practices, and habitat restoration projects to support long-term ecological health.

- Regeneration through Ecosystem Services Management and Local NbS (NbS), Design of New Ecosystems

Regeneration efforts in Christiania should leverage ecosystem services management and local NbS to create new, resilient ecosystems. This involves designing ecosystems that provide multiple benefits, such as water purification, air quality improvement, and habitat provision.

Projects like constructed wetlands, green roofs, and urban forests can enhance biodiversity while offering ecosystem services that support urban resilience.

- Hybrid Pathways

Combining strategies from the IUCN, DGNB, and Christiania's own sustainability initiatives, hybrid pathways can be developed to address biodiversity change. These pathways should integrate traditional conservation approaches with innovative NbS, ensuring that both regulatory requirements and community values are met. Hybrid strategies could include the use of both green and grey infrastructure to manage stormwater, enhance habitat connectivity, and support diverse species populations. Hybrid pathways also mean approaching ecosystems with a nuanced perspective on their resilience to climate adaptation strategy that takes place at regional and supra-national levels. Considering the adaptation of the ecosystem and landscape designed that has been planned to this day to current urban needs and understanding of environmental change drivers, may require hybrid pathways to both preserve and restore certain ecosystems; but also, to design new ones that can co-evolve in a healthy way with the expected environmental changes taking place due to climate and urbanisation change. Our project will pursue to embody this hybrid scenario, both attempting at preserving the lakes of Christiania, while making room for their expansion as demand for nature-based stormwater management rises across Copenhagen in general and in Amager and Christianshavn in particular, and with compatibility with the Lynetteholm execution scenario, due to its high likelihood of occurrence, in connection with the organisations behind its promotion and the incremental steps already being taken towards its fully fledged construction.

Local Biogeochemical Nutrient Cycle Change

In a regime scenario aligned with DGNB standards, Christiania's urban development would focus on mitigating the global output of nitrogen, phosphorus, and other nutrient cycle-related chemicals. This involves adhering to lifecycle assessment (LCA) protocols to minimize the impact of construction activities and urban living on local and global nutrient cycles. Eutrophication, resulting from excessive nutrients in water bodies, leads to algal blooms and oxygen depletion, severely affecting aquatic life. Addressing this issue involves implementing stringent regulations on nutrient emissions from residential, commercial, and industrial sources within Christiania.

Mitigation strategies would include the installation of advanced wastewater treatment systems that specifically target nutrient removal. Technologies like enhanced biological phosphorus removal (EBPR) and nitrogen removal through nitrification-denitrification processes would be pivotal. Additionally, promoting sustainable agricultural practices within urban farms, such as using organic fertilizers and implementing crop rotation, can reduce nutrient runoff into water bodies.

- Managing Nutrients Globally and Locally through Ecosystem Services (ES) and Management of NbS (NbS) for Co-Evolutive Regeneration [IUCN + Christiania + DGNB]

Under a niche scenario championed by IUCN, the focus shifts towards ecosystemic design and the implementation of NbS (NbS) to adapt to and manage changes in nutrient cycles. This

approach aims to restore and protect existing ecosystems while creating new ones that can thrive under altered nutrient conditions.

NbS in Christiania could include the establishment of constructed wetlands, which naturally filter out excess nutrients from stormwater and wastewater, thus preventing eutrophication through excessive N and P accumulation. These wetlands can also serve as habitats for various species, enhancing local biodiversity. The integration of green roofs and green walls across buildings in Christiania would contribute to nutrient management by absorbing rainwater, reducing runoff, and providing spaces for urban agriculture. These green infrastructures can act as biofilters, capturing and utilizing nutrients within the urban ecosystem.

Floating gardens and artificial reefs in the brackish waters of the Baltic Sea near Christiania would further enhance nutrient cycling. Floating gardens can absorb excess nutrients directly from the water, while artificial reefs can support marine life that helps maintain the nutrient balance. These solutions not only address nutrient pollution but also create additional ecological niches, supporting a diverse range of species.

Urban Heat Island Effect

- Passive Bioclimatic Built Environment Adaptation in Connection with Climate Change and Rising Temperatures

Utilizing DGNB standards, passive bioclimatic design principles can be integrated into the urban fabric to adapt to rising temperatures. This involves designing buildings and urban spaces to naturally regulate temperature, minimizing reliance on artificial cooling systems. Strategies include optimizing building orientation to maximize natural ventilation, using reflective materials to reduce heat absorption, and incorporating shading devices such as green facades and awnings. The use of high-albedo materials for roofs and pavements can also help reflect more sunlight, thereby reducing heat absorption and subsequent radiation. Additionally, enhancing insulation and incorporating thermal mass in buildings can help stabilize indoor temperatures, further mitigating the effects of UHIE.

- Green Infrastructure, Blue Infrastructure, and Ecosystem Design for Urban UHIE Mitigation

Green and blue infrastructures play a crucial role in mitigating the UHIE by leveraging ecosystem services. According to IUCN guidelines, green spaces such as parks, green roofs, and urban forests can significantly cool urban areas through evapotranspiration and shading. Integrating blue infrastructure, such as ponds, lakes, and water features, further contributes to cooling through evaporative cooling processes. Designing ecosystems that support biodiversity while providing these cooling services is essential. For instance, creating interconnected green and blue corridors can enhance the overall cooling effect while promoting habitat connectivity and biodiversity. Implementing urban wetlands and rain gardens can also help manage stormwater, reduce runoff, and enhance cooling through water management processes. Furthermore, increasing the urban tree canopy and planting native species adapted to local climatic conditions can offer long-term resilience against UHIE.

- Hybrid Pathways

A hybrid approach, combining strategies from Christiania's sustainability initiatives, DGNB standards, and IUCN guidelines, is essential for a comprehensive UHIE mitigation plan. Hybrid pathways integrate traditional conservation methods with innovative NbS (NbS), ensuring regulatory compliance and community engagement. This approach involves using both green and grey infrastructure to create a resilient urban environment. For example, integrating green roofs with solar panels can provide both energy efficiency and cooling benefits. Utilizing permeable pavements alongside vegetated swales can manage stormwater and reduce surface temperatures. In Christiania, hybrid strategies could include community-driven greening projects that blend local cultural practices with modern sustainability techniques. Moreover, developing urban green spaces that serve both recreational and cooling purposes can enhance community well-being while addressing UHIE. Collaborative efforts between local authorities, environmental organizations, and the community are crucial to implementing these hybrid solutions effectively.

GHG Emissions and Sequestration

Following DGNB standards, mitigating GHG emissions in urban development requires a comprehensive approach focusing on the entire lifecycle of buildings. This includes selecting low-carbon and sustainable building materials, optimizing construction processes to reduce emissions, and ensuring energy-efficient building operations. Implementing lifecycle assessment (LCA) methodologies helps in understanding and minimizing the carbon footprint of materials and processes. For instance, using recycled and locally sourced materials can significantly cut down emissions associated with transportation and production. In construction, adopting modern techniques such as prefabrication and modular construction can reduce waste and energy consumption. Once operational, buildings can achieve carbon neutrality by integrating renewable energy systems like solar panels and wind turbines, optimizing energy use through smart building technologies, and employing passive design strategies to reduce heating and cooling demands. Additionally, retrofitting existing buildings with energy-efficient technologies and improving insulation can contribute to substantial emission reductions.

- Active Sequestration through Green and Blue Infrastructure and NbS (Carbon Sink – Net-Positive Impact)

Sequestration efforts focus on actively removing carbon from the atmosphere and storing it in natural systems. According to IUCN and Christiania's initiatives, enhancing green and blue infrastructures is key to achieving net-positive impacts. Urban forests, parks, green roofs, and vertical gardens serve as significant carbon sinks by absorbing CO₂ through photosynthesis. Blue infrastructures like wetlands, ponds, and urban water bodies also contribute to carbon sequestration by trapping organic carbon in sediments and supporting aquatic plant growth. Implementing NbS (NbS) involves designing urban landscapes that maximize carbon capture while providing additional ecosystem services. For example, creating green corridors that connect fragmented habitats can enhance biodiversity and improve the overall ecological health of urban areas. Restoring degraded ecosystems, such as reforestation of deforested areas and rehabilitating wetlands, further boosts carbon sequestration capacity. Moreover, integrating agroforestry practices in urban agriculture can enhance soil carbon storage and promote

sustainable food production. Community involvement in planting and maintaining green spaces ensures the long-term success and sustainability of these initiatives.

- Hybrid Pathways

Combining DGNB's regulatory frameworks with IUCN's and Christiania's innovative approaches results in hybrid pathways that effectively address GHG emissions and sequestration. These pathways integrate regime-based strategies for emission reductions with niche solutions for carbon sequestration, creating a balanced and sustainable urban environment. For instance, implementing urban planning policies that mandate green building certifications alongside community-driven greening projects can harmonize top-down regulations with bottom-up initiatives. Developing multifunctional urban spaces that incorporate both green and grey infrastructures ensures resilience and adaptability. In Christiania, hybrid approaches might involve collaborative projects that blend local cultural practices with modern sustainability techniques, such as community gardens that also function as carbon sinks. Utilizing advanced technologies like nature-based carbon capture and storage (CCS) in conjunction with NbS can further enhance sequestration efforts. Ensuring continuous monitoring and assessment of these hybrid solutions allows for adaptive management and optimization, aligning urban development with climate goals.

Addressing GHG emissions and sequestration in Christiania and Copenhagen requires a multifaceted approach that combines emission mitigation strategies with active carbon sequestration efforts. By integrating DGNB's regime-based methods with IUCN's and Christiania's niche and hybrid solutions, urban planners can create a sustainable and resilient urban environment that effectively combats climate change.

Resilient Urban Resource Management DGNB + CHRISTIANIA] IUCN

- Mitigating Lifecycle Impact of New Construction (DGNB/Regime)

Mitigating the lifecycle impact of new construction involves adopting sustainable practices throughout the building's lifecycle, from material selection to construction and operation. DGNB standards emphasize the use of low-carbon and locally sourced materials to reduce embodied emissions. Sustainable construction techniques, such as prefabrication and modular building, minimize waste and resource consumption. Energy-efficient designs, including passive heating and cooling systems, solar panels, and high-performance insulation, reduce operational emissions. Lifecycle assessment (LCA) tools help identify and mitigate environmental impacts at each stage of construction, ensuring that new buildings contribute positively to urban sustainability.

- Ecosystem Service Design and Net-Positive Systemic Evolution

Designing urban ecosystems to provide multiple ecosystem services ensures that urban development contributes positively to environmental health. Integrating green and blue infrastructures, such as parks, green roofs, urban forests, and wetlands, enhances biodiversity, improves air and water quality, and offers recreational spaces. Constructed wetlands with reed-bed systems in Christiania, for instance, provide decentralized wastewater treatment while

supplying reeds for thatch roofs, showcasing a net-positive impact. Urban agriculture projects, like community gardens and rooftop farms, support local food production and enhance food security. These designs promote systemic evolution by creating multifunctional spaces that address ecological, social, and economic needs.

- Self-sufficiency Tactics for Decentralisation of Christiania's Urban and WEFE Systems

Decentralizing water, energy, food, and ecosystem (WEFE) systems enhances local resilience and sustainability. NbS (NbS) play a crucial role in this decentralization. Constructed wetlands in Christiania not only treat wastewater but also provide materials for thatch roofs. Renewable energy sources, such as solar panels and wind turbines, reduce reliance on centralized power grids. Community gardens and urban farms support local food production, reducing transportation emissions and enhancing food security. Rainwater harvesting and greywater recycling systems promote water self-sufficiency. These tactics foster local resource management, reduce environmental impacts, and increase community resilience.

- Reliance on WEFE Management and Urban Management at the Regional (Regime) Level

While decentralization enhances local resilience, effective resource management requires regional coordination. Integrated WEFE management at the regional level ensures efficient resource use, equitable distribution, and long-term sustainability. Regional policies and collaborative efforts between municipalities and stakeholders optimize resource allocation and reduce environmental impacts. For example, the Sponge City concept in Copenhagen focuses on managing stormwater through green infrastructure, enhancing urban resilience to climate change. Regional water management strategies, such as integrated watershed management and coordinated flood control measures, support sustainable development and ecological health.

- Hybrid Pathways

Hybrid pathways combine regime-based frameworks with niche innovations and local practices, creating resilient urban systems that adapt to changing conditions. These pathways leverage the strengths of each approach, ensuring flexible and adaptive resource management. For instance, hybrid strategies might involve using constructed wetlands for wastewater treatment while harvesting reeds for sustainable building materials, mitigating the impacts of the maintenance phase of the lifecycle of its built environment, provided such techniques were used for the construction of roofs.

Integrating advanced technologies with traditional practices ensures that urban development aligns with sustainability goals while meeting local needs. Collaborative projects that blend local cultural practices with modern sustainability techniques enhance community engagement and resilience.

RCSR urban resource management in Christiania and Copenhagen requires integrating various strategies to manage resources that are both urban and WEFE systems oriented. By combining DGNB standards for urban development, IUCN standards for WEFE integration, local initiatives and urban planners can create sustainable environments that effectively manage resources, support ecological health, promote community well-being and create local economic independence through a higher degree of self-sufficiency and by actively understanding ecosystems as the resource and service providers they are for human life.

Pollutants, Soil Health, Groundwater Quality and other Hazards

DGNB-DK (the Danish branch of the German Sustainable Building Council) emphasizes a proactive approach to preventing soil pollution by ensuring that no harmful pollutants are used in construction materials and processes. This includes stringent criteria for selecting non-toxic, low-emission, and sustainable materials. During construction, techniques such as soil sealing with impermeable barriers are employed to prevent contaminants from leaching into the ground, thereby protecting groundwater quality. DGNB-DK standards also incorporate regular monitoring and assessment to ensure construction activities do not introduce new pollutants, maintaining soil health and integrity.

- IUCN Approach: Active Phytosanitary Measures

The IUCN (International Union for Conservation of Nature) guidelines focus on active phytosanitary measures to improve soil health and remediate polluted sites. This approach utilizes NbS (NbS) for bioremediation and phytoextraction, employing plants and microorganisms to remove contaminants from soil and water. Constructed wetlands, for instance, not only filter and purify wastewater but also provide habitats for wildlife, enhancing biodiversity. Phytoextraction involves planting hyperaccumulator species, such as willow trees and sunflowers, which absorb heavy metals and other pollutants from the soil. These plants are then harvested and safely disposed of or utilized in bioenergy production, contributing to ecological restoration and sustainable resource use.

- Christiania's Alignment with DGNB-DK and IUCN Approaches

Christiania integrates both DGNB-DK's preventive measures and IUCN's active phytosanitary strategies to manage soil pollution and enhance soil health. By adhering to DGNB-DK standards, Christiania ensures that construction projects do not introduce new pollutants, maintaining a clean and safe environment. Concurrently, the community employs IUCN's NbS to address existing soil contamination, leveraging local initiatives and community-driven projects to implement bioremediation and phytoextraction. This dual approach allows Christiania to effectively manage soil health and pollution, fostering a resilient and sustainable urban ecosystem.

- Hybrid Scenario: Comprehensive Soil Pollution Management in Christiania

A hybrid scenario in Christiania encompasses a full spectrum of soil pollution concerns, combining preventive measures with active remediation strategies. This approach integrates the strengths of DGNB-DK and IUCN frameworks, tailored to address the unique challenges and needs of Christiania.

In this hybrid model, new construction projects in Christiania adhere strictly to DGNB-DK standards, ensuring no pollutants are used in building materials and processes. This preventive strategy is complemented using impermeable barriers and sustainable construction techniques to protect soil and groundwater quality. Regular environmental monitoring ensures compliance and early detection of potential contamination.

Simultaneously, Christiania implements IUCN's active phytosanitary measures to remediate existing soil pollution. Constructed wetlands are established to treat wastewater, providing both ecological benefits and raw materials like reeds for thatch roofs. Phytoremediation projects

involve planting hyperaccumulator species in contaminated areas for targeted pollutant extraction processes, with harvested plants being utilized in bioenergy production or reintegrated in the biosphere in a cost-benefit-risk conscious manner.

Community engagement is a cornerstone of this hybrid approach. Residents would be tasked with participating in monitoring and remediation efforts, enhancing local capacity and environmental stewardship. Educational programs raise awareness about soil health and pollution prevention, fostering a culture of sustainability and resilience.

Key strategies for managing pollutants and enhancing soil and water quality involve integrating local approaches within regime-level frameworks with local initiatives. The Sponge City concept in Copenhagen focuses on managing stormwater through green infrastructure, reducing surface runoff, and preventing pollutants from entering water bodies. This approach enhances urban resilience to climate change and improves water quality. The Lynetteholm project, guided by DGNB-DK standards, aims to create sustainable urban developments with integrated pollution mitigation strategies. These include using permeable pavements, green roofs, and rain gardens to manage stormwater and filter pollutants. Local projects like Spongetown in Christiania emphasize community-driven NbS, combining local knowledge with advanced sustainability practices. Initiatives such as community gardens and green spaces enhance soil health, support biodiversity, and provide recreational areas. Collaborative efforts with international initiatives such as DGNB Planet, IUCN, and Horizon Europe provide additional resources and frameworks for effective pollution management and environmental restoration.

Managing pollutants, soil health, groundwater quality, and other hazards in Christiania and Copenhagen requires a multifaceted approach that integrates DGNB-DK standards, IUCN guidelines, and local initiatives. By leveraging NbS for bioremediation, sealing and removing pollutants, and adopting hybrid strategies, urban planners can create sustainable environments that effectively manage pollution, enhance ecological health, and promote community well-being. These comprehensive strategies ensure long-term resilience and sustainability, aligning urban development with environmental and community goals.

5.3.3 Social Impact Scenarios

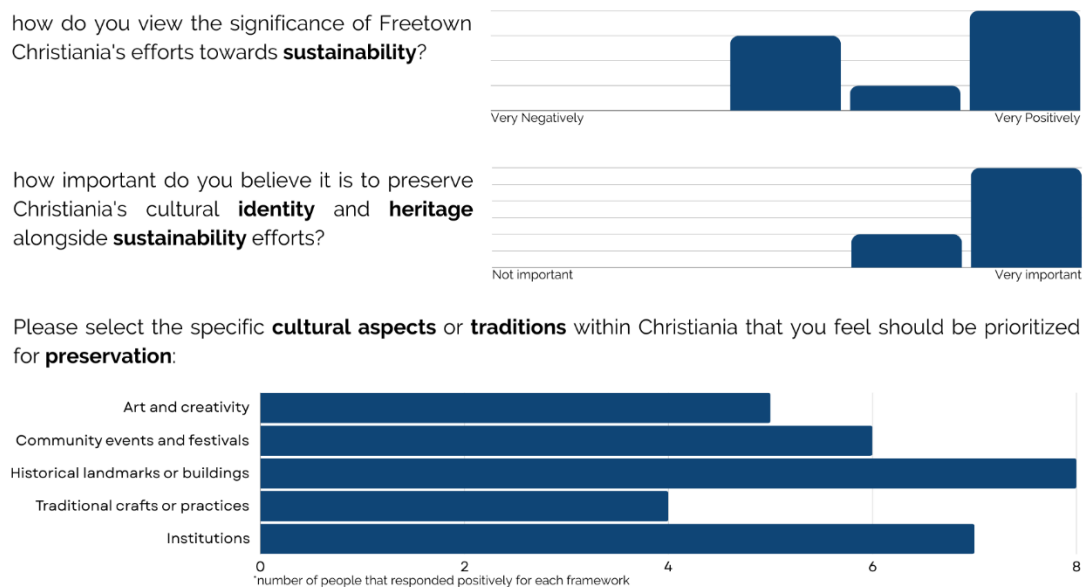
Christiania's strong identity, curious institutional autonomy, creative and entrepreneurial spirit cast a wide web of cultural underpinning, but the perception of most inhabitants, visitors and local stakeholder was widely positive in our survey about sustainability (Fig. 68). Fig. 67 refers to the SWOT perception over the main diagnosed scenarios for Spongetown Christiania's social impact.

CHRISTIANIA AS AN URBAN LIVING LAB SWOT-PESTEL ANALYSIS | SOCIAL DIMENSION

<u>internal factors</u>	<u>positive</u> STRENGTHS	<u>negative</u> WEAKNESSES
	• STRONG COMMUNITY IDENTITY AND CIVIC PARTICIPATION CULTURE • AUTONOMY TO SUSTAIN CULTURAL AND SOCIAL DIVERSITY • TOLERANT AND INCLUSIVE EMPOWERMENT OF MINORITIES	• AGING POPULATION AND DEMOGRAPHIC CHALLENGES • SOCIAL ISOLATION AND STIGMATISATION
<u>external factors</u>	OPPORTUNITIES	THREATS
	• EDUCATIONAL AND AWARENESS PROGRAMS • LEVERAGING SUPRA-NATIONAL POLITICS THROUGH EU INVOLVEMENT	• GENTRIFICATION PRESSURES • BALANCING SUSTAINABILITY SCIENCE AND TECHNOLOGY WITH CULTURAL PRESERVATION AND COMMUNITY AGENCY

67 - SWOT-PESTEL Analysis of Spongetown NbS ULL | Social Dimension

In a curious side note, most Christianites placed the historical landmarks of the city which they inhabit at the top of the benefits of the community and a priority for preservation – which contradicted our assumption that the greatest matter of concern would be the contemporary cultural expression in Christiania over old heritage – as we can also see in Fig. 68



68 - Survey Results – Insiders: Sustainability significance of Christiania

Thermal Comfort, Air Quality and Ventilation [DGNB - REGIME]

- DGNB-DK Approach: Optimisation of Bioclimatic and Passive Factors

DGNB-DK standards emphasize optimizing bioclimatic and passive factors in urban design and building architecture to enhance thermal comfort, air quality, and ventilation. This involves designing buildings and urban spaces to naturally regulate temperature and airflow, reducing reliance on artificial heating and cooling systems. For instance, building orientation and layout are optimized to maximize natural ventilation and sunlight, while minimizing heat gain in summer and heat loss in winter. High-performance insulation and glazing are employed to maintain indoor temperatures and reduce energy consumption. Shading devices, such as external shading, green walls, and facades, are implemented to block excessive sunlight, reduce heat absorption, and improve air quality. Incorporating materials with high thermal mass stabilizes indoor temperatures, and using reflective surfaces reduces heat absorption.

- IUCN Approach: Optimisation through NbS and Ecosystemic Design

IUCN guidelines focus on mitigating UHIE, improving air quality, and controlling climatic phenomena through NbS and ecosystemic design. This approach leverages natural processes and ecosystems to enhance urban environments. Urban green spaces and vegetation, such as parks, green roofs, and urban forests, are created to improve air quality, provide shade, and reduce urban heat island effects through evapotranspiration. Constructed wetlands, bio-swales, rain gardens and other water features are integrated into urban areas to cool the surrounding environment through evaporative cooling and enhance air quality by filtering pollutants. Biodiverse planting schemes use a variety of native plants to enhance biodiversity, improve air quality, and create resilient urban ecosystems that support human well-being. Eco-corridors and green networks are designed to facilitate airflow, reduce pollution, and provide cooling effects, creating healthier urban microclimates.

- Hybrid Focus: Integrating DGNB-DK and IUCN Standards in Spongetown Christiania

A hybrid approach in Christiania combines the strengths of DGNB-DK's bioclimatic and passive design principles with IUCN's NbS and local sustainability initiatives. This comprehensive strategy addresses the unique challenges and needs of Christiania's urban environment.

In this hybrid model, urban design and building architecture in Christiania adhere to DGNB-DK standards, optimizing building orientation, insulation, and shading devices to enhance thermal comfort and reduce energy consumption. These measures are complemented by IUCN's NbS, integrating urban green spaces, constructed wetlands, and biodiverse planting schemes to improve air quality and provide natural cooling.

For example, new buildings in Christiania are designed with high-performance insulation, reflective materials, and green facades to regulate indoor temperatures and improve air quality. Simultaneously, urban planning initiatives create interconnected green spaces and eco-corridors, enhancing natural ventilation and reducing heat island effects. Community gardens and rooftop farms provide additional green spaces, supporting local food production and contributing to urban cooling and air purification.

Community engagement is essential in this hybrid approach, with local residents participating in the design, implementation, and maintenance of green spaces and sustainable building

projects. Educational programs raise awareness about the benefits of bioclimatic design and NbS, fostering a culture of sustainability and resilience.

This integrated strategy ensures that Christiania not only meets high standards for thermal comfort and air quality but also creates a sustainable and resilient urban environment that supports biodiversity and community well-being.

Acoustic Comfort and Noise

- Managing Acoustic Comfort and Noise: Christiania and Copenhagen

Addressing acoustic comfort and noise in Christiania and Copenhagen requires integrating DGNB-DK standards, IUCN guidelines, and local initiatives. This comprehensive approach includes reducing noise from events and public spaces, prioritizing human comfort and sound insulation in various land uses and building types, and considering acoustic impacts on biodiversity with NbS (NbS).

- Reduction of Noise from Events and Public Spaces

Managing noise from events and public spaces is a common matter of concern in urban areas like Christiania and Copenhagen. Strategies to mitigate noise pollution in these areas include implementing noise barriers, soundproofing event venues, and regulating event times and locations to minimize disruption to residents. Establishing designated zones for events away from residential areas can also help reduce noise impact. Additionally, promoting quieter public spaces using natural sound buffers, such as tree belts and green walls, can further enhance acoustic comfort. Regular monitoring and community feedback mechanisms ensure that noise management strategies are effective and adaptive to changing urban dynamics.

- Prioritisation of Human Comfort, Housing and other Land Use and Building Types, Urban and Built Environment Solutions for Noise Reduction and Sound Insulation (DGNB)

DGNB-DK standards prioritize human comfort by implementing noise reduction and sound insulation measures in housing, commercial, and public buildings. This involves designing urban and built environments to minimize noise intrusion and enhance acoustic comfort. Key strategies include using high-performance sound-insulating materials in walls, windows, and doors to block external noise. Building layouts are optimized to locate quieter areas, such as bedrooms and living spaces, away from noise sources like roads and commercial zones. Urban design principles, such as creating buffer zones with vegetation and constructing noise barriers, are also employed to shield residential areas from traffic and industrial noise. Additionally, the DGNB-DK framework encourages the integration of green roofs and walls, which not only provide insulation but also absorb and dissipate sound, contributing to quieter indoor and outdoor environments.

- Acoustic Impacts on Biodiversity and Ecosystemic Integrity, NbS for Acoustic Quality (IUCN + Christiania)

IUCN guidelines and Christiania's local initiatives emphasize the importance of acoustic quality for biodiversity and ecosystemic integrity, and how these environments bring forth the acoustic quality of being exposed to natural sounds. Noise pollution, however, can significantly impact

wildlife, disrupting communication, mating, and feeding behaviours – and Christiania does not have public events around the lakes for that reason. Implementing NbS (NbS) to improve acoustic quality involves creating green spaces and buffer zones that absorb and deflect noise. For instance, urban forests, parks, and wetlands can serve as natural sound barriers, reducing noise levels and providing healthier environments for humans as well. Incorporating biodiverse planting schemes and maintaining natural landscapes within urban areas help mitigate the acoustic impact on ecosystems. These strategies not only enhance acoustic comfort for human residents but also support the health and resilience of urban biodiversity.

- Hybrid Focus: Integrating DGNB-DK, IUCN, and Christiania Approaches

A hybrid approach in Christiania combines the strengths of DGNB-DK's noise reduction and sound insulation principles with IUCN's NbS and local sustainability initiatives. This comprehensive strategy addresses the unique acoustic challenges and needs of Christiania's urban environment.

In this hybrid model, urban design and building architecture in Christiania adhere to DGNB-DK standards, incorporating sound-insulating materials and optimizing building layouts to enhance acoustic comfort. These measures are complemented by IUCN's NbS, integrating urban green spaces, constructed wetlands, and biodiverse planting schemes to improve air quality and provide natural cooling.

For example, new buildings in Christiania are designed with high-performance sound-insulating materials to reduce noise intrusion. Simultaneously, urban planning initiatives create green buffer zones and eco-corridors, enhancing natural sound absorption and reducing noise levels. Community gardens and urban forests not only improve acoustic quality but also support biodiversity and provide recreational areas for residents.

Community engagement is essential in this hybrid approach, with local residents participating in the design, implementation, and maintenance of noise reduction measures and green spaces. Educational programs raise awareness about the benefits of sound insulation and NbS, fostering a culture of acoustic comfort and environmental stewardship.

This integrated strategy ensures that Christiania not only meets high standards for acoustic comfort and noise reduction but also creates a sustainable and resilient urban environment that supports biodiversity and community well-being.

- Visual Comfort and Lighting [DGNB – REGIME]
 - Reduction of Artificial Lighting from Events and Public Spaces [Common Matter of Concern]
 - Prioritisation of Human Comfort, Housing and other Land Use and Building types [DGNB]
 - Optimisation through NbS and Ecosystemic Design [IUCN]
- Reduction of Artificial Lighting from Events and Public Spaces

Managing artificial lighting from events and public spaces is a common matter of concern in urban areas like Christiania and Copenhagen. Strategies to mitigate light pollution include implementing curfews for outdoor lighting, using low-intensity and directional lighting to minimize light spills, and installing motion sensors to ensure lights are only on when needed. Establishing designated zones for events away from residential areas can also help reduce light

impact. Additionally, promoting the use of warm-colored lighting can reduce glare and enhance visual comfort for residents. Regular monitoring and community feedback mechanisms ensure that lighting management strategies are effective and adaptive to changing urban dynamics.

- Prioritisation of Human Comfort, Housing, and Other Land Use and Building Types (DGNB)

DGNB-DK standards prioritize human comfort by implementing effective lighting strategies in housing, commercial, and public buildings. This involves designing urban and built environments and ecosystems to maximize natural light and ensure appropriate artificial lighting levels.

Several strategies can be pursued to ensure human comfort in light conditions. By optimizing natural light, using large windows, skylights, and light wells to maximize the penetration of natural light into buildings can help reduce the need for artificial lighting during the day. Implementing systems for daylight harvesting that adjust artificial lighting based on the availability of natural light, ensuring consistent and comfortable lighting levels while saving energy. Installing dimmers, timers, and occupancy sensors to provide the right amount of light where and when it is needed, can improve control and increase adaptability and effectiveness. Using fixtures that minimize glare and provide uniform light distribution can help us create comfortable and visually appealing indoor environments.

- Optimisation through NbS and Ecosystemic Design (IUCN)

IUCN guidelines focus on optimizing visual comfort and lighting through NbS and ecosystemic design. This approach leverages natural processes and ecosystems to enhance urban environments. Urban green spaces, such as parks and green roofs, help to diffuse light and reduce glare, creating visually comfortable outdoor spaces. Vegetation can be strategically placed to provide shade and reduce the intensity of direct sunlight, improving visual comfort in public areas. Natural light can be maximized by designing buildings and urban spaces to enhance light diffusion and reduce the need for artificial lighting. Additionally, incorporating water features can create reflective surfaces that enhance natural lighting in surrounding areas. Biodiverse planting schemes and maintaining natural landscapes within urban areas help to create visually pleasing environments that support human well-being.

- Hybrid Focus: Integrating DGNB-DK, IUCN, and Christiania Approaches

A hybrid approach in Christiania combines the strengths of DGNB-DK's lighting strategies with IUCN's NbS and local sustainability initiatives. This comprehensive strategy addresses the unique visual comfort challenges and needs of Christiania's urban environment.

In this hybrid model, urban design and building architecture in Christiania adhere to DGNB-DK standards, incorporating large windows, skylights, and light wells to maximize natural light penetration. Artificial lighting systems are equipped with dimmers, timers, and occupancy sensors to ensure appropriate lighting levels and reduce energy consumption. These measures are complemented by IUCN's NbS, integrating urban green spaces, reflective water features, and strategic vegetation placement to enhance visual comfort and reduce glare.

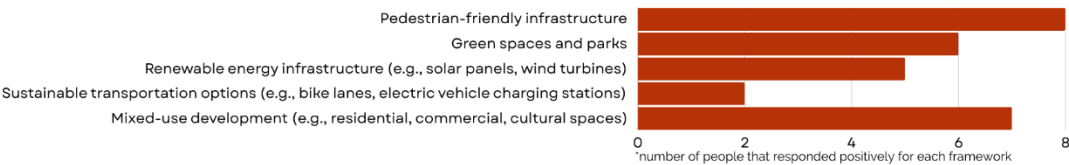
For example, new buildings in Christiania are designed with ample natural light access and effective artificial lighting controls. Simultaneously, urban planning initiatives create green buffer zones and eco-corridors that diffuse light and provide shaded areas, enhancing visual comfort in public spaces. Community gardens and green roofs not only improve visual aesthetics but also contribute to natural light diffusion and reduce the reliance on artificial lighting.

Community engagement is essential in this hybrid approach, with local residents participating in the design, implementation, and maintenance of lighting solutions and green spaces. Educational programs raise awareness about the benefits of natural lighting and NbS, fostering a culture of visual comfort and environmental stewardship.

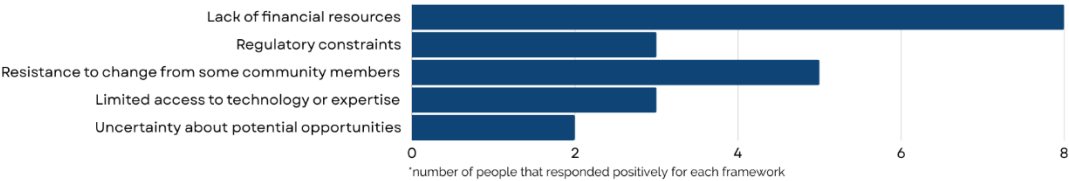
This integrated strategy ensures that Christiania not only meets high standards for visual comfort and lighting but also creates a sustainable and resilient urban environment that supports biodiversity and community well-being.

Access to WEFE Assets and Facilities

select the **urban design feature** that you believe to be most important for the future **development** of Christiania



select the **main barriers** or **challenges** that you believe Christiania faces in implementing sustainable practices and urban design initiatives



69 - Survey Results – Insiders: Most Important Features, Challenges and Barriers to Sustainability

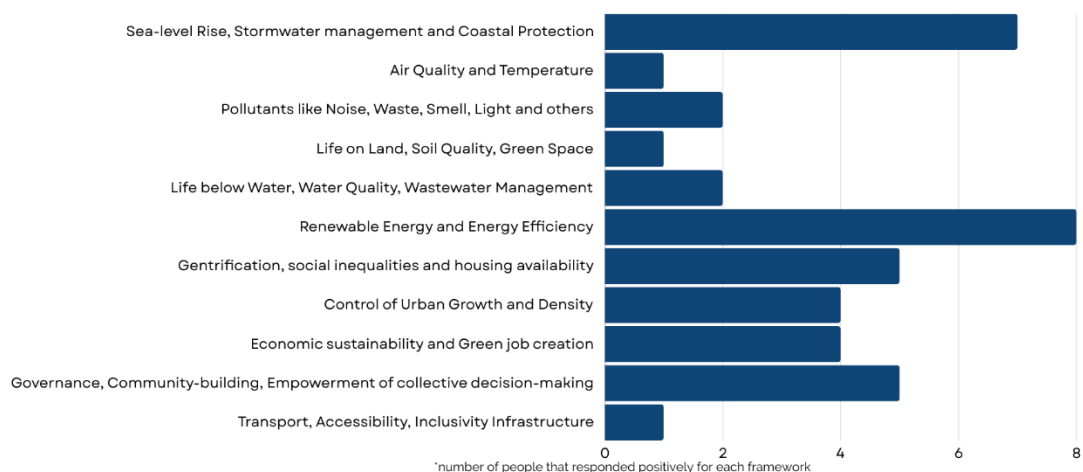
DGNB-DK standards prioritize sanitation, energy consumption, and biodiversity to ensure sustainable urban development. Effective sanitation systems are crucial for public health and environmental protection. This involves using water-efficient fixtures, greywater recycling, and sustainable wastewater treatment technologies – being so important, they seem to be out of focus from Christiania’s major matters of concern, with no respondents from the local and inhabitants to put water resource management as a priority design feature in the area, which we found peculiar.

Energy consumption is addressed through the implementation of renewable energy sources, energy-efficient building designs, and smart energy management systems. For instance, solar panels, wind turbines, and geothermal systems are integrated into building designs to reduce reliance on non-renewable energy sources. Biodiversity is supported by creating green spaces, promoting native vegetation, and incorporating biodiversity-friendly practices in urban planning. These strategies help create a balanced urban ecosystem that supports both human and environmental health in Christiania and are projects that should take even deeper root in forthcoming urban plans.

- Focus on WEFE Systems, NbS, and Ecosystem Services (IUCN)

IUCN guidelines emphasize the integration of WEFE systems, NbS, and ecosystem services to enhance urban resilience and sustainability. NbS such as constructed wetlands, urban forests, and green roofs are utilized to manage water, enhance biodiversity, and provide ecosystem services. For example, constructed wetlands not only treat wastewater but also provide habitat for wildlife and recreational spaces for residents. Urban forests and green roofs help in regulating temperature, improving air quality, and supporting urban biodiversity. Ecosystem services, including water purification, air quality regulation, and pollination, are integrated into urban planning to create multifunctional landscapes that support human well-being and environmental health. These solutions leverage natural processes to enhance the sustainability of urban WEFE systems. Additionally, IUCN addresses the food aspect of WEFE by promoting urban agriculture, community gardens, and local food production, thereby contributing to food security and aligning with SDG 2 (Zero Hunger).

select the following **sustainability challenges** that you believe Christiania should address as priorities in its future **urban planning**:



70 - Survey Results – Insiders: Major Challenges that Christiania should address in its Urban Plan

- Focus on Full Scope of SDGs and PBs (Christiania + IUCN + DGNB)

A hybrid approach in Christiania combines the strengths of DGNB-DK's focus on sanitation, energy consumption, and biodiversity with IUCN's emphasis on WEFE systems, including food, and NbS, all aligned with the full scope of Sustainable Development Goals (SDGs) and Planetary Boundaries (PBs). This comprehensive strategy addresses the unique challenges and needs of Christiania's urban environment.

In this hybrid model, Christiania ensures access to clean water and effective sanitation by implementing water-efficient fixtures, greywater recycling, and sustainable wastewater treatment technologies. Renewable energy sources such as solar panels, wind turbines, and geothermal systems are integrated into building designs to reduce energy consumption and promote energy self-sufficiency. Urban planning initiatives create green spaces and promote native vegetation to support biodiversity and enhance ecosystem services.

Additionally, IUCN's focus on urban agriculture is incorporated to address the food component of WEFE. Community gardens, rooftop farms, and local food production initiatives support food security, enhance biodiversity, and contribute to local resilience. These projects are designed to align with multiple SDGs, such as clean water and sanitation (SDG 6), affordable and clean energy (SDG 7), sustainable cities and communities (SDG 11), and life on land (SDG 15), while also addressing zero hunger (SDG 2) through urban agriculture.

For example, community-driven projects in Christiania establish constructed wetlands for wastewater treatment, providing both ecological benefits and recreational spaces. Urban gardens and rooftop farms support local food production, enhance biodiversity, and contribute to food security.

Community engagement is essential in this hybrid approach, with local residents participating in the design, implementation, and maintenance of WEFE systems and green spaces. Educational programs raise awareness about the benefits of sustainable practices and NbS, fostering a culture of stewardship for ecosystems, rooted in a sense of community and place-based development at a personal and collective level of identity.

This integrated strategy ensures that Christiania not only meets high standards for sanitation, energy consumption, and biodiversity but also addresses food security through urban agriculture. By leveraging NbS, ecosystem services, and hybrid strategies, urban planners can create sustainable environments that enhance human well-being, support ecological health, and promote community resilience. These comprehensive strategies ensure long-term sustainability and align urban development with global environmental and community goals.

Universal, Participatory Design, and Social Inclusivity

- Standards, Regulations, and Planning for Accessibility and Inclusivity Compliance (DGNB + IUCN)

DGNB-DK and IUCN emphasize the importance of standards and regulations to ensure accessibility and inclusivity in urban planning and design. Compliance with these standards involves creating environments that are accessible to all individuals, regardless of their physical abilities or social backgrounds. This includes designing buildings, public spaces, and transportation systems that meet universal design principles, such as barrier-free access with ramps, elevators, wide doorways, and tactile paving for the visually impaired. Providing inclusive facilities like accessible restrooms, seating, and clear signage in multiple languages and formats is also essential. Ensuring regulatory compliance with national and international standards for accessibility and incorporating these requirements into local building codes and urban planning policies are crucial steps. Participatory planning, which engages diverse stakeholders, including people with disabilities, elderly residents, and other marginalized groups, ensures their needs and perspectives are addressed systematically.

However, the standardization required by DGNB-DK and IUCN can sometimes be at odds with the ethos of Christiania. Christiania's history of experimental communitarian living, with buildings constructed using upcycled materials and non-traditional methods, often leads to non-compliance with current regulations. While these methods reflect the community's spirit of

experimentation and countercultural identity, they can create challenges in meeting accessibility and inclusivity standards.

- Improvisational, Liberal, Solidary, Equitable, and Contextual Adaptation to User Needs (Christiania)

Christiania's approach to universal design and social inclusivity is characterized by its improvisational, liberal, and contextually adaptive methods. This community-driven model emphasizes solidarity, equity, and responsiveness to the specific needs of its residents. Christiania's method allows for rapid iterations in planning, implementing, and managing urban spaces. Spaces and facilities can be adapted quickly based on immediate user feedback and evolving needs. The liberal policies promote an open and inclusive community ethos that values diversity and supports equal access to resources and opportunities for all residents. Solidary and equitable practices ensure that community resources are shared fairly, providing access to essential services and facilities for all members. Contextual adaptation involves designing and modifying spaces based on the unique cultural, social, and environmental context of Christiania, ensuring relevance and effectiveness in meeting the community's needs.

This improvisational approach allows Christiania to quickly respond to residents' needs, fostering a dynamic and inclusive community environment. However, the lack of regulatory compliance can sometimes result in gaps in accessibility and inclusivity, which are addressed more sporadically rather than systematically.

- Hybrid Focus: Integrating DGNB-DK, IUCN, and Christiania Approaches

A hybrid approach in Christiania combines the strengths of DGNB-DK's and IUCN's regulatory compliance with Christiania's improvisational and contextually adaptive methods. This comprehensive strategy ensures that universal, participatory design, and social inclusivity are central to urban development in Christiania.

In this hybrid model, new construction and renovations in Christiania strive to adhere to DGNB-DK and IUCN standards, ensuring compliance with accessibility regulations and promoting inclusive design. These measures are complemented by Christiania's community-driven approach, which emphasizes flexibility, creativity, and responsiveness to user needs. For example, while new buildings and public spaces are designed to be barrier-free and inclusive, with features like ramps, elevators, and accessible restrooms, community initiatives continue to promote inclusive practices through shared resources, cooperative projects, and participatory design processes that involve all residents.

Community engagement is essential in this hybrid approach, with local residents participating in the planning, design, and implementation of inclusive spaces and facilities. Educational programs and workshops raise awareness about the importance of accessibility and inclusivity, fostering a culture of equity and collaboration. This integrated strategy ensures that Christiania not only meets high standards for accessibility and inclusivity but also preserves its cultural identity and experimental spirit.

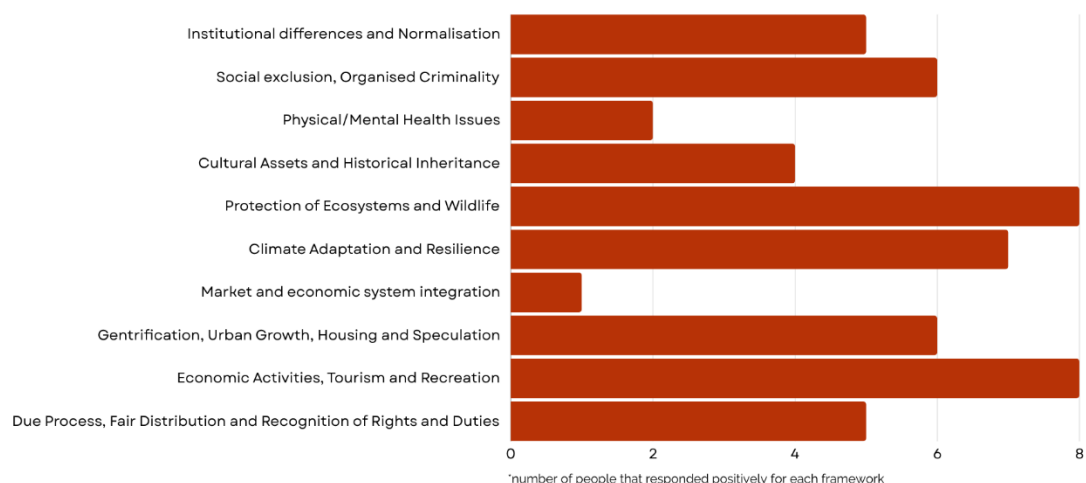
In conclusion, managing universal, participatory design, and social inclusivity in Christiania and Copenhagen requires balancing the benefits of standardized regulations with the flexibility and responsiveness of community-driven approaches. By integrating DGNB-DK standards, IUCN guidelines, and local initiatives, urban planners can create environments that promote equality, inclusivity, and resilience. These comprehensive strategies ensure long-term sustainability and

align urban development with both global standards and local needs, while protecting the unique cultural value of Christiania.

Gentrification and Community Identity

Christiania faces the challenge of maintaining its population within a self-imposed limit of circa 1300 inhabitants. This restriction aims to preserve the community's close-knit and countercultural ethos, but it also results in an aging population needing external renewal – however, the internal sample (Fig. 71) was still more optimistic regarding the gentrification threat than the outsiders' one. Unlike Copenhagen, where property rights and inheritance are straightforward, Christiania's strict private ownership policies prevent automatic inheritance of property, complicating population renewal. These policies create a barrier against gentrification but can lead to social isolation and demographic stagnation, necessitating a balance between preserving cultural identity and fostering demographic diversity.

which major **challenges** do you think Christiania should tackle in its relationships with Copenhagen



71 - Survey Results – Insiders: Major Challenges that Christiania should address in its relationship with Copenhagen

- Changes to the Community and Place Identity through Normalization Pathways and Urban Growth

Urban growth, symbolized by projects like Lynetteholm, reflects Copenhagen's need for continual expansion. Initially, Christiania was invited to expand its urban territory by 30,000 sqm, which was later renegotiated down to 15,000 sqm in recent years. These efforts aim to integrate Christiania into the broader urban fabric of Copenhagen, promoting standardized development and regulatory compliance. However, such expansion often leads to gentrification, displacing lower-income residents and altering the community's social fabric. While Lynetteholm and similar projects aim to integrate sustainable practices, the push for urban growth can dilute local identities and prioritize economic interests over social cohesion.

In contrast, Christiania's commitment to limiting population growth underscores a resistance to the endless expansion model. The community's emphasis on self-imposed limits and sustainable living contrasts sharply with Copenhagen's expansionist policies, highlighting the tension between preserving cultural integrity and adapting to urban pressures.

- Changes to the Community and Place Identity through Endogenous Regeneration and Urban Renewal

Christiania's approach to community and place identity focuses on endogenous regeneration and urban renewal. This model prioritizes internal development driven by the community, emphasizing sustainability and ecological preservation. By adhering to IUCN and DGNB principles, Christiania promotes projects such as upcycling and eco-friendly construction, which enhance infrastructure while preserving cultural identity.

However, the strict private ownership policies in Christiania, which prevent automatic property inheritance, create challenges in maintaining a stable and diverse population. These policies act as a barrier against gentrification, ensuring that property remains accessible and affordable to new community members. Nonetheless, they also lead to an aging population and social isolation, as descendants of current residents do not automatically gain property rights, necessitating external population renewal to maintain demographic vitality.

- Hybrid Focus: Integrating DGNB-DK, IUCN, and European Investments for Sustainable Regeneration

Christiania can leverage European investments and frameworks, particularly through Horizon Europe, to become a laboratory for community and place-based development guided by IUCN and DGNB standards. This hybrid approach combines regulatory compliance with the community's improvisational and contextually adaptive methods, creating a dynamic and sustainable urban environment.

In this model, Horizon Europe and European investments provide the necessary funding and support for implementing NbS (NbS) and innovative sustainability measures. These investments enable Christiania to pursue anti-gentrification strategies that align with the Responsible, Circular, Sustainable, and Regenerative (RCSR) paradigm.

New construction and renovations in Christiania adhere to DGNB standards, ensuring sustainability and regulatory compliance while respecting the community's cultural values and experimental spirit. At the same time, community-driven initiatives promote inclusive practices, shared resources, and participatory design processes that involve all residents.

For instance, European funding can support the development of constructed wetlands for wastewater treatment, urban gardens, and rooftop farms to enhance biodiversity and food security. These projects not only improve infrastructure but also foster a sense of ownership and pride among residents. Christiania's approach to urban renewal prioritizes maintaining its distinct cultural identity while adapting to contemporary challenges.

Community engagement is essential in this hybrid approach, with local residents actively involved in planning, designing, and implementing inclusive spaces and facilities. Educational programs and workshops raise awareness about the benefits of accessibility, inclusivity, and sustainability, fostering a culture of equity and collaboration. Investing in new housing can be crucial to maintain a population renewal capacity. Public housing offers to people interested in working, research and studying NbS and participating in the local projects in Christiania can be

a highly attractive feature for prospective inhabitants of the community, for short and long terms alike.

Managing gentrification and community identity in Christiania and Copenhagen requires balancing the pressures of urban growth with the principles of community-driven regeneration. By integrating DGNB-DK standards, IUCN guidelines, and European investments through Horizon Europe, Christiania can become a leading example of sustainable, anti-gentrification development. This comprehensive strategy ensures long-term sustainability and aligns urban development with both global standards and local needs, preserving the unique cultural value of Christiania while addressing the challenges of demographic renewal and gentrification. Through this hybrid approach, Christiania can achieve its vision of urban, community, and place regeneration within the city of Copenhagen.

Biophilic Design, Education, Awareness and Stewardship

- Preservation of Local Ecosystems and Lifeforms as Land Use and Biodiversity Criteria [DGNB]
- Ecosystems as Value for Place and Community Based Sustainability, Ecosystem Regeneration, Novel Ecosystems and Ecological Stewardship Approach to Climate Adaptation [IUCN + Christiania]

Addressing biophilic design, education, awareness, and stewardship in Christiania and Copenhagen involves integrating regulatory frameworks, community-driven methods, and strategies for sustainable urban growth. This comprehensive approach examines the preservation of local ecosystems, the value of ecosystems for place and community-based sustainability, and approaches to climate adaptation through ecological stewardship.

- Preservation of Local Ecosystems and Lifeforms as Land Use and Biodiversity Criteria (DGNB)

DGNB standards emphasize the preservation of local ecosystems and lifeforms as a crucial aspect of land use and biodiversity criteria. This involves integrating natural elements into urban planning to maintain ecological balance and support biodiversity. Preservation efforts include protecting existing green spaces, creating wildlife corridors, and incorporating native plant species into landscaping projects. Urban developments are designed to minimize their ecological footprint, ensuring that natural habitats are preserved and enhanced. The implementation of green roofs, vertical gardens, and permeable surfaces helps manage stormwater, reduce urban heat island effects, and support urban biodiversity.

For example, DGNB's criteria for sustainable urban development include measures to protect natural habitats, reduce pollution, and promote biodiversity-friendly practices. These standards ensure that urban growth does not come at the expense of local ecosystems, fostering a harmonious relationship between urban areas and the natural environment.

- Ecosystems as Value for Place and Community-Based Sustainability, Ecosystem Regeneration, Novel Ecosystems, and Ecological Stewardship Approach to Climate Adaptation (IUCN + Christiania)

The IUCN and Christiania emphasize the intrinsic value of ecosystems for place and community-based sustainability. This approach integrates ecosystem regeneration, the creation of novel ecosystems, and ecological stewardship as key strategies for climate adaptation. By viewing ecosystems as valuable assets, communities can develop sustainable practices that enhance both human well-being and environmental health.

Ecosystem regeneration involves restoring degraded areas to their natural state, enhancing biodiversity, and improving ecosystem services. This can include reforestation, wetland restoration, and the rehabilitation of urban green spaces. Novel ecosystems, which arise from the intentional design and management of new ecological communities, offer innovative solutions to environmental challenges. These ecosystems are tailored to local conditions and provide critical services such as carbon sequestration, water purification, and habitat provision.

Christiania's approach to ecological stewardship emphasizes community engagement and education. Residents are actively involved in maintaining and enhancing local green spaces, participating in biodiversity monitoring, and implementing sustainable practices. Educational programs and workshops raise awareness about the importance of ecosystems, fostering a culture of environmental stewardship.

- Hybrid Focus: Integrating DGNB, IUCN, and Christiania Approaches

A hybrid approach in Christiania combines the regulatory compliance and preservation efforts of DGNB with the community-driven, innovative strategies of IUCN and Christiania. This model fosters a dynamic and resilient urban environment that supports biodiversity and ecological health.

In this hybrid model, urban planning and development projects in Christiania adhere to DGNB standards, ensuring that local ecosystems and lifeforms are preserved. At the same time, community-driven initiatives promote ecosystem regeneration, the creation of novel ecosystems, and active ecological stewardship.

For example, new developments in Christiania incorporate green roofs and vertical gardens to enhance urban biodiversity, while community projects focus on restoring local wetlands and creating new green spaces. Educational programs engage residents in sustainability practices, such as composting, rainwater harvesting, and native planting, enhancing their connection to the environment and promoting long-term ecological stewardship.

Community engagement is essential in this hybrid approach, with residents actively involved in planning, designing, and implementing biophilic design elements and sustainability initiatives. Workshops and educational programs raise awareness about the benefits of preserving local ecosystems and adopting sustainable practices, fostering a culture of environmental responsibility.

5.3.4 Technological Scenarios

Managing urban development and sustainability in Christiania and Copenhagen requires a comprehensive approach that integrates structural design, climate adaptation, fire protection,

and mobility systems – different potential solutions imply strategic scenario establishment and contemplating the agenda and drivers underlying transitions taking place at higher systemic levels. This approach to scenario building (Fig. 72) of WEFE systems in connection to whole infrastructural domains of the city strategy balances the strengths, opportunities, and threats of Christiania's autonomy with the normalization pathways promoted by regulatory frameworks like DGNB and IUCN.

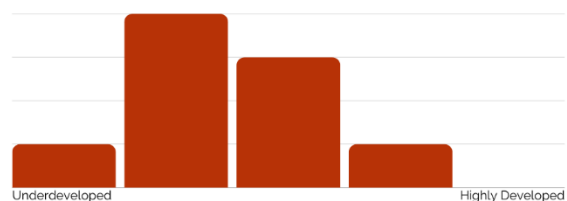
CHRISTIANIA AS AN URBAN LIVING LAB SWOT-PESTEL ANALYSIS | TECHNOLOGICAL DIMENSION

<u>positive</u>		<u>negative</u>	
<u>internal factors</u>	STRENGTHS		WEAKNESSES
	• INNOVATIVE ARCHITECTURAL SOLUTIONS AND EXPERIMENTAL COMMUNITY IDENTITY • SPONGE CITY STRATEGIES AND NATURE-BASED SOLUTIONS EXPERIENCE WITH IN-HOUSE PIONEER PROJECTS		• LIMITED TECHNOLOGICAL INTEGRATION AND SCEPTICISM OF TECHNOCENTRISM • DEPENDENCE ON EXTERNAL TECHNOLOGICAL FRAMEWORKS • ADVOCACY OF DIY SLOW TECHNOLOGY
<u>external factors</u>	OPPORTUNITIES		THREATS
	• INTEGRATION OF SMART TECHNOLOGIES AND IOT • EUROPEAN FUNDING FOR COLLABORATIVE AND PARTICIPATORY PROJECTS BACKED BY LOCAL COMMUNITY-BASED IMPLEMENTATION		• TELEOLOGICAL, TECHNOLOGICAL AND REGULATORY MISALIGNMENT • RAPID TECHNOLOGICAL CHANGES IN A SETTING OF HIGH WICKEDNESS (VOLATILITY, UNCERTAINTY, COMPLEXITY, AMBIGUITY)

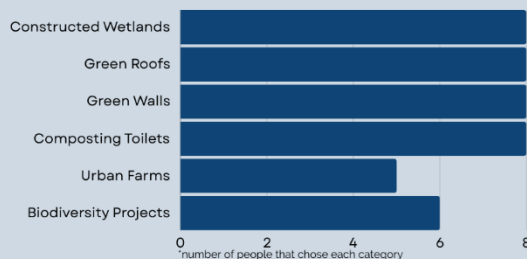
73 - SWOT-PESTEL Analysis of Spongetown NbS ULL | Technological Dimension

Here we explore various dimensions, including floating architecture, sponge city strategies (Fig. 73.), and multi-modal transport systems.

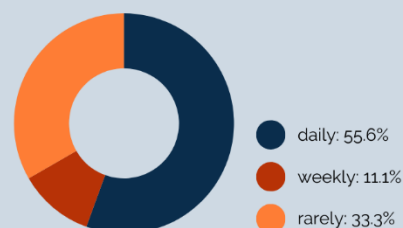
how would you describe the current state of **sustainability** practices within Christiania?



which of the following nature-based solutions are you **aware** of in Christiania?



how often do you **interact** with or directly use any of these nature-based solutions?



72 - Survey Results – Insiders: Sustainability Practices and NbS in Christiania

Structural Design Possibilities in Relationship to Main Risks

- Floating Architecture and Alternative Urban Systems [Christiania]

Christiania's experimental spirit has led to the exploration of floating architecture as a solution to rising sea levels and urban density challenges. Floating structures offer flexibility and resilience against flooding, aligning with the community's innovative approach to sustainable living. These systems can be complemented by bio-retention and infiltration strategies, enhancing the area's ability to manage stormwater and reduce flood risks. Christiania's urbanisation scope of action is however limited to its urban core and both the lakes and sea water bodies in its urban vicinity are considered out of the boundaries of the community's urban and landscape design agency.

- Sponge City Strategies

Copenhagen's implementation of sponge city strategies, including bio-retention, infiltration, and green-blue infrastructure (GBI), serves as a model for managing urban water challenges. By incorporating green roofs, rain gardens, artificial reefs, bio-retention basins and permeable pavements, and constructed wetlands the city enhances its capacity to absorb and manage stormwater, reducing flood risks and promoting urban resilience. Christiania can continue to adapt its long traditions of usage of these strategies to its unique context, integrating green infrastructure into its urban fabric. Political and Legal dimensions of sustainability are uniquely important to alter the current prospects of the community, which is being persuaded to abandon its ambitions of expansion towards the nature-core of the city's heritage landscape surrounding its centennial fortifications.

- Construction on New Buildings, Mobility and Accessibility Structure on Stilts

Building new structures on stilts offers a practical solution to mitigate flood risks, particularly in low-lying areas. This approach not only protects buildings from water damage predicted from the rise of the groundwater table and the sea-level in combination, but also preserves the natural flow of water, reducing the urban heat island effect and enhancing biodiversity. Incorporating elevated walkways and ramps ensures accessibility, aligning with universal design principles, and would be linked with this climate change resilience strategy to urbanisation.

- Externalising Climate Adaptation to the Regional (City) Level

Externalising climate adaptation to the regional level involves aligning local initiatives with broader city-wide strategies like Lynetteholm and other coastal adaptation projects. Christiania's unique approach to sustainability can be integrated into Copenhagen's larger climate adaptation plans, leveraging regional resources and expertise. This collaboration would ensure that localised efforts contribute to the city's overall resilience.

- Hybrid Pathways

Hybrid pathways combine top-down regulatory frameworks with bottom-up community initiatives. Christiania's autonomous, experimental methods can be harmonized with DGNB and IUCN guidelines, creating a balanced approach to urban development. This integration fosters innovation while ensuring compliance with sustainability standards, but uncharted trade-offs might arise from this increased project VUCA factors.

- Fire Protection and Safety (REGIME/NICHE/HYBRID)

Ensuring fire protection and safety is critical in urban planning. Adhering to DGNB and IUCN standards, Christiania can implement advanced fire safety measures, including the use of fire-resistant materials and the installation of comprehensive fire detection and suppression systems. These measures protect both residents and the unique built environment.

- Standards, Regulations and Planning for Accessibility and Inclusivity Compliance [DGNB + IUCN]

Compliance with accessibility and inclusivity standards is essential for creating equitable urban environments. DGNB and IUCN guidelines provide a framework for ensuring that all buildings and public spaces are accessible to everyone. This includes barrier-free design, clear signage, and inclusive facilities. Christiania can adapt these standards to its context, enhancing inclusivity while preserving its cultural identity.

- Improvisational, Liberal, Solidary, Equitable, and Contextual Adaptation to User Needs [Christiania]

Christiania's approach to urban development emphasizes flexibility, solidarity, and contextual adaptation. This involves rapidly iterating on design and implementation based on user feedback and evolving needs. By fostering a culture of inclusivity and equity, Christiania ensures that all residents have access to essential services and facilities, promoting social cohesion and resilience.

- Quality of the Built Environment and Building Envelope (REGIME/NICHE/HYBRID)

The quality of the built environment is crucial for sustainability and livability. Adhering to DGNB standards, Christiania can ensure that buildings are energy-efficient, comfortable, and durable. High-performance building envelopes reduce energy consumption and enhance indoor environmental quality. Christiania's innovative building techniques can complement these standards, creating unique, sustainable structures.

- Technical and Infrastructural Systems Adaptability (REGIME/NICHE/HYBRID)

Adaptable technical and infrastructural systems are vital for resilient urban development. DGNB and IUCN frameworks emphasize the need for flexible, scalable infrastructure that can respond to changing conditions. Christiania's community-driven approach allows for rapid adaptation and innovation, ensuring that infrastructure meets the evolving needs of residents.

- Disassembly, Recycling and System Boundaries (REGIME/NICHE/HYBRID)

Sustainable urban development involves considering the entire lifecycle of buildings and materials. DGNB standards promote disassembly and recycling, reducing waste and environmental impact. Christiania's commitment to upcycling and reusing materials aligns with these principles, fostering a circular economy and reducing the ecological footprint.

- Mobility Systems (REGIME/NICHE/HYBRID)

Efficient and inclusive mobility systems are essential for urban sustainability. DGNB and IUCN guidelines advocate for multi-modal transport systems that reduce reliance on private cars and promote public transit, cycling, and walking. Christiania's vision includes a ban on private cars,

emphasizing electric, shared micro-mobility, and accessible transport options. This approach reduces traffic congestion and pollution, enhancing urban livability.

- Communication Systems and Internet of Things (REGIME/NICHE/HYBRID)

Advanced communication systems and the Internet of Things (IoT) are integral to modern urban environments. DGNB and IUCN standards encourage the use of smart technologies to enhance efficiency and sustainability. Christiania can leverage IoT for real-time monitoring and management of resources, improving energy efficiency and service delivery.

- Electric, Shared Micro-Mobility and Accessibility; Private Car Ban [CHRISTIANIA]

Christiania's strategy to ban private cars and promote electric, shared micro-mobility ensures a sustainable, accessible transport system. This reduces environmental impact and enhances the quality of life for residents.

- Multi-Modal Transport and Electric Mobility of All Scales [DGNB and Copenhagen Municipality]

Copenhagen's approach to multi-modal transport and electric mobility aligns with DGNB standards, promoting a comprehensive, sustainable transport system. This includes public transit, cycling infrastructure, and electric vehicle integration with the transition from fossil fuelled personal motorised vehicles to a shared economy of accessible electric vehicles for personal use, on par with development of key public transport systems like buses, trains, and metro.

5.3.5 Economic Scenarios

- DGNB Approach to the Valuation of Christiania

The DGNB approach emphasizes lifecycle costs (LCC) and sustainable building practices to ensure economic efficiency throughout the lifespan of buildings. This methodology is effective for reducing long-term maintenance costs and optimizing resource use. DGNB's structured framework can help Christiania achieve financial sustainability in its built environment by focusing on the economic aspects of construction, operation, and maintenance.

However, DGNB's focus on the built environment often overlooks the broader economic benefits derived from ecosystem services and natural capital. While the approach is excellent for ensuring that buildings are economically sustainable, it does not fully capture the value of NbS. These solutions are critical for Christiania, where the community aims to integrate green-blue infrastructure to support WEFE systems.

DGNB's standards primarily address the economic aspects of the built environment, potentially missing opportunities for broader ecosystem-based economic planning (one of the weaknesses we highlight for that scenario, in Fig. 74). For example, while DGNB can ensure that buildings are cost-effective and resource-efficient, it may not fully support the integration of nature-based

economic activities that are crucial for Christiania's self-sufficiency and sustainable development.

CHRISTIANIA AS AN URBAN LIVING LAB SWOT-PESTEL ANALYSIS | ECONOMIC DIMENSION

<u>internal factors</u>	<u>positive</u> STRENGTHS	<u>negative</u> WEAKNESSES
	• LOCAL DIVERSITY OF ECONOMIC ACTIVITIES IN MULTIPLE SECTORS • CO-OPERATIVE MANAGEMENT OF INFRASTRUCTURE, PROPERTY AND ORGANISATIONS	• NARROW ECONOMIC FOCUS • CONFLICT IN ECONOMIC TELEOLOGY (GROWTH/DEGROWTH/POSTGROWTH)
<u>external factors</u>	OPPORTUNITIES	THREATS
	• HYBRID ECONOMIC MODELS AND INTERNATIONAL EXPERIMENTS • LIFECYCLE COST EFFICIENCY • ECOSYSTEM SERVICES VALUATION	• REGIME AND NICHE ECONOMIC POLICY AND INSTITUTIONAL MISALIGNMENTS • ECONOMIC PRESSURES FROM URBAN EXPANSION OF NEIGHBOURING AREAS

74 - SWOT-PESTEL Analysis of Spongetown NbS ULL | Economic Dimension

- IUCN Approach to the Valuation of Christiania

The IUCN approach focuses on the valuation of ecosystem services, natural and social capital, promoting NbS that align with Christiania's ethos of cooperation and sustainability. This framework emphasizes the economic benefits of maintaining and enhancing ecosystem services, which are essential for supporting the WEFE nexus.

Integrating LCC with ecosystem services assessment (ESA) and natural capital accounting (NCA) under the IUCN framework provides a comprehensive valuation method. This approach helps quantify the economic benefits of green infrastructure, biodiversity, and ecosystem health. For Christiania, leveraging these methods can demonstrate the economic viability of its sustainable practices and attract further investment.

The IUCN approach is well-suited for planning urban development that prioritizes ecosystem-based economic activities. It emphasizes the tangible economic value of ecosystem services, supporting initiatives such as the maintenance and monitoring of local lakes and waterways. This focus can generate economic activities and contribute to community well-being, aligning with Christiania's goals of self-sufficiency and sustainable development.

However, while the IUCN approach excels in integrating ecosystem services into economic planning, it may not fully address the economic efficiency of the built environment to the same extent as DGNB. This gap can lead to challenges in ensuring that all aspects of urban development are economically sustainable.

- Hybrid Approach

A hybrid approach that combines DGNB and IUCN standards can leverage the strengths of both frameworks, promoting economic resilience and sustainability in Christiania. This model integrates the lifecycle cost savings of DGNB with the economic benefits of ecosystem services

valued by IUCN, creating a balanced path towards economic viability and environmental sustainability.

- Economic Integration

By combining DGNB's focus on lifecycle costs with IUCN's emphasis on ecosystem services and natural capital, Christiania can achieve comprehensive economic planning. This integration ensures that buildings are economically efficient while also capturing the broader economic benefits of NbS. Such an approach can help Christiania align its urban development with broader sustainability goals, ensuring long-term economic and environmental resilience.

- Urban Value and Quality of Life

The hybrid approach enhances urban value by promoting high-quality design and well-maintained landscapes, which attract investment and enhance property values. At the same time, it integrates NbS that supports biodiversity, manage stormwater, and provide recreational spaces, improving the quality of life for residents.

- Built Environment and Ecosystem Services

Maintaining the value of the built environment through regular risk assessments and maintenance, combined with ecosystem-based economic planning, addresses both environmental risks and the economic value of ecosystem services. This comprehensive strategy ensures that all aspects of urban development are economically sustainable and resilient, supporting Christiania's goals of self-sufficiency and sustainability.

- Leveraging European Investments

The hybrid approach can leverage European investments and frameworks like Horizon Europe to implement its advanced sustainability measures and steering the conflictive relationship and agendas between Copenhagen Municipality and Freetown Christiania. Funding for green infrastructure, renewable energy projects, and NbS can support economic growth while enhancing environmental and social outcomes. This model ensures long-term resilience and aligns urban development with global sustainability goals, making Christiania a leading example of responsible, inclusive urban regeneration.

By integrating these strategies, Christiania can ensure long-term economic sustainability while preserving its unique cultural and ecological identity. Urban planning that incorporates both DGNB and IUCN standards can help create a vibrant, resilient community that benefits from sustainable economic development and enhanced quality of life and would be a pioneer-level innovation project that is bound to attract novel stakeholders and the community alike, provided that the engagement procedures are effective.

5.3.6 Legal Scenarios

The legal and political landscape for urban planning and development in Christiania and Copenhagen involves historical, cultural, and environmental considerations (Fig. 75). This

analysis focuses on the implications of current regulations and the tensions between different urban planning agendas, particularly the role of Lynetteholm, Christiania's heritage fortifications, and the community's push for NbS.

CHRISTIANIA AS AN URBAN LIVING LAB SWOT-PESTEL ANALYSIS | LEGAL DIMENSION

<u>internal factors</u>	<u>positive</u> STRENGTHS	<u>negative</u> WEAKNESSES
	• SUPPORTIVE LEGAL FRAMEWORKS FOR SUSTAINABILITY • INTEGRATION WITH INTERNATIONAL SUSTAINABILITY CRITERIA AND AGENDA	• REGULATORY CONSTRAINTS ON INNOVATIVE PRACTICES • REGULATORY NON-COMPLIANCE ON NUMEROUS URBAN SOLUTIONS IN CHRISTIANIA
<u>external factors</u>	OPPORTUNITIES	THREATS
	• LEGAL ADAPTATIONS FOR HYBRID GBI INFRASTRUCTURE • LEVERAGING EUROPEAN INVESTMENTS AND POLITICAL INFLUENCE IN LOCAL AFFAIRS	• LEGAL AND REGULATORY MISALIGNMENTS WITH LOCAL COMMUNITY AGENDA • ECONOMIC PRESSURES FROM URBAN EXPANSION OF NEIGHBOURING AREAS

75 - SWOT-PESTEL Analysis of Spongetown NbS ULL | Legal Dimension

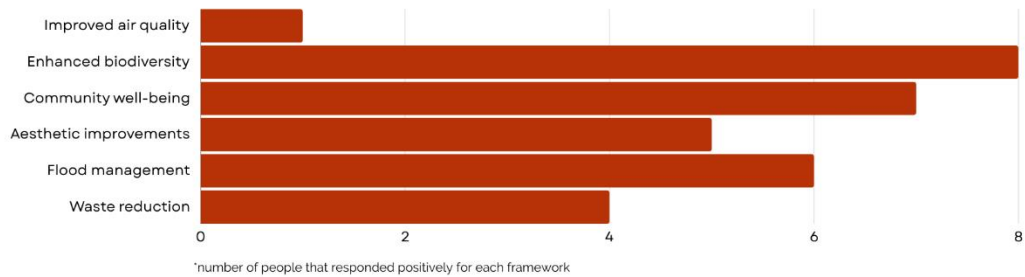
Municipal Regulations (REGIME/NICHE/HYBRID)

- Alteration of Current Urban Center Development Restrictions; Redesign of Heritage Landscapes

Christiania faces significant constraints due to stringent municipal regulations that prioritize the preservation of historical fortifications deemed unalterable by the Agency of Property and Palaces under the Danish Culture Ministry. This legal stance restricts the community's ability to adapt these areas for modern ecological and communal benefits – some NbS projects related to infrastructure are highly restricted and have been historically shunned by the municipality and national authorities in previous negotiations. The legal framework emphasizes the preservation of military history over the community's need for sustainable development – which might prevent benefits credited by NbS to the local community (Fig. 76) Compliance with Enshrined Land-Use Plans and Previous Urban Policy Agreements with Christiania

Christiania must adhere to existing land-use plans and urban policy agreements, which often favor traditional urban planning approaches. These agreements mandate specific land uses, building codes, and environmental standards, limiting the community's capacity to implement innovative, nature-based urban development practices. Compliance with these policies helps maintain legal harmony but often conflicts with Christiania's sustainable goals.

in your opinion, what are the most significant **benefits** provided by the **nature-based solutions** in Christiania?



have you noticed any personal or community benefits from the implementation of NBS in Christiania?

-  *Green roofs beautify the city and provide food for the bees*
-  *Yes, for me, nature-based solutions are associated with a less stressful life for people and animals*
-  *The incorporation of NBS in Christiania is what makes the place unique and enhance its identity*

76 - Survey Results – Insiders: Greatest benefits of NbS in Christiania

Infrastructural Regulations (REGIME/NICHE/HYBRID)

- NbS and Adoption of Green and Blue Infrastructure Planning [IUCN]

IUCN guidelines advocate for integrating NbS and green-blue infrastructure to enhance urban resilience and ecological health. These solutions are crucial for Christiania's vision of sustainable urban development. However, Danish urban development laws prioritize lifecycle assessment (LCA) facilitated by Environmental Product Declarations (EPDs), which are standardized and widely used in the built environment. The lack of a standardized process for assessing ecosystem services presents a barrier to low-investment projects in Christiania, which may struggle to incorporate comprehensive, case-by-case analyses.

- Adoption of Grey Infrastructure due to Compliance with Existing Regulations and Institutions [DGNB]

Existing regulations necessitate the use of grey infrastructure to comply with safety and durability standards. DGNB's framework supports this by emphasizing LCA and sustainable building practices, ensuring that construction projects are economically efficient. However, this focus can conflict with Christiania's aim to promote NbS and achieve economic self-sufficiency through ecosystem services.

- Hybrid Pathways

A hybrid approach that integrates green-blue and grey infrastructure can potentially align with legal requirements while supporting innovative solutions tailored to Christiania's needs. This pathway would require significant legal adaptations and support from municipal and national regulatory bodies to facilitate the integration of NbS alongside traditional infrastructure.

Culture and Heritage Regulations & Law (REGIME/NICHE/HYBRID)

- Alteration and Exception for Heritage Landscape and Buildings Policy in Christiania

Christiania's efforts to revitalize its heritage landscapes with modern sustainable practices face legal barriers due to stringent heritage preservation policies. While Lynetteholm's expansion is justified as a modern defense against climate change, Christiania's similar aspirations to adapt its historical fortifications for current ecological and communal needs are restricted. This discrepancy highlights a legal inconsistency and potential bias in urban development policies.

- Compliance with Preservation Policies and Prohibition of Alteration to the Fortifications and Connecting Water Bodies [Kobenhavns Kommune and Danish State]

Strict adherence to preservation policies maintains the historical integrity of fortifications and water bodies in Christiania. These regulations, however, can stifle the community's ability to implement NbS and other ecological enhancements, disregarding the evolving needs of the community.

- Hybrid Pathways

A hybrid approach could involve revising heritage preservation laws to allow for sustainable modifications that enhance ecological and community benefits. This would require legal frameworks that balance historical integrity with contemporary needs, promoting a dynamic and adaptive approach to heritage conservation.

Construction Regulations & Law (REGIME/NICHE/HYBRID)

- DGNB and BR Compliance for Sustainable Building Lifecycle

Compliance with DGNB standards and the Danish Building Regulations (BR) ensures that construction projects are sustainable and legally compliant. These standards focus on lifecycle costs, resource efficiency, and environmental impact, aligning with broader regulatory expectations.

- IUCN Criteria for NbS Construction

IUCN's criteria for NbS emphasize ecological benefits and sustainability. However, the gaps in legal and regulatory frameworks present challenges for fully integrating these solutions into construction practices. Christiania's reliance on NbS necessitates legal adaptations to facilitate the implementation of such practices within existing construction laws.

Economic Activity Regulations & Law (REGIME/NICHE/HYBRID)

- Prohibition of Private Ownership over Community Land in Christiania [Christiania]

Christiania's communal land ownership model, prohibiting private ownership, supports cooperative management and sustainable resource use. However, this model conflicts with broader legal frameworks favoring private land ownership, creating challenges for integrating Christiania's unique governance structure into the wider urban planning context.

- Normalization of Land Asset Ownership Scheme in Christiania [Kobenhavns Kommune and Danish State]

Efforts to normalize land ownership in Christiania aim to align the community's practices with broader legal and economic frameworks. This involves transitioning from communal to more standardized ownership models, potentially integrating private and public ownership to facilitate

investment and development. Such normalization could dilute Christiania's communal ethos and complicate its sustainable development agenda.

5.4 SWOT Analysis of PESTEL factors for Spongetown Christiania

Christiania's urban development is deeply entangled in a complex legal and political landscape. The juxtaposition of Lynetteholm's climate defense justification with the rigid preservation of Christiania's historical fortifications underscores significant inconsistencies in urban development policies. By integrating DGNB and IUCN standards within a hybrid legal framework, leveraging European funding mechanisms like Horizon Europe, and adapting legal frameworks to facilitate the incorporation of NbS, Christiania can promote sustainable development that aligns with both its unique cultural values and broader legal requirements. This approach can bridge the gap between preserving historical integrity and adapting to contemporary ecological and communal needs, ensuring that Christiania becomes a model of responsible, inclusive urban regeneration.

Strengths

1. Alignment with Sustainability Agendas (Political/Environmental; Economic/Legal)
2. Community-driven Governance and Engagement (Political/Social)
3. Nature-based Solutions (NbS) (Environmental)
4. Innovative Architectural Solutions (Technological)
5. Lifecycle Cost Efficiency (Economic)
6. Supportive Legal Frameworks for Sustainability (Legal)
7. Integration with International Sustainability Criteria (Legal)
8. Cultural and Social Diversity (Social)

Weaknesses

1. Regulatory Constraints (Political/Environmental; Legal)
2. Environmental Data Gaps (Environmental)
3. Limited Technological Integration (Technological)
4. Conflicts in Economic Frameworks (Economic)
5. Narrow Economic Focus (Economic)
6. Aging Population and Demographic Challenges (Social)
7. Social Isolation Risks (Social)

Opportunities

1. Hybrid Governance and Infrastructure Models (Political/Environmental/Technological; Legal)
2. Leveraging European Investments and Funding (Political/Environmental/Economic; Technological/Legal)
3. Integration with Regional Climate Strategies (Environmental)
4. Educational and Awareness Programs (Social)
5. Integration of Smart Technologies (Technological)

Threats

1. Conflicts with Broader Legal Frameworks (Political/Legal)
2. Inconsistencies in Urban Development Policies (Political/Legal; Environmental)
3. Climate Change Impacts (Environmental)
4. Gentrification Pressures (Social/Economic)
5. Rapid Technological Changes (Technological)
6. Regulatory and Economic Misalignment (Economic/Legal)

This synthesis chart highlights the key strengths, weaknesses, opportunities, and threats identified in the multi-dimension SWOT-PESTEL analysis, summarizing the critical factors affecting Christiania's urban development.

6. Spongetown Christiania: Urban Design Proposal for an NbS ULL

6.1 Master-plan Overview, Land-Use and Green-Blue Infrastructure

1. Flood Management and Water Reservoirs

- Emergency Water Reservoirs: We propose establishing new reservoirs to handle excessive rainwater and seawater during massive flooding events. These will be integrated into Christiania's existing fortifications, extending towards the western margins of Dyssen and Christianshavn Vold. These reservoirs will also serve as emergency water sources and potential electricity generators.
- Floating Architecture: We believe floating architectural solutions on the lakes and canals can be relevant, as they echo the community's lifestyles and previous housing experiments like the Pirate Harbour, particularly along the eastern margin of Refshaleøenvej, secured by a new wall to mitigate flood risks due to rising sea levels. We believe these solutions can be expanded towards the lakes and integrated with supporting NbS for infrastructure such as the expansion of the RBS.

2. Green Infrastructure and NbS (NBS)

- Green Roofs and Facades: We propose implementing green roofs and facades across new and existing buildings to improve insulation, reduce urban heat island effects, and enhance biodiversity
- Rainwater Gardens and Constructed Wetlands: We envision the integration of rainwater gardens in the public space and investing in floating and constructed wetlands to manage stormwater runoff, improve water quality, and create habitats for local wildlife in adaptation to climate change.
- Urban Permaculture and Food Forests: We recommend urban gardening, farming and permaculture practices to generate food forests and other productive biotopes to promote local food production and enhance urban green spaces.

- Composting Toilets and Waste Management: Continuing composting toilets and advanced waste management systems to reduce environmental impact and promote circular economy principles can be pursued in connection with broader compost management and soil recovery activities.

3. Mixed-Use Development and Community Spaces

- Mixed-Use Buildings (15,000 sqm total): Allocate 15,000 sqm for mixed-use development, combining residential, commercial, and cultural spaces. This includes both new constructions and renewals of existing structures.
- Residential Areas: Eco-friendly housing options must incorporate sustainable building materials and energy-efficient passive designs.
- Commercial Spaces: Create spaces for local businesses, including cafes, restaurants, workshops, and retail stores that support the local economy and provide employment opportunities based on Nature-based Solutions projects as a primary economic activity and secondary transformation micro-industries.
- Cultural and Community Hubs: Establish cultural and community centers that serve as focal points for social interaction, events, and educational activities.

4. Urban Fabric and Connectivity

- Enhanced Connectivity: We propose pedestrian and bicycle pathways to enhance connectivity within Christiania and to neighbouring areas. Ensure accessibility and promote sustainable modes of transportation.
- Public and Green Spaces: Expanding public and green spaces is a measure to foster community interaction, recreation, and biodiversity. This includes parks, community gardens, and recreational areas which will be opened in a broader manner to the public, to increase social inclusivity and community visibility towards destigmatising the public space and the recent memory of Pusher Street and Pusher Square.

5. Innovative Architectural Solutions

- Sustainable Building Techniques: Innovative sustainable building techniques using bio-based local materials for new constructions and renovations can be pursued. This approach includes the use of recycled materials, energy-efficient systems, and passive solar design, design for disassembly, design for emotional attachment and similar measures that replicate the community ethos.
- Adaptive Reuse of Historical Structures: Preserve and adapt historical structures to new uses, maintaining the cultural heritage while meeting modern needs.

6. Community and Economic Development Initiatives

- NbS Incubator Hub: We propose establishing an incubator hub focused on NBS, providing resources and support for startups and organizations developing innovative solutions for urban resilience and sustainability.
- Educational Programs and Workshops: The offer educational programs and workshops on sustainable living, permaculture, and green building practices to engage residents and

visitors should be augmented and planned in connection with NbS, Urban Lifecycle and ES

Land Use Plan for 15,000 sqm of New Construction

Housing (9,000 sqm)

- Floating Residential Units: We are developing in this concept 5,000 sqm of floating residential units on the lakes and canals, to envision an alternative scenario of an adaptive reservoir transition for this ecosystem which can be an integral part of the new development's infrastructure. These units will cater to new and existing residents displaced by the new water reservoir. This includes:
 - 2,000 sqm of floating homes particularly around the Peace Harbour and the canal east of Christiania in the Refshaloenvej shoreline
 - 2,000 sqm of floating homes on stilts foundation on the lake's shores north of the Dysselbro bridge of Christiania
- Eco-Friendly Apartments: 4,000 sqm of eco-friendly apartment buildings are foreseen to take place in the urban core of "downtown" Christiania. These will be located near existing residential areas to maintain community cohesion. Each apartment complex will include green roofs and facades to enhance sustainability.

Commercial and Service Spaces (3,000 sqm)

- Local Businesses and Shops: 1,500 sqm shall be allocated to local businesses, including cafes, restaurants, and retail stores. These will be distributed throughout Christiania to support local economic activities and provide amenities for residents.
- Workshops and Studios: 1,000 sqm are proposed for workshops and art studios. These spaces will support local artisans and craftspeople, fostering creativity and economic self-sufficiency in a community with a long tradition of crafts and arts. These can be pursued in a complementary manner and in synergy with NbS programs for the area.
- Healthcare and Community Services: 500 sqm for healthcare and community service centers, including clinics and spaces for social services, namely geriatric support for active ageing of the elderly community members.

Public and Institutional Buildings (3,000 sqm)

- NbS Hub and School Complex: 2,000 sqm are foreseen for a combined NbS Hub and school complex near the lakes and canal shoreline. This facility will serve as a center for education and innovation, providing classrooms, laboratories, and research facilities for sustainable urban development, bridging research across biotopes.
- Community and Cultural Centers: 1,000 sqm for community and cultural centers. These spaces will host events, meetings, and cultural activities, reinforcing community bonds and promoting social engagement.

NbS (NBS) Incubator Program for Christiania

- Vision and Objectives: The NbS (NBS) Incubator Hub in Christiania aims to integrate land, freshwater, brackish water, and seawater systems to create a resilient, circular, symbiotic, and regenerative urban development. This includes green infrastructure, innovative water management systems, and community-driven initiatives, targeting a total population of 1,000 residents with the capacity to support additional inhabitants.

Key Components of the Incubator Hub

1. Land/Urban Systems

- **Food Forests and Urban Permaculture:** Food forests and permaculture gardens promote local food production and enhance biodiversity. These areas support approximately 200 residents by providing fresh produce and reducing reliance on imported food.
- **Green Roofs and Green Facades:** Green roofs and facades are proposed on the entirety of new and as many existing buildings as convenient and feasible to improve insulation, reduce urban heat island effects, and provide habitats for local wildlife. These also help manage stormwater effectively.
- **Community Gardens and Parks:** Community gardens and parks for recreation and social interaction, fostering community engagement and well-being.

2. Freshwater Systems (Protected Biotope)

- **Constructed Wetlands:** 2,000 sqm of constructed wetlands for wastewater treatment, providing a natural method for water purification and creating habitats for amphibians and birds. For a total population of 1,250, constructed wetlands will require approximately 6,250-12,500 sqm based on treatment needs – this decentralisation experiment could be realised locally resorting to our NbS in the proximity of abundant water bodies in Christiania's surrounding territory.
- **Rainwater Gardens:** Install 500 sqm of rainwater gardens to manage stormwater runoff and enhance urban green spaces.
- **Biodiversity Enhancement:** Protect and enhance local freshwater biotopes to support native species and maintain ecological balance.

3. Brackish Water Systems (Lakes and Reservoir)

- **Floating Wetlands:** Floating wetlands in the lakes and reservoir are designed to improve water quality and provide habitats for aquatic life. These contribute to biodiversity and water purification.
- **Artificial Reefs and Habitats:** Artificial reefs to support marine biodiversity and enhance fish populations, as well as taking part in the structuring of sea-level rise shoreline defence systems, through bio-retention and sediment capture.
- **Innovative Floating Architecture:** 3,000 sqm of floating residential units and public spaces, equipped to adapt to variable water levels. These can house approximately 188-250 additional residents based on housing standards of 30-40 sqm per person.

4. Seawater Systems (Canals)

- Kelp Forests and Oyster Beds in the canals to improve water quality, sequester carbon, and provide habitats for marine life. These systems enhance biodiversity and support sustainable food sources.
- Seagrass Meadows: Seagrass meadows to stabilize sediment, enhance biodiversity, and support marine ecosystems.
- Sustainable Aquaculture: Implement 500 sqm of sustainable aquaculture projects to provide local food sources and promote marine conservation.

Rationale for Dimensions

1. Food Forests and Urban Permaculture:

Supporting Local Food Production: Urban food forests can yield substantial fresh produce, supporting about 200 residents by providing fresh produce and reducing the need for imported food. This area is designed to ensure sufficient yield and biodiversity support.

2. Green Roofs and Green Facades:

Stormwater Management: Green roofs help manage stormwater, reducing runoff and mitigating flood risks. The area is based on existing and new buildings' roof areas that can be feasibly converted to green roofs, ensuring significant coverage for stormwater management.

3. Constructed Wetlands:

Wastewater Treatment: Constructed wetlands require about 5-10 sqm per person for effective wastewater treatment. For 1,250 inhabitants, this equates to 6,250-12,500 sqm to meet water purification standards and support local biodiversity.

4. Floating Wetlands:

Water Quality Improvement: Floating wetlands help in nutrient uptake and water purification. The area is proportional to the size of lakes and reservoirs to ensure significant impact on water quality.

5. Artificial Reefs and Habitats:

Marine Biodiversity Enhancement: Artificial reefs support marine life, promoting biodiversity and ecological health. The area is based on the capacity to support additional marine biodiversity and ecological balance.

6. Kelp Forests and Oyster Beds:

Water Quality Improvement: Kelp forests and oyster beds filter water, sequester carbon, and provide essential ecosystem services. The area is based on suitable locations in the canals where these systems can thrive.

7. Seagrass Meadows:

Sediment Stabilization: Seagrass meadows stabilize sediment and prevent erosion. The area is based on suitable coastal areas within the canals for seagrass growth, ensuring effective sediment stabilization and biodiversity support.

8. Sustainable Aquaculture:

Local Food Production: Sustainable aquaculture provides seafood, contributing to local food security. The area is calculated to supplement the dietary needs of the community with sustainable seafood, ensuring environmental capacity and sustainability.

By following these criteria and dimensions, the proposed NBS in Christiania ensure a balanced approach to enhancing urban resilience, ecological health, and community well-being.

6.2 Resilience in Climate Adaptation

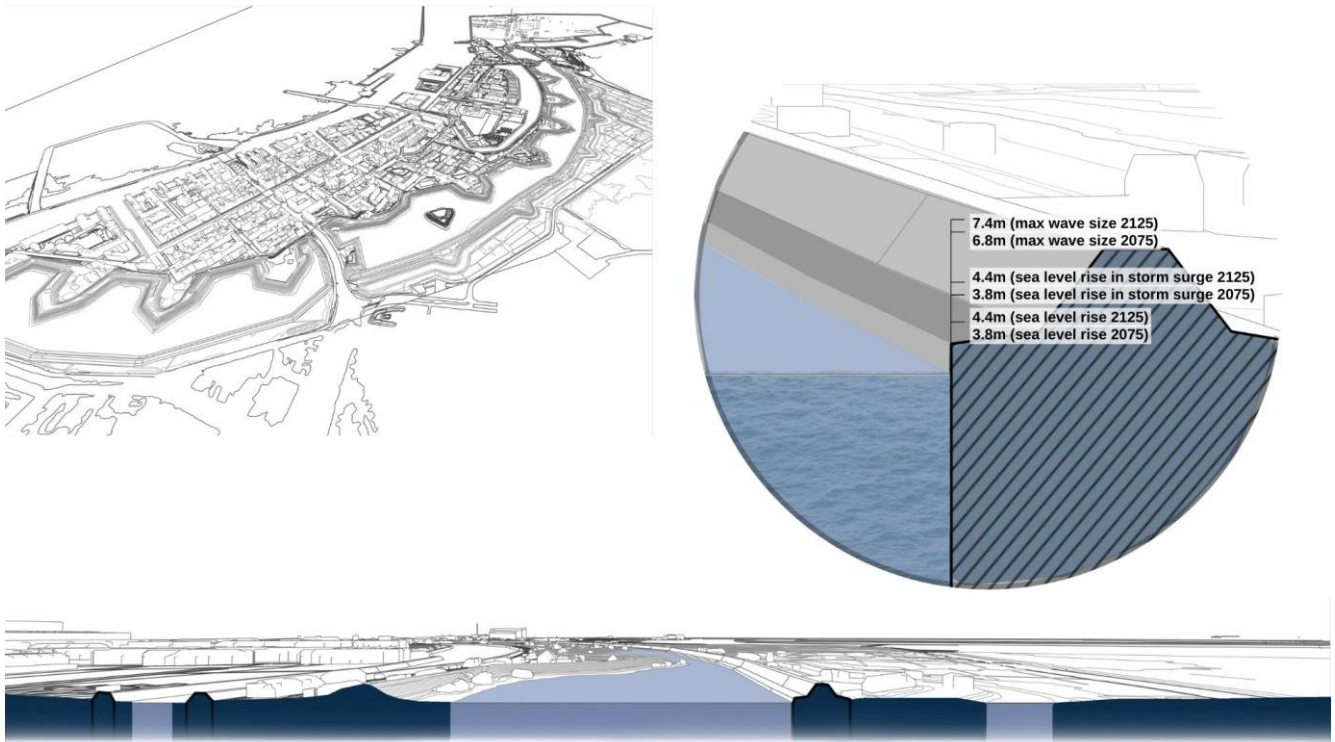
This ambitious proposal centers around a multifunctional reservoir system designed to address the primary climate risks of excessive rainfall, storm surges, and sea-level rise (Fig. 77). The development of this innovative infrastructure could safeguard Christiania, Christianshavn, and parts of Amager, while providing additional benefits such as drought resilience, emergency water supply, and potential energy generation.

At the heart of the Spongetown project is the idea of creating a reservoir system that integrates seamlessly into Christiania's existing fortifications. This reservoir is envisioned not merely as a containment strategy but as a comprehensive solution for managing excessive rainwater and seawater during massive flooding events. By acting as a buffer, the proposed reservoir could protect surrounding neighborhoods from floodwaters, significantly reducing the risk of damage to infrastructure and homes. The ability to manage vast quantities of water during extreme weather conditions would position this reservoir as a critical component in Christiania's flood defense strategy.

In addition to its flood management capabilities, the proposed reservoir could serve as a vital water storage solution during times of drought. As climate change makes weather patterns increasingly unpredictable, having a reliable water source is essential. The reservoir would ensure that Christiania and its neighboring communities have access to water when natural supplies are scarce, thereby maintaining continuity in daily life and reducing the strain on municipal water resources. This dual functionality underscores the reservoir's potential importance not only for flood mitigation but also for enhancing water security in the face of drought.

The design of the reservoir could incorporate floating constructed wetlands, a key nature-based solution that provides multiple ecological benefits. These wetlands would adapt to water level fluctuations, offering a dynamic solution for managing varying water volumes. They would not only improve water quality through natural filtration processes but also create habitats for local

wildlife, enhancing biodiversity in the area. This innovative approach would ensure that the reservoir remains effective and beneficial regardless of changing environmental conditions.



77 - Resilience and Climate Adaptation (Reservoir and Sea Wall Infrastructure Axonometry, Perspective, Cut Section and detail)

Moreover, the landscape architecture surrounding the reservoir would be redesigned to enhance flood resistance. This could include the use of natural flood barriers, permeable surfaces, and strategic vegetation to manage and redirect excess water efficiently. Such measures would reduce runoff, increase groundwater recharge, and create aesthetically pleasing, functional spaces that enhance the community's resilience to flooding. The integration of these green-blue infrastructure elements would transform Christiania into a sponge city, capable of absorbing and managing water in a sustainable manner.

The project also envisions the development of floating architectural solutions on the lakes and canals, particularly along the eastern margin of Refshaleøenvej. These floating structures would not only mitigate flood risks due to rising sea levels but also exemplify adaptive design in the face of climate change. By securing these buildings with a new flood wall, the project would provide safe, resilient housing options that can withstand the challenges posed by a changing climate. This architectural innovation would demonstrate how urban areas can adapt to environmental threats while maintaining livability and aesthetic appeal.

Green infrastructure would be further enhanced by the implementation of green roofs and facades across both new and existing buildings. These elements would significantly improve insulation, reduce urban heat island effects, and enhance biodiversity. Rainwater gardens and constructed wetlands would be strategically installed to manage stormwater runoff, improve water quality, and create habitats for local wildlife, contributing to the overall ecological health of Christiania. These nature-based solutions would integrate seamlessly with the built environment, creating a harmonious balance between urban development and natural systems.

The multifunctional reservoir system would not only manage floods but also serve as a critical water storage solution during droughts. By storing excess water, the reservoir would ensure a reliable supply during dry periods, supporting both residential needs and agricultural activities. In times of emergency, such as fires, the reservoir would provide an accessible water source for firefighting efforts, enhancing community safety and resilience. Additionally, the design could include provisions for integrating renewable energy generation methods, such as micro-hydropower systems, which would harness the movement of water within the reservoir to contribute to local energy needs, promoting sustainability.

By focusing on these interconnected strategies, the "Resilience in Climate Adaptation for Spongetown Christiania" project proposes a new standard for urban resilience. Through the innovative use of reservoirs, constructed and floating wetlands, and integrated green-blue infrastructure, Christiania could not only protect itself from the immediate threats of excessive rainfall, storm surges, and sea-level rise but also create a sustainable and adaptive urban environment. This visionary approach aims to ensure that Christiania remains a vibrant and resilient community, capable of thriving amidst the challenges of a changing climate.

6.3 WEFE Circularity

We propose a multifunctional reservoir system designed to address climate risks while integrating for WEFE circularity that would have to be accounted through an ESA-LCA framing that our project does not have the scope to measure, but to propose and conceptualise. Our infrastructure vision aims to foster community-based governance and management from a lifecycle perspective, ensuring a sustainable and adaptive urban environment.

Central to this vision is the creation of a reservoir system that not only manages excessive rainwater and seawater during massive flooding events but also supports a holistic, permaculture-inspired approach to community resilience. This reservoir would serve as the keystone of an integrated system that enhances water management, energy production, food security, and ecosystem health.

The reservoir's design incorporates floating constructed wetlands, which provide multiple ecological benefits. These wetlands adapt to water level fluctuations, offering a dynamic solution for managing varying water volumes. They naturally filter water, improving quality and creating habitats for local wildlife, thereby enhancing biodiversity. This nature-based solution ensures that the reservoir remains effective and beneficial, regardless of changing environmental conditions.

A SCC approach to water management in Christiania (See Appendix B interviews 16, 17 and 21), where this was proposed and discussed) would see rainwater gardens and constructed wetlands strategically installed to manage stormwater runoff, improve water quality, and create habitats for local wildlife. These features not only serve functional purposes but also integrate into the community's green spaces, promoting biodiversity and ecological balance.

To ensure food security, urban permaculture practices would be implemented alongside the reservoir. Food forests and community gardens would be developed, providing fresh produce and reducing the community's reliance on imported food, but also healing the soil through

selective crop rotation and use of bioremediation species like hyperaccumulators, and other nature-based practices. These green spaces would be managed using sustainable practices that enhance soil health, support pollinators, and create resilient local food systems. By fostering a deep connection with nature, these practices would enhance community well-being and sustainability.

Energy generation within this system would be harnessed through renewable methods integrated into the reservoir's design. Micro-hydropower systems could be employed to generate electricity from the movement of water, contributing to local energy needs and promoting sustainability. Additionally, green roofs and facades on surrounding buildings would support solar panels, further enhancing energy efficiency and reducing reliance on non-renewable sources.

Community-based governance and management are central to the lifecycle approach envisioned for this infrastructure. The project proposes a governance model where residents actively participate in decision-making processes, ensuring that the community's needs and values are reflected in the management of resources. Regular workshops and educational programs on sustainable living, permaculture, and green building practices would engage residents, fostering a culture of sustainability and resilience.

The lifecycle management perspective also involves planning for the long-term sustainability of the reservoir and its associated systems. This includes regular maintenance, monitoring of ecological health, and adaptive management practices that respond to changing environmental conditions. By involving the community in these processes, the project ensures that local knowledge and expertise are leveraged, and residents feel a sense of ownership and responsibility towards their environment.

Permaculture principles extend to waste management, where composting toilets and advanced waste processing systems would be introduced. These systems would reduce environmental impact, promote nutrient recycling, and support the community's circular economy. Waste materials would be composted and returned to the soil, enhancing soil fertility and supporting local food production.

The multifunctional reservoir system proposed in the "Resilience in Climate Adaptation for Spongetown Christiania" project exemplifies how permaculture principles can create a resilient and sustainable urban environment. By integrating water, energy, food, and ecosystem management into a cohesive system, Christiania can protect itself from climate risks while enhancing community well-being and ecological health. This visionary approach aims to ensure that Christiania remains a vibrant and resilient community, capable of thriving amidst the challenges of a changing climate. Through community-based governance and a lifecycle perspective, this project proposes a sustainable future where residents actively contribute to and benefit from a harmonious relationship with their environment.

6.4 Transportation and Mobility Circularity

A pivotal element of this vision is the integration of Copenhagen's renowned cycle superhighways, known as Supercykelstier, atop the proposed reservoir's wall along the eastern

margin of the city moat. This strategic placement not only enhances the reservoir's functionality as a flood management and water storage solution but also transforms it into a vital infrastructure for sustainable urban mobility. The Supercykelstier network, a collaboration between the Capital Region and multiple municipalities, provides safe, smooth routes designed to prioritize the needs of commuters, making cycling a competitive and sustainable mode of transportation.

The proposed supercycle highway would create a seamless connection between Amager, Indre By (Inner City), Refshaleøen, and the forthcoming neighborhood of Lynetteholm. By providing a direct and efficient route for cyclists, this infrastructure promotes the use of bicycles and other soft mobility transport means, reducing reliance on motor vehicles and contributing to the city's overall sustainability goals.

Moreover, the project includes the construction of bridges that cross the lakes of Christiania and the fortification wall in a single sweep. These bridges are designed to allow people to traverse Christiania without entering and disturbing its slow traffic, maintaining a smooth and uninterrupted cruise speed for cyclists and other soft mobility users. This design respects the unique character and tranquil atmosphere of Christiania, ensuring that the influx of through-traffic does not disrupt the community's way of life.

The elevated supercycle highway and bridges will be designed with safety, accessibility, and aesthetics in mind. The infrastructure will feature wide lanes, gentle slopes, and clear signage to accommodate a range of users, including pedestrians, cyclists, and people using mobility aids. Additionally, green design elements such as planted barriers and natural shading will enhance the user experience, making the route not only functional but also pleasant and inviting.

By linking key neighbourhoods, the super cycle highway atop the reservoir's wall will facilitate easier and faster commutes, promoting active transportation and healthy lifestyles. This connectivity supports the broader goals of urban resilience and sustainability, as it encourages the use of environmentally friendly transport options and reduces greenhouse gas emissions associated with vehicular traffic.

Furthermore, this integrated approach to urban design exemplifies how multifunctional infrastructure can serve diverse purposes, from flood management and water conservation to sustainable mobility and community connectivity. The project not only addresses immediate climate risks but also creates long-term benefits for the city's residents and environment.

The proposed design underscores Christiania's commitment to innovation and sustainability, demonstrating how forward-thinking urban planning can harmonize with the community's values and lifestyle. By linking the city through sustainable mobility solutions, the "Resilience in Climate Adaptation for Spongetown Christiania" project sets a new standard for urban resilience, connectivity, and ecological harmony.

In summary, the integration of the Supercykelstier atop the reservoir's wall, coupled with the construction of bridges across Christiania's lakes and fortification wall, presents a visionary approach to urban design. This proposal enhances connectivity between key areas of Copenhagen, promotes sustainable transportation, and preserves the unique character of Christiania. Through this multifaceted infrastructure, Christiania can lead the way in creating a resilient, sustainable, and interconnected urban future.

6.5 Water-based and Land-based Solutions

Our proposed Water and Land-based NbS structure (Figs. 80 and 81) intends to increment the already expressive endeavours of Christiania to promote biodiversity and climate adaptation, especially in connection with the Gardeners' Group and the Frie Natur Biodiversity Association of Christiania. We believe that designing future ecosystems around Christiania through NbS projects can be a main interestment device in future negotiations with the City of Copenhagen, especially regarding the landscape transformations we are proposing on the heritage sites, which would become more interwoven than they are already with Christiania's community as their formal stewards

Marine and Brackish Water Biotopes

The proposed multifunctional seawall will be a linchpin in Christiania's coastal protection strategy. This seawall will be integrated with marine nature-based solutions such as constructed and floating wetlands, seagrass meadows, kelp forests, and artificial mussel reef formations. These components collectively aim to shield Christiania from sea-level rise, storm surges, and excessive rainfall while simultaneously improving water quality, stabilizing sediment, and supporting marine biodiversity.

- Constructed and Floating Wetlands: These wetlands will act as natural filters, improving water quality by removing pollutants. They will also provide critical habitats for amphibians, birds, and aquatic plants, supporting species such as the common frog and smooth newt, which thrive in clean, undisturbed water bodies.
- Seagrass Meadows and Kelp Forests: These underwater ecosystems are essential for maintaining the health of coastal waters. Seagrass meadows help stabilize sediment and prevent erosion, while kelp forests provide habitats and food sources for a wide range of marine species. Both ecosystems play significant roles in sequestering carbon, thereby contributing to climate change mitigation.
- Artificial Mussel Reefs: These structures will enhance marine biodiversity and improve water quality by filtering out excess nutrients and pollutants. Mussel reefs also serve as natural barriers against erosion and storm surges, adding another layer of protection for Christiania's coastline.

Terrestrial Biotopes: Shrubland and Forests

The project also emphasizes the restoration and enhancement of terrestrial biotopes within Christiania, including shrubland and forests. These areas are crucial for supporting local wildlife and maintaining ecological balance.

- Shrubland: The preservation and expansion of dense scrub areas, featuring native shrubs like hawthorn and elderberry, will provide essential nesting and foraging habitats for small birds and mammals. These biotopes are vital for species such as the European robin and blackbird, which rely on dense undergrowth for their habitat needs.

- Forests: Mature woodlands with trees like oak and beech are preserved for their high ecological value. These forests support a variety of birds, insects, and mammals, playing a key role in maintaining biodiversity. The presence of old trees, particularly those providing nesting cavities, is crucial for species like the great spotted woodpecker.

Freshwater Biotopes and Reservoirs

The project proposes the transformation of existing freshwater biotopes and the development of a new reservoir to manage excessive rainwater, creating an almost freshwater, low-salinity brackish environment.

- Reservoir: The reservoir will function as a storage solution for excessive rainwater, reducing flood risks and supporting a low-salinity brackish biotope. This environment will be conducive to species that thrive in transitional water conditions, contributing to the overall biodiversity of Christiania.
- Freshwater Biotopes: Existing freshwater biotopes, such as the storage ponds at Carl's Bastion and Frederik's Bastion, will be cleaned and expanded to improve water quality and habitat conditions. These enhancements will benefit species like the common frog and smooth newt, which require clean, undisturbed water for survival.

Symbiosis and Ecosystemic Regeneration

Central to the project is the transformation of the old gunpowder and ammunition storage facilities into a Nature-based Solutions incubator. This incubator will focus on developing sustainable freshwater management practices, integrating reedbed systems for natural wastewater treatment. These reedbeds will not only treat wastewater but also create habitats for amphibians and birds, thus enhancing local biodiversity.

The integration of hyperaccumulator plants for soil bioremediation is another innovative aspect of the project. These plants will help extract heavy metals and chemical compounds from the soil, addressing historical contamination and creating healthier environments for both people and wildlife.

Urban farming initiatives will complement these efforts by providing local food production and reducing the community's reliance on imported food. The introduction of green walls, green roofs, and compost toilets will further enhance sustainability by improving energy efficiency, reducing waste, and promoting circular economy principles.

Community-Based Governance and Lifecycle Management

Community-based governance and lifecycle management are central to the project's success. By involving residents in decision-making processes and providing regular workshops and educational programs, the project ensures that the community's needs and values are reflected in the management of resources. This approach fosters a culture of stewardship and resilience, leveraging local knowledge and expertise to create sustainable urban environments.

Moreover, the project includes innovative mobility solutions to enhance urban connectivity. By integrating Copenhagen's renowned cycle superhighways (Supercykelstier) atop the seawall

along the eastern margin of the city moat, the proposal creates a seamless connection between Amager, Indre By (Inner City), Refshaleøen, and the forthcoming neighborhood of Lynetteholm. Bridges will be constructed to allow people to traverse Christiania without entering and disturbing its slow traffic, maintaining a smooth and uninterrupted cruise speed for cyclists and other soft mobility users. This strategic placement not only enhances the reservoir's functionality but also promotes sustainable transportation, reducing greenhouse gas emissions and fostering active lifestyles.

6.6 Biotope Resilience, Symbiosis and Ecosystemic Regeneration

The core of this project lies in the seamless integration of various nature-based solutions to create continuous ecological corridors that support the movement and interaction of species across different habitats and biotopes. This approach ensures that each biotope—whether marine, brackish, terrestrial, or freshwater—contributes to a unified ecological network.

Marine and Brackish Water Integration

The multifunctional seawall is designed not only as a defensive barrier but as an ecological bridge that connects marine and brackish water ecosystems. Constructed and floating wetlands will serve as transition zones, providing habitats that facilitate the movement of aquatic species between the seawall and the interior water bodies. Seagrass meadows and kelp forests further link these environments, stabilizing sediments and offering rich feeding and breeding grounds that support marine biodiversity.

Artificial mussel reefs, integrated into the seawall, enhance this connectivity by creating complex habitats that support diverse marine life. These reefs act as nodes in the ecological network, filtering water and providing shelter and food, thereby fostering a robust marine ecosystem.

Terrestrial and Freshwater Connectivity

Inland, the project emphasizes the connectivity between terrestrial and freshwater biotopes. The new reservoir, designed for rainwater management, creates a brackish environment that supports species adapted to both freshwater and slightly saline conditions. This reservoir is a critical component of the network, linking freshwater biotopes like ponds and streams through a series of vegetative buffers and water channels.

Reedbed systems around the reservoir naturally treat wastewater, creating clean water outflows that support healthy aquatic environments. These reedbeds serve as critical nodes for amphibians and birds, ensuring that freshwater species have access to clean water and connected habitats for breeding and feeding.

Continuous Terrestrial Corridors

To ensure that terrestrial wildlife can move freely between different habitats, the project includes green corridors that link shrubland, forests, and open grasslands. These corridors consist of native vegetation, such as hawthorn and elderberry, which provide essential resources for small

mammals and birds. Mature woodlands with oak and beech trees are interconnected with these green corridors, creating a continuous habitat network that supports a variety of species.

These continuous corridors are essential for maintaining genetic diversity and ecological resilience, as they allow species to migrate, find new habitats, and access diverse food sources. This connectivity is particularly important for birds, insects, and small mammals that rely on a variety of habitats throughout their life cycles.

Ecosystemic Regeneration and Symbiosis

The transformation of old gunpowder and ammunition storage facilities into a Nature-based Solutions incubator further enhances ecosystem connectivity. This incubator will focus on developing sustainable practices that integrate with the broader ecological network, promoting symbiosis between human activities and natural systems. By fostering innovation in sustainable water management, soil bioremediation, and urban farming, the incubator will contribute to the overall resilience and health of Christiania's ecosystems.

6.7. Population Renewal and Community Regeneration through Public Housing and Nature-based Projects

With an aging population, a semi-stigmatized reputation, and a history of anti-capitalist and radical politics, this unique community faces significant challenges. However, recent efforts to eliminate illegal substance sales and organized crime in its downtown area have opened new pathways for transformation and regeneration. The "Resilience in Climate Adaptation for Spongetown Christiania" project proposes using Nature-based Solutions (NbS) to heal the community, attract new, younger residents, and reinforce Christiania's values of post-growth and decentralized development.

Nature-based Solutions are not just about ecological improvements; they are about fostering community resilience and sustainability. By integrating NbS into Christiania's urban fabric, we can create a healthier, more attractive environment that aligns with the community's values. This approach can rejuvenate Christiania, making it a vibrant hub for innovation and sustainable living.

Our proposal centers on the integration of Nature-based Solutions to address climate risks and enhance the ecological and social fabric of Christiania. The multifunctional seawall will serve as both a protective barrier and an ecological bridge, connecting marine and brackish water ecosystems with terrestrial and freshwater habitats. Constructed and floating wetlands, seagrass meadows, kelp forests, and artificial mussel reefs will collectively improve water quality, stabilize sediment, and support biodiversity, creating a resilient coastal environment.

Within the community, the creation of a new reservoir for rainwater management will establish a low-salinity brackish environment that supports diverse species. Reedbed systems will treat wastewater naturally, enhancing water quality and creating habitats for amphibians and birds.

These systems will be interconnected with the terrestrial biotopes through green corridors that link shrubland, forests, and open grasslands. This network of connected habitats will facilitate the movement of wildlife, ensuring ecological resilience.

The transformation of old gunpowder and ammunition storage facilities into a Nature-based Solutions incubator will be a cornerstone of this project. This incubator will focus on developing and implementing sustainable practices, such as soil bioremediation using hyperaccumulator plants and urban farming initiatives. These projects will provide local food production, reduce the community's reliance on external resources, and enhance biodiversity.

Nature-based Solutions also offer practical solutions to Christiania's demographic challenges. By linking public housing to employment opportunities within NbS projects, we can attract younger residents committed to sustainability. These residents will work as urban farmers, ecological technicians, and environmental educators, contributing to the maintenance and enhancement of Christiania's ecological infrastructure. This approach not only provides employment but also integrates new residents into the community's fabric, fostering a sense of belonging and stewardship.

The project also proposes enhancing community governance through a selective process that ensures new residents align with Christiania's values. This process, based on consensus democracy, will empower current residents to shape the future of their community, maintaining its integrity and values.

Furthermore, the NbS incubator will serve as an educational hub, promoting sustainable practices and fostering innovation. By hosting workshops, training programs, and community outreach initiatives, the incubator will spread knowledge and awareness, positioning Christiania as a leader in urban sustainability and post-growth development.

Our proposal envisions Christiania welcoming 500 new inhabitants, primarily young people who will bring energy and innovation to the community. These new residents will play a vital role intending to the NbS projects, ensuring their success and sustainability. By providing housing linked to these employment opportunities, we create a model of integrated living where residents contribute directly to the community's ecological and social well-being.

7. Conclusion

RCSR paradigms are still in their infancy when it comes to disrupting our institutionalized development models across the globe. LCA and ESA methodologies have inherent complexities that are challenging for laypeople and small-scale organizations to master. The effectiveness of LCA is largely dependent on the availability of data through EPDs, while ESA lacks binding ISO standards and is only partially required for specific ES based on economic impact perceptions. This externalization of ESA has hindered even leading GBCs worldwide from fully assessing the territorial lifecycle and true land impact of their projects from an NCA perspective.

The VUCA factors inherent in ESA-LCA are significant, preventing straightforward recommendations of BMPs in a quantitative manner due to the absence of international

agreement on mandatory indicators. Consequently, our focus has been on high-level impact quantitative data, such as rough area and volume measurements, to guide the dimensioning of critical urban infrastructure for Christiania.

Our recommendation to Christianites, interested organizations, prospective partners, and stakeholders is to navigate the complexity of planning Christiania within its unique organizational and institutional context. Given the urgent need for climate adaptation, we propose using our findings as a conceptual framework to be tested and refined by an interdisciplinary committee. This committee should manage data, weigh scenarios and criteria between DGNB and IUCN standards, and ensure that decisions are adequately communicated to and made with the local population.

To the people of Christiania, the places, and all the wonderful beings that inhabit it, we acknowledge and honor your uphill battles. Your unique position, both ahead of and behind your historical time, is a testament to your resilience and vision. We hope that those entrusted with managing and designing Christiania's urban renewal will recognize how this anarchist eden within a welfare state can inspire profound societal transformation in times of dire need.

Reflections and Lessons

Christiania has often been excluded from recent urban policy discussions, such as the Lynetteholm Project, and is notably absent from many NbS publications. This exclusion highlights a gap in both research and recognition and redistributive justice. The community deserves recognition and rewards for its innovative approaches and investments in sustainability. Integrating Christiania into the broader urban fabric of Copenhagen is essential not only for destigmatizing the community but also for learning from its unique and pioneering experiences.

Christiania's journey offers invaluable lessons at global, European, national, and regional levels. Worldwide, it demonstrates the potential of grassroots innovation in creating resilient, sustainable communities. Christiania's approach to integrating NbS highlights the importance of ecological connectivity, community involvement, and sustainable urban planning. It serves as a model for how communities can leverage natural systems to enhance resilience and sustainability while maintaining their unique cultural identities.

At the European level, Christiania exemplifies the potential for post-growth development models that prioritize ecological health and social well-being over economic expansion. This aligns with the European Green Deal's goals of achieving climate neutrality and fostering sustainable development. Christiania's experience underscores the importance of flexible, community-driven approaches to urban planning and climate adaptation, providing a valuable case study for other European cities.

Nationally, Denmark can draw on Christiania's innovative approaches to urban sustainability as it strives to meet its ambitious climate goals. Christiania's success in using NbS to address ecological and social challenges offers practical insights into how other Danish communities can implement similar strategies. Moreover, Christiania's emphasis on community governance

and participatory planning aligns with Denmark's commitment to democratic and inclusive decision-making processes.

Regionally, Christiania's experience highlights the importance of context-specific solutions. The community's ability to adapt and thrive in a unique urban environment demonstrates the need for tailored approaches to urban planning and sustainability. Regional planners and policymakers can learn from Christiania's successes and challenges, applying these lessons to develop resilient, adaptable urban areas that reflect the values and needs of their inhabitants.

Incorporating the frameworks of the CEWP and SCC, Christiania can further enhance its water management and urban resilience strategies. By adopting SCC principles, Christiania can improve its flood management, water conservation, and urban cooling efforts. The CEWP provides a collaborative platform for sharing knowledge and best practices in water management, fostering international cooperation and innovation.

Furthermore, Christiania can benefit from the Nordics Co-operation on NbS, which emphasizes regional collaboration in developing and implementing sustainable environmental practices. This cooperation can provide additional resources, expertise, and support for Christiania's NbS initiatives, ensuring their long-term success and sustainability.

Deeper Insights and Future Prospects

Christiania's approach to integrating NbS goes beyond simple environmental stewardship; it embodies a holistic model that intertwines ecological health, social equity, and economic resilience. This multifaceted strategy provides a template for other urban communities worldwide, illustrating how NbS can be effectively integrated into urban planning to create resilient, adaptive cities.

One profound insight from Christiania's journey is the importance of community-driven governance in achieving sustainability goals. The consensus-based decision-making process ensures that the community's diverse voices are heard and valued, fostering a sense of ownership and accountability. This inclusive approach is crucial for the long-term sustainability of NbS projects, as it aligns the community's values with environmental objectives.

Christiania's experience also highlights the critical role of interdisciplinary collaboration in addressing complex urban challenges. By involving experts from various fields—ranging from ecology and urban planning to social sciences and economics—the community can develop comprehensive solutions that address multiple aspects of urban resilience. This interdisciplinary approach is essential for navigating the VUCA factors associated with LCA and ESA methodologies, ensuring that solutions are robust, adaptive, and context specific.

Looking ahead, Christiania's model can inspire other cities to adopt similar NbS strategies, emphasizing ecological connectivity, community involvement, and interdisciplinary collaboration. As global environmental challenges intensify, the lessons from Christiania's journey can guide urban planners, policymakers, and community leaders in creating sustainable, resilient urban environments that are both innovative and inclusive.

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