VERFREMDUNG II: Lichen Lens

An interactive, biophilic, naturally ageing living wall in the exterior public space

Final master project
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Introduction

More and more people are moving to crowded, urban areas and living in highly artificial, man-made environments[1,2]. The impact of this rapid urbanization has affected the social environment[3], per capita green space[4], city climate[5], pollution levels, mental health[6], loss of vegetation, biodiversity and more. It is known that humans derive significant benefits from being surrounded by natural environments due to an inherent ''bond'' they have with nature, also known as the phenomenon of Biophilia[7]. For example, it was shown that cultural ecosystem services used for recreation and tourism-purposes within urban green spaces can be beneficial for both physical and psychological well-being[8,9]. Taking this human need to be connected to nature and the previously described impact of rabid urbanisation into account, this results in a growing emphasis towards both governments and citizens to incorporate greenery into cities[10]. What is more, increasing the biodiversity within such urban greenery is also known to enhance general wellbeing of the people surrounded by these urban green spaces[11]. Hence, establishing urban greenery in the first place is not the only important aspect; incorporating sufficient varieties of species within these green spaces is also essential.

As urban populations expand and the boundary between nature and culture becomes increasingly blurred, there is a need to restore the inherent bond that has always existed between humans and nature. This can be done by designing an urban green space that has a rich biodiversity, is climate-adaptive, can be as dynamic as the process of urbanisation while also accommodating the aspect of time in which ecological transformation occurs. Designing such a new aesthetic and functional green space in urban environments presents unique challenges and opportunities, particularly when aiming to enhance public well-being and ecological balance. Central to this project is the exploration of biophilic design, which emphasises and sustains the intrinsic human need to connect with nature. All in all, this project aims to provide a public invitation to experience and comprehend the complexity of our surroundings, their health, and our role within them, fostering a harmonious coexistence between human and non-human life in urban environments.

This line of thought about restoring the human and non-human connection by designing a biodiverse, climate-adaptive and naturally ageing concept for urban greenery has paved the way for this project to

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[1] TEDxTalks. (2016). Radical Design For Environmental Health | Natalie Jeremijenko | TEDxSydney [Video]. YouTube https://www.youtube.com/watch?v=QOTZVLQIkDE

[2] Muahram, A., Kennedy, J., Kanaani, M., & Demircay, V. (2019). Creating urban health through the promotion of green walls. Int. J. Adv. Eng. Res. Sci, 6, 451-457.

[3] Anguluri, R., & Narayanan, P. (2017, 2017/07/01/). Role of green space in urban planning: Outlook towards smart cities. Urban Forestry & Urban Greening, 25, 58-65. https://doi.org/https://doi.org/10.1016/j.ufug.2017.04.007

[4] Xia, Y., Yabuki, N., & Fukuda, T. (2021). Development of a system for assessing the quality of urban street-level greenery using street view images and deep learning. Urban Forestry & Urban Greening, 59, 126995.

[5][5] Ghazalli, A. J., Brack, C., Bai, X., & Said, I. (2018). Alterations in use of space, air quality, temperature and humidity by the presence of vertical greenery system in a building corridor. Urban Forestry & Urban Greening, 32, 177-184.

[6] Elsadek, M., Liu, B., & Lian, Z. (2019). Green façades: Their contribution to stress recovery and well-being in highdensity cities. Urban Forestry & Urban Greening, 46, 126446.

[7] Wilson, E. (1984). The human bond with other species. Cambridge, MA, USA: Harvard.

[8] Jennings, V., & Bamkole, O. (2019). The relationship between social cohesion and urban green space: An avenue for health promotion. International journal of environmental research and public health, 16(3), 452.

[9] Jennings, V., Larson, L., & Yun, J. (2016). Advancing sustainability through urban green space: Cultural ecosystem services, equity, and social determinants of health. International journal of environmental research and public health, 13(2), 196.

[10] Goel, M., Jha, B., & Khan, S. (2022). Living walls enhancing the urban realm: a review. Environmental Science and Pollution Research, 29(26), 38715-38734.

[11] Carrus, G., Scopelliti, M., Lafortezza, R., Colangelo, G., Ferrini, F., Salbitano, F., Agrimi, M., Portoghesi, L., Semenzato, P., & Sanesi, G. (2015). Go greener, feel better? The positive effects of biodiversity on the well-being of individuals visiting urban and peri-urban green areas. Landscape and urban planning, 134, 221-228.

stumble upon lichen. Lichen is a mysterious and aesthetically beautiful species, which can be found everywhere one looks, yet is seldom noticed, let alone understood by people. This window of opportunity has sparked the interest to use lichen as the central component within this design project, utilising its often overlooked interesting qualities and potential for integration into the final conceptual outcome this project will establish.

This Final Master Project (FMP) is a continuation of the M2.1 design project. A final prototype ''Verfremdung'' was built in VR, proposing a speculative world where participants are exposed to lichen as part of a flexible artefact called ''lichen panels'' that grow along with its environment and time. Starting this FMP, the goal was to iterate on the lichen panels concept and to explore the interactive elements, meaning how lichens can become more visible, experienceable, dynamic, and reflective by people, while contextualising the design in both the virtual and real world. The initial aim of the design project was to let people experience the temporality of lichen, by making their slow lifespan and ecological change more visible and tangible. This also ties in with the project's aim of designing a green space while also considering the influence it has on people's connection with nature. Taking these aims into consideration, the project was eventually finalised with the development of a final design concept: the Lichen Lens.

Design approach

The project uses the design-thinking framework proposed by the Nielson Norman Group[12] (NNG) as a general layout, which follows an overall flow of understanding, exploration, and materialism. Within these design phases there are six sub-phases: empathize, define, ideate, prototype, test, and implement (IDEO, n.d.). As described by the NNG the framework is flexible and can be tweaked as needed. To define this flexibility, the Design Thinking process will be combined with the Reflective Transformative Design (RTD) process[13,14]. This process consists of five activities that take place within the societal setting without a specific order. This supports the open approach and the flexibility of the process, occurring every time when a switch between an activity or phase happens. This continuing process generates new insights into the design opportunities, which are often physicalized. To design for, with and within the context, multiple design perspectives are applied; i. the first-person perspective, ii. The second-person perspective and iii. the third-person perspective[15]. A fourth perspective will be incorporated as well; a ''lichen-eye point of view'', further adding insight and value to the context of the eventual design.

To delve into the RTD process and to relate to this feeling and experience of the context, a large part of this project has been approached through daily (first-person perspective) introspective walks, inspired and similar to the Reflective work ''Reveries of the Solitary Walker'' from the philosopher Jean-Jacques Rousseau[16]. The essay consists of introspective walks that traverse both physical landscape and the landscapes of his memory and imagination. It presents the book as a series of ten walks, of which each

[12] Gibbons, S. (2016). Design thinking 101. Nielsen Norman Group, 31.
[13] Hummels, C., & Frens, J. (2009). The reflective transformative design process. In CHI'09 Extended Abstracts on Human Factors in Computing Systems (pp. 2655-2658).
[14] Hummels, C. C. M., & Frens, J. W. (2011). Designing disruptive innovative systems, products and services: RTD process. In D. Coelho (Ed.), Industrial Design - New Frontiers (pp. 147-172). InTech. https://doi.org/10.5772/22580
[15] Tomico Plasencia, O., Winthagen, V. O., & van Heist, M. M. G. (2012). Designing for, with or within: 1st, 2nd and 3rd person points of view on designing for systems. In NordiCHI '12 Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design (blz. 180-188). Association for Computing Machinery, Inc. https://doi.org/10.1145/2399016.2399045
[16] Barcham, R. C. (1985). Reveries of the solitary walker. https://doi.org/10.17863/CAM.25716

delves into his experience of solitude and his view on various topics ranging from human nature, society, personal reflection, observation of the surroundings, contemplation of existence and connection with nature's beauty and simplicity. In order to evaluate the final design concept, a participatory design technique called co-constructing stories[17] will be applied.

Problem definition

During this phase extensive literature research was done in order to develop a better understanding of designing new types of aesthetics within the public context and green space. Herewith both the user's needs as well as the societal and ecological needs are explored.

Designing for public and natural environment

This project revolves around the urban public space which plays a crucial role in the context of well-being. The design of such spaces affects how people respond to them and utilize them[76]. To effectively design and manage a public environment it is imperative to understand the role that these spaces play in people's lives and why they are used or neglected. According to Carr et al.[18] there are five reasons that account for people's needs in public spaces, which are: comfort, relaxation, passive engagement with the environment, active engagement with the environment and discovery.

Urban natural environments and structures are commonly defined as urban green spaces or greenery. The urban design incorporates these green spaces to provide adequate green areas and to reduce the impact of buildings within the urban landscape. Urban green spaces can serve as everyday areas where people come together for social activities, leisure and recreational purposes while also offering the opportunity for people to get outside, spectate and have interaction with nature and others. Examples are; gardens, greenways, parks and other places covered with trees, grass and bushes.

Humans derive physical and psychological benefits from being in natural environments or from being exposed to elements of nature, and also have an innate tendency to connect with nature and other forms of life[31]. This instinctive bond has been referred to as biophilia, introduced by Edward O. Wilson in 1984[19]. The biophilia hypothesis proclaims the existence of an inherent, human need and preference to affiliate with nature and describes the human urge to seek intellectual, cognitive, aesthetic, and spiritual fulfilment through their relationship with the natural world[20].

The aesthetic qualities of green spaces have been recognized as a key factor in supporting human health and well-being[21,22]. In this report, the term 'aesthetic' fundamentally refers to the qualities in the world

[17] Ozcelik, D., & Terken, J. M. B. (2012). Co-constructing stories: a participatory design technique to elicit in-depth user feedback and suggestions about design concepts. In PDC '12 Proceedings of the 12th Participatory Design Conference: exploratory papers, workshop descriptions, industry cases (Vol. 2, pp. 33-36). Association for Computing Machinery, Inc. https://doi.org/10.1145/2348144.2348156
[18] Carr, S., Francis, M., Rivlin, L., & Stone, A. (1992). Needs in public space. I M. Carmona & S. Tiesdell (Red.), Urban Design Reader, 230–240.

[19] Wilson, E. (1984). The human bond with other species. Cambridge, MA, USA: Harvard.
[20] Bird, W. (2007). Natural thinking: A report by Dr. William Bird, for the Royal Society for the Protection of Birds (RSPB). Investigating the links between the natural environment, biodiversity and mental health. Reading: RSPB.
[21] Stoltz, J., & Grahn, P. (2021). Perceived sensory dimensions: An evidence-based approach to greenspace aesthetics. Urban Forestry & Urban Greening, 59, 126989.
[22] Xia, Y., Yabuki, N., & Fukuda, T. (2021). Development of a system for assessing the quality of urban street-level greenery using street view images and deep learning. Urban Forestry & Urban Greening, 59, 126995.

experienced through sensory perception[23,21]. This also ties in with biodiversity. Research has found a direct relationship between floristic biodiversity and psychological well-being in urban environments. Urban green spaces with higher biodiversity are experienced more positively[24]. Additionally, studies on therapeutic landscapes have shown that environments with a high variety of plant species can be particularly effective in promoting well-being compared to environments with low biodiversity[25]. However, rapid human sprawl, urbanization, and climate change are a major factor in causing disproportionate levels of ecological resources, significant habitat loss and local extinction of plant species at the local, regional and global scales. Loss of green areas and biodiversity endorses people to break ties with nature and to get disconnected from their natural environment. Nonetheless, we have to acknowledge that humans are also species themselves. As described by William Bird:

"Humans are a species with as much need for the natural environment as any other. However, we are also a social species that thrives in towns and cities and has prospered with the use of technology. But neither technology nor cities can replace our need for the natural environment. We have to keep a balance." (Bird, 2007, p. 4)

On that note we have alienated ourselves from our natural habitat and our equals. Bringing this challenge into the public context, it becomes evident to re-think the role of nature and biodiversity as a part of the shared infrastructure, acting on both the non-human and human benefits. This implies that far-reaching ideation is essential and that designing the interface between nature and humans involves finding new ways of symbiosis, considering human and multi-species perspectives, and developing low-energy and low-cost solutions. This report aims to maintain a balance between human and non-human factors. It explores the natural environment and encourages people not simply to stay in touch with nature but also to become part of it and interact with it. Consequently, the following research question was formulated:

How can a green space structure be created as a new aesthetic that appeals to the general public?

Ideation

How the green space is designed is interrelated with the built state of the city. Therefore, this project begins to explore the current state of natural environments and their corresponding frameworks in modern cities from a top-down perspective. In the European Circular Cities Declaration Report of 2024[26], which is designed to help accelerate the transition from a linear to a circular economy in Europe, it is described that rather than positioning nature against development, cities can develop and grow along with nature instead. Many cities try to strike a balance between urban growth and the preservation of natural elements and focus on master plans to intentionally create new natural spaces, such as pocket parks and urban forests within the city[26]. Frameworks and strategies that are often used are the Urban

[23] Harper, D. (n.d.). Etymology of aesthetic. . Online Etymology Dictionary Retrieved January 30 from https://www.etymonline.com/word/aesthetic

[24] Carrus, G., Scopelliti, M., Lafortezza, R., Colangelo, G., Ferrini, F., Salbitano, F., Agrimi, M., Portoghesi, L., Semenzato, P., & Sanesi, G. (2015). Go greener, feel better? The positive effects of biodiversity on the well-being of individuals visiting urban and peri-urban green areas. Landscape and urban planning, 134, 221-228.

[25] Marcus, C. C., & Sachs, N. A. (2013). Therapeutic landscapes: An evidence-based approach to designing healing gardens and restorative outdoor spaces. John Wiley & Sons.

[26] ICLEI - Local Governments for Sustainability, Circle Economy Foundation, & Ellen MacArthur Foundation. (2024). Circular Cities Declaration Report 2024. Circular Cities Declaration. https://circularcitiesdeclaration.eu/about/ccd-report

Nature Plans by the European Commission[27], the Green Space Factor[28] and the 3-30-300 rule developed by Nature-Based Solutions Institute[29]. However, these tools are meant to create and reserve space for nature and thus are used as a more practical tool by city planners, referring to master plans and land use plans. Although the design solution can definitely be a part of one of these master or land use plans, this project has a different focus; designing a new type of green space and zooming in on how this affects someone's connection or experience with nature. One concept that captures this challenge very well is Biophilic design.

Biophilic design framework

This project will apply the biophilic design framework proposed by Stephen R. Kellert and Elizabeth F. Calabrese[30,31]. This approach aims to create good habitat for people as biological organisms in the built environment and strengthening the bond between man and nature in an ecological and sustainable manner, while also advancing people's fitness, health, and wellbeing. 'Good habitat' refers to the sense of productive and ecologically sound environments where people can function to their optimal potential. The biophilic design framework is intended to be a practical methodology for the effective design of the built environment. The successful application of biophilic design requires consistent adherence to certain basic principles, which show fundamental conditions for the effective implementation of biophilic design[30]. The principles include:

- Biophilic design requires repeated and sustained engagement with nature.
- Biophilic design focuses on human adaptations to the natural world that have advanced people's health, fitness and wellbeing over evolutionary time.
- Biophilic design encourages an emotional attachment to particular settings and places.
- Biophilic design promotes positive interactions between people and nature that encourage an expanded sense of relationship and responsibility for the human and natural communities.
- Biophilic design encourages a mutually reinforcing, interconnected and integrated architectural solution

The application of biophilic design

The practice of biophilic design concerns the application of varying design strategies, these are referred to as experiences and attributes. The basic categories of the biophilic framework are represented by three kinds of experience of nature: I. the direct experience, II. the indirect experience and III. the experience of space and place (see table 1). Each of these experiences has its own defined biophilic design attributes as listed in the table. The aspects of biophilic design can be experienced through various human senses.

[27] https://environment.ec.europa.eu/topics/urban-environment/urban-nature-platform_en
[28] Kruuse, A., TCPA, & GRaBS Project Partners. (2011). The green space factor and the green points system. Town and Country Planning Association. https://tcpa.org.uk/wp-content/uploads/2021/11/EP6_FINAL.pdf
[29] Nature-Based Solutions Initiative. (2021). The 3-30-300 rule. Nature-Based Solutions Institute. https://nbsi.eu/the-3-30-300-rule/
[30] Kellert, S., & Calabrese, E. (2015). The practice of biophilic design. London: Terrapin Bright LLC, 3, 21-46.
[31] Kellert, S. R., Heerwagen, J., & Mador, M. (2011). Biophilic design: the theory, science and practice of bringing buildings to life. John Wiley & Sons

However, the visual sense is the most dominant way in which people perceive and respond to nature[30]. Therefore, this project will mainly zoom in on the visual aesthetics of the design.

The role of time within biophilic design

The major building construction and development currently happening inevitably result in the alteration of natural systems. Therefore, the application of the biophilic design should also support a sustainable, natural and ecologically robust community. On the other hand, the transformation of the natural environment is also caused by all biological organisms in the process of inhabiting it. In other words, the design should be dynamic and take time into account to be functional and resilient in natural systems. Therefore, the question is not if any ecological change occurs, but if the outcome over time will be a more resilient and productive natural environment, measured by essential ecosystem indicators, such as biodiversity[30].

Indirect experience- Age, change and the patina of time

One kind of experience that fits this line of thought very well is the *indirect experience* of nature, which includes; ''The transformation of nature from its original condition and or the exposure to particular patterns and processes characteristics of the natural world'' (see table 1)[30]. Within this category, there was one attribute that caught the attention, due to its mutualistic and collaborative nature; the *''age, change, and the patina of time''* - attribute (see table 1).

The attribute is described as follows: *''Nature is always changing and in flux, life especially reflecting the dynamic forces of growth and aging. People respond positively to these dynamic forces and the associated patina of time, revealing nature's capacity to respond adaptively to ever-changing conditions. These dynamic tendencies are often most satisfying when balanced by the complementary qualities of unity and stability. Change and a patina of time can be achieved through such design strategies as naturally aging materials, weathering, and a sense of the passage of time and in other ways''.* – Kellert, 2015, p.17

Designers and architects often dislike that what grows is unpredictable and has patchy patterns, because they are trained to control geometry, and to focus on cleanliness and hygiene. The patchy random occurrence on a surface is often seen as ugly or unpleasant. However, these patterns known as biocolonisation, occur everywhere; there is no material that is not biocolonised at some point in time in the exterior environment[32]. Interestingly, there was a period when designers did appreciate this phenomenon: Romanticism[32]. During this era, the beauty of impure aesthetics was celebrated. Designers accepted that this patchy unpredictable growth was taking over surfaces and in fact created a positive dialogue with our built environment, rather than a disturbance. Another concept that fits this vision very well is Wabi-Sabi[33] from the Japanese philosophy of life. This concept occasionally refers to the acceptance and appreciation of the beauty found in the imperfect, impermanent and incomplete aspects of nature. A modern example of this notion is the very active and top 1% ranked by size reddit page r/Wellworn[34], described as *''a subreddit dedicated to the tools that take a beating.''*; a page where people post their ''beaten'', patchy findings. All-in all, we can learn from the fascinating adaptation and intelligence

[32] Cruz, M., & Beckett, R. (2016). Bioreceptive design: a novel approach to biodigital materiality. *Architectural Research Quarterly*, *20*(1), 51–64. doi:10.1017/S1359135516000130
[33] Koren, L. (2008) Wabi-sabi for artists, designers, Poets & Philosophers. Point Reyes, CA: Imperfect Publishing.
[34] Reddit. (n.d.). *For your things that have been through hell and back.* r/Wellworn. https://www.reddit.com/r/Wellworn/

embedded in these patterns, as the patterns can change and adjust to the climate and occupy the surfaces that we have designed.

Lichen

Exploring this attribute of ''age, change and the patina of time'' and its related design strategies and principles, with the aim to design a naturally ageing structure, has guided the project to the aesthetically beautiful, small, and mysterious species called ''lichen''. Although lichen can be found almost everywhere, on trees, tiles, and in and out of the city, and covering almost 8% of the earth's surface, most people do not know what they are or are aware of their vast impact on the environment. As described by Zonca[35] ; *''lichen is familiar to everyone but known to no one''.*

What are lichen?

We all know mosses, but lichen is something completely different and in fact unique. Lichen consists of a strange and complex life form. It's neither plant nor animal. Lichen is an extraordinary relationship between algae and fungi, a mutual beneficial partnership between the two organisms. The fungi need the algae for its photosynthesises, converting CO2 (carbon dioxide) and water into glucose (sugar) and oxygen, similar to plants and trees. While the algae need the fungi to produce structure and provide water, minerals, and protection against sunlight, thus both maintaining each other[36].

This happy marriage unfolds in beautiful bright colours, patterns, organic forms and details. Especially from up close, it is like looking at an alien landscape, full of coral-like shapes and colours, which invites us to reflect on the imaginary. A century ago, these shapes caught the attention of the artist Ernst Haeckel[37], who drew a beautiful plate of Lichen shapes. Lichen also presents itself in a wonderful range of colours and can therefore often be used to make natural dye.

''They are one of those organisms that seem to offer nothing to hold our gaze. But the more time we spend with lichens, the more they reveal their beauty, their mysteries, and their strange power of attraction. '' - Zonca, 2022, pp. 262

In the Netherlands, we have around 800 lichen species and they all have their own unique shapes and names[38,36]. Some lichen species are very difficult to find, whereas others can be found practically everywhere and each year new species are discovered. Lichen has three main growth types, Crustose, Foliose, and Fruticose;

- Crustose species are powdery or smooth and lie close to the substrate.
- Foliose species are large species, attached to the substrate with small rootlets.

[35] Zonca, V. (2022). Lichens - Toward a Minimal Resistance. Polity Press.
[36] van Herk, C. M., & Aptroot, A. (2022). Veldgids Korstmossen.
[37] Haeckel, E. (2012). Art forms in nature. Courier Corporation.
[38] Aptroot, A., C.M. van Herk, L.B. Sparrius & J.L. Spier (2004). Checklist van de Nederlandse Korstmossen en korstmosparasieten, Buxbaumiella 69, 17-55.

- Fruticose species are Bundles of branching, ribbon-like, or round lobes, attached to the substrate on one side.

Lichens are in general an underappreciated, lesser-known organism and as a result, people tend to pass by or remove them. Lichens micro-scale and slow growth make it difficult for the public to empathize with, contemplate, experience, understand, and respond to. For example, in botanic gardens and parks there's no sign that points out or refers to lichens, let alone a reserved place for them to colonize[35]. Some people see lichen as weeds, whereas others can see and appreciate their beauty and are more accepting and open to embrace its natural beauty of rawness and transience. Interestingly, lichens have long been considered a parasitic, morbid and repulsive organism; a killer that is harmful to its surroundings, even though studies point out the opposite[39].

Because lichens do not have any roots they hold on to the surface and retrieve their nutrients directly from the air, rainwater and light. Lichens do not have a defense system for hydration. They are in fact poikilohydric, meaning they can almost immediately switch between being in either a hydrated or desiccated (air-dried) state when they get some level of hydration[40]. This intelligence make them change shape and color, endure moments of lack of water and to spread everywhere, including extreme environments. This lack of protective tissue also causes lichen to be highly sensitive to atmospheric changes, as pollutants can penetrate deep in their tissue. Lichen-flora respond and adapt to these changing conditions in remarkably clear and dynamic way[41].

In the Netherlands, sulphur dioxide, ammonia, and nitrogen oxides are the main air pollutants that had a significant impact on lichens over the past fifty years[42]. The Netherlands still ranks among the top countries worldwide in terms of ammonia air pollution due to high livestock density and its landscape is still heavily colonised according to this pollution.

So, despite the fact that lichen has often been overlooked or perceived by some as unsightly, lichens do have the extraordinary ability to make air pollution visible to humans and therefore have much to teach us about our relationship to our environment and our place within nature[43]; inviting us to a new path in this Anthropocene age.

Lichen and time

To incorporate the ''change and a patina of time'' attribute lichens passage of time needs to be understood along with why, where and how its colonization starts and ends.

An interesting example to visualize the role of species in relation to time and the environment is the Phenology Clock created by Natalie Jeremijenko[1]. This clock shows the mutualistic relationships among

[39] Rijksdienst voor Archealogie, Cultuurlandschap en Monumenten (2008). Algen, Mossen en Korstmossen. Brochure Techniek 16.
[40] francischeefilms. (2012, March 15). Lichens time lapse [Video]. YouTube. https://www.youtube.com/watch?v=FWfPMOKnW2M
[41] van der Kolk, H., Sparrius, L. B., & van Herk, C. M. (2023). Effecten van ammoniak op korstmossen in Gelderland in de periode 1989-2022. BLWG-rapport 31. BLWG.
[42] van Dobben, H.F. (1990). Effekten van luchtverontreiniging op korstmossen, resultaten van meerjarige studies. De Levende Natuur 91(4), 179-183.
[43] Haraway, D. J. (2016). Staying with the trouble: Making kin in the Chthulucene. Duke University Press

species in the natural world, that we actually experience time through seasons and that 95 percent of the species are in symbiosis. Strangely enough lichens are believed to be species that have always been and will always be in symbioses with earth. As a matter of fact, lichens happen to play a pioneer role in the process by which habitats and species in an area change over time, defined as primary succession. Lichens are remarkably resilient and can thrive in the most hostile places, establishing itself in barren environments where no other plants live. Around 500 million years ago, when the Earth's surface resembled a moon landscape, lichens where the species that pioneered the land by breaking down rocks. With their tiny filaments and self-produced lichen acids they dissolved the top layer of the rocks and eventually led to the production of soil. This gradually paved the way for other species like plants to take over. Overtime new micro plants like moss were first to appear, these plants reproduced faster, spread out and outcompeted the pioneer Lichen and created the forestry land we know today[44]. Lichens are still full filling their pioneering role to this day, attaching to substrates no other plant can grow on. Despite lichens being a pioneer and resilient, its community is temporal and does not remain as it is, as it eventually will be replaced, mixed, or overlapped by other communities. In brief, lichens create conditions that subsequently allow different plants and related animal communities to thrive and as result can initiate habitats, enhance the number of species and create this rich biodiversity that seem to be hostile in the first place. This project aims to utilize these capacities by designing a structure that triggers biological succession initiated by lichens.

Important to consider here, is that lichen grow very slowly with an average of 0.2 to 1 millimetre per year[36]. This once again emphasizes that their colonization and aging process will take place in a more than human time frame and therefore requires special attention in terms integrating the design as sustainable structure as well as people experiencing and observing its subtle change over time through different aesthetics of interaction.

Integrating lichen as part of the design

As the urban population is increasing, the environment is under pressure to be dynamic, expandable, and sustainable. Therefore, a green space structure should be flexible with surfaces that act as a facilitator for lichen to grow to its full potential and on own time, while at the same time preserving lichen when the urban environment changes. When the structure is not flexible lichen might outlive the ever-changing architectural buildings and not survive in this way, throwing away the amount of time that was invested to let lichen grow. To become more up-to-speed with the dynamic character of urban spaces the structure should be using surfaces that can be built separately from the architectural built, constructed and deconstructed, relocated and reapplied and to be expandable when needed. The first iteration on this idea of a flexible lichen structure were lichen panels, which has been developed into a full VR video within the previous project Verfremdung I. The flexible structure characteristic of these panels was used as initial starting point to move forward from within this final master project Verfremdung II.

[44] Yuan, X., Xiao, S., & Taylor, T. N. (2005). Lichen-like symbiosis 600 million years ago. *Science (New York, N.Y.)*, *308*(5724), 1017–1020. https://doi.org/10.1126/science.1111347

To elicit direct feedback on these initial lichen panels concept an in-depth interview was conducted at the time with a Laurens Sparrius, a lichenologist and the director of the BLWG; *the bryological and lichenological working group association for mosses and lichen research in the Netherlands*[45]. The interview took one hour and the main focus was to collect general insights about lichen and its context, to get a better understanding of designing for and with lichen and to get information about which lichen characteristics need to be taken into account in order to make its colonisation feasible and its change experienceable. Thus, all information gained from this interview was used along with other relevant literature, to move forward from the flexible lichen structure idea towards a final design concept that involves lichen. The interview has been thematically analysed and its results will be discussed throughout the report. A thematic overview can be found in the appendix (A).

Lichen and the built environment

From the interview it became clear that lichen are indeed resilient as they can grow on a great number of supports in different (harsh) conditions where other greenery would struggle, yet they still need specific conditions to grow. Moreover, due to lichens' slow growth, they can not outcompete the modern higher plants or mosses, but they can be found in places where other plants, struggle, for example, due to prevailing nutrition poverty or because the roots of higher plants cannot penetrate the substrate[36]. The project should embrace this extraordinary ability by means of creating a suitable space with the right conditions, where lichens have enough space and time to grow without being dominated. Although the green space should not exclude other organisms, and over time make room for them as well.

As described in the book *Bioprotopia*[46]*; ''We can speculate that forms of lives from flora and fauna to bacteria and fungi have no comprehension of the human made world other than to experience it as an environment within which to grow and adapt''* (p. 40). As described by a mycologist at Harvard*; ''When we think about how these lichens species move through the new landscapes that were created by humans, it becomes very much easier to understand that these species were able to very quickly cope with the change and take advantage of the change. They are, in fact, here because we put the structures in place to let them grow.''*[47]. This can also be seen when exploring lichens; they grow in spaces unintentionally or intentionally altered by humans, meaning they can be widely found in our cities, abandoned areas and on the margins of urban and rural landscapes where it was never intended to grow[35]. That's also why they grow in places people don't want them to grow in. This in line with the theory of "third landscape," introduced by French landscape architect Gilles Clément[48]. It represents a category of land that falls outside traditional managed or cultivated spaces, areas such as wastelands or abandoned sites, which are characterized by their spontaneous vegetation and ecological diversity, often serving as refuge for biodiversity in human-dominated landscapes. The "third landscape" highlights the importance of these often-overlooked areas in contributing to ecological resilience and environmental sustainability. Thus, perhaps it is about intentionally designing a third landscape. This also demonstrates that the city is itself

[45] BLWG | Bryologische + Lichenologische werkgroep. (n.d.). https://www.blwg.nl/
[46] Morrow, R., Bridgens, B., & Mackenzie, L. (Eds.). (2023). Bioprotopia. Basel, Switzerland: Birkhauser.
[47] Harvard Museum of Natural History. (2014, 7 oktober). Studying Lichens [Video]. YouTube. https://www.youtube.com/watch?v=Wqg7AeDDYus
[48] Clément, G. (2004). Manifesto of the Third Landscape. Editions Sujet/Objet.

nature and not opposite to the idea of nature. Therefore, it's important to look into building ecologically and to know how the built-environment inevitably leads to evolutionary change.

Lichen and ecology

The green space should not only prioritise a human-centric approach, but should also take into account the designs' impact on the surrounding non-human ecology; being an ecologically interrelated design that encourages connections that contribute to an overall coherent whole[49]. This means the project has to zoom-out and has to focus on the environmental aspect and its ever-changing conditions. Asking the question *''how should the green space be situated, in terms of ecology*?

''Lichen [..] allows us to conceive of an ecology that is no longer based on distinctions between nature and culture, urban and rural, competition and cooperation'' - Zonca, 2022, p. 11.

Lichens are just like plants and therefore bound to a specific biotope. A biotope is often defined as the habitat or an area with a uniform landscape type where a community of interacting organisms can thrive. If this biotope changes, the lichens will respond according to these changes. The ecosystem consists of biological processes considering biotic factors and abiotic factors. Biotic factors are flora and fauna, and microorganism and abiotic factors are such as, soil, nutrition richness, climate, air pollution, and natural resources such as wind, sunlight and Moisture. All of these conditions affect lichen growth and many of them are influenced by Density of the environment, the exposition, inclination, orientation and the openness/lightness or darkness/degree of shelter of the place. Furthermore, each lichen species has its own preferences; one species might like acidification, or nitrogen, or a warm sunny climate, while the other species does not[36]. Consequently, to invite a variety of lichen species the ecosystem has to be rich and varied as well.

The conditions are closely related to the type of environment, concerning its density, humidity and pollution. The forest for example has completely different lichen species than the city or the countryside. As also described by the lichenologist; *''In cities you see more lichen, because there are fewer open areas, thus there's less wind with lower speeds, higher levels of humidity and some pollution, altogether a city provides better circumstances for lichen than the countryside".* In general, a factor that has a great influence and can be controlled is that the structure should not be overshadowed by its surroundings, because this will have a negative effect on the lichen-flora, like being closely surrounded by high buildings or trees. Another factor is humidity, water in general is always a challenge, all living organisms require water yet this can also lead to chemical, biological or even mechanical degradation of the structure, therefore it needs to withstand the outdoor weather conditions as well, sustaining a balance[46].

It is clear that lichens have to work with with local conditions and are in that sense similar to plants, however lichens are very different in terms of traditional garden practices. Lichen can not be planted, at least not as straightforward as planting a seed in the ground. Lichen use spores rather than seeds to propagate, making it inherently difficult to predict when, how and which type of lichen will appear. This makes this transformative design approach rather unique because the designer does not have the certainty and control that conventional processes of designing embrace. However, there are some

[49] Den Ouden, E. (2011). *Innovation design* (2012th ed.) [PDF]. doi:10.1007/978-1-4471-2268-5

similarities to the practice of gardening. In the book garden futures[50], garden design is described as a discipline that is predicated on collaboration with non-humans. As described by psychologist and gardener Sue Stuart-Smith, I quote*: ''I see gardening as a repetition, I do something, then nature does its part, then I respond, and so on, not unlike a conversation. there's no whispering or shouting or talking, but in that back and forth there is a delayed and sustained dialogue''*. This project also plays out this delayed and sustained dialogue, but on a different scale, the '' I do something'' has been replaced by ''we do something'', It is not just the Choice of material, the substrate and the life that will inhabit that Co-designs the output of the project over time, but also we as humans, as a collective, actively influencing the environment. This also underlines that lichen is a very suitable choice of flora for public greenery, as it concerns a public issue. Furthermore, it also demonstrates that the goal is not about designing the ending, like a full-grown façade of greenery, but to start small, initially designing lichens' foundation instead. This brings us to the next chapter, the substrate.

Choice of material – substrate

Which material and substrate promote lichen growth? The first part that can be constructed and designed for are substrates which are the surface where lichen can attach to and grow. Many lichen species are limited to one substrate type but there are also exceptions. For example, there are also species that can grow on almost anything. Lichens can therefore be classified according to the substrate type on which they grow. In general, these are trees (epiphytic), Woods (lignicool), stones (epilitic) and grounds (territric)[36]. This means the choice of substrate plays a key factor in the invitation of lichen.

However, the main differences in the occurrence of various lichen species are not determined by only the type of substrate, the overall behaviour of the lichen also involves the substrates hardness, roughness, porosity, shape and its acidity, also known as the ph-value. The substrate is often even subordinate to the acidity. Many lichens have distinct preferences for a particular acidity of a substrate. For example, an acidic rock or calcareous stone. Because of this different species can be found on a brick, which is acidic, compared to mortar, which is basic. Most substrates have a somewhat standard level of acidity. This also suggests that a wide variety of lichen species can be invited by applying different types of substrates within the design. As stated by the lichenologist:*'' Imagine if you were to create a brick wall and you place a piece of concrete next to it, then eventually two different things will grow on both substrates. This is due to the acidity of the different substrates; theoretically you could create different lichen patterns with different levels of acidity''*.

Even though the acidity of a particular type of substrate is not fixed, the acidity can be heavily influenced by its surroundings and Lichens respond fairly quickly to these changes, being particularly vulnerable to air pollution. For example, ammonia rich environments have a great impact on the composition of the lichen-flora. Ammonia neutralizes the substrate and increases the pH value. This leads to the disappearance of acidophytes (acid lovers) and stimulates nitrophytes (nitrogen lovers) to grow. This neutralizing effect also shows that the same type of substrate, such as a particular tree species, can host

[50] Kries, M., & Stappmanns, V. (2023). Garden futures: Designing with nature. Vitra Design Museum.

different types of growth depending on the area's cleanliness—whether it has low ammonia emissions, or is heavily polluted.

In the Netherlands Epiphytic lichens have been used as bio-indicator to monitor ammonia and sulphur dioxide pollution in a standardized monitor network since 1989, designed and developed by LON, the Lichenological Research Bureau of the Netherlands[51]. During each survey, all lichens and mosses on ten oaks are recorded. The monitoring network is also used to map the effects of climate change[52,53].

Taking this into account, the project aims to select a variety of substrates with properties that increase the likelihood of attracting a diverse range of species. This will result in a rich lichen flora and include species that the public can easily interpret and reflect upon, similar to the standardised oak network.

Bioreceptive substrate

The lichenologist emphasized that it is challenging to find substrates that guarantee lichen growth, yet it's possible. Doing literature research on this topic has brought the term *bioreceptivity*, defined by Guillitte[54] as *''the aptitude of a material to be colonised by one or several groups of living organisms without necessarily undergoing any biodeterioration.''* And for a material to qualify as bioreceptive, it must provide conditions that allow living organisms to find shelter, grow, and reproduce. Bioreceptivity can also be defined as the totality of material properties that contribute to the development of fauna and or flora[54]. Stones seem to be the most suitable choice of substrate to experience clear visible biological succession. Thereby, stones are generally robust, sustainable and available in many types. In Stony materials, for instance, bioreceptivity relates mainly to properties of the area exposed to climatic elements such as porosity, moisture, mineral composition, ph, geometry, roughness of the surface layer. Guillitte[54] categorises four types of bioreceptivity that will be used as reference in this report, which are:

- primary; initial phase of colonisation.
- secondary: under the action of colonisation organisms or external factors material properties can involve and change over time and result in a new type of bioreceptivity, such as the acidity influenced by its surroundings
- Tertiary: human activity affecting material to promote colonisation, like coating. This also applies to lichen and can be achieved by systematically applying nutritions such as yogurt, seaweed, buttermilk, or beer mixed with a small amount of polyvinyl acetate to the material[39].
- Extrinsic: Colonization occurs due to the accumulation of dust, soil and organic particles on which plants thrive.

Doing a benchmark on bioreceptive stones as green infrastructure resulted in three relevant projects:

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[51] van Herk, C.M. (1999). Mapping of ammonia pollution with epiphytic lichens in the Netherlands. Lichenologist 31, 9-20.
[52] van Herk, C.M., A. Aptroot & H.F. van Dobben (2002). Long-term monitoring in the Netherlands suggests that lichens respond to global warming. The Lichenologist 34(2), 141-154.
[53] Aptroot, A. & C.M. van Herk (2007). Further evidence of the effects of global warming on lichens, particularly those with Trentepohlia phycobionts. Environmental pollution 146(2), 293-298.
[54] Guillitte, O. (1995). Bioreceptivity: a new concept for building ecology studies. Science Of The Total Environment, 167(1–3), 215–220. https://doi.org/10.1016/0048-9697(95)04582-l

- *The Poikilohydric Living wall project* by Marcos Cruz[55], which focuses on creating cementious living walls that can adapt to fluctuating moisture levels, similar to poikilohydric organisms.
- *Respyre*[56], mentioned by the lichenologist. This project works on the development of bio-receptive concrete panels that facilitates the growth of mosses.
- *KAPKAR/TO-RXD landscape observatory*[57], an artefact of tree bark concrete, where the bark slowly rots away and accelerates the growth of mosses.

All of these projects show that these concrete mixes can be sensitive to natural processes when 1. The concrete is complemented and accelerates by organic substrates that provide nutritions such as bark or cork and 2. The concrete surfaces being shaped as porous and organic frameworks[58] with rough textures[59] for moisture to retain and slow down and species to hook onto[60,61]. In general, concrete stands out as particularly well-suited material for bioreceptivity in the built environment due to their robustness and low cost. However, regarding concretes reliance on non-renewable resources and carbon-intensive production we should consider more sustainable and readily available stone substrates as well. For example, utilizing recycled aggregates from construction granular materials like gravel, crushed stone, recycled asphalt, recycled concrete and recycled brick. This also leads to the opportunity to avoid transport and act and produce on a local level[46]. Thereby, locally sourced material does offer a varied catalogue of substrates and is unique in terms of offspring, which might emotionally attach people to the structure due to its history with the environment. These aggregates are not required to be rare; many as ten lichen types can already form on a regular paving stone[36]. However, it is expected that recycled natural stones will attract more unique lichen types, like tuff. This insight has inspired the project to do further research on stony environments that already present a natural, unintentional occurring of rich lichen vegetation. The most remarkable finding are dry stone walls[62]. These structures are traditionally used as field boundaries in the upland areas of Britain and Ireland, built with a variety of natural stones and without cement. Having this cohesive triangle structure holding a collection of stones with unique characteristics and shapes while being exposed in the open creates this habitat that leads to a rich lichen-flora and biodiversity, being very attractive for a variety of plants and animals[63]. This occurs because of its unique interplay of surfaces, light / shade, wind, temperature, moisture and shelter. In general, the bare rock composition triggers a biological succession that gradually stain the wall with different plant communities, starting with algae followed by lichen, mosses, bryophytes and higher plants[64]. Similar conditions causing typical lichen to appear are Dutch graveyards[65] due to their exposition and variety in natural stones, such as granite, hard limestone, sandstone, quartzite, and lava stone. Three Graveyards and other open environments with stony substrates have been explored to experience and feel how and why these are actually colonised by lichens.

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[55] Cruz. M. (2022). *Poikilohydric Living Walls by Marcos Cruz*. Issuu. https://issuu.com/bartlettarchucl/docs/design-research-cruz-poikilohydric-walls-04

[56] *Respyre*. (n.d.). https://www.gorespyre.com/nl/

[57] *KAPKAR / TO-RXD | Landscape Observatory 2009-2020 | Studio Frank Havermans*. (n.d.). https://frankhavermans.space/project/landscape-observatory/

[58] Mustafa, K. F., Prieto, A., & Ottele, M. (2021). The Role of Geometry on a Self-Sustaining Bio-Receptive Concrete Panel for Facade Application. In Sustainability (Vol. 13, Issue 13, p. 7453). MDPI AG. https://doi.org/10.3390/su13137453

[59] Miller, A. Z., Sanmartín, P., Pereira-Pardo, L., Dionísio, A., Saiz-Jimenez, C., Macedo, M. F., & Prieto, B. (2012). Bioreceptivity of building stones: A review. In Science of The Total Environment (Vol. 426, pp. 1–12). Elsevier BV. https://doi.org/10.1016/j.scitotenv.2012.03.026

[60] Tomaselli, L., Lamenti, G., Bosco, M., & Tiano, P. (2000). Biodiversity of photosynthetic micro-organisms dwelling on stone monuments. In International Biodeterioration & Biodegradation (Vol. 46, Issue 3, pp. 251–258). Elsevier BV. https://doi.org/10.1016/s0964-8305(00)00078-0

[61] Miller, A. Z., Dionísio, A., Laiz, L., Macedo, M. F., & Saiz-Jimenez, C. (2009). The influence of inherent properties of building limestones on their bioreceptivity to phototrophic microorganisms. In Annals of Microbiology (Vol. 59, Issue 4, pp. 705–713). Springer Science and Business Media LLC. https://doi.org/10.1007/bf03179212

[62] Webley, P. (Ed.). (2004). Dry Stone Walling Techniques and Traditions. Milnthorpe, England: Dry Stone Walling Association of Great Britain.

[63] Manenti, R. (2014). Dry stone walls favour biodiversity: A case-study from the Appennines. Biodiversity and Conservation, 23. 10.1007/s10531-014-0691-9.

[64] Hardcastle, J., & Nisbet, M. (2008). Lifelines. Bristol, England: Mendip Hills AONB Service.

[65] Van der Kolk, H. (2018). Begraafplaatsen: Hotspots voor korstmossen. De Levende Natuur, 119 (1), 7-11.

Second iteration: Lichen Lens

Iterating on the flexible nature of the initial Lichen Panels concept, while mimicking this environment of bringing together different kinds of stones and transforming it into an architectural shape to be integrated in the open and public built environment has eventually led to the final concept of the Lichen Lens. The Lichen Lens is similar to a gabion structure, in terms of structural flexibility. Because the Lichen Lens is filled with heavy rocks the structure does not have to be fixed to the ground and can therefore be easily constructed and deconstructed, located and relocated, while being built strong enough to withstand significant forces. However, different from a traditional gabion the Lichen Lens acts as a stand-alone 'living wall', like a vertical land reef that is envisioned to gradually come alive as lichen initiate growth and local flora and fauna to take hold. Furthermore, the stone landscape can act as a vessel to create nesting and hibernation for a wide mix of wildlife: insects, invertebrates, small mammals, and even possibly birds. As the name already suggests, a magnifying lens that is also able to slide across the gabion structure is added, to make visible and enhance the perception of lichen growth on the stones within. Supplementary to the structure, a QR code is added that provides access to a website. This website contains more information on and visuals of lichen species, to further inform and possibly educate the user about the meaning of the Lichen Lens, how it can be used and lichens in general. In addition, the Lichen Lenses are envisioned to be placed on multiple locations to create a network of them, to show how different environments can affect the different Lichen Lenses' growth. In the next part, this iteration of the Lichen Lens will be evaluated through the method of Co-constructing stories[66].

Co-constructing stories

As the Lichen Lens concept is radically new and the long-timespan is a crucial part of the concept, it is important to envision the future context of use and to understand how future use situations will be affected by the Lichen Lens. Therefore, a participatory design technique called Co-constructing stories is used to elicit in-depth user feedback and suggestions about the Lichen Lens concept, to reveal attitudes and motivations of the user and to inform and inspire the concepts' future and development. A more detailed description of the used method and an authentic representation and explanation of the results, retrieved from a thematic analyses, can be found in appendix (B).

[66] Ozcelik, D., & Terken, J. M. B. (2012). Co-constructing stories: a participatory design technique to elicit in-depth user feedback and suggestions about design concepts. In PDC '12 Proceedings of the 12th Participatory Design Conference: exploratory papers, workshop descriptions, industry cases (Vol. 2, pp. 33-36). Association for Computing Machinery, Inc. https://doi.org/10.1145/2348144.2348156

Final design: Lichen Lens

The gabion structure

Taking the results of the co-constructing stories sessions into account, this has led to the third and final iteration of the Lichen Lens in this project. The gabion structure is meant to house a variety of flora and fauna. To increase lichen growth, animal habitation, and structural stability, the shape of the Lichen Lens is inspired by the composition of a dry stone wall, mimicking an interplay of conditions caused by stones, posed in a triangle with a steep slope, a thin top, and a wide base. Inspired by the structure of a Wardian case, a classic container for plants that is shaped to protect the anatomy of higher plants. However, to attach the Lichen Lens to the rectangular built environment, the triangular shape is cut in half, creating a right-angled back surface. Yet, you can mirror two Lichen Lenses to get the triangle form back. Furthermore, the structure can be expanded sideways as well due to it two right angled side panels. These panels are made of corten/weathering steel, a long-lasting robust material with low maintenance. Its rusty appearance is chosen to blend in well with the natural landscape. The panels act as stable and uniting factor of the structure, balancing the overall dynamic appearance it encloses, holding together this aging material that is colonised by alien-like species. As a result, showing its contrast with the artificial and thus highlighting its natural and lively appealing. The Lichen Lens' strong appearance and overall human-size dimensions are designed to act as a landmark and to invite people towards the structure. Meanwhile, the structure aims to feel like it is in harmony; not a disturbance to its surroundings, but an asset of wild aesthetics that blend naturally into the landscape. A Verfremdung in control. In brief, the Lichen Lens embraces the aesthetics of transience, but also implies a sense of liveliness as well as actively contributing to the environment.

Lichen Lens substrates

From the co-constructing stories sessions, it became apparent that the use of stones with varying pH values as a substrate could promote sustainable and low-cost biological succession considering lichen growth. The gabions are envisioned to be filled with three types of bioreceptive stones:

1. Locally quarried recycled aggregates.
2. Imported natural stones. Such as basalt, which has been used in Dutch dikes[67] before and now full of lichen, or granite boulders, which since the dolmens[68] has not naturally occur in the Netherlands but is the only rock to host a great diversity of acid-loving epileptic lichens. Both of these stone-types can be imported. These stones would probably already have some lichen, if so, the question is whether relocated lichen will take hold at all and adapt to a new environment, demonstrating its true resilience to survive. As a more stand-alone integration it has been proven to be successful as well, an example of this are large granite boulders used as sockles for an artwork in Soest[69], introducing many new and rare lichens and mosses in the Netherlands, where most species seem to survive or even thrive.
3. Concrete mixed boulders, developed with a combination of recycled concrete and waste materials that can decay overtime.

[67] Sparrius, L.B., Aptroot, A., & Nat, E. (2011). Natuurwinst door hergebruik van natuursteen bij dijkverzwaringen. H2O, 2011(12), 12-13.
[68] Sparrius, L.B., A. Aptroot & L. van Duuren (2011) Landelijk Meetnet Korstmossen, Inhoudelijke Rapportage 2011. BLWG-rapport 13.
[69] Aptroot, A., & BLWG. (2009). Buxbaumiella 84. Buxbaumiella, 36–40. https://digitale.cbnbl.org/documents/R837.84.pdf

The choice of stone type and their layout, how they are patterned by colour and type depends on local feasibility and the aesthetic preferences of the stakeholders. Despite the dynamic and unpredictable process, the project envisions that the Lichen Lens structure can sustain for decades. This will trigger ''full'' biological succession, where the stones and their environment engage in a long-lasting and ongoing dialogue, presenting the constant flux of change caused by our dominant human activity throughout the years. This also shows that an aging Lichen Lens with particular stone properties is not stuck to one outcome, but heavily influenced by the environment it is located in. To make the influence of the environment more visible to the users the project proposes a network of multiple Lichen Lenses.

Contextualisation: Lichen Lens network

Considering this Lichen Lens network, it is important that the Lichen Lenses must not be overshadowed by their surroundings. As lichens on trees in Europe primarily grow on the southwest side due to its availability of light and water, the front (steep slope) is suggested to be directed to the southwest[39]. From the sessions, it came forward that it could be a good idea to establish these networks across existing hiking trails, both in rural and urban areas, canals, dunes, and 'Klompenpaden'[70] so humans and non-humans can naturally encounter them. This idea is in line with the exploratory nature of the old 'ANWB-paddenstoelen'[71] concept designed in 1919. The network will demonstrate how different species thrive and move through the landscape over a period of several decades. For example, lichens being pushed north due to climate change or completely disappear because of air pollution. Over time each Lichen Lens will portray the conditions of its environment with unique lichen-flora and local biodiversity.

It was also mentioned that environments where similar lichen vegetations already thrive should be avoided to prevent redundancy. Within the co-constructing stories sessions it was mentioned that the user-target audience should be aimed at people who have the time to really look around and perceive their environment. This statement came from the contrast that can be seen between the slow nature of lichen growth and modern society's fast pace, posing a challenge as it underlines the need for patience in general in order to successfully appreciate and implement the Lichen Lens. Klompenpaden and nature reserves can be characterised as 'slow' and leisurely, prone to be visited by nature enthusiasts and tourists who want to unwind, meaning they have the time and take their time as well. For these reasons, the target audience of Lichen Lens users will be aimed at tourists, nature reserve-recreationists, hikers or occasional strollers.

This idea of installing a Lichen Lens network also sparked the idea of making use of pre-existing substrates that are readily available in any environment, thus by superimposing a magnifying lens over a tree, boulder or wall where lichens are already visibly thriving. In doing so, people will be attracted to the substrate simply because something is superimposed over it, even though in reality nothing has significantly changed and the substrate remains the same. Consequently, a ''travel light'' option is created, which can be an addition to the gabion-Lichen Lens structures. It will have the same purpose and design language as the original Lichen Lens structure in terms of sliding mechanism and QR code, inviting people

[70] *Wandelen over boerenland in Gelderland en Utrecht - klompenpaden.nl*. (2024). klompenpaden.nl. https://klompenpaden.nl/
[71] *De paddenstoel: wegwijzericoon in het landschap*. (n.d.). ANWB. https://www.anwb.nl/over-anwb/geschiedenis/de-paddenstoel-wegwijzericoon-in-het-landschap

to notice the connection between the two and seeing them as part of one coherent network. This additional travel light-option could potentially be easily implemented as it makes use of pre-existing substrates as opposed to the placement of a new more costly structure that takes up more space, while also emphasizing the abundance and variety of (historical) lichen growth on different substrates and in different environments.

Aesthetics of interaction

The network encourages people to explore different Lichen Lenses and places, to discover distinctions between the Lichen Lenses and reflect on the environment they are situated in. The open-ended character of the Lichen Lenses gives people a reason to explore, re-explore and return to the structure. However, the question remains how people can feel this responsiveness and temporality of lichen? And how can the Lichen Lens' subtle signs of change, growth and aging be brought to the public's attention, be more visible, understandable and experienceable to people?

Exploration and sense of intimacy: Sliding Lens

The Lichen Lens's appearance was perceived as beautiful and timeless within the sessions, though possible ambiguity about its purpose were also mentioned. People will likely notice the Lichen Lens due to its size. However, instead of a quick observation from a distance, in order to really draw people into the micro landscape of lichen, people need to stand still and take the time to observe. Therefore, the experience with lichen needs to be intensified. As described by the lichenologist, the charm of lichen lays in its bright colours and small details, and this is why they always let people look through a magnifying lens during excursions. In other words, the Lichen Lens should be an invitation and has the option for people to look at lichen from a close distance, zooming-in on different scales to reveal its hidden details and species. The small size of the lichens can also be a reason to physically draw people towards the lichen lens. For this reason, the Lichen Lens is equipped with a playful element: The Sliding lens. The Sliding Lens is part of the front side of Lichen Lens, a 2-axis linear rails that holds a magnifying glass, a lens that can be slid vertically and horizontally over the gabions front grid surface and hover over its stones. The sliding lens aims to give people a peak in the Lichen Lens' small but local scene of nature and to interact with these non-human inhabitants on an intimate level. When this aspect of the structure was discussed in the sessions, it was said that the Lichen Lens will likely evoke the emotions of having a connection with nature, feeling curious and feeling amazed among its users because of this capacity of revealing this previously hidden micro landscape. The lens has two magnifications of 10 and 5. 5 to do a quick scan and 10 to have a detailed view. The human-sized dimensions of the front surface and its sloped angle aims to stimulate users to actively explore and embody the structure.

To embrace the intuitive and user-friendly interaction the simplistic form language of the lens is inspired by the archetype of a magnifying glass, while its shape is designed around the functionalities and safety of the sliding mechanism. Users can move and lock the lens with an ergonomic knob. Locking the lens give users the option to take their time and freeze what they have found. Therewith, making it easier to share their frozen findings with others that are present during the interaction, or leaving it in a particular spot for others to observe the same, being a shared system.

Education: Website

To follow lichens slow life-span people need to be able to speed-up, slow-down or pause the dynamic process of the Lichen Lens. This has led to development of an interactive website: https://immersivelichen.wixsite.com/verfremdung, appendix (C). Each Lichen Lens has a sign with textual information and a QR-code that leads to the website. The website aims to be a permanent and accessible interface to inform people about two main chapters ''Lichen Lens'' and. ''Lichen''.

Envisioning the Lichen Lens' expected lapse of time

The website communicates the Lichen Lens' meaning and usability and presents an envisioned view of a fully colonised Lichen Lens. These visuals aim to contribute to the solution by helping people visualizing potential future outcomes, and as a result influencing their perspectives, expectations, and beliefs[72].

The aging process of the Lichen Lens might take decades, and therefore it requires people to be patient and to appreciate and focus on its small and subtle details and changes, while being aware of the habitat's transience, where lichen species can suddenly disappear and plant communities be overgrown. Therefore, this website aims to make these temporalities visible and experienceable in a more immediate manner for users by stimulating users to contribute to this visibility themselves and to share what they have found and captured[73]. Therefore, the website gives the option to upload a personal documentation, consisting of a photo, small description and biodiversity log. All these uploads are merged together and visualised in an interactive chronological timeline that correspond to a particular Lichen Lens. This brings us to the Lichen Lens network; a visual map of the network is displayed on the website consisting of each Lichen Lens being numbered on the basis of their date of instalment, number one being the oldest. Selecting a number on the map will display its corresponding timeline and specification, such as type of stones. This overview makes it easy for people to know where to find the Lichen Lenses, but also to make a clear comparison and connection between the Lichen Lens' timelines and how these relate to their corresponding environments. In addition, as the Lichen Lenses are part of hiking trails, the website asks users to share information about the lichens they have encountered during their walking route, encouraging other people to see the same, to continue their exploration and to take new paths led by lichen, communicated by humans.

Enlightening more about Lichen

For users to fully understand and appreciate the lichens they encounter or have magnified through the Lichen Lens, education is essential. It helps users to grasp what they are seeing and what it actually portrays. Learning about these non-human organisms might change users' perceptions and encourage them to reflect critically on their surroundings. As described by the lichenologist: *"When I give a lecture about lichen, people tell me they cannot walk anywhere without seeing them everywhere."* Lichens are self-evident, meaning people can easily see and judge based on lichen growth if the environment is green or not. However, the challenge is to translate the complex world of lichen to something accessible to most people in public spaces. The lichenologist suggested prioritizing certain lichen species and selecting those commonly found in the Netherlands, focusing on their colours, shapes, and relationships to their

[72] Sanders, E.B. (2001). Virtuosos of the Experience Domain.
[73] Roto, V., Law, E., Vermeeren, A., & Hoonhout, J. (2011). User Experience White Paper.

environment. To help with this, he provided the BLWG search map[74], an educational tool often used during excursions to help people discover what trees indicate about air quality. Similar to this project, the map aims to be appealing to people new to lichen, and was therefore used as main inspiration and guideline for the website. The websites describe general information about lichen: its extraordinary life-form, where they can be found and their role as bioindicator. The website provides an overview of three groups: lichens that thrive in ammonia-rich environments, those that disappear due to ammonia, and a third group, the "reindeer moss types," which highlight the general alien-like appearance of lichens. Each group has two taxonomic sub-groups (families), each with its own representative species.

To further explore the sophisticated details and complex structures of lichens, this overview is enhanced with five embedded interactive 3D models. These models offer a comprehensive visual representation of the aesthetic diversity of these groups, including their growth types and colours. All models and texture are fully designed in Blender, where detailed lichen photographs are used as primary references.

To enrich the learning experience and make it more engaging and enjoyable, users can manipulate the models. They can click, zoom, and scroll through the models, and can highlight lichen features supported by textual information, enabling active learning and interaction with lichens. In addition, the website offers the option to experience the models through augmented reality (AR) or virtual reality (VR) technology, adding another layer of immersion and exploration.

The website contains imaginary 3D environments that correspond to each of the three lichen groups, allowing users to truly connect these lichens with their surroundings. These environments depict typical Dutch landscapes invaded and overgrown by large lichens, creating a dystopic colonization effect. 3D maps from Google Earth form the main foundation of the models to further enhance the recognizability of these vistas. Another aim of these environments is to highlight the alien-like nature of lichens and their aesthetic contrast with their surroundings, emphasising their unique and intriguing appearance. The virtual environments facilitate experiential learning by immersing users in similar interactions as the lichen models. The highlighted features give information about the lichens' substrates and the factors that led to their colonization.

Practice implications

Even though the potential of gabion structures to enhance biodiversity was confirmed within the co-constructing stories sessions, the importance of having attention for maintenance and vulnerability (e.g. vandalism) was also pointed out. In response, the involvement of national and local stakeholders such as municipalities and land management organisations were proposed to aid in the strategic placement and long-term maintenance of the Lichen Lens. Moreover, it was believed that the Lichen Lens should ideally be placed in somewhat guarded areas, to make periodic management easier and to establish more clarity about which stakeholder is held responsible as well. It was also suggested that it would be more efficient to initially approach larger national institutions, as the aim of the Lichen Lens implementation is also province-wide oriented. After securing their involvement for management on a larger scale, local municipalities can naturally be involved as well to aid in constructing the Lichen Lens, preventing vandalism and performing overall maintenance. As municipalities also have access to multiple areas of

[74] BLWG Webshop. (n.d.). *Zoekkaart korstmossen en ammoniak (10 stuks)*. https://shop.blwg.nl/products/zoekkaart-korstmossen-en-ammoniak-10-stuks

expertise and can adjust to the local demands coming from inhabitants, incorporating them could help with successful implementation (*see also sub-theme 'Environment')*. Lastly, a hypothetical approach was discussed within the sessions about how implementing the Lichen Lens should be carried out. It was implied that a suitable approach could be to just build the Lichen Lens and place it within the suggested environments and wait and see what happens with it. Perhaps, starting with the implementation of the travel light option could be in place to gradually validate the intended user interaction, which also addresses the challenge of otherwise having to wait a long time for lichen growth to occur. Yet, the travel light option is more difficult to design for as the shape of the sliding mechanism has to be customary to the substrate it is intended to be placed on, thus it is far more context- and substrate-bound as the original Lichen Lens.

Future work

Even though the general components, scales and shapes of the Lichen Lens have been deliberately designed, the technical aspects of the sliding-lens mechanism and the lens itself is still in its early stages. Thus, further specifying is necessary to gain more insight into the mechanical and material properties. A possible iteration on the scale of the Lichen Lens could be to decrease the structure's size, which reduces footprint in terms of cost & spatial use. Even though a smaller version will not be able to acquire as much biodiversity as the original size, a similar outcome will be maintained in terms of the interaction between the micro landscape and users. Further adding onto this idea of down-scaling, is the possibility of offering a smaller version as a product for private use, where people can buy and place the product onto their private terrain/gardens. In this way, people can experience the same benefits the original Lichen Lens has to offer, yet on a more personal level; directly contributing to their own garden's biodiversity, adding their own rocks to fill up the lichen lens and reflecting on the air quality of their direct environment, and also becoming even more aware of the time statement lichen pose as more close observation is now made possible. Moreover, it can establish the feeling of being a member of a 'product-family' when other individuals possess the same product and are willing to share their observations & vice versa. Lastly, an idea for future work on the Lichen Lens could be to stimulate public contribution to aid in its implementation, by the sponsoring of the of substrate-stones. A beautiful example of this is the Lugtsingel[75]; a pedestrian bridge in the centre of Rotterdam, which is constructed on 17.000 personalised planks that were contributed by citizens. This idea could also provide users with a sense of control or responsibility, even though the public space is managed by other institutions.

[75] Koreman, K., & Van Boxel, E. (2015). City of Permanent Temporality. Rotterdam, Netherlands: NAI.

Conclusion

This project started with the goal to design a green space structure as a new aesthetic that appeals to the general public. By including the concept of biophilic design in the process, the intention was to restore the intrinsic connection between people and nature, which eventually guided the project towards lichen. Iterating on the previous design of the lichen panels within the overarching project 'Verfremdung (I&II)', a final design concept was developed: the Lichen Lens, which is a man-made gabion structure situated within public environments of Dutch landscapes. The Lichen Lens is an open-ended gabion structure that facilitates an ongoing dialogue between dominant human activity and how it is naturally colonized, thus it acknowledges nature's dynamic forces of growth, change and ageing, all shown through the under-appreciated yet extraordinary world of lichen. Furthermore, the Lichen Lens introduces a sense of intimacy to users that can evoke the emotion of feeling connected with nature, simply by revealing this previously hidden micro landscape. This experience is supported by an educational digital platform that informs the user about lichen, their potential to change and what this tells us about the state of our environment. Moreover, the platform connects different Lichen Lenses by documenting user's experiences, which stimulates the user to explore further and enables them to closely follow the process of biological succession occurring on a Lichen Lens. In terms of further development of the final design, a lower-cost and less time-dependent 'travel light' version of the Lichen Lens can be initially developed to validate the design within its public context and to gain more insight into the user interaction with the concept. In addition, it will be useful to introduce the project to larger national institutions, as the Lichen Lens will also be implemented on a nation-wide scale, and in order to obtain funding. All things considered, the Lichen Lens has the potential to promote biodiversity of varying scale within public spaces, and can reveal people's situatedness within their, often overlooked, natural environment, restoring that inherent connection; ''*How from the inside we.. are just.. not one with nature; we áre nature.*'' **(- Quote 7).**

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