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How can standardized construction practices for the Netherlands be used for increased integration of Nature-Based Solutions within substations?

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List of abbreviations

Abbreviation	Abbreviation in full
ACM	Authority for Consumers & Markets
BO	Basic Design (Dutch: *Basis Ontwerp*)
CE	Circular Economy
DER	Distributed Energy Resources
DO	Detailed Design (Dutch: *Detail Ontwerp*)
DSO	Distribution System Operators
ERP	Enterprise resource planning
ICES	Integrated Community Energy Systems
kV	Kilo volts
LLM	Large Languages Model
LTS	Large Technical Systems
MB	Modular Building / Standardized Building
MVA	Mega volts ampere
NBS	Nature-Based Solutions
NLP	Natural Language Processing
PV	Photovoltaic
SAP	Systems Applications and Products
SDG	Sustainable Development Goals
Sub-TSO	Sub-Transmission System Operator
TSO	Transmission System Operator
UM	Urban Metabolism

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1. Introduction

The Sustainable Development Goals (SDGs), as set out by the United Nations in 2015, focusses on providing guidelines and actionable options to end poverty, protecting the planet and to enable and ensure peace and prosperity across the world (UN, 2015). Making sure that these goals are being met must be a priority for the future of this planet, especially in the face of ongoing climate change. In this chase for sustainability, renewable energy sources and energy efficiency are paramount (Bexell & Jönsson, 2017). Grid operators, who are responsible for managing and operating the electrical grid, play a fundamental role in realizing the SDGs that are connected to the energy sector (WBCSD, 2021).

In the Netherlands, grid operators, also known as (sub-)transmission system operators (sub-TSO), are involved in an ongoing challenge to deal with grid congestion, making it more difficult to align their strategic goals with the SDGs (ACM, 2022; Beetstra et al., 2022). The overall land use for energy infrastructure has raised concern about the sustainability, especially looking at the historical impact the land use has had and if this use is in alignment with the SDGs. (Wagner et al., 2023). As the grid operators play a pivotal role in the energy transition, they have a responsibility to contribute to those SDGs (Kanabar et al., 2022; O'Shaughnessy et al., 2021).

Despite the crucial role played by the grid operators, an existing research gap is present. There is no comprehensive study that has delved into the integration of nature-based solutions (NBS) in energy infrastructure and the extent to which grid operators have adopted sustainable land use practices. NBS provides proven ways of promoting sustainable land use, enhancing biodiversity, and mitigating environmental impacts of energy infrastructure, strengthening the potential for reaching the SDGs (Cohen-Shacham et al., 2016; Faivre et al., 2017; Sowińska-Świerkosz & García, 2022). Thus, these strategies help to build sustainable capacities of grid operators in climate mitigation, nature conservation, and an overall more sustainable energy transition. Nevertheless, this knowledge gap showcases the need for further research in this area. To be consistent with SDGs as well as mitigate climate change; grid operators must take up sustainable responsibility for their operations (Beetstra et al., 2022). One part requiring attention is land use within their infrastructural premises. While developing and expanding the grid infrastructure into larger land areas, grid operators must consider ecological aspects and seize opportunities for integrating NBS so as to perform their SDG-related responsibilities (Langemeyer & Baró, 2021). This is underlined even more by the fact that the total land use of grid operators in the Netherlands exceeds 900 km² and is growing rapidly every year (Alliander, 2022b; Groene Netten, 2022).

Currently, net congestion is a national challenge in the Netherlands, the electricity grid in the Netherlands is demanding a faster expansion and strengthening of the grid than ever seen before (Alliander, 2022a; Hirth & Glismann, 2018; Weiffenbach, 2022). This situation provides a stage where grid operators can showcase their strategic focus based on the SDGs when expanding the grid. What is now considered as common practice for minimizing costs is the application of one best way – a standardized construction approach - as grid operators are state-owned and need to report on their financial decisions and use of funding to the government (Alliander, 2022b; Bouwmeister, 2021; Qirion, 2023b). Furthermore, a technically superior design of (sub-)stations is considered best practice in terms of reliability and maintenance, as also emphasised by the standardized construction method of the grid operators (Kezunovic et al., 2010; Parandehgheibi & Modiano, 2013; Qirion, 2023b). Combining the sustainable responsibility of the grid operators with their land use, this research will therefore focus on the implementation and integration of NBS within the standardized construction methods of energy infrastructures in the Netherlands. The focus will lie specifically on energy (sub-)stations ranging from 10 kilovolts (kV) to 150kV and 10 mega-volt-ampere (MVA) to 160MVA; this is in the Netherlands considered the domain of the sub-TSO. Given these challenges and sustainable responsibilities, grasping and applying the principles of Large Technical Systems (LTS) becomes important for sub-TSOs (Hirsh & Sovacool, 2006). Technically referred to as LTS' 'social science systems approach' to technology, it provides a comprehensive framework of how humans organize and optimize contrasting materials or functions to make them efficient in a given technique, process or goal (Hughes, 1987). For sub-TSOs operating in this complicated energy infrastructural landscape, the theory offers some insight about the interplay between social-technical dynamics that influence accomplishing sustainable and effective grid operations (Dorst et al., 2021; Vleuten & Kaijser, 2006).

This research seeks to bridge the knowledge gap concerning NBS, and grid operators' responsibility for overseeing the expansion of the electricity grids in the Netherlands. There is shortage of detailed studies into their adoption of sustainable land use practices as well as integration of NBS despite their crucial role in attaining SDGs by 2030. This research aims to fill that vital gap because over time there have been concerns about the sustainability of land use within the energy sector and its alignment with SDGs (Buonocore et al., 2019; Wagner et al., 2023).

In the context of LTS, the role of historical financial analysis in relation to expenditure in comparison with standard substations and associated land use becomes very important. This paper seeks to determine whether grid operators can afford to exercise their mandate in implementing SDGs by way of advocating for sustainable land use practices in light of the NBS. The paper has been able to interrogate the integration of nature-based principles into standardized construction, taken a detailed analysis of the financial land use patterns of substations, and relates it with the relevant actionable that may influence grid operators toward making an environmentally friendly decision in line with the SDGs. This greatly enriches the academic discourse on sustainable energy transitions with a practical framework for balancing financial considerations against ecological imperatives.

The main research question is focused on the social responsibility of grid operators and the implementation of NBSs, considering their contribution to the SDGs within the framework of LTS.

How can standardized construction practices for the Netherlands be used for increased integration of Nature-Based Solutions within substations?

To effectively address the main research question and explore related topics, four sub-questions are defined to provide a wider frame of field on this topic:

1. What have been the trends in NBS expenditure at (sub-)stations in the Netherlands for the period 2018–2023?
2. What are the challenges and opportunities to grid operators in implementing cost-effective nature-based solutions into their standardized (sub-)station construction?
3. How do current design considerations and practical examples lead to the inclusion of NBS in the present land use and site design processes of (sub-)stations in the Netherlands?
4. How can the operational priorities of grid operators be aligned with the integration of NBS to increase technical reliability and environmental sustainability?

It provides insight into the financial aspects of land use, site layout, and the adoption of NBS from sub-TSOs. Drawing on insights from LTS, it unfolds a nuanced understanding of the multiple social and technical dynamics interwoven in grid operators' decision-making processes. This nuanced understanding challenges conventional approaches that want to put the emphasis on safety and technical considerations, providing a compelling rationale as to why grid operators should embrace the implementation of NBS. The outcome of this research is incredibly relevant in academic terms, given its totally novel insight into the avenues through which sustainable land use practices within the energy sector can be financially feasible.

2. Literature review

The energy sector has been associated with concerns over its alignment with SDGs in the historical land use sustainability perspectives. (Niet et al., 2021; Wang et al., 2023). However, a considerable research gap exists as only a few studies have addressed issues to do with sustainable land use practices in the context of electricity grid infrastructure. Consequently, this literature review closes this gap by analysing two different literature streams. First, Nature-based solutions combined with transmission system operators (TSO) and secondly; Large technical systems (LTS) combined with nature-based solutions.

The first of these streams (*Stream A – NBS & TSO*) focuses on the role of the TSO in integrating NBS into grid operations and provides practical insights into the implementation of sustainable practices. The second stream (*Stream B – LTS & NBS*) presents the more general concept of LTS and its relationship with NBS, offering theoretical frameworks underpinning both challenges and opportunities for including NBS within LTS. The two streams are validated by the careful selection of three key articles each, based on specific literature criteria detailed in Appendix VII.

It provides a holistic and widened perspective by discussing and presenting various concepts from these streams of literature, including NBS and LTS, further deepened by the standardized construction as a concept within that frame. It also covers related topics of interrelations of climate change and circular economy, urban metabolism models, and smart city perspectives as sustainable social-ecological systems. While studies like Romero-Perdomo et al. (2022) and Perrotti & Stremke (2020) add valuable insight in these areas, neither of them is focused on how NBS can be integrated into grid operations or has pointed out exact responsibilities borne by grid operators. Contributions from authors such as Pereira et al. (2018); Sovacool et al. (2018) and Van der Vleuten (2004) make one aware of the state-of-the-art technologies in LTS, societal shifts, and smart grid transitions, but have not elaborated on the intersection in respect to sustainable land-use practice and NBS, along with the responsibilities of grid operators within the Dutch context.

Literature *stream A* addresses the interlinkages of climate change and the circular economy. Romero-Perdomo et al. (2022) present a 'regenerative system' that generates the minimum possible amount of waste, materials used, and energy consumption; thus, it can contribute to mitigating greenhouse gasses. Their mixed-method approach covers 789 peer-reviewed publications, demonstrating a field in exponential growth that is rather interdisciplinary in nature and mainly led by European research. The most shared strategy connected with climate change is waste management. Nevertheless, Romero-Perdomo et al. (2022) realize that there are gaps to be filled, such as the integration of the social axis and climate change adaptation. In other research, Perrotti & Stremke (2020) discuss under-exploited urban metabolism models in their potential for assisting with green infrastructure planning. Models of urban metabolism do measure material and energy flows within urban systems and may hence contribute to making resource-efficient development in cities a reality. According to the authors, it is relevant that ecosystem services are integrated into urban metabolism models, as nature is intrinsically valuable for human well-being but at the same time instrumental in making cities energy efficient and hence promoting sustainable urban development (Perrotti & Stremke, 2020).

In Literature *stream B* (LTS & NBS), Colding et al. (2020) hold a view that is opposite to the conventional understanding of smart cities. They wish to build a broader perspective that takes up cities as sustainable social-ecological systems and relate them to LTS. What they underline, instead, is low-tech technologies and nature-based solutions, warning about potential environmental and social risks with the set of information and communication technology solutions. According to Colding et al. (2020), a holistic approach drawing from the container of interdisciplinary perspectives is needed to deal with the complexities of urban environments. Contributing to the further elaboration of such an exploration, Van der Vleuten (2004) introduced a nuanced framework that categorized four moments of co-construction in the relations between infrastructural and societal changes. This paper underlines the necessity to comprehensively understand the dynamic relationships of infrastructures and societies. Building upon the discussion, the contribution of Sovacool et al. (2018) becomes important in further raising awareness about LTS and their dynamic changes at different times. The contribution of Sovacool et al. (2018) advances our understanding of LTS by analysing their evolution through the phases of reconfiguration, contestation, and decline. They use historical case studies to illustrate how LTS adapts and changes over time in complex interplays between technological systems and societal needs. This study enriches the broader discourse by offering nuanced insight into the coevolution of technology and society. It underlines the requirement that the needs of system users deserve attention for their consequences in terms of policy and societal development. In a study exploring the challenges and opportunities related to the transition of the electricity distribution system operator to smart grids, Pereira et al. (2018) make use of the LTS conceptual framework to map complex evolution and adaptation needs of the energy distribution sector. This research, drawing on nine multi-stakeholder workshops, emphasizes a number of uncertainties and barriers—such as resistance to change and traditional regulations—but points out opportunities like the integration of variable energy sources. The paper focuses on the need for such a holistic dynamic approach to be carried out with regard to understanding and guiding the adaptation process within the context of the electricity sector (Pereira et al., 2018; Sovacool et al., 2018).

The literature review analysis has exposed a significant research gap within the context of sustainable land use practices and the integration of NBS by grid operators, especially in a Dutch context. While the literature is mainly focused on the junction of themes like climate change, circular economy, urban metabolism models, smart cities, LTS, and transition to smart grids, it has not been considered as a line of research how the exact combination of sustainable land use practices, NBS integration, and grid operators' responsibilities really works.

3. Conceptual framework

The overarching conceptual framework is of key importance for connecting NBS and LTS within the context of standardized grid infrastructure in the Dutch energy sector. As such, the research in this chapter is therefore based on, and directed towards the specific gap revealed from the literature review, pointing at an evident shortcoming in current research on sustainable land use by grid operators for implementing NBS.

3.1 Nature-Based Solution

According to Nelson et al. (2020), NBS is an inclusive approach that combines natural processes and urban and rural infrastructure to enhance sustainability. Having shared features such as urban green spaces, green roofs, constructed wetlands, and even ecological corridors, according to Adams et al. (2023) and Seddon et al. (2020), NBS offers a twin benefit of carbon repossession and emission reduction coupled with enhanced natural resilience. Critically, these works point to the fact that there is a clear necessity for assessing issues of governance, equity, participation, valuation, infrastructure integration, scale and feedback in complex systems (Adams et al., 2023; Seddon et al., 2020). To this regard, a holistic methodology is universal because multifunctional landscapes attempt to take on global environmental challenges more effectively by considering interlinkages across ecological, social, and technical systems.

NBS has been in existence for years (La Rosa et al., 2021), but its increasing relevance for climate change mitigation and urban issues has received specific attention within the last decade (Kalantari et al., 2020; Mell et al., 2022). The rise in the demand for action to reduce climate change brings about an increased quest for remedies. As such, the issue of NBS has rightly evolved to become an area of increasing interest and research for both scholars and practitioners (Parker et al., 2020). Integrating initiatives of NBS in the energy sector may significantly contribute to mitigation against urban heat, improving air quality, and conserving biodiversity (Adams et al., 2023). Embedding NBS in climate mitigation strategies helps sustain solutions relevant to human societies and the environment (Pötz, 2022; Tuunanen & Kuo, 2015). It provides a link between NBS and climate mitigation strategies, further enriching the energy sector with social, economic, and ecological benefits (Seddon et al., 2020).

Through mitigating actions like creating urban forests and green roofs, the NBS reduces the urban heat island effect by improving air quality and reducing noise pollution (Adams et al., 2023). Interventions such as constructed wetlands and natural drainage systems enhance water management, thus improving water quality and reducing flood risk in this context (Seddon et al., 2020). These nature-based solutions ensure that biodiversity is conserved, habitat is restored, and ecological connectivity is maintained and restored by planning and designing energy infrastructures that retain and restore ecosystems (Boano et al., 2020; Razzaghi Asl, 2022). Moreover, there are the social co-benefits of NBS in relation to the improvement of well-being and quality of life of communities (Seddon et al., 2020). Green spaces and urban green infrastructure can be utilized around the energy infrastructure to create areas for recreation, doing physical exercise, and other activities to improve mental health. A number of studies have shown that access to nature in the built environment is likely to lead to reductions in stress and raise social cohesion and community engagement (Seddon et al., 2020). Another study shows an increase in community engagement and emphasizes meaningful public engagement for successful NBS implementation (White House Council on Environmental Quality et al., 2022).

Economically, there are a number of benefits associated with NBS that make it cost-effective and sustainable within the energy infrastructure. Reduced operational costs can be achieved with NBS through reduced energy consumption by means of resource management and reduced maintenance expenses (Faivre et al., 2017). An example would be that of green roofs and vertical vegetation systems, which improve building energy efficiency as they act to a large extent as insulation, hence reducing the energy used for heating and cooling. NBS can also enhance property values, attract investments, and stimulate economic development through the creation of green jobs and tourism opportunities (Pötz, 2022). In addition, the combination of energy facilities infrastructure with that of NBS provides many co-benefits for sustainable development goals (Gómez Martín et al., 2020). Green areas for renewable energy production—such as the introduction of photovoltaic panels within urban parks or wind turbines along coastlines—contribute to a low-carbon energy system. NBS also improves energy infrastructure resilience to climate change, including extreme events and sea-level rise (Gómez Martín et al., 2020). By moving away from traditional infrastructure and adopting more NBS solutions, the energy sector can become much more sustainable, resilient, and responsive to the challenges ahead (Pötz, 2022). On the other hand, shifting focus to the integration of NBS within the domain of grid operator activities, it is arguable that land resources under grid operators' control for use in support and enriching natural elements is a strong argument for alignment with the SDGs.

Since technical considerations, not to mention the safety of the personnel in the area, take precedence in (sub-)station siting (Qirion, 2023a), integration with NBS would offer the potential to complement a technically oriented design process of energy infrastructure (Seddon et al., 2020). These may involve roof-based photovoltaic systems, green roofs and walls, surrounding green spaces of infrastructure buildings, activities to enhance biodiversity, circular purchasing policies, natural water systems, emission-free construction process, and provision for local biodiversity. This can be done with sustained adherence to the standards of technical excellence and safety protocols.

3.2 Large technical systems

The large technical systems concept is an overarching framework that indicates the complicated organization of materials within socio-technical systems and underlines their dynamic interplay between technological and social elements (Hughes, 1987). In this respect, grid infrastructure in the energy sector serves as an excellent example of an LTS, given that it coordinates various interconnected elements for the purpose of optimizing the generation, transmission, and distribution of electricity (Hughes, 1987). While they embody technical infrastructures, like power plants, telecommunication networks, and energy grids, these systems are also strongly socially embedded in the social constructs and dynamics that engage them and hence influence their technological development and use (Atkins et al., 2008; Grabowski et al., 2017). To this end, these systems should be able to accommodate fluctuating demands from society, regulate shifts towards greener policies, and financially incentivize for sustainable development. Indeed, this very dynamic nature lays the need for permanent interaction between technology and society so that grid infrastructure can serve not just current but also future demands—from integrating renewable sources of energy into the grid to increasing grid resilience in view of the impacts brought about by climate change (Vleuten & Kaijser, 2006).

These dynamic and complexities of grid operators having to navigate these necessitate comprehensive change management strategies that are informed by LTS. Applicable is Kotter's model of change, which involves creating a sense of urgency, forming a powerful coalition, developing vision and strategy, communicating the vision, removing obstacles, generating short-term wins, consolidating gains, and anchoring changes in corporate culture (Kotter, 1995). Grid operators can systemically apply Kotter's model to attain solutions for the energy transition challenge. Creating urgency underlines the need for sustainable systems, long-term sustainability, and the formation of coalitions to provide strong leadership. A vision developed and communicated will build the effort toward standardized practices and interoperable systems, both conducive to grid consistency and reliability.

As Hughes (1987) puts it, LTS embraces 1) all tangible technological artifacts and 2) complex organizational, regulatory, and financial structures which support and govern their functioning. Therefore, this two-way clarification underlines how technological innovation is not able to march alone on the way to success, but is linked with the success and efficiency of the LTS enveloping it within the societal context: the actors, inventors, engineers, and managers; the financing machinery; and the regulatory environment. This perspective that LTS contributes goes beyond technical considerations alone. It helps grid operators understand broader concerns relating to societal and environmental implications of their decisions. Therefore, this holistic two-way elaboration lines up perfectly with the goals on sustainability, resilience strategies, and transition to renewable energy, standardizing harmonic construction of grid operators within the intricate framework of LTS (Savic et al., 2023).

In this respect, energy grid projects give evidence to the interdependence between standardized construction and LTS. Grid operators strategically choose common technical specifications, interoperable systems, and standardized approaches to bring about enhancement of consistency and reliability within LTS while entrusting continuous development and improvement for standardized construction practices (Chatzimisios et al., 2013).

3.3 Standardized construction

Standardized construction refers to the systematization or uniformity and predictability of structures, systems, or component building and/or assembly (Akbar et al., 2015; United Nations Global Marketplace, 2022). This approach focuses on efficiency, effectiveness, and saving resources; it is widely used in industries such as manufacturing, civil engineering, and building industries (Aapaoja & Haapasalo, 2014; Aldridge et al., 2001). Essentially, standardized construction involves predefined designs, materials, processes, and techniques that are then applied across multiple projects, just as Toyota originally pioneered it in their LEAN thinking production methods (Gao & Low, 2014; Shang et al., 2014). The overall goal is to achieve efficiency, affordability, and reliability through adherence to set standards and best practices. This approach is often used in fields where consistency, quality, and efficiency matter—for example, manufacturing, infrastructure development, and some areas of construction (Gao & Low, 2014).

Major grid operators in the Netherlands, such as TenneT, Alliander, Qirion, and Enexis, emphasize setting uniform construction standards within their area of operations (Alliander et al., 2021; Stedin, 2023; TenneT, 2023). From a strategic perspective, this aligns overall efficiency and cost-effective solutions but also further illustrates the applicability of LEAN Thinking integrated with sustainability principles in real-world scenarios. “Modulair Bouwen" aka Modular Building (MB) is a term used by Alliander as a synonym for their standardized construction method and standardization program. They have standardized the most common type of (sub-)station within this program. Appendix XIX shows each of the MB -(sub-)station types. Starting with the acronym MB, it is followed by the electrical specification, for example 10kV/40MVA, and the main type of use like control station – RS, switching station – SS, and substation – OS. These technical standards are laid down in so-called "S-documents" (standardization documents) (Appendix XIII). The standardization documents offer detailed insight into the integration of nature-based solutions and modular construction methodologies during the development of electrical substations and energy infrastructure.

As standardized construction is becoming the standard practice in the grid infrastructure sector of the Netherlands, looking into how land is used within such standardized constructions becomes relevant. Inquiry into this issue is needed for producing estimates of the ecological impact of construction, which is currently required in a number of environmental reports and governmental rules (Qirion, 2023b). As of 2022, an area of at least 900 square kilometres is used by national infrastructure companies in the Netherlands alone (Alliander, 2022b; Groene Netten, 2022). As the grid operators of the Netherlands are owned by multiple and diverse Dutch governmental bodies, the pursuit of the SDGs will be a natural course of action to align in their interest. Grid operators now stimulate a shift in the consumption pattern of customers and the contribution to the energy supply via local production and demand during off-peak periods (Avramidis et al., 2023; Netbeheer Nederland, 2022). Especially in the sectors of residential, office, and commercial buildings, this is very important, since these three sectorial areas amount to more than half of the total energy consumption. This includes meeting the energy requirements of these sectors in a sustainable way by grid operators, and therefore contributing to the general objectives of sustainability in the Netherlands.

Integration of standardized energy grid infrastructures with NBS has huge potential for enhancing both urban sustainability and resilience. This concept of energy management infrastructure works toward enhanced energy efficiency, reduced carbon emissions, and stronger ecosystem services, contributing to global sustainability through the promotion of renewable energy use, creation of green jobs, and enhancement of urban environments for the purpose of climate control and biodiversity (Pinto et al., 2023; Sowińska-Świerkosz & García, 2022). Standardization will ensure that the systems are compatible and reliable in their operations, hence less costly in maintenance (Pinto et al., 2023). Therefore, it synthesizes the energy standardization with NBS for presenting a strategic pathway to create more sustainable, resilient, and livable cities. Standardization is already coined as best practice by most grid operators in the Netherlands. TenneT, Qirion and Enexis develop programmes regarding standardized construction for grid infrastructure projects (Alliander et al., 2021; Enexis, 2020; Qirion, 2023b; Stedin, 2023; TenneT, 2019).

First and foremost, standardization increases efficiency and cost-effectiveness when implementing NBS within the energy infrastructure. Secondly, the standardized designs and procedures for the implementation of NBS can be streamlined, hence cutting down on the overall project cost and timeframe. This would promote the scalability of the NBS solutions and their replicability for different energy systems and locations (IIASA, 2023). Thirdly, standardization, following the LEAN principles of Toyota and applied in standardized construction, will improve sharing and collaboration among the energy stakeholders concerning their requirements (Barber et al., 2023; Gao & Low, 2014; McEachen & Lewis, 2023; Shang et al., 2014). Shared standards and practices will enable stakeholders to share experiences, data, and good practices related to NBS implementation. It is in collaborative effort that the development of innovative solutions, speeding up of technological advancement, and creation of the learning required for a successful transition are facilitated; hence, benefiting an expedited way for achieving a more sustainable practice. Finally, the integration of standardized energy infrastructure with NBS has transformative benefits for urban environments. Reconciling technical standards and guaranteeing the interoperability of systems, this approach eases the seamless integration of NBS within energy systems. Through this interaction, improved efficiency and greater system interoperability lead to collaborative innovation (Hobbie & Grimm, 2020). In the end, that will sustain a resilient energy transition, leveraging the multifunctionality of NBS toward an address of urban climate challenges and enhancement of ecosystem services for renewable energy sources.

3.4. Conceptual framework integration

In this concept framework, NBS complement LTS and standardized building practices to give an overview with respect to the Dutch energy sector's grid infrastructure. This integrative approach will enable grid operators to have an informed decision in attaining the triple bottom line returned by the management of the system for environmental, societal, and economic performance in an effective grid manner, where natural, technical, and social systems interact harmoniously.

Change management is the part of the framework where the unifying theme in integrating this conceptual framework lies. It clearly conceives that transitioning to a more sustainable and resilient energy infrastructure will have to take a systemic approach as one makes the way through intricacies and barriers. This transformation is guided through Kotter's transformation model of change management (1995) in order to ensure that all the actors are working in harmony, are actively involved, and are motivated to have this application of NBS in the energy sector applied and become successful.

There is overlap among the conceptual framework, principles, and practices of NBS, LTS, and standardized construction and change management, which support the integration of NBS within the LTS.

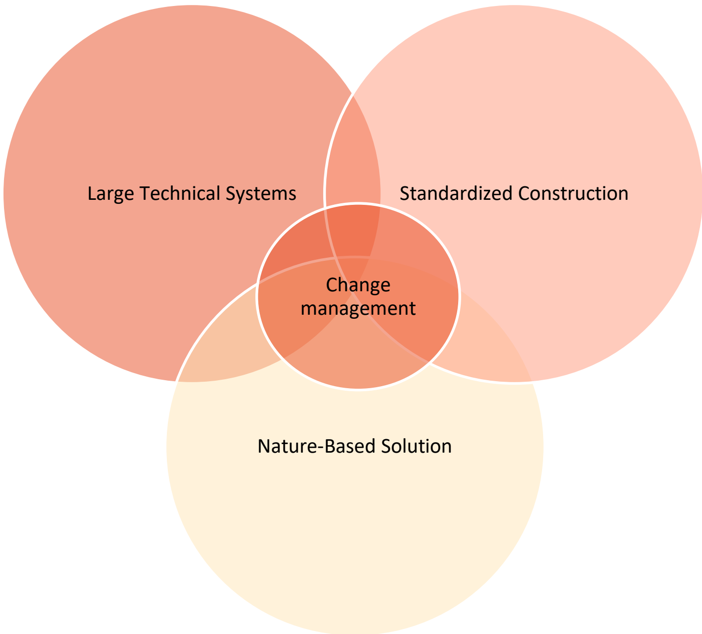


Figure 1 - Venn diagram overview of interconnectivity

NBS within the context of LTS is placed in view of the complex socio-technical interactions that shape grid infrastructure development. Change management supports organizational and cultural shifts towards the adoption of NBS in the energy system. It uses standardized construction practices in laying the foundation, which ensures uniformity, efficiency, and cost-effectiveness in the execution of NBS.

Change management enforces adoption and adaptation by dealing with probable resistances to changes and guarantees that actual implementation will be smooth. The framework will promote stakeholder collaboration by means of experience and data sharing, together with best practices that relate to NBS implementation. Change management must be carried out to ensure effective communication, build trust, and create a holistic environment that is regarded as supportive of knowledge sharing and innovativeness.

The framework is built on the platform of the change management overarching theme and reflects that embedding NBS, LTS, and standardized construction is hardly a technical exercise but actually a transformation process that involves all stakeholders in lockstep with a common vision for a sustainable energy future.

4. Methods

This research used the multi-perspective approach in relation to financial analysis, document review, and interviews. A combination of the LTS framework is used to understand grid infrastructure with standardized construction methods and structured the research according to the Integrated Community Energy Systems (ICES) framework by Koirala et al. (2016). The ICES framework is only used as a tool to structure the data collection and analysis. Having organized these findings within ICES's dimensions, the research offers a thorough analysis of NBS contributions to enhancing the sustainability and resilience of LTS. The ICES consist of four dimension that are used for the structure of this research; technological, socio-economic, environmental, and institutional dimensions.

To start, a literature review was conducted following the strict criteria for the needed literature as outlined in Appendix VII - Table 8. Based on these criteria relevant articles were selected (Appendix VII-Table 10) within the two primary literature streams: **Stream A** focused on NBS and TSO, and **Stream B** is centred on LTS and NBS. The chosen literature streams and articles provided the existing context of this research and helped to formulate the methodologies and choice of data sources.

The financial analysis drew on historical project investment data to examine trends and anomalies, this aligned with the socio-economic dimensions of NBS integration within a broader ICES framework. Document research delved into historical trends in NBS practices in projects as well as current standardization practices in the case company, utilized legal records, design documents, technical drawing and records, standardization documents (S-documents), regulation files and legislation documents to understand the institutional and regulatory landscape within ICES structure, as well as technical and environmental project details. Interviews, also structured by the ICES framework, captured real-time insights, providing a technical, institutional, and environmental dimension to explore technological advancements, institutional frameworks, and financial considerations.

4.1. Case selection

The choice of Stake (1995) case selection technique was theoretically based, arguing for Qirion as a suitable case study company. Theoretical sampling is one in which cases are chosen where rich information is expected to be drawn that will test or develop theory and have certain characteristics relevant to the research question (Bryman & Bell, 2007). Grid operators play a fundamental role in a comprehensive national energy transition (Kanabar et al., 2022). Qirion's commitment, as grid operator, to this transition is perhaps best reflected in their standardization efforts and alignment with the SDGs, making them a particularly suitable subject for this research (Qirion, 2023b). Moreover, as the researcher has been an employee of Alliander it facilitated access to information that would have been hard to obtain as an outsider. Therefore, this case selection might be a unique case, as the researcher has an exclusive opportunity for data accessibility previously inaccessible to others (Yin, 2009).

Alliander is the leading grid operator in the Netherlands, managing the electricity and gas grids that supply energy to homes, businesses, and institutions. Their focus is on delivering dependable, affordable energy while advancing the shift toward cleaner, renewable energy solutions (Alliander, 2022b). Their operations revolve around the use of land for the strategic positioning of substations, transformers, and power lines in different landscapes. Good land use is central to diminishing environmental impact, realizing regulations, and transforming the grid to accommodate emerging technologies and decentralized energy generation (Alliander, 2023). Qirion is a daughter company of Alliander and deals exclusively with complex energy infrastructure. Their scope of experience ranges from electricity through the integration of renewable energy sources to smart grid solutions.

The largest grid operator in the Netherlands was selected for this study due to their extensive land use and their influential position within the sector. Furthermore, having spotlighted Qirion as subsidiary of Alliander involved the share of green included in their grid expansion. Since the building space necessary for one (sub-)station is at least 160m² and a maximum of 890m², not considering the area of land required around the sites, Qirion stands out for offering capacity for increased energy infrastructure in the course of the energy transition (Qirion, 2023b; Sinke, 2022).

With an administrative focus on sustainability from a legislative perspective, Qirion is involved in extensive land use with respect to the construction of energy infrastructure projects. This includes the construction of new substations, laying of underground cables, and power lines above the ground. Their methodology includes responsible land use that is environmentally sensitive and responsible to community needs, together with the need for compliance with regulations. The outlook on energy will change the way Qirion continues taking responsibility for land use by treating the integration of renewables and enhancing grid resilience as part and parcel of the strategy (Qirion, 2023a). According to another market parties—with which one would include competitors and contractors—in comparable areas of expertise, Qirion has functioned as an example for other grid operators regarding efforts in standardized construction (Bouwmeister, 2021; Qirion, 2023b; Sinke, 2022). These were some of the factors that met the key criteria for choosing Qirion as a case for this research (Bryman & Bell, 2007).

4.2. Data collection

The data collection consisted of three successive parts; **1)** In-company research focussing on financial data as well as **2)** documents reviewing guidelines, requirements and designs; and **3)** interviews with stakeholders within the company. The data collection continued building upon the structure of the ICES framework to ensure that all relevant fields of interest were covered.

Source	Information Content	Relevance to ICES Framework
Financial Data Analysis	Examining historical project financial investment data	Provided financial insights within the socio-economic part of the ICES context
Document Research	Validating arguments regarding the design choices, providing context regarding financial choices, standardization documents and expenditures based on the financial data.	Offered context, institutional insights, guidelines and requirements, and regulatory and institutional aspects within NBS application, including the detail of the standardization files.
Interviews	Gathering perspectives on ongoing NBS initiatives, strategies, trial projects, policymaker viewpoints, company culture toward NBS and additional context about design choices	Captured current NBS status, technical and environmental aspects, and stakeholder perspectives

Table 1 - Data context

4.2.1. Financial data

The research analysed financial data from the period 2018 to 2023, this period provided between 50 to 100 investment projects annually. This specific timeframe was selected because standardized construction policy framework, as mentioned earlier also known as Modular Building (MB), commenced in 2012. The six year gap between the start of MB and the financial analysis is to provide the new MB framework to growth and to mature as a policy framework. Also so that the first projects using the MB framework has actual finalized costs of the relation phase of the projects, as a investment project takes at least five to six years to be finalized (Nederlandse Vereniging Duurzame Energie, 2022). This resonates with the fact that the research focused explicitly on standardized construction, hence finding other timelines irrelevant to the course of the research study. Put another way, it was intended to indicate that the MB framework will be the base point for any of the projects selected, and not that all of them are developed using only the MB design: some form of custom design work is typically almost always necessary. The data of these projects relate to the budgeted/planned costs associated with the implementation of NBS in the energy grid infrastructure, rather than the actual costs. Furthermore, these project all have to follow the standardization framework documents, also known as S-documents.

Qirion uses a financial system with Cost Breakdown Structure (CBS) to organise and categorise cost in each investment project, specific number related to NBS are "xx10" (Site layout) and "xx73" (PV systems), an elaborate explanation of these two CBS numbers can be found in Appendix X. Furthermore, a complete list of all CBS numbers can be found in Appendix IX in this research, the earlier mentioned CBS codes were used to filter and select the data.

Potential limitations and considerations to these codes are the aspect of obligation and mandate, wherein CBS usage is obligatory from the customer side and ACM (Authority for Consumers & Markets), it's also guaranteeing standardization but, at the same time, probably decreasing flexibility. Only a few CBS codes are in use, thus excluding other CBS numbers. This narrow focus is meant to capture the costs related to NBS but could actually overlook some aspects not covered by these codes. This is mainly because there is no guarantee that costs are forecasted on the correct financial code, as human error within the financial accountability per project is a persistence issue within Qirion. It simply means that there could be room for error when analysing the CBS codes and related costs.

Only the two of these CBS codes were used because no other code combination had a relation to NBS, and thus no other code combination was going to be included. Furthermore, only investment projects for (sub-) stations from 20MVA and 10kV up to 160MVA and 150kV were used for the data collection. The data collection only used direct material and service costs. No external engineering or internal personal costs were included because, according to the Qirion financial structure, it is impossible to split these costs from each other. The data collected did not contain profit, risk, general and overhead costs. Information was extracted from the ERP[1] system—SAP[2]—which contained all the financial data of Qirion, with a particular focus on data gathering in the 2018–2023 period. Financial data was anonymized so that data cannot be referred back to a specific investment project by its name, only a region, project number (which is only known internally), and timestamp.

4.2.2. Project documentation

All legal, permitting, design, and environmental requirement documents were reviewed to gather more in-depth information on historical and current trends of land use. Other documents included design standardization files and project documentation. The applicable information gathered from these documents were summarized and presented for the projects that are, based on financial data, outliers. These documents focus on spatial integration, (technical) design, and standards of the governmental welfare committee of various municipalities, design choices, to what extent they comply with the standardization documents, and land use. Such information gave qualitative information to supplement the financial information by giving a more complete view of the land use and standardization level. The financial data was evaluated by carefully checking all internal documents related to the respective outlier and perfect fits of the investment projects, such as legal and permitting documents, design files, standardization documents, and environmental requirements. Also, it involved a review of the standardization documents (S-Documents) detailing Qirions' general framework of standardization for its (sub-)stations and other potential policy documents and information sheets for external use. The main documents are **1)** the environmental documents, **2)** the basic design document (BO), **3)** any other design report, ecological and/or environmental assessment, study report, permit report and/or regulatory document and **4)** standardization documents. These are the written foundations for each of Qirion's investment grid projects, although not all the projects will have all the mentioned documents. The number and depth of the documents per project depend on the size and complexity of the project

[1] ERP software (Enterprise Resource Planning) integrates various business processes and functions into a single comprehensive system to streamline operations and improve efficiency.

[2] SAP software (Systems, Applications, and Products) is a leading ERP solution that integrates core business processes across finance, HR, manufacturing, and supply chain, providing real-time data and analytics to enhance efficiency, decision-making, and overall business management.

(Appendix VIII). These documents have been standardized for over many years starting from 2010 and detail the drawings, arguments, and documentation of what is being built, why, how, and which standards are being followed. The documents contain the details regarding site layout plans after, and during, the completion of a project, spatial integration plans for nature, the legal frameworks that need to be complied with, and the details of how the environment is impacted by the project. These documents are available for all Qirion employees including the researcher. Also, the standardization documents with a link to NBS were studied to understand the procedures and extent of NBS of standardization.

4.2.3. Qualitative interviews

In-depth interviews were conducted with stakeholders in the field of NBS and the standardised building frameworks of Qirion, also known as Modular Building (MB), explaining the used function titles of the interviewees. This provided data on valuable qualitative data relating to the challenges, opportunities, and perceptions of integration of NBS into grid infrastructure and the aspects of standardization in the construction of (sub-)stations. For that reason, multiple persons associated with standardized building, in Alliander's internal terminology; Modular Building, were being interviewed. With the scope of MD, NBS initiatives were included, creating a synergy for the purpose of these interviews and provided a multi-perspective angle from some of the interviewees. Furthermore, interviewees were also requested to provide insights into the potential impacts of NBS on climate mitigation efforts and the possibility of including NBS within standardized construction practices (Appendix I). The table below shows the interview details, and for reasons of privacy the names of the employees will not be mentioned[3]:

ID	Function titel	Duration (min)	Date	Location
a	Innovation Manager Modular Building,	50	22-4-2024	Offline
b	Manager Engineering and Legal,	50	5-5-2024	Online
c	Chairmen Modular Building,	40	23-4-2024	Offline
d	Product Owner Modular Building,	40	23-4-2024	Offline
e	Department coach & Project Manager Modular Building,	45	14-3-2024	Offline
f	Chairmen Biodiversity Team.	50	24-5-2024	Offline

Table 2 - Interview details

The interviews were semi-structured, with a set of open-ended questions that were used to obtain experiences, opinions, and viewpoints of the respondents following the ICES framework as a guideline to strengthen a complete knowledge exchange (Appendix II). The interviews were either held face-to-face or through a secure online platform, Microsoft Teams, depending on availability and preference of the interviewee. The following areas on which the interview guide has focused are:

- Standardized construction,
- Nature inclusive building,
- “Green-first” versus “technical superiority” philosophy,
- Financial opportunities,
- Social responsibilities,
- Potential of NBS for Qirion,
- Company culture.

A detailed interview guide, guaranteed consistency, transparency, and replicability of the interviews, is in Appendix I. The guide defines Qirions’ thematic areas of possible impacts by NBS. Explained in a codebook for analysis are criteria for characteristics of concise and equal interviews (Appendix II). In this

[3] The interview findings have been anonymized at the request of the interviewees, as some statements may be sensitive within the organization under study. Therefore, in this research no interview outcome or quote will be connected to a specific interviewee of interview to protect the data sources.

way, enabling systematic data analysis, this guaranteed that the results were structured based on the ICES framework, the details of this codebook can be found in Appendix II.

4.3. Data Analysis

The researcher has adopted a multilateral approach to analysis with regards to the integration of NBS within the standardized building frameworks at Qirion. Financial data analysis, powered by Python and Excel, conducted an analysis of expenditure patterns and trends using regression analysis and trend analysis. Document review analysis drew insights from outlier and perfect fit projects, based on the aforementioned financial analysis, and standardization documents with technical, environmental, institutional, and legal reports. This included details of the standardization documents and other relevant policy documents and internal and external information sheets. The qualitative analysis of interviews in this study was informed by a codebook (Appendix II) and used a color-coding system using the software "MAXQDA". This provided a structured manner to explore the perceptions of the stakeholders' views. The combination of the three methods allowed for a holistic and broad understanding and integration of the challenges, opportunities, and decision-making regarding NBS integration within standardized grid infrastructure construction.

4.3.1. Trend analysis and forecasting

The financial data analysis consisted of the following parts:

- Data cleaning by verifying accuracy, addressing inconsistencies, and handling missing data,
- Trend analysis for plotting financial metrics over time and space to identify trends and anomalies, per region,
- Forecasting based on the trends and anomalies,
- Interpretation of the trends and forecasts.

The main tools for the analysis was MS Excel and Python. These tools provided the flexibility and the opportunity to work with large datasets from the ERP software SAP source. The methodology followed based itself on regression analysis (Bryman & Bell, 2007; Diaz, 2022). Having started off with 4487 records from the ERP systems, encompassing all Alliander projects within the specified timeframe. This ended up with 158 projects, covering the date range from 2018 to 2023, including 19 fictitious, theoretical complete modular construction standard projects, the so-called Modular Building (MB) projects known as MB projects (Appendix III).

The right choice of approach for conducting the regression analysis was very important to correctly model the relationships between variables and reduce possible issues within the financial data. At the most basic level, linear regression is one of the best ways to capture a linear nature relationship of the variables over time. For intrinsic complexity in the dataset and the necessity to focus on some of the CBS codes related to NBS costs, other methods like lasso, polynomial, and ridge regression have distinctive benefits and are tried for the advantages. Next to these analyses, compounding annual growth rate and yearly average change calculations for NBS expenditure and overall investment were used to provide additional details on the dataset.

Three different regression analysis methods were used, to find the best fit for the regression analysis. Firstly, lasso regression was tested, as it has the potential for variable selection. It does this by penalizing some of the coefficients to zero; hence, filtering out irrelevant variables and only important features related to NBS costs are used in the model. This therefore cured the limitations of CBS codes and trim down the analysis to only the factors that have impact.

Secondly, ridge regression was a remedy for the common problem of multicollinearity in cases where one is dealing with several predictor variables. Adding a penalty term on the right-hand side of the regression equation stabilized the model from becoming too sensitive to small changes in the data by avoiding coefficients that are overly sensitive. It is this regularization technique that offered improved robustness of analysis and reduced the risk of overfitting, hence improving the reliability of the forecasts.

Finally, polynomial regression generalized the concept of a linear model by fitting more complex, nonlinear curves. This technique squares or raises independent variables to higher powers, which capture subtle trends in the dataset that a simple linear model would miss. While polynomial regression may greatly raise the accuracy of predictions through modelling nonlinear relationships, it risks overfitting, or sensitivity to the fluctuations in the training data, for a model.

Though linear regression provided a very simple way of modelling relationships, lasso, polynomial, and ridge regression offered other tools to handle specific pitfalls that were present in the dataset. Regional trends metrics were analysed for the financial dataset from 2018 through 2023 also using linear, ridge, polynomial, and lasso regression models built for each region (Appendix V). The best fitting regression method based on the mathematical scope and outcome were selected for the analysis, overall the linear regression method seemed to be the best fit.

The overall results of the financial analysis were summarized into four sequential sections as follows.

General overview; Firstly, a general view of the expenditure for the specific CBS codes are shown for the standardized construction designs without any custom design work or deviant regulatory remarks, to provide an initial context and frame of reference for the rest of the data. The analysis showcased a general overview of the average expenditure on the mentioned CBS codes per region as a ratio to the total investment and per region. It gives the overall understanding of the average expenditure on the selected CBS code in comparison with the overall cost. From here, the highest region expenditure ratio was dissected per year, to potentially view a trend line in each region.

Outliers; The outliers are defined as 10 projects in terms of highest level of expenditure on the selected CBS codes. This was meant to analyse if a visible correlation between the total investment costs and the ratio of expenditure for the selected CBS codes for these outliers was present. The relationship correlation was calculated with a Pearson correlation test. Furthermore, the top 3 projects per region were analysed based on the relative percentage expenditure on the selected CBS codes. Next, the standardized MB theoretical (sub-)stations were used as a benchmark and as showcase for an all standard (sub-)station following only the S-documents without any compromise or custom design.

Trends; A view of the average expenditure per year in percentage of the total cost was made, to visualize a possible trend in the expenditure of the selected CBS codes, both overall and per region. The correct technique was determined for the regression analysis. This was done by comparison between three different techniques, linear, lasso, polynomial and ridge (Appendix VI and Appendix V).

Comparison; This section presents the best-fitted regression model for each region and used these results to predict future trends by extrapolating the regression outcomes. Additionally, the expenditure and potential trends were contextualized by comparing them with standardized projects (MB theoretical projects). The regression comparison showed the most fitted regression method for the year-on-year comparison and the region trends were made by the earlier mentioned Python code that can be found in Appendix V and Appendix VI.

The outcome of these part resulted in the following:

- Average expenditure on specific CBS codes per project and per region showcased spending patterns,
- Trends in regions with the highest expenditure were identified,
- Outliers, particularly the 10 projects with the highest expenditure on selected CBS codes, were analysed to detect any significant correlations between investment costs and expenditure ratios,
- Selecting the best fitting regression methods, then used to make predictions and compared against standardized projects.

For the final results, the financial analysis were combined with the other data analysis results for an overall overview and aggregation of the findings.

4.3.2. Qualitative content analysis

Based on the outcomes of our financial analysis, the outlier projects were analysed using all relevant document for the analysis. (Appendix VIII). This methodology merged qualitative content review with Large Languages Modelling (LLM) techniques where ChatGPT version 4.0, February 2024 version, was used. With increased usage of LLM, it can also reliably be used to summarize and review documents with the use of safeguards (Antu et al., 2023; Koh et al., 2023; Liu et al., 2023; Mandvikar, 2023). The used prompt and details of used software can be found in Appendix XI. This prompt for the use of the LLM has been reiterated with the help of the LLM by back-and-forth to make sure that the structure of the output is conformed to the desirable structure of the output (Appendix XI). The process the LLM used involved an in-depth review of the documents and summarizing them with respect to the context of NBS. It extracted all the information about any wording related to NBS and the earlier mentioned CBS codes like trees, nature, site planning, terrain, biodiversity, shrubs, natural layout, solar panels, spatial planning, nature maintenance, plants, green infrastructure, water management, ecological connections, sustainable building, green roofs, rainwater harvesting etc. The output of the LLM was manually spot checked for possible errors and hallucination of the LLM.

The results of this content analysis were structured according to the ICES framework with the additional of the potential consideration, impacts and/or advantages, and potential compliance and strategy (Appendix XII). These analyses have explained the outliers and trends, providing a strong basis to understand decisions related to NBS expenditures. This document review, together with an analysis of the financial data, was used to focus future interviews. The structure following the ICES framework provided the contextual framework for setting up the interviews in a later stage.

Additionally, there are other key documents, such as flyers targeting governmental bodies, other potential policy documents, information sheets for external use and various standardization design documents (Appendix VIII). These documents were summarised to reflect all mentions of NBS and the mentioned CBS code concerning NBS, including the example list mentioned above, with the same LLM prompt as mentioned earlier and in Appendix XI. One summary was made similar to the project specific documents and another summary was made around the earlier mentioned NBS terminology and how it is mentioned in each standardization file (Appendix XIII), both of the summaries adhere to the ICES framework. As results, an overview of the projects selected in the financial data analysis was presented with their connection to NBS and selected CBS codes. This was accompanied by an overview of the NBS incorporation in the standardisation files. It was finally closed with a summary of quantifiable requirements, which are hard rules, and the recommended guidelines, which are soft rules.

4.3.3. Interview analysis

Code Category
Technological Dimension
Socio-Economic Dimension
Environmental Dimension
Institutional Dimension

Table 3 - Interview code families

Interview analysis is a type of qualitative research analysis method done on data retrieved from interviews, using a codebook and color-coding (Bryman & Bell, 2007). The interview analysis involved the creation of a codebook—that is, a list of codes with categories capturing major themes and ideas in the data (Appendix II). These interviews helped in discussing possibilities for the strengthening of NBS design considerations in the standardized construction method. Every code is, in itself, a concept or idea relevant to answering the research question, and the researcher applied each code to relevant segments of the data using the forementioned software MAXQDA. The key code families in Table 3 came directly from the ICES framework to keep consistency in the data analysis, the complete code list can be found in Appendix II.

In the interviews, NBS terminology was used in a multitude of ways for simplification and exemplification, e.g. Nature Inclusive Building was used as example of NBS. The analyzation of the data from the interviews, identification of the related segments, which fall under each code, was done by studying the transcripts of each interview. This process of segmenting and identification the data is called coding (Sekaran & Bougie, 2016). For this research this was done using a program called MAXQDA. After coding, the software MAXQDA was also used to structure the data according to the codes. This was done by color-coding, by giving each code segment a specific colour for convenient analysis over providing a colourful representation of each interview. This approach helps in pattern recognition and in structuring and forming clusters across the codes (Bryman & Bell, 2007; Rädiker & Kuckartz, 2020).

After the data was coded and then colour-coded, the analysis continued to identify patterns and themes in the data. In order to identify patterns and themes, the first step was to group the codes that have similar meanings or present similar concepts, termed "code families," as presented in Appendix II. The researcher was then able to look for any patterns that occurred within these code families, like similarities in content, context, or frequency of codes. Different functions of the software MAXQDA have supported this process. First of all, a summary overview of frequency per code and per code family was made. Secondly, a code matrix was created in order to visualize the different frequencies per interviewee per code. In this way, the similarities and differences per interviewee showed up based on the codes and colours. Thirdly, it also generated a document comparison chart that looked at the flow of each interview per code, this provided a comparison method to check if each interview was done in a similar order. Fourthly, the relation between the codes and code families was analysed by the intersection of codes in every coded segment. Finally, the code relationship was supported by a different relationship analysis of the codes based on the occurrence of codes in the same interview. Statistical analysis related to the data—like the frequency of which the codes appeared or the percentage of participants to mention one of the themes or codes—was also being done using the software MAXQDA.

These analyses are a quantified method for finding patterns and themes. The themes nuances and variations within these patterns were further analysed by searching for sub-themes or categories within the overarching family code or themes, and by exploring ways in which the themes vary across different cases or contexts. Finally, a qualitative summary of all the interviews was provided to present the minute details of each interviewee and the tendencies of all of them as a whole, these summaries also followed the ICES framework for overall consistency across all analysis methods and data sources.

4.4. Ethical Considerations and positionality

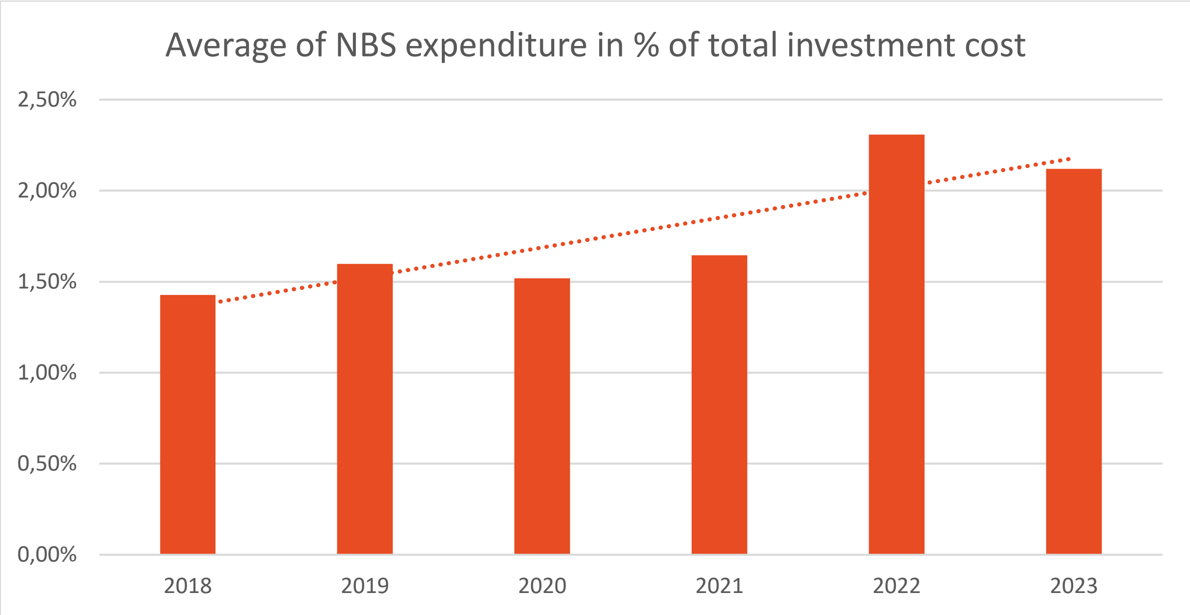
The research followed the ethical principles formalised by the University of Twente, taking into account the informed consent of participants during the interviews, maintaining confidentiality, and absence of harm. The data collected during this study is kept securely on Qirion's servers and used only for the research purposes. The financial data is anonymized; therefore, it could not refer to a certain investment project name but only to a region, project number and timestamp. The names of all the interviewees were not disclosed throughout the research, only the formal position; this information is not in the public domain. The fact that the researcher is an employee at Qirion may mean that there is a personal bias that could have a bearing on the outcome of the research. Hence, to ensure the reliability and validity of the research, there was a concern for constant reflection on whether or not the data analysis is done neutrally and in a careful manner. Therefore, seeking different opinions by way of literature reviews attempted to overcome these biases. To minimize biases, it was crucial to maintain a critical and objective perspective throughout the research process. It implied a robust, explicit design and using data from multiple sources and stakeholder perspectives. In addition, possible biases needed to be acknowledged and addressed within the data collection and analysis process itself. The ethics committee from the University of Twente reviewed this research and accepted the proposal concerning data collection and data storage, based on internal academic standards.

5. Results

Thematic organization of the Results Section covers the qualitative and quantitative data in detail for findings analysis on the study. This structure will permit the discussion of complex relationships across the financial perspectives and sustainable land-uses with the broader socio-technical context conditioning grid infrastructure development. It investigates the evolution of NBS spending, compares theoretical standards with actual costs, challenges together with opportunities in the integration of NBS, and perceptions of divergence within the organization.

5.1. NBS expenditure in space and time

Overall, the average NBS expenditure has a positive linear slope of 0.16, this means that every year, on average, the expenditure increases with 0.16% compared to the year before. This is shown in Graph 1 below. The linear growth per year is deemed reasonable accurate based on the MSR[4] (0.0289) and R-squared[5] of 73% and is best fitting of the four tested regression methods (Appendix VI). This growth rate is corrected for annual inflation.

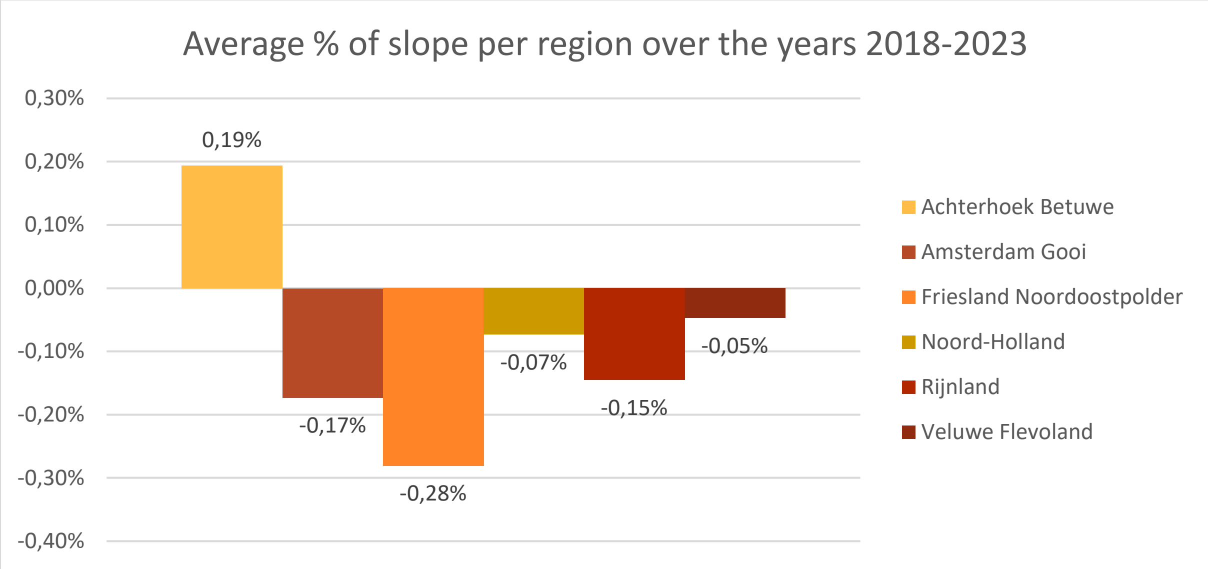


Graph 1 - Average % of NBS expenditure

When the trend is split into regions, as shown in Graph 2, we see that only one region, "Achterhoek Betuwe", has a positive slope for the average expenditure on NBS, 0.19%, all other regions show a negative slope on NBS expenditure over the years, meaning that on average the regions spend less on NBS compared to the year before. This trend is based on the regression analysis in Appendix V. The positive trend of the region "Achterhoek Betuwe" is further supported by document analysis, which indicates that projects in that region, and in the region of "Friesland Noordoostpolder", place a higher emphasis on community engagement, actively communicating with and involving of local communities, all indicators of NBS, over the years which in turn leads to a higher expenditure on NBS (Appendix XII).

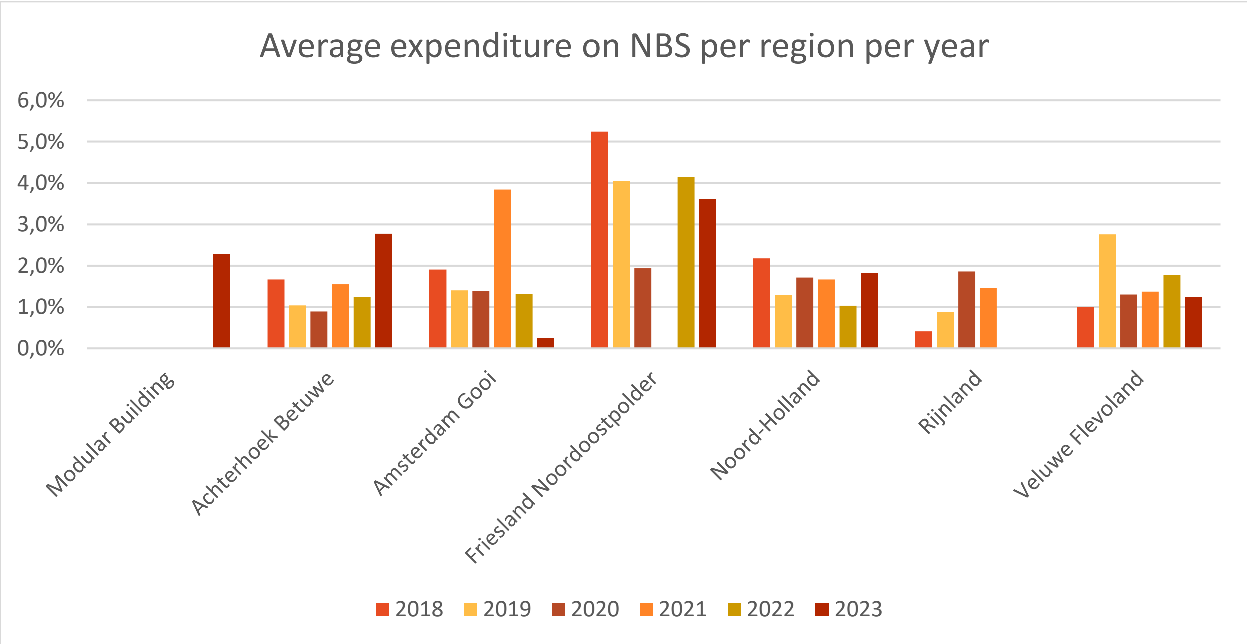
[4] Mean Squared Error produces a number that gives an idea of how close the predicted values are to the actual value. It is the average of the squares of the differences between the predicted and actual values. The lower the MSE, the better the model fit.

[5] R^2 (R-squared) is a statistical measure that calculates the proportion of variation in an independent variable related to a dependent variable or variables. Simply stated, R^2 informs you of the percent of the variation in the data that your model accounts for. The higher the R^2, the better the fit generally is.



Graph 2 - Trend per region in %

The region "Friesland Noordoostpolder" has an average spending on NBS higher then regulated by Modular Building program, as shown in Graph 3 and Table 4 below, even though it has a decreasing average spending trend. The regional differences are also noticeable in the regression analysis, supporting the regional differences mentioned in the interviews (Appendix V and Appendix XII).



Graph 3 - Average % of NBS expenditure per region per year

"Friesland Noordoostpolder" consistently spends more on NBS annually than MB, except for the years 2020 and 2021, as shown in Graph 3, even though the region shows a decreasing expenditure trend. Despite these outliers, cumulatively, "Friesland Noordoostpolder" spending on NBS is almost double that of all other regions. Four out of the six regions have at least one year where the average spending on NBS exceeds MB program standards.

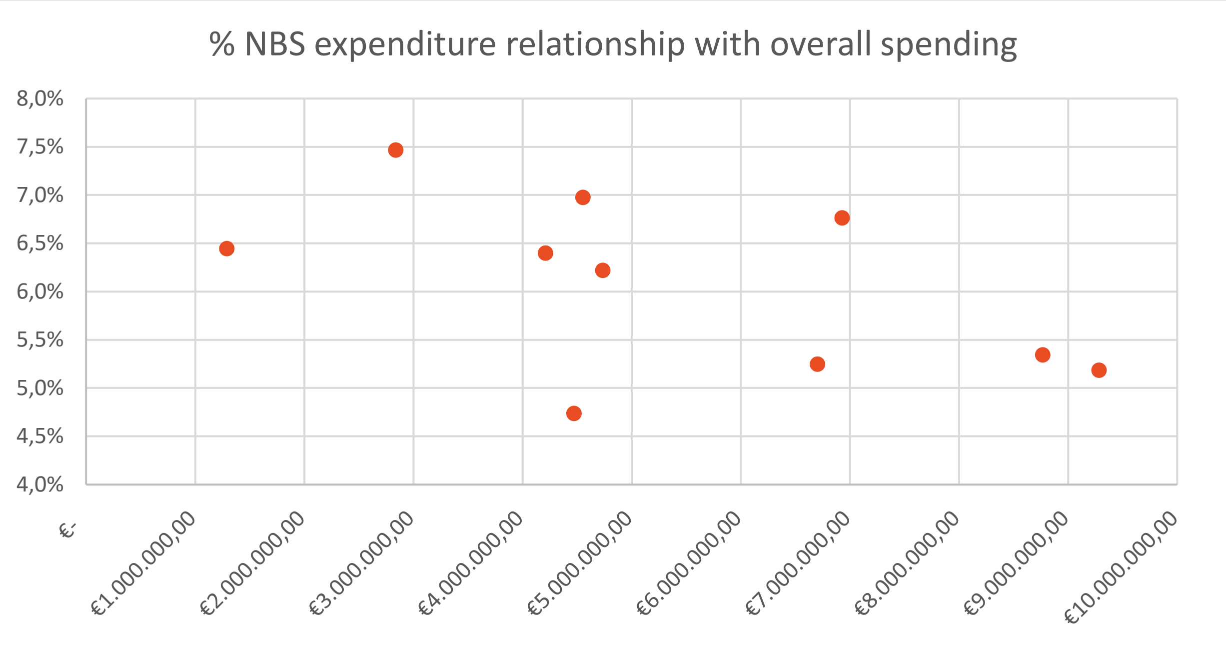
Region	Average spending
Modular Building	**2,28%**
Achterhoek Betuwe	1,53%
Amsterdam Gooi	1,69%
Friesland Noordoostpolder	3,16%
Noord-Holland	1,62%
Rijnland	0,77%
Veluwe Flevoland	1,58%

Table 4 - Average spending on NBS in %

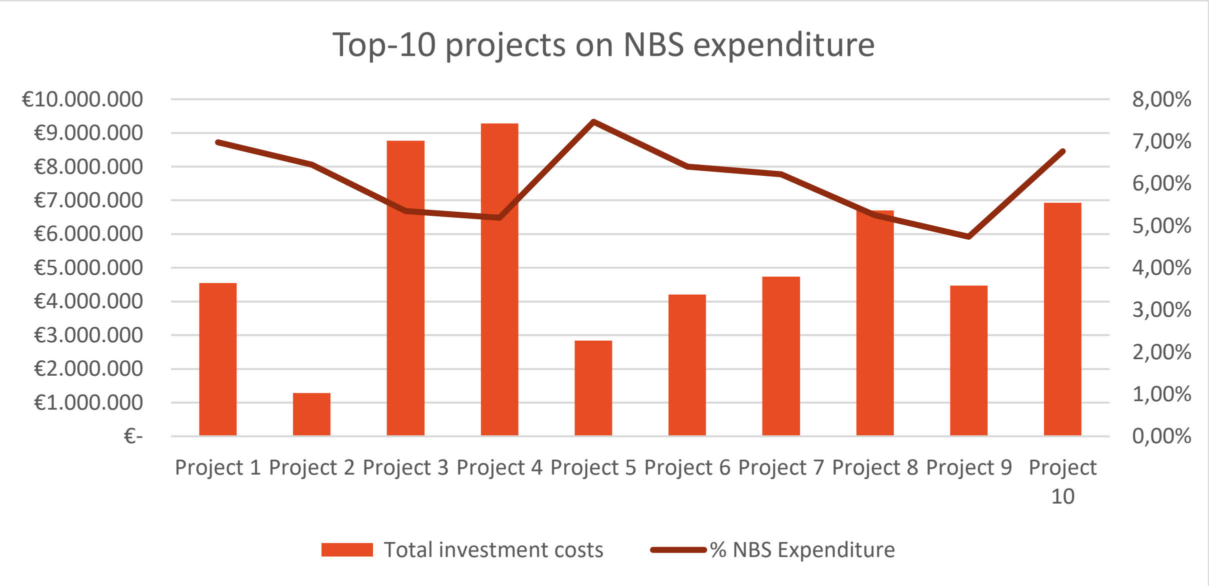
5.2. From paper estimates to real costs of NBS in Modular Building

The theoretical financial standards of Modular Building (MB) have a range of NBS expenditure between 1.08% and 3.43%, averaging on 2.3% for all different configurations (Appendix XIX). These percentages of NBS spending are in stark contrast to the projects researched. Only 34 out of 158 projects (21,5%) have an expenditure equal or greater than the average of MB, averaging on 4.04%. When taking a look into the top 10 highest expenditure on NBS of the 6 year researched, there is a no noteworthy relationship between the spending on NBS and the overall project costs, as shown in Graph 4 and Graph 5 below (Appendix XXII).

The financial outliers, the aforementioned top 10 projects, are further substantiated by the document analyses (Appendix XII and Appendix XX). From the document analysis of these 10 projects, it is shown that external stakeholders pushed for additional spending on NBS compared to the NBS spending standardized by the modular building program (Appendix XIX). Showcasing an external motivation to spend additional funds on NBS.



Graph 4 - % NBS expenditure relationship with overall spending



Graph 5 - Top-10 projects based on NBS expenditure

The most frequent code family mentioned in the interviews, as shown in Table 5, mentioned across all projects is the environmental code family with 31%. Particularly the integration of NBS and the projects' pioneering status and role-model qualities (Appendix XIV).

Code Family	# code uses
Technological Dimension	136
Institutional Dimension	82
Environmental Dimension	146
Socio-Economic Dimension	109

Table 5 - Code family count

The findings from the 10 outliers were further explored during interviews, which provided a more detailed perspective on the financial and documented results. During these interviews, the following key findings where highlighted:

- The environmental benefits of integrating NBS into construction projects are strongly emphasized across all interviews,
- The interviewees emphasize the need for organizational commitment and regulatory support to drive the integration of sustainable practices into construction projects,
- The interviewees agree that incorporating natural elements into building projects can significantly contribute to environmental sustainability, providing tangible ecological benefits that extend beyond the immediate project areas,
- There is a recognition of the growing institutional awareness of the value of NBS, but also a call for greater commitment and clear guidelines to overcome existing barriers,
- The participants note the importance of both top-down leadership and bottom-up initiatives in creating and cultivating a culture that values and prioritizes sustainability,
- The interviewees point out the traditional risk-averse and technically driven mindset within their organizations, which can impede the adoption of innovative sustainable practices according to the interviewees,
- The overall lack of ownership and creating a feeling of urgency to continue after a pilot or initiative sometimes leaves much to be desired.

Overall, the 10 outliers have a higher-than-average expenditure on NBS compared to MB standards. The interviews reveal a strong intrinsic motivation among Alliander's managerial and administrative employees, in contrast to the director level interviewees and engineering staff connected to MB, to enhance NBS integration as they recognize the importance of sustainability but have difficulties integrating these viewpoints in their field of expertise. Furthermore, there is a lack of commitment and feeling of ownership for long-term standardization of the integration of NBS in the standardization frameworks (a.k.a. Modular Building). The visibility and willpower from a top-down perspective are not in line with the bottom-up perspectives and the potential to leverage grassroots initiatives beyond the initial pilot phase is limited due to this. The interview analysis and documents analysis indicate that the current standards are perceived as the bare minimum. When a project exhibits a higher level of NBS commitment, mainly due to external motivators, it is internally regarded as a pilot project, and the lessons learned are not incorporated into the standardization documents (Appendix XIII) nor used during consecutive projects as mentioned during the interviews. Even though these top 10 projects showcase a higher spending, and the managerial and administrative interviewees show a high level of intrinsic motivation toward NBS implementation, this is not reflected in the standardization documents which are managed by top level managers, directors and engineering staff. The document analysis showcases multiple practical examples of NBS implementation, such as green roofs, tree stumps, grass tiles, hedges, insect hotels, sedum, stone insect walls, brushwood fences, and shrubs. These examples demonstrate low-cost NBS options that could be utilized in future standardizations requirements. Currently, the examples are from a specific document "Inspirational guide to Biodiversity", which is recently published internally and showcases these low-costs examples and serves merely as an inspiration guide only rather than setting new standards or policies as strongly emphasised during some interviews. A snippet of this document can be found in Appendix XXI.

5.3. Inequality in standardization

The analysis of documents reveals a significant difference between the types of documents (Appendix XII and Appendix XIII). The design documents for technical aspects (S-documents) are highly detailed, with strict guidelines and requirements that must be followed precisely and are checked at multiple project milestones. These S-documents ensure that all technical, electronic, and construction elements are clearly specified and meticulously implemented. In contrast, the chapters and paragraphs in these standardization documents on NBS integration, as outlined in Appendix VIII and Appendix XIII, lack such rigorous wording and context. While these documents mention site layout and nature, they do so in a suggestive manner without strict rules, using phrases like "...when possible, try to..." and "...if needed then...". Consequently, each project only needs to meet the minimal requirements set by municipal and government regulations to comply with MB standards. Interviews highlighted this disparity, with multiple participants noting the difficulty of integrating NBS with technical reliability. They emphasized that the grid operator's primary focus is on maintaining grid reliability and affordability, which makes combining NBS with technical requirements challenging even though many interviewees also show an intrinsic motivation to integrated NBS in the grid infrastructure.

These following themes were mentioned multiple times and are shown via two different analyses, relationship by intersection and relationship per proximity (Appendix XVI and Appendix XVIII). This interview analysis identified the following recurring themes combinations:

- Company culture - Challenge to standardize NBS,
- NBS - Potential of NBS for grid operator,
- Social responsibilities - Potential of NBS for grid operator.

The combination of these themes, company culture, potential of NBS and challenge to standardize NBS, are suggestive for the internal contradictions the company has, especially in combination with the differences in interests between the managerial employees and the engineering employees concerning the intrinsic motivation on NBS implementation. These aforementioned theme combinations were mentioned most frequent, six times or more, within the same segment of each interview.

A following proximity analysis, Appendix XVII, of the interview codes showed similar patterns of contradictions, with the highest scoring code proximities (15 or higher) including:

- Potential of NBS for grid operator – NBS,
- Potential of NBS for grid operator - Social responsibility,
- Challenges to standardize NBS - Company culture.

A thematic analysis of the interviews summarizes the data from a list in Appendix XIV by showing the number of codes used in all interviews. The table shows that the most frequently mentioned codes during the interviews are directly related to the topic of challenges to standardize NBS, NBS, company culture and social responsibility. Company culture is the odd result in this list as the interviewee questions did not mention this topic as shown in Appendix I.

Code family	Code	# Code used	% Code used
Technological Dimension	Standardized Construction	43	9,09%
Institutional Dimension	Company culture	41	8,67%
Environmental Dimension	Social Responsibilities	35	7,40%
Environmental Dimension	Nature Inclusive Building	31	6,55%
Environmental Dimension	Potential of NBS for Qirion	31	6,55%
Socio-Economic Dimension	Financial burdens	31	6,55%
Technological Dimension	NBS in standardization construction	31	6,55%
Technological Dimension	Tension between nature and reliability	27	5,71%
Technological Dimension	Challenges to standardize NBS	23	4,86%

Table 6 - Summary of interview quantified code summary

The document analysis shows that the grid operator struggles to standardize NBS to the same level as the technical aspects but at the same time the interview analysis also shows the potential of the standardization of NBS. From the interview we learned that the company culture is heavily focused on risk aversion, therefore leaving out NBS all together, or diminishing it at the least from a standardization standpoint, instead of focussing on it. Interviews reflected this company culture, with participants consistently pointing out that a traditional, risk-averse, and technically driven mindset within their organizations impedes the adoption of innovative sustainable practices, without being able to clearly identify the reason, even though they emphasise the importance of NBS. The interviewees emphasized the need for a greater degree of awareness and overall commitment at all organizational levels. This absence of awareness and commitment, according to the interviewees, prevents effective integration of NBS into standard practices.

5.4. Clashing priorities

The results show a significant divide within the organization regarding the implementation of NBS in investment projects, based on the interviews concerning the themes of company culture and risk awareness. While managerial and administrative employees see NBS as a hygiene factor – a new founded foundation - and a crucial part of social responsibility. Others, especially those focused on technical and engineering aspects, view NBS as unnecessary and as a potentially risk for the overall grid reliability. This divide reflects differing prioritizations and perspectives within the company, highlighting tensions between innovation and traditional technical reliability and risk averseness. This is also reflected from a hierarchical perspective; higher managerial employees (directors alike) see NBS as a risk to the overall company goals and do not see the need to focus on it as there is no incentive, nor imminent need, to report NBS integration to their directors. It is important to understand that the managerial and administrative employees can, and do, provide input to the standardization team; however, it is ultimately the engineering and technical staff who decide how, why, and if it is implemented, and provide the know-how to implement these inputs technically, the director level provide the potential funds for this implementation.

The grid operator does take multiple actions to adhere to its social responsibilities in terms of implementing NBS in its standardization (sub-)station construction, as minimal as it might be in comparison to the technical requirements. In term of actual NBS implementation, as shown in the latest S-documents of NBS implementation (Appendix XIII), it is calculated in Table 7 that the costs related to these implementations are minimal in comparison to the cost of the overall project, 1,4% to 2,3% of the overall cost.

Year	Average of total investment	Average of NBS expenditure	Average NBS % expenditure	Average change investment (from previous year)	Average change NBS (from previous year)
2018	€ 4.999.835	€ 87.845	1,43%		
2019	€ 8.379.541	€ 123.100	1,60%	67,60%	40,13%
2020	€ 7.348.441	€ 106.416	1,52%	-12,30%	-13,55%
2021	€ 8.218.479	€ 136.578	1,64%	11,84%	28,34%
2022	€ 5.877.350	€ 145.574	2,31%	-28,49%	6,59%
2023	€ 7.406.734	€ 135.307	2,12%	26,02%	-7,05%
Grand average	€ 6.866.540	€ 117.095	1,72%	12,93%	10,89%
Compound annual growth rate	8,18%	9,02%			

Table 7 - Average expenditure per year

Table 7 also shows the annual average expenditures per project on total investment and NBS from 2018 to 2023. The compound annual growth rate for NBS expenditure is with 9,0% higher than the 8,2%

compound annual growth rate for total investment. This indicates that, while both investment categories have an annually growth rate, NBS expenditures have increased at a marginally higher rate.

The grand average yearly change for total project investment costs is 12,9%, while the grand average change rate for NBS expenditure is 10,9%. Rapid changes in standardization documents, as highlighted during the interviews, including the difference of the average change of the overall investment and the average change for NBS expenditure, suggest that it has become more expensive to adhere to the regulatory framework for the overall investment costs compared to NBS-related costs. As the average change year on year per investment growth faster than the expenditure for NBS per project.

This indicates a potential increase in expenses related to complying with the overall S-documents/standards, rather than an increase in only the NBS component costs. It suggests that the regulations for NBS did not change as significantly as those for technical aspects, highlighting the difference in prioritization of S-documents changes/improvements and the company's technically focused culture. This is also supported by the interviewees; the interviewees whom where directly engineering for the overarching program Modular Building have a strong focus on the technical aspect and reliability of the grid - as this is the core task of the program while also facing an increase in building rate - and view NBS as a nuisance and a risk to grid reliability.

5.5. Divergent perspectives

Interviewees have reported significant technical challenges of NBS integration into infrastructure projects and mentioned financial maintenance as a relevant factor. It underlines the importance of careful project planning so that NBS would not interfere with the primary functions of the infrastructure - to facilitate reliable grid infrastructure – and also would not affect the financial performance of the investment directly. This statement on maintenance costs has been allocated in the interviews with the code "financial burden" in the context of NBS. This code occurred only once in combination with the code "Missing knowledge on NBS" (Appendix XVI). This could indicate that, even though there are internal documents, like the Inspirational guide to Biodiversity, contradicting high maintenance costs for NBS implementation, information sources are not properly distributed to the right employees to gain that knowledge. This could be linked to the aforementioned company culture of technical superiority and risk-aversion as the focus of the company is not on gaining knowledge on NBS.

Public sector financial investment raises a host of questions on the challenges related to cost-effectiveness and a balanced approach in measuring benefits against costs. Being public money, prudence and accountability need to be ensured that the investment is finally in the public interest. This is also reflected in the document analysis with the projects that have the highest expenditure of NBS. Those projects also had the most extreme implementation of NBS based on local regulations and an extensive program of requirements from the external environment, as imposed by local governmental bodies. This stands in sharp contrast to the guidelines based on the multiple S-documents that provide low cost, high impact options (Appendix XIII) and the many options the “Inspirational guide to Biodiversity Alliander” offers (Appendix XXI). Though all interviewed stakeholders realized challenges, there was unanimous support for the environmental values delivered by NBS. These benefits reach beyond improving biodiversity and the local ecosystems, contributing to broader environmental goals like the SDGs.

The level of integration of NBS differed in the views of the interviewees, with some advocating for comprehensive integration while others suggest more context-specific applications and therefore leaving it out the standardization program. Proof of the economic value of NBS to stakeholders range from detailed cost-benefit analysis to representation through case studies. Regulatory compliance was agreed on by all interviewees, while the opposite occurred when considering the competence of already existing regulations and standardization documents, with some calling for stricter guideline examples.

The degree of internal motivation to go beyond compliance also varies, with some expressing strong commitment to go beyond compliance, while others focus on only meeting existing requirements. Additionally, some believe that higher NBS integration could expedite the licensing process due to a more favourable attitude from regulatory bodies and that small steps in NBS integration can have a significant impact on biodiversity without substantial additional costs. This could make a great difference in the overall speed/potential of grid expansion (maakbaarheid)[6] of the energy transition, considering that the licencing process could take up to 70% of the total time needed to finalize an investment project.

[6] "Maakbaarheid" is the Dutch term describing the possibility of attaining an energy transition in a controlled and feasible way. That means it has to be technically feasible, economically viable, and socially accepted; regulatory-wise, properly supported; and with enough resources.

6. Discussion

6.1. Cultural Barriers

One critical distinction that shows between the literature and the research is the role of risk averse and technical driven company culture. These were underlined in the case study as leading factors to act as a barrier against NBS integration. Notably, NBS is seen as a risk to grid reliability by some of the interviewees. This sociocultural barrier is working against the existing motivation to further implement sustainability, where grid reliability goes ahead in the queue at the cost of NBS integration, instead of working besides and with each other. In contrast, the literature on LTS focuses on structural and organizational aspects of technical systems, with no explicit reference to company culture or risk aversion. Although the LTS framework stresses the dynamic interplay between technological developments and social contexts as the systems evolve and change their character over time (Hughes, 1987; Sovacool et al., 2018; Sovacool & Hess, 2017). The theory of LTS does focus on the social context of its users and the expressed values but does not analyse the contextual interplay and potential changing dynamics between managers and users and their values and believes. It does strongly emphasis the influence of the social world on the technological changes, exemplified by what the local communities and the local engagement did to the region with a higher-than-average NBS expenditure.

The results show that for successful integration of NBS in standardized grid construction, there are cultural barriers that need to be overcome. An intrinsic motivation among managerial and administrative employees to integrate NBS appeared in the interviews but was not matched by a top-down (director level) commitment to long-term standardization just as it was not matched by engineering staff. Even though engineers and directors, like administrative and managerial functions, were very much enthusiastic about NBS and mentioned both environmental benefits and a general alignment of NBS with sustainability goals, higher management's main focus on technical reliability and financial prudence had often sidelined NBS. The engineering staff had an overall stronger professional focus on technical superiority.

This underlines the need for a cultural shift within the organization itself as regards the adoption of sustainability. For there to be a readjustment toward a more balanced view in which environmental sustainability would be considered an equal of technical and economic values, setting integration of NBS practices into the standard operational framework central. This is further substantiated by evidence from the literature, indicating that organizational culture, goals, and leadership commitment are preconditions for a cultural company change, including the change toward the integration of sustainability into business (Kotter, 1995).

Kotter's (1995) change model places much emphasis on the need to establish a sense of urgency, to form powerful guiding coalitions, and to create and communicate a vision of change. Applying those principles within the context of NBS integration, one may note that the leadership commitment and clear communication are vital in overcoming the inaction of the resistance rooted in risk-averse culture. In effect, leaders should mobilize the organizational mindset through the active promotion of environmental and long-term economic benefits related to NBS (Kotter, 1995; Levasseur, 2001).

Moreover, as Dorst et al. (2021) discuss, it is aligning the sustainability initiatives with organizational goals that is critical in driving successful integration. This alignment will involve not only changes to policies, and in effect the standardization framework, but also cultural values and practices. While there seems to be some intrinsic motivation among interviewees, which would drive change from the bottom upward, this should be supplemented from a top-down structure and concretization into standard practices and processes of operation.

6.2. Standardized Construction

The findings of this research indicate practical and cultural challenges for the implementation of NBS in standardized construction for constructing (sub-)stations. On the one hand, standardized construction is conceived as an instrument for an efficient and uniform process; on the other hand, this case indicates regional differences regarding NBS expenditure and that a wide array of possible interpretations of the NBS regulations within the standardized construction programme exist. This contradicts the principles of standardized construction of the MB program. The literature on implementing standardized construction gives indication of these regional differences and possible interpretations. For instance, while areas like "Friesland Noordoostpolder" continuously invest more in NBS than the standardized MB program, others lag behind. This contrast makes the assumption that local factors, such as community participation, human factors, and pressures from other stakeholders, are relevant to NBS adoption. These local factors are not addressed in the literature regarding standardized construction but are mentioned in the literature of LTS in the form of large geographical differences, a.k.a. different countries or continents, not regions of provinces of a small country like the Netherlands (Sovacool & Hess, 2017).

The results also underline the challenge of balancing technical reliability with sustainable practices mentioned in the literature (Bouwmeister, 2021; Sowińska-Świerkosz & García, 2022). Possible additional financial burdens and a rather conservative risk management attitude further complicate the adoption of NBS within standardized construction for energy grid infrastructure projects (Hirth & Glismann, 2018; Weiffenbach, 2022). Although Modular Building provides the framework for the integration of NBS, from the interviews and document analysis, one can see that the lack of detailed and prescriptive requirements instead of guidelines leads to different projects interpreting and implementing NBS differently. This means that most projects, driven by financial concerns and a conservative attitude toward risk management, will tend to adhere to the minimum requirements rather than find ways to innovate with NBS.

The literature on LEAN production and standardized construction points to the need for detailed requirements and consistent practices toward efficiency and sustainability (Gao & Low, 2014; Shang et al., 2014). This makes the case for applying the principles of LEAN production to sustainable practices, since reducing waste and promoting efficiency with the same processes are directly applicable to the latter (Pinto et al., 2023). The results, however, have shown that the implementation of NBS is very different in various projects in the absence of clear and detailed requirements. This variability, in effect, undermines the potential benefits that can be had from standardized construction and points to the need for a more structured approach for NBS integration.

For instance, in the province of "Friesland Noordoostpolder", where expenditure on NBS is higher than the national average in relation to the standardized MB program (and all other regions), there is indeed a local prioritization of sustainability, just as the only region with a positive slope in terms of NBS expenditure; "Achterhoek Betuwe". This indicates that community engagement and pressure from outside influences/stakeholders could result in more robust integration of NBS, as also mentioned by the literature (White House Council on Environmental Quality et al., 2022). But without rigid requirements, these are patchy and often dependent on (very) local contexts. The lack of a harmonized approach means some areas perform above average in NBS integration, while others only do the minimum in terms of the adoption of sustainable practices.

6.3. Integrating NBS

Both the literature review and this research point to challenges with regard to the integration of NBS in standardized construction grid infrastructure. While the literature mostly stresses theoretical challenges and the necessity of holistic, interdisciplinary approaches (Pinto et al., 2023; Seddon et al., 2020), the case study reveals specific organizational, cultural and technical barriers: lack of clear requirements, internal motivation, and both top-down and bottom-up steering. These factors were also mentioned in the literature streams despite being less exposed. Nevertheless, these differences, literature and research results have repeatedly underscored the environmental, social, and economic gains NBS can deliver in terms of improved biodiversity, enhanced air quality, reduced heat island effects, or generally improved liveability in urban areas (Adams et al., 2023; Seddon et al., 2020).

The key findings from the research support a number of aspects from the literature, in which major barriers to the integration of NBS were found, including the resistance to change and the need for regulatory support (Adams et al., 2023; Faivre et al., 2017). The contradiction, however, would be that literature would suggest a broader theoretical understanding of the potential benefits that NBS could offer within LTS and standardized construction frameworks (Seddon et al., 2020), while the case study reveals practical and cultural challenges and that actual implementation is often limited by financial constraints and regulatory ambiguities.

There is no clear relationship between the overall investments and the expenditure on NBS based on the financial analysis. Further analysis of the top 10 projects with the highest NBS expenditures in the last six years does not reveal any direct relationship between the NBS spending and the total cost of the project. It is this unpredictability that resonates with literature concerning the challenges of integrating new practices within LTS, where stakeholder influences might produce variable results. This unpredictability in the NBS spend arising from the financial results is further supported by the literature (Hirsh & Sovacool, 2006; Hughes, 1987; Sovacool et al., 2018).

One critical aspect not addressed in the LTS literature or standardized construction literature is the significant regional differences in NBS expenditure, more specific very small geographical distance and large expenditure differences. Whereas Sovocool & Hess (2017) discusses geographical differences between countries and continents based on technological differences, the results here show different trends, and implementation, even despite this missing relation between expenditures. The case study highlights that regions like "Friesland Noordoostpolder" consistently spend more on NBS than the standardized MB program, while other regions lag behind with different margins. Even though the region "Achterhoek Betuwe" has a positive slope on NBS expenditure, the overall expenditure was still below the standardized level of NS expenditure. This difference suggests, based on the document analysis and the interviews, that local factors, such as community engagement, human factors, and external stakeholder pressure, play a crucial role in NBS adoption. The regional variations in NBS spending indicate that standardized guidelines alone are insufficient to ensure uniform adoption of sustainable practices across different regions.

6.4. Large Technical Systems Framework

Application of the LTS framework in this study puts forward a holistic perspective interplaying with social and technical elements relating to grid operators. The LTS framework highlights the dynamic interplay between technological development and society (Hirsh & Sovacool, 2006; Hughes, 1987; Markard & Truffer, 2006; Van der Vleuten, 2004). This fact was also reflected in the research findings supplemented with how the integration of NBS is being shaped by the regulatory requirements and expectations within communities.

The results showed that community engagement and regulatory mandate were key factors in the extent NBS were adopted across differing regions in the standardized method. This corresponds to an LTS perspective: Technological systems are not developed in isolation but are, instead, deeply embedded and influenced by their social contexts (Van der Vleuten, 2004). Such requirements of regulations, community expectations, and pressures from relevant stakeholders thus play a big role in how and to what extent NBS are integrated into standardized grid infrastructure projects. Internal cultural, and company cultural, barriers are not accounted for within the literature on the LTS framework. Even though could be said that company culture could be seen as a form of social construct and a form of social community, the literature of LTS does not made that argument. This study revealed that a traditional, risk-averse, technically driven mindset at the organizational level was actually a main barrier to integrating NBS. This means a conservative approach to grid reliability and financial cautiousness, was taken priority rather than making efforts to adopt innovative sustainable practices despite the social responsibility the grid operator has based on the interviews and the literature. Although the LTS framework provided a lens to some of the structural and organizational dynamics at play it lacked a broadened field of view for addressing company cultural issues.

These findings point toward a more holistic approach, in combination with LTS, which will need to be originated from an understanding of organizational culture and its associated risk aversion to surmount complex challenges of standardized grid infrastructure integration. Understanding cultural barriers within the LTS framework involves the role of risk aversion and the cultural shift toward valuing sustainability. Such an integrated approach could provide more holistic insights into the challenges and allow for more effective strategies regarding the adoption of NBS in grid infrastructures. Combining insights from the literature on organizational culture and change management with the LTS framework could eventually make the framework more applicable in practice, considering human factors in the drive toward technological and organizational change (Dorst et al., 2021; Kanabar et al., 2022; Kotter, 1995). These views underline the fact that commitment from top leadership, employee engagement, and a shared vision toward sustainability are very important in bridging the gap of resistance to change and in building a supportive environment for innovation.

6.5. Research method

This study looked at the mainstreaming of NBS in regular construction practices of energy infrastructure in the Netherlands through the study of one of the principal grid operators in the country, Qirion. This is a multi-perspective study structured by an ICES framework using financial analysis, document review, and interview methods.

The data were collected in the following manner:

- The research was carried out through a financial analysis, using investment data on projects between the years 2018 to 2023. The research sought to establish trends in NBS investment expenditures and unravel any inconsistencies in the investment,
- Document Review: Legal, Permitting, Design, and Environmental Requirement Documents are reviewed for an insight into NBS practices and standardization vis-à-vis current practices,
- Interviews with Stakeholders: Semi-structured interviews are conducted with various stakeholders about the current challenges, opportunities, and perception regarding the integration or inclusion of NBS in their work.

For the analysis, a mixed approach was done:

- Analysis of financial data: The tools of Python and Excel have been used to analyze financial data in terms of trend analysis, forecasting, and interpretations were necessary on results of regression analysis,
- Analysis of document reviews: The literature review conducted was supplemented both by the qualitative content review of documents and by LLM processing in order to generate summaries and pull key information extracted from documents,
- Analysis of interviews: Use of a codebook through MAXQDA software and color-coding in a systematic manner to find patterns, recurring themes, and variations in stakeholders' views.

While a three-way data collection could have been more pronounced had the literature review been broader. Particularly, literature on change management could have been included, offering leverage in the understanding of cultural issues. The meaning of "local context" was also not clear, as the literature interpreted it as continents and countries where as this research defines it as regions within provinces within a country.

Although the method was a very comprehensive financial analysis, it still could be improved since it does not have enough statistical rigor and a theoretical basis. The analysis of the interviews could have been further interpreted upon sound academic underpinning. The selection of cases was justified by the role of Qirion in the energy transition and by the commitment to standardization, just as the unique data accessibility. The financial analysis showed that at some area the data was too contaminated for further detailed analysis and in a number of areas there were not enough data points for a conclusive result.

The research provides insights regarding the integration of NBS in standardized construction practices and points to the importance of cultural change, community engagement, and the potential to build on existing examples for success. In terms of strength, the multi-faceted approach to data collection was noted, while further research, aiming at an improved literature review and a more detailed financial analysis methodology, should be carried out. The research could have been more detailed but was limited to the available data. For example, the differences in size of land used per project in relation to the standard size of an investment lot and how that relates to the NBS expenditure could have been an interesting additional, unfortunately, the size of each lot is not available in a centralized database with in the case company.

In hindsight, the role of change management was underrated and should have been given a more prominent role from the start. The combination of change management with a need of company cultural change in light of a sustainability challenges could prose a very interesting research.

7. Conclusion

This research looks into the integration of nature-based solutions (NBS) within standardized construction practices of energy infrastructures—especially (sub-)stations ranging from 10kV to 150kV and 10MVA to 160MVA —in the Netherlands. The grid operators are at a crossroads: on the one hand, they have to increase the capacity of the grid rapidly due to net congestion; on the other, they face ambitious targets set by the SDGs. This research builds from investigating financial trends in NBS expenditure from 2018 to 2023, practical challenges and opportunities for cost-effective NBS adoption, the impact of pre-existing design considerations and examples of practices on NBS incorporation, and how grid operators can meet operational priorities with technical reliability and environmental sustainability.

To better integrate NBS within substations in the Netherlands, standardized construction practices should stipulate strict NBS specifications, and be complemented with a detailed regulatory framework. Cultural change in grid operators towards sustainability is required, making sure that community outreach and stakeholder involvement go up the agenda. Incentives are created by building on successful examples, focusing on the long-term benefits and emphasizing low cost with high impact.

The financial analysis from 2018 to 2023 shows an overall national linear positive trend in expenditure related to NBS at an annual growth rate of 0.16%. Despite this overall rising tendency, there are considerable regional differences. The region of “Friesland Noordoostpolder” tends to be above average in NBS expenditure according to the Modular Building standardization program, which indicate a strong emphasis on sustainability at the local level, as found in the document analysis. Other provinces show a decrease in spending on NBS over the years, suggesting the importance of local contexts and stakeholder engagements as in other region the local engagement and focus was not found. Except for the region of “Achterhoek Betuwe” where there is a positive trend on NBS spending, as that region has a strong focus on community engagement, actively communicating with and involving local communities for their investment plans.

There are several barriers to the adoption of NBS by grid operators in standardized construction, which includes financial constraints; risks-aversion mindset through conservative approaches; and the lack of rigorous, standardized, and repeatable NBS guidelines and requirements—absence creates inconsistencies in project delivery. Financial constraints in most cases result in low investment in NBS compliance and defeat the need for innovation. Community engagement and pressure from other stakeholders often ensure the adoption of NBS. Success cases, such as the experiences from “Friesland Noordoostpolder” and the increasing NBS expenditure from “Achterhoek Betuwe”, show good community participation levels resulting in higher investments in NBS and, eventually, more sustainable interventions. Existing design considerations and practical examples play a significant role in NBS incorporation. As this research shows, different practical implementations of NBS like green roofs, grass tiles and insect hotels were successfully introduced into the design of non-standardized substations. All these examples show workability and profit from NBS like biodiversity improvement and increasing environmental quality. Other examples supporting the standard design procedure are presented in the document "Inspirational guide to Biodiversity Alliander" with several low-cost, high-gain examples for the applicability of these solutions.

Grid operators have to transform their organizational culture toward much more environmental sustainability values equal to the technical reliability in the operational priorities, to be more aligned with NBS integration. The specific crucial shift should be from a risk-averse, purely technical focus to a culture of environmental sustainability and technical reliability. Cultural change is one of the most complex things possible, and this cannot be introduced by strict specifications on NBS that will just overcome strong habits in priorities and practices. Therefore, the study must establish whether such resistance of NBS adoption evidences the cultural abhorrence of risk or whether it actually represents the greater priority regime of the organization but at even higher levels.

Such cultural change requires top-down commitment and bottom-up initiatives related to sustainability, led by strong and clear communication and leadership about the benefits of NBS. This would be achieved through the long-term economic and environmental benefits that NBS offers and applying detailed and strict regulations concerning NBS at par with current regulations for technological aspects. The prevailing risk-averse culture results in minimal NBS requirements within standardized construction practices, limiting opportunities for innovation and wider NBS adoption. To overcome these cultural barriers, grid operators should foster interdisciplinary collaboration, incentivize NBS innovation, and incorporate sustainability metrics into performance evaluations.

Guaranteeing proper uniformity across different regions or projects through general guiding principles with explicit criteria on design, operation, and maintenance would increase technical reliability and environmental sustainability. Moreover, the standardized construction standards may be further developed to include NBS through an addition of strict specifications. Further, greater emphasis on community participatory and external stakeholder engagements at local levels might bring out specific contextual factors that influence the adoption of NBS. Further research is therefore particularly required on the organizational dynamics and decision-making processes within grid operators, in an attempt to understand the deeper causes for the resistance of NBS and to develop a culturally targeted strategy for change. This may comprise an examination of the role played by different stakeholders, incentive structures, and styles of communication and leadership in driving the integration of NBS.

Cultural change within grid operators needs to be enabled to appreciate sustainability as much as the technical reliability. This would include top-down support, alignment of engineering, managerial and administrative staff, communication of the benefits of NBS, and the harmonization of organizational goals with sustainability initiatives. Building on existing examples of practice and design considerations offers a source of inspiration for the integration of NBS into standardized construction for a resilient and sustainable energy infrastructure.

These findings contribute to the academic discourse of sustainable energy transitions by profiling organizational culture, regulatory framework conditions, and community engagement as central conditions for facilitating broad NBS diffusion. The research underlines the need for a balance between technical reliability and environmental sustainability and provides ground for further investigations into the dynamic interplay between social, technical, and ecological factors in energy infrastructure development.

8. Future research and recommendations

The research identifies a significant cultural barrier inside grid operators—characterized by traditional risk aversion culture, and a technically driven mindset. Overcoming this would require structuring it into organizational culture, driving innovation and sustainability. Top-down support is required from the ranks of people who actively prioritize sustainability and NBS integration. Workshops and training sessions on NBS benefits for sustainable practices should be conducted among employees. Such adoption can further be incentivized by rewarding departments and teams for the integration of NBS in their projects.

The literature and this research both argued that clear and strict standardization requirements and regulatory frameworks should be setup to support the integration of NBS at the same level of strictness as the technical requirements. In essence, this would mean that the development of comprehensive requirements for NBS implementation, with clear criteria on design, execution, and maintenance, is of prime importance. With the NBS costs embedded in the overall project budgets from the outset, under strict NBS requirements, the case of them being treated as an integral part is made easy, as this is strengthened further by standardization requirements. On the other hand, it could be standardized construction practices that make the systematic integration of NBS easier—the already existing modular building program—with theoretical elements like green roofs, hedges, and insect hotels potentially fitted into the standard design templates for substations. Standardized construction methods guarantee the feasibility of replicability of NBS across a number of projects with increased scalability, efficiency and lower costs compared to unique design strategies.

Pilot projects and case studies can do wonders in showing the feasibility of NBS and achieving momentum. In this respect, the "Friesland Noordoostpolder" case studies give a good example of the impacts that can be achieved through successful NBS projects, thus inspiring more. In addition, a best practices document, like the "Inspirational guide to Biodiversity Alliander", with lessons learned from pilot NBS projects can lead to future initiatives and consequently larger-scale implementation of NBS.

Further research is also needed on the organizational dynamics of grid operators and their decision-making processes in order to really understand the sources of resistance to NBS and to tailor appropriate strategies for cultural change. This means that contributions made by different stakeholders, incentive structures, and styles of communication and leadership that will propel further integration of the NBS have to be analysed. It is necessary to learn how different structures and cultures of organizations influence the adoption of NBS and also how to efficiently surmount internal obstacles. On this point, expanding the literature review to include change management within the context of LTS would provide a theoretical underpinning for comprehending and bringing about the cultural shift needed to generate sustainability-oriented behaviour in grid operators.

Regional variations in expenditure and implementation of NBS warrant further investigation to understand local regional influence. Knowing why a region like "Friesland Noordoostpolder" and "Achterhoek Betuwe" puts NBS first and another region does not could be relevant. This can give new founded insight into the role of community engagement, local policies, and stakeholder pressure in driving NBS adoption. This research can help in the formulation of specific strategies for lagging regions in the implementation of NBS by learning from examples of good practice and leading regions.

Combining the LTS framework with insights from the organizational cultural literature can provide a holistic understanding of the challenges associated with NBS integration. The study found that community engagement and regulatory mandates significantly influenced the extent to which NBS were adopted in different regions. Studying how technological developments relate to organizational culture can therefore help future research design more effective integration of NBS in grid infrastructure.

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10. Appendix

Appendix I

Interview Guide

The interview guide has been set up to systematically explore stakeholder perspectives on the integration of Nature-Based Solutions (NBS) in standardized construction at Qirion. Recognizing the multifaceted nature of the research, the guide serves as a structured framework, employing a semi-structured approach to extract in-depth insights. By posing targeted questions on the focus areas as discussed, the interview guide aims to unravel nuanced viewpoints. This methodical approach ensures a comprehensive understanding of key themes, subsequently enabling rigorous qualitative analysis in accordance with academic standards. This interview guide is based on the principles of Oxford (Bryman & Bell, 2007).

Interview Guide: NBS integration in standardized construction at Qirion

Introduction

- Welcome and introduce yourself and your role in the research.
- Clearly explain the purpose of the interview and how their insights will contribute to the study.
- Obtain informed consent, ensuring the participant understands their rights, including confidentiality and the voluntary nature of their participation.
- Briefly describe the concept of NBS integration in standardized construction to ensure a common understanding before starting the interview.

Participant Information

- Collect basic demographic information to understand the diversity of perspectives
    - Can you please share your department and role within Qirion?
    - How many years of experience do you have in your current field?
    - Without specifying age, could you categorize your years of experience in the industry? (e.g., 0-5 years, 6-10 years, 11-15 years, more than 15 years)
    - Could you describe your involvement with projects or initiatives that include Nature-Based Solutions (NBS)?
- Ask about the participant's role and specific involvement in projects related to NBS and standardized construction at Qirion.

Interview Structure

Reiterate the semi-structured nature of the interview, emphasizing flexibility in discussion while maintaining focus on key themes.

Open-ended questions aligned with ICES framework

- Technological aspects;
- Socio-economic aspects;
- Environmental aspects;
- Institutional aspects.

Ensure each question is open-ended to encourage detailed responses.

Be prepared to probe or ask follow-up questions based on participants' responses to gain deeper insights.

Maintain a neutral tone and avoid leading questions to ensure unbiased responses.

The examples question mention here provide a starting point for the conversation with the interviewee. Not all examples questions needs to be ask but all area should be touched upon.

Technological aspects & standardized construction (SC)

- (SC & TA) What key technological considerations do you prioritize in modular construction to ensure the integration of nature?
- (NBS) How have technological advancements facilitated the inclusion of nature in our building projects?
- (TA) Have you noticed any trends in how technology is used to merge modular construction with environmental goals?
- (SC) Can you share a challenge or success story where technology played a crucial role in implementing NBS within a standardized construction project?

Socio-economic aspects: Financial opportunities (FO) & social responsibilities (SR)

- (FO) What financial opportunities or barriers have you encountered when trying to integrate NBS into modular construction?
- (SR) How do you see our social responsibility in choosing to integrate nature into our construction projects?
- (FO & SR) In what ways have financial strategies impacted the social outcomes of our NBS initiatives?
- (SR) Can incorporating NBS into modular construction enhance Qirion's contribution to the community's well-being?

Environmental aspects: Nature Inclusive Building (NBS)

- (NBS) Could you describe how integrating natural elements into project planning has impacted the environment positively?
- (NBS) Are there simple but impactful ways we have or could incorporate nature into our modular buildings?
- (NBS) How does the choice of materials in modular construction influence our environmental footprint?
- (NBS) Share an example where NBS significantly improved the sustainability of a modular construction project.

Institutional aspects: Green-first philosophy (GF) & potential of NBS (PQ)

- (GF) How does the "Green-first" philosophy compare to "Technical Superiority" in our project designs?
- (PQ) What potential do you see for NBS to be more integrated into our future modular construction projects?
- (GF & PQ) How do our company policies support or limit our ability to follow a "Green-first" approach in modular construction?
- (GF) Can you provide an example where institutional support or policy helped foster the integration of NBS into a project?

Conclusion

- Summary of interview structure and analysis process
- Next steps in the research process
- Thanking the interviewee

Interview guide in Dutch:

Introductie (5 minuten)

"Goedendag, fijn dat u tijd kunt vrijmaken voor dit gesprek. Mijn naam isRobert-Paul van Campen en ik onderzoek de integratie van Natuur inclusief bouwen (NBS) in de gestandaardiseerde bouw (Modulair Bouwen) bij Qirion. Uw inzichten zijn zeer waardevol voor dit onderzoek. Vindt u het goed als ik dit gesprek opneem voor analyse?"

"Ik wil graag beginnen met een korte uitleg van het concept 'integratie van NBS in gestandaardiseerde bouw' om te zorgen dat we een gemeenschappelijk begrip hebben voordat we verder gaan. Bent u bekend met dit concept? Bent u het eens met de volgende definitie: 'De integratie van Natuur inclusief bouwen in gestandaardiseerde bouw refereert aan het systematisch inbedden van natuurlijke elementen en processen in de bouwontwerpen, -methoden en -materialen, met als doel het verhogen van de ecologische, sociale en economische waarde van bouwprojecten'?

Begrijpt u wat de bedoeling is van het gesprek en dat uw deelname vrijwillig is?"

Algemene Informatie (5 minuten)

- "Kunt u kort vertellen over uw rol bij Qirion en wat uw afdeling doet?"
- "Hoe lang werkt u al in deze sector?"
- "Heeft u persoonlijk ervaring met projecten waarbij geprobeerd is natuur te integreren in de bouw? Zo ja, kunt u daar een voorbeeld van geven?"
- "Zou u uw ervaring met NBS-projecten kunnen omschrijven, specifiek binnen de context van gestandaardiseerde bouw?"

Structuur van het Interview

"We gaan verder met een semi-gestructureerde vorm van interviewen, wat betekent dat we flexibel zijn in de discussie maar wel focussen op de volgende kernthema's, afgestemd op het ICES-framework."

Technologische aspecten & Modulair Bouwen (SC)

- Op welke manier worden technologieën overwogen om natuur te integreren in modulaire constructies?
- Op welke wijze hebben recente technologische ontwikkelingen bijgedragen aan het opnemen van natuur in bouwprojecten?
- Zijn er trends waarneembaar in het gebruik van technologie voor het combineren van modulaire bouw met milieudoelstellingen?
- Kunt u een voorbeeld geven van hoe technologie heeft bijgedragen aan het succesvol implementeren of juist de uitdagingen bij het integreren van NBS binnen een standaard bouwproject?

Sociaal-economische aspecten: Financiële kansen & maatschappelijke verantwoordelijkheden (FO & SR)

- Welke financiële kansen of uitdagingen komt u tegen bij het integreren van NBS in modulaire constructies?
- Hoe ziet u de rol van onze organisatie in het integreren van natuur in bouwprojecten vanuit maatschappelijk oogpunt?
- Op welke manier beïnvloeden financiële strategieën de sociale resultaten van onze NBS-initiatieven?
- Hoe kan het toevoegen van NBS aan modulaire constructies bijdragen aan het welzijn van de gemeenschap volgens u?

Milieuaspecten: Natuurinclusief bouwen (NBS)

- Kunt u voorbeelden noemen van hoe de integratie van natuurlijke elementen in de planning een positieve invloed heeft gehad op het milieu?
- Welke eenvoudige methoden zijn er om natuurlijke aspecten te integreren in onze modulaire gebouwen?
- Welke invloed heeft de keuze van materialen voor modulaire bouw op onze ecologische voetafdruk?
- Kunt u een project benoemen waarbij NBS significant bijdroeg aan de verduurzaming van een modulair bouwproject?

Institutionele aspecten: Groen-eerst filosofie & potentieel van NBS (GF & PQ)

- Hoe wordt binnen projectontwerpen gekozen tussen een 'Groen-eerst' benadering en technische oplossingen?
- Wat ziet u als het toekomstige potentieel voor de integratie van NBS in modulaire bouwprojecten?
- Op welke wijze ondersteunen of beperken bedrijfsbeleid en regelgeving het volgen van een 'Groen-eerst' benadering in modulaire constructies?
- Kunt u een situatie beschrijven waarin bedrijfsbeleid of regelgeving de integratie van NBS in een project heeft bevorderd of juist belemmerd?

Appendix II

Codebook

The codebook provides a standardized set of codes to organize and analyse qualitative data gathered from the interviews. If new important factors emerge during the interview process, extra code categories might be added.

Code list

Code Abbreviation	Code Category	Description
TD	**Technological Dimension**	
TN	Tension between Nature and Reliability	Examination of the challenges in balancing natural elements with reliability in NBS construction.
NBS	NBS in Standardization Construction	Insights into how nature is incorporated into project planning.
KN	Missing Knowledge on NBS	Identification of gaps in current knowledge and understanding of NBS.
SC	Challenges to Standardize NBS	Exploration of difficulties in creating standards for NBS.
STC	Standardized Construction	Key considerations and factors related to standardized construction.
SE	**Socio-Economic Dimension**	
CT	Change in Timeline/Processes	Insights into how timelines and processes are altered in NBS projects.
FTA	Financial Trends Analysis	Analysis of financial data trends and outliers.
FO	Financial Opportunities	Exploration of financial opportunities related to NBS implementation.
FB	Financial Burdens	Examination of financial challenges and burdens.
FR	Financial Responsibility	Discussion of financial accountability in NBS projects.
CB	Cost-Benefit Analysis	Analysis of the costs versus benefits, indicating that NBS may be more expensive but better.
FP	Finance at Project Level	Examination of financial management at the project level.
ED	**Environmental Dimension**	
NIB	Nature Inclusive Building	Insights into incorporating nature into building designs.
MI	Mitigating Issues	Strategies for addressing and mitigating environmental issues.
GF	Green-First Philosophy	Examination of prioritizing green solutions over technical superiority.
SN	Shift Toward Normalization of Green	Discussion on the movement towards making green solutions the norm.
SR	Social Responsibilities	Perspectives on social responsibilities regarding environmental sustainability.
PN	Potential of NBS for Qirion	Beliefs about the potential for NBS integration at Qirion.
ID	**Institutional Dimension**	
PC	Policy Considerations	Insights into internal policy considerations for NBS.
EP	External Policies for NBS	Examination of external policies affecting NBS implementation.
PT	Policy Trends	Analysis of trends in policies relevant to NBS.
CC	Company Culture	Discussion on how company culture impacts NBS adoption.

Coding Process in MAXQDA:

1. Identification of Relevant Segments:

What to do: Begin by thoroughly reading each interview transcript to find passages that relate to your study's themes, as outlined in the codebook. Look for any mention or discussion that fits the predefined codes, including both explicit mentions and subtler, related discussions.

How to do it: Open each transcript in MAXQDA and use the highlight function to mark relevant passages. If a passage relates to "Standardized Construction," highlight it and think about how it connects to your codes. Is it a direct example? An opinion? A challenge faced? This initial step is about mapping out where your data will fit into your analysis framework.

2. Coding of Transcripts:

What to do: Assign the correct code from your codebook to the highlighted segments within your transcripts. This step categorizes the data, making it manageable and ready for deeper examination.

How to do it: With your transcripts still open in MAXQDA, drag and drop the highlighted segments into the corresponding codes that have been set up in your "Code System." If a segment relates to more than one theme, MAXQDA allows to assign multiple codes. For instance, if a discussion about a construction project touches on both environmental impact (NBS) and financial considerations (FO), assign both codes to this segment.

3. Grouping Codes into Families:

What to do: Organize related codes into broader categories, or "code families," to simplify the analysis process. This helps in seeing bigger patterns and themes emerge from your data.

How to do it: In MAXQDA, use the "Code System" feature to create these families. Right-click in the "Code System" area, select "New Code Family," and then drag the relevant codes into this family. For example, you might create a family titled "Environmental Impact" and include codes like NBS and GF. This grouping will aid in later analysis when you're looking to draw broader insights from specific coded data.

4. Identifying Patterns and Themes:

What to do: Analyze your coded data to uncover recurring patterns, themes, and insights. This step is where your data starts to tell its story, revealing the underlying trends, opinions, and experiences of your participants.

How to do it: Utilize MAXQDA's "Code Frequency" and "Code Relations" tools to identify which codes are most prevalent and how they interact. This can highlight the most discussed topics or reveal unexpected connections between different aspects of your data.

Visualization in MAXQDA:

1. Color-Coding Technique:

What to do: Assign specific colors to each code and code family. This visual distinction aids in quickly identifying related data segments during analysis.

How to do it: In the "Code System," right-click on a code or code family, select "Color," and choose a color. It's helpful to use a consistent color scheme, such as warm colors for one family of codes and cool colors for another, to make the distinctions clear at a glance.

2. Enhancing Data Visualization:

What to do: Leverage MAXQDA's visualization tools to create graphical representations of your data. This includes code matrices, code relations browsers, and thematic maps, which can illustrate the relationships between codes, show how themes distribute across your data, and identify which themes are most prominent.

How to do it: Explore the "Visual Tools" menu in MAXQDA. To create a code matrix, select "Code Matrix Browser" and choose the codes you're interested in comparing. MAXQDA will generate a matrix that shows how those codes intersect across different interviews or data segments. This visual can be particularly enlightening, showing at a glance where certain themes converge or diverge across your dataset.

Appendix III
Financial data

Data Collection Process

Source: Extracted all key project information from Bobi (SAP Business Intellegence) to Excel tables (2012 to 2028 year plan).

Initial Records: Started with 4487 records, encompassing all Alliander projects within the specified timeframe.

Filters Applied

A list of the filters applied on the corresponding columns with data:

- *Current Status*: Filtered for non-empty cells, and projects marked as "Won," "In Progress," and "Open."
- *Work Type*: Filtered for phases containing the letter 'R' (e.g., SBDR, DOR, BDR, REAL) to exclude study projects without execution plans.
- *Client Name*: Filtered for Qirion's clients, including Liander N.V. (9100) and TenneT TSO B.V. (AM).
- *Business Unit:* Focused solely on Qirion station-related activities across various regions.
- *Timeframe:* Considered projects from the annual plans of 2018 to 2023 for a comprehensive and complete dataset.
- *Project Number*: Ensured project numbers were not empty for cross-referencing.
- *Contract Amount*: Set a threshold of over 1 million euro for significant projects requiring fieldwork, amount lower than 1 million cannot be (sub-)station investments.

Data Refinement:

Initial Set: Started with 161 records after applying filters.

SAP Extraction: Downloaded all financial project information for the remaining 161 projects.

Detailed Inspection:

- WBS Structure: Semi-automatically extracted financial amounts per WBS and CBS for each project.
- Manual Verification: Ensured accuracy by manually reviewing projects with descriptions like "landscape integration."

Scope Adjustment: Excluded 14 projects with unknown start dates.

Fictitious Projects: Included 19 fictitious MB standard projects (these are companywide examples project) based on 2023 data for a comprehensive overview.

Final Cleanup: Removed 8 projects not related to station construction (e.g., frequency security, TESEC, transformer exchange, fault actions).

Result:

Actual Projects: 158 projects, covering the date range from 2018 to 2023 including 19 fictitious MB standard projects.

Anonymization: Project names were anonymized while retaining project numbers for confidentiality.

Appendix IV
Document collection

Step 1: Gather relevant documents

Collect all the documents mentioned in the text, including the BO report, DO report, environmental scans, and legal documents. These documents are found in the internal server storage of Alliander in Q4 of 2023 and recheck for compleetness in Q1 of 2024.

Step 2: Prepare the tools and resources

Ensure that you have access to the necessary tools and resources, including the custom large language model (LLM) trained by Alliander and any other NLP tools or software that may be required.

Step 3: Define the scope

Clearly define the scope of your analysis. Determine what specific information or insights you are looking to extract from the documents.

Step 4: Keyword identification

Use the NLP tools and custom LLM to identify relevant keywords and phrases within the documents. These keywords should be related to financial choices, expenditures, outliers, and trends.

Step 5: Document summarization

Utilize the NLP tools to generate summaries of the documents. Extract the overall vision, key points, and main findings from each document.

Step 6: Extract arguments and reasons

Employ NLP techniques to extract arguments, reasons, and statements within the documents that support financial choices and expenditures. This involves identifying persuasive or explanatory content.

Step 7: Systematic examination

Systematically examine each document using the hybrid approach of qualitative content analysis and NLP. This involves a detailed review of the content, with a focus on the identified keywords, summaries, and extracted arguments.

Step 8: Data interpretation

Interpret the data obtained from the document analysis. Identify outliers and trends within the documents and assess their significance in the context of financial choices and NBS (Nature-Based Solutions) expenditure.

Step 9: Report preparation

Prepare detailed reports summarizing the outcomes of the document analysis. Include findings related to outliers, trends, and supporting arguments for financial choices.

Step 10: Integration with financial data analysis

Combine the results of the document analysis with the outcomes of the financial data analysis mentioned in the text. Ensure that both aspects complement each other and provide a comprehensive understanding of the subject.

Step 11: Scope setting for interviews

Based on the insights gained from the document analysis and financial data analysis, set the scope and objectives for the following interviews. Determine the questions and areas that need further exploration through interviews.

Step 12: Document findings

Document all the findings, methodologies used, and any recommendations or action points resulting from the analysis. This documentation will serve as a reference for decision-makers and future actions.

Appendix V
Output regional regression fit test

Output regional regression fit test:

Region: Qirion Achterhoek Betuwe
Best Model: Linear
Mean Squared Error: 0.00021197
Coefficients:

- Intercept: 0.016126025500000002
- Year: 0.001940815

Region: Qirion Amsterdam Gooi
Best Model: Lasso
Mean Squared Error: 6.697855670895314e-06
Coefficients:

- Intercept: 0.01702147675
- Year: -0.0

Region: Qirion Friesland Noordoostpolder
Best Model: LinearRegression
Mean Squared Error: 7.053124360882511e-09
Coefficients:

- Intercept: 3.5677394740000006
- Year: -0.0017470740677966105

Region: Qirion Noord-Holland
Best Model: LinearRegression
Mean Squared Error: 1.8957886491958686e-05
Coefficients:

- Intercept: 3.5677394740000006
- Year: -0.0017470740677966105

Region: Qirion Rijnland
Best Model: LinearRegression
Mean Squared Error: 9.800309840719824e-07
Coefficients:

- Intercept: 3.5677394740000006
- Year: -0.0017470740677966105

Region: Qirion Veluwe Flevoland
Best Model: Lasso
Mean Squared Error: 9.813164680740854e-05
Coefficients:

- Intercept: 3.5677394740000006
- Year: -0.0017470740677966105

```
import pandas as pd
from sklearn.model_selection import train_test_split
from sklearn.linear_model import LinearRegression, Ridge, Lasso
from sklearn.preprocessing import PolynomialFeatures
from sklearn.metrics import mean_squared_error
# Load the dataset
data = {
  'Year': [2018, 2019, 2020, 2021, 2022, 2023],
  'Qirion Achterhoek Betuwe': [0.016629446, 0.010386715, 0.008927961, 0.015470016,
0.012400892, 0.027705233],
  'Qirion Amsterdam Gooi': [0.019087963, 0.014000658, 0.013901955, 0.038432119, 0.013216537,
0.002535296],
  'Qirion Friesland Noordoostpolder': [0.052467314, 0.040480914, 0.019341452, pd.NA,
0.04146438, 0.03608506],
  'Qirion Noord-Holland': [0.021744314, 0.012946947, 0.01712707, 0.016652592, 0.010279504,
0.018314445],
  'Qirion Rijnland': [0.004109854, 0.008768347, 0.018631397, 0.014605975, pd.NA, pd.NA],
  'Qirion Veluwe Flevoland': [0.009969021, 0.027586793, 0.013060528, 0.013741464, 0.017755042,
0.012428293]
}
df = pd.DataFrame(data)

# Initialize variables for best model and best mean squared error
best_model = None
best_mse = float('inf')
best_model_coefficients = None

# Features are all columns except 'Year' and the target columns
features = df.columns.difference(['Year'])
for feature in features:
  # Extract relevant columns
  X = df[['Year']]
  y = df[feature]

  # Drop rows with missing values in the target variable
  not_nan_index = ~y.isna()
  X = X[not_nan_index]
  y = y[not_nan_index]

  # Split the data
  X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)

  # Initialize variables for the best model and its MSE
  best_model_for_feature = None
  best_mse_for_feature = float('inf')

  # Try different regression models
  for model_class in [LinearRegression, Ridge, Lasso]:
    model = model_class()
    model.fit(X_train, y_train)
    y_pred = model.predict(X_test)
    mse = mean_squared_error(y_test, y_pred)
```

```
        # Check if it's the best model for this feature
        if mse < best_mse_for_feature:
            best_mse_for_feature = mse
            best_model_for_feature = model_class.__name__
            best_model_instance = model

    # Check polynomial regression (4th degree)
    poly = PolynomialFeatures(degree=4)
    X_poly = poly.fit_transform(X)
    X_train_poly, X_test_poly, y_train_poly, y_test_poly = train_test_split(X_poly, y, test_size=0.2,
random_state=42)

    poly_model = LinearRegression()
    poly_model.fit(X_train_poly, y_train_poly)
    y_pred_poly = poly_model.predict(X_test_poly)
    mse_poly = mean_squared_error(y_test_poly, y_pred_poly)

    # Compare with the best model so far
    if mse_poly < best_mse_for_feature:
        best_mse_for_feature = mse_poly
        best_model_for_feature = 'Polynomial (4th degree)'
        best_model_instance = poly_model

    # Check if the best model for this feature is the best overall
    if best_mse_for_feature < best_mse:
        best_mse = best_mse_for_feature
        best_model = best_model_for_feature
        if best_model == 'Polynomial (4th degree)':
            best_model_coefficients = {
                'Feature': ['Intercept'] + poly.get_feature_names_out(['Year']).tolist(),
                'Coefficient': [best_model_instance.intercept_] + best_model_instance.coef_.tolist()
            }
        else:
            best_model_coefficients = {
                'Feature': ['Intercept'] + X.columns.tolist(),
                'Coefficient': [best_model_instance.intercept_] + best_model_instance.coef_.tolist()
            }

    # Print the best model and its coefficients for each region
    print(f"Region: {feature}")
    print(f"Best Model: {best_model_for_feature}")
    print(f"Mean Squared Error: {best_mse_for_feature}\n")
    coefficients = pd.DataFrame({
        'Feature': ['Intercept'] + (poly.get_feature_names_out(['Year']).tolist() if best_model_for_feature
== 'Polynomial (4th degree)' else X.columns.tolist()),
        'Coefficient': [best_model_instance.intercept_] + best_model_instance.coef_.tolist()
    })
    print(coefficients)
    print("\n" + "=" * 50 + "\n")
```

Appendix VI
Overall regression fit test

Output:

```
Region: Average_of_%_Terrein_PV
Best Model: Linear
Mean Squared Error: 0.028976190476190 49

     Feature  Coefficient
0  Intercept    -327.282857
1       Year    0.162857

==================================================
```

```
import pandas as pd
import numpy as np
from sklearn.model_selection import train_test_split
from sklearn.linear_model import LinearRegression, Ridge, Lasso
from sklearn.preprocessing import PolynomialFeatures
from sklearn.metrics import mean_squared_error

# Dataset
data = {
   'Year': [2018, 2019, 2020, 2021, 2022, 2023],
   'Average_of_%_Terrein_PV': [1.43, 1.60, 1.52, 1.64, 2.31, 2.12]
}

df = pd.DataFrame(data)

# Initialize variables for best model and best mean squared error
best_model = None
best_mse = float('inf')
best_model_coefficients = None

# Feature to be analyzed
feature = 'Average_of_%_Terrein_PV'

# Extract relevant columns
X = df[['Year']]
y = df[feature]

# Split the data
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)

# Initialize variables for the best model and its MSE
best_model_for_feature = None
best_mse_for_feature = float('inf')

# Try different regression models
for model_class in [LinearRegression, Ridge, Lasso]:
   model = model_class()
```

```
    model.fit(X_train, y_train)
    y_pred = model.predict(X_test)
    mse = mean_squared_error(y_test, y_pred)

    # Check if it's the best model for this feature
    if mse < best_mse_for_feature:
        best_mse_for_feature = mse
        best_model_for_feature = model_class.__name__
        best_model_instance = model

# Check polynomial regression (4th degree)
poly = PolynomialFeatures(degree=4)
X_poly = poly.fit_transform(X)
X_train_poly, X_test_poly, y_train_poly, y_test_poly = train_test_split(X_poly, y, test_size=0.2,
random_state=42)

poly_model = LinearRegression()
poly_model.fit(X_train_poly, y_train_poly)
y_pred_poly = poly_model.predict(X_test_poly)
mse_poly = mean_squared_error(y_test_poly, y_pred_poly)

# Compare with the best model so far
if mse_poly < best_mse:
    best_mse = mse_poly
    best_model = 'Polynomial (4th degree)'
    best_model_coefficients = {
        'Feature': ['Intercept'] + poly.get_feature_names_out(['Year']).tolist(),
        'Coefficient': [poly_model.intercept_] + poly_model.coef_.tolist()
    }

# Print the best model and its coefficients for the feature
print(f"Region: {feature}")
print(f"Best Model: {best_model}")
print(f"Mean Squared Error: {best_mse}\n")
coefficients = pd.DataFrame(best_model_coefficients)
print(coefficients)
print("\n" + "=" * 50 + "\n")
```

Appendix VII
Literature review criteria

The table below shows the different search criteria for the literature streams, the search string used, the amount of articles founded and the final articles selected for review.

		Stream A	Stream B
Topic		NBS and TSO	LTS & NBS
Search criteria		"Nature-Based solution*"	"Large Technical System*"
	AND	Energy	NBS
	AND		Infrastructure
	AND NOT	Water	Water
	AND NOT	Temperature	
	AND NOT	Heat	
	AND NOT	Wetland*	
	OR	TSO	LTS
	OR	DSO	"Nature-based solution*"
	OR	"Grid Operator*"	"Nature-based Design*"
Document criteria	Subject area	Social Science	
	Document type	Article	Article
	Sources type	Journal	Journal
	Open access	All open access	All open access

Table 8 - Literature review criteria

These search criteria resulted in the following string and amount of results:

	Stream A	Stream B
String	(TITLE-ABS-KEY ("Nature-Based solution") AND TITLE-ABS-KEY (energy) AND NOT TITLE-ABS-KEY ("Water") AND NOT TITLE-ABS-KEY ("temperature") AND NOT TITLE-ABS-KEY ("Heat") OR TITLE-ABS-KEY ("TSO") OR TITLE-ABS-KEY ("DSO") OR TITLE-ABS-KEY ("Grid Operator?")) AND (LIMIT-TO (SUBJAREA , "SOCI")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (EXACTKEYWORD , "Nature-based Solution") OR LIMIT-TO (EXACTKEYWORD , "Nature-based Solutions")) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (OA , "all"))	(TITLE-ABS-KEY ("Large Technical Systems") AND TITLE-ABS-KEY ("NBS") OR TITLE-ABS-KEY ("LTS") OR TITLE-ABS-KEY ("Nature-based Solution*") OR TITLE-ABS-KEY ("Nature-based Design*") AND TITLE-ABS-KEY ("Infrastructure") AND NOT TITLE-ABS-KEY ("Water")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (OA , "all"))
Amount of articles found	7	3
Selection criteria	More than 5 citations	More than 5 citations
Amount of article selected	3	3

Table 9 - Literature review string

Based on these criteria the following papers are selected to analysis:

Article number	Research stream	Author surname	Publication year	Journal name
1	**Stream A**	Romero-Perdomo F.	2022	Sustainability (Switzerland), 14(1), 521
2	**Stream A**	Perrotti D.	2020	Environment and Planning B: Urban Analytics and City Science, 47(4), pp. 678–694
3	**Stream A**	Colding J.	2020	Smart Cities, 3(2), 22
4	**Stream B**	van der Vleuten, E.	2004	Technology Analysis and Strategic Management, 16(3), pp. 395–414
5	**Stream B**	Sovacool, B.K.	2018	Science Technology and Human Values, 43(6), pp. 1066–1097
6	**Stream B**	Pereira, G.I.	2018	Energy Policy, 121, pp. 426–440

Table 10 - Literature review selection

The results of the analysis of NBS, TSO/grid operators and LTS challenges and solutions are summarised per article. We explore the diverse range of NBS related challenges in relation with LTS and TSO/grid operators and the innovative solutions proposed across these analyses with a continues focus on NBS.

Appendix VIII

Document list

Documents name (Dutch)	Document type
S2030 Definities Cost Breakdown Structure Liander.docx	Standardization documents
S2010_-_Brochure_Ruimtelijk_Inpassing_Modulair_Bouwen.pdf	Standardization documents
S2020_-_Brochure_Duurzame_elektriciteitstations.pdf	Standardization documents
S8010_Algemeen_PvE_Terreinen_en_Gebouwen_OS_RS_en_SS.pdf	Standardization documents
S8016_Modulebeschrijving_Terrein.pdf	Standardization documents
S8021_Ontwerpen,_plaatsen_en_aansluiten_van_een_PV-systeem.pdf	Standardization documents
ALL230074 Interactief inspiratiegids Alliander-PGv15 Vertrouwelijk.pfd	Standardization documents
B11100 Beleidsnotitie meerkosten.pfd	Policy document
S2011_-_Flyer_Onderstations_110_en_150kV.pfd	Standardization documents
S2012_-_Flyer_Onderstations_50_kV.pfd	Standardization documents
S2013_-_Flyer_Regelstations_20-10_kV.pfd	Standardization documents
S2014_-_Flyer_Regelstations_20-20_en_10-10_kV.pfd	Standardization documents
S2015_-_Flyer_Schakelstations_20kV_en_10kV.pfd	Standardization documents
RLI-00000237 - Basis ontwerp Oosterwolde 1.0 incl. bijlage.pdf	BO report
RLI-00000237 - Basis Ontwerp Reddyn Oosterwolde versie1.0.pdf	BO report
RLI-00000237 - Bijlage 6.0 Vergunningenoverzicht.pdf	Other design report
RLI-00000237 - Bijlage 7.4.3 Situatietekening Nieuw.pdf	Other design report
RLI-00000237 - Bijlage 7.4.4 20kV Gebouw Bouwkundig.pdf	Other design report
RLI-00000237 - 1807l625 Rapportage ecologisch onderzoek Nanningaweg te Oosterwolde.pdf	Environmental documents
RLI-00000361 - Bijlage 2.2 Programma van Ambitie duurzaam en circulair station.pdf	Other design report
RLI-00000361 - RLO2697MW20181012 - SS Laarberg 31822A - Basis Ontwerp.pdf	BO report
RLI-00000361 - Bijlage 4.3 Omgevingsscan de Laarberg.pdf	Environmental documents
RLI-00000422 - RLI422MS210422 Basisontwerp RS Tollebeek v.1.0.docx	BO report
RLI-00000422 - RLI422MS210422 Basisontwerp RS Tollebeek v.1.0.docx	BO report
RLI-00000422 - RLI422MS210422 Basisontwerp RS Tollebeek v.1.0.pdf	BO report
RLI-00000422 - Bijlage 2 omgeving v.0.3.pdf	Environmental documents
RLI-00000656 - RLI-656 UMS-31369 Basisontwerp OS Nieuwe Meer 2 V2.0.docx	BO report
RLI-00000656 - RLI-656 UMS-31369 Basisontwerp OS Nieuwe Meer 2 V2.0.docx	BO report
RLI-00000656 - Bijlage 1.8.4 Quickscan Flora en Fauna.pdf	Environmental documents
RLI-00000656 - Bijlage 2.4.2 Ruimtelijke Programma van eisen.pdf	Other design report
RLI-00000656 - RLI-656 UMS-31369 Basisontwerp OS Nieuwe Meer 2 V2.0.pdf	BO report
RLI-00000711 - RLI-711 Basisontwerp OS Hemweg Datacenter Westpoort v2.0.docx	BO report
RLI-00000711 - RLI-711 Basisontwerp OS Hemweg Datacenter Westpoort v2.0.docx	BO report
RLI-00000711 - COMMERCIÓLE_RLO2676 OS HW 50kV Datacntr Westpoort AC7 Studie V1.0 incl Bijlage.pdf	Other design report
RLI-00000711 - RLI-711 Basisontwerp OS Hemweg Datacenter Westpoort v2.0.pdf	BO report

RLI-00000789 - 20221102 GRO RS Drogeham.docx	Other design report
RLI-00000789 - RLI789MS220912 Studie Drogeham.docx	Other design report
RLI-00000789 - 20221102 GRO RS Drogeham.docx	Other design report
RLI-00000789 - RLI789MS220912 Studie Drogeham.docx	Other design report
RLI-00000789 - Bijlage 1 Quickscan Archeologie RS Drogeham.pdf	Other design report
RLI-00000789 - Bijlage 2 Verkennend bodemonderzoek RS Drogeham.pdf	Other design report
RLI-00000789 - Bijlage 3 Vooronderzoek OO RS Drogeham.pdf	Other design report
RLI-00000789 - Bijlage 4 Watertoets.pdf	Other design report
RLI-00000789 - Bijlage 5 Ecologie RS Drogeham.pdf	Environmental documents
RLI-00000789 - Omgevingsvergunning-bouw_Ingediende-aanvraag_melding-(PDF)_23-12-2022.pdf	Other design report
RLI-00000789 - RLI789MS220912 Studie Drogeham.pdf	Other design report
RLI-00000789 - Bijlage 3.1.8. Locatie RS Drogeham v2.pdf	Other design report
RLI-00000789 - Bijlage 3.3 Planning.pdf	Other design report
RLI-00000789 - Bijlage 4 Haalbaarheidsstudie RS Drogeham.pdf	Other design report
RLI-00001057 - 20230115 HengeloOldeKaste_Evaluatierapport.pdf	Other design report
RLI-00001057 - 20230515-I-0016.pdf	Other design report
RLI-00001057 - 220303_Hengelo regelstation inpassing.pdf	Other design report
RLI-00001057 - Besluit 12-06-2023 Omgevingsvergunning.pdf	Environmental documents
RLI-00001057 - RLI-1057 UMS24642A Basisontwerp RS HNG nwb 20-10kV v1.0.pdf	BO report
RLI-00001121 - RLI1121MS220203 Studie Akkrum v2.0.docx	Other design report
RLI-00001121 - RLI1121MS220203 Studie Akkrum v2.0.docx	Other design report
RLI-00001121 - Bijlage 3.1.8 inpassing RS Akkrum.pdf	Other design report
RLI-00001121 - Bijlage 4.1 Afwegingsnotitie regelstation Akkrum def.pdf	Other design report
RLI-00001121 - RLI1121MS220203 Studie Akkrum v2.0 DEF.pdf	Other design report
RLO-00001711 - Ecologisch werkprotocol uitbreiding OS De Weel - definitief.pdf	Environmental documents
RLO-00001711 - Ecologische begeleiding uitbreiding OS De Weel - definitief.pdf	Environmental documents
RLO-00001711 - Quickscan WNB realisatie schakelvelden Transformatorstation De Weel - de_._.pdf	Other design report
RLO-00001711 - RLO1711JA170630 Basis Ontwerp Reddyn.pdf	BO report
RLO-00002635 - 25010 PvE OS WV Uitbreiding nieuwbouw variant definitief_.docx	Other design report
RLO-00002635 - Toekomstige situatie OS Wolvega.docx	Other design report
RLO-00002635 - 25010 PvE OS WV Uitbreiding nieuwbouw variant definitief_.docx	Other design report
RLO-00002635 - Toekomstige situatie OS Wolvega.docx	Other design report
RLO-00002635 - 19.0128.2 ecol. begeleiding OS Wolvega.pdf	Environmental documents
RLO-00002635 - 19.0128.2 verslag ecol. begeleiding OS Wolvega.pdf	Environmental documents
RLO-00002635 - Ecologisch werkprotocol uitbreiding OS Wolvega - definitief_20181025.pdf	Environmental documents
RLO-00002635 - OS Wolvega.pdf	Other design report
RLO-00002635 - RLO2570 - Basis Ontwerp Reddyn v1.0.pdf	BO report

Table 11 - Document list

Appendix IX

CBS codes

Definition	Code
Definities Liander APM	LAM-0000XXXX-0000 t/m 0029
Voor DT goedkeuring	LAM-0000XXXX-0000 t/m 0005
Na DT goedkeuring	LAM-0000XXXX-0011 t/m 0016
Opbrengsten	LAM-0000XXXX-0021
Grondkosten	LAM-0000XXXX-0022
Afvalstroom opbrengsten	LAM-0000XXXX-0023
Aanbesteding directieleveringen componenten	LAM-0000XXXX-0025
Plankosten Gemeente	LAM-0000XXXX-0026
Erpachtkosten	LAM-0000XXXX-0027
Definities Service provider	LAM-0000XXXX-0050 t/m 0099
Projectmanagement	LAM-0000XXXX-0061
Maandelijks projectoverleg voeren Projectservices	LAM-0000XXXX-0062
Leadengineer	LAM-0000XXXX-0063
Sitemanagement	LAM-0000XXXX-0064
Beheer	LAM-0000XXXX-0065
VGM	LAM-0000XXXX-0066
Vergunningen/verklaringen	LAM-0000XXXX-0067)
ZRO&schade	LAM-0000XXXX-0068)
Contractmanagement	LAM-0000XXXX-0069
Bouwrente	LAM-0000XXXX-0070
CAR-verzekering premie	LAM-0000XXXX-0071
Ak-toeslag	LAM-0000XXXX-0072)
Inefficiency Reddyn	LAM-0000XXXX-0073
Contingency/Onvoorzien	LAM-0000XXXX-0074
Escalatie/indexering	LAM-0000XXXX-0075
Stationsbenodigheden	LAM-0000XXXX-0076
Grond	
Aan / verkoop/ bouwrijpmaken en saneringen/asbest	LAM-0000XXXX-XX01)
Erfpacht	LAM-0000XXXX-XX02)
Gebouwen &Terreinen	
Engineering Gebouwen incl GGI & Terreinen	LAM-0000XXXX-XX03
Real. bouwkundig incl. GGI/Civiel algemeen	LAM-0000XXXX-XX04
Gebouwen	LAM-0000XXXX-XX05
Gebouw gebonden installaties	LAM-0000XXXX-XX06
Staalwerk	LAM-0000XXXX-XX07
Heipalen	LAM-0000XXXX-XX08
Afwatering/bemaling gebouwen	LAM-0000XXXX-XX09
Terrein inrichting	LAM-0000XXXX-XX10
LS-aansluiting	LAM-0000XXXX-XX11
Bouwkundig/ civiele werkzaamheden incl. keet	LAM-0000XXXX-XX12
E-Houses	LAM-0000XXXX-XX70
Dakbedekking en platte daken	LAM-0000XXXX-XX71
Terreinbewaking	LAM-0000XXXX-XX72
Zonnepanelen	LAM-0000XXXX-XX73
Primaire installaties	

Eng. primaire installatie algemeen	LAM-0000XXXX-XX13
Real. primaire installatie algemeen	LAM-0000XXXX-XX14
Primaire componenten	LAM-0000XXXX-XX15 t/m 16/18 t/m 19
Primaire componenten	LAM-0000XXXX-XX20 t/m 33
HS/MS-rail	LAM-0000XXXX-XX34 en XX35
Sterpuntsaarding	LAM-0000XXXX-XX36 en 37
Stationskabel	LAM-0000XXXX-XX39 en 40
Vermogenstransformatoren	
Eng. Vermogenstrafo	LAM-0000XXXX-XX47
Real. Vermogenstrafo	LAM-0000XXXX-0048
Vermogenstransformatoren	LAM-0000XXXX-XX49 t/m 59
Secundaire installatie	
Eng. secundaire inst.	LAM-0000XXXX-XX60
Real. secundaire installatie	LAM-0000XXXX-XX61
Besturings- beveiligingsinstallatie	LAM-0000XXXX-XX63
Accu batterij/Gelijkstroom installatie	LAM-0000XXXX-XX64
Comptabele meting	LAM-0000XXXX-XX65
Toonfrequent apparatuur	LAM-0000XXXX-XX66
Lijnen 50kV	LAM-0000XXXX-XX67
Amoveren	LAM-0000XXXX-X469
Toonfrequent apparatuur	LAM-0000XXXX-XX66)
Lijnen 50kV	LAM-0000XXXX-XX67)
Amoveren	LAM-0000XXXX-X469)

Table 12 - Cost Breakdown Structure list

Appendix X

CBS code NBS

Terrein inrichting (LAM-0000XXXX-XX10)

Hieronder vallen alle materialen en diensten (M/D) welke benodigd zijn voor de oplevering van de terrein inrichting zoals:

- Bestrating (betonklinkers) aanhelen;
- Terrein verharding en omheining hekwerk/poort;
- Beplanting.

Zonnepanelen (LAM-0000XXXX-XX73

Hieronder vallen alle kosten (M/D) voor de werkzaamheden t.b.v. plaatsen van zonnepanelen zoals:

- Engineering en plaatsing (dienst);
- Zonnepanelen;
- Opstelconstructies;
- Omvormers;
- Bekabeling;
- Etc.

De engineering werkzaamheden (P), die nodig zijn voor de realisatie van de zonnepanelen dienen te worden geboekt onder engineering/realisatie van Engineering Gebouwen incl. GGI & Terreinen (LAM-00XXXX-XX03).

Appendix XI

LLM prompt

Used version of LLM: OpenAI. (2024). GPT-4.0 (Version February 2024) [Computer software]. Retrieved from https://openai.com/gpt-4

Project Analysis Prompt:

"Based on the provided documents, analyze essential information pertaining to a specific project and structure it into a comprehensive table with consistent headings and rows. The table should encompass environmental considerations, technological advancements, socio-economic impacts, and institutional frameworks, focusing on Nature-Based Solutions (NBS) and modular construction methodologies.

1. Examine and summarize key information from each document, paying particular attention to references and contexts related to specified keywords such as 'trees', 'nature', 'site planning', 'biodiversity', 'solar panels', 'spatial planning', 'green infrastructure', 'water management', 'sustainable building', 'modular construction', etc. The model may also look for related keywords to provide a comprehensive analysis.

2. Contextualize the findings within the framework of Nature-Based Solutions (NBS), following the ICES model (Environmental, Technological, Socio-Economic, Institutional), to provide a structured summary.

3. Aggregate the insights into one comprehensive table, categorizing all relevant information under unified headings. The table should prominently feature the project name as its heading.

4. Detail any specific mentions of modular construction or related innovative approaches, elucidating how these elements are woven into the project's design and implementation strategy.

Ensure that the table consistently uses the following headings and rows:
Headings: Category, Considerations & Examples, Impacts/Advantages & Examples, Compliance/Strategy & Examples
Rows: Environmental, Technological, Socio-Economic, Institutional, Nature-Based Solutions, Modular Construction

The "Considerations & Examples" column should be very elaborate and include examples directly drawn from the files provided with the prompt.

Safeguards:
The model should primarily and only rely on information explicitly provided in the documents and the prompt.
Related keywords may be considered to ensure a comprehensive analysis but should not deviate from the core content of the documents.
Ensure the output remains factual, accurate, and suitable for academic analysis, adhering to ethical standards and avoiding speculation."

This prompt allows the model to explore related keywords while analysing the documents, ensuring a thorough examination while maintaining focus on the provided information.

Appendix XII

Project document summary

Project RLI-00000237:

The project demonstrates a holistic approach to environmental preservation, with careful consideration given to the preservation of local flora and fauna alongside compliance with regulations. The project emphasizes biodiversity enhancement through habitat preservation and efficient management systems, including the use of natural barriers for noise reduction. Furthermore, it adopts modular construction methods for technical and safety advantages, showcasing a commitment to adaptability and sustainability. Socio-economic benefits such as job creation and improved infrastructure are highlighted through stakeholder engagement strategies, while institutional engagement ensures smooth regulatory compliance. Nature-based solutions are integrated to protect wildlife, promoting green infrastructure and resilience to climate change. Modular construction techniques not only enhance efficiency but also align with sustainability goals through material reuse and reduced environmental impact.

Project RLI-00000237			
Category	**Considerations & Examples**	**Impacts/Advantages**	**Compliance/Strategy**
Environmental	The project plans include the preservation of local flora, with eight oaks specifically mapped, although three will be removed to facilitate construction. This decision underscores a careful approach to maintaining the site's natural elements where possible. Additionally, the ecological study indicates areas of concern for bats, birds, amphibians, and reptiles, showing the project's comprehensive environmental considerations.	Compliance with environmental regulations has led to enhanced biodiversity through the preservation of local habitats and efficient water and noise management systems, such as using natural barriers for noise reduction.	Environmental assessments and stakeholder consultations have been key, with strategies including public hearings and the integration of feedback into project planning.
Technological	The design documents for the 20kV building detail the use of demountable and pressure explosion panels, reflecting a modular approach to construction that enhances both safety and flexibility. This modular aspect allows for easy adaptation and expansion in the future, demonstrating a commitment to using innovative construction methods to meet technical and safety standards.	The project benefits from increased safety, adaptability, and sustainability of infrastructure. The use of modular construction allows for easier updates and expansions, showcasing a forward-thinking approach to infrastructure development.	Strategic decisions during the project review emphasized safety and sustainability, with a focus on selecting technologies that offer long-term benefits and adaptability to future needs.
Socio-Economic	Engaging with the socio-economic aspects primarily through the lens of the project's impact on the local community and economy, although specific socio-economic examples drawn directly from the documents are limit. The emphasis on stakeholder engagement and compliance with environmental regulations indirectly suggests efforts to align the project with community values and economic benefits, such as job creation during construction and improved infrastructure.	Enhanced community engagement has led to socio-economic benefits, including job creation during the construction phase and improved infrastructure for the community. The project has also aimed to boost local economies by sourcing materials and labour locally where possible.	Engagement strategies have included public forums, risk management workshops, and ongoing communication channels to keep stakeholders informed and involved throughout the project lifecycle.

Institutional	The permits overview document outlines a detailed procedure for obtaining necessary permits for construction, environmental management, and traffic planning, indicating thorough institutional engagement. This meticulous approach ensures adherence to both local and national regulations, demonstrating the project's commitment to navigating the complex regulatory landscape efficiently.	Adherence to legal and environmental standards has streamlined permit acquisition, reducing delays and ensuring the project progresses smoothly. The comprehensive approach to regulatory compliance has facilitated a smoother implementation process.	A detailed permits overview was prepared, highlighting compliance with governing bodies and laws. This strategy ensured a clear path for obtaining necessary approvals and fostering institutional support.
Nature-Based Solutions	The project's ecological research outlines the importance of conserving bats, birds, amphibians, and reptiles, integrating nature-based solutions to protect local wildlife. These efforts to assess and mitigate the project's impact on local ecosystems exemplify the integration of NBS in project planning, aiming to preserve biodiversity and natural habitats within the construction framework.	The harmonization with the natural environment promotes green infrastructure, enhancing the project's sustainability and resilience to climate change. These NBS elements contribute to creating a more liveable and environmentally friendly infrastructure.	Spatial planning and the incorporation of NBS elements were guided by principles of sustainability and resilience, with planning phases including assessments of ecological impact and potential for enhancing natural habitats.
Modular Construction	The modular construction methods are exemplified by the inclusion of demountable components and pressure explosion panels in the 20kV building desi. This approach not only facilitates future modifications and expansions but also aligns with sustainability goals by allowing for the reuse of materials and reducing construction waste. This strategy demonstrates how modular construction principles are applied to enhance the project's adaptability, efficiency, and sustainability.	Modular construction techniques have led to efficiency in construction, with reduced timelines and lower environmental impact. The flexibility offered by modular construction also allows for future expansion or modification with minimal disruption.	The focus on modular construction included the selection of sustainable materials and construction practices that minimize environmental impact while enhancing the project's adaptability and sustainability.

Project RLI-00000361:

The project demonstrates a multifaceted approach to environmental conservation, leveraging various strategies to enhance sustainability and biodiversity preservation. Examples include the integration of sedum roofing and timber frame construction, which not only improve water management but also contribute to the preservation of local flora and fauna. Additionally, the project's adherence to regulations and engagement with stakeholders ensures compliance with environmental standards while addressing community concerns. This approach fosters economic growth through job creation and local sourcing, enhancing the project's socio-economic impact. The project incorporates advanced technological solutions like solar panels and modular construction techniques to further bolster sustainability efforts. These technologies not only reduce the project's environmental footprint but also increase its resilience and adaptability to future needs.

Project RLI-00000361			
Category	**Considerations & Examples**	**Impacts/Advantages**	**Compliance/Strategy**
Environmental	The project demonstrates a commitment to conserving flora and fauna. The documents indicate that the area is partially developed as a business park and partially agricultural, with no significant tree removal expected, which helps preserve existing natural elements??. The design incorporates sedum roofing for the switch station, contributing to water management and positively impacting local biodiversity. Additionally, the project is cognizant of protected species like the boomvalk, buizerd, ransuil, steenuil, and various bat species, ensuring the protection of these species in line with regional plans.	By adhering to environmental regulations, the project preserves local biodiversity. Additionally, the sedum-covered roofs and the buffering of soil around the building enhance water management and local biodiversity.	Environmental assessments and stakeholder consultations, including annual monitoring of natural values, are integral to the project's planning, ensuring compliance and incorporation of feedback.
Technological	Technologically, the project is set to include houtskeletbouw (timber frame construction) from sustainable inland wood species and modular components for flexibility, such as prefabricated sections for certain building parts, enhancing adaptability and sustainability. The use of pressure-explosion panels in construction is considered to ensure safety while maintaining design adaptability.	The project leverages solar panels and innovative water management techniques like the use of a Wadi or nearby ditch for water runoff, contributing to energy efficiency and sustainability.	The project's technological aspects are aligned with sustainable building practices, ensuring long-term benefits and adaptability, with strategic use of renewable energy sources and sustainable materials.
Socio-Economic	The socio-economic approach engages various stakeholders, including local communities, aligning the project with community standards and addressing concerns, which is exemplified by the establishment of community forums to discuss the project's impacts and benefits??. Job creation during the construction phase and improved local infrastructure are also key considerations, with sourcing materials and labour locally to boost the economy.	The construction phase is expected to create jobs and enhance the local economy by using local materials and lab. The green infrastructure and biodiversity support can lead to improved well-being and property values in the area.	Engagement strategies include public forums and risk management workshops, emphasizing the inclusion of local labour and sourcing, and ongoing communication with stakeholders throughout the project lifecycle.

Institutional	The project navigates complex regulatory landscapes, including obtaining permits for construction, environmental impacts, and traffic management, while adhering to local and national regulations. A comprehensive overview of required permits for building transformer cells and managing ecological impacts ensures compliance??. In water management, considerations include the potential use of construction site dewatering within the jurisdiction of the Waterschap Rijn en Ijssel and complying with the regulations for groundwater extraction.	Adherence to legal and environmental standards facilitates a smoother project implementation. The project's comprehensive approach to regulatory compliance has streamlined permit acquisition, reducing potential delays.	A detailed permits overview was prepared, emphasizing compliance with governing bodies and environmental laws, ensuring a clear path for obtaining necessary approvals and fostering institutional support.
Nature-Based Solutions	NBS elements are extensively incorporated, with terrain and ecological features integrated into the infrastructure components. Examples include the use of natural vegetation to enhance ecological connections and the incorporation of green infrastructure like green roofs and ecological corridors??. The project also contemplates water management solutions like discharging water into a nearby ditch or creating a Wadi for onsite water management, which will be determined in the Design phase.	Integration with the natural environment through NBS promotes sustainability and climate resilience, with the added benefit of creating more liveable and environmentally friendly infrastructure.	Spatial planning and the incorporation of NBS are guided by principles of sustainability and resilience, with planning phases including assessments of ecological impact and potential for enhancing natural habitats.
Modular Construction	The project utilizes modular construction methods, with the design of the 20kV building featuring modular panels that can be easily assembled, disassembled, and reused, reducing waste and increasing the project's flexibility. This reflects a clear preference for sustainable and innovative construction practices??.	Modular construction techniques lead to reduced construction time and environmental impact. The flexibility offered allows for future expansion or modification with minimal disruption, ensuring the project's adaptability and scalability.	The project's strategy for modular construction includes the selection of sustainable materials and construction practices that minimize environmental impact, highlighting the project's adaptability and commitment to sustainability.

Project RLI-00000422

The project prioritizes environmental preservation by carefully selecting the project site and implementing measures to minimize disruption, such as tree removal and soil investigation. Advanced technological solutions, including modular construction and modern electrical installations, enhance efficiency and operational safety while supporting future scalability. Socio-economic benefits are emphasized, with the project positioned as a catalyst for regional development and job creation. Institutional coordination ensures compliance with regulations and alignment with community expectations. Nature-based solutions are integrated to enhance ecosystem services, contributing to climate resilience and environmental stewardship. This integration includes landscaping strategies, green spaces provision, water management practices, and sustainable land use principles, all aimed at promoting biodiversity, mitigating climate change impacts, and fostering environmental stewardship within the project site and surrounding areas.

Project RLI-00000422			
Category	**Considerations & Examples**	**Impacts/Advantages**	**Compliance/Strategy**
Environmental	The project site is carefully selected to minimize environmental disruption, with an emphasis on avoiding Natura2000 areas and preserving the local ecosystem. Specific considerations include the removal and replanting of trees to maintain ecological balance, and a detailed soil investigation to assess and mitigate any contamination risks. Environmental impacts are meticulously evaluated, including potential effects on local wildlife and water management strategies to prevent flooding and ensure sustainable water use. Future integration of solar panels is planned to promote renewable energy.	The project's location and design aim to maintain the landscape's openness, with future plans for solar panel installation to promote renewable energy use.	Environmental studies, including soil investigation and flora and fauna QuickScans, ensure compliance with regulations, aiming to protect local biodiversity and minimize pollution.
Technological	Embraces modular construction to enhance efficiency, with a focus on adaptability and scalability. Technological considerations include the implementation of state-of-the-art electrical installations, such as a 20 kV switchgear and regulation transformers designed for N-1 operational safety. The project also integrates advanced communication systems for reliable operation, including telecom networks for security and monitoring, and provisions for future technological upgrades to maintain operational excellence. Specific attention is given to the modular design to ensure rapid assembly and ease of future expansion.	Modular construction allows for rapid assembly and scalability, improving project timelines and reducing environmental impact. Advanced technology ensures the station's operational safety and energy efficiency.	The project specifies deviations from standard modular construction to accommodate site-specific requirements, ensuring technological adaptability while maintaining safety and reliability standards.
Socio-Economic	Aims to address the growing demand for electrical power in the region, supporting economic growth and infrastructure development. The project is positioned as a catalyst for regional development, enhancing the reliability and capacity of the power supply to meet both current and future demands. Considerations include the socio-economic benefits of improved energy infrastructure, such as enhanced business operations, job creation during the construction phase, and long-term economic stability. The project's role in supporting sustainable development and contributing to the local economy is highlighted.	By enhancing the reliability and capacity of the local power supply, the project contributes to socio-economic development, supporting both existing and future demand.	Engagements with stakeholders and compliance with local regulations are integral, ensuring the project's benefits are realized while minimizing negative impacts on the community.

Institutional	Navigates a complex regulatory landscape, including securing necessary permits and ensuring compliance with local and national regulations. Institutional considerations involve close coordination with local authorities, regulatory bodies, and stakeholders to align the project with public policies, community expectations, and environmental standards. The process includes detailed planning for land acquisition, environmental assessments, and community engagement to ensure the project meets all legal and operational standards. The project exemplifies effective institutional collaboration and compliance.	Effective coordination with local authorities and stakeholders ensures the project aligns with public policies and community expectations, facilitating a smooth implementation process.	A comprehensive approach to managing stakeholder interests and regulatory compliance underscores the project's commitment to institutional frameworks, ensuring legal and operational standards are met.
Nature-Based Solutions (NBS)	Incorporates NBS to enhance ecosystem services and contribute to climate resilience. This includes landscaping strategies that integrate the station into the surrounding environment, promoting biodiversity through the planting of native species and creating green spaces. Considerations also extend to water management practices that mimic natural processes to manage stormwater and reduce runoff, and the potential for incorporating green roofs or walls to support local flora and fauna. The project demonstrates a commitment to leveraging NBS for environmental and community benefits.	These solutions are intended to enhance biodiversity, support ecosystem services, and contribute to climate change mitigation, showcasing the project's environmental stewardship.	The project's design and execution reflect a strong commitment to NBS principles, aligning with broader environmental and sustainability objectives, while also considering local ecological impacts.
Modular Construction	The project's modular construction approach is designed for efficiency, scalability, and minimal environmental impact. This innovative construction method is chosen for its ability to reduce on-site construction time, lower costs, and decrease environmental disturbance. Considerations include the selection of sustainable materials, the use of prefabricated components to reduce waste, and the ability to adapt and expand the station as future needs evolve. The project highlights specific design choices and materials used in modular construction to optimize the building process and ensure sustainability.	Modular construction reduces on-site construction time, minimizes environmental disturbances, and allows for future station expansions with minimal disruption, showcasing its benefits in sustainability and efficiency.	The detailed planning and execution strategy for modular construction demonstrate compliance with best practices and innovation in construction methodologies, ensuring the project's efficiency and sustainability goals are met.

Project RLI-00000656:

The project incorporates environmental assessments, spatial planning, and modular construction methodologies to align with Nature-Based Solutions and sustainability goals. Documents detail considerations for local flora and fauna, technological innovations for efficient construction, and socio-economic benefits like job creation and urban green space enhancement. Institutional frameworks ensure regulatory compliance and stakeholder engagement. The project emphasizes modular construction for scalability and flexibility, integrating green infrastructure to enhance biodiversity and manage water sustainably.

Project RLI-00000656			
Category	**Considerations & Examples**	**Impacts/Advantages**	**Compliance/Strategy**
Environmental	The "Quickscan Flora en Fauna" document detailed the presence of species like bats, nesting birds, and specific plants, indicating habitats that may be affected by construction. Measures such as timing construction to avoid breeding seasons and installing bat houses were suggested. It also highlighted areas requiring additional surveys for species like the Common kingfisher and European eel.	These considerations lead to targeted mitigation strategies that minimize ecological disruption, ensuring the project's alignment with biodiversity conservation goals.	The document emphasizes compliance with the Nature Conservation Act by conducting further studies and implementing mitigation measures, such as relocating protected species and adjusting construction timelines.
Technological	The "Basisontwerp OS Nieuwe Meer 2 V2.0" outlines the use of modular construction techniques, which allow for prefabricated elements to be easily assembled on-site, reducing construction time and environmental impact. It also mentions the integration of advanced water management systems to control runoff and promote water conservation.	Modular construction not only speeds up the building process but also reduces waste and energy consumption, exemplifying a shift towards more sustainable construction practices.	Strategies include leveraging technological innovations to ensure environmental compliance and efficiency, such as using renewable energy sources and implementing smart grid technologies.
Socio-Economic	The "Ruimtelijke Programma van Eisen" focuses on integrating the substation within the urban landscape, proposing green roofs, walls, and landscaping to enhance aesthetic and ecological value. It discusses the project's role in supporting Amsterdam's transition to renewable energy, highlighting socio-economic benefits like job creation and improved infrastructure reliability.	By enhancing urban green spaces and contributing to the energy transition, the project supports economic development and social well-being, providing long-term benefits to the community.	The document outlines strategies for stakeholder engagement and public consultation to ensure the project meets community needs and expectations, fostering social acceptance and collaboration.
Institutional	Detailed stakeholder engagement plans were outlined, including consultations with local government agencies, environmental groups, and the community. The documents emphasize the need for regulatory compliance, obtaining necessary permits, and aligning with local and national environmental policies.	Institutional cooperation ensures the project is carried out in accordance with legal and regulatory frameworks, facilitating a smoother implementation process.	Compliance strategies are detailed, including a timeline for permit applications, engagement with regulatory bodies, and adherence to construction and environmental standards.
Nature-Based Solutions (NBS)	Emphasis on integrating NBS is evident in plans for green infrastructure, such as planting native species, creating habitats for local fauna, and sustainable water management practices like rain gardens and permeable pavements. The documents highlight the role of these solutions in enhancing biodiversity, managing stormwater, and improving air quality.	NBS offer significant environmental benefits, including enhanced ecosystem services, improved resilience to climate change, and increased urban biodiversity.	Strategies for implementing NBS include collaborative design processes with ecologists, landscape architects, and urban planners to ensure that green infrastructure is effectively integrated into the project.

Modular Construction	The project's design is based on modular construction methodologies to enhance flexibility and scalability. This approach is highlighted as key to accommodating future energy needs and technological advancements. Specific examples include the prefabrication of substation components and the use of modular office buildings for onsite personnel.	Modular construction reduces on-site construction time and environmental impact, exemplifies efficient resource use, and enables rapid adaptation to future needs.	The strategy involves close collaboration with modular construction firms and engineering consultants to ensure design specifications meet both current and future requirements, focusing on sustainability and adaptability.

Project RLI-00000711:

The project exemplifies a holistic approach to development, intricately weaving together environmental stewardship, technological advancement, socio-economic growth, and institutional collaboration. By conducting thorough assessments of soil quality, water management strategies, and biodiversity conservation efforts, the project ensures minimal ecological disruption. Technologically, the project employs cutting-edge solutions like a 50kV gas-insulated switchgear (GIS) system and modern telecommunications infrastructure to guarantee reliable and efficient power distribution. While explicitly not mentioning modular construction, the project showcases elements of efficiency and innovation akin to modular methodologies. Collaboration with various stakeholders, including government authorities and utility companies, underscores institutional commitment to regulatory compliance and public engagement. This multifaceted approach embodies an indirect application of Nature-Based Solutions, fostering harmony between the built environment and natural ecosystems.

Project RLI-00000711			
Category	**Considerations & Examples**	**Impacts/Advantages**	**Compliance/Strategy**
Environmental	The project closely examines environmental factors such as soil integrity, water management practices, and the conservation of natural habitats. It involves detailed assessments to ensure minimal disturbance to local ecosystems and compliance with strict environmental standards. For example, the project includes studies on the potential impact on local water bodies, ensuring that construction does not adversely affect water quality or drainage patterns. Moreover, it involves evaluations to prevent harm to protected species or significant natural features, adhering to regulations on nature conservation. This approach reflects a commitment to sustainable development and the preservation of biodiversity.	Positive environmental impacts include careful planning to minimize ecological disruption and adherence to environmental regulations.	Compliance with regulations related to archaeology, soil, water management, external safety, and nature conservation. Measures include conducting soil quality assessments, ensuring water management aligns with local regulations, and planning construction to avoid negative impacts on protected nature areas.

Technological	Technologically, the project is advanced, incorporating a 50kV gas-insulated switchgear (GIS) system, state-of-the-art cable circuits for electricity distribution, and modern telecommunications infrastructure. These components are carefully selected to ensure reliability, safety, and efficiency in powering the data center. The use of GIS, for example, minimizes space requirements and enhances safety by reducing the risk of faults. The document details the specifications for these systems, emphasizing their role in achieving a high level of operational efficiency and resilience against electrical failures, thereby supporting the data center’s critical functions.	The technological advancements enable the data center to meet its high-capacity power requirements with efficiency and reliability.	Strategies include utilizing a gas-insulated switchgear (GIS) and modernizing electrical infrastructure to ensure the efficient distribution of power, while also incorporating safety and quality standards in the design and implementation. Compliance with technical specifications and standards is crucial.
Socio-Economic	The socio-economic considerations of the project highlight its role in supporting the region's technological infrastructure, contributing to economic growth, and providing employment opportunities during the construction phase. The establishment of the data center is expected to enhance digital connectivity and services for businesses and the community, underscoring the project's importance in the digital economy. This development is poised to attract further investment in the area, stimulate job creation in both the construction and operational phases, and support the broader socio-economic objectives of enhancing Amsterdam's position as a key technology hub in Europe.	Benefits include job creation during the construction phase and enhanced digital infrastructure supporting economic growth.	The project aligns with regional development plans and leverages partnerships with utility companies, municipalities, and the data center client to ensure socio-economic benefits are maximized.
Institutional	Institutionally, the project navigates complex regulatory landscapes and engages with multiple stakeholders, including government authorities, utility companies, and the local community. This involves securing necessary permits, ensuring compliance with urban planning and construction regulations, and aligning with environmental protection standards. The documentation reflects thorough planning and coordination efforts to meet institutional requirements, such as property rights negotiations and adherence to public law. These efforts are critical for the project's success, facilitating smooth implementation and minimizing potential legal or regulatory hurdles.	Institutional cooperation ensures the project's alignment with public policy objectives and regulatory compliance.	Strategies for managing institutional frameworks include stakeholder engagement, navigating regulatory requirements for construction and environmental protection, and securing necessary permits and approvals.

Nature-Based Solutions	While the documents do not explicitly describe traditional nature-based solutions like green roofs or rain gardens, the environmental strategies employed—aimed at minimizing ecological disruption and integrating the project within the existing landscape—align with the principles of NBS. These include measures to protect local biodiversity, manage stormwater effectively, and reduce the environmental footprint of construction activities. The emphasis on preserving natural habitats and ensuring sustainable water management reflects an indirect application of NBS principles, focusing on harmony between the built environment and natural ecosystems.	The integration of the project with careful consideration of environmental impacts promotes sustainability and resilience.	The strategy involves adhering to environmental protection standards, conducting ecological assessments, and ensuring that construction and operational activities do not adversely affect local biodiversity and ecosystems.
Modular Construction	Although modular construction is not explicitly mentioned, the project's approach to infrastructure development suggests an inclination towards efficiency and innovation, which are key attributes of modular construction methods. For example, the prefabrication of electrical components and the detailed planning for site installation reflect a modular mindset, aiming to reduce on-site construction time, minimize environmental impact, and enhance quality control. These strategies, while not labeled as modular construction, embody its principles by prioritizing off-site fabrication of components for rapid assembly and reduced site disturbance.	Potential benefits of modular construction, if applied, include reduced construction time and minimized environmental disturbance.	Although not explicitly stated, the project's approach to detailed planning, prefabrication of electrical components (GIS), and efficient site management could incorporate modular construction principles in aspects of the development. Compliance with design and safety standards would be essential in integrating modular components.

Project RLI-00000789

The project melds environmental stewardship, innovative construction methods, socio-economic benefits, and robust institutional frameworks into its design and implementation. Environmental considerations include integrating the project within the local landscape, enhancing biodiversity, and implementing effective water management strategies. Technological advancements are highlighted through modular construction and renewable energy integration. Socio-economic impacts involve local job creation and infrastructure improvements, while institutional compliance ensures alignment with regulatory standards.

Project RLI-00000789			
Category	**Considerations & Examples**	**Impacts/Advantages**	**Compliance/Strategy**
Environmental	Site selection prioritizes minimal environmental disruption, preserving existing trees and natural land contours. Implementation of water management strategies, including rainwater harvesting and sustainable drainage systems (SuDS) to mitigate flood risks and enhance groundwater recharge. Biodiversity considerations include creating habitats for local fauna and incorporating native plant species to support ecological networks.	Reduced carbon footprint through site-sensitive planning and use of renewable energy sources. Enhanced local biodiversity, contributing to ecosystem resilience and providing natural habitats.	Adherence to environmental protection laws and regulations. Development of a green infrastructure plan as part of the project's environmental management strategy.

Technological	Adoption of modular construction techniques for the regulation station, emphasizing off-site fabrication to minimize on-site environmental impact and enhance construction efficiency. Integration of solar panels and other renewable energy technologies to reduce dependency on non-renewable energy sources.	Improved efficiency and sustainability in construction processes, leading to shorter project timelines and reduced waste. Lower operational energy costs and increased use of clean energy.	Alignment with sustainable construction standards and guidelines. Use of cutting-edge spatial planning tools for optimal site utilization and minimal environmental impact.
Socio-Economic	Employment opportunities generated through the construction phase and ongoing operation of the facility. Infrastructure improvements, including upgrades to local roads and utilities, benefiting the wider community. Engagement with local communities through consultations and participatory planning processes to ensure the project meets local needs and priorities.	Stimulation of local economic development through job creation and infrastructure investments. Enhanced quality of life for residents through improved local amenities and services.	Strategic engagement with local stakeholders to foster community support and collaboration. Conducting socio-economic impact assessments to inform project planning and development.
Institutional	Compliance with zoning and land use planning regulations to ensure the project aligns with local development goals. Collaboration with water management authorities to integrate the project's water management plans with regional strategies. Obtaining necessary permits and approvals through effective coordination with local, regional, and national regulatory bodies.	Efficient project approval and implementation processes. Enhanced capacity for integrated water management and environmental conservation.	Development of institutional partnerships and frameworks to support project implementation. Active participation in regulatory review processes to ensure full compliance.
Nature-Based Solutions (NBS)	Utilization of ecosystem-based approaches for site planning, such as green roofs, permeable paving, and natural landscaping to enhance urban biodiversity and ecosystem services. Designing the project to contribute to climate change mitigation and adaptation by enhancing green spaces and carbon sequestration capabilities.	Increased resilience to climate change and natural disasters. Improved air and water quality, contributing to healthier living environments.	Incorporation of NBS principles into all stages of project planning, design, and implementation. Monitoring and evaluation of NBS outcomes to inform future projects.
Modular Construction	Detailed planning for the use of pre-fabricated modules that can be quickly assembled on-site, reducing construction time and environmental disturbance. Design considerations include scalability and adaptability for future expansion or modifications, with a focus on sustainability and energy efficiency.	Significant reduction in construction waste and site disturbance. Flexibility to adapt to changing needs or expand facilities with minimal disruption.	Implementation based on industry best practices for modular construction. Continuous improvement approach to integrate feedback and lessons learned into future modular construction projects.

Project RLI-00001057

The project prioritizes environmental sustainability and community engagement through various means. Technologically, it employs modular construction methodologies and advanced materials to ensure efficiency, adaptability, and a reduced environmental footprint in the development of the transformer station. Socio-economically, the project integrates recreational spaces, such as walkable paths and fruit-picking areas, to enhance community well-being and promote local engagement. Additionally, the project preserves archaeological sites, highlighting a commitment to cultural heritage and historical significance. Institutionally, collaboration with regulatory bodies, such as the Waterboard "Waterschap Rijn en Ijssel "and the Municipality of Bronckhorst, ensures compliance with regulations and permits, facilitating smooth implementation and long-term viability of the project.

Project RLI-00001057			
Category	**Considerations & Examples**	**Impacts/Advantages**	**Compliance/Strategy**
Environmental	The project emphasizes enhancing local biodiversity through the integration of native plant species and green spaces. For instance, the landscaping plan includes the creation of a walnut orchard and the use of native trees and shrubs to ensure seamless integration with the natural surroundings. This approach is aimed at not only beautifying the area but also contributing positively to the local ecosystem.	Enhanced local biodiversity and improved aesthetics create a more appealing and environmentally friendly space. The use of native plantings supports local fauna and contributes to the ecological balance.	The project aligns with local environmental guidelines and regulations, ensuring that the construction and landscaping plans do not adversely impact the local ecosystem. Collaborative efforts with Urban Synergy and Liander highlight a commitment to sustainable development practices.
Technological	Modular construction methodologies are highlighted for their efficiency and adaptability. The project leverages advanced materials and sustainable design principles to minimize environmental impact while ensuring the infrastructure is resilient and adaptable to future needs. The focus on modular construction allows for quicker assembly and less waste, demonstrating an innovative approach to construction that aligns with modern sustainability goals.	Modular construction reduces construction time, minimizes waste, and enhances flexibility for future modifications. The use of sustainable materials and design principles improves energy efficiency and lowers the overall carbon footprint of the project.	Adoption of modular construction techniques aligns with industry best practices for sustainable development. The project's design and implementation strategies are compliant with modular construction standards, ensuring efficiency and sustainability are at the forefront of development efforts.
Socio-Economic	Community engagement and socio-economic benefits are central to the project's design, with the development of recreational opportunities such as walkable paths and areas for fruit-picking in a mixed orchard. These features aim to enhance community well-being and promote local engagement with the project area. Additionally, the archaeological findings from the Iron Age to the early Roman period offer educational and tourism opportunities, emphasizing the site's historical significance.	The project strengthens community ties by providing recreational and educational opportunities, thereby enhancing the socio-economic fabric of the area. The preservation and promotion of the archaeological site as a point of interest could foster a sense of pride in local heritage and stimulate tourism.	The project incorporates community feedback and historical considerations into its planning and design, demonstrating compliance with socio-economic objectives and local heritage preservation efforts. Engagement with local authorities and the community ensures the project benefits are aligned with local needs and values.

Institutional	Coordination with Waterschap Rijn en IJssel and compliance with the Municipality of Bronckhorst's regulations are key institutional considerations. The project has navigated the regulatory landscape effectively, securing necessary permits and ensuring that the construction does not adversely impact surface water or contravene local regulations. This demonstrates a well-managed approach to institutional compliance and stakeholder engagement.	By securing all necessary permits and effectively managing stakeholder relations, the project ensures smooth implementation and long-term viability. Compliance with local and regional regulations supports the project's acceptance and integration into the community fabric.	Regular communication with local and regional authorities, along with adherence to legal and regulatory requirements, underscores the project's commitment to institutional compliance. This strategic approach facilitates project approval and implementation, ensuring a collaborative relationship with regulatory bodies.
Nature-Based Solutions (NBS)	The project incorporates NBS through the use of green infrastructure elements like green roofs, water management systems, and biodiversity enhancement areas. The strategic inclusion of trees and native vegetation in site planning exemplifies the project's commitment to leveraging nature-based solutions for environmental, social, and economic benefits. These elements are designed to improve the site's microclimate and contribute to stormwater management and biodiversity.	NBS contribute to the mitigation of the urban heat island effect, enhancement of stormwater management, and improvement of local biodiversity. These benefits align with broader environmental objectives, such as climate adaptation and ecosystem services enhancement.	The project's implementation of NBS follows the ICES model guidelines, integrating environmental considerations into overall planning and design. This ensures that nature-based solutions are effectively utilized in conjunction with modular construction to achieve sustainable development goals.
Modular Construction	The project employs modular construction techniques for the development of the control station and associated infrastructure. This approach is characterized by scalability, adaptability, and a focus on minimizing environmental impact through efficient construction practices and reduced material waste. The use of modular units allows for a flexible design that can be easily adapted or expanded based on future needs, making it an exemplary case of sustainable infrastructure development. The strategic planning and execution of modular construction demonstrate a forward-thinking approach that aligns with environmental and socio-economic objectives, ensuring the project's design is both innovative and adaptable.	Modular construction techniques streamline the construction process, significantly reducing on-site construction time and associated environmental impacts. This approach enables a more sustainable construction process, with less waste and a reduced carbon footprint, contributing to the overall sustainability of the project.	The project's modular construction approach complies with established standards and best practices, ensuring that the methodology is effectively integrated into the overall project framework. Strategic planning and adherence to modular construction principles facilitate the alignment of the project with sustainability goals, showcasing a commitment to innovative and responsible construction projects

Project RLI-00001121

Project RLI-1121 integrates similar principles as Nature-Based Solutions in the design and construction. The project emphasizes the environmental integration of the station with its surroundings through strategic tree planting, potential solar panel installations for renewable energy, and biodiversity enhancements. Technologically, it adopts modular construction for efficiency and scalability, alongside advanced control and security systems. Socio-economically, it addresses local energy demands, incorporates community engagement, and explores economic benefits from renewable energy generation. Institutionally, it involves coordination with local authorities to comply with planning and environmental regulations, demonstrating a holistic approach to sustainable infrastructure development.

Project RLI-00001121			
Category	**Considerations & Examples**	**Impacts/Advantages**	**Compliance/Strategy**
Environmental	The project incorporates NBS through the strategic placement of trees to integrate the station with its surroundings. Solar panels are considered for renewable energy generation. The design includes measures for biodiversity enhancement and water management.	Trees reduce the visual impact and enhance local biodiversity. Solar panels contribute to sustainable energy generation.	Compliance with environmental regulations involves integrating NBS in the design phase, aligning with local biodiversity and sustainability goals.
Technological	Modular construction methodologies are applied to various station components, including transformer and switchgear rooms. The design incorporates advanced SES for control and security. Solar panel integration is considered for energy generation.	Modular construction enhances efficiency and scalability, while SES improves reliability and security. Solar panels offer renewable energy benefits.	The project aligns with standards for modular construction and SES, ensuring technological compliance and adaptability.
Socio-Economic	The project addresses local energy demands and incorporates community engagement in environmental planning. It also considers the socio-economic implications of renewable energy generation and infrastructure development.	Improvements in energy infrastructure resilience and potential economic benefits from renewable energy generation.	Engagement with local stakeholders and alignment with socio-economic development plans are key strategies.
Institutional	Coordination with local authorities for compliance with zoning and planning regulations is emphasized. The project involves discussions with municipal and provincial authorities for environmental and construction permits.	Supports sustainable development goals and facilitates project approval and implementation through institutional cooperation.	Adherence to regulatory frameworks for construction, environmental management, and modular construction principles is critical for institutional compliance.
Nature-Based Solutions	Integration of trees for site aesthetics and biodiversity, along with considerations for sustainable water management, exemplifies the project's commitment to NBS.	Enhances local biodiversity and improves the microclimate, contributing to the project's environmental sustainability.	NBS are integrated from the planning phase, following the ICES model for environmental, technological, socio-economic, and institutional considerations.
Modular Construction	The project employs modular construction techniques for efficient and scalable infrastructure development, highlighting the	Reduces construction time and environmental impact, demonstrating cost efficiency and scalability of modular	Implementation based on modular construction principles ensures standardization

	adaptability and efficiency of using prefabricated components.	construction in infrastructure projects.	and efficiency, aligning with the project's design and implementation strategy.

Project RLO-00001711

Project RLO-1711 integrates modular construction and nature-based solutions, emphasizing environmental protection, technological innovation, and socio-economic benefits within a robust institutional framework. It aims to minimize ecological impact by protecting local biodiversity, such as the natterjack toad and breeding birds, through mitigation strategies like amphibian barriers and habitat management. Modular construction techniques reduce construction time and environmental disturbance, aligning with sustainable practices. Compliance with nature conservation laws and engagement with community and regulatory bodies ensure the project's alignment with environmental, legal, and socio-economic goals, demonstrating a balanced approach to infrastructure development and ecological preservation.

Project RLO-00001711			
Category	**Considerations & Examples**	**Impacts/Advantages**	**Compliance/Strategy**
Environmental	Environmental considerations include habitat protection for species like the natterjack toad and breeding birds, and water management issues due to bronbemaling (groundwater pumping). Measures taken include installing amphibian barriers and managing construction activities to avoid disturbing breeding birds and habitats.	Project aims to minimize ecological footprint through careful site planning and mitigation strategies, ensuring protection of local biodiversity and adherence to environmental regulations.	Compliance with Wet Natuurbescherming through ecological assessments, habitat preservation efforts, and the implementation of mitigation measures to protect local wildlife and ecosystems.
Technological	The project involves modular construction techniques for the substation and switchyards, aiming to reduce construction time and environmental impact. The design accommodates specific building dimensions outlined in the environmental permit from 2012.	Modular construction offers benefits such as reduced site disturbance, lower construction waste, and alignment with sustainable building practices, facilitating a quicker and more efficient construction process.	The project's technological strategies, including modular construction and careful planning, ensure environmental compliance and reduce the need for nature conservation law exemptions, demonstrating an innovative approach to substation construction.
Socio-Economic	The project supports the regional energy infrastructure's enhancement, with potential impacts on local biodiversity and socio-economic factors due to construction activities and increased capacity for renewable energy integration.	Enhances local economy and energy reliability by improving infrastructure, while ecological measures ensure responsible development with minimal impacts on biodiversity and water resources.	Community engagement and adherence to environmental laws ensure a balanced development approach, fostering social acceptance and emphasizing the project's benefits to local communities and ecosystems.

Institutional	The project operates within frameworks of national and EU nature conservation laws, focusing on species protection and environmental impact assessments. It involves collaboration between Liander and TenneT, reflecting an integrated approach to managing technical, environmental, and community aspects.	Institutional frameworks provide structured environmental management, ensuring legal compliance, sustainable development, and fostering institutional accountability through detailed ecological assessments.	Strategies include detailed ecological assessments, mitigation measures, and community engagement, demonstrating institutional accountability and compliance with legal frameworks.
Nature-Based Solutions (NBS)	Incorporates ecological work protocols and habitat management strategies to protect species and manage water efficiently. The project integrates NBS for water management and habitat creation, focusing on species like the natterjack toad and breeding birds.	Enhances biodiversity and ecosystem services, contributing to climate adaptation and resilience. NBS approaches support sustainable water management and biodiversity conservation.	Ecological measures and mitigation strategies align with nature conservation laws, promoting ecosystem-based management principles and sustainable development.
Modular Construction	Utilizes modular construction techniques for rapid assembly, minimizing site disturbance and ecological footprint. The approach is integrated with ecological guidance to ensure environmental compliance while reducing construction waste and enhancing efficiency.	Offers environmental benefits by reducing construction waste and site disruption, aligning with sustainable building practices and supporting efficient project execution.	Modular construction methods are carefully planned to ensure environmental compliance and reduce the need for legal exemptions, demonstrating a commitment to sustainable and responsible construction practices.

Project RLO-00002635

The project RLO-2635 is an expansion project that integrates ecological guidance, technological advancements, and socio-economic considerations within an institutional framework, emphasizing Nature-Based Solutions and potential for modular construction methodologies. Environmental strategies focus on biodiversity, particularly protecting nesting birds, while technological upgrades aim to meet rising energy demands with minimal impact. Socio-economic benefits include enhanced community resilience and infrastructure for future growth. Institutional compliance ensures effective risk management and stakeholder engagement. Although modular construction is not explicitly detailed, the project's approach suggests openness to incorporating such methodologies in future phases to enhance efficiency and sustainability.

Project RLO-00001711			
Category	**Considerations & Examples**	**Impacts/Advantages & Examples**	**Compliance/Strategy & Examples**
Environmental	Initial site assessments identified limited green elements, yet the proximity of high trees and dense bushes necessitated biodiversity considerations, especially for nesting birds such as black crows.	Implementing ecological guidance minimized disturbances to nesting birds, demonstrating a	Adherence to Wet Natuurbescherming was evident through ecological monitoring, consultations, and the

		commitment to enhancing local biodiversity.	application of an ecological work protocol.
Technological	The expansion includes constructing new transformer cells and a 10kV wing, with specifications aiming for minimal environmental impact while enhancing the electrical infrastructure's capacity and reliability.	Technological advancements support increased energy demands, ensuring a reliable power supply with improved efficiency and future growth capabilities.	Technical and environmental specifications were detailed, focusing on innovative construction practices to maintain system reliability and efficiency.
Socio-Economic	The project addresses rising energy demands and involves extensive stakeholder collaboration, emphasizing the need for reliable energy for community growth and technological advancements.	The expansion supports socio-economic development by providing essential infrastructure to meet future energy needs, enhancing community resilience.	Strategies include stakeholder engagement, regulatory compliance, and community communication, highlighting the project's broader social benefits.
Institutional	Collaboration and compliance with national regulations underscore the project's planning, emphasizing environmental assessments and stakeholder communication to manage project risks effectively.	Institutional frameworks facilitate effective risk management, ensuring the project aligns with planning, permit processes, and environmental considerations.	Emphasis on stakeholder communication and detailed risk management strategies demonstrate a comprehensive approach to institutional compliance.
Nature-Based Solutions	Ecological considerations integrated into construction practices focused on protecting biodiversity, specifically through the monitoring and protection of nesting birds and potentially bats.	The adoption of NBS mitigates ecological disturbances, promoting conservation and biodiversity through targeted ecological assessments and adjustments.	Ecological strategies were adapted based on the presence of protected species, with ecologists playing a key role in monitoring compliance and guiding practices.
Modular Construction	Although not explicitly detailed in the documents, the emphasis on ecological guidance and technological advancements suggests openness to incorporating modular construction methodologies in future phases.	Modular construction could offer reduced environmental impacts and improved efficiency, though its specific application in this project remains to be detailed.	Future documentation may explore modular construction techniques to enhance efficiency and sustainability in project implement

Appendix XIII

Standardization files summary

The standardisation documents offer comprehensive insights into the integration of nature-based solutions and modular construction methodologies in the development of electrical substations and energy infrastructure. Each document emphasizes the importance of sustainability and environmental considerations, highlighting the incorporation of trees, greenery, and other natural elements into site planning to enhance biodiversity, mitigate environmental impact, and create visually appealing surroundings. Modular construction principles are also discussed, emphasizing scalability, adaptability, and efficiency in infrastructure development. By integrating NBS and modular construction, these projects aim to enhance environmental sustainability while meeting the growing demand for energy infrastructure.

S-documents			
Category	**Considerations & Examples**	**Impacts/Advantages**	**Compliance/Strategy**
Environmental	Emphasis on reducing CO2 emissions, enhancing biodiversity, and promoting sustainable energy sources. Examples include the integration of solar panels and the planning of station layouts to minimize environmental disruption.	Reduction in carbon footprint, preservation of natural habitats, and promotion of renewable energy sources.	Adherence to national and international environmental standards and goals, such as the Klimaatakkoord for CO2 neutrality by 2050.
Technological	Adoption of modular construction for substations to facilitate rapid and efficient expansion of the electrical network. Integration of advanced materials and sustainable technologies, including solar panels and energy-efficient transformers.	Enhanced efficiency and flexibility in the expansion of the energy network. Use of sustainable materials and technologies reduces environmental impact.	Strategies include phased construction based on energy demand forecasts and the modular principle, allowing for scalable and adaptable infrastructure development.
Socio-Economic	Focus on ensuring reliable, affordable, and accessible energy supply to meet increasing demand and support socio-economic development. Consideration of public engagement in planning processes to address community needs and concerns.	Supports economic growth and development by ensuring energy security and resilience. Public engagement enhances social acceptance and integration of infrastructure projects.	Policies and practices aimed at balancing technological advancement with socio-economic benefits, ensuring energy affordability and accessibility while engaging with communities.
Institutional	Collaboration between various stakeholders, including government agencies, energy providers, and communities, to facilitate the transition to sustainable energy systems. Regulatory frameworks supporting NBS and modular construction.	Streamlines the implementation of energy infrastructure projects. Regulatory support for sustainable practices enhances project feasibility and alignment with broader environmental and energy goals.	Compliance with regulations and standards governing energy infrastructure, environmental protection, and community engagement. Strategic planning and investment based on national energy scenarios for 2050.

Nature-Based Solutions (NBS)	Integration of green infrastructure elements, such as vegetation and water management systems, to enhance ecosystem services and biodiversity around substations.	Improves local biodiversity, supports ecosystem services, and enhances the resilience of energy infrastructure to climate change.	Implementation of NBS as part of environmental impact assessments and site planning processes. Adoption of landscape integration strategies to minimize ecological disruption.
Modular Construction	Utilization of standardized modules for the construction of substations, allowing for efficient and adaptable expansion. Examples include the design of transformer rooms, switchgear rooms, and cable rooms based on modular principles.	Enables rapid deployment and expansion of energy infrastructure. Reduces construction times and costs while allowing for future scalability.	Adoption of modular construction principles in the design and development of energy infrastructure, with a focus on sustainability, efficiency, and adaptability to changing energy demands

Table 13 - Summary S-documents ICES framework

Document ID	File Name	Summary	Key Information & Mentions	NBS Context
S2010	Brochure Ruimtelijk Inpassing Modulair Bouwen.pdf	Discusses the integration of modular construction within the electrical grid, focusing on sustainable energy transition, increasing electricity demand, and modular construction for grid upgrades.	Emphasizes the need for sustainable building practices in energy infrastructure development. Highlights the role of modular construction in meeting evolving energy demands efficiently. Discusses spatial planning to optimize the integration of modular substations into existing infrastructure.	The document highlights the importance of integrating nature-based solutions (NBS) into substation design to enhance sustainability. It emphasizes incorporating natural elements such as trees and green spaces into site planning to improve biodiversity, mitigate environmental impact, and create aesthetically pleasing surroundings. It suggests that spatial planning should prioritize the preservation of natural habitats and the incorporation of green infrastructure to maximize ecological benefits.
S2011	Flyer Onderstations 110 en 150kV.pdf	Details on 110 and 150 kV substations for areas with significant energy demands, emphasizing modular construction for scalability and environmental considerations.	Mentions modular construction principles applied to transformer rooms, switchgear rooms, and cable rooms. Discusses spatial planning for substations to minimize environmental impact and optimize energy distribution. Emphasizes the adaptability of substations based on	The flyer acknowledges the importance of incorporating nature-based solutions (NBS) into substation design to enhance environmental sustainability. It suggests integrating trees and greenery into the spatial planning of substations to improve biodiversity, reduce heat island effects, and create more visually appealing surroundings. It emphasizes the role of spatial planning in optimizing the environmental integration of substations and maximizing their ecological benefits.

			energy demand forecasts.	
S2012	Flyer Onderstations 50 kV.pdf	Outlines 50 kV substations' design and function for areas with significant energy growth, modular construction, and environmental considerations.	Highlights the use of modular construction for transformer, switch, and cable rooms to facilitate efficient expansion. Discusses spatial fitting to integrate substations into the environment effectively. - Emphasizes capacity scalability based on projected energy demand.	The flyer underscores the importance of integrating nature-based solutions (NBS) into substation design to enhance environmental sustainability. It proposes incorporating trees and vegetation into the site planning of substations to improve biodiversity, reduce environmental impact, and blend substations into the surrounding landscape. It emphasizes the need for effective spatial fitting to optimize the environmental integration of substations and maximize their ecological benefits.
S2013	Flyer Regelstations 20-10 kV.pdf	Describes the role and design of 20-10 kV substations in energy distribution, focusing on modular construction, environmental integration, and sustainability.	Discusses the application of modular construction principles to enhance flexibility and sustainability. Mentions considerations for environmental integration in substation design. Emphasizes the role of these substations in supporting sustainable energy distribution networks.	The flyer highlights the importance of integrating nature-based solutions (NBS) into substation design to enhance environmental sustainability. It suggests incorporating trees and vegetation into the site planning of substations to improve biodiversity, mitigate environmental impact, and create aesthetically pleasing surroundings. It emphasizes the need for effective environmental integration in substation design to maximize their ecological benefits.
S2014	Flyer Regelstations 20-20 en 10-10 kV.pdf	Explains 20-20 and 10-10 kV substations' integration into the grid, with an emphasis on modular construction for environmental and operational efficiency.	Details the benefits of modular construction in improving environmental and operational efficiency. Mentions considerations for environmental integration and operational optimization in substation design. Emphasizes the importance of sustainable building practices in energy infrastructure.	The flyer acknowledges the importance of integrating nature-based solutions (NBS) into substation design to enhance environmental sustainability. It suggests incorporating trees and green infrastructure elements into substation design to improve biodiversity, mitigate environmental impact, and create visually appealing surroundings. It emphasizes the need for effective environmental integration and operational optimization to maximize the ecological benefits of substations.

S2015	Flyer Schakelstations 20kV en 10kV.pdf	Details the function of 20kV and 10kV switch stations, highlighting modular construction for network expansion to meet increasing energy demands.	Discusses the use of modular construction for efficient network expansion. Mentions the adaptability of substations to meet growing energy demands. Emphasizes the importance of modular design principles for scalability and flexibility.	The flyer emphasizes the importance of integrating nature-based solutions (NBS) into substation design to enhance environmental sustainability. It suggests incorporating trees and greenery into the site planning of substations to improve aesthetics, provide shading, and mitigate the urban heat island effect. It highlights the role of spatial planning in optimizing the environmental integration of substations and maximizing their ecological benefits.
S2020	Brochure Duurzame elektriciteitstations.pdf	Emphasizes sustainable electric substations, integrating green technologies, biodiversity importance, and circular economy principles in construction and operation.	Highlights the integration of green infrastructure elements such as vegetation and water management systems. Discusses the importance of biodiversity and circular economy principles in substation design. Emphasizes the role of sustainable building practices in energy infrastructure development.	The brochure underscores the importance of integrating nature-based solutions (NBS) into substation design to enhance environmental sustainability. It proposes incorporating trees and vegetation into substation design to improve biodiversity, mitigate environmental impact, and create visually appealing surroundings. It discusses the integration of green infrastructure elements and circular economy principles to optimize the ecological benefits of substations.
S8010	Algemeen PvE Terreinen en Gebouwen OS RS en SS.pdf	General specifications for substations and their surroundings, focusing on sustainability, safety, and operational efficiency in energy infrastructure development.	Discusses the general requirements for sustainable building practices in substation design. - Emphasizes safety and operational efficiency in energy infrastructure development. Mentions considerations for environmental impact and spatial optimization.	The document highlights the importance of integrating nature-based solutions (NBS) into substation design to enhance environmental sustainability. It suggests incorporating trees and green spaces into substation design to improve biodiversity, provide natural shading, and enhance the overall aesthetic quality of the infrastructure. It emphasizes the need for effective spatial optimization to maximize the ecological benefits of substations.

S8016	Modulebeschrijving Terrein.pdf	Module description for terrain, detailing environmental impact considerations, modular construction benefits, and sustainable space use strategies in substation design.	Details considerations for environmental impact assessment and site planning in substation design. Mentions the benefits of modular construction for sustainable space use and optimization. Emphasizes the importance of sustainable building practices in substation development.	The module description emphasizes the importance of integrating nature-based solutions (NBS) into substation design to enhance environmental sustainability. It suggests incorporating trees and greenery into the site planning of substations to improve biodiversity, mitigate environmental impact, and create visually appealing surroundings. It discusses the benefits of modular construction for optimizing space use and sustainability in substation design.
S8021	Ontwerpen, plaatsen en aansluiten van een PV-systeem.pdf	Outlines the design and implementation of photovoltaic systems, focusing on efficiency, environmental impact, and integration with existing infrastructure for sustainable power generation.	Discusses the design and integration of solar panels for sustainable power generation. Mentions considerations for environmental impact and integration with existing infrastructure. Emphasizes the importance of sustainable energy solutions in power generation.	The document underscores the importance of integrating nature-based solutions (NBS) into substation design to enhance environmental sustainability. It suggests incorporating trees and vegetation into the site planning of substations to improve biodiversity, mitigate environmental impact, and create visually appealing surroundings. It discusses the role of solar panels in generating sustainable energy and their integration with existing infrastructure to optimize environmental benefits.
D2023	B11100 Beleidsnotitie Meerkosten 1.0 (5).docx	Details policies regarding acceptable additional costs when spatially integrating stations, with a focus on modular construction deviations.	Discusses the regulatory and financial frameworks for accommodating additional infrastructure costs due to environmental and aesthetic standards in station construction. Outlines specific financial allowances for different types of stations based on their location and environmental impact.	Emphasizes the importance of integrating natural elements and complying with local biodiversity requirements during station construction. It highlights financial strategies for embedding nature-based solutions (NBS) within the constraints of modular building practices, aiming for minimal ecological disruption.

D2024	Biodiversiteit Besturingsmodel voor Netwerkbedrijven - Maart 2024	Introduces a governance model designed to enhance biodiversity through operational practices within network companies.	Provides a comprehensive overview of the roles and responsibilities of various company departments in fostering biodiversity. Includes detailed descriptions of biodiversity needs, the impact of network activities on biodiversity, and measures to mitigate negative impacts.	The document offers a structured approach to incorporating biodiversity considerations into all aspects of company operations, from procurement to project execution. It discusses the implementation of nature-friendly practices in the design, construction, and management of infrastructure, ensuring alignment with ecological sustainability goals.
Q8001	Besluitvormingsdocument groene daken transportstations 1.0.pdf	Discusses the decision-making process for implementing green roofs at transport stations.	Outlines the benefits and challenges of green roofs, including temperature control, UV protection, and improved water retention. Details the decision to use modular green roof systems for easier maintenance and potential issues like integration with PV panels.	Emphasizes the environmental benefits of green roofs, such as enhancing local biodiversity, reducing heat islands, improving rainwater management, and extending the lifespan of roofing materials. Intended to integrate seamlessly with the landscape, promoting ecological balance and aesthetic enhancement of urban spaces.
S2025	Inspiratiegids Biodiversitiet Alliander	The guide focuses on biodiversity-enhancing measures in the development and maintenance of energy infrastructure, emphasizing nature-inclusive practices to foster ecological sustainability.	The document details various measures such as green roofs, windbreaks, and eco-friendly lighting. It includes guidelines for implementing these measures to improve biodiversity, reduce environmental impact, and enhance aesthetic and functional aspects of energy infrastructure. It also highlights the importance of collaboration with ecologists and adherence to local regulations.	The guide emphasizes the integration of nature-based solutions (NBS) in energy infrastructure projects. It suggests incorporating green roofs to improve insulation and provide habitats for insects, windbreaks using native trees and shrubs to reduce wind erosion and enhance landscape connectivity, and eco-friendly lighting to minimize light pollution affecting nocturnal wildlife. Additionally, it recommends the creation of amphibian ponds, the use of grass pavers for parking areas to allow water infiltration, and the installation of insect hotels to support pollinator populations. It advocates for a balanced ecosystem around infrastructure to minimize pest issues and improve environmental integration, ensuring that infrastructure projects contribute

				positively to local biodiversity and ecological health.
Q8002	Besluitvormingsdocument groene gevels transportstations 1.0.pdf	Details the decision-making process for implementing green walls at transport stations.	Discusses the types of green walls, focusing on systems with irrigation and growth media. Analyzes the potential for integrating green walls into transport stations and addresses the challenges of maintenance and vandalism.	Highlights the role of green walls in improving aesthetic appeal, enhancing biodiversity, reducing urban heat effects, and contributing to sustainability goals. Facilitates a natural cooling effect, supports local wildlife, and improves the overall environmental quality of urban areas.

Table 14 - Stndardization file analysis

Appendix XIV

Interview quantified code summary

Colour	Code family	Code level 1	Code level 2	Code used	% Code used	# Documents
●	Technological Dimension	Technological Dimension	Standardized Construction	43	9,09%	6
●	Institutional Dimension	Company culture		41	8,67%	6
●	Environmental Dimension	Social Responsibilities		35	7,40%	6
●	Environmental Dimension	Nature Inclusive Building		31	6,55%	6
●	Environmental Dimension	Potential of NBS for Qirion		31	6,55%	5
●	Socio-Economic Dimension	Financial burdens		31	6,55%	6
●	Technological Dimension	Technological Dimension	NBS in standardization construction	31	6,55%	5
●	Technological Dimension	Technological Dimension	Tension between nature and reliability	27	5,71%	6
●	Technological Dimension	NBS in standardization construction	Challenges to standardize NBS	23	4,86%	3
●	Socio-Economic Dimension	Change in timeline/processes		22	4,65%	5
●	Socio-Economic Dimension	Financial Opportunities		18	3,81%	4
●	Environmental Dimension	Green-first Philosophy	Shift towards normalisation of green	17	3,59%	5
●	Environmental Dimension	Nature Inclusive Building	Mitigating issues	17	3,59%	5
●	Socio-Economic Dimension	Financial responsible	Cost more, but is better	15	3,17%	5
●	Institutional Dimension	Policy		13	2,75%	3
●	Institutional Dimension	Policy	Policy trends	12	2,54%	5
●	Technological Dimension	NBS in standardization construction	Missing knowledge on NBS	12	2,54%	4
●	Environmental Dimension	Nature Inclusive Building	Green-first Philosophy	10	2,11%	4
●	Institutional Dimension	Policy	External policies for NBS	9	1,90%	2
●	Socio-Economic Dimension	Financial responsible	Finance at project level	9	1,90%	4
●	Socio-Economic Dimension	Financial responsible		9	1,90%	4
●	Institutional Dimension			7	1,48%	3
●	Environmental Dimension			5	1,06%	2
●	Socio-Economic Dimension	Financial Trends Analysis		5	1,06%	3
●	Socio-Economic Dimension			0	0,00%	0
●	Technological Dimension			0	0,00%	0

Table 15 - Interview quantified code summary

Appendix XV

Code use per interview

Code name and path	Interview 1	Interview 2	Interview 3	Interview 4	Interview 5	Interview 6	SUM
Technological Dimension	0	0	0	0	0	0	**0**
Technological Dimension > Tension between nature and reliability	8	5	6	1	3	4	**27**
Technological Dimension > NBS in standardization construction	2	6	4	14	0	5	**31**
Technological Dimension > NBS in standardization construction > Missing knowledge on NBS	4	1	1	6	0	0	**12**
Technological Dimension > NBS in standardization construction > Challenges to standardize NBS	2	9	12	0	0	0	**23**
Technological Dimension > Standardized Construction	4	6	10	7	13	3	**43**
Socio-Economic Dimension	0	0	0	0	0	0	**0**
Socio-Economic Dimension > Change in timeline/processes	2	9	1	3	0	7	**22**
Socio-Economic Dimension > Financial Trends Analysis	0	1	0	1	0	3	**5**
Socio-Economic Dimension > Financial Opportunities	0	2	0	5	5	6	**18**
Socio-Economic Dimension > Financial burdens	10	5	6	2	4	4	**31**
Socio-Economic Dimension > Financial responsible	2	1	0	0	2	4	**9**
Socio-Economic Dimension > Financial responsible > Cost more, but is better	0	5	1	4	3	2	**15**
Socio-Economic Dimension > Financial responsible > Finance at project level	0	0	3	3	1	2	**9**
Environmental Dimension	3	0	2	0	0	0	**5**
Environmental Dimension > Nature Inclusive Building	2	5	3	4	16	1	**31**
Environmental Dimension > Nature Inclusive Building > Mitigating issues	0	4	3	1	4	5	**17**
Environmental Dimension > Nature Inclusive Building > Green-first Philosophy	1	0	0	3	3	3	**10**
Environmental Dimension > Nature Inclusive Building > Green-first Philosophy > Shift towards normalisation of green	0	4	1	5	1	6	**17**
Environmental Dimension > Social Responsibilities	6	4	3	6	7	9	**35**
Environmental Dimension > Potential of NBS for Qirion	0	6	3	4	13	5	**31**
Institutional Dimension	0	0	1	0	4	2	**7**
Institutional Dimension > Policy	0	0	0	1	9	3	**13**
Institutional Dimension > Policy > External policies for NBS	3	0	0	0	0	6	**9**
Institutional Dimension > Policy > Policy trends	0	4	2	1	2	3	**12**
Institutional Dimension > Company culture	6	10	9	7	3	6	**41**
SUM	**55**	**87**	**71**	**78**	**93**	**89**	**473**

Table 16 - Code use per interview

Appendix XVI

Code matrix relationship by intersection; Number of intersections of codes in a segmented code

Code System	NBS in standardlization construction	Social Responsibilities	Company culture	Mitigating issues	Potential of NBS for Qirion	Standardized Construction	Nature Inclusive Building	Financial Opportunities	Financial burdens	Cost more, but is better	Shift toword normaisation of green	Policy	Policy trends	Change in timeline/processes	Tension between nature and reliability	Finance at project evel	Institutional Dimension	Challenges to standalize NBS	Extra belangrijk	Green-first Philosophy	Financial Trends Analysis	Missing knowledge on NBS	External policies for NBS	Technological Dimension	Socio-Economic Dimension	Financial responsible	Environmental Dimension	Paraphrases	SUM
Extra belangrijk	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	5
Technological Dimension	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Technological Dimension > Tension between nature and reliability	0	1	2	0	0	0	0	0	3	0	0	1	0	0	0	0	0	4	0	0	1	0	0	0	0	0	0	0	12
Technological Dimension > NBS in standardlization construction	0	2	0	0	1	4	2	3	0	1	1	0	2	1	0	0	0	1	1	0	0	1	0	0	0	0	0	0	20
NBS in standardlization construction > Missing knowledge on NBS	1	1	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
NBS in standardlization construction > Challenges to standalize NBS	1	0	6	0	0	2	0	0	0	0	0	0	2	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	15
Technological Dimension > Standardized Construction	4	2	0	2	4	0	4	0	0	0	0	0	1	1	0	1	1	2	0	0	0	0	0	0	0	0	0	0	22
Socio-Economic Dimension	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Socio-Economic Dimension > Change in timeline/processes	1	0	0	0	0	1	0	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6
Socio-Economic Dimension > Financial Trends Analysis	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	4
Socio-Economic Dimension > Financial Opportunities	3	1	0	2	3	0	2	0	0	0	2	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	16
Socio-Economic Dimension > Financial burdens	0	1	0	2	0	0	0	0	0	1	2	0	0	1	3	0	0	0	0	1	1	3	0	0	0	0	0	0	15
Socio-Economic Dimension > Financial responsible	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Financial responsible > Cost more, but is better	1	1	1	0	1	0	0	0	1	0	1	0	0	1	0	4	0	0	0	0	1	0	0	0	0	0	0	0	12
Financial responsible > Finance at project evel	0	0	0	0	0	1	1	0	0	4	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	9
Environmental Dimension	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Environmental Dimension > Nature Inclusive Building	2	3	0	2	8	4	0	2	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	25
Nature Inclusive Building > Mitigating issues	0	2	1	0	1	2	2	2	2	0	1	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	16
Nature Inclusive Building > Green-first Philosophy	0	0	0	0	2	0	1	0	1	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	7
Green-first Philosophy > Shift toword normaisation of green	1	3	0	1	3	0	1	2	2	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	16
Environmental Dimension > Social Responsibilities	2	0	3	2	7	2	3	1	1	1	3	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	27
Environmental Dimension > Potential of NBS for Qirion	1	7	2	1	0	4	8	3	0	1	3	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	33
Institutional Dimension	0	0	2	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	6
Institutional Dimension > Policy	0	0	1	1	1	0	1	1	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	8
Policy > External policies for NBS	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2
Policy > Policy trends	2	0	1	0	0	1	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	9
Institutional Dimension > Company culture	0	3	0	1	2	0	0	0	0	1	0	1	1	0	2	0	2	6	1	0	0	1	0	0	0	0	0	0	21
Paraphrases	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUM	20	27	21	16	33	22	25	16	15	12	16	8	9	6	12	9	6	15	5	7	4	6	2	0	0	0	0	0	312

Table 17 - Code matrix relationship by intersection

Appendix XVII

Code matrix relationship by proximity; Based on proximity of code in the same document, maximum distance of 1 paragraph

Code System	Financial burdens	Social Responsibilities	Nature Inclusive Building	Standardized Construction	NBS in standardization construction	Company culture	Financial Opportunities	Tension between nature and reliability	Potential of NBS for Qirion	Cost more, but is better	Change in timeline/processes	Shift toword normaisation of green	Policy	Mitigating issues	Challenges to standalize NBS	Policy trends	Institutional Dimension	Financial Trends Analysis	Missing knowledge on NBS	Finance at project evel	Green-first Philosophy	Environmental Dimension	External policies for NBS	Financial responsible	Technological Dimension	Socio-Economic Dimension	SUM
Technological Dimension	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Technological Dimension > Tension between nature and reliability	11	8	5	6	5	9	2	0	0	2	4	2	2	0	12	0	0	2	0	0	0	3	0	0	0	0	73
Technological Dimension > NBS in standardlization construction	9	4	8	13	0	2	8	5	5	4	7	2	0	4	6	6	0	0	4	0	0	2	0	0	0	0	89
NBS in standardlization construction > Missing knowledge on NBS	9	3	2	0	4	4	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	24
NBS in standardlization construction > Challenges to standalize NBS	4	4	0	4	6	15	2	12	0	0	0	0	0	0	0	6	0	2	2	0	0	0	0	0	0	0	57
Technological Dimension > Standardized Construction	2	7	12	0	13	3	3	6	10	3	5	0	4	6	4	3	5	0	0	2	0	0	0	0	0	0	88
Socio-Economic Dimension	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Socio-Economic Dimension > Change in timeline/processes	7	0	0	5	7	0	6	4	2	3	0	2	0	0	0	0	0	0	0	2	0	3	0	2	0	0	43
Socio-Economic Dimension > Financial Trends Analysis	2	0	0	0	0	2	0	2	0	2	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	12
Socio-Economic Dimension > Financial Opportunities	4	2	8	3	8	0	0	2	9	2	6	4	2	6	2	0	0	0	0	0	0	0	0	2	0	0	60
Socio-Economic Dimension > Financial burdens	0	8	10	2	9	4	4	11	6	6	7	5	2	6	4	0	0	2	9	0	6	4	4	0	0	0	109
Socio-Economic Dimension > Financial responsible	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Financial responsible > Cost more, but is better	6	4	2	3	4	2	2	2	4	0	3	2	0	0	0	0	0	2	0	7	0	0	0	0	0	0	43
Financial responsible > Finance at project evel	0	0	2	2	0	0	0	0	0	7	2	0	0	0	0	0	0	2	0	0	0	0	2	0	0	0	17
Environmental Dimension	4	2	0	0	2	0	0	3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
Environmental Dimension > Nature Inclusive Building	10	11	0	12	8	8	8	5	20	2	0	2	12	8	0	5	4	0	2	2	2	0	0	0	0	0	121
Nature Inclusive Building > Mitigating issues	6	4	8	6	4	4	6	0	6	0	0	4	4	0	0	0	2	0	0	0	0	0	0	0	0	0	54
Nature Inclusive Building > Green-first Philosophy	6	0	2	0	0	0	0	0	4	0	0	4	0	0	0	0	2	0	0	0	0	0	3	0	0	0	21
Green-first Philosophy > Shift toword normaisation of green	5	8	2	0	2	0	4	2	8	2	2	0	0	4	0	0	0	0	0	0	4	0	0	0	0	0	43
Environmental Dimension > Social Responsibilities	8	0	11	7	4	13	2	8	18	4	0	8	6	4	4	6	3	0	3	0	0	2	0	0	0	0	111
Environmental Dimension > Potential of NBS for Qirion	6	18	20	10	5	3	9	0	0	4	2	8	5	6	0	0	2	0	0	0	4	0	0	0	0	0	102
Institutional Dimension	0	3	4	5	0	6	0	0	2	0	0	0	5	2	0	3	0	0	0	0	2	0	0	0	0	0	32
Institutional Dimension > Policy	2	6	12	4	0	7	2	2	5	0	0	0	0	4	0	6	5	0	0	0	0	0	0	0	0	0	55
Policy > External policies for NBS	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	3	0	0	0	0	0	11
Policy > Policy trends	0	6	5	3	6	7	0	0	0	0	0	0	6	0	6	0	3	0	0	0	0	0	2	0	0	0	44
Institutional Dimension > Company culture	4	13	8	3	2	0	0	9	3	2	0	0	7	4	15	7	6	2	4	0	0	0	0	0	0	0	89
SUM	109	111	121	88	89	89	60	73	102	43	43	43	55	54	57	44	32	12	24	17	21	14	11	4	0	0	1316

Table 18 - Code matrix relationship by proximity

Appendix XVIII

Code matrix relationship by occurrence; Code relations per occurrence in the same document

Code System	Company culture	Policy trends	External policies for NBS	Institutional Dimension	Potential of NBS for Qirion	Social Responsibilities	Shift toword normaisation of green	Green-first Philosophy	Mitigating issues	Nature Inclusive Building	Finance at project evel	Cost more, but is better	Financial responsible	Financial burdens	Change in timeline/processes	Standardized Construction	Missing knowledge on NBS	NBS in standardization construction	Tension between nature and reliability	Financial Opportunities	Financial Trends Analysis	Challenges to standalize NBS	Policy	Environmental Dimension	Technological Dimension	Socio-Economic Dimension	SUM
Technological Dimension	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Technological Dimension > Tension between nature and reliability	6	5	2	3	5	6	5	4	5	6	4	5	4	6	5	6	4	5	0	4	3	3	3	2	0	0	101
Technological Dimension > NBS in standardlization construction	5	4	2	2	4	5	4	3	4	5	3	4	3	5	5	5	4	0	5	3	3	3	2	2	0	0	85
NBS in standardlization construction > Missing knowledge on NBS	4	3	1	1	3	4	3	2	3	4	2	3	2	4	4	4	0	4	4	2	2	3	1	2	0	0	65
NBS in standardlization construction > Challenges to standalize NBS	3	2	1	1	2	3	2	1	2	3	1	2	2	3	3	3	3	3	3	1	1	0	0	2	0	0	47
Technological Dimension > Standardized Construction	6	5	2	3	5	6	5	4	5	6	4	5	4	6	5	0	4	5	6	4	3	3	3	2	0	0	101
Socio-Economic Dimension	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Socio-Economic Dimension > Change in timeline/processes	5	4	2	2	4	5	4	3	4	5	3	4	3	5	0	5	4	5	5	3	3	3	2	2	0	0	85
Socio-Economic Dimension > Financial Trends Analysis	3	3	1	1	3	3	3	2	3	3	2	3	2	3	3	3	2	3	3	3	0	1	2	0	0	0	55
Socio-Economic Dimension > Financial Opportunities	4	4	1	2	4	4	4	3	4	4	3	4	3	4	3	4	2	3	4	0	3	1	3	0	0	0	71
Socio-Economic Dimension > Financial burdens	6	5	2	3	5	6	5	4	5	6	4	5	4	0	5	6	4	5	6	4	3	3	3	2	0	0	101
Socio-Economic Dimension > Financial responsible	4	3	2	2	3	4	3	3	3	4	2	3	0	4	3	4	2	3	4	3	2	2	2	1	0	0	66
Financial responsible > Cost more, but is better	5	5	1	3	5	5	5	3	5	5	4	0	3	5	4	5	3	4	5	4	3	2	3	1	0	0	88
Financial responsible > Finance at project evel	4	4	1	3	4	4	4	3	4	4	0	4	2	4	3	4	2	3	4	3	2	1	3	1	0	0	71
Environmental Dimension	2	1	1	1	1	2	1	1	1	2	1	1	1	2	2	2	2	2	2	0	0	2	0	0	0	0	30
Environmental Dimension > Nature Inclusive Building	6	5	2	3	5	6	5	4	5	0	4	5	4	6	5	6	4	5	6	4	3	3	3	2	0	0	101
Nature Inclusive Building > Mitigating issues	5	5	1	3	5	5	5	3	0	5	4	5	3	5	4	5	3	4	5	4	3	2	3	1	0	0	88
Nature Inclusive Building > Green-first Philosophy	4	3	2	2	3	4	3	0	3	4	3	3	3	4	3	4	2	3	4	3	2	1	3	1	0	0	67
Green-first Philosophy > Shift toword normaisation of green	5	5	1	3	5	5	0	3	5	5	4	5	3	5	4	5	3	4	5	4	3	2	3	1	0	0	88
Environmental Dimension > Social Responsibilities	6	5	2	3	5	0	5	4	5	6	4	5	4	6	5	6	4	5	6	4	3	3	3	2	0	0	101
Environmental Dimension > Potential of NBS for Qirion	5	5	1	3	0	5	5	3	5	5	4	5	3	5	4	5	3	4	5	4	3	2	3	1	0	0	88
Institutional Dimension	3	3	1	0	3	3	3	2	3	3	3	3	2	3	2	3	1	2	3	2	1	1	2	1	0	0	53
Institutional Dimension > Policy	3	3	1	2	3	3	3	3	3	3	3	3	2	3	2	3	1	2	3	3	2	0	0	0	0	0	54
Policy > External policies for NBS	2	1	0	1	1	2	1	2	1	2	1	1	2	2	2	2	1	2	2	1	1	1	1	1	0	0	33
Policy > Policy trends	5	0	1	3	5	5	5	3	5	5	4	5	3	5	4	5	3	4	5	4	3	2	3	1	0	0	88
Institutional Dimension > Company culture	0	5	2	3	5	6	5	4	5	6	4	5	4	6	5	6	4	5	6	4	3	3	3	2	0	0	101
SUM	101	88	33	53	88	101	88	67	88	101	71	88	66	101	85	101	65	85	101	71	55	47	54	30	0	0	1828

Table 19 - Code matrix relationship by occurrence

Appendix XIX

Modular Building investments

Station config	Sum of %_PV	Sum of %_Site-Layout	Sum of %_Site-Layout_PV	Sum of total investment	
OS KOP 50-10kV 80MVA - Gestapeld	0,3%	0,8%	1,08%	€	9.527.997
OS KOP 50-10kV 80MVA	0,4%	1,2%	1,64%	€	9.463.926
OS RAP 150-10kV 106MVA - Gestapeld	0,5%	1,3%	1,74%	€	11.212.735
OS RAP 150-10kV 106MVA	0,6%	1,2%	1,80%	€	10.689.385
OS RAP 150-20kV 160MVA	0,6%	1,3%	1,82%	€	11.118.703
OS KOP 20-10kV 40MVA	0,6%	1,3%	1,88%	€	6.996.102
OS RAP 20-10kV 40MVA	0,9%	1,1%	1,96%	€	7.971.012
OS KOP 50-10kV 40MVA	0,6%	1,5%	2,08%	€	6.118.801
OS KOP 20-10kV 20MVA	0,6%	1,6%	2,24%	€	4.672.555
OS RAP 150-10kV 53MVA-2023	0,6%	1,6%	2,26%	€	7.074.039
OS RAP 20-10kV 20MVA	0,8%	1,5%	2,27%	€	5.517.286
OS KOP 50-20kV 40MVA	0,6%	1,7%	2,28%	€	5.332.920
SS 20kV 40MVA	0,0%	2,4%	2,39%	€	2.716.105
SS 10kV 20MVA	0,0%	2,4%	2,39%	€	2.716.105
SS 20kV 20MVA	0,0%	2,8%	2,77%	€	2.167.010
SS 10kV 10MVA	0,0%	2,8%	2,81%	€	2.141.194
RS 20-20kV 40MVA	1,0%	2,1%	3,12%	€	4.122.827
RS 10-10kV 20MVA	1,1%	2,2%	3,28%	€	3.674.372
RS 20-20kV 20MVA	1,1%	2,3%	3,43%	€	3.180.333

Table 20 - Overall modular construction expenditure

Appendix XX

Project document overview summary

Project ID	Expenditure in % of NBS	Environmental dimension	Technological	Socio-economic	Institutional dimension	Nature-Based solutions
RLI-00000237	6,20%	Holistic approach; biodiversity enhancement, modular construction	Modular construction methods, stakeholder engagement	improved infrastructure	Regulatory compliance, stakeholder engagement	Wildlife protection, green infrastructure
RLI-00000361	6%	Multifaceted approach; sustainability, biodiversity preservation	Solar panels, modular construction techniques	Engaging with local community forums	Compliance with regulations, stakeholder engagement	Water management, community concerns
RLI-00000422	7,50%	Prioritizes environmental preservation; site selection, mitigation measures	Modular construction, modern electrical installations	Regional development	Institutional coordination, compliance with regulations	Ecosystem services, climate resilience
RLI-00000656	5,20%	Aligns with Nature-Based Solutions; environmental assessments, spatial planning	Modular construction methodologies, technological innovations	urban green space enhancement	Regulatory compliance, stakeholder engagement	Biodiversity enhancement, water management
RLI-00000711	5,30%	Holistic approach; environmental stewardship, technological advancement	Cutting-edge solutions, collaboration with stakeholders	Minimal ecological disruption	Regulatory compliance, institutional commitment	Integration of green infrastructure
RLI-00000789	4,70%	Environmental stewardship, innovative construction methods	Modular construction, renewable energy integration	infrastructure improvements	Compliance with regulatory standards	Effective water management
RLI-00001057	7,00%	Prioritizes environmental sustainability; community engagement	Modular construction methodologies, advanced materials	Recreational spaces, preservation of archaeological sites	Collaboration with regulatory bodies, compliance with regulations	Cultural heritage preservation, sustainability
RLI-00001121	6,40%	Integrates Nature-Based Solutions; environmental integration, technological adoption	Modular construction, advanced control systems	Community engagement	Coordination with local authorities, compliance with regulations	Renewable energy generation, biodiversity enhancements
RLO-00001711	6,80%	Integration of modular construction and nature-based solutions; environmental protection	Modular construction, technological innovation	Minimization of ecological impact, socio-economic benefits	Compliance with conservation laws, engagement with community and regulatory bodies	Habitat management, biodiversity protection
RLO-00002635	5,20%	Expansion project with ecological guidance, technological advancements	Technological upgrades, socio-economic benefits	Enhanced community resilience	Institutional compliance, effective stakeholder engagement	Biodiversity protection, minimal environmental impact

Appendix XXI

Regression analysis Friesland Noordoostpolder

The table consists of annual percentages for the years as follows:

Row Labels	Average of %_Terrein_PV
Qirion Friesland Noordoostpolder	**3,1%**
2018	5,2%
2019	4,0%
2020	1,9%
2022	4,1%
2023	3,6%

Objective

The goal is to analyse the trend in these percentages over the given years and predict future values. Initially, a linear regression model was employed, and subsequently, polynomial regression models of various degrees were tested to find the best fit.

Linear Regression Analysis

A linear regression model was fitted to the data to determine the relationship between the year and the percentage. The linear model provided the following results:

- y =−0.169768 x Year+342.559
- R-squared Value: 0.086 (indicating a very poor fit)

The low R-squared value of 0.086 indicates that the linear model does not explain the variation in the data well. This prompted the need to explore more complex models.

Polynomial Regression Analysis

To improve the model fit, polynomial regression models of degrees 2 to 4 were tested. The polynomial regression model of degree 4 provided the best results:

The polynomial regression of degree 4 yielded the highest R-squared value and lowest Mean Squared Error (MSE), indicating a significantly better fit compared to the linear model.

- Best Polynomial Degree: 4
- R-squared Value: 0.744
- Mean Squared Error (MSE): 0.294

The polynomial regression model of degree 4 can be expressed as:

Percentage =a4 x (Year)4+a3 x (Year)3+a2 x (Year)2+a1 x Year+ a0

Where the coefficients a4, a3, a2, a1, a0 are determined through regression analysis.

Predicted Values

The predicted values from the best fit model (polynomial regression degree 4) are as follows:

Year	Actual Percentage	Predicted Percentage
2018	5.2%	5.44%
2019	4.0%	3.21%
2020	1.9%	2.69%
2022	4.1%	3.71%
2023	3.6%	3.76%

Table 21 - Predicted values "Friesland Noordoostpolder"

The polynomial regression of degree 4 seems to fit much better to the data than linearity in the model, as indicated by the higher R-squared value of 0.744. This indicates that approximately 74.4% of the variance in percentages is explained by this polynomial model.

However, the following need to be noted:

- Small sample size: The analysis is based on only five-point data, which badly affects the reliability and robustness of the model. The trend would have been better understood if there were more data points.
- Overfitting risk: Higher order polynomials sometimes fit the training data very well, but often turn out to be very inaccurate on new, unseen data—overfitting—which needs to be checked through additional validation.
- Validation: More data points and other validation techniques, such as cross-validation, should be used to ensure the reliability of the model.

Appendix XXII

Relationship top-10 project versus NBS expenditure

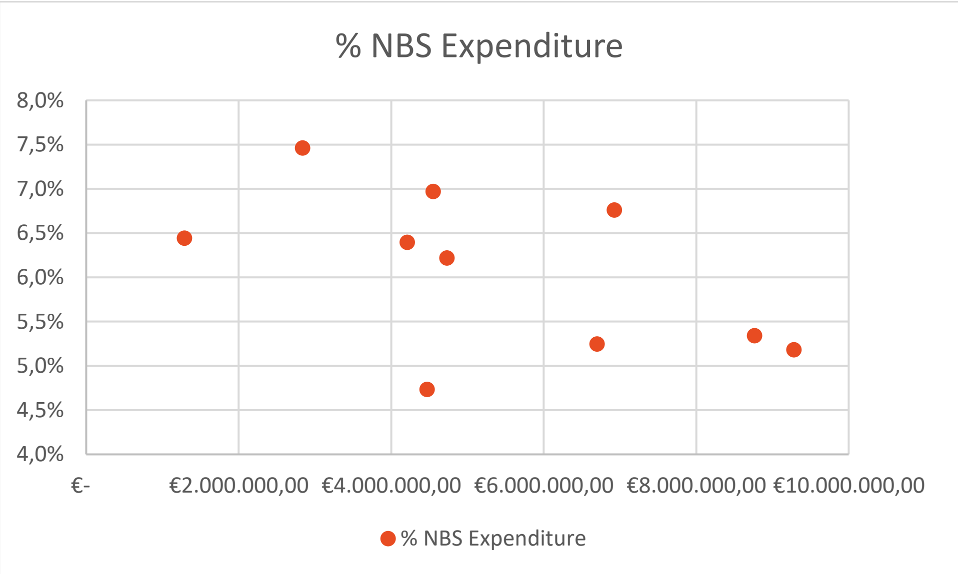
Detailed Correlation Test and Analysis

The correlation analysis between total investment costs and NBS expenditure percentages reveals a Pearson correlation coefficient of approximately -0.54, with a p-value of 0.107. This indicates a moderate negative correlation, suggesting that as total investment costs increase, the NBS expenditure percentage tends to decrease slightly. However, since the p-value is greater than 0.05, this correlation is not statistically significant at the 95% confidence level.

The table below summarizes the total investment costs, NBS expenditure, and NBS expenditure percentage for each project:

Projectnummer	Total investment costs	Total NBS expenditure	% NBS Expenditure
Project 1	€ 4.551.029,00	€ 317.354,10	7,0%
Project 2	€ 1.288.000,00	€ 82.999,40	6,4%
Project 3	€ 8.767.615,00	€ 468.405,47	5,3%
Project 4	€ 9.283.223,00	€ 481.273,00	5,2%
Project 5	€ 2.837.479,00	€ 211.800,90	7,5%
Project 6	€ 4.209.803,00	€ 269.388,70	6,4%
Project 7	€ 4.732.790,00	€ 294.312,60	6,2%
Project 8	€ 6.701.688,00	€ 351.619,57	5,2%
Project 9	€ 4.471.426,00	€ 211.754,10	4,7%
Project 10	€ 6.927.568,00	€ 468.405,47	6,8%

The scatter plot below illustrates the relationship between total investment costs and NBS expenditure percentages:



1. **Positive Relationship in Absolute Terms:**

Projects with higher total investment costs generally have higher absolute NBS expenditures. For example, Project 4 and Project 10, both with higher total investment costs, also have relatively high NBS expenditures in absolute terms.

2. **Percentage Expenditure is Not Directly Proportional:**

The percentage of NBS expenditure does not significantly increase with higher total investment costs. Instead, there seems to be a cap or a fixed budget allocation strategy for NBS expenditures across different projects. This is supported by the negative correlation coefficient and the non-significant p-value.

3. **Fixed Budget Allocation Strategy:**

The consistency in NBS expenditure percentages (mostly ranging between 5% to 7%) across projects with varying total investment costs suggests a relatively fixed budget allocation for NBS. This indicates that the NBS budget is planned independently of the total project cost to a large extent.

4. **Outliers:**

Project 5 has the highest NBS expenditure percentage (7.46%), while Project 9 has the lowest (4.74%). These outliers may indicate specific project needs or differing priorities in NBS implementation.

Conclusion

The analysis suggests that while there is a positive relationship in absolute terms between total investment costs and NBS expenditures, the percentage of NBS expenditure does not proportionally increase with higher total costs. This implies a standardized approach to budgeting for NBS, which could be due to organizational policies, regulatory frameworks, or predefined budgetary constraints. The moderately negative correlation, along with the non-significant p-value, further supports the observation of a fixed budget allocation strategy for NBS across different projects. This means that higher total investment costs do not necessarily result in higher percentages of NBS expenditure, highlighting a relatively consistent and independent budgeting approach for NBS within these projects.

Inspiratiegids biodiversiteit Alliander

Ideeën voor natuurinclusieve maatregelen bij aanleg en onderhoud van onze energie-infrastructuur

Start Inhoudsoverzicht Leeswijzer

Voorwoord

Als organisatie die middenin de samenleving staat, met een duidelijke maatschappelijke opdracht, nemen wij de impact die wij op de maatschappij hebben, heel serieus. Van oudsher maken wij ons op veel verschillende manieren hard om ons werk aan de energienetten zo verantwoord mogelijk te realiseren. Het speerpunt biodiversiteit is hier sinds enkele jaren aan toegevoegd vanwege de schrikbarende urgentie om de forse wereldwijde teruggang van biodiversiteit een halt toe te roepen. De impact die het verlies van biodiversiteit (al) op ons als mensheid heeft, is uitermate zorgwekkend. Het goede nieuws is dat wij met onze energie-infrastructuur juist een positieve bijdrage kunnen leveren aan biodiversiteit en kunnen helpen het tij te keren. Hier staan we als bedrijf voor en ook jij speelt hierin een belangrijke rol.

Met deze gids willen we jou graag inspireren over de mogelijkheden die er zijn om met onze infra daadwerkelijk die positieve bijdrage te leveren aan onze leefomgeving. Het is een opsomming van biodiversiteit bevorderende (of natuurinclusieve) maatregelen; voor zowel aanleg en aanpassing, als onderhoud van de energienetten. Hiermee bouwen we in onze distributie- en transportnetten voort op de versie die TenneT heeft ontwikkeld voor de transportnetten.

Het natuurinclusief werken legt ons overigens ook bepaald geen windeieren. De opgave voor de komende jaren is zoals we allemaal weten, fors. Dit vraagt dat we ons werk anders organiseren dan voorheen. Sneller, maar

óók slimmer. 'Natuurinclusief werken' kan hier een grote positieve invloed op hebben. Door samen te werken mét de natuur ontstaan vele voordelen, zoals hittebestrijding en lagere beheerkosten. Ook vraagt onze omgeving steeds vaker en steviger om integratie van biodiversiteit in onze assets en terreinen, en een goede landschappelijke inpassing.

In deze gids lees je hoe biodiversiteit op een *gezonde* en *kostenbewuste* manier geïntegreerd kan worden in ons werk. Zo geeft het werk dat wij doen zowel letterlijk als figuurlijk energie aan de samenleving en aan de ketensamenwerking die noodzakelijk is om de uitbreiding van de netten te realiseren.

Ik ben ervan overtuigd dat biodiversiteit en onze infrastructuur samen moeten en kunnen gaan. Ik hoop dat jij ook die ruimte voelt én pakt om natuurbewust te bouwen en te werken.

Marlies Visser
COO Alliander

Inleiding

Deze inspiratiegids is voortgekomen uit de inspiratiegids van TenneT. De gids biedt dan ook een overzicht van maatregelen die zich in onze praktijk al bewezen hebben en kan zo als opmaat dienen voor nieuw Alliander beleid.

Het geeft collega's een beeld hoe wij onze energie-infrastructuur meer natuurinclusief kunnen maken. Het biedt hen direct een mogelijkheid om het gesprek aan te gaan met opdrachtgevers, gemeentes en de directe omgeving, en hen te voorzien van voorbeelden. Het is geen catalogus van waaruit vrij gekozen kan worden door derden, maar wel een instrument om inzicht en overzicht te bieden.

Focusteam Biodiversiteit

Dit focusteam is sinds het najaar van 2022 in oprichting, met vertegenwoordiging van afdelingen die directe invloed uitoefenen op het toevoegen van biodiversiteit aan onze energie-infrastructuur. Andersom zijn dit ook de afdelingen die bewaken dat de maatregelen veilig, kostenbewust en uitvoerbaar zijn. Zij zetten de gestelde doelen[1] met betrekking tot biodiversiteit en natuurinclusief bouwen om in concrete acties, zoals de ontwikkeling van deze gids. Het focusteam zorgt ervoor dat de voorgenomen positieve bijdrage ook daadwerkelijk gerealiseerd wordt en tegelijkertijd het belang van Alliander dient. Heb jij nog ideeën die je met ons wilt delen, heb je vragen, of pas je maatregelen toe die nog ontbreken in deze gids, neem dan contact op via ondergetekende.

Maatwerk

Niet iedere locatie is altijd geschikt voor elke maatregel uit de gids. Maatwerk is dan ook altijd nodig. Aangezien het maken van de juiste afweging ecologische kennis vraagt, hebben we bij Alliander een ecoloog in dienst genomen. De ecoloog van Alliander moet altijd betrokken worden bij de plannen. Zo wordt ecologie integraal meegewogen naast kosten, de functionaliteit en de veiligheid van de infrastructuur.
Belangrijke aandachtspunten hierbij zijn juiste ecologische uitvoering van de maatregel (bijvoorbeeld in verband met vigerende wet- en regelgeving), impact op beheer en onderhoud en monitoring van het effect op biodiversiteit. Als een maatregel zich bewijst in de praktijk, kan deze in aanmerking komen om een nieuwe standaard op te baseren.

Proces als vanuit een overheid extra eisen komen m.b.t. biodiversiteit, dan:

1. Gebruiken eerstelijns contactpersonen voor overheden met betrekking tot nieuwe assets (o.a. omgevings- en projectmanagers) deze inspiratiegids.
2. Na overleg met de overheid wordt een maatwerkvoorstel uitgewerkt door een ecoloog van de aannemer; **altijd in overleg met de ecoloog van Alliander**:
   a. Integrale afweging criteria; ecologie, veiligheid, kosten, uitvoerbaarheid (inclusief beheer en onderhoud).
   b. Uitvoering maatregel volgens ecologische richtlijnen, waaronder vigerende wet- en regelgeving.
   c. Monitoring van het effect van de maatregel.
3. De driehoek Omgevingsmanager, Netarchitect en Strategisch assetmanager (HS) heeft binnen bepaalde financiële marges (volgens beleid 'Meerkosten') mandaat om te besluiten. Bij LS is dit de project- of omgevingsmanager.
4. Bij succes van de maatregel dient deze als opmaat naar mogelijke nieuwe standaard via het 'Focusteam Biodiversiteit'.

Even voorstellen...

Wout Egging is op 4 maart 2024 begonnen als de eerste adviseur ecologie in dienstverband bij Alliander.

Wout Egging
+31 6 4252 6438

Roland Vink
PO biodiversiteit en coördinator Focusteam Biodiversiteit

[1] In 2030 willen we positieve waarde leveren aan biodiversiteit middels onze infrastructuur. Ook hebben we ons gecommitteerd binnen het Groene Netten-verband om onze infrastructuur in te zetten voor grootschalig natuurherstel in Nederland middels de 'Ecologische HoofdInfrastructuur'.

Beheer en veiligheid

De informatie in deze gids is bedoeld ter inspiratie. Toepassing van de maatregelen in deze gids moet samengaan met de wettelijke taak van Alliander om de gas- en elektriciteitsnetwerken veilig te beheren en te ontwikkelen. Met natuurinclusief bouwen, zorgen wij voor veilig, doelmatig en duurzaam beheer van onze assets en terreinen met de blijvende garantie op leveringszekerheid. De focus ligt daarbij op een veilige en prettige werkomgeving met ruimte voor natuur. De opgave is om de kernwaarden en doelstellingen van Alliander met infranatuurmaatregelen te verbinden, zodat zij elkaar versterken.

Veiligheid en leveringszekerheid voor de klant
- De kerntaak van Alliander is het garanderen van betrouwbare, betaalbare en bereikbare energievoorziening voor iedereen.

Veilige en prettige werkomgeving voor de medewerkers
- De infranatuurmaatregelen mogen de veiligheid van Alliander medewerkers, de asset of derden niet schaden en moeten blijvend voldoen aan Alliander beleid en Arbowetgeving.
- Bij een terrein dat in beheer is bij Alliander en waarbij het ecosysteem in balans is met de omgeving zal minder snel overlast ontstaan en is beter ruimtelijk ingepast.
- Een ecosysteem dat in balans is, heeft een positief effect op bepaalde soorten, waardoor de kans op overlast door bijvoorbeeld plaagdieren sterk verminderd.
- Ruimte voor natuur draagt bij aan een prettige en daardoor veilige werkomgeving.

Doelmatig en duurzaam beheer van assets
- De juiste maatregelen en keuzes dragen bij aan betrouwbaar beheer.
- Natuurinclusieve maatregelen dragen bij aan een efficiënt beheer en houden rekening met toekomstige uitbreidingen, aanpassingen, renovatie en modernisering van de assets.
- De juiste maatregelen en/of keuzes dragen bij aan een meer doelmatig, duurzaam en kostenefficiënt beheer.

Ruimte voor de natuur
- De energie-infrastructuur van Alliander levert een positieve bijdrage aan biodiversiteit in Nederland met de kerntaak van Alliander als blijvende prioriteit.

Leeswijzer

Deze inspiratiegids is een levend document

Dit is een inspiratiegids en inspiratie vraagt om regelmatige updates. Ten opzichte van de versie van TenneT zijn in deze uitgave maatregelen voor de distributienetten van Alliander, een score voor impact op biodiversiteit en aandachtspunten vanuit de operatie toegevoegd. Ook de poster voor natuurinclusief bouwen (ontwikkeld binnen het 'Kennis Natuurlijk!'-project) en de lijst van infranatuurmaatregelen (ontwikkeld door Naturalis in opdracht van Stedin in het Groene Netten- verband) zijn gebruikt. Aanvullend worden de ambities van Alliander in de loop van de tijd steeds verder aangescherpt en vanuit ervaring in de praktijk ontstaan nieuwe inzichten. De inspiratiegids is daarom als een vrij en open e-book formaat gepubliceerd. Hiermee is het een levend document dat steeds digitaal wordt bijgesteld naar aanleiding van voortschrijdend inzicht of wanneer nieuw beleid daar om vraagt. **Gebruik dus ook altijd de laatste versie!**

Categorieën type assets

Voor de toepassing van de maatregelen in deze gids maken we onderscheid in drie verschillende categorieën type assets: gebouwen, terreinen en verbindingen. Per maatregel geven we met onderstaande symbolen aan bij welke categorie ze *in principe* van toepassing zijn[2].

	Type assets	Bijvoorbeeld
●	Gebouwen	Bouwwerken, bijvoorbeeld op een stationsterrein
●	Terreinen	Buitenruimte rondom de assets in eigendom en/of beheer van Alliander
●	Verbindingen	Onder- en bovengrondse verbindingen in eigendom of beheer van Alliander

Ecologische impact

De invloed op biodiversiteit geven we per maatregel aan met:

	Laag	Midden	Hoog
Invloed	●	●●	●●●

Deze score is grotendeels gebaseerd op de lijst van infranatuurmaatregelen die is opgesteld door Naturalis in opdracht van Stedin, waarbij de score is gegeven door 40 ecologen en biologen. Ook hier blijft maatwerk echter altijd noodzakelijk[3]. Het uitgangspunt is dat als de kosten gelijk zijn, in principe de meest impactvolle maatregel gekozen wordt.

[2] Maatwerk blijft nodig om de toepasbaarheid van de maatregel op locatie te bepalen met betrekking tot ecologie, kosten, veiligheid, onderhoud en beheer.
[3] Een ecoloog zal de effectiviteit en toegevoegde waarde van een maatregel moeten toetsen aan de lokale context van de locatie, waarvan voorkomen van soorten flora en fauna in de omgeving, morfologie en bodemsoort voorbeelden zijn.

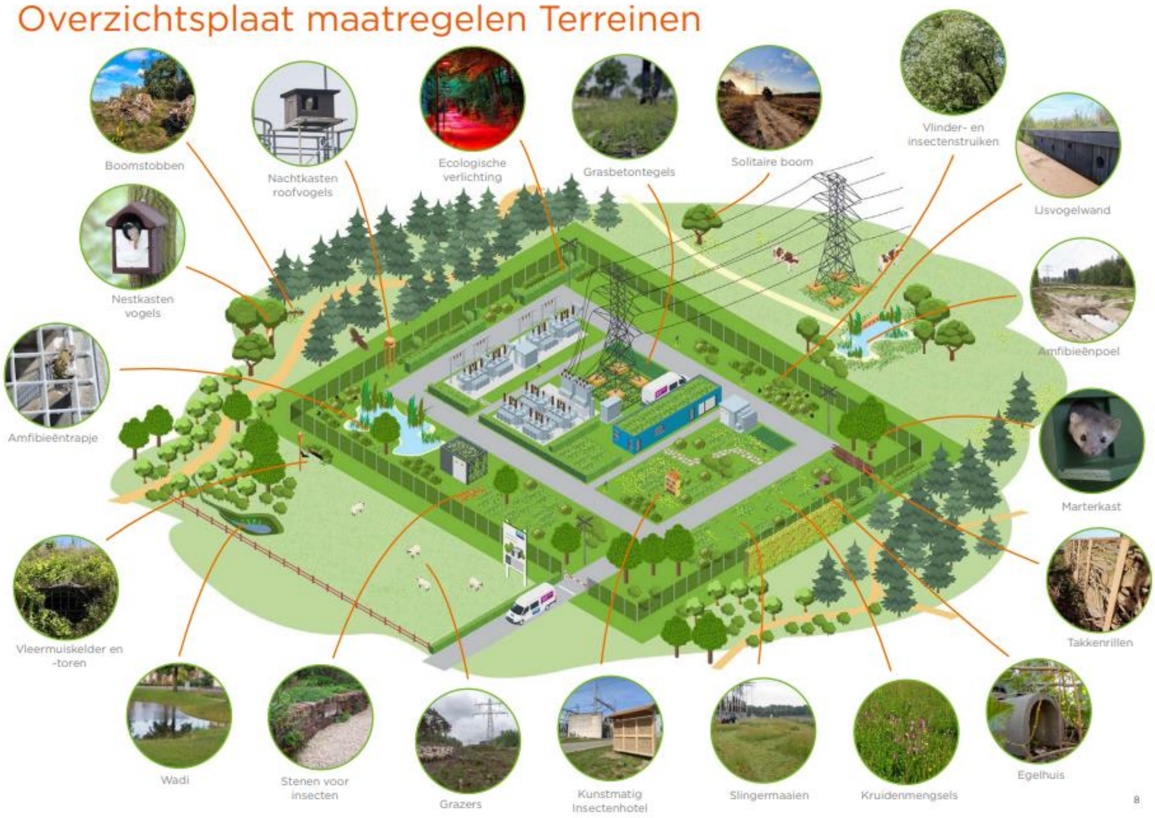
Inhoudsoverzicht

*klik op de maatregel om deze in te zien

Overzichtsplaat maatregelen Gebouwen

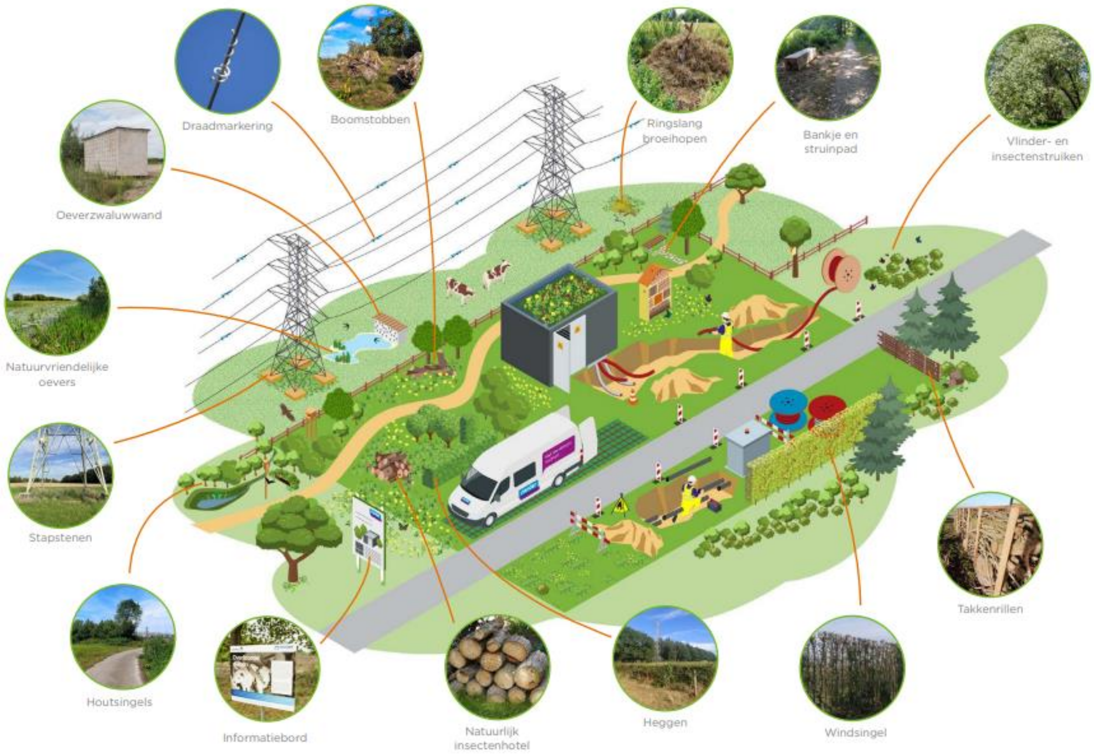
7

Overzichtsplaat maatregelen Terreinen



8

Overzichtsplaat maatregelen Verbindingen



9

‹‹ Start Inhoudsoverzicht Leeswijzer ››

Amfibieënpoel

Poelen zijn van belang voor amfibieën zoals kikkers, padden en salamanders. In het grootste deel van Nederland is voldoende geschikt landhabitat voor amfibieën beschikbaar. Echter, geschikte voortplantingswateren ontbreken veelal.

Door het aanleggen van poelen kan een gebied geschikt worden voor amfibieën. Poelen zijn niet alleen belangrijk als voortplantingswater voor amfibieën, maar brengen daarnaast ook variatie in een landschap. Meer variatie in een landschap betekent altijd meer plant- en diersoorten. Poelen kunnen dienen als groeiplaats voor water- en moerasplanten, als leefgebied voor insecten en andere ongewervelden, en als drinkplaatsen voor vogels en zoogdieren. Niet alleen de poel zelf, maar ook het talud boven de waterlijn kan bij uitstek geschikt zijn voor bepaalde soortgroepen. Denk aan insecten die hun nesten kunnen maken in de zonnige noordoever.

Aandachtspunten:

Bij het aanleggen van een poel moet rekening gehouden worden met diverse voorwaarden:
- Stilstaand of hooguit zwak stromend water;
- Niet te sterk beschaduwd, i.v.m. voldoende zoninstraling;
- Ondiep, zodat ze snel kunnen worden opgewarmd door de zon;
- Zo diep, dat er in de zomer voldoende water is voor de ontwikkeling van de larven;
- Rijk aan algen en plankton (voedsel voor larven);
- Voorzien van voldoende watervegetatie, i.v.m. de ei-afzet en schuilmogelijkheden;
- Rustig gelegen, zonnige, noordelijke wal;
- Voorzien van geleidelijk aflopende oevers met een minimale taludhelling van 1:3.

Zie voor meer informatie:
Poel-aanleggen (Ravon.nl)

10

Wadi

Een wadi is een groene greppel in voornamelijk stedelijk gebied. Wanneer het hard regent, krijgt de grond niet de kans om al het water te absorberen. Dit komt vooral door de verharding en betonnering.

Wadi's worden steeds vaker aangelegd in Nederland om regenwater tijdens extreme buien te bergen en om het grondwater op peil te houden. Het water stroomt dan van het straatoppervlak naar een wadi, via bijvoorbeeld goten en wegen. Wadi's hebben verschillende functies in het stedelijke gebied en zijn er in verschillende vormen en maten. Zo draagt een wadi bij aan waterinfiltratie, biodiversiteit en esthetiek. Vaak zit er een infrastructuur onder om het water te bergen en af te voeren naar elders als de wadi tijdens een extreme bui is volgestroomd. Wadi's kunnen aangelegd worden op bijvoorbeeld stationsterreinen. Het water kan dan tijdens extreme buien van daken en verhardingen (op stationsterreinen) stromen naar de gerealiseerde wadi, waarmee de stationsterreinen klimaatbestendiger worden.

Aandachtspunten:

- Reken uit hoe groot de wadi moet worden;
- Bepaal van tevoren hoe je het water in de wadi krijgt.

Zie voor meer informatie:

Stappenplan en tips voor een wadi

Colofon

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