**FACULTY OF SCIENCE AND TECHNOLOGY**

# MASTER'S THESIS

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“TO THE BRAVE WOMEN OF IRAN

WOMAN, LIFE, FREEDOME”

# Contents

# Abstract

A sustainable future depends on achieving energy efficiency since it lowers energy use and greenhouse gas emissions. In order to attain energy efficiency, the adoption of nature-based solutions (NBS) is growing in popularity since it offers numerous environmental, social, and economic advantages. This paper will define NBS, examine their role in energy efficiency, and discuss how they might be employed to further sustainable development. From greenhouse gas emissions to waste generation, college campuses can have a substantial negative impact on the environment. However, through green campus initiatives, several colleges are taking proactive measures to minimize their ecological footprints. This applies to Stavanger University's campus as well, which could learn a lot from NBS about how to become a more sustainable and environmentally friendly institution.

The introduction of the essay defines NBS and emphasizes their potential as a tool for attaining energy efficiency. NBS include a variety of tactics that make use of natural resources and processes, including reforestation, green infrastructure, and the restoration of wetlands, among others. These solutions have a number of benefits, such as lower energy use, better air and water quality, increased biodiversity, and carbon sequestration. The overarching objective of reducing greenhouse gas emissions and combating climate change can be achieved by integrating NBS into energy systems and infrastructure. Finally, recommendations for improving the UiS campus and strategies to implement NBS there are made based on the learned insights.

# Introduction

As the world becomes increasingly urbanised, the built environment has a significant impact on energy consumption and greenhouse gas emissions. As a result, there has been a growing interest in nature-based solutions as a means of reducing energy usage and promoting sustainability in buildings. However, the effectiveness of these solutions can be influenced by various factors, including building typologies and orientations.

Nature-based solutions, such as green roofs, living walls, and urban forests, have been found to have numerous benefits for buildings, including reducing energy consumption, improving air quality, and reducing the urban heat island effect. However, the performance of these solutions can be influenced by various factors, such as climate, building materials, and building orientation. Building typology, in particular, has been found to have a significant impact on the effectiveness of nature-based solutions, with different building types having different energy consumption patterns and requirements (Saelens et al., 2019).

The UiS campus is a diverse built environment, consisting of a range of buildings with varying typologies, orientations, and energy requirements. For instance, the campus includes traditional office buildings, laboratories, and lecture halls, each with unique energy needs and consumption patterns. Furthermore, the orientation of the buildings is also diverse, with some buildings facing north, south, east, or west, each with different levels of solar exposure.

The campus of the University of Stavanger (UiS) in Norway is a great example of a complex built environment with a variety of building types and orientations, making it the perfect case study for examining the effectiveness of nature-based solutions in it and how is it possible to reach a more sustainable campus.

The questions, which may be raised by examining the UiS campus, is,

"How is it possible to implement nature-based solutions into the campus to bring sustainability and establish a green campus?"

“what is the nature-based solutions? And what solutions are suitable for UiS campus?”

“What are the current plans of making a green campus? And how to improve them?”

# Methodology

Utilising qualitative analytical techniques, notably literature review and case study, this study attempts to delve into the research on nature-based solutions and green campus development, with an emphasis on the case study of Stavanger University. By looking at these methods, one can obtain a thorough understanding of the theoretical underpinnings, advantages, difficulties, and practical techniques related to nature-based solutions for developing sustainable campuses.

An extensive literature survey was used as the first strategy in this study and was a key building block for developing a conceptual framework. A detailed review of the literature on green campus development and nature-based solutions has been conducted. The literature review helped to clarify the underlying theories of nature-based solutions, their associated advantages, and the critical elements affecting successful green campus development. Common themes and trends were discovered through the analysis of a wide range of literature, enabling a more nuanced understanding of the subject.

A case study was done to learn more about the efficacy of nature-based components on the Stavanger University Campus, building on the findings of the literature review. Rich, contextualised data were gathered through direct observations and document analysis, giving important insights into the campus's green activities and their effects on environmental sustainability and well-being. The case study was concerned with evaluating the efficiency of numerous natural features found on the Stavanger University Campus. These components included natural landscaping, rain gardens, and green roofs. The information gathered made it possible to comprehend more fully how these components enhanced campus life and promoted environmental sustainability.

## NBS Energy efficiency solutions

An innovative and sustainable strategy for cutting energy use and advancing a low-carbon future is to implement energy efficiency solutions based on Nature-Based Solutions (NBS). NBS refer to the application of natural systems, including soils, water bodies, and plants, to alleviate environmental issues and enhance human wellbeing. Energy efficiency solutions built on NBS can help lower energy use and greenhouse gas emissions, boost energy security, and strengthen the resilience of energy systems to the effects of climate change.

The utilisation of green roofs and walls is one of the most promising NBS-based energy saving options. Living systems that use plants to cover walls and roofs are known as "green roofs" and "green walls," respectively. These systems have numerous advantages, such as lowering the impact of the urban heat island, enhancing air quality, lowering stormwater runoff, and boosting biodiversity. Additionally, by increasing the thermal insulation of structures, green roofs and walls can lower energy usage. According to a University of Toronto research, green roofs can save heating and cooling energy use by up to 25% in the summer and 31% in the winter (Li et al., 2014). The lifespan of roofs and walls can be increased by using green roofs and walls, which lowers maintenance costs and eliminates the need for replacement.

The utilisation of natural ventilation and daylighting is another NBS-based energy-efficiency option. In order to deliver clean air and remove indoor contaminants, natural ventilation uses natural airflows rather than mechanical ventilation systems. Daylighting is the practise of utilising natural light to illuminate interior spaces rather than artificial lighting. These techniques can increase indoor air quality and boost human comfort while consuming less energy. For instance, according to a research by the Lawrence Berkeley National Laboratory, mechanical ventilation uses up to 40% more energy for cooling than natural ventilation (Bauman et al., 2012).

Urban planning and design can also use NBS-based energy efficiency solutions. For instance, utilising urban green spaces and water features can enhance air quality, lessen the impact of the urban heat island effect, and decrease the demand for energy-guzzling air conditioning systems. Additionally, by encouraging walking, cycling, and public transportation, the use of compact and mixed-use urban forms can lower transportation energy use. In addition, the adoption of renewable energy technology in urban settings, such as solar photovoltaics and tiny wind turbines, can help promote decentralised energy generation and lessen reliance on fossil fuels.

NBS-based energy efficiency solutions can offer numerous co-benefits, such as bettering air and water quality, enhancing biodiversity and ecosystem services, and boosting social well-being, in addition to lowering energy use and greenhouse gas emissions. For instance, the utilisation of green walls and roofs can offer urban people educational and recreational options, encouraging physical activity and social connection. According to van den Bosch and Ode Sang (2017), using urban green spaces and bodies of water can also enhance mental health and lessen stress and anxiety. (Van den Bosch, M., & Sang, Å. O., 2017)

Energy efficiency solutions based on NBS are a viable way to cut energy use and encourage a low-carbon future. Some of the most successful NBS-based energy efficiency solutions are green roofs and walls, natural ventilation and daylighting, urban planning and architecture, and renewable energy technology. These solutions may also improve the quality of the air and water, support biodiversity and ecosystem services, and boost social well-being. To encourage their wider adoption, appreciate their potential benefits, and optimise their potential benefits, additional research and investment in NBS-based energy efficiency solutions is required. For instance, a green roof may be more effective in reducing energy consumption in a building with high cooling demands, while a living wall may be more effective in reducing energy consumption in a building with high heating demands.

## Plants and Facades: Exploring the Connection

In industrialised nations, buildings account for a sizeable portion of overall energy use. As environmental issues and the need to lower energy demand become more widely recognised, it is imperative to find solid and dependable solutions.  (2014) Perez et al. Although cities contribute to the issue of climate change, they can also be instrumental in discovering solutions (Kamal Chao et al., 2009). The majority of the energy consumed globally now comes from cities. Cities also have the authority to take action on urban problems and come up with suitable solutions to stop weather changes. They are reputable and capable of being accountable in a number of industries, including building.

Buildings currently account for 13% of $CO_2$ emissions and 19% of energy consumption in the European Union, according to estimates from the Council of Europe. Due to the goal of reducing greenhouse gas emissions by 80 to 95 percent by 2050. (European Commission, (2011) There are many methods to improve things; some of these include using better materials, greener energy sources, more efficient economic conditions, and better information and communication technology.  (SkouA, 2013)

In addition, buildings without the homogeneity of the roofs and walls are in conflict between the factors of the external environment and the internal needs of the residents. (Del Grosso, 2010) The primary determinant of the quality and control of internal conditions versus unstable external conditions is the building's outside shells. (Sadineni et al., 2011) Since the facades have been used as mediating filters between the conditions of the external and internal environments and the needs of the residents of the interior space, they have the potential and can play a significant role in creating principles and rules as well as controlling energy loss.  One of the most crucial design elements for controlling the internal physical environment that affects how much energy is utilised in buildings is the building envelope.  (Oral et al., 2003)

Facades and building shells have been the focus of numerous studies and research projects recently in relation to this useful role, and each one has attempted to increase productivity, efficiency, and performance in order to achieve the proper energy, comfort, or structure.  Since the design of suitable architecture can significantly reduce the amount of energy consumption and the need for less energy while achieving comfort in the space, there have been an increasing number of projects about improvement and progress, challenges, and the possibility of building shell design and its effect on the use of energy.  (Selkowitz, 2001)

Contrarily, adaptation is a process that assesses “the ability of living organisms to live better in nature.” (Dobzhansky et al., 1968) The environment and nature are no longer the only issues that concern biologists today; they are also a source of inspiration and ideas for cutting-edge technology.  This propensity is known to mimic the orderly structure of nature, which is necessary for development.

Giving in accordance with natural laws, which are applied in the domains of engineering and medical, has only just begun to be employed in architecture.  The systems present in nature provide us with a wealth of knowledge, guidelines, and options that can be applied to designing in harmony with nature.

Most definitions of facade and building shell are the outer fence and building area that separates the interior and exterior of the building in order to provide functions like support, control, aesthetics, and services in which It distributes. Adaptation is an evolutionary and dynamic process that living organisms find to be able to live in their habitat. (Dobzhansky et al., 1968) New difficulties are continually being presented by the environment. The elements affecting the building are the sun, temperature, relative humidity, rain, wind, disrupting elements, and carbon dioxide.  These elements have an impact on the occupants’ degree of comfort and convenience as well as the building’s effectiveness.

Additionally, because traditional and conventional facades are mostly static and inflexible and each region’s climatic features are different and changing, we use a lot of energy to regulate the comfort of the interior space.

The building’s exterior was typically and traditionally thought of as a thermal barrier, protective envelope, or shade to control sunlight in order to prevent thermal damage. This accomplishment nullifies many workable solutions because currently the building’s shell is viewed as a mediating feature rather than a barrier or protective measure. Traditional solutions, facades, and roofs are not made to react to needs and contextual circumstances in the best way possible. Our buildings were against external conditions and were not able to adapt to weather conditions and environmental changes. (Armstrong,2012)

Due to the fact that the majority of them are complicated, multifunctional, and have a high level of responsibility, we are now interested in solutions that fit the environmental structure. Therefore, the new adaptive architectural facades for Improving building performance are crucial, as opposed to the old traditional and stiff shells and facades.

One of the main objectives is to aid in energy conservation in the areas of heating, cooling, ventilation, and lighting, and the second objective is to ensure that those using the space are comfortable. As a result, the building shell is employed in structures as living shells that can incorporate a variety of technologies based on shells found in nature rather than being used as typical inert surfaces. (Beesley, 2006)

## Adaptive building shells

Building structures offer areas to shield occupants from the outside environment, particularly in arid climates where wind, rain, and harsh sunlight are common. Building shells are composed of fundamental components like windows, walls, roofs, and floors that stand in contrast to the surrounding environment and inside occupied spaces. They can also be utilised to store energy with the help of an appropriate solution to react to particular climatic circumstances. (Sadineni, 2011) The environment is continually changing, which presents new problems for building shells. (Hasselaar, 2006) Along with environmental elements including air movement, humidity, temperature, sunlight, air quality, and bothersome noises, occupants’ activities can also have an impact on how comfortable a building’s interior is. (Bar-Cohen, 2011)

Since the turn of the century, it has seen vital to shift from static and passive to active design aims. Moving facades are capable of responding fully to changes in the weather as environmental control systems. Some of these objectives, like Le Corbusier’s proposal (only one house for all nations, universal houses for all climates and a breathing house), which was put forth in 1930, remained purely theoretical.

These designs weren’t carried out because there wasn’t the technology available at the time to develop such future concepts. Later in the year 1970, William Zack refers to a type of architecture as a moveable facade, in which individual building parts or the entire structure might respond to changes by gradually deforming, returning to a previous state, or using other means of movement. The “multivalent wall” (Zuk, 1970), which is made up of thin layers capable of collecting water and reflecting, filtering, and transferring energies from the environment, is a key example of the theory from the 1980s. (Davies, 1981)

## Advanced architectural skins

The usage of high-tech manufacturing processes nowadays has made it possible to put complex concepts into practise. Buildings are now able to respond to a variety of climatic situations thanks to these technologies. (Wigginton, 2002) For adaptability, modern integrated materials and mechanical services are used. One of these building shells, Kunsthaus Graz (figure 1a), was created by architects Kook and Frontier and has both an aesthetic and utilitarian purpose.

It was in this location that the building shell freely stands between more conventional and traditional buildings, and the intelligent, brilliant outer shell is on display in response to the art initiatives. (Cook et al., 2004) Building of Council house 2 in Melbourne, designed by Mark Pearce (figure 1b), is another useful illustration. It received the Top Green Star certification. This building uses a number of technologies to control the ventilation, water, light, and cooling. As a result, the structure is stable and effective. (Paevere et al., 2008) Along with these recent advancements, there has been an increased interest in creating responsive, adaptive skins that show more of the movement principles.

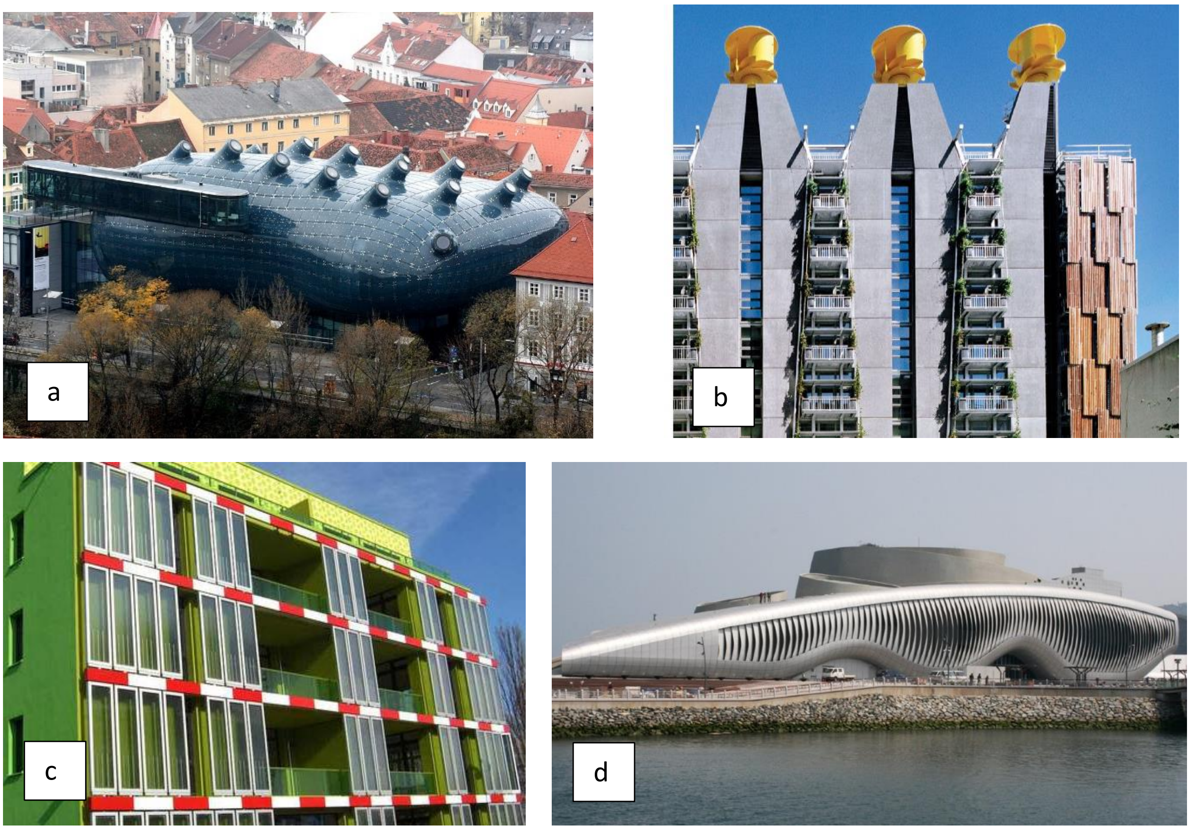


*Figure 1: Buildings built based on the biological model*

For instance, the intelligent building with biological structure quotient (BIQ) (figure 1c) by Arup and Splitter work is the one that absorbs heat and generates power because it has panels packed with algae and moss, whose survival depends on absorbing light. (Torgal et al., 2016)

Another illustration is the Thematic ocean pavilion (figure 1d), which was created by the SOME architecture firm and features a moving facade that alters the curvature of the blades to adjust the amount of daylight. (Knippers, 2012)

Another example is the Arab centre in Paris (figure 2a), which was designed by John Knoll and finished in 1987. It is one of the earliest and best-known examples of active facade application and is based on automatic response by environmental sensors.  Traditional Arabic sunshades served as the technological inspiration for automatic control shades. (Loonen, 2010) A computer balances the quantity of light in the south view by controlling 25000 solar cells, which function like camera lenses. (Fortmeyer, 2014)

Lunen installed thermal-functional shells in the interior of the Arab Institute project, and in this instance, the reasons for the adaptation and adaptation of the building's energy balance changed because the residents' behaviour affected this adaptation and their visual perception was taken into account. The ETFE shell was erected on three levels with inflatable layers within the Arab Institute building to create a vertical cloud that reflected sunlight.  A network of temperature sensors automatically activates this inflatable mechanism. (Loonen et al., 2013) It was discovered through experiments that the functional design is unsuccessful as an adaptive view and complicates the view system.

According to Coelho and Mass's studies (Coelho et al., 2009), facade panels are annoying, they break easily, they are highly automatic, and they don't give residents enough control over their personal space. As a result, we must adapt to the point where mechanical devices are created in order to reduce energy consumption. We can observe prominent examples of dynamic structures and adaptive skins from recent years.  Here, we focus on two initiatives that were inspired by their combined experiences and had creative and reformative elements.  Enric Ruiz Geli created the TIC building (figure 2b), while Doris Kim Sung created the Bloom Building. (figure 2c)

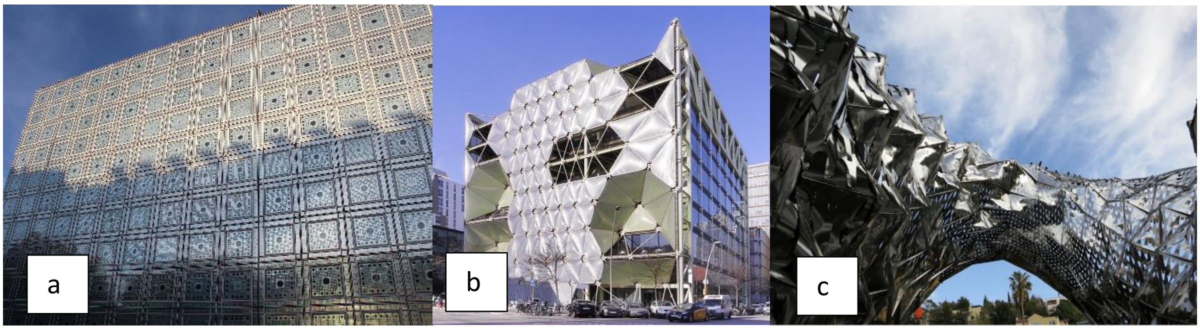


*Figure 2: examples of moving facades in the last decade*

In the first instance, the TIC office building, the architects used the “shell as an energy display” to create a practical architecture with the maximum level of energy efficiency. Through its ETF shell, which includes a photovoltaic roof and uses the rainwater cycle to cut carbon emissions by 95%, the building is connected to its surrounding environment. (Dent et al., 2014) The transparent ETFE exterior of the Eden Building in London, another structure whose facades have utilised ETFE technology, has generated a microclimate. Other examples of this type of architecture are the National Water Games Centre in Beijing and the arena stadium in Munich (Herzog and Dameron, 2014).

The adaptive shell, in contrast to other examples in the TIC media office building, resulted in a 65% reduction in carbon dioxide emissions, which was caused by the automatic ATP filter as well as by smart sensors that improved energy efficiency.

The southwest and southeast axes served as the foundation for the adaptive shell’s adaptation. The solar shade is an innovation that creates conditions using nitrogen gas, similar to a cloud utilising a fog system, and it reduces the solar heat obtained by 90% in this building where the sun’s rays are particularly intense. (Geli et al., 2011)

In the third scenario, Bloom’s structure functions as an environmentally friendly system. This structure has developed a model that responds to environmental challenges, this shell adapts to heat and light changes, using tested materials, structural advances, and computerised shapes. Finding solar-powered equipment helps to control the climate and lessens the demand for artificial cooling. Building temperature can be changed passively using bimetallic thermal panels (thermostatic metal). Environmental conditions are responsive to metallic buildings. The temperature inside the space doesn’t rise because of the curves and ventilation apertures. Smart materials have the power to alter the environment, as demonstrated by the Bloom Building. Without employing electrical drive mechanisms, which use the energy obtained from the building’s cooling systems, the temperature as a beginning factor and green drive in this building were able to construct a steady and responsive system. (López et al., 2015)

## Imitation of the biological structures of nature

From the Greek word bios, which meaning life, comes the phrase “biomimicry,” which is the copying of the structure of nature. The phrase “abstraction of the good design of nature” is defined by this phrase (Vincent et al., 2006). Or necessary regulation motivated by the patterns found in nature and the process of building a healthier and more stable planet. Although this discipline has occasionally been employed in other industries like engineering and medical, study in recent years has focused on using nature mimics as architectural solutions. Michael Pawlyn is the top architect in the field of nature-inspired design ideas. He replicated the biological structure of nature’s forms, their biological processes, and the solutions that are oriented towards adaptability and sustainability. (Pawlyn, 2011) His work takes inspiration from the natural environment and looks for ways to build structures with more personality, develop zero-loss systems, or produce energy for the building. Other scholars have attempted to develop various cognitive techniques for generating building shells based on nature imitation in recent years.

This section explains many initiatives with adaptive shells and how they react to changes in energy and the environment to promote energy efficiency. These plant-inspired examples could start a trend in the area of developing systems that adapt to ongoing environmental changes. Flectofin, created by ITKE (ITKE, 2011) is the first. The process of “Bird of Paradise” flower pollination served as an inspiration for this invention. The employment of technology through the use of materials with reversible deformation can solve this issue. Inspired by this flower, when an external mechanical force applies, reversible deformation is formed and will cause bending and movement that is inspired by nature.

The Flectofin project resulted from this abstract perspective of nature and focus on the individuality of materials. The main column’s bending pressures forced the blade’s temperature to be replaced, supported, or changed because of dependence on the vertical system, which was finally able to shift direction up to 90 degrees.

The ideas Flectofin employed for outside shading systems were one of its widely used uses. (figure 3a) With the use of double curved surfaces that were not constrained by geometry, this dilemma opened up new possibilities for the usage of organic forms. There is a tremendous potential to minimise energy consumption thanks to the functional advantages of the best shading systems in buildings, which can lower energy consumption in mechanical cooling systems and increase passive energy in winter. (Schleicher et al., 2015)

The second piece is the Thematic ocean pavilion. (figure 3b) Together with Knipper from Advanced Engineering, SOME Architecture Group constructed this structure for the 2012 Yeosu pavilion in Korea. The Flectofin project and other studies on planetary motions and kinetic mechanisms served as inspiration for the development of its adaptable shell system. A shade system comprised of curved, thin plates that can adjust to the lighting, control the building’s physical conditions, and react to the sun’s position throughout the day. (Schinegger et al., 2012)

The third instance is the Meteoro sensitive pavilion, which was proposed by Achim Menges in conjunction with Krieg and Reichert and was known as Hygroskin. (figure 3c) The pavilion’s basic design was inspired by the pine tree’s fruit, which reacts passively to humidity fluctuations. When used as a building material, hygroskin can react to the environment by using relative humidity as a green stimulus.


*Figure 3: (a) Flectofin building, (b) Thematic ocean pavilion, (c) Meteoro sensitive pavilion (hygroskin)*

Due to the amount of moisture in wood, an unstable crust forms that is sensitive to climatic change and can open and close on its own without the use of energy management tools or electrical or mechanical controls. With a range of 30% to 90%, shell apertures adjust their light transmission and visual penetration capabilities in response to relative humidity. (Reichert et al., 2014)

The development of adaptive skins that are more responsive to environmental changes and that may “behave” like live beings is now greatly facilitated by modern construction processes. (Loonen, 2015) It is crucial to remember that copying nature does not mean making an exact replica of it; rather, it refers to a functional and abstract understanding of how nature is structured. (Kennedy et al., 2015)

## Adaptation strategies in plants

Plants’ inability to move hinders their ability to defend themselves from environmental changes. (darkness, light, humidity, rain, fire, temperature, cold, quality, and movement of the wind) Because of this, it is possible to take into account how well they can adapt to their environment. This adaptability reacts to changes often and at various periods. Relates to the environment. Morphology, physical structure, and behaviour are the three basic ways that living organisms gradually evolve and adapt to their environment (Azcón et al., 2000).

### Morphology

Living things have different shapes, sizes, patterns, and structures depending on their unique environments and optimal strategies for survival. For instance, both the male and female Gynandriris stofolia plants (figure 4a) have hairy leaves. Due to their surface’s ability to reflect sunlight and adapt to the hot, dry environment, these hairy hairs are used.

## Physical or functional structure

This problem relates to how living things function chemically.  To sustain vital balance, vital processes or individual reaction systems to certain external stimuli are needed.  Some plants can grow like Echeveria Glauca (figure 4b) (American tropical plants from families that have fleshy petals), which they can grow in dry weather conditions. These plants use CAM photosynthesis (Crassulacean Acid Metabolism) to adapt to dry weather conditions. They use water to increase efficiency.


*Figure 4: Different solutions of plant adaptation. (a) fluffy leaves of Gynandriris stofolia plant, (b) fleshy leaves of the Echeveria Glauca plant with CAM photosynthesis, (c) leaves of Mimosa Pudia plant that fold inward upon contact with an external agent.*

## Behavioural

It is related to how living organisms It has to do with how living things work and behave.  Living things act in this way in order to survive.  The behavioural indicators of this sort of adaptation are responses between living organisms and their environment, which is related to the feedback system of organisms.  For instance, the Mimosa Pudia plant (figure 4c), whose leaves fold inward in response to touch with anything, has leaves that respond to external stimuli.

# Transition from nature to architecture

The first accomplishment that enables us to apply the solutions discovered in nature as architectural solutions is the classification and organisation of the received bio-structural information.  Plants use both static and dynamic mechanisms to adapt to their surroundings. There are micro and macro scales for these two key accomplishments.

## Dynamic mechanism

The basis of movement or response depends on the direction and position of the stimulus because plants move in tendencies, also known as plant kinetic reactions. In this study, the emphasis is on responsive plants, which are those with fast displays and reactive movements.  Some plants have visible-scale reactions to changes in light, temperature, or water, and these changes can be observed both with and without a microscope. For instance, the leaves of Rhododendron flowers rotate when they come into contact with warmth and the seeds of numerous

Mesembryanthemum flowers scatter when they come into contact with precipitation as a stimulus.  On a broad scale, they are dynamic.  On the other hand, examples of dynamic mechanisms at the micro scale include the movement of stomata in response to water, light, temperature, and carbon dioxide.  (Vogel, 2012)

### Static strategy

Here, we concentrate on the structure and multifunctional characteristics of plant leaf surfaces.  Different adaptations have been made by plants to the harsh environment in hot and arid places.  For their environmental conditions, plant surfaces can reflect light, have hydrophobic or hydrophilic properties, or any combination of these.  (Gibson, 2008) Macro-scale static strategies, such as those used by the plants Cerastium tomentosum and Fenestraria rhopalophylla to filter sunlight inside their cells or shield them from direct sunlight and obstacles, are examples.  In hot and dry areas, they lose too much water through evaporation. The leaves of Colocasia esculenta, a self-cleaning plant with nanoparticles and a good example of a micro-scale static approach, are recognised for their lotus effect and have anti-water qualities.

## Creation of design concept

The process of creating a design that resembles the structure of nature might begin after gathering data and knowledge on plants, organising them, and observing how they respond to their surroundings.  This approach results in the design of architecture shells that are interoperable and flexible.  From biological structure to architecture, there are four stages in the imitation and copying of nature: decomposition, composition, evaluation, and execution.  (Speck, 2012)

As a result, there are two key steps to the work procedure.  The first level makes reference to nature and discusses how plants adjust to various climatic conditions as well as their coping strategies.  The second step deals with architecture and how the chosen concepts might be reshaped and condensed to produce novel architectural solutions.  The stage of architecture, which is more imaginative and deductive, is paired with the stage of nature, which is more of an investigation of scientific principles. Because the goal is to adapt to the environment, climate data is taken into account directly in both the architectural and natural phases.

### Climate

The relationship between climate and the distribution of living organisms on Earth is the subject of the biological discipline known as bioclimatology, often known as plant geography.  The science of plant geography examines the interactions between the environment and the community of plants as well as the transient processes that temporarily alter them. (Azcón et al., 2000)

The ability of plants to deal with their environment is the foundation of their success, and this ability depends on their physical makeup and level of environmental adaptation. For this reason, the climatic context of the chosen plants is crucial. One of the best innovations for lowering building energy use is climate design. (Omer, 2008) This creates a variety of variables, such as temperature, precipitation, humidity, and so forth. This information is particularly relevant as preliminary elements to biological analysis as well as architectural goals.

The physiological principles that investigate the interaction between plants and climate with the physical and physiological elements of the environment and the relationship between them and how they can influence their spread is one of the most crucial topics. Climate variables include wind speed and direction, as well as the intensity and regularity of heat, light, rain, and relative humidity. In other words, it is biological climatology and can be regarded as the source of the biological climatology categorization system. These factors result in the distribution of plants in various climates. (Rivas-Martínez, 2011)

## First stage: Nature

The biological discovery of living things, including plants, is being reviewed in this first step. How do plants in the Mediterranean region obtain, use, and store water? How are they able to endure the severe challenges of night-time temperature differences or dehydration? The link between structure, morphology, and function is examined in order to comprehend such distinct behaviours in the direction of adaptation and specific function. It is feasible to extract the performance of mechanisms and strategies, apertures, reflectors, controllers, or absorbers by using the scale of small observations and the scanning electron microscopy of small images as a suitable tool for the accomplishment of static strategies. The approach will demonstrate how these creatures generate their unique environmental adaptations, and it will also provide the context necessary to comprehend why these plants can thrive in particular climates. These outcomes will decide the design concept's viability. The primary attribute of the plant and its implementation are then decided. (Gibson, 2008)

## Second stage: Architecture

In the second step, we are able to similarly take the key concepts and change them and employ them in technical and executive solutions for adaptive architectural shells in the future, based on the fundamental ideas of plant compatibility and adaptability. The three key working methods used in this stage are innovation, practical ideas, and overall design concept.

## The first solution: Practical ideas

Application concepts call for some level of compatibility with either statically or dynamically compatible skins.  The ability of adaptable plants to organise themselves in response to mobility and environmental changes has already been discussed.  Based on its intended use, adaptive architecture shells can be categorised into two categories.  Adaptive behaviour may be based on the motion of dynamic mechanisms or, via the use of a static strategy, the properties of materials.

In adaptive architectural shells, the first form of adaptability is based on precise visible movement, and the outcome of these changes in spatial arrangement and configuration is accomplished through the movement of various sections in the shell.  Folding, sliding, expanding, hanging, rolling, swell, turning, spinning, and crawling are a few examples of this type of movement.  Other forms of adaptive architectural shells exhibit adaptability through unique traits or traits like light reflection or absorption capabilities or through the conversion of energy from one form to another.  Changes immediately impact the internal structure of the materials in these structures. (Badarnah, 2015)

## The second solution: Innovation

Shell design requirements can lower the energy needed for lighting, ventilation, and heating and cooling systems.  (Pacheco et al., 2012) and creative ideas can be used to address the issue of energy consumption optimisation.  According to Omrany et al. (2016), plants’ responses to their surroundings can lead to creativity and innovation.  Because of these design benefits and obstacles, some new concepts build their objectives on them.  Why are these design solutions superior to those currently in use?  This solution aims to develop adaptive architectural shells or demonstrate the energy optimisation of novel applications in comparison to standard systems by utilising the advantages and positive qualities of design methodology and nature imitation. (Badarnah, 2015)

## The third solution: The overall idea of the design

The observation of the biological structure provides an overall sense of the design.  As a result, it also entails adapting and summarising biological structure to architectural construction requirements.  Although the inspiration for design ideas comes indirectly from plant adaptations through the study of function, morphology, and nature.  Discovering these systems in novel ways will be crucial.  Based on the study of adaptive plants in response to the prior inquiries, basic designs, building details, and tools are created and employed to facilitate expert shaping and implementation.

A building or operational notion with fundamental and functional features that are detected with motion, geometry, patterns, or material attributes is referred to as a “industrial application.”  In addition to meeting physical requirements, the entire design idea should take human conduct in space into account.  It is crucial to recognise that user behaviour is a key factor. Throughout the entire process, from design to implementation, principles should constantly be taken into account. For instance, techniques for shading systems can impact the interior space's comfort, not just in terms of thermal comfort but also in terms of highly essential visual elements. (Fiorito, 2016)

This means that in addition to energy conservation, design elements like interior and visual comfort, acoustic performance, and access to fresh air are equally crucial for owner pleasure. Human aspects such as system interaction and resident behaviour are essential for the building to operate efficiently and effectively.

## Living walls

A novel and creative approach to incorporate nature into the built world is through green walls, commonly referred to as living walls or vertical gardens. Numerous advantages of green walls have been demonstrated, including increased biodiversity, less noise pollution, and better air quality. Green walls can be included into building plans to increase energy efficiency in addition to these advantages. The use of green walls in building designs to increase energy efficiency and lower energy use will be discussed in this essay.

The potential of green walls to lessen the urban heat island effect is one of the main ways they can increase energy efficiency. Because of the large concentration of heat-absorbing surfaces, such as buildings and roads, urban regions tend to be substantially warmer than their rural neighbours. Increased energy use for cooling and air conditioning systems in buildings may result from this. By offering shade and lowering the amount of heat absorbed by buildings, green walls can help reduce the urban heat island effect. A green wall can lower a building's temperature by up to 10 degrees Celsius, based on a University of Melbourne study (Bass et al., 2014). For cooling systems, this drop-in temperature may result in significant energy savings.

The potential of green walls to act as insulation is another manner in which they might increase energy efficiency. Green walls can serve as an extra layer of insulation for buildings, minimizing heat gain and loss in the summer and winter. A green wall can minimize heat loss from a building by up to 25%, per a study from the University of Sheffield (Gago et al., 2013). This decrease in heat loss may result in significant energy savings for building heating systems.

Green walls can decrease the amount of direct sunlight that enters a building, which can increase energy efficiency in addition to lowering the urban heat island effect and offering insulation. The amount of heat that a structure absorbs from direct sunlight can rise dramatically, increasing the energy required to run cooling systems. By providing shade and light diffusion, green walls can lessen the amount of direct sunlight that enters a structure. A green wall can lower the amount of direct sunlight that enters a structure by up to 85%, according to research from the University of Bologna (Santamouris et al., 2017). For cooling systems, this decrease in direct sunlight may result in significant energy savings.

There are a number of things to take into account when incorporating green walls into building designs for energy efficiency. The green wall's direction is one of the most crucial elements. For greatest shading during the hottest hours of the day, green walls should be facing south or west. Additionally, it's crucial to carefully choose the plant species to guarantee that the green wall offers enough insulation and shading. Considerations including plant height, leaf density, and growth rate should be taken into account when choosing plant species. Finally, it's critical to maintain the green wall to make sure it keeps offering the advantages it was designed to. For their health and vitality, green walls need to be pruned and watered on a regular basis.

Green walls can be a useful strategy for increasing a building's energy efficiency. Green walls can provide insulation, lessen direct sunlight exposure, and diminish the urban heat island effect, all of which can result in significant energy savings for cooling and heating systems. Building designs should take into account elements like orientation, plant species selection, and upkeep when using green walls. Green walls are a great addition to any building design because they can offer a number of advantages for the environment and building occupants with careful planning and design.

## Previous studies on university campuses

From greenhouse gas emissions to waste generation, college campuses can have a substantial negative impact on the environment. However, through green campus initiatives, several colleges are taking proactive measures to minimize their ecological footprints. Escobedo, Clerici, and Staudhammer examined the efforts made by institutions to carry out these activities in their 2019 study, which looked at sustainability goals. Here, we'll look at some of the most effective tactics colleges can employ to lessen their environmental impact and advance environmental sustainability.

Reduced ecological footprints on college campuses can be achieved in large part by improving energy efficiency. Building design is one of the most efficient ways to cut back on energy use. By installing energy-efficient windows, insulation, and lighting systems, universities can boost the energy efficiency of their buildings. Infrastructure for campuses can also contain renewable energy sources, such as solar panels, wind turbines, and geothermal heating and cooling systems, to lessen dependency on fossil fuels. Universities should also encourage energy-saving behaviours among their students, teachers, and staff, such as unplugging electronics when not in use and turning off lights when not in use (Escobedo et al., 2019).

On college campuses, transportation is a substantial contributor to ecological footprints. To lessen reliance on personal vehicles, many institutions have created alternate transportation systems, such as bike-sharing programs, public transportation, and carpooling. Universities can also promote the usage of hybrid or electric vehicles and set up charging stations to help them. Another possible approach that can encourage healthier lifestyles and lower carbon emissions is to encourage students, professors, and staff to walk or cycle to campus (Escobedo et al., 2019).

Another key component of minimizing the ecological footprint of college campuses is waste management. To lessen the amount of waste transported to landfills, universities can adopt waste reduction and recycling programs. Promoting composting, minimizing packing, and encouraging the use of reusable containers are a few examples of how to do this. To further reduce their ecological footprints, universities can apply waste reduction strategies including limiting printing and boosting digital communication (Escobedo et al., 2019).

On-campus landscape management techniques can also have a big impact on lowering ecological footprints. Universities can improve stormwater management and support biodiversity by incorporating sustainable landscaping strategies into their campus designs, such as native plant species and rain gardens. Universities can also use green walls and roofs to save energy and lessen the impact of urban heat islands (Escobedo et al., 2019).

Collaboration across the university is crucial to attaining sustainability objectives. To encourage and put into practice sustainable practices on campus, faculty, staff, and administration must collaborate. The promotion of sustainability education, student involvement in sustainability projects, and the formation of sustainability committees to encourage cooperation and communication are all examples of this.

A holistic strategy that takes into account building design, transportation, waste management, landscape management, and cooperation is needed to reduce ecological footprints on college campuses. Universities have a special chance to encourage environmental sustainability and act as role models for their neighbourhoods. Universities can lessen their ecological footprints, improve the campus environment, and encourage sustainability for future generations by implementing green campus initiatives (Escobedo et al., 2019).

The use of nature-based solutions for sustainable cities, which includes sustainable campuses, is thoroughly reviewed in the book Nature-Based Solutions for Sustainable Campuses by De Sousa and Simas (2020). Infrastructure, ecological, and social innovation are the three key areas where the authors claim NBS can be used. In order to address problems with water management, heat reduction, air quality, and energy efficiency, infrastructure-based NBS uses natural solutions. Ecological-based NBS emphasizes the use of natural remedies to rebuild ecosystems, protect biodiversity, and lessen the impact of the urban heat island. Utilizing natural remedies to create social and cultural values, encourage community involvement, and improve quality of life are all aspects of social innovation-based NBS. (De Sousa et al., 2020)

De Sousa and Simas (2020) highlight a variety of natural remedies that can be used in environmentally friendly campuses. These include urban forests, rain gardens, green walls, and green roofs. Buildings can be equipped with vegetated surfaces like green walls and roofs to help with energy efficiency, air quality, and wildlife habitat. With the help of vegetation, rain gardens can absorb and filter runoff, lessening the strain on the stormwater system. Rain gardens are small depressions that are planted with flora. Large-scale plantings of trees and other plants are known as urban forests, and they can assist to enhance the quality of the air, lessen the impact of the urban heat island, and offer home for wildlife. (De Sousa et al., 2020)

Through student engagement, Krasny, Lundholm, and Plummer (2019) emphasize the adoption of nature-based solutions to improve the campus environment and develop ecological literacy. The authors contend that using nature-based solutions can help educate students about sustainability challenges and motivate them to take an active role in campus sustainability initiatives. The authors emphasize several natural approaches that can be utilized to accomplish these objectives, such as ecological restoration, urban agriculture, and sustainable landscaping. (Krasny et al., 2019)

Native plants and other vegetation are used in sustainable landscaping to design landscapes that are both functional and aesthetically beautiful. According to De Sousa and Simas (2020), this can involve the use of green roofs, green walls, rain gardens, and urban woods. Urban agriculture is the practice of growing food and other plants in populated places. It can increase food security, lessen the impact of urban heat islands, and offer opportunities for student learning and engagement. Ecological restoration entails restoring natural ecosystems and habitats, which can aid in the conservation of biodiversity and advance ecological literacy. (De Sousa et al., 2020)

Green infrastructure, green spaces, green buildings, and green behaviour are the four primary categories of NBS that are included in the framework provided by Mokhtar et al. (2021), who examine the literature on the use of NBS for attaining green campuses. In order to manage water, energy, and waste, green infrastructure uses natural systems and technologies. Examples of this kind of infrastructure include green roofs, rain gardens, and artificial wetlands. Parks, gardens, and other natural places are examples of green spaces that offer chances for leisure, instruction, and biodiversity preservation. In order to save energy, enhance indoor air quality, and reduce waste, green buildings use sustainable design, materials, and technologies. Promoting environmentally friendly practices among all parties involved on campus, such as students, faculty, and staff, is known as "green behaviour." (Mokhtar et al., 2021)

In each of these categories, Mokhtar et al. (2021) suggest several NBS that can be used. Rainwater harvesting, greywater recycling, and bioremediation are examples of green infrastructure-based NBS techniques that can lower water use and enhance water quality. Native landscaping, urban trees, and green roofs are some examples of green spaces-based NBS that can enhance biodiversity, offer possibilities for entertainment and education, and improve air quality. Energy-efficient lighting, eco-friendly building materials, and renewable energy are some examples of green building-based NBS that can help cut down on energy use and greenhouse gas emissions. Green behaviour-based NBS can include programs that encourage sustainable behaviours among campus stakeholders, such as trash reduction, active transportation, and sustainability education. (Mokhtar et al., 2021)

The efficiency, difficulties, and potential future directions of NBS for attaining a green campus are also covered by Mokhtar et al. (2021). According to the authors, NBS can be useful in minimizing negative environmental effects, promoting quality of life, and boosting campus reputation. But there are obstacles to implementing NBS as well, including as financial limitations, a lack of technical know-how, and institutional hurdles. The authors recommend more multidisciplinary research, stakeholder involvement, and creative financing structures as solutions to these problems. The authors also point out how cutting-edge technologies like the Internet of Things (IoT) and artificial intelligence (AI) have the potential to boost NBS's effectiveness and efficiency. (Mokhtar et al., 2021)

Schütt et al.'s 2019 essay, "Integrating nature-based solutions into university campus planning and design: A case study of the Technical University of Munich," published in 2019, offers suggestions on how universities might incorporate NBS into their campus planning and design. The Technical University of Munich (TUM), a sizable university with a campus that is 570,000 square meters in size, is the subject of a case study in the article. The authors emphasize the advantages of NBS, including preserving biodiversity, enhancing air and water quality, minimizing the effects of urban heat islands, and encouraging health and welfare. They also stress the significance of including stakeholders in the planning and design process, including university personnel, students, and the larger community. (Schütt et al., 2019)

The creation of a green infrastructure master plan was one of the major methods TUM used to incorporate NBS into its campus planning and design. This proposal identified potential locations on campus for NBS, including green roofs, rain gardens, and urban woods. The plan also includes instructions for their implementation as well as a thorough analysis of the potential advantages and disadvantages of each NBS action.

TUM's strategy made use of interdisciplinary and participative processes, which was a key component. The planning and design process involve a variety of disciplines, according to the authors, including engineering, ecology, and landscape architecture. This made it possible to integrate NBS in a more comprehensive way and guaranteed that social, ecological, and technical factors were all taken into account. A variety of stakeholders, including students, teachers, and locals, were also engaged by TUM through workshops, open forums, and other types of outreach.

The case study focuses on a number of particular instances of NBS integration at TUM. For instance, a green roof was put on one of the university buildings, which enhanced insulation, decreased stormwater runoff, and created a habitat for wildlife. Another illustration is the establishment of a campus forest, which served to reduce carbon emissions, enhance air quality, and give employees and students access to recreational options. The authors point out that these modifications improved the campus's aesthetic appeal and feeling of place while also benefiting the environment. The TUM case study highlights the significance of developing a master plan for green infrastructure, involving stakeholders, and utilizing transdisciplinary and participatory approaches. The authors also highlight the need for ongoing monitoring and evaluation of NBS interventions to ensure their effectiveness and address any challenges that arise. (Schütt et al., 2019)

# Stavanger university campus

## Background

In the charming Norwegian city of Stavanger, there is a renowned educational facility called Stavanger University Campus. This vast campus serves as a bustling centre for higher learning that promotes intellectual brilliance, inventiveness, and cultural variety. The Stavanger University Campus has established itself as a top location for students, academics, and professionals looking for a transformative learning experience because to its long history and dedication to cutting-edge research. This article goes into great detail about the campus's setting, circumstances, history, and contributions to Norway's academic scene.

## Location and Situation

The Stavanger University Campus is conveniently located in the city of Stavanger on Norway's southwest coast. As the "Energy Capital of Norway," Stavanger is a dynamic city with a booming economy supported by the oil and gas sector. The city provides a stimulating setting for scholarly endeavours and outdoor activities because it is surrounded by beautiful natural settings, such as fjords and mountains. Since the campus is situated close to the city core, it is easy to access many facilities and services. Its ideal location gives students the chance to explore the area's natural splendour while simultaneously immersing them in a bustling metropolitan atmosphere.

## History

The founding of Stavanger University College in 1969 served as the foundation for Stavanger University Campus. After starting out with a small selection of programs, the institution quickly increased its academic options. In 2005, it was granted university status and changed its name to Stavanger University. Today, it serves a wide range of subjects as a comprehensive university with a diverse range of faculties and departments.

The university has been essential in establishing Stavanger's educational landscape and advancing the metropolis throughout its history. The institution has made a name for itself as a leader in a number of sectors, including energy studies, technology, business, social sciences, and the arts by committing to academic quality and research.

## Campus Facilities

Modern amenities are available on the Stavanger University Campus to support academic aspirations, research projects, and extracurricular activities. Modern lecture rooms, well-equipped labs, libraries with enormous collections, and special areas for group work and cooperation are also present on the campus.

The campus offers a variety of amenities to improve student life in addition to academic facilities. These include of athletic facilities, leisure spaces, dining halls, and dorms for students. Additionally, the university hosts a variety of cultural and social activities to promote a lively campus community and a sense of belonging among students and employees.

# UiS plans on sustainability and going green

On September 2020, Stavanger University published its new campus development plan. The management of the University of Stavanger (UiS) has given Statsbygg the task of developing a new campus development plan as the current plan from 2013 no longer meets the requirements set by the Ministry of Education and Research. The university's growth projections have also been revised since 2012, with the estimated number of students reduced. Additionally, the Covid-19 outbreak in 2020 resulted in a setback to the Norwegian economy, leading the government to propose an increase in the number of study places. The campus development plan needs to be updated to address these changes. The new plan aims to support green transition and create an open, attractive university with a good study and work environment. The plan conducts following conclusions. (UiS development plan, 2020)

UiS recognizes the pressing need to transition towards a sustainable and environmentally conscious campus. The campus development plan aims to address this goal by incorporating various strategies to promote green practices, enhance biodiversity, and optimize the use of available space. While the plan does not specifically address air travel emissions or individual building solutions, it emphasizes key areas such as efficient space utilization, green mobility, preservation of biological diversity, and adaptation to a wetter climate.

Efficient Space Utilization:

To optimize the existing areas, UiS plans to assess and restructure the campus space, including the utilization of temporary buildings. By analysing the functional needs of different user groups, the plan aims to create a more efficient and attractive campus environment. This approach will minimize the need for additional construction, thus reducing the overall environmental impact. (UiS development plan, 2020)

Green Mobility:

Recognizing the importance of reducing carbon emissions, the campus development plan prioritizes the promotion of sustainable transportation options. This includes encouraging the use of public transport among students, faculty, and staff. By improving accessibility to public transportation and providing adequate infrastructure for cyclists, UiS aims to reduce the reliance on private vehicles, thereby decreasing carbon footprint and traffic congestion on campus. (UiS development plan, 2020)

Preservation of Biological Diversity:

The plan recognizes the significance of preserving and enhancing biodiversity on campus. By incorporating sustainable landscaping practices, UiS aims to create green spaces that support local ecosystems, promote biodiversity, and provide a pleasant and stimulating environment for the campus community. This may involve planting native species, creating green corridors, and integrating green roofs or living walls into the campus infrastructure. (UiS development plan, 2020)

Adaptation to a Wetter Climate:

UiS acknowledges the challenges posed by a changing climate, including increased rainfall and the potential for extreme weather events. The campus development plan takes these factors into account and incorporates measures to adapt to the wetter climate. This may include sustainable stormwater management systems, such as rainwater harvesting and permeable paving, to minimize the impact of heavy rainfall and reduce water runoff. (UiS development plan, 2020)

Collaboration and Feedback:

The campus development plan has undergone extensive consultation with both internal and external stakeholders. This collaborative approach ensures that the objectives and principles of the plan align with the expectations and needs of the campus community. By considering the feedback received during the consultation process, UiS aims to ensure broad support and successful implementation of the plan’s sustainability goals. (UiS development plan, 2020)

Future Considerations:

While the text does not provide explicit details regarding air travel emissions or individual building solutions, it is important to note that these factors are likely to be considered as part of UiS’s broader sustainability initiatives. As the plan progresses, it is conceivable that strategies to reduce air travel emissions, increase energy efficiency in buildings, and adopt renewable energy sources will be explored. The specific solutions for individual buildings may involve retrofitting existing structures with energy-saving technologies, implementing sustainable building practices in new constructions, or exploring renewable energy generation on campus. (UiS development plan, 2020)

# Implementation of nature-based solutions on UiS Campus

Numerous final solutions can be adopted on the Stavanger University Campus based on the information gathered. Among all of them, a select handful are more appropriate for the campus's setting and the external environment than the rest. However, it's important to keep in mind that major changes require a lot of time and money to implement, which could ultimately have an impact on the students and the University. The following will examine some of the workable solutions.

## Green roofs

It is crucial to use nature-based solutions to reduce the harmful effects of human activity as the globe faces environmental concerns like climate change. The use of green roofs, which involve including vegetation on rooftops, is one such approach. Numerous environmental advantages of green roofs include increased biodiversity, better storm water management, higher energy efficiency, and a less urban heat island effect.

### Benefits of Green Roofs

A desirable alternative for sustainable building design, green roofs offer a number of benefits. The first way they boost energy efficiency is by serving as an extra layer of insulation and preventing heat transfer between the building and the outside environment. This results in less energy being used for heating and cooling, which lowers carbon emissions and lowers energy prices. Furthermore, by absorbing and releasing heat, green roofs reduce the urban heat island effect and produce a cooler microclimate in the campus.

Additionally, green roofs help with efficient stormwater management. They lessen the strain on stormwater infrastructure, lower the risk of floods, and ease pressure on sewage treatment facilities by holding onto and gradually discharging rainwater. On green roofs, vegetation and soil serve as natural filters that remove pollutants and enhance water quality.

Green roofs also increase biodiversity in urban settings. They support urban ecology and the preservation of biodiversity by providing habitat for birds, insects, and other species. A more robust and sustainable ecology is a result of the greater biodiversity.

*Figure 5: design ideas of implemented green roof on an educational building*

## Implementing Green Roofs in UiS Buildings

Careful planning, design considerations, and cooperation among numerous stakeholders are necessary for the successful deployment of green roofs in university buildings. The procedure is outlined in the following steps:

Assess Feasibility:

Conduct a feasibility assessment to determine the building's structural capacity, waterproofing prowess, and load-bearing prowess before introducing green roofs. Make sure the structure can sustain the additional weight of the green roof by consulting with structural engineers and roofing specialists.

Set Objectives and Goals:

Establish precise aims and objectives for the green roof project. These could include things like increasing biodiversity, storm water management, energy efficiency, or student learning opportunities. Setting objectives will aid in directing the design and implementation process.

Engage Stakeholders:

Include all necessary parties, such as the campus administration, academic staff, undergraduate and graduate students, facility managers, and landscape architects. To guarantee that everyone's viewpoints are taken into account and to promote a sense of ownership and dedication to the project, encourage open communication.

Design Considerations:

Develop a plan that satisfies the unique requirements and objectives of the university in cooperation with landscape architects and green roof specialists. Take into account elements like plant selection, watering techniques, soil depth, and upkeep necessities. Select local or adaptable plant species to promote biodiversity and reduce water usage.

Secure Funding:

Find potential sources of funding, such as collaborations, grants, or sponsorships. Ask for assistance from university departments, regional governmental organisations, and environmental non-profits. To obtain funding, outline the project's advantages from an economic, social, and environmental perspective.

Install Green Roofs:

To ensure the green roofs are installed properly, work with knowledgeable professionals. Ensure adherence to waterproofing requirements, safety laws, and construction rules. The building phase will benefit from routine inspections to identify any problems early on.

Implement Maintenance Plan:

Create a thorough maintenance schedule to guarantee the green roofs' success over the long term. The health and vitality of the vegetation depend on routine monitoring, which includes weeding, watering, and insect control. Contract for specialised maintenance services or hire facilities management personnel.

## Monitoring and Evaluation

It's essential to track and evaluate the performance of green roofs on university buildings to determine how well they contribute to sustainability objectives. The monitoring and assessment process is outlined in the phases below:

Data Collection:

Gather pertinent information to assess the effectiveness of the green roofs. Data on energy use, stormwater runoff, biodiversity assessments, and temperature monitoring may be included. Use specialised tools to collect precise and trustworthy data, such as weather stations or data loggers.

Energy Efficiency Analysis:

Assess the effect of green roofs on the building's energy efficiency by analysing energy usage data. To calculate energy savings, compare the energy use before and after installation. To assess the building's overall energy performance, take into account elements like heating, cooling, and lighting.

Stormwater Management Assessment:

To assess how well green roofs manage and lower stormwater runoff, track and analyse stormwater runoff. Compare the quantity and quality of runoff from green roofs to that from other types of roofs. Analyse how well green roofs can hold onto rainwater and lessen the strain on stormwater systems.

Biodiversity Surveys:

Conduct routine biodiversity assessments to gauge how green roofs are affecting the area's ecosystems. Species of plants, insects, birds, and other wildlife that can be found on the green roofs should be identified and recorded. To gauge how much green roofs contribute to the preservation of urban biodiversity, compare biodiversity data with the area's surroundings.

Temperature Monitoring:

Install temperature sensors to keep an eye on the surrounding regions' and green roofs' surface temperatures. To assess the cooling impact, compare the temperature differences between conventional and green roofs. Analyse how green roofs affect the local microclimate and the reduction of the urban heat island effect.

Stakeholder Feedback:

Engage stakeholders, such as faculty members, facility managers, and students, to get their opinions on how well green roofs are working. To determine how satisfied they are with the green roofs and to obtain suggestions for improvement, conduct surveys or interviews. Take into account this feedback when making plans and decisions in the future.

Education and Awareness

The installation of green roofs in academic buildings is a special chance to promote sustainability and environmental responsibility. Students, teachers, and the general public can learn about the advantages and significance of nature-based solutions for sustainability by introducing green roofs into the university's curriculum and outreach programmes.

Integration into Curriculum:

Include green roofs in pertinent academic courses, such as those in urban planning, architecture, and environmental studies. Give lectures or workshops on the creation, construction, and upkeep of green roofs. Encourage students to conduct research projects that examine the effects of green roofs on the environment and society.

Educational Signage and Interpretive Materials:

To educate the campus community and visitors about the advantages and features of green roofs, place interpretive signage and educational materials close to them. Explain the benefits of green roofs for the environment, society, and economy using infographics, diagrams, and descriptive panels. Describe the kind of plants found in green roofs, their biodiversity, and the sustainable practises that go along with them.

Demonstration Projects and Tours:

Set up guided tours of green roofs to highlight their advantages to the public, professors, and students. Organise workshops or other activities that showcase the methods for installing and maintaining green roofs. Encourage people to participate in hands-on learning activities that let them interact with the green roofs

Collaborations and Partnerships:

To promote the advantages of green roofs, form relationships with neighbourhood businesses, organisations, and community groups. Develop cooperative initiatives, outreach programmes, or research projects to extend the use of green roofs outside the university campus. Engage with local government organisations to promote laws that encourage the installation of green roofs throughout the community.

## Building orientation effects

Building orientation is an important aspect of architectural design that can greatly influence the amount and quality of natural light in a building. The way a building is positioned in relation to the sun can determine how much sunlight enters the building and where it falls, which in turn affects the overall lighting and comfort of the space (Nicol et al., 2010).

One of the key benefits of building orientation is that it can reduce the need for artificial lighting. By orienting a building so that it maximizes the amount of natural light, designers can reduce the amount of electrical lighting required, which can lead to energy savings and a more sustainable building. For example, orienting a building so that it faces south can ensure that it receives the most sunlight throughout the day. By positioning windows on the south-facing side of the building, the maximum amount of natural light can be captured, reducing the need for artificial lighting (Hu et al., 2010).

Building orientation can also help to control the quality of light in a building. By positioning windows on different sides of the building, designers can ensure that the light entering the building is diffused, reducing the amount of glare and shadows. This can lead to a more comfortable and visually appealing interior environment, which can be important in residential, educational, and other similar spaces (Baer, 1996).

Another way that building orientation can influence lighting is through the use of shading devices, such as overhangs, louvers, and screens. These devices can be designed to provide shade to the building when necessary, reducing the amount of direct sunlight entering the building and improving the quality of light. This can be especially important in hot climates, where excessive heat gain can cause discomfort and increase cooling costs (Baer, 1996).

Building orientation can also play a role in the design of passive solar heating systems. By orienting a building in a way that maximizes the amount of sunlight entering the building, designers can take advantage of the sun's energy to heat the building. This can lead to energy savings and a more sustainable building, as well as improving the overall comfort of the space (Hu et al., 2010).

Building orientation is an important aspect of architectural design that can greatly influence the amount and quality of natural light in a building. By orienting a building in a way that maximizes the amount of natural light, designers can reduce the need for artificial lighting, control the quality of light, and improve the overall comfort and sustainability of the space (Nicol et al., 2010). It can also have a great affection on the air flow and air quality inside a building.

## Air quality

Adequate air flow is essential for maintaining indoor air quality and thermal comfort in buildings. Poor air flow can lead to indoor air pollution, high levels of indoor carbon dioxide, and discomfort due to hot or stuffy air. In order to ensure proper air flow in buildings, there are several strategies that can be employed, including the use of natural ventilation, mechanical ventilation, and the design of the building envelope (Nicol et al., 2010).

One of the most effective ways to improve air flow in buildings is through the use of natural ventilation. This can be achieved through the building orientation, design of windows, doors, and other openings that allow air to enter and circulate freely within the building. For example, positioning windows and doors on opposite sides of the building can create a cross-ventilation system, where air flows through the building, helping to remove stale and contaminated air (Baer, 1996).

Another way to improve air flow in buildings is through the use of mechanical ventilation systems, such as air handling units, fans, and ductwork. These systems can be designed to bring fresh air into the building and remove contaminated air, providing a constant source of fresh air.

Mechanical ventilation systems can be especially important in buildings with high levels of indoor air pollution, such as those with heavy use of chemicals or indoor pollution sources, as well as in buildings with high occupancy levels, such as schools and office buildings (Nicol et al., 2010).

The design of the building envelope can also play a role in improving air flow. For example, the placement of vents and grilles in the envelope can help to direct air flow and control the amount of air entering the building. Additionally, the use of perforated materials, such as louvers or grilles, can help to improve air flow by providing pathways for air to enter and circulate within the building (Hu et al., 2010).

Another important consideration for air flow in buildings is the location and orientation of the building. For example, buildings located in windy areas or near large bodies of water can benefit from the natural movement of air, helping to improve air flow and reduce the need for mechanical ventilation. Additionally, buildings located on hillsides or elevated areas can benefit from natural air flow due to differences in air pressure (Baer, 1996). Proper building maintenance is also important for ensuring adequate air flow. This includes regularly cleaning air filters and ductwork, checking for air leaks, and ensuring that mechanical ventilation systems are functioning properly. Regular maintenance can help to prevent indoor air pollution and ensure that the building is providing a healthy and comfortable indoor environment (Nicol et al., 2010).

There are several strategies that can be employed to help improve air flow in buildings. These include the use of natural ventilation, mechanical ventilation, and the design of the building envelope, as well as the location and orientation of the building and proper building maintenance (Baer, 1996).

## Effect of the building design and orientation on UiS buildings

As previously discussed, the architecture of the building can have an impact on the interior lighting and air quality. Therefore, it can be a fantastic spot to apply nature-based solutions. A good example of employing a plant's form as a building shell is the design of the Flectofin building. The UiS buildings also has the ability to feature this style.

*Figure 6: design idea of Flectofin style on educational building*

## Conclusion

Nature-based solutions (NBS) refer to tactics that make use of and integrate natural resources to address a variety of environmental issues while benefiting communities in a variety of ways. A number of benefits can result from the implementation of NBS on the UiS campus, including improvements to sustainability and biodiversity, wellness promotion, and the creation of novel educational possibilities.

The promotion of environmental sustainability on a university campus is one of the main advantages of NBS. Campuses can lessen the heat island effect and enhance air quality by implementing green infrastructure components like green roofs and living walls. These actions support a healthier ecology and aid in the fight against climate change. The judicious positioning of trees for shade and natural ventilation can also help NBS increase energy efficiency by lowering the need for artificial cooling and heating systems.

Many universities have large grounds that can be important habitats for a variety of plant and animal species. The campus environment can be improved to assist local biodiversity by applying NBS. The preservation of regional flora and fauna is aided by the use of native plants, the creation of habitats that are conducive to animals, and the preservation of natural areas like wetlands and woodlands. These programs give students the chance to witness and study biodiversity up close, deepening their awareness and enjoyment of the natural world.

NBS-integrated campuses provide a real-world setting for research, instruction, and experiential learning. Students can work on projects that focus on sustainability, ecology, gardening, urban planning, and other topics. NBS projects offer practical learning opportunities that promote interdisciplinary cooperation, critical thinking, and problem-solving. Additionally, incorporating nature into the curriculum enables students to develop creative solutions and acquire a comprehensive awareness of environmental problems.

In the communities they are located in, universities are extremely important. NBS can promote social cohesion and community participation on the UiS campus. By establishing easily accessible green spaces, UiS encourages locals to engage with nature, fostering leisure, relaxation, and social relationships. A shared sense of environmental stewardship and sustainable living can be fostered by community gardens, nature walks, and educational initiatives that create relationships between the university and its neighbours.

The UiS campus could experience long-term financial savings by using NBS. Permeable pavements and other green infrastructure techniques like rainwater harvesting systems cut down on water use and the requirement for expensive storm water management equipment. NBS may reduce the need for air conditioning by offering natural cooling and shading, which further contributes to energy savings. Incorporating sustainable practices can also improve an institution's reputation and draw in environmentally conscious faculty and students, which will have a beneficial effect on enrolment and funding.

When used on a university campus, nature-based solutions have several benefits. They encourage environmental sustainability, preserve biodiversity, improve health and wellbeing, generate financial savings, inspire community engagement, and offer novel learning and research opportunities.

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