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The communication of sustainable qualities of the building

Understanding how communication contributes to the sustainability of the built environment, using different assessment tools

Master's thesis of M.Sc Sustainable Architecture

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Abstract

With growing concerns over climate change and finite resources, the construction industry has adapted to the concept of sustainability. Given the significance of green buildings on society and the environment, there rises a need to disseminate awareness and knowledge about the sector in a transparent and concise manner.

The thesis addresses the need for communication in sustainable building, and how it fosters sustainable performance and stakeholder engagement. Specifically, it investigates how some of the existing sustainable assessment methods assist this communication by comparing them with each other.

This is done by applying two sustainable assessment tools to a case study and evaluating the results based on literature and an experimental survey. To ensure that the assessment tools were analysed in-depth, the scope was restrained to certain parameters that suited the Norwegian context.

It is observed that the sustainability assessment methods do improve the overall sustainable performance of the building. Although the degree of this influence could not be deduced from the study, the results provided enough data to understand their impact on the decision-making process. While the Environmental Cost Indicator gauged the monetary value of the Global Warming Potential, BREEAM-NOR (BRE Global's environmental assessment method, adapted to the Norwegian context) presented a score, in percentage, to understand the potential reduction of GWP. Thus, it is hard to pick one particular assessment tool as a better method, since they communicate differently to stakeholders based on their interests and responsibilities.

Keywords : Sustainability, Communication, Stakeholders, Environmental Assessment tools, BREEAM-NOR, LCA, ECI, Monetary Valuation, Carbon Pricing, GHG emissions, GWP

Sammendrag

Med økende bekymring for klimaendringer og begrensede ressurser, har byggebransjen tilpasset seg konseptet bærekraft. Gitt grønne byggs betydning for samfunn og miljø, øker det et behov for å spre bevissthet og kunnskap om sektoren på en transparent og kortfattet måte.

Oppgaven tar for seg behovet for kommunikasjon i bærekraftig bygg, og hvordan det fremmer bærekraftig ytelse og interessentengasjement. Konkret undersøker den hvordan noen av de eksisterende bærekraftige vurderingsmetodene hjelper denne kommunikasjonen ved å sammenligne dem med hverandre.

Dette gjøres ved å bruke to bærekraftige vurderingsverktøy på en casestudie og evaluere resultatene basert på litteratur og en eksperimentell undersøkelse. For å sikre at vurderingsverktøyene ble analysert i dybden, ble omfanget begrenset til enkelte parametere som passet til norsk kontekst.

Det er observert at bærekraftsvurderingsmetodene forbedrer den generelle bærekraftige ytelsen til bygningen. Selv om graden av denne påvirkningen ikke kunne utledes fra studien, ga resultatene nok data til å forstå deres innvirkning på beslutningsprosessen. Mens Environmental Cost Indicator målte den økonomiske verdien av Global Warming Potential, presenterte BREEAM-NOR (BRE Globals miljøvurderingsmetode, tilpasset norsk kontekst) en poengsum, i prosent, for å forstå potensiell reduksjon av GWP. Det er derfor vanskelig å velge ett bestemt vurderingsverktøy som en bedre metode, siden de kommuniserer annerledes til interessenter basert på deres interesser og ansvar.

Acknowledgement

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Last but not least, I would like to extend a big thanks to my parents, friends and peers for their encouragement and motivation throughout my thesis.

Preface

It was first in 2016, on a construction site in Bangalore, India, that I first noticed the effects of a building on the neighbourhood and its microclimate. Since then, I have been to multiple sites, some under construction, some constructed. With every visit, my curiosity about the sustainability claims of the projects and their communication continued to increase. This interest intensified immensely during the course of my Master’s, where I came upon different environmental assessment methods.

How efficiently can we communicate sustainability to different contributors? Do we portray sustainability to the best of our current abilities? How much do these assessments drive the market? Can assessments help improve the performance, and thus the benchmark of green buildings? I was plagued by many such questions.

Because of the subjective and qualitative nature of sustainability, ‘awareness’ becomes necessary to avoid potential greenwashing and scepticism. This thesis is an attempt to understand, and in the process, find some solutions to some of these questions.

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Glossary of Terms

The following table describes the various abbreviations and acronyms in alphabetical order used recurringly throughout the thesis.

Abbreviation (Or Symbols)	**Meaning**
BREEAM-NOR	Building Research Establishment Environmental Assessment Method-Norway
CO_2	Carbon dioxide
CO_2.eq	Carbon dioxide.equivalent
EC	External Costs
ECI	Environmental Cost Indicator
EPD Norge	Environmental Product Declarations - Norge
GHG	Greenhouse Gasses
GWP	Global Warming Potential
LCA	Life Cycle Assessment
LCIA	Life Cycle Impact Assessment
NOK	Norwegian Kroner
PBD	Performance-Based Design
VGS	Videregående Skole
ZEB	Zero Emission Building
ZEB-O	Zero Emission Building-Operation
ZEB-M	Zero Emission Building-Material

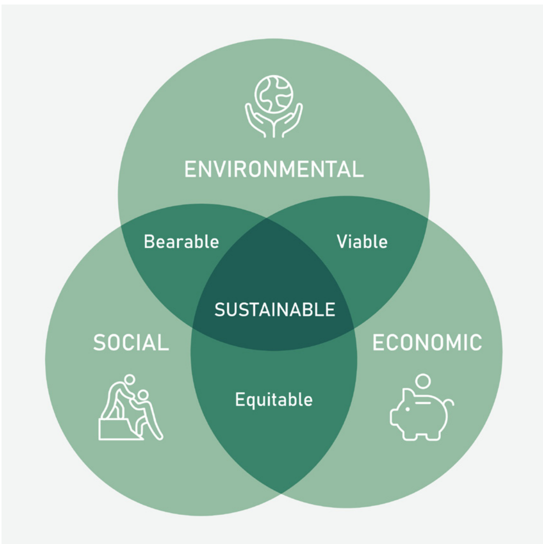
1. Introduction

The concept of sustainability, though a relatively new addition to public discussions and politics, has had its root much earlier in the human culture (ALEXIS J. BAÑON GOMIS, 2011). It measured the stability, durability, and continuity of communities. Over the years, the focus shifted from coexisting with the environment to prioritizing our needs over the environment. Progress and technology took over, and while the resulting change was beneficial, costs often accompanied it. Costs to nature, communities, and the future (GIBSON, HASSAN AND TANSEY, 2013). These costs generated a need to re-establish sustainability and ensure healthier growth, which was later termed "sustainable development". Thus, in 1987, the UN Brundtland Commission defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs (NATIONS, NO DATE). The three pillars that support sustainability are environmental, economic, and social. These pillars are interdependent and interrelated (PURVIS, MAO AND ROBINSON, 2019). This was the start of a sustainability discussion on a global scale.

Since then, multiple actions were taken to ensure that sustainability is practised. Many policies were created, organizations formed, and assemblies met to find the right solutions. The United Nations came up with a set of Sustainable development goals (SDG) as a "standard list" for countries to abide by[1] . One of the most famous examples is the 2015 Paris Agreement, which adopted the goal of limiting the rise in global mean temperature to 1.5–2 °C above pre-industrial levels to prevent severe damage from climate change and global warming (THE PARIS AGREEMENT | UNFCCC, NO DATE).

Figure 1: SDG (United Nations)

Figure 2: 3 Pillars (SNC- Lavalin)



1 (Sustainable Development Goals: 17 Goals to Transform our World | United Nations, no date)

Unfortunately, the interpretation of the word "sustainability" is very open-ended. The reaction to it differs across the spectrum. The ubiquitous nature of the word has given rise to several criticisms. Some call it 'ill-defined' and speculate high chances of greenwashing (Ross, 2009). It is evident that the topic of definitions of sustainability is one that is recurring and contested, especially, in its meaning, and the perception as to how it should be defined. Much of the debates focus on the imprecision, multitude or lack of meaning, and interchangeability of the different terms associated with sustainability (Dernbach and Cheever, 2015). The context plays a huge role in how one would describe or relate to sustainability. This often leads to the notion of doubts and vagueness associated with this noble and necessary cause. This stretches even to the realm of the construction industry, where most things are associated with measured quantities and can be correlated to physicality. Due to their huge capital investments and environmental factors coupled with societal adaptability, buildings have a big impact on sustainability (Global Construction Market Report, 2022). Figure 3 and 4 illustrate this impact clearly. This makes it imperative for there to be some common grounds in understanding the concept.

As the industry catches on to the market potential of sustainability, it becomes a catch-all term used to resolve current issues. To avoid greenwashing of the industry, communication starts playing a greater role (He et al., 2020). It generates an opportunity for dialogue and understanding between the built environment and all stakeholders. Logically, the next step would be to wonder about the clarity and transparency of this communication, about its nature and inclusivity.

The following sections will dive deeper into finding whether the communication helps improve the performance of the building and generate social engagements/ participation and understanding the part communication plays in building a strong foundation for sustainability. It also looks at the building sustainable assessment methods and reports as a tool to achieve this communication.

Figure 3: CO2 emissions by Construction Sector (The new net zero)

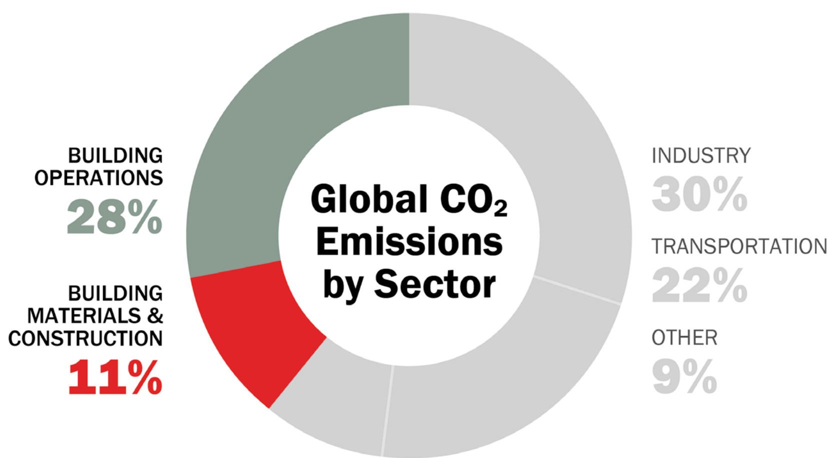
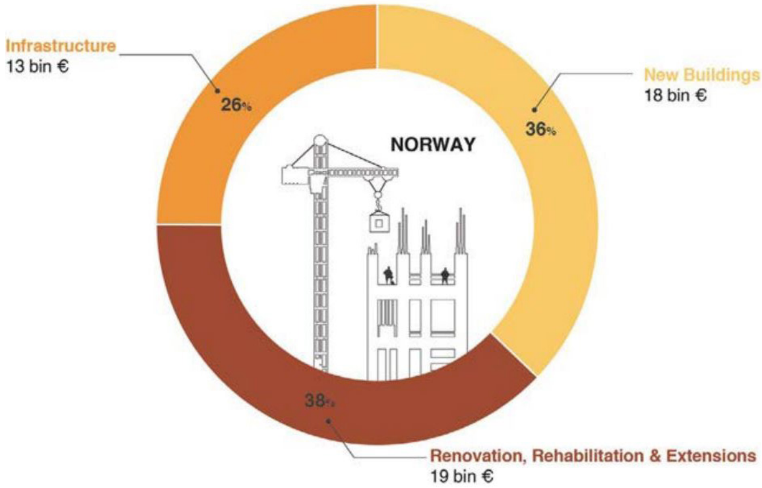


Figure 4: Investments in Norwegian construction sector, 2019 (Market Study: sustainable buildings in Norway)



1.1. Sustainability of the built environment

Shelter, along with food, water, and air has been a necessity for survival for humans since the beginning of time. What started as a roof on the head provided by nature has long since evolved into many different forms. Since early civilization, shelters have played a key role in shaping society. Subsequently, they had an impact on the economy and the environment, as can also be observed today (Global Forum on Environment and Economic Growth - OECD, no date). Soon, shelter seemed too simple a word to describe the role of these structures and was replaced by the term building. It was during the industrial revolution, with rapid construction, that the negative impact of buildings on the world was noticeable. But it was not until the 1970s that active measures were taken to mitigate the problem[2] . Newer concepts like "green buildings", "sustainable architecture", and "ecological design" emerged. Sustainable Architecture seeks to minimize the negative environmental impact of buildings through efficiency and judicious use of materials, energy, and the ecosystem, at large (Røstvik, 2021). The need for sustainability in the industry has only grown since then. To put in perspective the impact of the industry, in Norway, one of the most sustainable countries in the world[3] , the construction industry is responsible for 15% of the GHG emissions, where the total investments in the sector were about 50 Billion € ('Better growth, lower emissions – the Norwegian Government's strategy for green competitiveness', no date). It is easy to infer the impact of the industry on the economic, social and environmental pillars, and also the interdependency of the three pillars. Although not all effects had negative impacts on the modern world. The building sector also provided a sense of safety, community engagement and job opportunities. Many other outcomes benefited the people.

2 ('historystoneingreenbuilding.pdf', no date) (Heitz, 2021)

3 (Environmental Performance Index, no date)

The problem that currently persists is the lack of awareness about the consequences of the construction industry, especially those directly related to emissions, pollution, or wellbeing (Kongela, 2021). While there is no doubt that this is changing, and environmental sustainability is becoming more widespread, there are many who still do not have access to this knowledge. The socioeconomic context also plays a huge role in this perception (Mukherjee and Chakraborty, 2013). Although it would be an ideal scenario to reassess these subjective interpretations to precise analytical results, the right balance is hard to find, making decision-making hard. Clarity and transparency in conveying sustainability are of paramount importance (Klotz et al., 2009). It needs to be expressed in a manner that is relatable and understandable to all stakeholders involved, making communication an indispensable tool.

1.2. Communication in sustainbility

In the Oxford English Dictionary, communication is described as "The transmission or exchange of information, knowledge, or ideas, by means of speech, writing, mechanical or electronic media". It helps with knowledge distribution; relationship building and provides opportunities for interaction. It also provides humans with the ability to exercise influence over one another. Open, participatory information and communication processes contribute to inclusivity and to fairer sustainable growth. Effective communication is about dialogue. Therefore, communication in the context of sustainable development involves promoting dialogue and engagement amongst stakeholders. (At the Heart of Change: The Role of Communication in Sustainable Development, 2007)

This plays an essential role in bringing sustainability-related issues onto society's agenda. As a complex system, there are a lot of different measures taken to achieve sustainability in the built environment. The necessity to express this sustainability is already acknowledged. The logical question that comes to mind is how sustainability is then translated into a language well understood by humans? Sustainable communication is an approach to presenting various sustainability commitments of a product, in this case, a building, and engaging the stakeholders involved, while having a positive influence over them (The importance of communication in sustainability & sustainable strategies, 2020).

There is a clear boost in interest and awareness of climate change over the year, and with the construction industry playing a major role in the emissions of GHG gases, it becomes imperative to communicate both the sustainable targets and the achievements. Communication helps provide transparency and accountability and understanding trends and scope of improvement. It also potentially increases active and passive participation through social and economic aspects. (Tregidga, Milne and Lehman, 2012) (González-Díaz, García-Fernández and López-Díaz, 2013)

Any action plan should define the role of communication in sustainable development.

As previously mentioned, sustainable achievements are becoming drivers in construction projects, and as a complex concept, require diverse stakeholders. As powerful contributors to the decision-making processes, their absence or lack of participation may fail to address sustainability issues. Therefore, clear and concise communication with stakeholders is necessary to engender sustainability (Stocker et al., 2020).

1.2.1. Stakeholder engagement

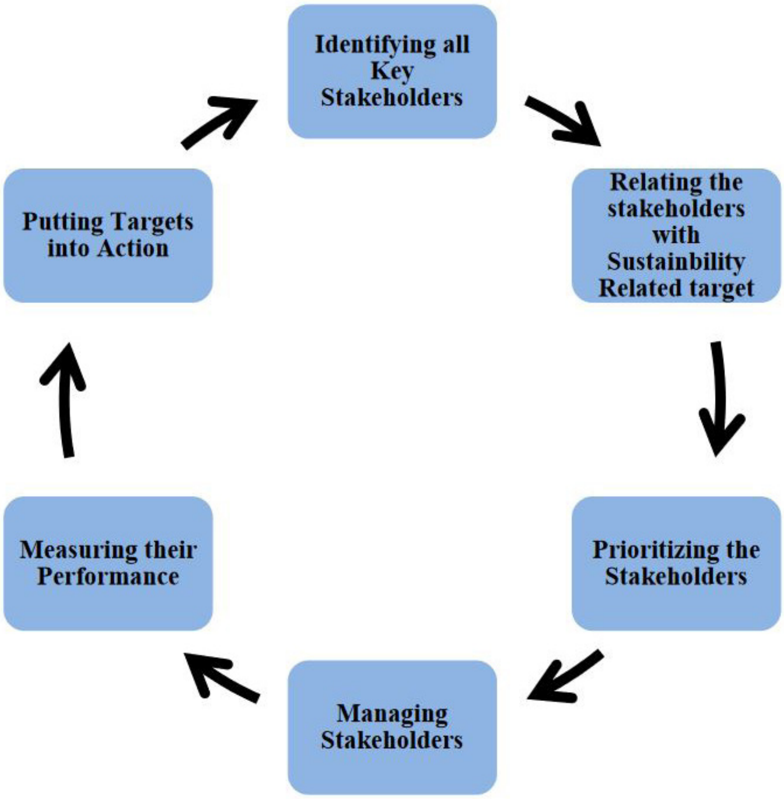
Involving and engaging stakeholders in communication will help reduce risks for the project. It builds trust and improves the dynamics of a team. In sustainability, where ambiguity is high, and the possibility of 'greenwashing' the industry a threat, trust becomes paramount. Stakeholders need to be active participants in the decision-making process to bring about a significant and positive impact. To do so, the sustainability targets of projects need to be communicated lucidly. It is also important to map the stakeholders early into the project, as their responsibility and influence over the project deviate appreciably (Horner et al., 2000).

Stakeholders involved in the sustainable building have a hierarchical structure. But the boundaries for these structures are superfluous and many of the stakeholders lie on multiple levels. The hierarchy also shifts depending on the sustainable targets to be achieved. While the client and the main contractor are generally recognised as the chief stakeholders, others like consultants, governing bodies and the consumers are often left out of the list as they often do not have direct control over project briefs, decision-making and the building process (Bal et al., 2013). It is obvious that where sustainability is concerned, a larger group of people get affected. Therefore, the stages at which these stakeholders should be informed and engaged vary. Those directly involved with the construction industry account for all the design and execution decisions and thus have direct impacts on the sustainability of the built environment. But to monitor and regulate these impacts, policies and laws are required, and these are assessed by the governing bodies (Marichova, 2020). Lastly, there needs to be awareness and demand for sustainability. This can only be assessed through current trends. These trends influence the processes and are set by the end-users/consumers. The end-users become a requisite in the process of communicating the sustainability of the industry, to bring about valuable improvements. The roles, thus demand effective communication that aligns with the interests and objectives of the stakeholders for active participation.

According to a study (BAL ET AL., 2013), six steps were suggested for a stakeholder engagement process:

1. Identification
2. Relating stakeholders to different sustainability-related targets
3. Prioritization
4. Managing
5. Measuring performance
6. Putting targets into action

Figure 5: Project stakeholder engagement process for sustainability (Bal et al., 2013)



3 out of the 6 steps require some form of communication to engage and improve stakeholder performance. While it is simple to put into words the idea of sustainability, how does one convey its importance in an analytical manner that accounts for both the quantitative and qualitative sides of the concept? This is where the multiple environmental assessment methodologies come into play.

1.2.2. Building sustainability assessment methods

Sustainability assessments can be defined as processes that "direct the planning and decision-making process toward achieving sustainable development" (Sustainability Assessment - an overview | ScienceDirect Topics, no date). They cover natural and societal sciences and work on a local and global scale. Multiple tools are used for these assessments to ensure easier communication of the results. Often, it is necessary to simplify them for a smoother transition of knowledge. Their main purpose is to elaborate on the sustainable performance of the building and highlight the scope of improvement in a comprehensive manner (Bragança, Mateus and Koukkari, 2010). It essentially simplifies the sustainability results to a language that can be understood easily. How these tools represent the targets makes a difference.

In the field of construction, where many different systems come to form a complex ecosystem, the assessment tools are necessary to measure sustainability and decrease ambiguity in the process. Additionally, the information helps improve the performance of the building. While social, economic, and cultural indicators are substantial contributors to the sustainability of a building, it is the environmental aspect that takes precedence in measuring the performance of the building (St Flour and Bokhoree, 2021). Thus, most assessment methodologies develop their tools in a direction that measures the environmental consequences, which can be precise and subjective (Berawi et al., 2019).

Thus, the assessment processes take both qualitative and quantitative approaches to a building. Due to intricacies, sustainable assessment tools are hard to follow, despite the facilitation. The message can often be missed or overlooked by the stakeholders. In some scenarios, a lack of complete clarity of information may lead to assumptions by stakeholders. Consequently, R&D and standardization are concentrated on the utilisation and transparency of these assessment tools for better communication. There is an effort to reduce the emphasis on subjective outlooks of the assessment (Bragança, Mateus and Koukkari, 2010). The following subsection explores the different types of methodologies of environmental assessments and their inclusion or dependency on the other 2 pillars of sustainability.

Types of building sustainability assessments

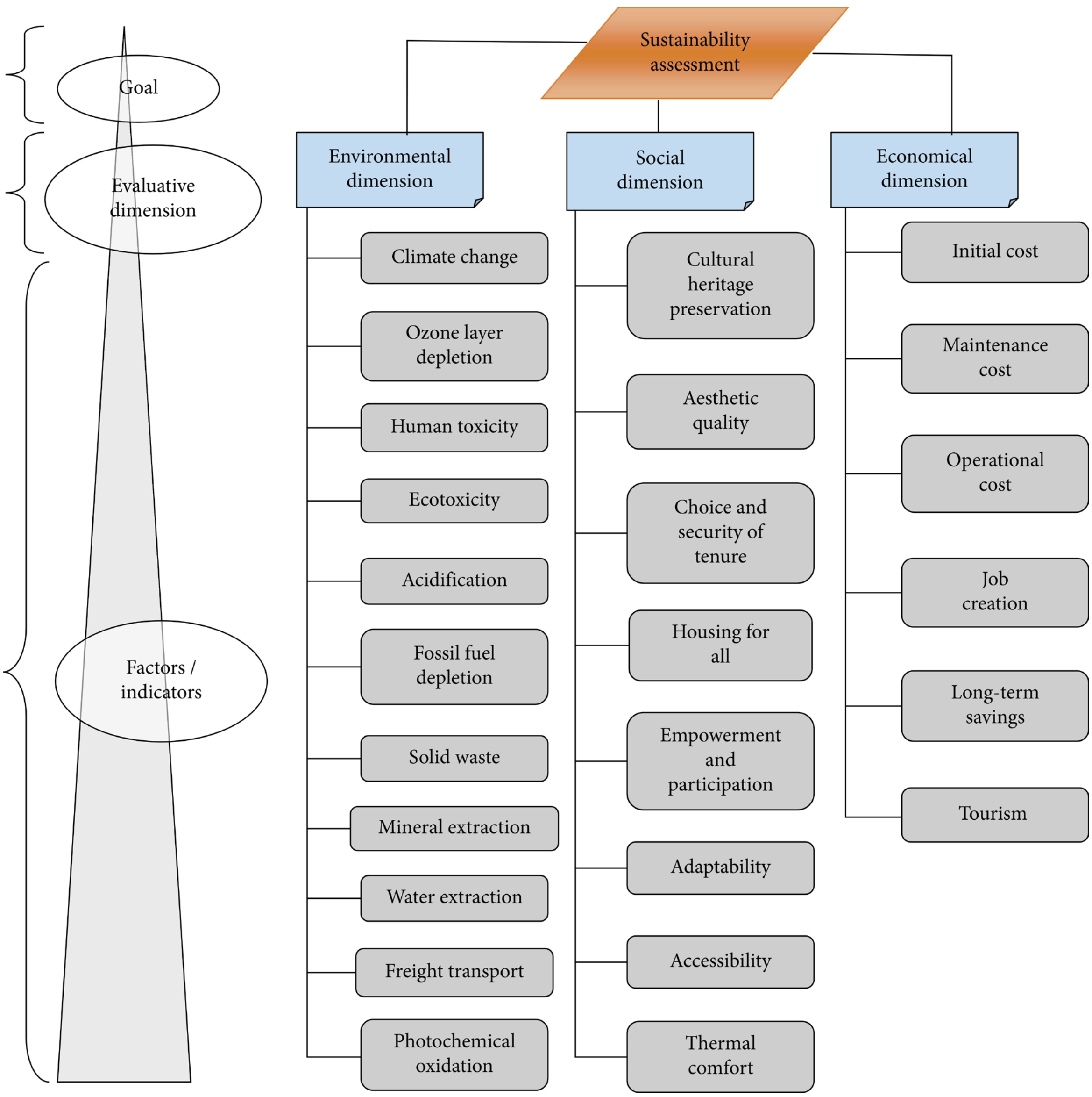
Several goals can be observed in most sustainability assessment methodologies (Bragança, Mateus and Koukkari, 2010). They are as follows:

1. Site optimization
2. Preservation of culture and regional identity
3. Minimization of energy consumption

4. Use of eco-friendly materials
5. Judicious water consumption
6. Health
7. Maintenance

The tools usually assess a building on these criteria and accordingly indicate the performance. It is also interesting to observe the human-centric approach to these assessments. While the intention is to give preference to 'greener' choices that are equally beneficial to the world, human needs usually take over. Based on a survey (Identification of Key Indicators for Sustainable Construction Materials, no date), it can be seen that in all three dimensions, categories directly affecting humans take priority. The trend might be noticeable in the different types of environmental assessment methods. Economic and social costs, therefore, must be considered in environmental assessments for a more comprehensive result.

Table 1: Survey (Identification of Key Indicators for Sustainable Construction Materials)



The main intention of the tool is to find the right balance between sustainability dimensions and practicality while being transparent and flexible. It is also important that these tools continue to adapt to building typologies and technologies. Their development is still a challenge in both academia and practice. For any assessment methodology, sustainable indicators are the information sources about the influences of construction, operation, and other built assets. Due to variations in a context like societies, geography and even industrial traditions, the approach for indicators and assessments differs. It is observed that the selection of a particular methodology or assessment tool relies on the stakeholders involved (Wen and Qiang, 2022).
By assessing the many different tools used in the market, Building Sustainable assessment methodologies can be categorised into three main types:

1.2.2.1. Performance-based design

Perform based design focuses on the required outcomes of the processes, and addresses criteria that are performance-related such as energy use, daylighting, HVAC etc. (CE Center - The Benefits of a Performance-Based Design Process, no date). The approach uses iterative analysis for decision making and depends on three key areas:

1. Describing the appropriate building performance requisites early in the process.
2. The methods and process of how these requirements will be delivered.
3. The methods with which these requirements will be assessed.

Performance-based designs, as an evaluation methodology attempts to create inclusive and collaborative building processes for stakeholders from the start of a project. They allow for all design solutions that fulfil the design objectives, while also delivering the required performances. As the name suggests, this methodology is specific to design and performance. This kind of method is beneficial to end-users and other participants involved in the construction process, as it promotes the betterment of the overall performance of the building and encourages the use of more sustainable solutions adapted to the use of the building. It also generates a ground for a better understanding and communication of client and user requirements. But more than a tool for communication PBD represents a design process that can potentially help architects, clients and firms meet the stringent sustainable standards that are increasingly becoming the norm.

1.2.2.2. Life cycle assessment (LCA) system

The process of constructing a building comprises many stages like procurement and construction, operations, and maintenance, and finally dismantling or demolition. At times there is also another step, which is reuse/recycling. In the integrated LCA methodology, the impacts of these different life cycle phases/ stages are calculated. To quote directly "LCA is a systematic analysis of environmental impact throughout the entire life cycle of a product, material, process, or other measurable activity" (What is life cycle assessment (LCA)? | Golisano Institute for Sustainability | RIT, no date). The whole process is divided into categories and their impacts are measured in detail. When accurately calculated, the results become valuable in providing data that supports and communicates sustainable initiatives.

The LCA methodology was originally applied to products. But soon, this was adapted to building processes too. The scale of these methodologies has a vast range. It can be applied even to the neighbourhood, but the system just gets more complex as the elements increase (Schlanbusch et al., 2016). There are now methods that integrate costs and social impacts into these assessment processes, making them more inclusive. But the methodology, due to its detailed nature, can be very tedious and complex. It often begins at the ideation stage before the construction commences. Through multiple changes, as the assessment evolves, the results are calculated well after the completion of the projects.

With a rise in environmental awareness, society has been finding ways to compensate for the damage. Monetary valuation of LCA results is one such method that converts environmental, economic, and social impacts to a single monetary score called the ecological cost (Schneider-Marin and Lang, 2020). These costs are more comprehensible. As an assessment tool, monetary valuation enables comparison and trade-offs between environmental issues ('ISO 14008 2019-03 Monetary valuation. pdf', no date).

At present, LCA can become exorbitant because of the data collection and time required for its calculation. In addition to the expense, the databases are often inconsistent and do not have information on all the stages, adding to the confusion (Bragança, Mateus and Koukkari, 2010). However, the method is used in many assessment tools and is continually being simplified. There are many user-friendly tools available in the market for the calculation of LCA and its variants like One-Click LCA, Tally etc.

1.2.2.3. Sustainable building and rating certification systems

The rating and certification system bolsters sustainability in construction and its various stages. Its primary focus is the integration of functional and cost-efficient criteria with environmental and societal concerns. Owing to its evaluation methodology, the rating and certification system enhances the sustainable design of the building. While the basics of the approach for this method are the same, the perspective of the different Sustainable building rating and certification tools may vary contextually. The main categories that the system focuses on are Site, water, energy, materials, and indoor environment (Bragança, Mateus and Koukkari, 2010). But the methods are based on local regulations, standards, and conventional building solutions. Socio-cultural preferences, economic standards and environmental conditions play a major role in the measurement of overall performance and weightage of indicators. There is now a proliferation of building rating and certification tools, mainly due to their local and regional scales.

There are also some examples of the methods used on a global scale, such as the Building Research Establishment Environmental Assessment Method (BREEAM), the Leadership in Energy and Environmental Design (LEED), and the Living Building Challenge which was developed in the U.S.A (Kudryashova, Genkov and Mo, no date). The certification method evaluates buildings based on their performance in different categories that match the sustainable goals and objectives. It is based on four major components which are (Mohamed, 2019):

1. Categories: These form a specific set of items relating to the environmental performance considered during the assessment.
2. Scoring system: This is a performance measurement system that cumulates the number of possible points or credits that can be earned by achieving a given level of performance in several analysed aspects.
3. Weighting system: This represents the relevance assigned to each specific category within the overall scoring system.
4. Output: This aims at showing, in a direct and comprehensive manner, the results of the environmental performance obtained during the scoring phase.

The rating and certification system is becoming increasingly common as an assessment methodology in the construction industry. It especially proves useful to stakeholders within the industry like the clients and contractors (Mohamed, 2019). The buildings, once completed, also act as reference studies, and help in the improvement of the methodology. However, like any other method, there are certain disadvantages to this system. It is a time and cost consuming process and gives weightage to certain subjective criteria. It has a dependency on external factors such as LCA, auditors etc ('Stakeholder-engagement-and-analysis-BREEAM-NOR-2021-report.pdf', no date). At times, the certification leads to the overshadowing of vernacular buildings that lack the 'credibility' (Heide, 2011).

The following figures illustrate the different types of assessments explained above.

Figure 6: Example of a PBD model (Bragança, Mateus and Koukkari, 2010)

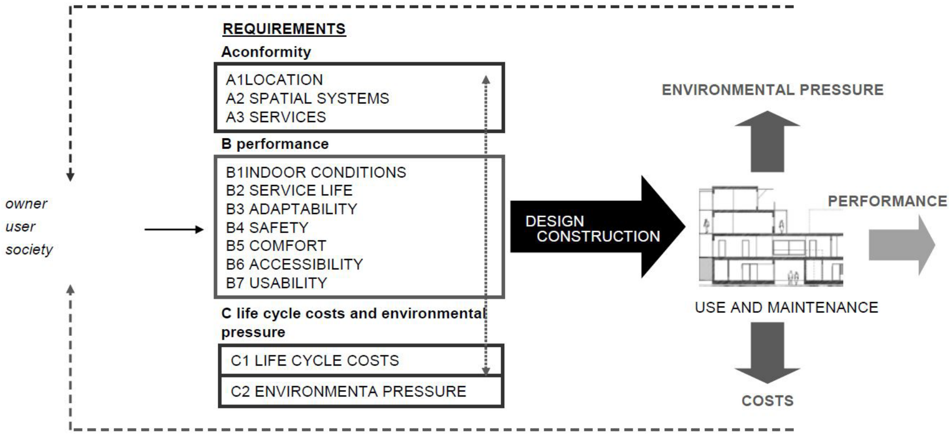


Figure 7: Phases of LCA (International Organisation for standardisation, 2006)

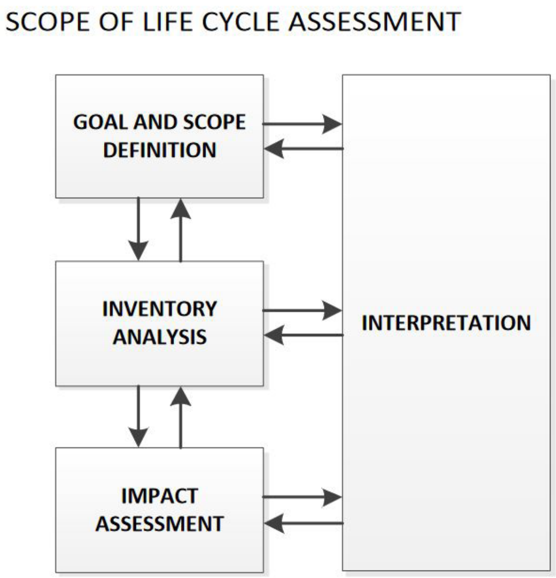


Figure 8: Classification of the Living Building Challenge 4.0 (ILFI org)

2. Statement of research questions and scope

2.1. Research questions

How can communication, as a tool, be utilised to ensure appreciation of sustainability in the built environment? How do the sustainable assessment tools that aid communication impact design decisions and therefore the overall performance and contribute to a better stakeholder engagement?

2.2. Scope

To observe and understand the significance of communication in sustainability assessment of the built environment by comparing different assessment methods, specifically certification systems (BREEAM-NOR) against the monetary valuation of the environmental impact (Environmental Cost Indicator). These tools are applied to a school in Trondheim, Norway. Both tools have certain overlaps and differences. Therefore, Global Warming Potential, due to its well-researched position, was taken as a common parameter to be measured to equal the ground of comparison.

3. Research background

The thesis was completed over a duration of 5 months. The first three months were allotted to research, data acquisition and literature review to understand the context of communication, its existence and importance in the built environment, and the tools used to assess and convey sustainability to stakeholders involved. Along with the general study, the focus was on finding a case study with sufficient data, on which an analysis of different assessment tools could be performed.

Many of the initial thought processes were reframed or changed during the process. The new relationships after the study helped reassess the direction of the study. For example, it originally focused on certain assessment methods, but a stakeholder mapping process helped understand that this may not be the correct path. The general approach throughout the thesis was focusing in and out, to answer the right questions. This background lays the ground for many of the decisions taken in the following sections.

4. Method and material

The research attempted to find a coherent relation between communication and its influence on the sustainable performance of a building and its stakeholders. The principles learnt in the previous section were applied in the form of two sustainability assessment tools that evaluated a case study. The results were compared against each other and were also tested on a sample of people, in the form of a non-representative survey, to understand which of the tool was more suitable.

4.1. Selection of parameters

The following section elucidates the motivation for selecting criteria that help in fathoming the role of communication. It sets the ground for the case study and the application of tools.

4.1.1. Case study

To test the significance of communication in sustainability, an attempt to study an existing building was made. The foremost parameter to select a building was the demographic context. Since the paper expands on various assessment methods in Norway, the project selected was also located in Trondheim, Norway. The building was easily accessible. Both in terms of understanding the project and its brief, and acquisition of information.

The second parameter considered was its performance. The building needed to meet market approved sustainability standards. It was also preferred that there were records to testify against this performance. To understand what must be communicated in terms of sustainable assessment, the building had to outperform a standard reference building (ZEB Report Project 34).

Another criterion was the scale. The urbanity, in this case, helped give weight to the social and economic impacts and further diversified the stakeholder profiles. Community/Neighbourhood, as an end-user, also became a key participant.

The selection of the typology was logically the next step. There were certain restrictions in selecting technical buildings like hospitals and healthcare facilities. Furthermore, it had to be an essential building with some ancillary benefits. Thus, a school seemed like the right choice for a case study.

The case study chosen was Heimdal Videregående Skole (Upper Secondary school) (Referred to as Heimdal VGS from here on)

Figure 9: Heimdal VGS Facade (Ramboll,Hundven Clements Photography)

4.1.2. Environmental parameters

With the rising awareness of climate change, GHG emissions are becoming a well-researched topic. These emissions warm the earth by trapping extra heat in the atmosphere, and when calculated over time (Usually 100 years) relative to CO2, and are called Global Warming Potentials (What are 'Global Warming Potentials' and 'CO2 equivalent emissions'?, 2012). The unit GWP is measured in is CO2.eq. It is clear from Figure 3 the building industry is a key contributor to the emission of GHG. There already exist well-established tools within these assessment methods that measure the GWP of the buildings.

Thus, to ensure a fair comparison of how the sustainable performances of buildings are expressed in these methods, the thesis limits its parameters to GHG emissions and their influences. The tools selected will only measure the weightage of GWP of the school and compare the results.

4.1.3. Sustainability assessment tools

As Performance Based Design method was focused more on the design stage of the construction process, LCA and Rating systems became the final choice of assessment methods. The tools representing the two were chosen based on regional context, availability of information and ease of application.

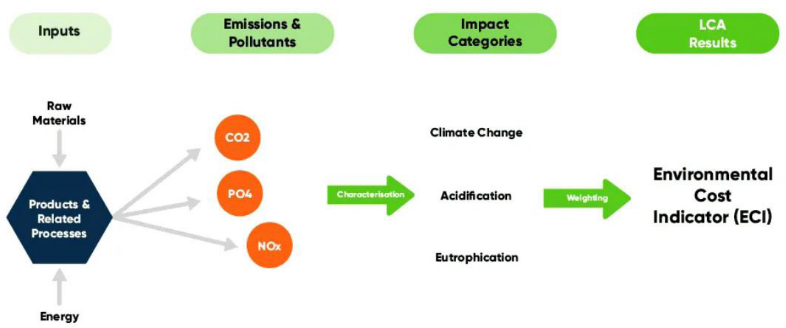
4.1.3.1. Environmental Cost Indicators

An environmental cost indicator is a tool that practices the conversion of relevant environmental impacts (LCIA results) to a single score of environmental costs ('Environmental Cost Indicator (ECI) - Overview', 2019). The calculation of ECI follows a simple procedure. It has 4 main steps involved:

1. Feed in the input data: The database from the correct sources needs to be collated and analysed. The information ideally requires all system boundaries
2. Calculation of emission: Once the information is in place, the emissions of the inputs are evaluated -for example, CO_2, PO_4^{3-}, and NO_x.
3. Characterisation of emissions: The emission data is then characterized into impact categories. Impact categories represent different environmental issues, with the same impact assigned to one unit. Eg. All atmospheric gasses related to climate change are considered into GWP (CO_2.eq).
4. The weighting of impact categories: The impact categories may be difficult to understand and need to be converted to actionable and comparable numbers like ECI. To achieve ECI the scores need to be weighted and merged.

The use of weighting/valuation methods varies in different tools, but the variations are not always related to the application; rather are dependent on traditions and policies. Monetary weights, using either endpoint or midpoint methods, are useful in all the selected tools (Schneider-Marin and Lang, 2020).

Figure 10: 4 steps of ECI (Ecochain)

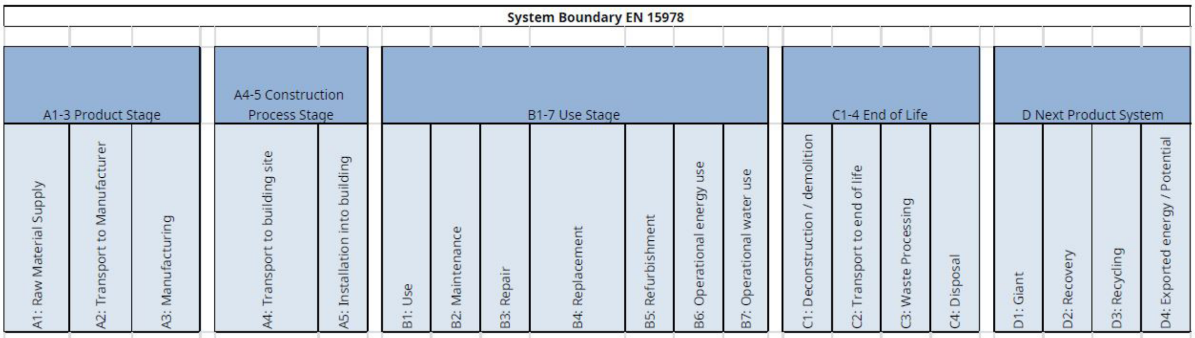


The design team had already calculated the LCA for the case study during its construction. The system boundaries considered were A1-A3, A4 and B4 (accordance with EN 15978). The tool used was ZEB Spreadsheet (named ZEB-M Tool[13]), and it considered only the GWP. The calculation methodology is according to note «0.7 ZEB M USER GUIDE 031114 »and other specifications from Sør-Trøndelag County Municipality (2014) (Heimdal VGS ZEB-M Detaljprosjekt). EPD Norge and Öekobaudat.de were used to understand the impact and relevance of the building on the other stages/

system boundaries.

For the case study, the principles of ECI applied would be adapted to the Norwegian context and therefore be measured in Norwegian Kroner (NOK), instead of Euro. Since the scope of the LCA has been fixed to measuring global warming, only the weighting score for GWP was examined. The building industry is not yet fully familiarised with the concept of monetary valuation, ergo different literature, and documents espoused carbon pricing[4] . Carbon pricing captures the external costs of GHG emissions. These costs (also known as the social cost of carbon)[5] estimate the cost of the damage that would result from emitting one ton of carbon dioxide into the atmosphere. They are currently externalities but have the potential to be included in the cost-benefit analysis. As the costs vary due to clarity, a minimum and a maximum value for the external costs were considered, as would be later explained.

Figure 11: System Boundaries / LCA Phases (ZEB-M tool [13])



4.1.3.2. BREEAM-NOR

One of the first green rating systems launched in 1990, the Building Research Establishment's Environmental Assessment Method (BREEAM) pushed the construction industry towards sustainability. It originated in the UK but is extensively used all over Europe. Norway implemented its version of BREEAM, called BREEAM-NOR. It was developed by the Norwegian Green Building Council (NGBC), operating under a license from BRE Global Ltd ('BREEAM-NOR-Engl-ver-1.1.pdf', no date). While predominantly focusing on the same issues, there are subtle changes between BREEAM and BREEAM-NOR, due to the adaptation of the Norwegian context (Christiaens, no date).

Like all certification systems, BREEAM-NOR aims to assess and alleviate the negative impacts of the construction industry. As directly taken from the BREEAM-NOR manual, the following are its aims:

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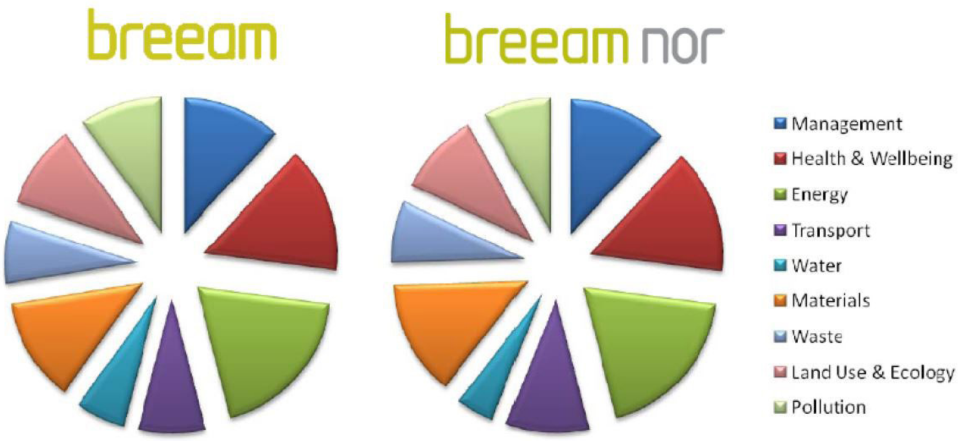
4 (Zakeri et al., 2015)

5 ('Social Cost of Carbon: What Is It, and Why Do We Need to Calculate It?', 2021)

• To mitigate the impacts of buildings on the environment
• To enable buildings to be recognised according to their environmental benefits
• To provide a credible, environmental label for buildings
• To stimulate demand for sustainable buildings

Figure 12: Differences in BREEAM and BREEAM-NOR (Christiaens, no date)



Objectives of BREEAM:
• To provide market recognition to low environmental impact buildings
• To ensure the best environmental practice is incorporated into buildings
• To set criteria and standards surpassing requisites of regulations and challenge the market to provide innovative solutions
• To raise the awareness of different stakeholders of the benefits of buildings with a reduced impact on the environment
• To allow organisations to demonstrate progress towards corporate environmental objectives

BREEAM-NOR is an assessment tool that is based on a 'credit list or point list'. It has a list of environmental weightings that are scored based on the building's performance in various sections. Table 2 explains how the scoring and the weighting of BREEAM-NOR works. Based on the credits achieved, the rating system issues certificates. The higher the score, the better the building's sustainable performance. The different classes considered are Pass, Good, Very Good, Excellent and Outstanding.

Since BREEAM-NOR assessments start usually from the design stage, it helps mitigate or reduce the GHG emissions of the buildings to be assessed. According to (Taylor, no date), BREEAM assessed educational buildings reduced around 20% CO2.eq emissions. Different building typologies are assessed through BREEAM-NOR. Since their objectives might differ, it is important to mention the typology at the commencement of the assessment process. There exist categories in BREEAM-NOR depending on the type of construction. The study is focused on 'New Construction'.

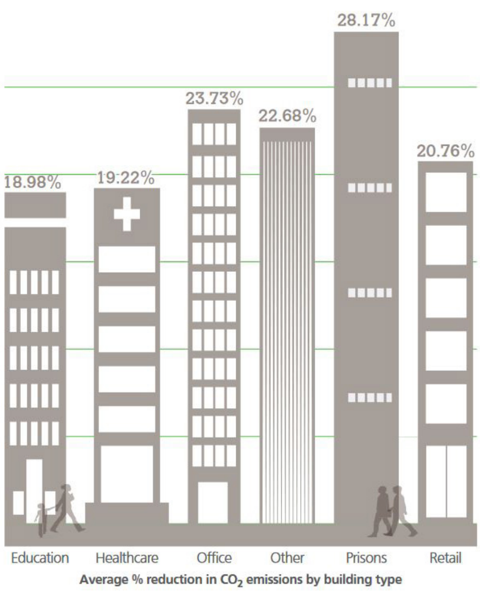
Table 2: Category weightings in BREEAM-NOR 2016 (BREEAM_NOR_NC 2016)

CATEGORY	Weighting (%)
MANAGEMENT	12
HEALTH AND WELLBEING	15
ENERGY	19
TRANSPORT	10
WATER	5
MATERIALS	13,5
WASTE	7,5
LAND USE AND ECOLOGY	10
POLLUTION	8
INNOVATION	10

Table 3: BREEAM-NOR rating benchmarks (BREEAM-NOR manual)

BREEAM Rating	% score
OUTSTANDING	≥ 85
EXCELLENT	≥ 70
VERY GOOD	≥ 55
GOOD	≥ 45
PASS	≥ 30
UNCLASSIFIED	< 30

Figure 13: Average reduction in CO2 emissions by building type (Taylor, no date)



BREEAM-NOR assessments are done at the end of the following 2 phases:
1. The design stage (DS) – assessment leading to an interim certificate
2. Post-Construction Stage (PCS) – assessment leading to a final certificate.

Both the phases require the presence of an external auditor and someone to guide them through the process. These assessments are usually one-time. For any renewal, additional costs must be paid[6] .

The ('Stakeholder-engagement-and-analysis-BREEAM-NOR-2021-report.pdf', no date) explains the advantages and disadvantages of the BREEAM-NOR application, according to the different stakeholders involved :

Some positive outcomes of BREEAM certification:
1. Good reputation for developer and project team.
2. Fewer hazardous materials in the building.
3. Better financing opportunities and increased property value.

Some challenges/problems with the current manual:
1. Higher process costs and construction costs.
2. Excessive documentation requirements.
3. Criteria are hard to understand and thus anticipate.

4.1.4. Survey

While literature and personal judgement helped compare and understand the two assessment tools, a survey was conducted to gain a larger perspective. The survey was conducted online, and feedback/interviews were conducted post results. The BREEAM-NOR and ECI results were simplified and graphically demonstrated, and questions based on the respondents' understanding of the two sustainability assessment methods and the school were asked. To ensure that the respondents understood the questionnaire as intended, feedback/interviews were also conducted. The demography was kept versatile. The age group and the professions were the two main parameters acknowledged while sending out the survey.

4.2. Stakeholder mapping

In the previous section (1.2.1), the relationship between stakeholders and sustainable communication was established. It was brought to notice that the method of communication is dependent on the interests and responsibilities of the stakeholders (Understanding stakeholders' approaches to sustainability in building projects, no date). Therefore, mapping the stakeholders is important to understand the assessment methods and tools.

6 ('FS021-Rev-23-BREEAM-In-Use-Fee-Sheet-2-1-1.pdf', no date)

The stakeholders considered here are categorised based on their field of expertise/ interest (4 Types of Stakeholders in Project Management, no date). Since the key focus is to understand how participation and communication can help make buildings more sustainable, two primary stakeholders are recognised here. The governing bodies like the municipality or other local regional bodies make policies and laws regarding construction and sustainability. In this particular context, the STFK is considered the regional body. They also are the clients of the school building, and therefore have a vested interest. The other stakeholders are the contractors/ developers, in this case, Skanska (And others). In addition, end-users are recognised as non-primary stakeholders to understand their relevance in the communication of the sustainability assessment tools. The community members would fall into this categorisation. As they are the ones that directly get impacted by the construction, their awareness of 'green building' would be an interesting dimension to dive into.

Figure 14: Stakeholder Mapping

5. Case study and application

5.1. Introduction to case study

Heimdal VGS is located in Saupstad, Trondheim, a densely populated area Southwest of the city centre. As the area grew rapidly in the 1970s, it became obvious to start an upper secondary school there. Today, Heimdal VGS is one of the largest upper secondary schools in the county of Trøndelag, Norway.

Figure 15: Heimdal VGS (ArcGIS)

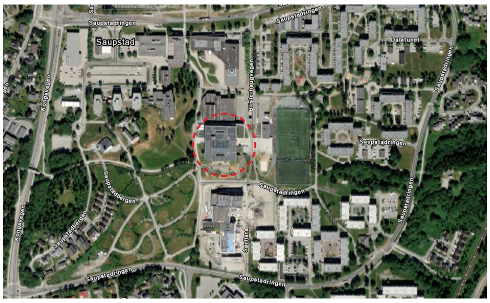


Figure 16: Cafeteria (Ramboll)

Figure 17: Audtitorium (RolvundogBrøndsted Arkitekter)

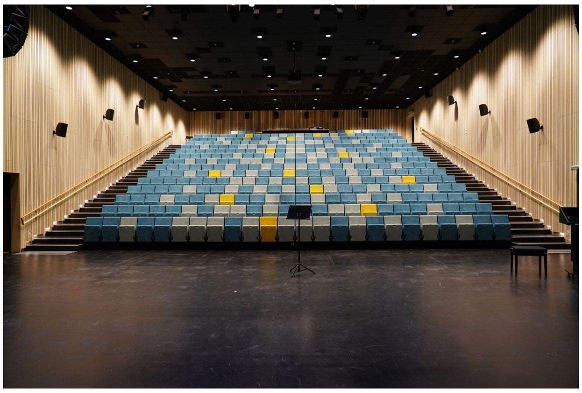
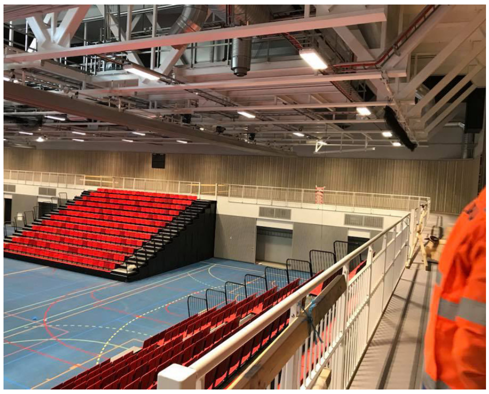


Figure 18: Sports arena (RolvundogBrøndsted Arkitekter)



The school neighbours Huseby Ungdom (Primary) School to its South and Tiller upper secondary school to its North. It also shares the perimeter with Huseby Swimming Pool. It is to be noted that the school offers 'special studies' or specializations along with the standard curriculum, and therefore attracts students throughout the city.

The purpose of these specializations is to train for a career. The courses offered are Sports, Music and Electrical, and are supported by state-of-the-art facilities provided within the campus. The facilities like 'multi-purpose hall' and auditorium are not only limited to the use of students and staff and can be utilised by the neighbouring community for different purposes like community meetings, cultural events etc. This is how the school becomes an integral part of the district program "Områdeløft Saupstad" [7], which intends to uplift the area and make the district a better place to live

7 ('https://saupstad.no/', no date)

through culture, sports, greenery, and education.

The school can accommodate more than 1000 students and faculty. Within these, usually, around 100 students are immigrants, their ages ranging from 16 years up to 22 years. The intention is to teach them the local language and aid their integration into society, both personally and professionally (ZEB Konferanse 2015-Nye Heimdal VGS). The school has two huge auditoriums that seat 350 and 90 students respectively. It is predominantly used by the music departments for concerts and practice. The school also has a huge multi-purpose hall that can handle up to 4000-5000 spectators. The hall along with the Kolstad arena is shared by the Kolstad handball team and Kolstad Football Club. This factor aided the neighbourhood reforms (Baer et al., 2020).

5.1.1. Planning

The construction of the current building was completed in 2018. The project was the first of its kind in achieving environmental emissions for a school building. It is also one of the largest Zero Emissions Buildings in Norway. The path to achieving this target was a long one, with a lot of challenges. In 2013 Sør-Trøndelag FylkesKommune (STFK), or the county of Sør-Trøndelag, invested to build new energy-efficient with good indoor environment and low GHG emissions schools in the county to develop the area. The municipality collaborated with the Norwegian Research Centre for Zero Emission Building (ZEB Centre) to achieve this aspiration (About the ZEB Centre, no date). As the name suggests, the centre aids with the construction of buildings that have no emissions during their lifespans, typically of 60 years. The idea is to produce enough renewable energy to compensate for the GHG emissions of the building. ZEB Centre classified the targets into various levels depending on the phases accounted for during the building's lifespan. Figure 20 explains the classifications.

In the case of the school, the aim was set to be ZEB-O, which translates to zero emissions for all the operational energy of the building. STFK introduced the building in the form of a competition that had multiple phases. The first phase was a competition between 8 design teams. It is to be noted that ZEB Centre provided multiple workshops and training sessions to facilitate the calculations and ensure that the design brief was met at the beginning of the competition.

Throughout the competition, the ambition levels varied. It raised from ZEB-O to ZEB-OM20%, which accounted for the additional 20% of the emissions from all the materials (excluding emissions from the transport), along with the emissions from the operational energy. The variation in targets, along with several communication challenges had to be tackled throughout the process of this collaboration (ZEB Report No.34).

Figure 19: ZEB levels (ZEB Centre)

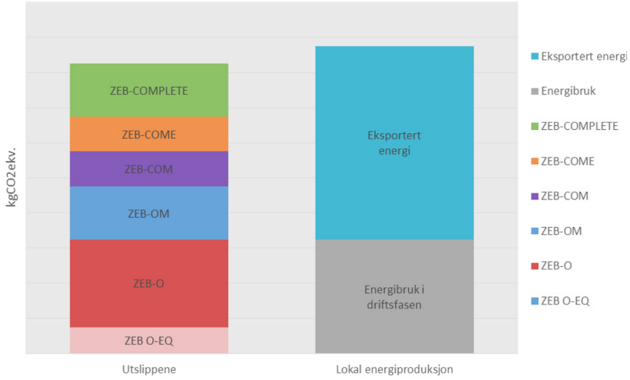


Figure 20: Results of different phases (Heimdal VGS - ZEB-M Detaljprosjekt)

Table 4: Phases and their emissions during the planning (Heimdal VGS - ZEB-M Detaljprosjekt)

Phase	Target (ZEB)	GHG emissions (Materials only)
		Kg.CO2.eq
Phase 1	ZEB-O	-
Phase 2	ZEB-O20%M	233623
Phase 4	ZEB-O and ZEB-20%M	246003
Phase 4 (2016)	ZEB-O and ZEB-20%M	256924
Reference building		284654
As-Built	**ZEB-O and ZEB-20%M**	**221501**

Skanska, with partners Ramboll and KHR, was selected as the finalist in 2015. Phase 3, or the pre-project phase commenced after the completion of the competition. Phase 4, or the design phase, observed multiple corrections, and changes to the pre-project phase. Many points from the brief were reassessed and hence impacted the material selection. With the new demands, the ambition of ZEB-O20%M was hard to achieve. The team instead decided to achieve ZEB-O and reduce 20% of the emissions from the material in comparison to a reference building (Schlanbusch et al., 2017). Thus, the final reports from the design phase and “as-built” consist of ZEB-O and ZEB-M results.

5.1.2. Final Design

The size of the campus was 26503 sqm (BRA). The heated floor area, along with the GHG Emissions were calculated separately for the school and the sports hall. The area for the school was approximately 21000 sqm and the hall was around 5100sqm. Though the sports hall was a part of the school, BRA (Useful/heated floor area) and the GHG emissions of the building were measured as two independent entities to ease the calculations of the LCA (in their respective categories). This hall was partially integrated and had entrances accessible directly from the outside and within the school boundaries. Additionally, the campus also has a huge car parking that is shared with the Clubhouse. All the ancillary functions add the built-up area (BYA) of the campus to be around 33000 sqm. All design considerations were in alignment with the STFK brief (Wigenstad, no date) (Schlanbusch et al., 2017).

Daylight and ventilation in the building were of primary concern, both to achieve a good indoor environment and improve the efficiency of the students and faculty. To utilize maximum daylight and reduce dependency on artificial light, various functions were designed around the central atrium. Energy-efficient and demand control lighting systems were installed, mostly LED Technology (Heimdal VGS - ZEB-M Detaljprosjekt).

As a project brief, the school had to reduce its emissions. The most recurring emission was caused by the heating, ventilation, and electric demands (equipment) of the building. Although the Norwegian grid is much cleaner than its other European counterpart, the intention was to increase the self-sufficiency of the building. The team used CHP (Combined Heat and Power) and solar PV (2000 sqm on the roof) for electricity production. Over time, the school produced more energy than the building consumes, and the eco-friendly surplus energy is redistributed. Figure 24 explains the energy flow of the building. According to Skanska, 71% of needed energy is produced on-site ('annual-and-sustainability-report-2018.pdf', no date). Any excess heat is used to warm an adjacent swimming pool, and extra power is exported to the grid. The emission of the delivered energy of the building is **3.59 kgCO2.eq/sqm/yr** whereas the total emissions from energy produced on-site (Used and exported) are **3.2 kgCO2.eq/sqm/yr** (Schlanbusch et al., 2017). The ventilation units have an average SFP number of about 0.8 and an efficiency of rotating recyclers of about 85%. The systems have combi-batteries that provide air heating in the winter and cooling during the summer months. Figure 25 explains the materiality of the school building. Concrete and steel were the largest contributors to the overall material emissions. Because of the design change on the deck/multi-purpose, the use of steel and concrete was increased in quantity.

While the building strived for high sustainable targets, clear communication between ZEB Centre and the teams was lacking in the initial stages. This chaos translates into documentation, as many documents from the different teams involved claim varying results. The final documents that were used to support the calculations used in the thesis are (Heimdal VGS - ZEB-M Detaljprosjekt), (Schlanbusch et al., 2017).

Figure 21: Section of Heimdal VGS (ZEB Report)

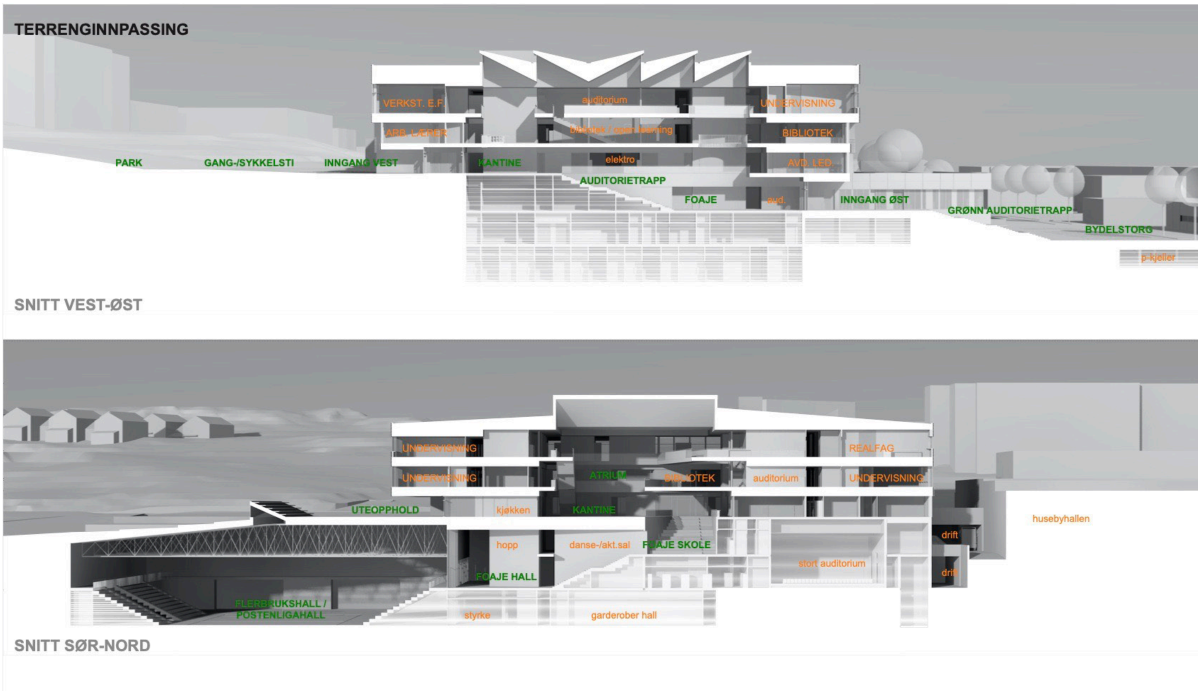


Figure 22: Level 1 Plan of Heimdal VGS (Heimdal VGS)

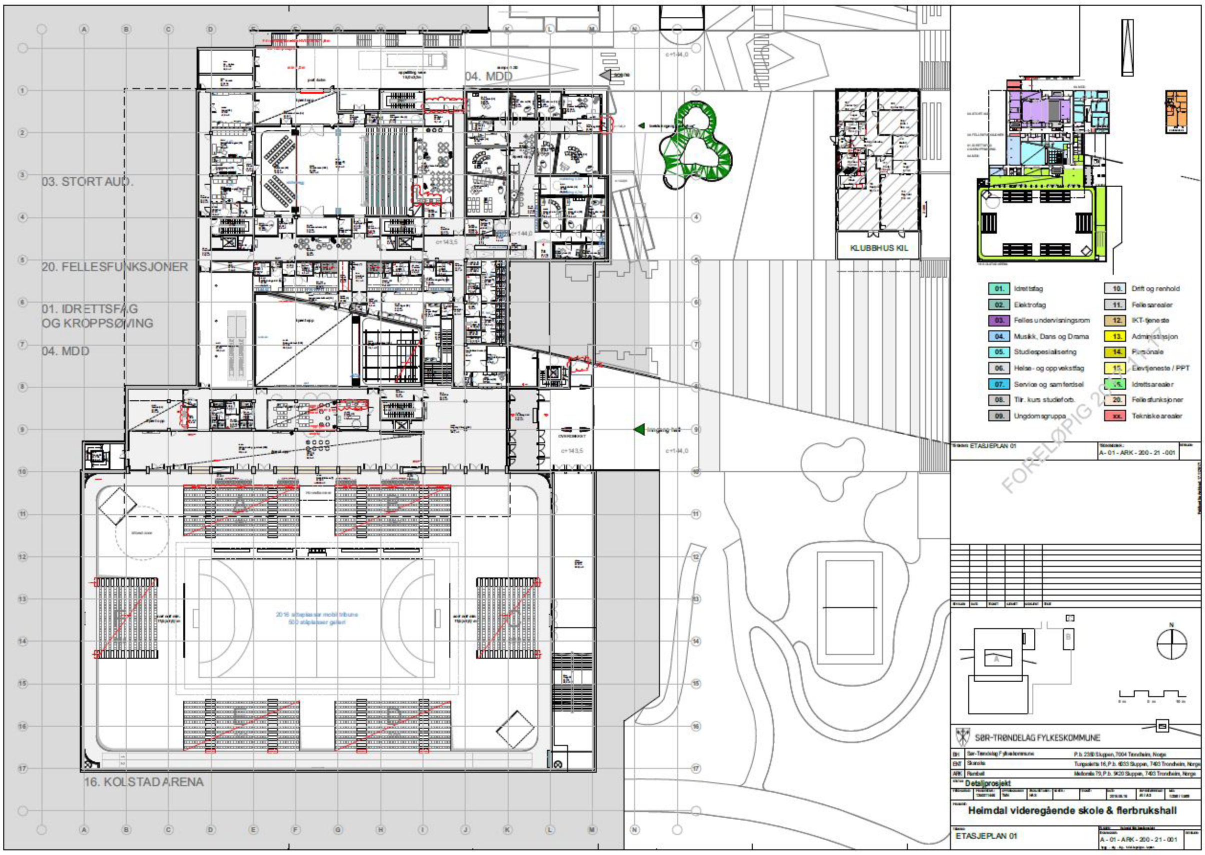


Figure 23: Energy flow in the supply system (100% operation of CHP machine) (Heimdal VGS - ZEB-O Documentation)

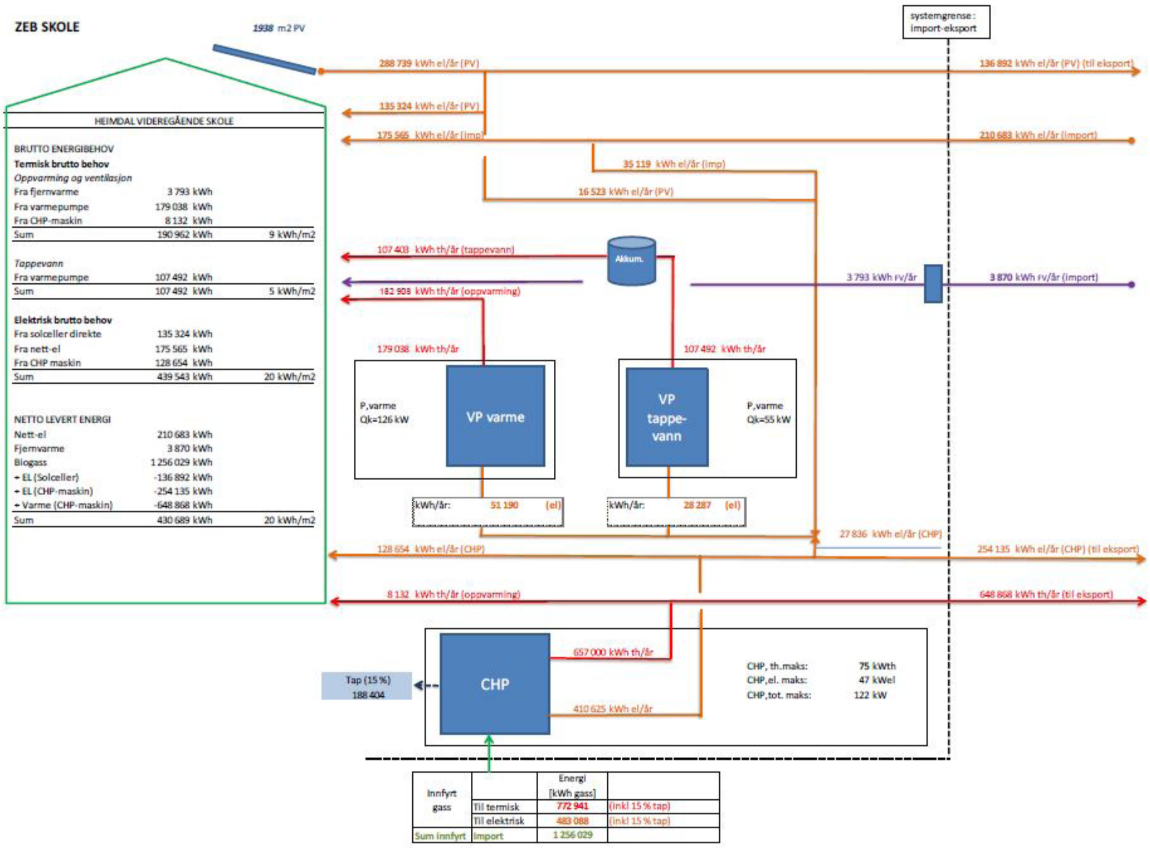
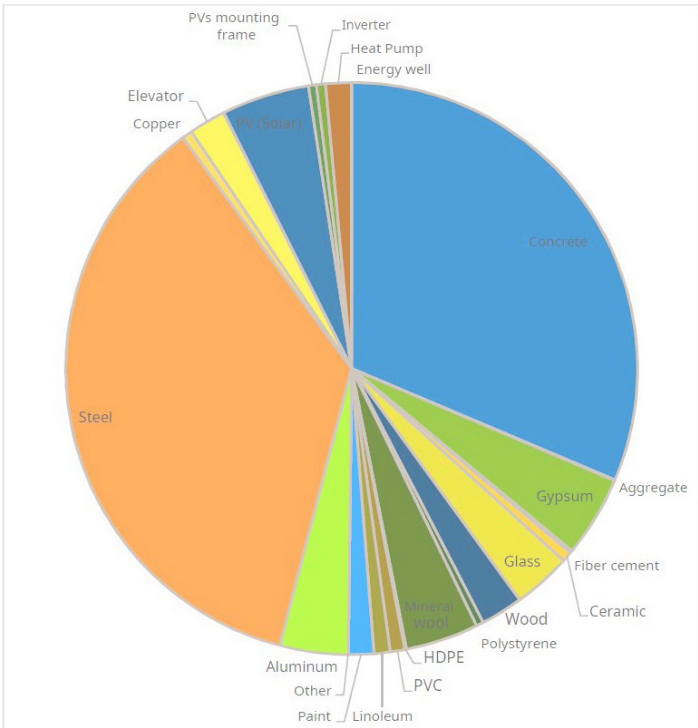


Figure 24: Detailed results for As-built divided into material categories (Heimdal VGS - ZEB-M Detailproject)



5.1.3. Interview

An interview was conducted during one of the site visits. The intention was to understand the perception of the school's environmental targets. There were around 15 participants, divided between students and staff. To split further, there were around 6 staff (faculty and technicians) and the remaining 9 were students. The results were surprising, to say the least. While the technicians were aware of the energy systems, they did not know of ZEB or its contribution. The other staff and students had a general awareness of the environmental performance of the building, but no one was able to specify it. The most sustainable contributions of the building pointed out by the students were of social relevance. The environmental benefits acknowledged were experiential, like the improvement in the daylight and atmosphere. It is conceded that the number of the interviewees is not proportionate to the total population of the school, nonetheless, this helped form the basis of the survey in the following section.

5.2. Application of assessment tools

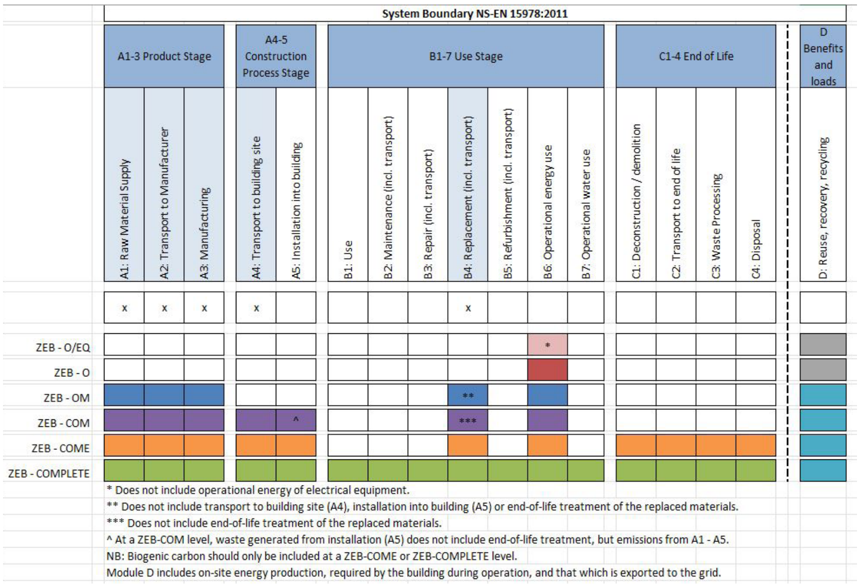
The school achieved its set target. It was an eco-friendly building that applied many innovative techniques to reach its ambition. But how were these ambitions communicated? As mentioned above, the process used for the calculation of the targets was confusing. It was also observed that despite the ZEB centre being a major stakeholder in the construction process, the end-users of the buildings, that is, the staff and students were not particularly aware of these environmental goals. Most achievements were translated through "word of mouth", despite results and documentation.

The building was also not BREEAM-NOR assessed. Though, the team claims it performs well on the certification system (Heimdal College, Norway, no date). This gave rise to the opportunity to test the role of communication and how the stakeholders (Sec 1.2.1) would benefit from it.

Two different types of methodologies were applied to the case study. The Environmental Cost Indicator (LCIA) and BREEAM-NOR (Rating and certification systems) were the final tools selected. As the LCA of the building for the system boundaries (Figure 26) A1-A3, A4 and B4 (accordance with EN 15978) were already calculated by ZEB Spreadsheet (ZEB-M Tool[13]) and «0.7 ZEB M USER GUIDE 031114 », the information on materials, structure and energy consumption and production were derived from these existing documents. Any additional information, like the LCA for the remaining system boundaries, etc. was inferred and assumed with the help of these documents, EPD Norge, and Öekobaudat.de. The application of the processes, particularly for ECI, was straightforward.

The first step for both tools was a common one. It was to collate the data that had a direct influence on the Global Warming Potential, to limit the scope and provide an unbiased ground for comparison of the two assessments (AUGUSTSSON, 2014). The next steps started diverging. The following paragraphs explain the procedure used for ECI and BREEAM-NOR respectively.

Figure 25: System boundaries, as applied (ZEB-M Tool [13])



As ECI requires a thorough Life cycle impact assessment, the existing results were utilised. With the list of materials and structures in the documents, the assessment for system boundaries A4, A5 (Transportation and construction), B1-B6 (Use stage) and C1-C4 (Demolitions stage) were calculated. Due to a lack of information on the exact specifications of the material, similar products in its stead (EPD Norge and Öekobaudat.de) were assessed. The impact from the demolition stage was calculated to be approximately 10% of the production stage (based on EPDs available). Since wood, although biogenic, was calculated as a fossil carbon in the initial stages itself, its end-use cycle was also considered to be similar to other materials like concrete (SCHLANBUSCH ET AL., 2017).

Table 5: Calculation of the total emissions of the school (ZEB-M Tool [13], EPD Norge)

As-built LCA	GWP (kg.CO2.eq/yr emission)	Remarks
A1-A3,A4 and B4	221501	as per ZEB-M TOOL
A5	9% of 221501	Based on EPD Norge steel and concrete
B1-B3,B5 and B6	0	ZEB-O
C1-C4	12% of 221501	Based on EPD Norge steel and concrete
Total	268061	

This provided the final LCA of the building. To eschew confusion, only the GWP of the 'as-built' was scrutinised (Heimdal VGS - ZEB-M Detaljprosjekt). There also existed uncertainty and contention in the details available about the final budget. There were multiple sources available with varying ranges, possible due to the many phases and teams involved[8] . This was caused by the increase in the size of the multi-purpose hall. The budget considered for the thesis is **580 million NOK**, as per Skanska (Skanska bygger videregående skole i Trondheim, no date). The final step was to multiply the LCA results with the External costs. $EC_{minimum}$ was estimated to be around **534 NOK** ('national-plan-2030_version19_desember.pdf', no date) and $EC_{maximum}$ was estimated to be **2000 NOK** (Norway proposes €200 per ton CO_2 tax by 2030, 2021). The two values are then compared against the construction budget and further broken down into contributors and materials. The intention is to understand the clarity of information that can be inferred from this and be cognizant of the scope of sustainability.

Table 6: Calculation of the total credits directly impacting GHG emissions(BREEAM-NOR 2016 Pre-assessment tool)

Environmental Section	No. credits available	Initial target setting Credits Achieved	Initial target setting % credits achieved	Weighting	Score Initial target setting
Management	20	13	65%	12%	8%
Health & Wellbeing	19	0	0%	15%	0%
Energy	25	21	84%	19%	16%
Transport	9	5	56%	10%	6%
Water	9	0	0%	5%	0%
Materials	11	10	91%	13.5 %	12%
Waste	5	4	80%	7.5 %	6%
Land Use & Ecology	10	2	20%	10%	2%
Pollution	13	6	46%	8%	4%
Innovation	10	6	60%	10%	6%
Sum	**131**	**67**			**59.3 %**
Indicative BREEAM-NOR rating					Unclassified*
Min. standards level achieved					Unclassified

* = The rating has been limited to the min. standards level achieved

The other tool that was applied to the case study to assess sustainability was BREEAM-NOR. It is a certification system that gives weightage to environmental impacts, social aspects and innovation. There are also a few subjective qualities of sustainability measured in the system. To limit the final assessment within the given parameter, the environmental weightings that influenced GHG emissions directly were identified. Within them, the different credits were marked. The assessment was supported by literature (Augustsson, 2014) ('SD-5075NOR-BREEAM-NOR-2016-New-Construction-v.1.2.pdf', no date) and the existing BREEAM tools (BREEAM-NOR-2016-Scoring-and-Reporting-tool_v1.05) and (BREEAM-NOR-2016-Pre-Assessment-Estimator_v1.08 TRIAL 1). From a total score of 100%, **about 59.3%** of the credit points contribute to the reduction of GHG emissions significantly. The final scores were measured against this **59.3%**, that is, environmental weighting

8 (Ny Heimdal VGS, Trondheim Kommunes Byggeskikkpris 2019, no date), (Skanska bygger videregående skole i Trondheim, no date), (Schlanbusch et al., 2017)

pertaining to the scores impacting the GHG emissions. It should be kept in mind that this assessment focused solely on GHG emissions and their communication, and therefore the actual scores could vary.

To measure and allot credits, BREEAM-NOR required a lot of documentation. Although, for the environmental weightings Energy and Material, the tool depended on LCA calculations (Same as ECI, and One-Click LCA). The scores were verified against existing analysis by BREEAM, the school's targets and the team's claim. Finally, a rating was appointed to the building. For some of the credits, assumptions were made as it required certain documentation that was not made public.

Calculations

The units of measurement for both tools are different. ECI or Monetary valuation is measured in NOK (Cost) and CO_2.eq (GWP) whereas BREEAM-NOR expresses the result in percentage or a rating.The results of the assessment tools were also compressed into single statements and graphical representations. They were used for a survey to further evaluate the role of communication in these assessment methods. This ensured a more unbiased analysis of the results.

5.3. Survey

An experimental survey was also conducted to understand how the 2 assessments are received by different demographic/stakeholders.

5.3.1. Demography

The demographic was versatile. 50 people responded to the survey. The division was 25 laymen, with almost 1/3rd of them dealing with sustainability in some form or the other, and 25 technical people, that is either architects or engineers in the field of sustainability. The age group and the cultural context also varied significantly. Out of the 25 laymen, about 8 people were around the age of 14-17, studying across Scandinavia. The remaining laymen ranged from 25 years up to 65 years.

The technical people had better awareness of the correct terms and calculations. They mostly formed the age group 20-40 years and were either practising or learning sustainability in the built environment.

5.3.2. Content

The attempt was to keep the survey quick and concise, but at the same time contain the important details without forming any obvious biases to choose from. The purpose was to compare which of the two methods communicated the environmentally friendly techniques of the school better. Since their results are displayed in different formats, the comparison was hard. A minor context was provided, and a graphic representation of the results was simplified after initial feedback.

The first section collected data about familiarity with sustainability and its 3 pillars. The following sections attempted to understand how the two representations were perceived, especially under the notion that they were assessing two different school buildings. The final section highlighted the sustainable targets of Heimdal VGS and asked the respondents to rate its sustainability, as per their understanding. Finally, it was clarified that the two methods were applied to the same building. The respondents were then asked to pick the assessment that represented the sustainability of the building more.

Figure 26: Question from the survey

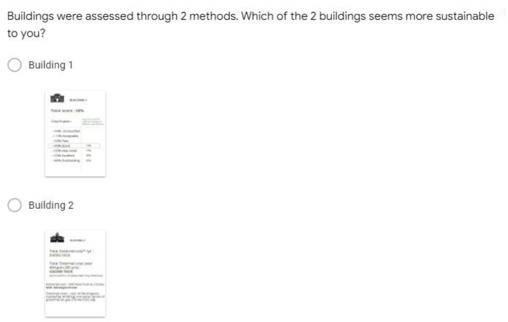
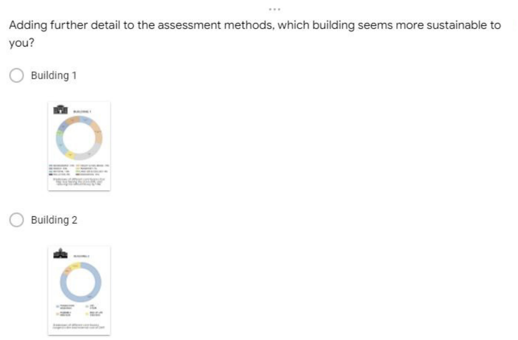


Figure 27: Question from the survey



5.3.3. Feedback

After the survey, feedback was taken from approximately 20 respondents, and 10 from both sides. In addition, 4 interviews were also conducted, just to test if the answers would differ after a verbal 'in depth' explanation.

There were several interesting points for the feedback in general. Many felt that the representation seemed too detailed and technical. Especially for people who were not familiar with the technical terms of sustainability. Relatability was another quotient that swayed decisions. On one end, just understanding and imagining the impact of GWP and a tonneCO_2.eq was hard. On the other end, for those of non-Norwegian background, relating to the currency and any economic significance was difficult.

For around 12 people, the questions and the choices were easier to follow but felt that the ground for comparisons was not solid, and hence chose what they related to more. Additionally, the externalities/external cost for CO2.eq felt morally and ethically wrong to 6 out of the 20 respondents Within this, few also felt that it was too nominal a price to pay for the emissions. To others, any value was a point of concern, as it dismissed the impacts or aspects of green buildings and disregarded the possible damage of the emissions. The rating of the school building also seemed to be based on speculation for a few, as there were no standards or references to compare the performance. But in general, it was the preferred choice, as it was relatively more comprehensive.

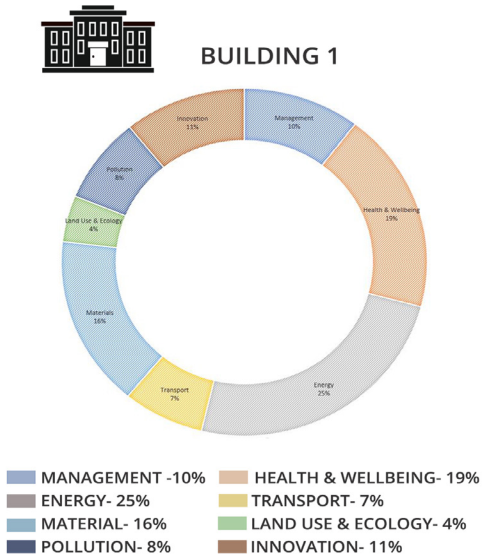
Figure 28: BREEAM-NOR representation, survey

BUILDING 1

Total score : 46%

Classification :	Avg CO2.eq (GHG) emissions savings of different classifications
- <10% Unclassified	
- > 10% Acceptable	
- >25% Pass	
- >40% Good	10%
- >55% Very Good	15%
- >70% Excellent	35%
- >85% Outstanding	55%

Figure 29: BREEAM-NOR division, survey



Breakdown of different contributors that help in achieving the score 46%, and reducing the GHG (CO2.eq) by 10%.

Figure 30: ECI representation, survey (Bruven and Dalen, 2006)

BUILDING 2

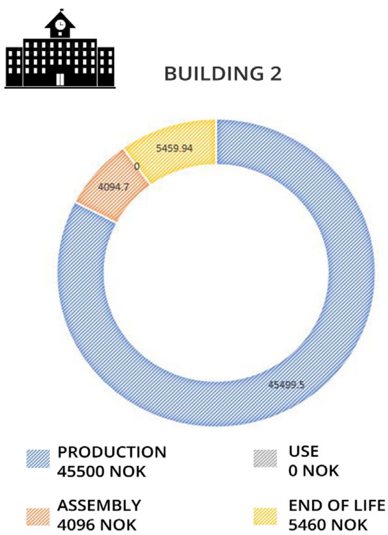
Total External cost* /yr :
55050 NOK

Total External cost over lifespan (60 yrs) :
330300 NOK
(External Cost of Global Warming Potential)

External cost : 300 Nok/Tonne.CO2eq
NOK : Norwegian Kroner

External costs : cost of the impacts caused by emitting one extra tonne of greenhouse gas (Tonne/CO2.eq)

Figure 31: ECI division , survey (Bruven and Dalen, 2006)



Breakdown of different contributors (stages) to the total external cost of GWP

5.4. Results

In this section, the results of the assessment tools and the survey are summarized. The performances of these tools are gauged. The major conditions that are appraised, in no particular order are:

1. How easy was the methodology to apply?
2. How much information can be inferred from it?
3. How is sustainability represented?
4. How were they perceived by different stakeholders?

Two final values were derived for the Environmental Cost Indicator. The total external $cost_{(Min)}$ (Carbon pricing of 534NOK/Tonne CO_2.eq ('NATIONAL-PLAN-2030_VERSION19_DESEMBER.PDF', NO DATE) (NORWAY PROPOSES €200 PER TON CO_2 TAX BY 2030, 2021) is **143122 NOK/yr** whereas the total external $cost_{(max)}$ (Carbon pricing of 2000NOK/Tonne CO_2.eq(NORWAY PROPOSES €200 PER TON CO_2 TAX BY 2030, 2021) is **536040 NOK/yr**. Over the lifespan of 60 years, the difference between the total external costs varies significantly.

The application is a simple process of multiplying the weighting factor by the results of the impact categories, which in this case would be GWP. Based on the literature (MARICHOVA, 2020), the assessment method aids policies, and therefore favourable to the Kommune (STFK) as stakeholders. The ECI provides quantitative analysis and can help understand the contribution of different stages during construction. Additionally, these values can be internalised for a more detailed cost-benefit analysis (SCHNEIDER-MARIN AND LANG, 2020). Since the tool is inherently dependent on LCA, detailed information on the ecological costs of materials can also be provided. This can help analyse the need for substitution of harmful materials.

The total external costs (for 60 years) of both cases (EC_{min} and EC_{max}) were also evaluated against their impact on the building's overall budget. As mentioned in the Sec 5.2, the budget considered was **580 million NOK** (as built). EC**min** is **1.48% of the budget**. EC_{max} is **5.54% of the budget**. EC**min** is based on the current prices (2021) and hints at the need for a better weighting factor. The monetary valuation of GHG emissions raises several critiques, the main one pointing to paying for the damages/pollution (ETHICS REVIEW OF CARBON TAXES, 2021). The uncertainties with the right carbon pricing also create confusion. Higher values may potentially prevent excessive emissions due to a steep impact on the economy (KLING, PHANEUF AND ZHAO, 2012). On another end, it causes social injustice and discrimination, as this would impact those with lesser means, especially if internalised (ETHICS REVIEW OF CARBON TAXES, 2021). From the survey, it was inferred that the lack of scale for comparison and relatability of CO_2.eq works in disfavour for some stakeholders. To simplify, it is hard to understand a clear distinction between a negative impact of the GWP, or where the social and economic factors tip over the environment.

Table 7: Calculation of the total external costs, based on Table 4 and literature

As-built LCA	GWP (t.CO_2.eq/yr emission)	Remarks	Total EC_{min}/yr	Total EC_{max}/yr
			At 534 NOK/t.CO_2.eq	**At 2000 NOK/t.CO_2.eq**
A1-A3,A4 and B4	221.501	as per ZEB-M TOOL	118286.34	443020
A5	19.93	Based on EPD Norge steel and concrete	10642	39860
B1-B3,B5 and B6	0	ZEB-O	0	0
C1-C4	26.58	Based on EPD Norge steel and concrete	14193.72	53160
Total	268.061	-	143122.06	536040

In the case of BREEAM-NOR, the building scored **46.3%**. This score was derived with the help of the spreadsheet tools made available by BREEAM-NOR. The scoring and rating tool was an aid for the pre-assessment tool, as it helped provide credit points that each environmental weighting received depending on its performance. This score would receive a rating of **"Good"** in the BREEAM-NOR (Refer to Figure 13). Based on (Taylor, no date), this means the building would help reduce about 10-15% of the GHG emissions as compared to a standard building.

Table 8: Calculation of BREEAM-NOR score, based on Table 5 and literature

Environmental Section	No. credits available	Initial target setting: Credits Achieved	Initial target setting: % credits achieved	Weighting	Score: Initial target setting
Management	20	8	40%	12%	5%
Health & Wellbeing	19	11	58%	15%	9%
Energy	25	15	60%	19%	11%
Transport	9	3	33%	10%	3%
Water	9	0	0%	5%	0%
Materials	11	6	55%	13.5 %	7%
Waste	5	0	0%	7.5 %	0%
Land Use & Ecology	10	2	20%	10%	2%
Pollution	13	6	46%	8%	4%
Innovation	10	5	50%	10%	5%
Sum	**131**	**56**			**46.3 %**
Indicative BREEAM-NOR rating					Unclassified*
Min. standards level achieved					Unclassified

* = The rating has been limited to the min. standards level achieved

Figure 32: Avg CO2 emissions savings associated with different BREEAM Ratings (Taylor, no date)

Since only the **credits for environmental weighting impacting the GHG emissions were marked, there is a distinct possibility that the building scored higher than 46.3%** . This aligns with the team's claim for a good to excellent rating on the BREEAM (Heimdal College, Norway, no date). It also provides a range making the comparison of the performance of the school with respect to a reference building much easier. Many consumers and developers found this method more informative and effective ('Stakeholder-engagement-and-analysis-BREEAM-NOR-2021-report.pdf', no date) (Al-Surf et al., 2021). The problem arises in justifying the score or the rating received. For many credit points, only documents are a requisite. Some credit points are qualitative in their description, and hence hard to measure (Caputo and Gaterell, 2018). Also, the overall percentage does not give an exact number to the emission or the sustainability level, but a generalised qualitative performance. This can be potentially misleading.

Additionally, the base of this step also requires LCA measurement to an extent. These assessments are an overhead cost and require a separate cost for renewal ('FS021-Rev-23-BREEAM-In-Use-Fee-Sheet-2-1-1.pdf', no date). Some stakeholders also claim that the assessment process is tedious ('Stakeholder-engagement-and-analysis-BREEAM-NOR-2021-report.pdf', no date).

Finally, the two results were also evaluated through the survey. For some, both tools lacked a clear form of communication and had detailed information that was hard to follow. Figure 34-37 illustrate the results from the survey. **70%** of the respondents chose **BREEAM-NOR (Building 1)** as a better assessment method, based on their understanding. This was mainly because of a scale to compare performances. Whereas for the remaining **30%, the ECI (Building 2)** was a better evaluation tool due to a clear description of the economic impacts of the emissions and a more quantitative representation of the emissions.

Figure 33: Survey - 1. Which aspect of sustainability would you personally rate higher?

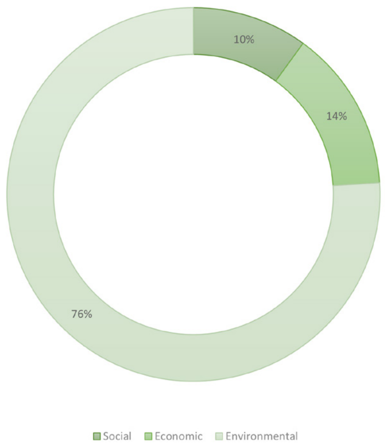
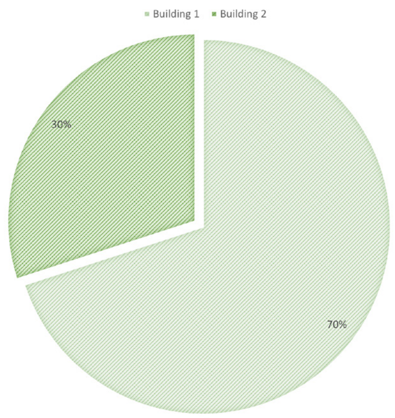
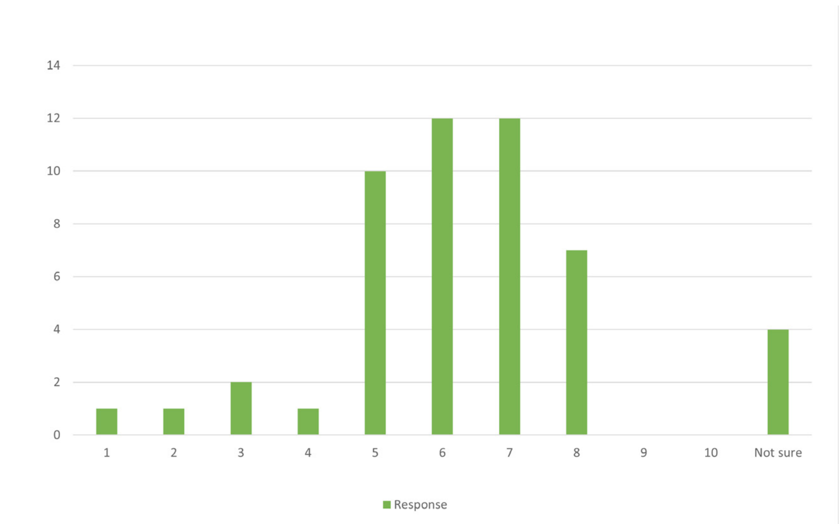


Figure 34: Survey - 2 & 3. Which of the 2 buildings seems more sustainable to you?



It was observed that demography, personal biases, and contexts affected the readability of the tools. One of the questions also tried to analyse the preference for different pillars of sustainability. And roughly **76% (38)** weighed the **environment** as more important. It was inferred that the cause for this high percentage was the coverage of environmental sustainability and climate change in recent years. The building was rated a **6 out of 10 (Average)** on its environmental performance based on its sustainable achievements. Post this, the respondents were asked to re-evaluate the results, and choose a method that represented the sustainability of the building more. There were minor changes to answers with **64% opting for BREEAM-NOR and 36% for ECI.**

Figure 35: Survey - 4. From a scale of 1-10 (1=low, 10 = high), how sustainable would you rate the building?



To surmise, the preference and suitability of the tools alter in accordance with the stakeholders, and the method of communication required. To generate more stakeholder engagement, both tools need to be simplified further. Additionally, the tools do have the power to improve the sustainable performance of the building, and they provide clear information to influence design decisions, especially as these building assessment methodologies are a part of the construction process since the commencement of the projects.

Figure 36: Survey - 5. Which assessment method would you say was more informative to explain the school building?

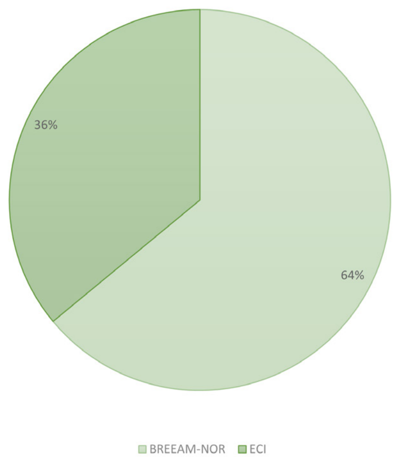


Table 9: Explanation of the results

Sustainability assessment method	Sustainability assessment tool	Unit of measurement	Representation in the study
LCA	Environmental Cost Indicator	NOK/yr	BUILDING 2 Total External cost* /yr : 55050 NOK Total External cost over lifespan (60 yrs) : 330300 NOK (External Cost of Global Warming Potential) External cost : 300 Nok/Tonne.CO2eq NOK : Norwegian Kroner External costs : cost of the impacts caused by emitting one extra tonne of greenhouse gas (Tonne/CO2.eq)
Building rating and certification	BREEAM-NOR	% (Or class)	BUILDING 1 Total score : 46% Classification : / Avg CO2.eq (GHG) emissions savings of different classifications - <10% Unclassified - > 10% Acceptable - >25% Pass - >40% Good 10% - >55% Very Good 15% - >70% Excellent 35% - >85% Outstanding 55%

6. Discussion and conclusion

The study shows that communication with relevant stakeholders, as supported by sustainable assessment methods, has the potential to influence the sustainability of a building over its lifetime. From the survey, it was observed that context, familiarity with sustainability assessment tools, and personal bias affect the perception and readability of the methods. Even the results, as calculated do not directly point to a specific direction. It is thus hard to claim which one of the methods is a better choice. Both the tools have their inherent benefits and drawbacks.

The ECI provides information in the form of monetary values and CO_2.eq. Monetary units are easy to understand and can be well communicated to a larger crowd, including a layperson. It also enhances the role of the government as a stakeholder in the building sector (Marichova, 2020) (van den Bergh and Savin, 2021). The process of applying the ECI on a project is simpler and thus has a huge potential in the market. It can also be internalised as a part of a detailed cost-benefit analysis. If internalised, the monetary valuations can significantly alter the economics, and hence the design decisions of the building industry. Moreover, standards and guidelines related to these communication tools could also include the option of weighting the LCA results through monetisation, providing the user with more tangible information in what relates to the potential life cycle environmental impact of the building. There are a few disadvantages associated with the ECI. The lack of precise data and many uncertainties associated with both LCA and the monetary valuation make it very difficult to achieve an absolute answer (Schlanbusch et al., 2016). The dependency on policies and governance also significantly affects the cost, thus increasing the uncertainty level. A need for fairer valuation of the emissions is also observed, especially since the current external costs are not proportionate to the building's budget. Additionally, several critics questioned the morality of this method on the grounds of social injustice, and other such criteria (Ethics Review of Carbon Taxes, 2021). This can be noticed within the study too, where the external costs for the **GWP spread over 60 years are 1.5% (EC_{min})/ 5.5% (EC_{max}) of the total budget**.

As an already established sustainability assessment tool, many stakeholders are already familiar with BREEAM-NOR. The BREEAM Manual also updates regularly as per the development of construction technologies and the data it infers from the case studies. The rating system also provides a scale for comparison to communicate the performance of the building. It can also be observed that BREEAM-NOR and many such global scaled certification methods use these certificates as a promotional tool, thus spreading further awareness. The potential increase in the cost of real estate is in the interest of clients and developers, as stakeholders ('Stakeholder-engagement-and-analysis-BREEAM-NOR-2021-report.pdf', no date). Therefore, there is no denying the existing popularity along with the rising potential of this method of assessment. However, there lie some drawbacks for BREEAM-NOR too. Since BRE Global is an organisation run by people within the industry, there rises a question of credibility during conflicts of interest (Heide, 2011) (Caputo and Gaterell, 2018). Although the promotional aspect of these certifications has been so far beneficial, there is a potential for greenwashing, especially since it has been observed that many vernacular non-certified buildings often perform better ecologically. It also depends on many external factors and specific documentation to be eligible for the assessment.

As deduced by the aforementioned findings, it is safe to conclude the significant role communication plays in promoting sustainability awareness and performance in the built environment. It is pertinent to mention that building sustainable assessment tools are integral to this communication amongst all stakeholders. The study also observes the scope for improvement in these assessment tools to encourage the usage of this and generate an even more transparent communication. Though in their current states, both tools are beneficial to the primary stakeholders recognised in the study, there is need for further simplification.

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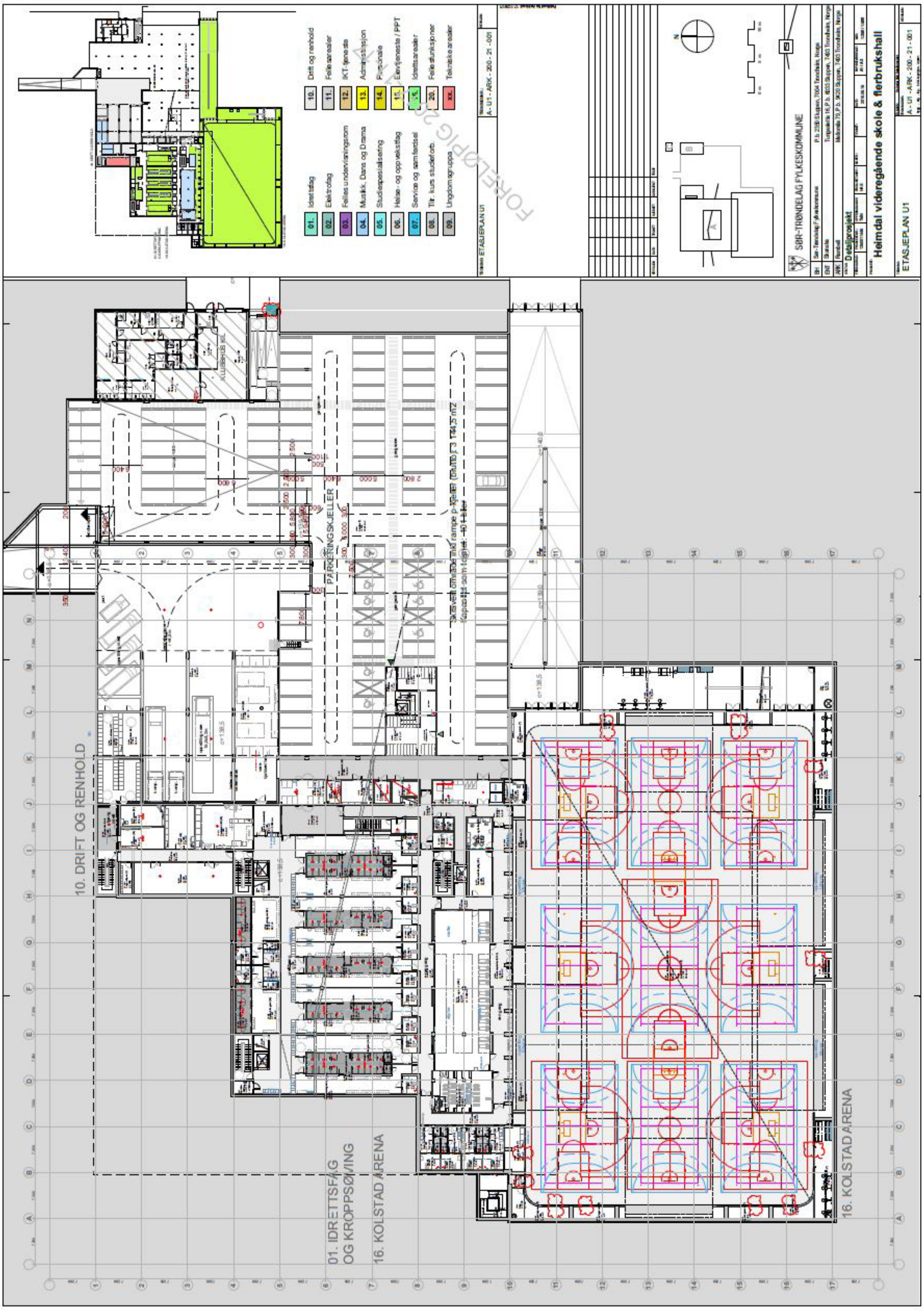
Appendices

Appendix 1: Level U1 plan Heimdal VGS (Heimdal VGS)



Appendix 2 : ECI weighting factor (Ecochain)

Impact category	Unit	Weighting Factor (€/ unit)
Global warming	kg CO_2-eq	0,05 €
Ozone depletion	kg CFC-11-eq	30,00 €
Acidification of soil and water	kg SO_2-eq	4,00 €
Eutrophication	kg PO_4^{3-}-eq	9,00 €
Depletion of abiotic resources – elements	kg Sb-eq	0,16 €
Depletion of abiotic resources – fossil fuels	kg Sb-eq	0,16 €
Human toxicity	kg 1,4 DB-eq	0,09 €
Freshwater ecotoxicity	kg 1,4 DB-eq	0,03 €
Marine water ecotoxicity	kg 1,4 DB-eq	0,0001 €
Terrestrial ecotoxicity	1,4 DB-eq	0,06 €
Photochemical oxidant creation (Smog)	kg C_2H_4	2,00 €

Appendix 3 b : BREEAM-NOR New construction 2016 sections (BREEAM-NOR 2016)

BREEAM-NOR 2016 sections and issues	
Management	Water
Man 01 Project brief and design Man 02 Life cycle cost and service life planning Man 03 Responsible construction practices Man 04 Commissioning and handover Man 05 Aftercare	Wat 01 Water consumption Wat 02 Water monitoring Wat 03 Water leak detection and prevention Wat 04 Water efficient equipment
Health and wellbeing	Materials
Hea 01 Visual comfort Hea 02 Indoor air quality Hea 03 Thermal comfort Hea 04 Microbial contamination Hea 05 Acoustic performance Hea 06 Safe access Hea 07 Natural hazards Hea 08 Private space Hea 09 Moisture protection	Mat 01 Life cycle impacts Mat 03 Responsible sourcing procurement of materials Mat 05 Designing for robustness

Energy	Waste
Ene 01 Energy efficiency Ene 02 Energy monitoring Ene 03 External lighting Ene 04 Low and zero carbon technologies Ene 05 Energy efficient cold storage Ene 06 Energy efficient transportation systems Ene 07 Energy Efficient Laboratory Systems Ene 08 Energy efficient equipment Ene 09 Drying space Ene 23 Energy performance of building structure	Wst 01 Construction waste management Wst 02 Recycled aggregates Wst 03 Operational waste Wst 04 Speculative floor and ceiling finishes
Transport	Land use and ecology
Tra 01 Public transport accessibility Tra 02 Proximity to amenities Tra 03 Alternative modes of transport Tra 04 Maximum car parking capacity Tra 05 Travel plan Tra 06 Home office	LE 01 Site selection LE 02 Ecological value of site and protection of ecological features LE 04 Enhancing site ecology LE 05 Long term impact on biodiversity LE 06 Building footprint
Innovation	Pollution
New technology, process and practices	Pol 01 Impact of refrigerants Pol 02 NOx emissions Pol 03 Surface water run-off Pol 04 Reduction of night time light pollution Pol 05 Noise attenuation

Appendix 3 b : Minimum BREEAM-NOR standards by weighting level (BREEAM-NOR 2016)

BREEAM issue	Comment	Pass	Good	Very Good	Excellent	Outstanding
Man 03: Responsible construction practices	*Crit 7/8				1 credit*	2 credits*
Man 04: Commissioning and handover	*Crit 1-4 **Crit 1-4+7	1 credit*	1 credit*	2 credits**	2 credits**	3 credits**
Man 05: Aftercare	*Crit 3				1 credit*	1 credit*
Hea 01: Visual comfort		Criterion 1	Criterion 1	Criterion 1	Criterion 1	Criterion 1
Hea 02: Indoor air quality	*Crit 1+7 **Crit 1+9			2 credits*	3 credits**	3 credits**
Hea 08: Private space	Residential only					1 credit
Hea 09: Moisture protection				1 credit	1 credit	1 credit
Ene 01: Energy efficiency					6 credits	8 credits
Ene 02a: Energy monitoring	Non residential only			1 credit	1 credit	1 credit
Ene 04: Low or zero carbon technologies					1 credit	1 credit
Ene 23: Energy performance of building structure and installations						2 credits
Wat 01: Water consumption					1 credit	2 credits
Mat 01: Life cycle impacts		Criterion 1	Criterion 1	Criterion 1	Criterion 1	Criterion 1
Mat 03: Responsible Sourcing		Criterion 1	Criterion 1	Criterion 1	Criterion 1	Criterion 1
Wst 01: Construction waste management						1 credit
Wst 03a&b: Operational waste					1 credit	1 credit

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Appendix 3 c : BREEAM-NOR assessment fee -Initial stage and renewal

Initial Certification

Part 1 Certificate – Asset Performance	£330 per asset
Part 2 Certificate – Building Management Performance	£330 per asset
Part 3 Certificate – Occupier Management	£330 per asset

Certificate Renewal

Parts 1 and 2 – Annual renewal (no significant changes)	£75 per certificate
Parts 1 and 2 – Annual renewal (significant changes)	£330 per certificate
Part 3 – Annual renewal	£330 per certificate

Appendix 4 a : Survey questions in order

1. Which aspect of sustainability would you personally rate higher?
2. Buildings were assessed through 2 methods. Which of the 2 buildings seems more sustainable to you?
3. Adding further detail to the assessment methods, which building seems more sustainable to you?
4. Building 1 and 2 are the same. The building is rated ZEB-O and ZEB-20%M (No emissions (CO_2.eq) for its operational energy and saves 20% Greenhouse gas emissions in construction). From a scale of 1-10 (Where 1 is low and 10 is high), how sustainable would you rate the building?
5. Which assessment method would you say was more informative to explain the school building?

Appendix 4 b : Table explaining survey demography

Age-group (Year)	**Country of residence**	**Occupation**	**Familiarity with Sustainability**
14-17	Finland	School Student	No
14-17	Finland	School Student	No
14-17	Finland	School Student	No
14-17	Finland	School Student	No
14-17	Norway	School Student	No
14-17	Norway	School Student	No
14-17	Sweden	School Student	No
14-17	Sweden	School Student	No
20-30	Sweden	Sus. Arch. Student	Yes
20-30	Sweden	Sus. Arch. Student	Yes
20-30	Norway	Sus. Arch. Student	Yes
20-30	Norway	Sus. Arch. Student	Yes
20-30	Norway	Sus. Arch. Student	Yes
20-30	Norway	Sus. Arch. Student	Yes
20-30	Norway	Sus. Arch. Student	Yes
20-30	Norway	Sus. Arch. Student	Yes
20-30	Norway	Sus. Arch. Student	Yes
20-30	Norway	Sus. Arch. Student	Yes
20-30	Norway	Sus. Arch. Student	Yes
20-30	Norway	Sus. Arch. Student	Yes
20-30	Norway	Engineer	Yes
20-30	Norway	Engineer	No
20-30	Norway	Radiologist	No
20-30	Norway	Urban Planner	Yes
20-30	USA	Sus. Arch. Student	Yes
20-30	USA	Sus. Arch. Student	Yes
20-30	USA	Sus. Consultants	Yes
20-30	USA	Sus. Consultants	Yes
20-30	USA	Urban Designer	Yes
20-30	Spain	Architect	Yes
20-30	Netherlands	Architect	Yes
20-30	India	Architect	Yes
20-30	India	Architect	Yes
20-30	India	Architect	No
20-30	India	Engineer	No
20-30	India	Engineer	No
20-30	India	Sus. Arch. Student	Yes
20-30	India	Sus. Arch. Student	Yes
30-45	Norway	Sus. Arch. Student	Yes
30-45	Norway	Sus. Arch. Student	Yes

30-45	Norway	Sus. Arch. Student	Yes
30-45	Norway	Sus. Consultants	Yes
30-45	India	Sus. Consultants	Yes
30-45	India	Software Engineer	No
30-45	India	Software Engineer	No
30-45	India	Software Engineer	No
45-65	India	Architect	Yes
45-65	India	Engineer	No
45-65	India	Retired	No
45-65	India	Retired	No

Appendix 5 a : ZEB-M of As-built -School (ZEB Report)

	(kg CO_2eq) lifetime 60yrs	(kg CO_2eq) per year	(kg CO_2 eq / sqm) BRA lifetime 60yrs	(kg CO_2 eq / sqm) BRA per year
* 21 Groundwork and Foundations	346 702	5 778	16	0.266
* 22 Superstructure	1 477 769	24 629	68	1,132
* 23 Outer walls	888 374	14 806	41	0.680
* 24 Inner walls	1,576,531	26 276	72	1,208
* 25 Structural Deck	1 822 699	30 378	84	1,396
* 26 Outer Roof	400 770	6 679	18	0.307
* 28 Stairs, balconies etc.	-	-	-	-
36 Ventilation and Air Conditioning	1 444 114	24 069	66	1,106
491 Solar thermal, PV systems + PV Roof constructions	515 249	8 587	24	0.395
492 Wind energy systems	-	-	-	-
493 Other renewables	447 324	7 455	21	0.343
62 Person and product transport (lifts)	180 350	3 006	8	0.138
Total	**9 099 882**	**151 665**	**418**	**6,970**
Initial Material Use (no replacement)	6 849 271	114 155	315	5,246
Use Phase Replacements	2 250 611	37 510	103	1,724

Appendix 5 b : ZEB-M of As-built -Sports hall (ZEB Report)

	(kg CO_2eq) lifetime 60yrs	(kg CO_2eq) per year	(kg CO_2 eq / sqm) BRA lifetime 60yrs	(kg CO_2 eq / sqm) BRA per year
* 21 Groundwork and Foundations	554 135	9 236	113	1,883
* 22 Superstructure	1 748 024	29 134	356	5,941
* 23 Outer walls	451 986	7 533	92	1,536
* 24 Inner walls	153 982	2 566	31	0.523
* 25 Structural Deck	449 924	7 499	92	1,529
* 26 Outer Roof	318 104	5 302	65	[illegible]
* 28 Stairs, balconies etc.	-	-	-	-
36 Ventilation and Air Conditioning	513 994	8 567	105	1,747
491 Solar thermal, PV systems + PV Roof constructions	-	-	-	-
492 Wind energy systems				
493 Other renewables	-	-	-	-
62 Person and product transport (lifts)				
Total	**4 190 150**	**69 836**	**854**	**14,241**
Initial Material Use (no replacement)	3 691 021	61 517	753	12,544
Use Phase Replacements	499 128	8 319	102	1,696

Appendix 6 : LCA Results - Reinforced steel NEPD-3294-1938 (EPD Norge)

ARMERING & SVEIS AS

LCA: Results

System boundaries (X=included, MND= module not declared, MNR=module not relevant)

Product stage			Assembly stage		Use stage							End of life stage				Benefits & loads beoyond system boundary
Raw materials	Transport	Manufacturing	Transport	Assembly	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	X	X	X	X	MNR

Core environmental impact indicators

Indicator	Unit	A1-A3	A4	C1	C2	C3	C4	D
GWP-total	kg CO2 eq.	4,71E-01	5,92E-03	2,13E-02	6,88E-02	2,01E-04	2,63E-04	-1,27E-02
GWP-fossil	kg CO2 eq.	4,43E-01	5,91E-03	2,13E-02	6,87E-02	1,90E-04	2,62E-04	-1,27E-02
GWP-biogenic	kg CO2 eq.	2,40E-02	1,31E-05	1,68E-05	1,31E-04	1,06E-05	8,13E-07	-8,23E-06
GWP-LULUC	kg CO2 eq.	5,88E-04	2,28E-06	1,69E-06	1,74E-05	3,86E-07	7,12E-08	1,84E-06
ODP	kg CFC11 eq.	2,82E-08	1,43E-09	4,60E-09	1,52E-08	2,10E-11	1,08E-10	-6,91E-18
AP	mol H^+ eq.	3,02E-03	3,81E-05	2,22E-04	2,68E-04	1,26E-06	2,48E-06	-2,28E-05
EP-freshwater	kg P eq.	5,65E-05	4,55E-07	6,44E-07	3,46E-06	7,56E-08	2,45E-08	-2,60E-09
EP-marine	kg N eq.	8,29E-04	9,26E-06	9,86E-05	8,71E-05	4,50E-07	8,64E-07	-3,40E-06
EP-terrestial	mol N eq.	1,12E-02	1,02E-04	1,08E-03	9,53E-04	4,96E-06	9,47E-06	-3,31E-05
POCP	kg NMVOC eq.	2,33E-03	3,28E-05	2,97E-04	3,44E-04	1,40E-06	2,75E-06	-1,74E-05
ADP-M&M	kg Sb eq.	5,31E-07	1,69E-08	8,61E-09	1,86E-07	1,27E-08	5,87E-10	-2,69E-08
ADP-fossil	MJ	6,28E-01	9,62E-02	2,93E-01	9,95E-01	2,48E-03	7,35E-03	-1,11E-01
WDP	m^3	1,07E-01	3,54E-04	3,76E-04	2,03E-03	1,01E-04	3,30E-04	-1,45E-03

GWP-total: *Global Warming Potential;* ***GWP-fossil:*** *Global Warming Potential fossil fuels;* ***GWP-biogenic:*** *Global Warming Potential biogenic;* ***GWP-LULUC:*** *Global Warming Potential land use and land use change;* ***ODP:*** *Depletion potential of the stratospheric ozone layer;* ***AP:*** *Acidification potential, Accumulated Exceedance;* ***EP-freshwater:*** *Eutrophication potential, fraction of nutrients reaching freshwater end compartment; See "additional Norwegian requirements" for indicator given as PO4 eq.* ***EP-marine:*** *Eutrophication potential, fraction of nutrients reaching freshwater end compartment;* ***EP-terrestial:*** *Eutrophication potential, Accumulated Exceedance;* ***POCP:*** *Formation potential of tropospheric ozone;* ***ADP-M&M:*** *Abiotic depletion potential for non-fossil resources (minerals and metals);* ***ADP-fossil:*** *Abiotic*

Appendix 7 a : BREEAM-NOR, Weighting of categories with direct GHG impact (Augustsson, 2014)

Table 3: Links between LCA processes, BREEAM categories and BREEAM subcategories together with actor choices.

LCA PROCESS	ACTOR CHOICES	SUB-CATEGORY BREEAM	CATEGORY BREEAM
Production phase (including raw material extraction and production of building materials)	Energy use at construction site	Man 3 - Construction site impacts	1.Management
	Choice of building materials	Mat 1 - Materials specification (major building elements) Mat 5 - Responsible sourcing of materials Mat 6 - Insulation Mat 7 - Designing for robustness	6.Materials
	Choice of landscape materials	Mat 2 - Hard landscaping and boundary protection	6.Materials
	Disposal of building materials at construction site	Wst 1 - Construction site waste management	7.Waste
	Re-use of building materials at construction site	Wst 1 - Construction site waste management	7.Waste
Use phase	Use of energy (including heating, cooling, ventilation, operation of installations (elevators, fans and pumps), domestic hot water use, ground heat and other kinds of electricity for the building such as external lighting).	Ene 1 - Energy efficiency Ene 5 - Low or zero carbon technologies Ene 8 - Lifts	3.Energy
	Transportation necessary to commute between home and office.	Tra 3 - Alternative modes of transport Tra 6 - Maximum car parking capacity	4.Transport
	Water consumption during the use phase.	Wat 1 - Water consumption	5.Water
End of life phase			

Appendix 7 b : BREEAM-NOR, calculation (for direct GHG impact only) (BREEAM-NOR 2016 Pre-assessment tool)

* = The rating has been limited to the min. standards level achieved

BREEAM-NOR 2016 Issue	Available cred	Credits	Contribution to score	Minimum standards level achieved	Respon-sible	Stat.	General comments
MANAGEMENT							
Man 01 Project brief and design	4	0	0.0 %	N/A			
Man 02 Life cycle cost and service life plannir	4	4	2.4 %	N/A			
Man 03 Responsible construction practices	6	2	1.2 %	Outstanding			
Man 04 Commissioning and handover	3	0	0.0 %	Unclassified			
Man 05 Aftercare	3	2	1.2 %	Outstanding			
Total performance management	**20**		**4.8 %**	Credits achieved: 8			
HEALTH & WELLBEING							
Hea 01 Visual comfort	4	4	3.2 %	Outstanding			
Hea 01 Visual comfort - Criteria 1	Yes/No	Yes	-	Outstanding			
Hea 02 Indoor air quality	6	3	2.4 %	Outstanding			Not sure if this should be counted
Hea 03 Thermal comfort	2	2	1.6 %	N/A			Same. Additonally, it is just about documentation
Hea 04 Microbial contamination	1		0.0 %	N/A			
Hea 05 Acoustic performance	2	2	1.6 %	N/A			
Hea 06 Safe access	0		0.0 %	N/A			
Hea 07 Natural Hazards	1		0.0 %	N/A			
Hea 08 Private space	0		0.0 %	N/A			
Hea 09 Moisture protection	3		0.0 %	Good			
Total performance health & wellbeing	**19**		**8.7 %**	Credits achieved: 11			
ENERGY							
Ene 01 Energy efficiency	12	9	6.8 %	Outstanding			Energy label C. Cross check if that works for ZEB O. How much should it be
Ene 02 Energy monitoring	3	1	0.8 %	Outstanding			
Ene 03 External lighting	1		0.0 %	N/A			
Ene 04 Low and zero carbon technologies	2	2	1.5 %	Outstanding			
Ene 05 Energy efficient cold storage	0		0.0 %	N/A			
Ene 06 Energy efficient transportation system	2	1	0.8 %	N/A			Not sure about the transportation system
Ene 07 Energy Efficient Laboratory Systems	1		0.0 %	N/A			
Ene 08 Energy efficient equipment	2	2	1.5 %	N/A			
Ene 09 Drying space	0		0.0 %	N/A			
Ene 23 Energy performance of building structure and installations	2		0.0 %	Excellent			
Total performance energy	**25**		**11.4 %**	Credits achieved: 15			
TRANSPORT							
Tra 01 Public transport accessibility	3	1	1.1 %	N/A			
Tra 02 Proximity to amenities	1		0.0 %	N/A			
Tra 03 Alternative modes of transport	2	2	2.2 %	N/A			
Tra 04 Maximum car parking capacity	2		0.0 %	N/A			
Tra 05 Travel plan	1		0.0 %	N/A			
Tra 06 Home office	0		0.0 %	N/A			
Total performance transport	**9**		**3.3 %**	Credits achieved: 3			
WATER							
Wat 01 Water consumption	5		0.0 %	Very Good			
Wat 02 Water monitoring	1		0.0 %	N/A			
Wat 03 Water leak detection and prevention	2		0.0 %	N/A			
Wat 04 Water efficient equipment	1		0.0 %	N/A			
Total performance water	**9**		**0.0 %**	Credits achieved: 0			

MATERIALS								
Mat 01 Life cycle impacts	7	3	3.7 %	Outstanding			
Mat 01 Life cycle impacts - Criteria 1	Yes/No	Yes	-	Outstanding			
Mat 03 Responsible sourcing of materials	3	3	3.7 %	Outstanding			
Mat 03 Responsible sourcing of mat. - Crit 1.	Yes/No	Yes	-	Outstanding			
Mat 05 Designing for robustness	1		0.0 %	N/A			
Total performance materials	**11**		**7.4 %**	Credits achieved: 6			

WASTE							
Wst 01 Construction waste management	3	0	0.0 %	Excellent			
Wst 02 Recycled aggregates	1	0	0.0 %	N/A			
Wst 03 Operational waste	1		0.0 %	Very Good			
Wst 04 Speculative floor and ceiling finishes	0		0.0 %	N/A			
Total performance waste	**5**		**0.0 %**	Credits achieved: 0			

LAND USE & ECOLOGY							
LE 01 Site selection	3		0.0 %	N/A			
LE 02 Ecological value of site and protection of ecological features	2	2	2.0 %	N/A			
LE 04 Enhancing site ecology	3		0.0 %	N/A			
LE 05 Long term impact on biodiversity	2	0	0.0 %	N/A			
LE 06 Building footprint	0	0	0.0 %	N/A			
Total performance land use and ecology	**10**		**2.0 %**	Credits achieved: 2			

POLLUTION							
POL 01 Impacts of refrigerants	3	3	1.8 %	N/A			Not sure
POL 02 NOx emissions	3	3	1.8 %	N/A			
POL 03 Surface water run-off	5		0.0 %	N/A			
POL 04 Reduction of night time light pollution	1		0.0 %	N/A			
POL 05 Noise attenuation	1		0.0 %	N/A			
Total performance pollution	**13**		**3.7 %**	Credits achieved: 6			

EXEMPLARY LEVEL AND INNOVATION (max 10 credits)							
Inn 01 - Man 05 Aftercare	1	1	1.0 %	N/A			
Inn 02 - Hea 02 Indoor air quality	1	1	1.0 %	N/A			Not sure
Inn 03 - Tra 03 Alternative modes of	1	0	0.0 %	N/A			
Inn 04 - Wat 01 Water consumption	1		0.0 %	N/A			
Inn 05 - Mat 01 Life cycle impacts	2	2	2.0 %	N/A			
Inn 06 - Mat 03 Responsible sourcing of materials	1		0.0 %	N/A			
Inn 07 - Wst 01 Construction site waste man.	1		0.0 %	N/A			
Inn 08 - Wst 02 Recycled aggregates	1	1	1.0 %	N/A			
Inn 09 - Approved innovation credits	10		0.0 %	N/A			
Total indicative environmental section performance	**10**		**5.0 %**	Credits achieved: 5			

Appendix 8 :Norwegian Co_2. taxes, 2019 (Norway BRA UNFCC 2020)

Table 4.2 Norwegian CO_2 taxes 2019

	Tax rate NOK/litre, NOK/kg or NOK/Sm^3	Tax rate NOK/tonne CO_2
Petrol	1.18	509
Mineral oil		
- Standard rate, light fuel oil	1.35	507
- Domestic aviation	1.30	510
- Fishing inshore waters	0.29	109
Domestic use of gas		
- Natural gas	1.02	513
- LPG	1.52	507
- Reduced tax natural gas[1]	0.06	30
Petroleum activities on the continental shelf[1]		
Light fuel oil	1.08	406
Natural gas	1.08	462
- natural gas emitted to air	7.41	462

Sources: Ministry of Finance and Statistics Norway

[1] Most of these emissions are also covered by the EU ETS.