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The Potential of Voluntary Sustainability Class to Leverage Sustainability in the Danish Construction Industry

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Abstract: As Denmark seeks to be a pioneering country in terms of sustainability, the voluntary sustainability class, also known as the frivillige bæredygtighedsklasse (FBK) in Danish, is the most recent initiative from the political and industrial sides to leverage more sustainability into the construction industry. Currently, there is an ongoing test period for FBK to obtain industrial experience and acquire feedback on the provisions and whether they fit the industry level. The intention is to investigate the possible integration of minimum requirements within the Danish building legislation. This paper will present the first results of a field research study of the potential of FBK within the Danish construction industry. The study adopts a qualitative comparative approach through triangulating knowledge obtained from literature reviews, the result of an actual studied case - a daycare institution in the test phase of FBK (located in Malling, Aarhus Municipality, Denmark) - and five semi-structured interviews. The interviews were conducted with professionals who were carefully selected based on their work with FBK while ensuring a nuanced picture of different working roles with FBK. It is concluded that the early design integration (i.e., the outline and project proposal) is very crucial for the final project outcome. The case study shows that the provisions need initial consideration in the design phase, as many key elements are decided here to avoid redesigning solutions later to accommodate the requirements of FBK. Further research can be carried out, exploring the final form of the provisions in the main project to investigate the development process through the design phase.

***Keywords*:** sustainable construction, voluntary sustainability class, early design integration, building certification systems, Danish building regulation

1. Introduction

There is an urgent need for studies to fill the existing gaps, given the suppressed demand for construction, which could have serious environmental impacts [1, 2]. Over the past years, Denmark's construction industry has paid more attention to sustainable construction [3]. In recent years, there has been a joint interest from the political and industrial perspectives to increase the level of sustainability in the industry. Denmark seeks to be a pioneering country in sustainability. Due to that, in 2020, the Danish Transport, Construction, and Housing Authority introduced the voluntary sustainability class, also known as the frivillige bæredygtighedsklasse (FBK) in Danish [4]. FBK is the most recent initiative to push the development of the construction industry towards an environmental transformation.

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The Danish government [2] considers FBK a central element in the green transition of the construction industry and a necessity if the target goals of 2030 and 2050 are to be reached. In recent years, building certification systems have been the early basis for constructing sustainable buildings [5]. They contributed a framework with a more systematic procedure for the actors to operate on a common platform. However, the certifications are generally considered a solution for larger buildings and more ambitious building projects. In contrast, the current state of certification is found inappropriate for regular and smaller building projects due to the additional cost and extensiveness of documentation requirements [6]. Thus, FBK was introduced as an easily assessable and uniform basis to work towards sustainability as a supplementary element to the current Danish Building Regulation 2018 (BR18) [7]. FBK is the most recent initiative to explore the minimum requirements that new construction must abide by to accommodate a more sustainable industry. However, FBK must undergo a test phase to see whether or not the requirements can be implemented in the building regulations (BRs) for Denmark. This includes a test period pivotal to determining the industry level moving towards 2023. Based on the test period, the first provisions are intended to become law in 2023. This political initiative reflects Denmark's ambition for sustainable construction through the national sustainable construction strategy to lower greenhouse gas emissions.

As has already been expected, this paper hypothesizes that there is considerable potential to increase and improve sustainable construction through FBK. From this perspective, the two main objectives of the current study are to investigate: (1) the FBK's potentials and barriers in the Danish construction industry; and (2) the role of political and industrial responsibility in its implementation. The proposed research will contribute at a theoretical and empirical level. This will provide an enhanced understanding of the Danish construction industry's FBK. The study will focus on the implementation of FBK into the life cycle of construction projects, integration of FBK into the BR, and investigation of FBK versus certification systems as well as actual building projects. This research aims to identify the potential of leveraging more sustainability in the construction industry by integrating the potential of FBK provisions into the current industry level. In comparison to conducting the test phase for the industry, it helps to acquire experience and prepare for the minimum sustainability requirements in the upcoming BR. Furthermore, it seeks to examine the prospective outcome of early integration into the design phases from a more holistic and long-term perspective.

2. Background

2.1 *Sustainability in the construction industry*

An unambiguous definition of sustainable construction and its components has yet to be established in the construction industry. As a result, recent years have seen efforts by the industry and researchers to fundamentally understand sustainability and develop a common understanding for working with sustainable construction. One crucial aspect of this is bridging the gap between industry, research, and political establishments to ensure that everyone is working towards the same goals in the transition to sustainable construction.

The Brundtland report in 1987 [8] is often considered the first reference for sustainable construction. The authors identified that current resource consumption could not be compromised to the disadvantage of future generations. Furthermore, the report presented the first framework to describe what sustainability should include, known as the triple bottom line (TBL), which incorporates social, economic, and environmental factors. The framework took a more holistic approach to the term "sustainability" by incorporating not only the obvious environmental means but also the social and economic dimensions to establish the sustainability trinity.

The three areas are correlated and must be used about one another. Thus, there must be a balance between these areas to obtain true sustainability. However, the correlation between the two areas frequently contradicts each other; if environmental sustainability improves, it may not be sufficient from an economic standpoint. Therefore, a trade-off between the areas will be present when using the TBL framework to determine sustainability. In addition, the TBL must be included in a broader paradigm shift towards a more holistic mindset that considers all three dimensions from a long-term perspective. This requires a comprehensive approach that evaluates the optimal solution for each situation rather than relying on obvious and intuitive solutions. Such an approach involves a thorough decision-making process that provides a more informed basis for sustainable design and project foundations. This also involves adopting a more systematic approach with greater transparency and traceability of solutions and decisions in the early stages of a project.

Studies have shown that making decisions early on in the project is less costly and demanding and can impact the initial decision-making process while defining the project more effectively [9]. By doing so, the project is defined to a higher degree and can better mitigate changes, ultimately decreasing the importance and cost of implementing additional solutions, as shown in Figure 1. This results in a more integrated process that provides a solid foundation for sustainable development.

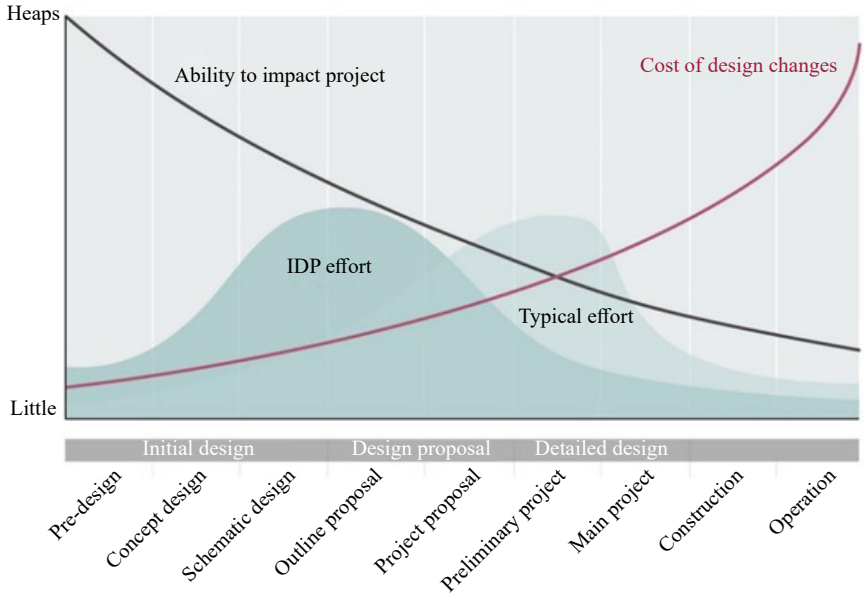


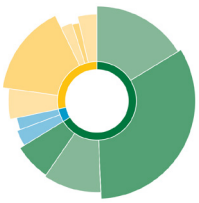
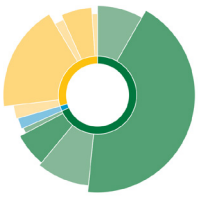
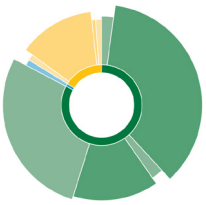
Figure 1. Decision impact and cost through project stages in integrated design process (IDP) [9]

2.2 *Sustainability certification systems in the construction industry*

Over the past years, certification systems for buildings have been the initial step in constructing sustainable buildings and, to some degree, dealing with the abovementioned issue. The certification systems have put sustainable construction into a more manageable process, gathering all the necessary work in one framework to ensure sustainability is represented throughout all the project stages.

Today, many different building certifications are available worldwide, with some being more frequently used than others depending on the national context. For instance, Leadership in Energy and Environmental Design (LEED) from the United States of America and Building Research Establishment Environmental Assessment Methodology (BREEAM) from the United Kingdom are the most well-known sustainable building certification systems worldwide. These two were also the first original building certification systems presented in the 1990s and are the most widely applied globally, based on their recognition from an international perspective. However, there is no explicit certification to be used, hence why many countries or regions use the certification systems that best fit their BR, norms, and traditions. This implies that the certification system may be adjusted to fit the national context better, which is the case in Denmark with the Deutsche Gesellschaft für Nachhaltiges Bauen Denmark (DGNB-DK). Closely related to Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB) is the Nordic Swan certification system, which has its origin in and focuses on the Nordic countries [10]. The different certification system's focus points and how the scoring system is formulated and rewarded have been summarized in Table 1.

Table 1. Certifications focus summary [10]

	BREEAM	LEED	DGNB	Nordic Swan
Focus areas, criteria or qualities	• Management • Health and well-being • Energy • Transport • Water • Materials • Pollution • Innovation	• Location and transportation • Sustainable sites • Water efficiency • Energy and atmosphere • Material and resources • Indoor environmental quality • Innovation • Regional priority	• Environmental quality • Economical quality • Social quality • Technical quality • Process quality • Area quality	• Energy and resources • Indoor environment • Materials and chemicals
Score system	Score points 0 to 100%	Score points 0 to 100%	Score points 0 to 100%	Pass or fail
Certification level or award	• Outstanding • Excellent • Very good • Good • Pass • Acceptable	• Platinum • Gold • Silver • Certified	• Platinum • Gold • Silver	• Nordic Swan eco-label
Certification fees (Danish Krone [DKK])	8.200 to 3.500	3.150 to 200.000	18.500 to 550.000	11.000 to 250.000
		Sustainability focus categories		
Environmental	66%	68%	33%	83%
Economic	5%	2%	30%	1%
Social	29%	30%	37%	16%
				

LEED, BREEAM, and DGNB are currently considered most useful for larger building projects due to the extensiveness of documentation required. The expenses of certification are more likely to be justified in a larger project due to the size and ambition of the building and the coherence of the economy. The Nordic Swan is most applicable to houses and residential construction, as it focuses on toxicity and material quality, which unfamiliar consumers of construction are more familiar with. In this paper, DGNB and Nordic Swan will be the primary focus, as they are the most frequently used systems in the Danish construction context and are closely related to FBK.

2.3 *FBK*

FBK was first presented on 29th May 2020, by the Danish Housing Ministerial as an optional additional element to the current BR18 [7]. The ambition of FBK, as stated by the Danish Transport, Construction and Housing Authority, also known as Trafik-, Bygge- og Boligstyrelsen (TBST) in Danish, is to formulate and provide an easily accessible and uniform foundation for sustainable construction. Furthermore, it includes all three dimensions of sustainability to build a holistic mindset of circularity in sustainable construction [4]. In the main publication about FBK, the following is stated about the goal and ambition of FBK: *"The long-term goal is to introduce requirements for sustainability in the BRs on a*

well-tested and documented basis, with broad involvement of the construction industry".

The experience obtained from the FBK projects will be evaluated to determine if the provisions can be implemented in BR or will need adjustments. Thus, FBK is intended to be a further addition to the building legislation in Denmark. The establishment of FBK will not affect the current requirements in the BR, but where necessary, it will be built upon them. FBK includes nine provisions similar to those currently in the Danish BR [4]:

a. Lifecycle assessment - the total environmental impact of a building.
b. Resource efficiency on the construction site.
c. Total cost-of-ownership analysis - expenses for construction, operation, and maintenance.
d. Plan for the operation and maintenance of the indoor climate.
e. Documentation of problematic and toxic materials.
f. Degasification of the indoor environment.
g. Detailed calculation and documentation of the daylight factor.
h. Noise from ventilation systems in housing (only for housing).
i. Room acoustics in housing (only for housing).

The provisions cover all three aspects of the TBL regarding social, economic, and environmental sustainability to reflect a holistic mindset. FBK has a two-year test phase, which is important to explore the level of sustainability in the industry and the possibility of adjusting the requirements. Furthermore, it enables clients, consultants, and contractors to try out the requirements to obtain experience while providing feedback on the class. In contrast to the current building certification systems, the voluntary sustainability class seeks to implement the BR in 2023. Thus, it is not an optional commercial system awarded with a certificate but rather one with mandatory minimum requirements to obey building legislation.

3. Research methodology and data collection

The research methodology used in this paper has a theoretical framework with a systematic approach based on applying qualitative comparative analysis (QCA) with the triangulation approach. The QCA method is applied to triangulate the three sources of knowledge, namely, the conducted literature, the performed interviews, and the examined case study [11, 12]. The QCA is used in the research when there is insufficient data to consider the coherence between the literature, interviews, and the case study.

3.1 *Interviews*

The interviews performed have been used to collect data on different opinions and experiences of FBK in its current state. The interviewees were carefully selected based on their relation to FBK while ensuring a nuanced picture of different working roles with FBK. Interviewees from the authorities, clients, and consultants (including engineers and architects) are present in five interviews conducted as semi-structured:

a. Danish Transport, Construction, and Housing Authority, Denmark
b. Department of the Built Environment (BUILD), Aalborg University, Denmark
c. Aarhus Municipality, Aarhus, Denmark
d. Gjøde & Partnere Arkitekter, Denmark
e. RUBOW Arkitekter, Denmark

It has been an essential part of the analysis to have a broad perspective on the interviewees; hence, the diversity of working roles has been prioritized to reinforce the study. The number of interviews also sets the boundaries of the extensiveness of the analysis. It would have been possible to perform more interviews and more extensive analysis. However, these interviewees have been prioritized to examine the potential of FBK.

3.2 *Case study*

The project is a daycare institution located in Malling, Denmark, as part of the Aarhus Municipal Authority's strategy to meet the demand of an increasing population, reflected in the number of childcare institutions. The project participates in the test phase of FBK, intending to test the expected upcoming requirements for the indoor environment

and sustainability, and as part of Aarhus Municipality's governmental strategy to support the sustainable transition of construction. The project period is expected to be from September 2020 until May 2022, with the construction period expected to begin in June 2021. The client in the project is Aarhus Municipality, and the consultant is an architect, as seen in Figure 2. The separate work contractors are yet to be decided, as a complete construction project is required before the tender stage.

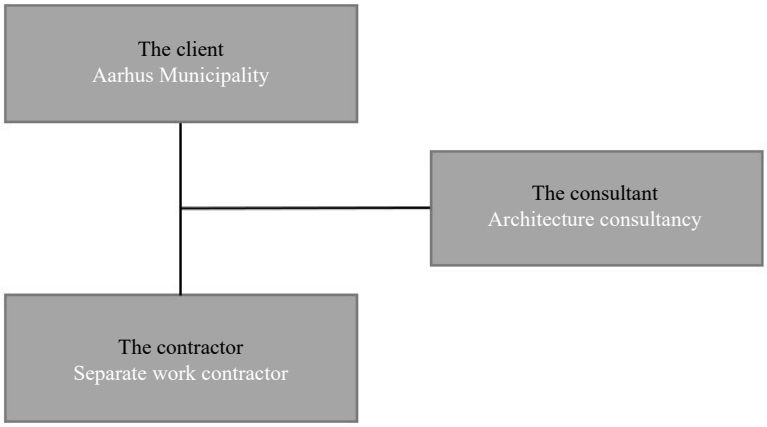


Figure 2. The overall organization of the case study project

4. Data collection

Overall international strategies with common targets to reach sustainability in the construction industry and their associated general guidelines related to the United Nations Sustainable Development Goals (UN SDGs) are the basis for the most recent development of the Level(s) framework in Europe [13] and so in Denmark. The Level(s) intends to streamline the documentation and measurement methods of sustainable construction in European countries. Thus, core indicators and metrics have been developed to measure the sustainable aspect of the building to create a common European language within sustainable construction. Level(s) was tested on 130 projects across 21 countries, based on three levels of documentation.

- Level 1: Minimum assessment
- Level 2: Comparison
- Level 3: Optimization

During the test of Level(s) in Denmark, the test panel found that the different levels of Level(s) must not be locked in place. Instead, it should be possible to switch between the three of them during the progression of the construction. Furthermore, as tests were performed, there was broad agreement among the participants that the manual should be rewritten into a more straightforward and comprehensible version [14]. The Level(s) framework can improve sustainability by considering it from a broad perspective to accommodate a common understanding across borders. In Denmark, BUILD was responsible for the evaluation of Level(s), which provided promising and challenging aspects related to Level(s), as summarized in Table 2.

Table 2. Evaluation of Level(s) in Denmark, summarized from [15]

Promising	Challenges
Futureproof building by following European standards and norms of sustainability, including performance improvement and increased focus on building materials.	The framework requires extensive experience and knowledge in sustainable design and construction (e.g., doing DGNB).
Suitable for different levels of ambition and available resources across multiple nations.	The lack of independent third-party control may compromise credibility.
Less demanding than a building certification while still ensuring minimum requirements in terms of sustainability.	The holism of sustainability lacks social sustainability and is not present throughout.
Establish a common European vocabulary and platform to communicate across member states and standards.	The system cannot be used for direct benchmarking across Europe due to differences in national laws, standards, methods, and climatic conditions. Thus, it could require a national adjustment of the framework or a division into different zones.
Establish benchmarks at the national level, enabling comparisons both nationally and internationally.	Resource demand, especially from gathering data at levels two and three.
Creating a more operational framework with targets to reach, to-do lists, checklists, etc., in a uniform manner with a high degree of freedom.	The absence of benchmarks and freedom of choice makes the comparisons more difficult.

The Danish work in terms of sustainability must have been reflected hereof, and thus the FBK intent was set to reflect the Level(s) framework primarily. Especially in terms of analysis for life cycle assessment (LCA) or life cycle costing (LCC), their methodology, procedure, and what was included in the scope of the study was considered crucial, enabling comparable results in Denmark with other European countries. In this regard, interviews with TBST indicated that it is essential for Denmark not to differentiate too much from the European perspective and should instead seek inspiration. This enables Denmark to be more valuable in the international picture, with the possibility of obtaining an interest. This could be in terms of industry level with related work and suppliers, and from a research perspective, Denmark could be a leading force.

Furthermore, FBK is also reflected in previous experience working with BRs as well as sustainability certifications such as DGNB and Nordic Swan, which were adjusted to fit the Danish construction culture and represent the European mindset. They are considered an important part of developing FBK requirements, as they have been used as the basis for working with sustainability in practice. Hence, those are the most reliable in-practice experiences, which were combined with initiatives such as TBL and Level(s), among others, to reflect the current state of sustainable construction into FBK.

4.1 *Integration of FBK vs. BR*

As mentioned earlier, there is currently an ongoing test period for the FBK to obtain industrial experience and acquire feedback on the provisions and whether they fit the industry level. The idea of a test period came up because the general conditions of the industry were not considered sufficient in terms of working with sustainability in practice. FBK intended to prepare the industry for this change in a slow and controlled manner by signaling to the industry what the future requirements would entail. In this view, the interviews conducted were geared towards determining how the industry can prepare itself and act adaptively to develop its products and processes for change in the coming years. The previous low-energy class has been the inspiration for this, as it has succeeded in formulating the requirements in advance to give the industry an incentive to prepare for the new requirements that will come. In this way, not only those currently working with DGNB but also those working only with conventional construction are motivated to explore what is coming.

The test period is relatively short, only two years, which is not the case for many construction projects. However, this was deemed necessary because time is needed thereafter for evaluation and some policy review of the cases. Ideally, the test phase should last five to seven years and consist of new projects that consider all phases of pre-design, design, construction, and operation, including time for subsequent evaluation. However, since this was not possible, the short test phase, which included various projects of different types and in different phases, was considered sufficient to cover the nine provisions.

The nine provisions of the FBK (as presented in Section 2.3) are equally important. However, some of the

provisions include more aspects that were considered new to the industry, e.g., FBK 1 to 3 on LCA, LCC, and on-site consumption measurements. Meanwhile, FBK 4 to 9 are often already present in the current BR standards and are seen more as an increase in requirements. So, the experience with LCA and LCC, in general, will be new, and therefore, it is crucial to know how the industry reacts to it as future mandatory requirements will come soon in 2023.

4.2 *Integration of FBK vs. certification systems*

The FBK is the first step in establishing minimum requirements for ensuring the green transition. Since the FBK method is relatively new, the current test phase will be used to test the requirements stated in the regulations to determine a sufficient requirement level. Thus, after the test phase is completed, the provisions will be adjusted depending on whether the requirements are found too rigid or too loose before they are made mandatory. In addition, it is also important to note that FBK and certification have different purposes and objectives in sustainable construction. The FBK is an addition to the current BR18 that aims to bring sustainable requirements into BR based on specific provisions that include requirements directly related to sustainability from one of the three TBL perspectives.

The certification system differs from the FBK primarily in that it is an optional solution that can be opted for if a certain level of suitability of the building must be met by certification. A key parameter for certification is the additional value it adds to a building because certification involves additional costs in the form of registration fees and requires more work through extensive documentation. This aligns with the conclusions from the studied case as well. Therefore, it must be economically attractive for the building owner to certify a building, as the additional costs must somehow be recouped. Certification can represent financial value through better quality materials and better futureproofing, using building certifications as an indicator of quality and desired performance. In addition, risk mitigation and long-term economic stability of value can be based on the analysis of LCA and LCC, which makes building certification attractive to clients and building owners [16].

DGNB and Nordic Swan are the most commonly used from a Danish perspective, as they seem to fit the Danish construction industry best. The Nordic Swan is the certification system of the northern countries, which is also very consumer-oriented as the certification goes beyond the building. Both organizations are non-profit and thus do not have commercial systems [17]. DGNB was selected as the primary certification system in Denmark based on the evaluation of four certification systems by both industry and policymakers.

FBK is nowhere near as comprehensive as DGNB or Nordic Swan, as the certification system includes a variety of requirements that involve the whole building from different perspectives. However, FBK addresses several areas of the certification systems, especially the criteria with a higher weight. This is also in line with FBK's ambition, as it should be an ambitious path with manageable and simple procedures. Table 3 in the following presents the similarities and relationships between the nine provisions of FBK and the two certification schemes.

Table 3. FBK's relation to DGNB and Nordic Swan

	DGNB	Nordic swan
FBK1	The overall intentions are similar. However, they diverge in terms of FBK-LCA, which includes more construction phases, while DGNB-LCA factors in the uncertainty of using generic data above EPD.	There is no requirement for LCA analysis. However, environmental requirements are present in terms of materials that must be more energy-efficient than those stated in BR18, for which an LCA is obvious to use.
FBK2	The score point is obtained for efficiently managing waste on-site in DGNB. The method and procedure are the same in DGNB as in FBK2. However, water consumption is not included in the DGNB.	The separation of waste by material type and quantity follows the same procedure. However, the Nordic Swan also rewards more points if materials are reused. The Nordic Swan is not concerned with transportation, energy and water consumption, or waste.
FBK3	DGNB has similar requirements for TCO of components as FBK. However, the DGNB-LCC also requires a TCO for the entity of the building.	There are no criteria that concern LCC and TCO considerations.
FBK4	DGNB points are awarded if operation and maintenance plans are delivered similarly to what is described in FBK4.	There are similarities between the operation and maintenance plans of FBK and Nordic Swan. However, Nordic Swan only requires that an optimal indoor environment be maintained, and it does not specify what this includes.
FBK5	Problematic substances must be documented in both DGNB and FBK. FBK5 does not include a reference value that must be obtained. In comparison, DGNB goes beyond the current legislation to have even further strict requirements.	Similar to the statement of DGNB. Nordic Swan goes far beyond the legislation and comes with a reference value.
FBK6	Degasification and TVOC must be documented before the commissioning of both DGNB and FBK. However, DGNB has more extensive requirements for the individual VOCs, whereas FBK only measures the total VOC of the indoor air.	The Nordic Swan does not contain requirements related to TVOC or VOC.
FBK7	Compliance with the FBK7 requirement of daylight also entails compliance with DGNB when using the 300 Lux method.	Compliance with the FBK7 requirement of daylight also entails compliance with the Nordic Swan using the 300 Lux method.
FBK8	DGNB does also include a sound requirement for technical installations. Thus, compliance of FBK8 with the sound of the ventilation system also entails compliance with the DGNB requirement, i.e., that other technical does not exceed the same sound requirements.	The Nordic Swan's requirements in terms of sound are twofold. For once, it must comply with sound class B of DS 490:2018 in terms of the ventilation system's sound. The second part requires the room acoustics of living spaces in sound class B. Compliance with the two is equivalent to FBK8 and FBK9.
FBK9	Similar requirements for DGNB are found in what is prescribed in FBK9.	The Nordic Swan's requirements in terms of sound are twofold. For once, it must comply with sound class B of DS 490:2018 in terms of the ventilation system's sound. The second part requires the room acoustics of living spaces in sound class B. Compliance with the two is equivalent to FBK8 and FBK9.

Note: TCO = total cost of ownership; EPD = environmental product declaration; VOC = volatile organic compound; TVOC = total volatile organic compound; and DS = Danish standard

As seen in Table 3, most of the FBK requirements are directly related to the DGNB and the Nordic Swan, and minor aspects differ. One common feature is the underlying purpose of the Danish design, which is to provide a better-documented project. Comparing the requirements of FBK and DGNB shows:

- Compliance with FBK1 entails the most DGNB points, especially as additional points are obtained from the early integration of LCA in the design phases.
- There is a potential to acquire more points in DGNB from more extensive use of LCC in FBK3.
- Compliance with FBK5 does not entail any points in the DGNB score, even though it has requirements to deliver documentation of problematic substances.
- FBK6 does not entail any further points to the DGNB, as the measurement method of the DGNB is more comprehensive.
- FBK8 does not contribute many score points for DGNB as the requirements go beyond the ventilation system to include all technical installations.

The Nordic Swan receives points from BR18 for the mandatory and optional criteria, and the FBK totals nine points. The minimum requirement for Nordic Swan certification is 17. In addition, some of the Nordic Swan requirements can be improved by including FBK, e.g., daylighting. Thus, working with FBK in parallel can increase the overall sustainability level of the building. The comparison of the requirements of FBK and Nordic Swan shows:

- FBK1 can entail an obligation to use LCA in the Nordic Swan certification to contribute with analysis to reach the requirement of 10% better energy consumption than what is stated in BR18.
- FBK3 (LCC) and FBK5 (problematic substances) are not considered in the Nordic Swan. Incorporation hereof could contribute to an overall increase in sustainability level.
- FBK4 can potentially increase the Nordic Swan as it requires a more detailed description of maintaining a good indoor environment.
- FBK7 can benefit from the Nordic Swan requirement with a more detailed method description.
- FBK8 and FBK9 must be fulfilled to obtain points in the Nordic Swan from sound requirements.

The commonalities can help FBK achieve a higher score in DGNB or Nordic Swan, but FBK compliance can be the entry point to obtaining building certification. DGNB 2020 has formulated requirements that relate directly to the FBK methodology [18].

The FBK class concerns 10 out of the 37 main DGNB criteria if the building type is residential. The results may differ slightly for offices and daycare centers (as was the case for the daycare project studied in this paper), as they have different requirements for daylighting, noise and acoustics, ventilation systems, etc.

4.3 *Integration of FBK vs. the case study*

4.3.1 *The client's perspective*

The sustainability requirements within the project must align with the overall municipality strategy in terms of the responsibility of the client's manager (Aarhus Municipality; see Figure 2). The client seeks to integrate as many of the requirements and wishes as possible into the project description and the Description of Service, also known as the Ydelsesbeskrivelse (YB) specification, which are the basis for the consultant's work. Furthermore, as part of the municipality's strategy, rather than making one section about sustainability, the term should be reflected in sections and sub-sections where it is relevant.

In general terms, the client is responsible for signing up the project for the FBK test. However, the consultant bears this responsibility for the given project, which is agreed upon in the contract. The consultant must provide all the documentation for the evaluation of FBK while also delivering all materials, such as calculations, data measurements, datasheets, etc., to the authorities and informing and delivering them to the client.

The motivation to integrate FBK into the project is to promote sustainable construction in Denmark, and in this case, to have a leading example in Aarhus Municipality. Furthermore, the environmental aspect should ensure a high-quality building with an excellent indoor environment that provides health and well-being for the users. Thus, the building should reflect sustainability's social, environmental, and economic perspectives by having a more holistic perspective, focusing on materials, recycling and reusability, operation and maintenance, and the end-of-life perspective. All of this is expected to be reflected in the seven requirements of FBK, as the project does not consider FBK8 and FBK9 since these are only direct provisions for housing. However, the noise from the ventilation system and the room's acoustics must still comply with the BR18 requirements.

4.3.2 *The consultant's perspective*

Based on the project descriptions and the client's requirements and wishes, the consultant is responsible for signing a project and fulfilling these for the client. The consultant is responsible for the building design that meets the client's expectations and stays within the budget framework (DKK 14 million for the studied case). According to the contract agreement, the consultant will provide full-service consulting and is responsible for the services beyond that. This includes engineering work on the structural system, ventilation, plumbing, electricity, energy, and public utilities. Throughout the project's design development, they must be presented and reflected in the outline and the project proposal, which is the project's current state.

Sustainability and FBK are incorporated in the combined conceptual design and outlined proposal as agreed upon in the YB description. The outline proposal contains the initial description of the prerequisites, the architectural idea, functions, suggestions for the overall choices of materials, design and installation principles, and considerations about operation and maintenance. Therefore, the initial thoughts of how to comply with FBK must be presented to the client at the proposal phase, with the following plan of when or how it will be incorporated. The consultant must also plan three

user meetings presenting the sustainability aspects of the building, the last one just before the building is commissioned.

4.3.3 *Overview of the case study*

The integration of sustainability and FBK is reflected in the current project material as an integrated part driven by the client's objective (Aarhus Municipality). The client's effort to write its requirements in the project description and YB specification is successfully transferred to the consultant's initial design in the outline proposal and project proposal. Table 4 summarizes the current state of incorporating the seven FBK provisions into the project.

Table 4. FBK's integration summary into the project

FBK provision	Summary of current work	Comments	Status
1. LCA	The core building materials are decided to be wood with wooden construction to ensure structural stability.	The initial LCA was made for the current building and developed throughout the project's development. The final LCA will be made based on the initial LCA and will occur during the construction project.	Initial: Completed Final: In progress
2. Resource consumption on site	The resource consumption is only based on the current LCA, which must be updated with resource consumption as the project develops.	The water and energy consumption must be measured on-site during the construction. Transportation must be estimated whenever possible. The amount of construction waste must be assessed and reported to the LCA.	In progress
3. LCC	The analysis of the three required variants has been completed.	The results of the material selections for the three variants can be found in the project proposal. The final LCC report will be updated and delivered with the remaining documentation.	Completed
4. Indoor environment operation and maintenance plan	Preliminary considerations regarding the indoor climate have been performed, including the initial energy framework calculation. An operation and maintenance plan must be made based on initial considerations.	The heating principle of rooms is decided. Ventilation calculation has begun. Sun protection is included in the design. The lighting concept has been prepared.	In progress: It will be final in the tender phase
5. Documentation of problematic substances	As far as possible, the use of problematic substances is avoided. The focus during the design phase has been to exclude materials from the candidate list.	There will be an ongoing focus on problematic substances throughout the project's development. Furthermore, this documentation will be written as a prerequisite for the contractors.	Not started. The expected start is at the tender stage
6. Degasification of the indoor environment	The design has limited the use of materials with high contents of formaldehyde and TVOC. During the design, DGNB recommendations have been used as a reference point.	The initial analysis will be used when preparing work descriptions for the contractor. However, as the measurement requirement for FBK6 includes furniture, this should be considered when choosing the furniture.	Soon to start
7. Daylight simulation	The initial demonstration of the daylight level based on the BR18 10% rule has been completed. The hourly simulation based on the FBK7 is still pending.	The engineer responsible for daylight has yet to complete the final simulation. However, the simulation is planned to be performed.	In progress

The incorporation of FBK into the project has begun, with the project's development needing to fulfill the requirements. However, having all seven provisions included in the design proposal is essential to maximizing the total value potential and achieving better results. The next step of the project is to complete the design specification with the development of the preliminary project and main project before the client can enter the tendering stage. The FBK provisions will continue to develop throughout the remaining design, construction, and in-use phases.

4.4 *Integration of FBK with the life cycle of building projects*

Part of the evolution of building dynamics is that engineers and architects are using suitability as a design criterion for the client to choose sustainable solutions that meet future energy needs. Therefore, integration into the early design phases begins with the inclusion of this change in the contractual agreement. The client and its consultants should clearly describe their sustainability requirements in the project documents based on a reference study period (RSF)

to consultants and further specify the deliverables in the project description. In this regard, interviews conducted indicated that sustainability requirements should be included throughout the project materials so that the design team can incorporate the client's needs into the project's design. Likewise, relevant to the studied case, integrated work was considered necessary to bring the client and consultant together early on in the process for greater project gain. This can improve the case for long-term product considerations resulting from using LCA and LCC in the design and construction phases. This way, sustainability can be incorporated as a general building condition rather than being considered an additional service to the project. The presence of suitability through the four main phases is explained in Sections 4.4.1 to 4.4.4.

4.4.1 *Initial design*

The initial design refers to the project's overall purpose, which must be examined and cover the general conditions of the client's needs stated in the construction program, in which the project intentions are specified. The initial design must include the general preliminary decisions and solutions as a basis for the preliminary and concept designs. Therefore, in the initial design phase, close collaboration between the client and the consultants is necessary to meet expectations. Many different aspects and competencies need to be brought together to achieve the greatest benefit for the building, which requires the consultants to work in an integrated manner. The LCA and LCC can also be advantageously started in this initial phase based on the core structure and materials to give an initial idea of the building. In the project's initial phase, estimated quantities and general data can be used to analyze the initial design considerations for the building. It is still relevant to compare alternatives to determine the best general structure and materials for the building.

4.4.2 *Project design*

As the project progresses, more detailed descriptions of the structures and core materials are determined based on the initial engineering design, and the architect's thoughts are incorporated into the design proposal. This includes key decisions about the structural and major technical systems in the design proposal. This can then continue in the LCA and LCC as more details on materials emerge, models are updated, and project materials are revised in the project proposal. Materials selection is critical in the early design phase because it has the greatest potential for influence. The analysis of building materials is based on LCA and LCC, both in terms of the environment and the economic prospects of the building. Therefore, when you move to detailed design and preliminary engineering, the project design is also firmer, and major changes are no longer possible. Instead, material descriptions need to be very clear at the beginning of the main project design, including a very detailed description of materials with sustainable elements. During project design, the level of detail of the LCA and LCC analyses can be increased once the project materials are defined. Product-specific data on the materials can be included to provide a more accurate calculation of the environmental and economic impacts of the building. However, there is less room for change as the project approaches bidding, and changes are impossible or costly.

4.4.3 *Construction*

With the additional work put into the initial design phase, the construction phase should be reflected in the planning and management of the project. The value of more detailed and thorough preparation should reduce the number of project errors. As design should be more precise in the material description, constructability should also be better. Emphasis should be placed on monitoring materials that match those specified to avoid performance gaps. At the same time, the LCA and the LCC can be updated with product-specific data so that the design and the as-built condition match the actual building.

4.4.4 *In-usage*

When the building is completed and the commissioning is done, it can be evaluated whether the project goal has been achieved. In terms of sustainability, the final LCA of the building can be designed to reflect the actual

environmental performance of the building. This includes the final handover of the LCA to the FKB and the operation and maintenance plans, some of which are designed to ensure a satisfactory indoor environment.

The latter two phases' success often depends on the initial work's success, which is based on the contractual agreement and the project description and is the precursor to the project design. The project description and coherent documentation are essential for linking the designed and executed solutions. Documentation will be an important part of sustainable construction because it is clear evidence of the difference achieved and provides a guarantee of it. As experience grows, the convenience of products and documentation evolves with a broader choice of materials at a more affordable price, making the development of sustainable materials the new normal. This leads to the broader use of LCA and LCC as complementary tools to implement alternatives that meet the project's needs. This requires a shift from the industry's short-term mindset to the long-term value of the building for both the client, builder, and occupants, working with more sustainable materials and solutions throughout all stages of the project.

5. Discussion

5.1 *FBK's potential and barriers in the Danish construction industry*

The introduction of FBK has the effect of shifting more of the design work earlier in the design process. This is partly because the FBK1 provision of LCA requires initial consideration of LCA. Most importantly, critical project decisions must be made earlier, requiring a clearer project at the outset. Thus, as with many previous conventional construction projects, decisions cannot be made in the late stages of the preliminary and main projects because even minor decisions can impact the project in terms of the three sustainable aspects. This means that the early design phase is more crucial, as the consultants' initial work and analysis are used earlier to develop the project. A more comprehensive early design phase requires more documentation and description. That makes the final building more homogeneous, with higher material quality and a better indoor environment.

An obstacle in this regard is that the documentation is more extensive, materials are often considered more expensive, and there is less experience in the industry, which means that more risks must be factored into the price. These factors are unavoidable as the industry is in a transitional phase toward sustainable construction, which is constantly evolving. Part of that transition is working with vulnerable solutions, testing them, as FBK does, and seeing the impact. More design and consulting works need to be done as the development of sustainable solutions is integrated into the design of the building. Continuous development brings new materials and products to the market that differ in functionality, expression, and installation knowledge. In addition, the norms and standards that need to be addressed in projects are changing as the development continues. The new or alternative materials usually have other functions, such as sound, fire, or substances, that can affect the design, constrain the project, and unleash new solutions. An example of a limitation is often fire safety, as the latest materials are not yet included in the DS or International Organization for Standardization (ISO) standards. Liberation is when the product is more natural, contains fewer substances, or is more recyclable to improve the indoor environment or the quality of the building.

5.2 *Political and industrial responsibility for FBK's implementation*

The Danish government [2] formulates the National Strategy for Sustainability on how sustainable construction must develop nationwide in the coming years. This is the overall plan that the Danish Housing and Planning Authority follows, and further in TBST to ensure regional planning. These authorities are responsible for translating policy ambitions into formulations and initiatives that the industry can act upon. The government's policy strategy, published in the ministry, sets out the overarching goals and targets to be achieved, including 2030 and 2050 targets for developing sustainable construction and embedding it in the construction industry. Since BR, including FBK, set the general terms and conditions for the industry, municipalities are bound by them and must incorporate this into their internal plans and strategies. Individual municipalities can decide how ambitious they want to be in terms of sustainability, as long as they stick to the minimum targets set by the government.

If sustainable construction and FBK are to be successful, public and private sector participation is required. TBST has made it a priority to work with industry representatives, incorporate practical knowledge of the industry, and consider the many small and medium-sized enterprises in Denmark. When working on new areas, authorities can benefit

from industry representatives' practical knowledge and input. Thus, working groups, advisory boards, and technical committees are formed to ensure dialogue between the industry and the ministry. This is mutually beneficial as the industry gains insight into the ministry's legislation and goals. This way, both sides can raise their voices and influence each other on which direction to take in the current transition.

6. Conclusions

This research echoed the finding that integrating sustainability and FBK in the building and construction industry is beneficial for reaching more sustainable values and outcomes. However, it was highlighted that FBK provisions entail more decisions that must be made early in the design process. The studied case showcased how FBK could be applied in the outline and project proposal. Underlining the importance of the initial sustainability analysis, how they affect the design decisions early in the project, and how they are expected to be developed throughout the project. Furthermore, it found the importance of contractual agreements, as these can affect how most sustainability goals can be achieved.

In FBK's nine provisions, LCA and LCC are both relatively new to the construction industry. Using LCA and LCC analysis can help the decision-makers make early key decisions based on an informed basis. However, these are considered essential tools for continuous development in the industry, exploring sustainable alternatives and enabling comparisons of them. This is partly decisive to the change to more sustainable solutions, as they can indicate environmental impact and the TCO when combined. Combining them can lead to robust analysis and decision-making for the best scenarios or solutions in the given situation.

Construction projects are often driven by economic revenue, hence, why the additional cost of sustainability has been considered a barrier. However, as the industry finds itself in a transition period, an indication of the allocation of expenses in some cases is related to a lack of knowledge. Some materials are more expensive in terms of the acquisition cost, but cost parameters such as quality, lifetime, and durability can be more financially advantageous in the long run. Thus, as experience working with materials becomes convenient, it is possible sustainable construction can become price neutral. However, the correlation between quality obtained and delivered must be visible to the client following a change of mindset that values the long-term perspective.

An important limitation of this study is that, as the FBK is still within its current test phase, it could be relevant to conduct similar research when it reaches its final form in 2023. This includes further investigating the construction industry's application to have a bigger sample size of projects and how BUILD evaluates the test phase results. It could further influence how TBST formulates the requirements and how many of the provisions end up in the upcoming BR. Likewise, this could give an insight into how the development of the industry has been during the test period, following the expectations for the future.

Future work also concerns the conducted case study project in Malling, to include also the late stages of the design phase. As the period of this project has ended, the project's current state is the project proposal. The preliminary and main project is the next and final design phase before entering the tender stage. A further examination of how the sustainable initiatives end up in their final form during the design phase will show how successfully the FBK has been integrated into the project.

Furthermore, future research could include a more extensive investigation of the LCA potential and its general usage, as carbon dioxide (CO2) requirements, will be present from 2023 onward. This entails that the construction industry should consider a larger integration of LCA in practice to prepare and readjust for this change. This can be directly related to FBK1 with an initial and a final LCA. Thus, a continuation of the study could examine a deeper investigation of LCA usage and the content of the modules and required documentation.

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Conflict of interest

There is no conflict of interest in this study.

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