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Challenges in creating a sustainable building certificate for single-family housing in Denmark through an Actor-Network Theory (ANT) lens

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ABSTRACT

Voluntary certification schemes are a necessary driver for sustainable transition in the building industry. In Denmark, the primary scheme is DGNB with its holistic understanding of sustainability, rewarding environmental, social, and economic sustainability equally. The DGNB scheme, however, does not currently have a manual contextualized for smaller building projects with corresponding economies, such as single-family housing. This research article explores what is needed to create and diffuse a certification scheme for small-scale building projects on the Danish market. It explores how standardized building companies present a unique opportunity for entry as they comprise a substantial market share. It also explores how enrolling a new user-base comes with new challenges, such as marketing sustainable building to ordinary people, balancing the reduction of complexity and need for documentation with retaining impact, and overcoming the knowledge gap on sustainable housing. The ambition of the research paper is to map the field of sustainability certification in the Danish building industry and help make visible some of the challenges to support the process of developing a new sustainable certification scheme for single-family housing or further development of this research field.

1. Introduction

The building industry is currently facing a challenge to reduce its carbon emissions and limit its negative impact on the climate. Globally, buildings contribute with 39% of energy related carbon emission; operation makes up 28% and material use and construction 11% (World Green Building Council, 2021). New targets are set and sustainability initiatives, like for instance the New European Bauhaus (European Union, 2021), must rethink the way we build and live to achieve a sustainable future. A driver in the necessary transitioning of the building industry are voluntary sustainability schemes because they can push the development of more sustainable materials and practices by making their impact visible. The external costs (not only monetary) of a product or service are paid for by other actors than the manufacturer, for instance, fossil fuel intensive products have a socio-economic cost for their implication to public health as well as an environmental one (Callon, 1998). Sustainability certifications are one way of internalizing these costs by re-negotiating what counts (Çalişkan and Callon, 2010), and thus rewarding those endeavors that support sustainable development.

Currently the DGNB certification scheme, which is the primary sustainable building scheme in Denmark, is only targeting larger building projects; multi-story newbuilds and larger renovations, as well as buildings in use and urban areas. Larger building economies are necessary for the cost associated with delivering the documentation work and assessment. Naturally, small-scale building projects like single-family housing cannot participate on this scale, but the impact of such building projects is equally as significant and important to contain.

Recent data from Statistics Denmark shows that there has been a large increase in newbuilt housing over the past approx. 10 years in Denmark (DI Analyse, 2021). In 2020 approx. 6000 detached houses and 6000 semi-detached and terraced houses were initiated; in comparison, 13,600 apartments were initiated (Statistics Denmark, 2021e). While the number of detached houses is roughly half the number of apartments

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(see Fig. 1), the total area of the houses built is more similar to that of the apartments (see fig. 1b), because the average size is nearly double. In 2020, the area of single-family housing was almost double that of apartments even, because there had been a halt on larger construction projects, while the number of detached houses was steady. The average size of existing apartments is 78,9 m^2 while detached houses are on average 153 m^2 (Statistics Denmark, 2021c). Furthermore, the average size for newbuilt houses has gone up significantly in the last few years. Today the average newbuilt detached house is 205 m^2. In comparison, in 1960 and 1990 the average newbuilt house was 115 and 137 m^2 respectively (Statistics Denmark, 2021d). This increase in both building quantity and size is resulting in an increased environmental impact, since every extra square meter entails a larger material, energy, and land use.

A case study from 2020 (Zimmermann et al., 2020) has compared the climate impact for 60 cases of different buildings in Denmark, from apartment buildings to detached single-family houses. The study found the median of the cases to be 9,5 kg CO_2 equivalents (e) per m^2 per year, with detached single-family housing not performing significantly worse per m^2. However, as detached homes are both larger and room less residents, the impact per person becomes higher as each resident consumes more space.

While single-family houses, especially newbuilt ones, may not be the most sustainable way one can live, they make up a large fraction of new building materials, resources and energy being used in the building sector. Their growth cannot seem to be haltered, not even by a global pandemic (DI Analyse, 2021), thus reduction and mitigation are necessary if we continuously want to make the building sector more sustainable.

A 2018 study carried out by The Danish Construction Federation (DI Byggeri) among their members showed that 60% of the member companies want to build sustainably. However, in 2018, less than 5% of all ongoing building projects could be considered sustainable (Rothenborg, 2019). If single-family housing makes up such a large fraction in current building projects, new tools and incentives are needed that seek to include this type of construction.

The new DGNB Villa scheme currently under development by Green Building Council Denmark (GBC DK) seeks to drive this development forward, reducing the impact of single-family housing. However, in order to make the DGNB system fit around this type of building, the criteria need to be modified accordingly. Editing the current comprehensive criteria manual for multi-story buildings to fit small-scale projects requires significant simplification. Not just so that laymen can understand the otherwise very technical and engineer-targeted measurements and calculations, but also so the cost is significantly reduced, all the while not losing sight of the impact and relevance of the certification.

1.1. Background

Building sustainably has not always been a priority in Denmark. With the 1970s oil crisis, suddenly an environmental concern regarding energy consumption was raised in the building industry, resulting in ecological modernization (Holm and Stauning, 2009). Thicker and better insulation materials were developed, energy saving technologies, such as low-energy windows and energy-saving light bulbs emerged and by the 1980s most of these developments became institutionalized through building standards. The State's Building Regulations (danish: Bygningsreglementet) also gave rise to new methods and tools for the qualification of sustainability parameters, e.g. Life Cycle Assessments (LCAs).

However, with the emerging necessity for sustainable construction, the State's Building Regulations with a strong focus on energy use and reduction suddenly are not broad and ambitious enough to embrace a sustainable development and far from bringing building projects within planetary boundaries. A more ambitious way to further sustainable transition of the building sector is through voluntary certification schemes, because they "…*offer the possibility to measure and compare the sustainable performance of buildings by applying a set of quantifiable criteria*" (Jensen and Birgisdottir, 2018). As opposed to the State's Building Regulations, a voluntary sustainability certificate can only be issued if a third-party body has performed a conformity check, making it not only more ambitious but also more reliable and trustworthy.

In Denmark, the primary sustainability certification scheme employed in the building sector is based on the German DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen) scheme which lends its structure and sustainability understanding to the Danish variant while adapted to fit the Danish Building Regulations and other Danish standards (Zimmermann and Birgisdóttir, 2018). BREEAM and LEED are other leading international certification schemes for sustainable building and have existed since the 1990s. Their framework is based on British and American standards respectively. In 2010 GBC DK was founded and DGNB was chosen to be the most suitable scheme for the Danish market and context, based on an analysis comparing BREEAM, LEED, HQE (from France) and DGNB (Birgisdóttir et al., 2010). The LEED and BREEAM certifications lay two thirds of their focus on environmental sustainability, the French HQE focuses more than half on social sustainability, but DGNB ultimately was chosen because of its holistic sustainability understanding in line with the Brundtland Reports' definition (Assembly, 1987); rewarding projects exercising equal levels of environmental, economic, and social sustainability (see Fig. 2). In the DGNB scheme, three different levels or benchmarks of sustainability can

Fig. 1. a and 1b:Overview over the development in both the amount of housing built and how many m^2 they contribute to in the Danish building sector. Even though there are only half the number of detached houses, the area is similar. This figure is made with selected data from Statistics Denmark: BYGV90 and BYGV11 (Statistics Denmark, 2021a, 2021b).

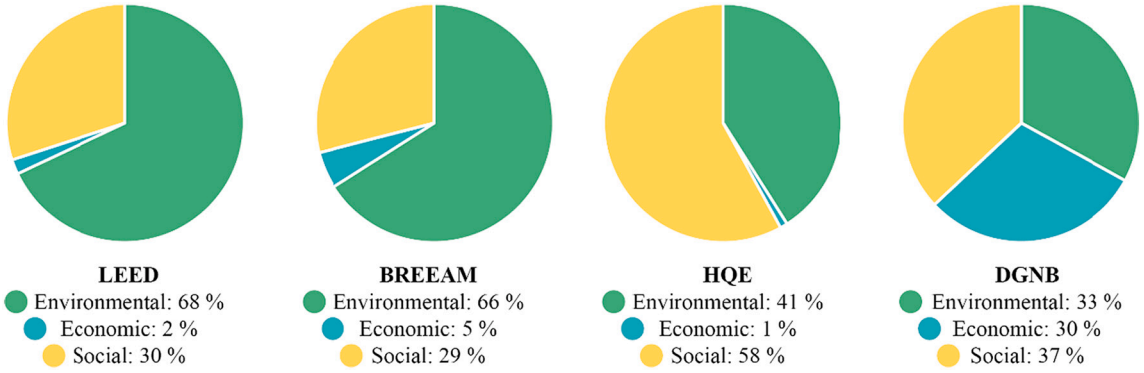

Fig. 2. Different international certification schemes and their respective weighing of the sustainability dimensions, as analyzed by Birgisdóttir et al. *(2010)*.

be achieved, silver, gold or platinum, thus different projects can have different levels of ambition depending on scale and budget while also focusing to different degrees on the three (Brundtland) dimensions of sustainability (DK-GBC, 2021a).

Several foreign schemes have their own version adapted for certification of single-family housing; BREEAM has the *Home Quality Mark* (CSTP, 2021), HQE the *NF Maison* (BRE, 2021), and while neither is unattainable for Danish projects, there is no local authority to perform the third-party conformity check and no version of the manual contextualized for Danish markets. In Germany, single-family housing has been DGNB certifiable since 2013 with the small-residential buildings scheme (DGNB, 2021). There has been some demand for this kind of scheme in Denmark, but so far nothing has successfully addressed the market. Most close is the Nordic Swan label which is well-known from supermarket shelves and everyday consumer products all throughout the Nordic region (Nordic Swan Ecolabel, 2021). This semi-public certificate officially adapted by the Nordic Council deals mainly with the toxicity and reusability of materials. The Nordic Swan label focuses on products during production and end-of-life, and has little weigh on the use-phase, thus neglecting aspects like indoor air quality for the user. This aspect is covered by another label, the Danish Indoor Climate Label (Danish: Indeklimamærket) which is a product certification focused exclusively on emissions and toxicity like other international counterparts e.g. Blaue Angel (D), Greenguard Gold (US) or EU Ecolabel (Indeklimamærket, 2021). Lastly, there is the ActiveHouse label, whose main focus is energy use (ActiveHouse Denmark, 2021) and thus does not live up to the broader sustainability focus currently practiced.

Adapting the Danish DGNB scheme to smaller construction, like single-family housing, therefore is appropriate and a necessary step in achieving drivers and incentives for green transition of the building industry.

1.2. Research question

This research article seeks to highlight some of the key challenges and hurdles to overcome when developing and implementing a sustainability certificate for single-family housing, using the impending DGNB Villa scheme as a case. Empirical insights are drawn from discussions raised during the meetings of a multidisciplinary advisory board formed to support the project. The article draws on terminology from Actor-Network-Theory (ANT) (Akrich et al., 2002; Carlile, 2002) to study the relationship and boundaries between relevant actors and to identify necessary translation of actors for the certification to succeed.

The main research question this article seeks to answer is:

How can human and non-human actors be translated into stable networks that support a new certification scheme for single-family housing?

While the process of translation is very complex and in this case involves a plethora of different actors, this research focuses mainly on two aspects; 1) the role of the standardized building companies (human actors) and how their necessary translation is aided by an LCA tool (non-human actor) being developed on a parallel track, and 2) the translation of the homeowners (human actors) through the certification manual itself (non-human actor) and how the manual needs to take shape in order to support the translation of other necessary actors.

2. Methodological framework

A designer often tackles wicked problems, which are ill-defined problems involving a network of many different actors with each their own set of conflicting views and ideas (Buchanan, 1992). Creating a stable design, in this case a functioning and impactful certification scheme, requires the support of a stable network. Through the socio-technical lens of Actor Network Theory (ANT), a design process is about translating networks into new ones that will support the design (Callon, 1986). Working with displacing networks, means working with different actors, and oftentimes requires transdisciplinary collaboration, as is the case with DGNB Villa.

2.1. Actor-Network-Theory (ANT)

ANT can help explain how change and innovation happen through changes in heterogeneous networks wherein human and non-human actors are interconnected (Olesen and Kroustrup, 2007). Throughout the translation of networks, four “moments” occur in a non-linear, iterative process: problematisation (the problem is defined), interessement (actors are negotiated to become part of a network), enrolment (terms and connections are defined and interrelated) and mobilization (the actors carry out the network’s agenda) (Callon, 1986). In short, successful innovation manages to enroll and mobilize actors, so the innovation can gain a foothold and saturate the market. For an innovation, like the DGNB Villa scheme to gain allies that enable its diffusion, interessement devices can be used. They are non-human elements that can help secure the actors’ involvement in a network (Akrich et al., 2002), and are exemplified in section 4.1.

2.2. Working transdisciplinary

Considering how successful translation requires negotiation with many different actors, working transdisciplinary is the only way to ensure all perspectives to be heard and included. The DGNB Villa project has a team of multidisciplinary professionals representing the different actors of the network in the advisory board that can help shed light on issues otherwise overlooked by the organization (GBC DK).

In addition to the advisory board, the editing of the manual draws on knowledge from and is reviewed by experts within their field that qualify the criteria, as the manual itself is made up of a vast field of studies, each interdependent yet part of a greater system.

When working across many different knowledge boundaries, as is the case with the DGNB manual, it is the designer's job to synthesize the gathered knowledge. Knowledge can be difficult to manage, because it is difficult to transfer between specialized domains (Carlile, 2002). While through a syntactic approach (language) knowledge is transmitted, and through a semantic level (meaning) it is transferred, a pragmatic approach is necessary for knowledge to be transformed (Carlile, 2002). Transdisciplinary work transcends the knowledge boundaries because it lets the designer alter their knowledge and influence other actors to do the same. On a more practical level, this happens, for instance, during the negotiations taking place at the advisory board meetings.

3. Case: creating a single-family housing certification scheme in Denmark

It has been established that a new certification scheme is necessary if the development of single-family houses in Denmark is to become more sustainable. This chapter identifies two important translation processes that are necessary when creating a certification scheme that both has a wide enough scope to entail a majority of building projects but at the same time has the potential to actually move the industry beyond the status quo and have a sizable impact:

1. The translation of the standardized building companies (and architects) through interessement with the new and desired LCA tool
2. The certification manual as a non-human actor to help empower the homeowners and translate them in the network

3.1. Translating the actor-network for a small-scale sustainable building certificate

In order to enter the market of sustainable building certification for single-family detached houses, the relevant actors need to be able to see the value of a certification scheme and be willing to pay for it. If the DGNB Villa certification scheme is to be diffused into the market and eventually become its own entity, actors external to GBC DK need to take over the task of driving the certification forward. The actors that will sustain the use of the scheme and thus become its spokespersons first need to be translated to become the certification scheme's allies (Callon, 1986). Fig. 3 shows the network of the key actors that need to be translated. The yellow actors are human, and the grey ones are non-human.

If the homeowners themselves are to be the ones paying for the certification, the building company or architect that the homeowners hire's role is critical because they are essentially the ones to pitch and sell them on the idea. For regular single house projects, the certification scheme goes through the consulting architects that advise the homeowners. Either the architects present the homeowner with the option of certification and must convince them, or the homeowner pushes for getting the certificate (realistically, very few cases). Regardless, the knowledge has to be present with the architect firm, as they will most likely be managing the certification, they are thus one of the actors that must be translated in order to stabilize the network surrounding DGNB Villa (see Fig. 3).

Many houses are being built and a large share of that market lies with standardized building companies (Danish: typehusproducenter), which are companies that sell newbuilt houses at a reduced cost because they are adapted from a range of prefabricated blueprints. The top 3–4 of these companies cover the demand from about three quarters of users (Licitationen, 2019). Therefore, it is a great opportunity, enrolling these companies as they give access to a large user base. This actor, besides the architects, also needs to be translated to stabilize the network around the certification (see Fig. 3). In either case, the building companies and architects should have an interest in selling certified houses. The next section will explore how a new, simplified LCA tool acts as an interessement device that has the potential to enroll these actors.

It is worth mentioning that a translation of actors in all parts of the supply and product chain is necessary for the scheme to be fully successful, as contractors and building material suppliers, for instance, can also be agents in the demand for sustainable certification. However, this research focuses mainly on the translation of the standardized building companies and the homeowners.

3.2. Enrolling standardized building companies through new LCA tool

Standardized building companies do not only hold a significant market share; they also operate in a manner that lends scalability to the certification in a way regular consulting architects do not. The advantage in using prefabricated blueprints is that there are only small

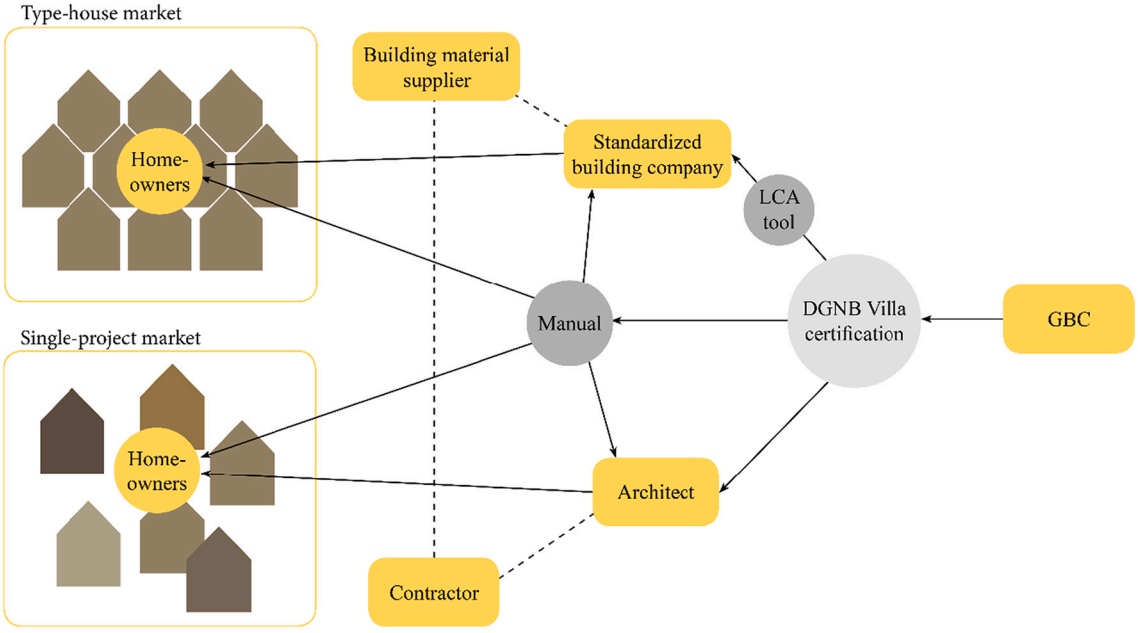

Fig. 3. The network that needs to be translated in order for the DGNB Villa scheme to succeed (own illustration).

variables from project to project and certification can therefore happen on a systemic level. When key building components are the same among a large portfolio of houses, a minimum level of certification can be achieved for the whole portfolio and remaining variables can easily be adjusted to the individual project (see Fig. 4). This also means a reduction in cost because the documentation workload for each individual home has been significantly reduced. Thus, the homeowners' willingness to pay becomes less critical, as much of the cost can be carried by the standardized building companies. The enrollment of such companies is thus crucial if the certification is to gain a broad scope and thus create an impact.

Through the participation of a couple of standardized building companies on the multidisciplinary advisory board, a definite interest in the certification scheme has been identified from this key actor, particularly fueled by the desire to comply with future State sustainability requirements.

The growing interest in incorporating environmental sustainability aspects in the building industry could become a crucial driver for a single-family housing certification scheme. Especially LCAs are becoming increasingly demanded, and by 2023 all newbuilt buildings are required by the Danish State's Building Regulations (BR18) to carry out an LCA. The voluntary sustainability class (FBK) introduced in 2020 already includes the requirement for an LCA, but with the LCAs becoming mandatory, it pressures building companies to perform better and heighten their sustainability profile, ultimately increasing environmental sustainability of the Danish building industry.

The certification scheme includes an LCA, which will be executed in a simplified LCA tool, currently being developed by BUILD, Aalborg University's Department of the Built Environment, in collaboration with GBC DK. The new tool is supposed to be a significantly reduced LCA tool in comparison to the currently used *LCAByg* which mainly draws on data from a German database. The tool is meant to make future LCAs more contextualized for a Danish market, and by simplifying and streamlining the method, making them comparable not just to each other, but to the State-imposed CO_2-emission limits, that will require buildings to emit no more than 12 kg CO_2 equivalents per m^2 per year in 2023. The tool, when finished, will also be a part of the DGNB Villa scheme under the environmental component, which is why GBC DK is participating in the development process. The goal is to gain statistical basis for more context specific calculations by collecting a variety of cases. Alternatively, cases could provide for a generation of standardized concepts for different types of e.g. heating sources, types of ventilation, type of housing unit, etc. which would significantly simplify the process of getting single-family houses assessed.

In ANT terms the collaboration with BUILD on the simplified LCA tool could help enroll actors among the architects and standardized building companies that seek to be first-movers on the environmental sustainability area (as highlighted in Fig. 5). If the simplified LCA tool is part of the DGNB Villa scheme, it gives an edge to those who have already implemented it when the time for mandatory LCAs comes, not just because they are already familiar with the practice, but because it strengthens their sustainability profile. Both among building companies and architects there could be such an interest, as more companies use sustainability as a competitive quality in their business model. The tool can thus act as an interessement device (Akrich et al., 2002) for the translation and stabilization of the network (Callon, 1986). Another objective for being interested in the simplified LCA tool, is that most companies want to use the simplest means possible to achieve compliance with regulation, so even those not necessarily interested in the environmental aspect would be given incentive to get on the bandwagon.

Whether for conforming to regulations or adding extra sustainability value, the more common the LCAs become, the more competition it will create between building companies who will want to profile themselves on sustainability. Product suppliers will also want to create their own Environmental Product Declarations (EPDs) to singularize their products which in turn will improve the LCA tool over time *(Jørgensen et al., 2021) and help stabilize its use.*

3.3. Translating the homeowners in the actor-network

With the introduction of a small-scale scheme, the end-users suddenly are not only big contractors, builders or projecting architects and engineers. With the inclusion of single-family housing, the new end-users are, besides the consulting architects and standardized building companies, regular people with all kinds of background. They are not professionals with exhaustive knowledge of the building field and enrolling them requires different strategies and is not only about getting them to choose the scheme in the first place, but also getting them to be involved in using it and equipping them for taking the necessary decisions throughout the process. If entering the market through the standardized building companies, the homeowners are only indirectly the customers, because they choose the company who will build their home. The housing company will be the direct customer, as it is their choice to commit to a sustainability scheme that will ultimately sustain the certification scheme. However, assuming that the housing company uses their commitment to the certification as a sales point to enroll the homeowners, they first need to convince them that certification is

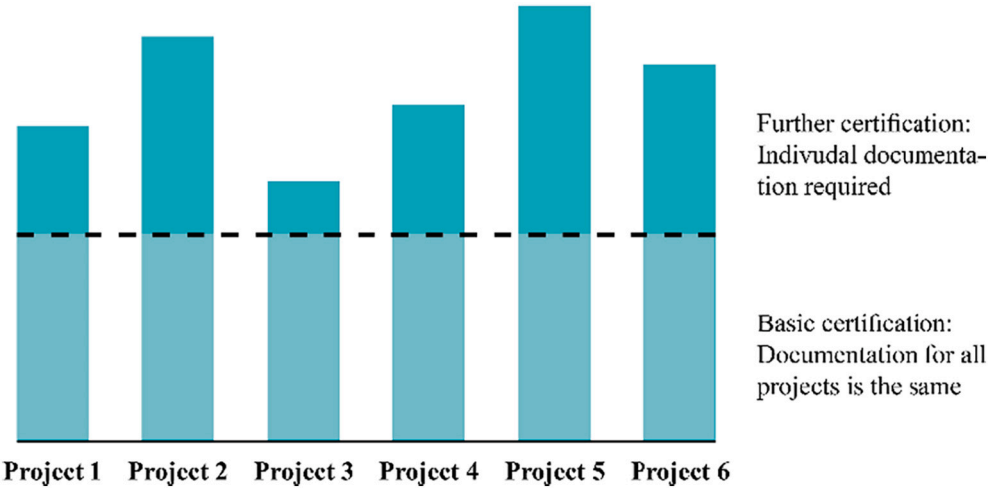

Fig. 4. The certification can be applied on a systemic level, as several projects achieve the same basic certification, with only a few variables requiring separate documentation (own illustration based on DGNB understanding of serial certification).

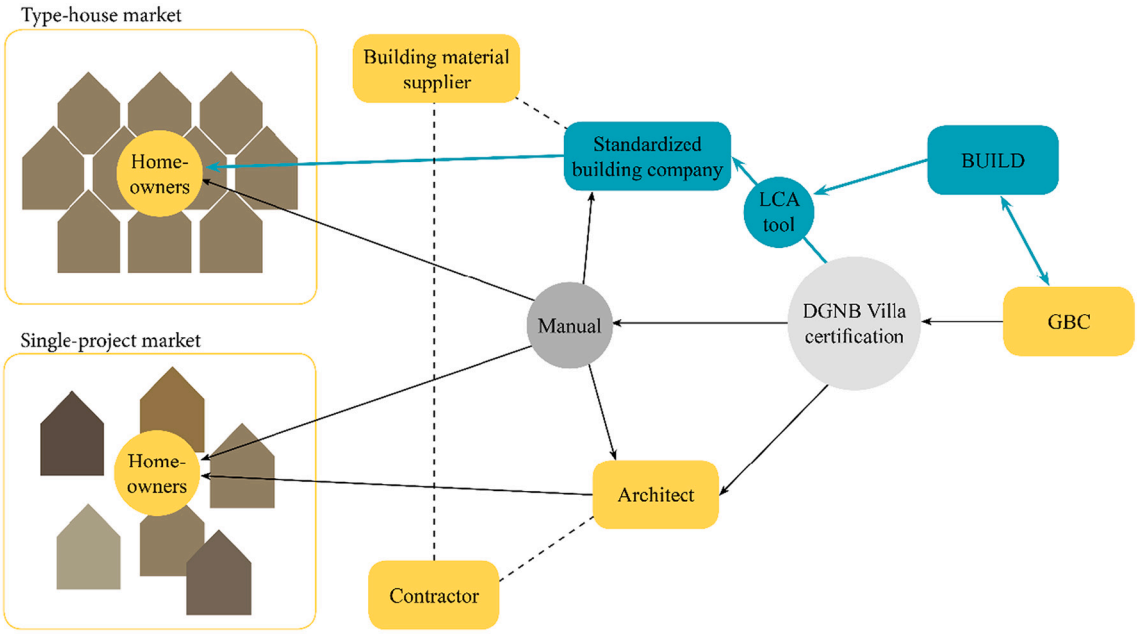

Fig. 5. Network that shows how the collaboration with AAU Build on the simplified LCA tool can help utilize its momentum and stabilize the certification scheme with enrolled actors (own illustration).

necessary and beneficial for their home.

3.3.1. Marketability and incentives for choosing a sustainable building certificate

The first issue is mainly one of marketing; what is going to make the homeowners buy in on a sustainable certificate for their house? The cost of building a house is already substantial in a private economy, so what will make the user want to budget an additional cost? Of the people that have already expressed an interest in the new scheme, many are current auditors and other professionals in the building sector with an extended knowledge of the certification. But among users of a wider population sustainability is not necessarily the first, or even second concern.

While paying for a sustainability certificate does not increase sustainability directly, it does so indirectly as a driver, because it commits the user to making more sustainable choices throughout the design process in order to achieve the certification. To get the user to commit to the certificate, framing it as a sustainability certificate alone is not enough. Most users will associate sustainability mainly with environmental sustainability, which is an abstract (and large scale) concept to many. The (small scale) economic and social advantages need to be made visible throughout, because they are what move most users in the end. It is a question of appealing to their emotions rather than assuming all decisions are made based on reason and knowledge. If emotion can lead to action, the users need to be made aware that the certificate does not only increase environmental sustainability, but it also increases such things as health, comfort, and general well-being for themselves and their family.

Criteria chosen for the DGNB Villa manual, are initially based on a selection of criteria from the main manual that contribute to the *DGNB Heart* distinction focusing on health and well-being that can be obtained in addition to a (main) DGNB certificate (DK-GBC, 2021a). Focusing on such parameters like indoor comfort and architectural quality that are more directly perceived by the end user, can become an important driver in getting the user to choose a sustainable building certificate. When it comes to their children, users are willing to pay a premium for products that advertise with health benefits e.g., toys and clothes that are organic, free of phthalates and other problematic chemicals and endocrine disruptors. The manual needs to make visible where the equally added advantages are and why they matter.

There is also an economic incentive for some aspects like the energy consumption and the added longevity and ease of maintenance that comes with choosing durable solutions. For example, energy labels do not matter to many users until the house needs to be sold. It is not the positive effect on the environment, rather the added value to the house that matters to the user. In a similar way, sustainability certifications also need to appeal to the user with other advantages, such as increasing the total value of the house, making it easier to sell. This effect is in general yet to be seen for sustainable building certification schemes.

Lastly, one cannot discuss incentives, without mentioning the role of government and policy, because positive change away from the status quo can be promoted through the right legislation. The Danish Government has the power to instigate sustainable development of the building industry through a variety of instruments, like regulation, subsidizing and tax deductions. The BR18 requirements for 2023 are an example of such regulation, but they still are not ambitious enough. Ambitious legislative incentives require political support and action, and their implementation and necessity for the transition of the building industry give rise to further study. Regulations need to have the desired environmental impact while also being made politically desirable and complying with the EU regulations, which is easier said than done. The certification can potentially become a driver for further policy making, if lawmakers see its positive effects as a benchmark for a more sustainable future.

3.3.2. The manual as a non-human actor

The current DGNB certification scheme is only viable for larger building economies. On average a building project requires between 400 and 500 consultant hours to gather the needed documentation, on top of the cost of the certificate itself, which varies between approx. 30.000 and 450.000 DKK depending on the size of the building (DK-GBC, 2021b). The cost and scope need to be reduced significantly to adapt the scheme to smaller projects. The goal with DGNB Villa is to achieve a reduction of about 75% of the current criteria and drastically reduce the documentation workload. The ambition is to pick the criteria that have the largest impact and/or highest relevance for single-family housing. The less criteria, however, the more each criteria weigh, thus their relevance becomes even more important. To reduce the cost, expensive analyses, calculations, and measurements must be removed and

alternatively replaced by examples, templates and checklists in the manual when possible. In general, DGNB Villa seeks to limit bureaucracy and encourage freedom with responsibility to lessen the documentation burden and bring down the cost.

The manual itself as a non-human actor presents an opportunity in translating key actors, if it is developed in a way that encourages innovation and supports the certification process for the homeowners, architects, and standardized building companies alike. Fig. 6 shows how the certification interacts with the actors through the manual. The manual is the face of the certification, so to speak, and its readability and ease of application will determine how the actors interact with the certification scheme. A too comprehensive, or too dense manual will deter potential users from applying the certification scheme and counteract the ongoing translation.

One way the manual influences the application of the certification, is how easy it is to interpret its inscriptions and how rigid these inscriptions are in terms of leaving room for innovation. The general DGNB scheme sets functional requirements for a building project, thus not prescribing a particular design solution, but rather an outcome that must be obtained in order to achieve certification. This allows for the builder and contractors to create new and innovative solutions within the frame. For private builders and project leaders, however, that may have a limited technical understanding of e.g., building materials and techniques, this type of freedom makes them vulnerable to being persuaded to choose certain solutions over others by other actors whose interest can sometimes be more economically than environmentally driven. Therefore, the criteria need to be strict and firm, because the building companies will try to reach the goal at the cheapest cost possible. By setting very strict requirements, however, conditions for innovation can sometimes be affected. The Danish State's Building Regulations, for instance, are often criticized for being too rigid, limiting certain solutions and maintaining the current technological paradigm. If it is assumed that contractors chose the cheapest option, the manual needs to be rigid enough so that qualified solutions are sustainable, but not so rigid that innovative approaches are eliminated.

To help the end user partake in this innovation, the DGNB Villa manual will contain examples of how the functional requirements can be successfully met, with examples that should represent state-of-the-art, innovative design solutions. Fig. 7 shows how such examples could be visualized, explaining their use, and added benefit. Showcasing some of the ways to solve a problem such as ventilation can help the end user, the homeowner, gain a higher level of control over the design process than in a conventional building process. In a digitalized manual, these sections could be filtered out to make an idea catalogue that can also serve as inspiration for building a sustainable house, even one that is not getting certified.

3.3.3. *Where the homeowners' and the industry's responsibilities meet*

The homeowners certainly hold some responsibility when it comes to building sustainable single-family houses, but they can only act within the restraints the market is setting. If sustainability only comes at an additional cost, and options are limited, the industry holds a responsibility for pushing the envelope further as well.

While certain aspects of a house are chosen by the end user, a majority of its materiality is predetermined or chosen by other actors. The homeowners may restrict the budget and location of the house, as well as request certain functional features and aesthetic properties, but in regards to many of the structural components, installations and other technical aspects, choices predating the particular building project have already determined those; choices made by actors, such as the construction company, the architect, the building material industry, and the public sector, who carries out regulation and oversight tasks (Holm and Stauning, 2009).

The choices that the end user does not participate in are often of equal, if not larger significance, because the aspects they seldom have an opinion on, are often the larger building components such as the foundation, insolation, etc. that make up a significant part of a building's environmental impact. These choices are made by building companies who hold a large part of the responsibility for building sustainably. On the aspects that the homeowner ultimately chooses, like roofing, windows, etc. they can only attempt at persuading them.

It is still important to accommodate the homeowner and their preferences on all the parameters they do have an opinion on, but all the aspects that the engineers are calculating on, those are the aspects where the industry can really move something, as was expressed by some of the advisory board members. The building company should add all the sustainability where the homeowner cannot see it. If there are restrictions for what cannot be built because it is unsustainable, the users

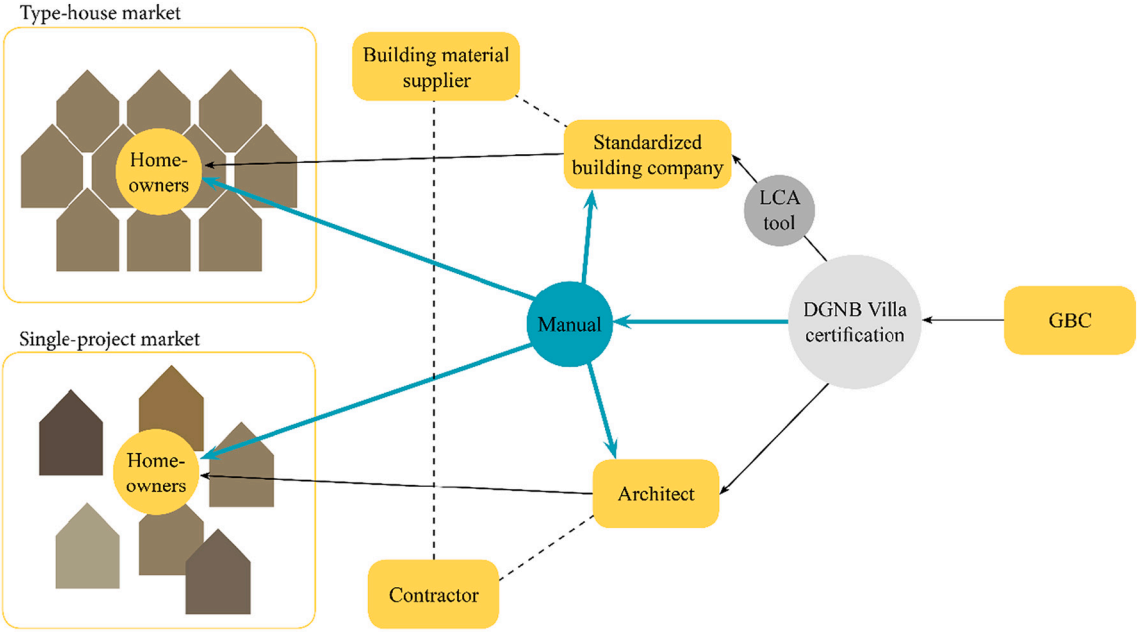

Fig. 6. Network that shows how the manual itself as a non-human actor can bridge the certification scheme to key actors if it is intentionally developed (own illustration).

Fig. 7. An excerpt from the DGNB Villa pilot manual (original language) that shows a list of examples to support the functional requirements and lend an alternative way of collecting points with simple documentation (permission for republishing given by Green Building Council Denmark). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

will go to another company that can.

Where the standardized building companies present a unique opportunity is with their ability to spread the cost of the documentation needed for the certification across multiple projects (hence the basic certification mentioned in section 3.2), and thus free the homeowners from having to support the entire economy of the certificate. They can also quickly scale up sustainable practices across projects and help support the homeowners in making the more sustainable choices along the way.

A recent user study (Ramboll Group, 2019) shows that more than half of Danes are already willing to pay for sustainable efforts to a certain degree. Regarding housing costs, more than 75% are willing to pay an additional 100 DKK a month, and about 20% would accept an additional monthly housing cost of 1400 DKK to live in more sustainable housing. Another user study, the Sustainometer 2021 carried out by Moos-Bjerre (MandagMorgen, 2021), shows that 47% are willing to pay up to 10% more for sustainable housing. However, as mentioned in the introduction, only around 5% of ongoing building projects are sustainable (Rothenborg, 2019). Whether this is due to a lack of information or decent systems that give the necessary incentives is unclear, but it underlines the importance of choosing an appropriate way to frame the certification scheme towards the consumers.

3.3.4. Bridging the knowledge gap

Lastly, the homeowners' willingness and interest in building sustainably is accompanied by a lack of knowledge and choices offered by the industry.

There is no question that we are taking up too much space when it comes to living. One study (Cohen, 2021) suggests that in order to uphold global levels of sustainable resource utilization and equity each person should take up no more living space than 20 m^2. For a family of four that means a house should be no larger than 80 m^2. Considering that the average newbuilt detached house in Denmark is 205 m^2 today, we are still far from that goal; the furthest we have ever been, as house sizes have nearly doubled over the past 60 years. The residential upsizing is largely due to incomes and productivity increasing and accumulated wealth being invested in larger property, as well as standards of living rising. Even though the latter is true, some studies also show that house satisfaction does not necessarily rise with increasing house size (Cohen, 2021). The Ramboll study suggests that 49% of Danes would reduce their housing size by 10% if it were more sustainable (Rothenborg, 2019). That begs the question; do they not know?

Another user study, carried out by the information center Bolius in 2019, has explored what people consider the largest barriers for living in sustainable housing, and has found the two largest ones to be 'cost' and 'missing knowledge' (Videnscenteret Bolius, 2021).

The missing knowledge aspect gives rise to further investigation and study. It is not only a question of how to communicate this knowledge to the people who need it for making sustainable choices. It is also a question of making people understand what is at stake; not just for the planet, but also for them. How does a sustainable house improve *their* life, how does it relate to them and their family?

4. Conclusion and future perspective

A sustainability certification scheme for small-scale housing such as single-family houses is necessary in Denmark, as there is currently no tool for accessing holistic sustainability prevalent on the market. Considering the network of actors that the certificate shall be stabilized on, there is a big potential in enrolling standardized building companies, because they account for a large market-share of single-family housing in Denmark and their way of building enables scalability of a certification scheme. There is a huge potential in utilizing the current momentum Life Cycle Assessments (LCAs) have in Denmark, with their performance becoming mandatory in 2023. The DGNB Villa scheme could "piggyback" this momentum and take advantage of the interest in the simplified LCA tool being developed by BUILD in collaboration with Green Building Council Denmark, by targeting building companies that are interested in being first movers on the environmental sustainability aspect.

Translating the network stabilizing the DGNB Villa Scheme comes with a number of challenges. Firstly, the end-user now including the homeowners changes the approach of how the certificate should be marketed. Other benefits than environmental ones need to be highlighted in order for the homeowners to gain interest. Secondly, the balance of reducing the scope while still maintaining impact is

addressed, as documentation needs to be significantly reduced, if the price of the certificate has to fit into smaller building economies. The role of the homeowners as the driver for the certification can be alleviated by standardized building companies being able to carry some of the economic weight, thus making the cost barrier easier to overcome. Lastly, there is a knowledge gap that still needs to be addressed, if regular people are to be expected to set demands regarding sustainability for the homes they build.

Further study can be made into how legislative and regulatory frameworks could help support the scheme and its diffusion on the Danish single-family housing market. A large part of incentivizing sustainable growth in the building industry could be through subsidy schemes, tax reductions and stricter regulations, but these tools need to be balanced carefully so that they do not present an added cost for the building companies and consumers. The regulatory tools can, like the certification schemes, help to internalize the socio-economic costs of unsustainable building practices (Callon, 1998) and should therefore be incorporated into a larger, more holistic societal context and not just present the added monetary cost of, for instance, performing an LCA.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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