Business model innovation for smart, healthy buildings

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Abstract. This paper looks at how the building industry can use the United Nations’ Sustainable Development Goal 3 (SDG3) - to ensure healthy lives and promote well-being for all at all ages. The research investigates SDG3-driven business model innovation for healthy buildings and the role of smart technology innovation in realizing the goal’s implementation. It is based on an organizational ethnography of the VELUX Group and interviews from four business model innovation cases to illustrate how the industry can use SDG3 to create more sustainable and healthy buildings. The research finds that whereas SDG3 highlights the significance of human factors in the building industry, smart technologies support value creation based on formerly unmeasurable qualitative aspects like indoor health. Further, challenges to SDG3-based business model innovation underscore the need for expanded cross-sector collaboration in order to establish markets for the resultant smart, healthy building solutions. Public-private partnership for the smart and healthy renovation of public schools is identified as a promising way to stimulate wider market adoption.

1. Introduction
The United Nations’ Sustainable Development Goals (SDGs) have created a language with which governments and organizations can strive for global sustainability. Goals that would not traditionally have been considered relevant to various sectors can now be sharpened and aimed for. This is due to an acknowledgement that the SDGs are interconnected and pursuit of one can have synergistic effects on others [1], especially when combined with policy measures [2]. These interconnected goals are especially imperative for the building industry, which is known as the ‘40% industry’, as it is responsible for roughly 40% of carbon dioxide emissions, energy consumption, and waste [3]. Whereas SDG 11 for sustainable cities and communities is an obvious action area for the building industry, its widespread challenges demand holistic efforts across several SDGs.

In particular, SDG 3 – ensure healthy lives and promote well-being for all at all ages – opens the possibility for organizations to tackle issues of indoor health in the built environment. Though poor indoor air quality can be harmful to human health due to variety of contributing factors [4], smart technologies can help to improve the healthiness of living spaces [5] and create a real-time link between the health of buildings and users’ health. Nonetheless, it is not well understood how the building industry can use SDG3 to create business around health and well-being. In other words, building organizations are experimenting with business model innovation for SDG3, but what more is needed to bring SDG3-based building to fruition?

This research is based on a 2-year organizational ethnography of the VELUX Group and four business model innovation cases developed with semi-structured interviews and secondary data. The
four cases are distinguished by their value creation and capture in different sectors: commercial, residential, social housing, and education. The overarching theme of the research is on business models for smart buildings; and the sub-question that is the focus of this paper is: How can the building industry use SDG3, and what more is needed?

2. Background
The background for this research touches on approaches to sustainable building, current applications of smart technologies for health, and the turn of the building industry towards SDG3 and smart health.

2.1. Sustainable Building
Sustainable building has long had its roots in the energy performance of buildings. As one of the largest carbon polluters, the building industry has sought to decarbonize buildings through energy efficiency measures and passive design [6], while the issue of operating already existing buildings has further driven efforts at energy retrofitting [7]. Voluntary sustainable building standards and policy development with governments, namely through green building councils, have successfully pushed the agenda [8]. Yet, the misalignment between planned energy performance and actual performance became known as the performance gap, and the behavior of people in buildings is considered one of the main contributors [9]. In this way, building design, energy use, and human behavior are considered interlinked. In addition to occupant behavior modeling techniques [10], smart technologies – with their proximity to building users and flexibility – are thought to play a significant role in shifting building energetics and thus transition the industry to smart, sustainable building [11].

2.2. SDG3 and Healthy Buildings
According to the United Nations, adults between ages 30 and 70 have a 18% chance of dying of cardiovascular diseases, cancers, chronic respiratory diseases or diabetes; and air pollution (including from households) contributes to the risk of cardiovascular and respiratory disease and is linked with an estimated 7 million deaths in 2016 [12]. SDG 3 specifies 13 targets, including two that directly relate to healthy indoor climate:
- Target 3.4: By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being.
- Target 3.9: By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination. [13]

Additionally, the UN notes that for more than half of the indicators, there is no established methodology of measurement [12].

As the building industry, particularly in Europe, is taking such strides to improve buildings’ energy performance, it can adopt renovation principles for both energy and health. As proposed by Morten Helveg Petersen, Vice Chair of the European Parliament’s Committee on Industry, Research and Energy, “When optimising the energy performance of our buildings, we should also use this opportunity to improve the immediate impact that buildings have on their residents’ health and quality of life” [14]. The Healthy Homes Barometer 2019 illuminates European research showing that not only do people spend 90% of their time indoors in potentially hazardous conditions; but one third of European children live in unhealthy homes, contributing to health complications such as asthma, allergies, eczema, and lower and upper respiratory issues [14]. Yet, broadly speaking, there has been a shortage of such research because of the limited ability to measure health factors objectively [15]. However, substantiation of the connection between health and indoor environments is increasingly robust [15,16,17,18], in part due to improving methodologies and metrics for indoor health, including such technologies as mobile, wearable sensors [15].

2.3. Smart Health
Whereas aiming sustainable building towards health considerations is fairly recent, cities have widely embraced their potential contribution to SDG 3 [19]. Internet communication technologies (ICT) and
Industry 4.0 are considered a promising way to develop sustainable cities and deliver on the SDGs [20, 21]. This is in part because of the ways that smart technologies (under the umbrella of smart cities) can contribute to the datafication and automation of healthcare, known as smart health or connected health. It is anticipated that this “will be realized by providing rich medical information to each individual by replacing infrequent, clinic-based measurements with unobtrusive, continuous sensing, monitoring and assessment” [22]. Smart home technologies for healthcare have been advancing for the management of diabetes [23] and dementia [24]; and the development of smart technology for improving indoor climate, air quality, and comfort is expanding [5,11]. These technologies make possible the measurement and analysis of previously difficult- and expensive-to-quantify value representing health conditions in buildings.

3. Literature
The research draws upon business models, and more specifically, sustainable business model innovation literature. Building upon the fundamentals of the Business Model Canvas [25] – such as value proposition, cost structure, and revenue streams – business model innovation is considered as rooted in ‘activity systems’ [26] wherein networks of organizations interact to develop new sources of and ways to capture value. Business model innovation is a way of challenging the status quo and can result in more sustainable, responsible ways of doing business through ‘sustainable business models’ or ‘sustainability-oriented business models’ [27]. Further, business models are significant for sharpening the delivery of innovations to the market. As Chesbrough points out, “the same idea or technology taken to market through two different business models will yield two different economic outcomes” [28]. They are the basis of attempting to ‘operationalize’ sustainability innovations, not only bringing them to market but also scaling them [29]. The significance of business model innovation for the SDGs is its role in systemically integrating sustainability-driven innovation into organizations and thus into the business ecosystems in which they operate [27]. The sustainable innovation literature has tended to overlook the need of businesses to bring together value propositions, value chains, and financial models to generate markets for such innovations [30]. In the case of SDGs, sustainability-related innovations for the goals depend upon these business-driven pathways from idea to implementation.

4. Method
This research uses qualitative techniques in order to paint a nuanced picture of sustainable business model innovation in the building sector and the business circumstances surrounding them.

4.1. Data Collection
The research is based on a 24-month organizational ethnography of the VELUX Group, semi-structured interviews concerning four research cases, and secondary data. Organizational ethnographies are significant for combining narratives, snapshots in time, and physical objects (such as smart technologies and buildings) to describe processes of change in the context of a given research question [31]. The ethnography follows changes regarding smart building business in the VELUX Group and the surrounding industry from January 2018 through December 2019 and is based on office attendance one to three times per week, internal and external meeting notes, and other field notes. The field notes consist of 66 distinctive field notes of meetings, observations, emerging questions, and interactions; 43 internal communication documents; and 19 secondary articles and reports. The business model innovation experiments focus upon (1) Green Solutions House in Bornholm, Denmark; (2) RenovActive in Brussels, Belgium; (3) Quayside in Toronto, Canada; and (4) Kokkedal Skole in Fredensborg, Denmark. These cases are developed from 60 semi-structured interviews with 68 interviewees. Secondary material supporting this data is mainly based on event and practitioner conference attendance, during which field notes were also recorded.

4.2. Data Analysis
The data was analyzed in accordance with the Gioia Methodology: wherein the analysis stems from a research question, links literature review with field observation, and oscillates between inductive and abductive lenses in order to formulate constructs [32]. In addition to the ongoing analysis inherent in field note taking [33] the three research data types (field notes, interviews, and secondary data) were triangulated [34]. The first order reference coding was done to establish references relating to comfort, health, technology, automation, sensors, economics, strategy, and business models; which narrowed the research case set to RenovActive, Quayside, and Kokkedal Skole, supplemented by field notes. These were then clustered into the second order themes of healthy buildings, smart home technology, and business cases. The interviews and events from which the analyses are drawn are outlined in Table 1.

Table 1. Data analysis sources: (a) Interviews, and (b) Events.

| (a) Interviews | Organization | Title |
|----------------|--------------|-------|
| A 16/10/2018   | Zehnder Group Product Manager |
| B 15/10/2018   | Renson Public Affairs Manager |
| C 15/10/2018   | Renson Head of Research |
| D 17/10/2018   | BENUHU Technical Adviser & Renovation Supervisor |
| E 17/06/2019   | Confederation Construction Innovation & Smart Buildings Consultant |
| F 18/06/2019   | Energyville Built Environment & Smart Cities Expert |
| G 18/06/2019   | Binhøme Architect |
| H 19/06/2019   | BBRI Researcher Lighting Laboratory |
| I 20/06/2019   | Somfy Training Manager |
| J 21/06/2019   | Foyer Anderlechts Real Estate Director |
| K 06/09/2018   | Dubbeldam Architecture + Design Principal and Architect |
| L 06/09/2018   | VELUX Canada Technical Manager |
| M 10/09/2018   | Rotman School of Management University Professor |
| N 13/09/2018   | City of Hamilton Smart City Officer |
| O 21/09/2018   | Grand Alarms Director of Operations |
| P 24/09/2018   | Mattamy Homes VP Sustainable Development |
| Q 19/09/2019   | Turncraft Advisors Founder and Principle |
| R 20/09/2019   | Greensoil Building Innovation Fund Managing Director |

| (b) Events | Organizer | Title |
|------------|-----------|-------|
| A 22/09/2018 | Sidewalk Labs and City of Toronto | 307: Open Sidewalk #3 |
| B 26/09/2018 | The VELUX Group | Healthy Buildings Day 2018 |
| C 20/11/2018 | BLOXHUB | Smart, Sustainable Buildings Conference |
| D 18/01/2019 | UN City | The Genuinely Intelligent Building |
| E 18/02/2019 | Copenhagen Business School | SDGs - An Inventory of Business Opportunities |
| F 25/04/2019 | Copenhagen Business School | SDGs: A Profitable Business? |
| G 06/06/2019 | DNV GL | How to use the Sustainable Development Goals: Insights across sectors |
| H 09/10/2019 | The VELUX Group | Daylight Symposium |
| I 10/10/2019 | The VELUX Group | Healthy Buildings Day 2019 |
| J 31/10/2019 | Building Green | Building Green Copenhagen 2019 |
5. Findings

The findings are structured into the following sections: from sustainability to healthy buildings, the role of smart home technology, and the development of business models, with special focus upon public sector buildings.

5.1. Healthy Buildings

The elaboration of health aspects to sustainability in buildings is expanding. In the case of the VELUX Group, a child who moved with his family into a ModelHome2020 house, Maison Air et Lumiere, no longer needed medication for his previously debilitating asthma symptoms. The family did not discuss this widely until they moved out after the testing period, and the child’s symptoms returned. “Since then we don’t only talk about sustainable buildings, we talk about healthy buildings” (Director of Sustainability and Architecture, VELUX Group, Event C). In addition to stories arising from building experiments, the research on health in buildings is growing and is increasingly recognized in the building industry: “There’s good research in the U.S., and I imagine there’s good research in Europe as well, that shows better housing, in a certain way, is better health” (Founder and Principal, Interview Q).

As the foundations of healthy buildings are growing, so are the understandings of the dimensions that contribute to how we consider and measure health. As cross-industry partnerships are growing, the research turns to aspects such as loneliness (Director, Heijmans Real Estate, Event I). And not only do spaces with more plants and better views result in less stress, but if the stress is unavoidable, people recover more quickly (Assistant Professor of Exposure Assessment Science, Harvard University, Event I). This is based on many elements coming together: “It’s not only about indoor air quality: it’s thermal, acoustic, visual, comfort that determines your health status” (Head of Research, Interview C).

On the other hand, the potential benefits of sustainable buildings are not yet recognized by end-users (Principal and Architect, Interview K). As one interviewee frames the challenge: “Are they concerned about health? Are they concerned about productivity? The Green Building Council has all these studies about improved productivity with better indoor climate. Does that resonate with people? Or do they need different information?” (Technical Manager, Interview L). There arises a need to illustrate and make relevant the issue of health in buildings.

5.2. Smart Home Technology

The European Commission is an early mover in so far as integrating health and comfort aspects – in addition to seven other parameters – into the standardization of smart buildings in the Smart Readiness Indicator for Buildings project (Vice President of Communications, Sustainability & Public Affairs, VELUX Group, Event B). There is an increasing movement towards deriving health, among other sustainability benefits from smart technologies. “We are not just putting technology for the sake of technology” (Chief Technology Officer, City of Toronto, Event A); “We need the smartness to make it sustainable” (Administrative Director, Schneider Electric, Event C). Some of the considered benefits include improving the longevity of buildings and the connection to users (Researcher Lighting Laboratory, Interview H), as well as helping building users to be more aware of their surrounding environment (Sustainability Director, Saint-Gobain, Event C).

In regards to health, smart technology is considered an avenue for helping to monitor and control air quality inside buildings. For example, Somfy describes its Tahoma building automation system as being both to protect the house and to “try to get more healthy air and fresh air inside” (Training Manager, Interview I). On the one hand, the health aspect possibly even trumps the benefit of user interaction: “It’s the ‘my kids aren’t going to get asthma’ kind of thing. […] You see it in terms of indoor air quality. But it’s more comfort- and health-oriented than it is that engagement piece” (Managing Director, Interview R). On the other hand, more ubiquitous quantification and awareness is needed. As an interviewee describes of being on the board for the Smart Readiness Indicator for Buildings project, most of the board members are not yet to this level. “Europe itself is looking at smartness with SRI [Smart Readiness Indicator], and if you look at the idea behind it the ideas are quite good;” but “I was
measuring over 3000 ppm [carbon dioxide parts per million, an indicator of unhealthy air] in the meeting room at the European Commission” (Public Affairs Manager, Interview B).

5.3. Sustainable Business Model Innovation

This problem of measurement and awareness affects development of all the SDGs. As aforementioned, the UN acknowledges the challenge, but the shortage of data influences business as well: “The SDGs need to define the world’s biggest problems. You could say that they are the world’s business plan. […] Some of these problems, they are so intangible. So you need some frameworks and guidelines to engage” (Senior Vice President of Corporate Strategy and Stakeholder Relations, Ørsted E). This kind of substantiation is part of building the business case around the SDGs: “One of the things I think we’re actually going to need to see is ‘proof points’” (Senior Director, DNV GL, Event G). And it forms the foundation of smart building and smart city development, especially in terms of justifying funding. “From my experience, qualitative is a better round two. You establish the baseline, you look for quantity, you look for measurable impact. And then you start to understand” (Smart City Officer, Interview N).

Another driver of business development for smart buildings is the anxiety that the tech industry will come to dominate the building business: “Architects are about to give up control of the environment and hand it over to the technologists” (Independent Consultant and Fellow, Illuminating Engineering Society of North America, Event H). This, in part, stems from the advent of smart home assistants such as Amazon’s Alexa and Google’s Home Assistant: “We can have a place in smart buildings because, in fact, if in five years we do nothing, it will be Google. It’s already Google” (Innovation & Smart Buildings Consultant, Interview E). But others in the industry take up the mantle and initiate change. In reference to its partnership with the smart thermostat company Ecobee, Mattamy Homes says, “It made us in the position in the market that we are the only builder who is acknowledging that transformation and making some serious steps in that direction” (Vice President of Sustainable Development, Interview P). And once some spaces are demonstrably healthier than others, companies will race to catch up (Built Environment & Smart Cities Expert, Interview F).

However, the involvement of the public sector is essential to stimulate market development. In reference to contributing to the SDGs, a prominent Danish businesswoman points out that “It’s great that Grundfos can take this one goal, water, and really work with this. But this is not enough: there also needs to be government” (Financial Sector and Telecom Leadership, Event F). For example, Realdania describes the systems in their Sunde Boliger (Healthy Housing) version of a smart home for controlling noise, humidity, temperature, CO₂ and particles, and then underlines that there was “no demand,” so they had this building designed to try and kickstart innovation (Project Manager, Event D). Although smart technologies can be quite affordable, they are still an added cost, which can serve as a disincentive for consumers (Director of Operations, Interview O). Thus, collaboration between the public and private sectors will likely be necessary for scaling smart technologies: “It’s going to have to be these public private partnerships, and I think in terms of the diffusion of interesting new technologies, it’s going to have to be public private partnerships” (University Professor, Interview M).

5.3.1. Social Housing

One of the major intersections between the public sector and the private building industry is that of social housing. Building degradation and quick turnover are not only building problems, but social sustainability problems (Principal & Architect, Interview K). This is exacerbated by a “divide in wellness” between the haves and have nots (University Professor, Interview M). Whereas some social housing companies perceive smart technology as necessary for improving people’s health (for example, by measuring quality with sensors and controlling humidity) (Technical Adviser & Renovation Supervisor, Interview D), others are hesitant to ‘technify’ buildings too much (Real Estate Director, Interview J) and to install technology that neither the facility managers nor the end users know how to handle (Architect, Interview G).

Further, the ability for social housing companies to undergo renovations – which the effectiveness of smart technology may rely upon – is limited. In the case of RenovActive, an ActiveHouse renovation in Brussels with the social housing company Foyer Anderlechtois, smart home technology successfully
maintains indoor air quality within healthy parameters. However, another company, BinHôme was barred from adopting the same renovation model: “The use of RenovActive is not very easy because it's really a big system, and as we have to make it with public tender, you know, we cannot say we want RenovActive” (Architect, Interview G). Whereas the RenovActive model is drawing attention from private homeowners in Slovakia, it is difficult to create the same business for social housing. “Because in social housing, the willingness to invest in add-ons like ventilation or smart home or whatever is very low, and they will only do it if it’s mandatory or if they get a big incentive money-wise over the lifetime of the house” (Group Product Manager, Interview A).

5.3.2. Education. Another intersection between public and private building is that of public schools. Here there is seen a different perception of the value of smart technology for indoor health. The Danish Association of Architectural Firms refers to the “positive externality” of teachers becoming ill less often because of a healthier schools and argues that “it is not enough to talk about what is cheapest” (CEO, Event J). This attitude has in fact been codified into law in France, where the government has made it mandatory to monitor indoor air quality at establishments receiving children; and the appropriate measures had to be in place by January 1, 2018. As a flagship project, the city of Marcey-les-Grèves paired with Medieco Conseil & Formation to renovate a public school into a smart school, engaging sensor-based roof window automation combined with mechanical ventilation to remove air pollutants before the start of school and during breaks (Project Manager, Medieco, Event B). This system successfully removes volatile organic compounds (VOCs) that have accumulated in the night with just 10 minutes of flushing; and it likewise drops CO2 levels by 30% with 10 minutes of flushing during the breaks (Project Manager, Medieco, Event B).

Another example, specifically targeting the SDGs, is the case of Kokkedal Skole in Fredensborg, Denmark. The 1970s-style school encounters difficulties with light and temperature management in addition to poor air quality; but its principal has embarked upon a mission to convert the school into ‘Studio 17’ in reference to the 17 SDGs. The aim of the project is to create a comfort zone for knowledge and to bring students into the digital realm via the sustainability goals (field notes January 25, 2019). In relation to renovating with smart technology for improving health, the principal says, “We try to do the best possible for our students – hire the best teachers and so forth – and this is part of that, too” (field notes June 24, 2019). The Facilities Manager makes reference to a regional concern for how poor air quality affects pupils’ learning and the six billion kroner (about 800 million euro) being dedicated to the health and energy renovation of schools in Fredensborg, starting at Kokkedal Skole. When reflecting upon the late start of smart technology use, he says, “You have not had the will, the aims, the policy to use it in a better way” (field notes June 24, 2019). Renovation of one of the school’s atria is planned from Summer 2020, when smart technologies will be piloted and contrasted with the baselines determined from Autumn 2018 to Summer 2019.

5.4. Discussion
The simultaneous development of SDG-driven business model innovation and smart technology innovation presents a salient opportunity for framing health (SDG 3) as a sustainability issue for the building industry. Framing is especially important for linking smart technology and sustainable development [21]. The use of smart technology promises to contribute to sustainability and can accelerate business model innovation, especially when the technology is close to the core activities of the business (such as green construction, or indoor climate management) [32]. Prior research indicates that such technological innovation can influence the extent of business model innovation [29] and lend to businesses’ agility for transforming [35]. The research herein likewise indicates that smart building technologies that can illuminate health metrics drive forward business model innovation in the building sector. This is especially interesting for moving the industry in the direction of incorporating design for more qualitative human dimensions into building projects. However, government policies also need to be in place [20]. In order to develop both policies and business models around SDG 3, experiments with different building typologies are needed. These so-called ‘living labs’ serve as a catalyst for smart,
sustainable development of buildings and cities [21], but are difficult to scale. The findings suggest that this is because there are few key customers able or willing to adopt more expensive, albeit innovative, sustainability solutions and that market incentives are needed.

The author ventures that similar incentives may be needed for any such business model that is based upon capturing value from previously intangible benefits – as is the case with many sustainable business model innovations [36]. Based on building industry health concerns and public demand for sustainability quantification, the findings herein suggest that valuation in public buildings can be strategic for stimulating both scalable innovation and government investment. Yet, public-private collaboration for business model innovation can reveal tensions over how these different sectors go about ‘valuing value’ [37]. In this case, given the different frames of bureaucracy and public funding between social housing and schools, schools appear to align valuation strategies better with the building industry. If enough business cases emerge from schools that demonstrate the impact of investing in smart, healthy buildings, similar business models can be applied to other government buildings (e.g. hospitals, government offices), as has been demonstrated with the scaling of green building certification business models [38, 39]. Thus, the main contribution to sustainable business model innovation literature is to indicate public-private partnership – with aligned valuation strategies – as the next step needed for scaling SDG-based business models.

6. Conclusion
The advent of the SDGs presents the opportunity for private industry to pursue sustainability as framed in a new, globally relevant way. The building industry has, after demonstration learnings and improved quantification, set its sights on health within buildings. SDG 3 specifically names non-communicable disease prevention, alleviation of mental health issues, and reduced illnesses and deaths from hazardous pollutants, all of which are part of healthy building. As the industry experiments with building techniques, smart technologies have arisen as tools for measuring health parameters, automating the indoor climate, and connecting with end-users to increase awareness. Quantification of health factors and measured impact of smart technologies for health can be the starting point of the business of healthy buildings. From the quantified value of indoor health follows a whole new health-based sustainability of the built environment. However, in the absence of a market for healthy buildings, government involvement is needed for scaling business model innovation. The research presents public-partnered business model development for public buildings as a way to trigger market development and suggests that schools in particular are gaining the most traction.

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