DOES INDUSTRIALISED HOUSING DRIVE SUSTAINABLE TRANSITION? SWEDISH EXPERIENCES

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Industrialised Housebuilding (IH) in Sweden have grown within Multi-Storey Housing made of Timber (MSHT) and most of the producers rely on this approach. Business models for Industrialised Housebuilding, often start with prefabrication. With the rapid growth of sustainability demands and circular construction as an uprising theme, a central question is, what is the sustainability element in Swedish industrialized housebuilders business models regarding MSHT? Sustainable transition theory is adopted. The method is a desk study of existing research, websites, annual reports and other material. The sustainability element in the business models of industrialized house builders is explored, with focus on circular construction. MSHT is described as reducing environmental impact compared to concrete and provides social values, enabling its diffusion, however with less apparent cost advantages. However, with the growth of circular thinking, IH may have potential to further develop. The findings show that sustainability is overall present in the development of IH within MSHT, where the companies show a homogenous picture with varying challenges and contribute to sustainable transition. Regarding circular construction, the study shows potential in additional steps needed from a life-cycle perspective.

Keywords: circular construction; industrialised housing; sustainability; Sweden

INTRODUCTION

Due to changes in building regulations in 1994, multi-storey housing in timber (MSHT) became allowed. Since then, this niche has grown, and MSHT-systems have developed. According to statistics from TMF (2020) apartments in building with 3 stories and more have increased from 1000 in 2015 to 1700 in 2019. There has also been an increase in available producers of MSHT, with industrialised housebuilding (IH) as a key component for the manufacturing and production. Increased volumes of MSHT, with its assumed positive environmental impact, has also been lifted as a key issue to reach climate goals by 2030, as well as a key to meet societal challenges (Brege *et al.,* 2017). The building sector is in this setting of high interest due to its huge environmental impact (see for example Manley and Rose 2017). In this setting, MSHT is a highly interesting alternative, with its environmental advantages in

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comparison with the current dominating structural material concrete (Erlandsson *et al.,* 2018, Penaloza 2015).

Over time the concept of circular economy has also been of rising interest. No common definition exists of the concept, but a relevant example is "an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes" (Kirchherr *et al.,* 2017: 229). This statement was based on an analysis of 114 definitions of the concept. Hence, this uprising concept clearly pushes sustainability forward, introducing higher ambitions and goals and subsequently also more pressure on society and the building sector, being a major source for negative impact on the climate.

Studies have also been made regarding business models of IH and MSHT, highlighting prefabrication as a starting point to which other elements should be adapted and related to (Brege *et al.,* 2014). Prefabrication is also a part in IH according to studies by Lessing (2006) who besides this element highlights seven others; planning and control of the process, developed technical systems, off-site manufacturing of building parts, long term relations between participants, supply chain management integrated into the construction process, customer focus, use of information and communication technology and systematic performance measuring and re-use of experience. Due to the developments since the work by Brege *et al. (*2014), with the rapid growth of sustainability as a key ingredient society and with circular construction representing an emerging new set of sustainability demands, a central question is, what is the sustainability element in Swedish industrialized housebuilders business models? A main point is also as the title of the paper entails, if this drives sustainable transition. The approach builds on sustainable transitions research since this allows for a broad approach to understanding (see Main approach later in this paper).

Sustainability, Circularity and Business Models

Regarding sustainability, this research uses the work by the Brundtland report "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (WCED, 1987) and emphasises the three dimensions of economic, social and environmental sustainability, where all three dimensions are given equal value and should be emphasized.

A main point in this paper is also what the sustainability element is in IH´s Business Models (BM). This paper aligns with Brege *et al. (*2014) view of business models, where the business model construct defines alignment between the environment, the company offering, internal and external resource base and activity systems. This covers three central building blocks: market position, i.e., roles taken in the market; offering, i.e., the value proposition toward customers; and operational platform, i.e., the resource base and its organisation. Brege et al-s' review of BM in relation to MSHT identify five elements: prefabrication mode (operational platform), role in the building process (market position), end-user segments (market position), system augmentation (offering) and complementary resources (operational platform). Based on their frame of reference they identified seven different BM's and this research builds on these results. However, the sustainability dimension as well as the theme of circular construction is not included and as they also point out BM´s change over time. This motivates a continuation of their research.

To update and include circularity and sustainability in the business model discussion, work by Lüdeke-Freund *et al. (*2019), who makes a review of circular business models, is included. They state that "The overarching goal of CEBMs is to help companies create value through using resources in multiple cycles and reducing waste and consumption" (pp 41, in line with previous references). Waste is avoided or reused in the best scenarios and only renewable energy is used and that all the process must be taken into consideration. They show several different options revolving around the key areas of value proposition, value delivery, value creation and value capture. Therefore, these concepts are used when reviewing sustainability and circularity of MSHT, especially since they present a number of different typical CEBMs where different areas are expressed in detail, based on the four key areas.

METHOD

Main Approach Used

A framework on the move forward in sustainability research is transitions research (Köhler *et al.,* 2019). A main driver in this type of research is that many environmental problems require radical shifts to new socio-technical systems. These shifts are called "sustainability transitions" (Elzen *et al.,* 2004; Grin 2010) and "a central aim of transitions research is to conceptualize and explain how radical changes can occur in the way societal functions are fulfilled" (Köhler *et al.,* 2019:2). A stream of interest that this paper focuses on is "businesses and industries in sustainability transitions", focuses on "how firms and other organizations contribute to (or slow down) transitions and how changes in the organizational and business dimension affect transformation more broadly, i.e., institutional, political, societal change" (Köhler *et al.,* 2019: 11). This is useful in understanding changes taking place. For the paper, the Multi-Level Perspective (MLP) of sustainable transition by Schot and Geels (2008) is used.

Theories inside MLP view innovation in a sector as a socio-technical phenomenon and identify three levels of socio-technical interaction, in which innovations in sectors can be explained: micro, meso and macro (Schot and Geels 2008). A main point is that niches form the micro-level in which radical novelties develop, in this case the theme of MSHT. A socio-technical regime forms the meso-level, i.e., the dominating stabilized socio-technical pattern of interaction reproduced by institutionalized learning processes. The socio-technical landscape forms the macro-level (e.g. macro-economics, deep cultural patterns, macro-political developments). Sociology of technology research and evolutionary economics have highlighted the importance of niches as driver of innovations, where new socio-technical regimes can develop (Geels and Kemp, 2007; Schot 1998 and Levinthal 1998). Through the niches, new ideas can develop with less influence from traditional selection mechanisms of the marketplace. In this setting, MSHT can be regarded as a possible uprising new socio-technical regime with a growing market and increased acceptance, challenging concrete as a main structural material. To show this in the approach in the paper, we go through changes in the context, i.e., increased pressure on increased sustainability, how MSHT has developed and in specific how sustainability and circularity are visible in the current situation of the studied companies and then we reflect on what has happened regarding these levels in the analysis and discussion.

Since the cases selected for the study has grown from established timber companies, where other business areas have financed the development, they have been able to finance the development and maturation of ideas taking place over time (cf Lindgren

and Emmitt 2017) and hence with building of social networks and learning processes occurring, all essential for these activities to take place (Schot *et al.,* 1994; Kemp *et al.,* 2001). The development of niches through these activities is achieved through ongoing project-based learning processes which over time provides a certain direction /rationality. As Schot and Geels (2008) and Koehler *et al. (*2019) highlight, regimes can be capable of changing sectors and/or nations in a sustainable direction.

Method - Selection and Studies of Companies

The method is a desk study of existing research, websites, annual reports and other material useful for describing MSHT, business models and business model development. Google Scholar was used to find relevant literature regarding existing research, and authors prior knowledge and material was useful for finding relevant material on the companies. Google and the company homepages were also used. The method relates to an argumentative literature review (see for example Coleman, 2017), following the steps 1) formulating a valid and interesting research question 2) reviewing literature based on the research question 3) collecting and assessing relevant findings in literature and based on this write, describe and formulate the paper leading up to the conclusions made. The framework by Brege *et al. (*2014) is used in order to describe the business models of the studied companies, and the cited work by Lüdeke-Freund *et al. (*2017) is used to study the circular elements in specific detail, specifically used in the discussion and analysis of the findings. Of the companies selected, three of them were studied in Brege *et al.,* while the fourth, Derome bought Setras production, which was studied in Brege *et al.*'s research.

Besides this, the organisations studied were also suitable due to their size, i.e., being the larger producers of industrialised MSHT-systems. They are furthermore naturally developed from a timber-focused company and have been in the area more than 15 years, providing a fair possibility of developing businesses that consider all three elements of the sustainability concept. Furthermore, the companies have a published sustainability report, which was central for the desktop-study. To discuss transition, the growth of MSHT is reviewed in general and short, and the cases studied provide detail of their current status, to enable a valid analysis according to the approach used.

Multi-Storey Housing and Studied Companies

The growth of MSHT and its characteristics

As stated in the introduction, the rise of MSHT, has resulted in a niche being established on the market. This niche is dominated by IH, and it can roughly be divided into a number of different sub-niches basically from three types of structural systems: column-beam systems, massive wood elements and timber frame systems (Stehn *et al.,* 2008). These are combined into on-site construction, prefabricated elements and prefabricated volume elements (Stehn *et al.,* 2008), where On-site construction becomes more and more rare (Swedish Wood 2016). It is mainly used as a part of a learning process when moving towards IH (see for example Lindgren and Emmitt 2017). In addition, there has been huge investments in production of Cross-Laminated Timber (CLT), enabling the use of massive elements, finished in factories with holes for windows, doors etc. (See for example, Dagens Industri 2018).

Altogether, modular housing systems dominates the market with the others as sub-niches (Swedish Wood, 2016). There is also a substantial amount of production taking place with one to two story buildings, dominated by timber as structural material. The advantages of MSHT have mostly been directed towards lower environmental impact by using timber as the structural material. A report by IVL

comparing five different building systems show that timber-based systems have the lowest environmental impact, but there is still work to be done, like using climate improved concrete in the foundation, transportation with HVO-fuel and using energy-efficient sheds on site. Life-cycle studies by Penaloza (2015) also conclude that timber has the lowest environmental impact and the biggest challenge for timber to lower impact further, is to reuse the material more after demolition.

Many traditional efficiency parameters have also been raised about MSHT but there has however been a debate taking place about the cost for MSHT, for example in the magazine Betong (Betong, 2019), but the current expansion at least indicates MSHT as cost competitive. As stated in the introduction, there has also been an increase with 70 % regarding MSHT over a five-year period. There has also been a discussion about the stability and usefulness of timber is as a material in relation to concrete (the existing regime, see for example Engström, S and Hedström 2012).

Looking back at the development regarding MSHT, Stehn *et al. (*2008) reported on three-year observations of MSHT and concluded that the development between 1995-2008 is characterized by a start in using the material, increased prefabrication, use of weather protection, new actors on the market, development of technology both in terms of the systems as a whole and their technical details. This development is also typically described in Lindgren and Emmitt (2017), where the resources and width of a major company enabled development of MSHT through a broad portfolio of business areas generating resources for development. It would be suitable to call this a start-up and learning stage in the development. Main development areas highlighted here relates to coordination of the process and technology development. The MSHT-sector had a turnover already at this stage of 2,4 BSEK, with an increase from a market share of 5 % (2004) to 10-12 % (2008). It is also quite evident that there are many technical issues that are at hand to manage, but projects were driven by environmental and quality arguments, with specific considerations regarding fire, acoustics, installations, moisture/weather protection and the no of stories.

A later review by Brege *et al. (*2017), points out that in 2015 MSHT had a turnover of 3,5 BSEK and in this forward-looking report, they highlight that the share of MSHT must increase to 50 % given that traditional concrete stays the same to have a chance to make the climate-goals. The concrete industry is also pointed out as working hard on being climate-neutral by 2030 mainly through a more efficient use of energy in cement-manufacturing (transfer to bioenergy), optimisation of cement-recipes for different areas of use and catch and store the carbon-dioxide that is created in manufacturing. A main point in their report is that a heavy expansion is needed within MSHT, highlighting that timber is in an expansion stage, becoming mature and stable, while there are uncertainties regarding expanded concrete production since the climate issue at the moment is insecure.

These current advantages with MSHT, especially the lower environmental impact, has also most likely put pressure on current building methods (concrete) and this also shows in how they display themselves as well as in their development of solutions. Strängbetong has for example introduced Strängbetong Studio, a combination of precast elements with a subfloor system in metal, reducing environmental impact as well as providing more flexibility in the erection process. There has also been a growing interest in hybrid-solutions, where different materials are combined to get the best result in terms of all sustainability dimensions.

Business models of industrialized housebuilders
In this section of the paper, the studied organisations are described, and then regarding the five elements of the business models based on Brege *et al. (*2014).

Derome has a long tradition of working in timber, which has developed over the years and now the company has 6 Business areas covering businesses from sawmills to real estate companies with a turnover of 7,6 BSEK. Through this, the company as a total has many different roles in the market and regarding IH, they deliver to their own business areas as well as to external customers. Moelven byggmodul, belongs to the larger forest company Moelven with a turnover of 11,8 BSEK but they also have more flexible solutions coming from a building system using CLT (Moelven Töreboda). Byggmodul, active in modular housing has a turnover of 1091 MSEK and Töreboda has one factory and a turnover of 295 MSEK. The level of prefabrication differs between the two areas, where Byggmodul has a clearly higher level of prefabrication. Lindbäcks stems from a sawmill but has continuously developed into a producer of modular housing and owner and manager of buildings, with a turnover of 1,7 BSEK and the company as a whole consists of the producer and real estate companies. Martinson was recently bought by the larger company Holmen, a large forestry-centred company with a turnover of 16,3 BSEK. Martinson, with a turnover of 1,9 BSEK has a business areas covering saw-milled products, building products in CLT and Glulam and building systems covering different types of buildings.

Moelven and Lindbäcks are producing and supplying volumetric modules, while Derome supplies both volumetric modules and elements. Martinson makes elements in CLT and thereby is a frame-system for MSHT. Regarding the offering and end-user segments Derome, Moelven and Lindbäcks at large address the same type of customer with similar offerings. Brege, *et al. (*2014) address this as medium level living in typical suburbs, for medium income earners and students or elderly people (but a review of conducted projects however indicates that Moelven moves towards Martinsons customer-segments). Martinson targets both the customers that the others focus on, but also high-income earners in city centres. Regarding prefabrication mode, all suppliers have a high degree of prefabrication level.

How do the selected companies currently express sustainability and circularity?
After studying the latest information from the companies (websites and sustainability reports), all of them highlight all three sustainability dimensions, however to different extent. They all in different ways highlight fast erection time, lowered amount of transportation, social aspects with a sound living environment and what they do to create good social living spaces and solutions, for example mutual social areas and car-pools. They especially highlight the positive environmental effects with timber, how they replant trees and invest in the forest and also the positive sides with timber as a construction material. A main issue in the manufacturing is to use raw materials from the nearby surroundings, with both CE and FSC/PEFC-classification, which guarantees a sustainable forestry holding. They also emphasize local values, for example having production-sites in the countryside (a heritage from the past when being close to water and forest was important) thereby enabling societies to continue and develop in the countryside. All companies emphasize a safe and sound work-environment.

They also highlight that they have a good control of their supply chain. They continuously reduce waste throughout the construction process, by sorting and reducing waste and a resource-efficient design. Different examples of how they also

try to develop in the supply chain are given. Moelven for example, are mapping their use of plastics, to lower costs and environmental impact. The plastic is made to 95 % by reused plastics and trials are done with a PE-laminated fluid-carbon to lower impact. Derome have a transportation fleet of their own that is run to 60 % with fossil-free fuel (with the aim of increasing with 5 % each year), they decrease the use of road transportation and increase on railroad, trials are made with trucks that run on biogas and also 74 tonnes-trucks (can take 8 tonnes more than conventional trucks) are used. The companies also express how they work with bioenergy and Lindbäcks for example show how they work with solar panels. The use of reused materials is also apparent at all companies. A main issue when it comes to the sustainability reports is that these to a high extent contain much of the same focus areas and major similarities are found, but there are differences in where they are and what they work with. They provide measurements covering all sustainability dimensions and how they progress within all these areas. They also highlight which of the UN sustainability goals that they are working with. Moelven has an overall focus on objectives 3, 4, 8, 13, 15. Derome on 5, 11, 12, 13, Martinson 5, 7,8,9, 10, 11, 12, 13, 15 and Lindbäcks 3,5, 8, 9, 11, 12 13.

When it comes to circularity, a main issue is that the companies show a lot of focus on the process from the raw material timber from the forest, through production/manufacturing and over into real estate management. Moelven though, highlight that renovation and extension of building life cycles is good for the environmental impact and that much work is needed here. They have for example developed office-solutions that can be modified and used for new needs, and they highlight that current buildings can be developed by adding extra stories in timber. This is also highlighted by Martinson, but not in relation to circularity. So, in this area there seems to be a potential in working with solutions that reduces the need to tear down buildings and instead prolong their lifecycle.

ANALYSIS AND DISCUSSION

What is the sustainability element in the BM of IH? Do they drive sustainable transition?

Reviewing the development so far, the change in building regulations opened up for a window of opportunity with MSHT. This is the starting point. The first years characterised by technical development was at large enabled by the developing companies' resources in combination (micro-level) with an increasing pressure on more sustainable alternatives in building (macro-level). This start consisted of development in which technical and processual issues were developed and improved, i.e., better and more stable products, leading up to more stable systems, enabled by internal development at large timber-based organizations. This reflects what happened on micro-level and can be viewed as basic factors needed for further development. In the stages following, there are two seemingly strong drivers, a stronger focus and pressure on sustainability (macro-level) and an increased acceptance for MSHT shown by an increase in turnover (meso-level). BMH It is however a point of discussion regarding what drives what? but after this an interplay takes place between different levels, undoubtedly important for future development and for sustainable transition.

As can be noticed, sustainability and all its dimensions are visible in all the businesses and business models studied. The growth of MSHT imply financial feasibility, as well as the visibility of the other dimensions and they seem to have been strengthened

over time, but the environmental dimension is a key driver initially (even if the timber companies also saw a possibility to expand their business). In the forward-looking work by Brege *et al. (*2017), MSHT must expand and drive development forward to reach climate goals, but this also creates a need for increased capacity. Hence, a challenge is therefore to manage a heavy expansion in a controlled way, with an increased pace regarding sustainability. It can also be concluded that circularity can be developed in many different areas. As of today, much of the focus is on the actual production and on the real estate management part, but there is a need to find solutions for renovation and development of already existing buildings, to increase their life cycles and put greater emphasis on the final parts of the life cycle of buildings, otherwise it comes to focus on how to use the waste that comes from buildings that are tear down.

If we return to CEBMs, the focus areas in the sustainability work are in the majority to reduce waste and switch to more environmentally friendly solutions, thereby reducing environmental impact. The companies continuously try to reduce and reuse material in different forms. However, when reflecting on the reuse and consumption, the lifecycle concept comes into focus. There are basically two ways that come into question when addressing the end of a building in use; tear it down and use the scrap material in other settings or prolong the lifecycle by adjusting or developing the building. The latter is to a minor extent addressed by Moelven (and not outspoken by Martinson) and the first area is not addressed at all at this stage (if one cannot generously see that reuse of material is occurring in the process). The use of scrap material can be processed again into other products but requires a systematic approach in the demolition of buildings to sort and reuse the scrap material. Hence, a conclusion to make is that the final steps show a potential to develop, at least in how the companies express this issue and then work with it, in line with Penaloza (2015).

So, does industrialised housing with regard to MSHT drive sustainable transition? Reviewing the changes taking place with a development in cycles, it is taking ground and winning more of the market shares available, and it should thereby put pressure on the existing regime of housing built by concrete in a similar manner as depicted in transition theory (Schot and Geels 2008). The systems have for some time been well developed technically and the growth with regards to market share, delivered apartments and turnover, indicate that the cost level is competitive and the work taking place on improving sustainability indicates that it does contribute to sustainable transition, and is challenging the incumbent regime. As its often seen in transition studies it is however not only a new more sustainable product that challenges the incumbents, but it is also other dynamics such as macro level legislation (ie from EU) that pushes the development (Köhler *et al.,* 2019) But more focus is needed on prolonging the life cycle of buildings in terms of developing buildings and solutions that enables reuse of the material.

CONCLUSIONS

The contribution set out to answer two main questions: What is the sustainability element in Swedish industrialized housebuilders business models? And does this drive sustainable transition? The findings show that sustainability is overall present in the development of industrial housing (IH) with regard to Multi-Storey Housing made of Timber (MSHT) and the studied companies show a fairly homogenous picture in their work. Depending on company the sustainability dimensions and work and development areas differ. Hence, the research conducted indicate that IH with regard

to MSHT contribute to sustainable transition, but in tandem with other dynamics such as renewed legislation coming from macro actors on national and European level. Regarding circular construction, the companies show a clear focus on working with the supply chain in their control with using and reusing products and materials in an efficient way. But many other aspects of circularity are not covered. The study shows that additional steps need to be taken, mostly when it comes to prolonging the life cycle of buildings and in terms of how demolished buildings come into further use.

This being a desk-top study, several interesting ways to move forward arise. There is an expectation that things might be hidden beneath the surface, i.e., it is fairly likely that the companies conduct activities, even of less sustainable character, that are not presented here. Interviews based on the results with the companies involved would shed more light on the findings and if and what the companies are working with in a circular direction, i.e., future plans. It could be suitable to present this study as a basis and study reactions from the involved organisations to see if and what more is in the development plans by the companies.

Furthermore, views from concrete industry representatives would be of interest to validate findings and find opposing arguments not least from the existing regime. It is also evident in this short paper that the meso-level needs to be both described and expressed more thoroughly, in order to deepen the analysis of what happens. One key factor of interest to retrieve a better answer for the main question here, is to more deeply describe and analyse what happens on the meso-level. Does MSHT drive the concrete-industry forward, or is it a result of the general development on macro-level?

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