

The 'circular' building materials challenge: a case-based policy approach

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Abstract

The transition to a Circular Economy requires enabling conditions that remove existing barriers in product utilisation and material recovery operations. The adoption of circular business models is one of the key building blocks of the Circular Economy, but the viability of such businesses is often dependent on supporting policies. This contribution reviews the literature on resource efficiency policies, relevant to building materials and the construction sector, and discusses how current and new policies can support circular business models, building upon two company case studies. The companies are specialising in construction solutions, by providing highly durable, reusable and fully recyclable building components. The cases are built on semi-structured interviews with company representatives and follow-up surveys. Both companies agree that building passports and material passports, along with design for deconstruction, building modularity, durability and reuse/recycling at materials level should be established, so that reusable building materials can be efficiently salvaged and returned for further utilisation or recycling. Green public procurement can play a fundamental role in increasing the uptake and use of durable and recyclable products. Economic instruments such as tax reductions for recycled materials can boost greater utilisation of secondary materials in buildings. Given the long lifetime of buildings, it is considered essential to encourage design improvements and circular business models through appropriate policy instruments.

KEYWORDS

Circular economy; Reuse; Recycling; Building materials; Construction materials; Resource efficiency policies.

1. INTRODUCTION

Policy efforts at a strategic level in the European Union (EU) in recent years highlight the significance of gradually moving away from our current linear economic system to one that is based on closing material loops, the so called Circular Economy (CE). This suggests moving up the waste management hierarchy by promoting waste prevention and the efficient use of resources through designing more durable products, and stimulating product re-use, repair, and recycling.

Despite the fact that the basic principles that define CE have been laid out several decades ago (Ghisellini et al. 2016), only recently the EU capitalised on this knowledge to deal holistically with resource efficiency in Europe. With the launch of the new Circular Economy Action Plan (EC, 2015a), the European Commission outlined a preliminary agenda to improve resource efficiency and material management in the EU. However, the Action Plan provides only a narrative on what CE is, as it lacks any binding targets related to resource usage or resource intensity, and most policy proposals are at an early stage of development. Despite that, in the Annex to the CE Action Plan, a list of specific actions that the European Commission will undertake from 2016 onwards is presented, targeting policy support measures and development of regulations at different stages of products' life-cycle as well as for certain waste streams (EC, 2015b).

In the CE Action Plan, a number of priority areas are identified, including a strong focus on the efficient use of construction and demolition materials. In the EU, the construction sector is very material intensive, consuming in average between 1.2 and 1.8 Mt of construction materials every year (Herczeg et al., 2014). Construction and demolition activities also generate a large amount of waste, which in 2012 amounted to 821 Mt, equal to one third of the total waste generated (Eurostat, 2017). Many of the materials found in buildings are recyclable, or can be reused, but reuse and recycling rates vary widely across the EU Member States (Deloitte, 2016). The Waste Framework Directive (EC, 2008) includes a dedicated target for the preparing for reuse, recycling

and other material recovery of construction and demolition waste to a minimum 70% (by weight) by the year 2020, but several practical challenges still have to be addressed if waste management in this sector is to improve.

Despite the fact that there are several policies in place at EU level to improve the sustainability of the sector, the transition to a CE requires necessary enabling conditions that remove existing barriers in product utilisation and material recovery operations (Wilts et al., 2014). The adoption of new circular business models is considered to be one of the key building blocks of the Circular Economy, but the viability of such business models is often dependent on supporting policies (Planing, 2015). Business' barriers are complex and are the sum of institutional, organisational, behavioural, technological, and market based barriers, combined in a 'web of constraints' (Bastein et al., 2014). A wide range of policy measures are therefore needed at various levels, including both changes in regulatory frameworks, public spending and consumer engagement (Bastein et al. 2014; Westblom, 2015).

Much of the recent CE thinking and policy are focused on short- and medium-lived consumer products (Benton et al., 2015; Pollard et al., 2016). However, given the long lifetime of buildings, it is essential to consider more carefully design improvements that will increase the durability and recyclability of materials and components. Currently, there is only limited research of CE in the built environment at the product and component level. Most of the existing research has focused on recycling of construction and demolition waste (CDW) with little attention on the reuse of products and the use of secondary sourced materials (Yuan and Shen, 2011).

In this contribution we will examine policies that relate to the uptake of innovative secondary building materials in construction applications. The line of thinking in this endeavour is based on the fact that building materials can be designed to be fully recyclable and reusable from the start, thus eliminating the need to consider them as 'waste' at the end of life of buildings. However, proper arrangements are necessary for the take-back and reuse or recycling of the products after their first life cycle. The research therefore focuses on the enablers for such 'circular' products and will examine holistically the barriers and opportunities, taking a life cycle perspective in policy interventions (Dalhammar, 2015). Potential environmental gains of the uptake of fully reusable and recyclable materials relate to: less depletion of resources, the reduction of global warming potential and the potential to close the loop for effective handling of toxic materials (Sundin and Lee, 2012). In this paper, we will first review the relevant literature on policies to support the transition to a Circular Economy in the construction sector. Then, we will account for two cases with companies which produce innovative building products from secondary raw materials. The two cases allow for an in-depth understanding of the barriers the companies face in order to scale up their business, and what kind of policy interventions could be potentially helpful to their operations. A cross-case analysis will enable a discussion on the requirements for effective policy interventions in relation to the identified barriers, leading to the conclusions of the paper.

2. POLICIES TO SUPPORT 'CIRCULAR' BUILDING MATERIALS

2.1 Policies for the transition to a Circular Economy

There is a large number of existing policies in the EU that can contribute to CE objectives (Milios, 2016). Policies related to waste management and producer responsibility, eco-design, and chemicals are of high significance as they regulate design, durability and chemical content of products (Dalhammar, 2017). However, there is an increasing concern that these policies can be in conflict with each other. For instance, companies that want to use recycled materials in their products may still choose virgin materials because they are not certain that recycled materials will comply with EU legislation on chemicals (Tojo and Thidell, 2012). This implies that a big part of the policy task in the coming years is to review and address the conflicts among existing policies; this is also brought up in the EU Action Plan (EC, 2015a).

When it comes to proposing new policies, the EU CE Action Plan discusses a range of potential policies, from eco-design regulations and durability labelling to public procurement and economic instruments, as well as the development of quality standards for secondary raw materials (EC,

2015a). At this point however, the only policies quite certain to emerge concern durability requirements under the eco-design and labelling directives (Dalhammar and Milios, 2016). Furthermore, the most effective application of policies for CE is considered to take the form of a policy mix rather than a set of separate policies. The potential policy mix must be coherent, consistent and predictable (Ekvall et al., 2016). However, it is not certain that this could be possible since, in reality, policies are implemented and improved in a rather ad-hoc manner, reflecting the political processes at EU and national levels. A further problem concerns the coordination between EU and national policies (Dalhammar, 2017). While rules on eco-design, chemicals and waste are primarily decided at the EU level, rules on taxation, public procurement and waste infrastructure are primarily decided at national level. EU member states, as well as regions and municipalities, have already started to adopt a number of policies to promote the Circular Economy, including procurement of remanufactured and reused goods, recycling parks and public spaces for repair, differentiated producer responsibility fees, and web platforms for sharing (Avfall Sverige, 2015).

Companies that want to develop more circular business models (for an overview of different circular business model configurations, see Bocken et al., 2016) often face a 'web of constraints' (Bastein et al. 2014) making this transition difficult. The findings of a recent interview study with Swedish companies demonstrate that the current economic and policy regime is hindering circular business models to scale up and that the necessary enabling conditions are not currently in place (Westblom, 2015). Therefore appropriate policy interventions were requested, though the desired intervention was slightly different depending on economic sector. For some companies, taxes on labour and resources were the main issues, for others it was consumer acceptability that was the main concern. This means that the policies required for helping these businesses vary. In the same study, the five most pressing issues to deal with politically are: 1) get the prices right for second hand vs. new products; 2) inform consumers to make the right choice; 3) use public procurement to create demand; 4) regulate product development and design; 5) provide political leadership through long term strategies and targets. More research is needed in order to understand how policies should be designed, and what policies can benefit different types of business models.

2.2 Policies for a resource efficient construction sector

The general policy framework in the EU is strongly focused on the recycling of construction and demolition waste, rather than on waste prevention or reuse of building components/products (EC, 2008; 2011; 2015a). Construction and demolition (C&D) waste management is driven largely by the Waste Framework Directive (2008/98/EC) and in particular the 2020 target of 70% recovery and recycling, including the separate collection of C&D waste fractions on site (EC, 2008).

Standards for recycled materials, building codes, and Environmental Product Declarations (EPDs) appear to be important components of regulating secondary materials in construction. Despite the fact that the majority of building codes fail to incorporate sustainability principles in regard to material use and 'green' product specifications, there have been concerted efforts in recent years to amend the codes and promote the sustainable use of resources (Deloitte, 2016). In addition to the official building codes (specific to a Member State), there is a variety of well-known building certification schemes (BREEAM, DGNB, HQE, LEED etc.) that also take into account material resource use and the sound management of C&D waste. However, these schemes are voluntary and currently cover only a small fraction of the construction market (Herczeg et al., 2014).

Environmental Product Declarations (EPDs) provide standardised information about the environmental performance of a given product or material, and are used extensively for building products and materials. They allow the environmental performance of products to be traced upstream and facilitate more transparent and easier environmental declarations of intermediate and final products. On the down side, there is currently a variety of different EPD schemes throughout Europe, which means that product manufacturers must often prepare multiple EPDs for a given product to access different markets or satisfy different customers. Some Member States (e.g. Netherlands and Germany) have also established standards for recycled waste materials (Deloitte, 2016).

Selective demolition is an important process in providing clean, recyclable waste fractions. Pre-demolition audits can help achieve this by providing a comprehensive inventory of materials in the

building that is to be demolished. These tend to be primarily focused on identifying and isolating waste that is or could be hazardous and ensuring that it is collected separately, thus increasing the purity of the waste fraction. However, these audits can also be used to investigate opportunities for direct utilisation or recycling of materials, either in the project itself or in another building elsewhere. Selective demolition and pre-demolition audits have not been applied widely in regulation so far, however, this is about to change as there is already an example of mandatory application in the new 'Recycled Construction Materials Ordinance' (Recycling Baustoffverordnung, BGBl. II Nr. 181/2015) in Austria (Deloitte, 2016).

Not least, a number of economic instruments have been used to reduce virgin raw material consumption in construction. Taxes on virgin materials (e.g. aggregates) are applied in the majority of EU Member States (EEA, 2016). The Czech Republic went a step further to apply a reduced Value Added Tax (VAT) for recycled materials (Deloitte, 2016), thus facilitating the uptake of such materials in construction, but also in other sectors as well.

A recent study based on a survey and a follow-up workshop with UK construction and demolition stakeholders found that they indeed face several barriers for scaling up circular business models within the sector (Adams et al, 2017). The findings demonstrate that the current economic and policy regime is hindering any potential 'circular' operations. In the study, many fundamental issues were identified that need urgent action, and the most significant ones are 1) lack of incentives to design for end-of-life uses of construction products; 2) lack of market mechanisms to aid greater material recovery; 3) low value of products at end of life; 4) ambiguous end-of-waste regulations. The construction industry's structure, with a fragmented supply chain, was also viewed as a significant barrier. There is also a perceived general lack of interest, awareness, and knowledge among the actors. Moreover, due to the differences in various construction products used in buildings and the associated product lifespans, different types of approaches and solutions are needed.

3. METHODOLOGY

The method used in this research included an initial literature review on the state-of-the-art in policy development in construction, with emphasis on material resource use and resource efficiency, coupled with two company case studies in order to deepen our understanding of the 'bottom-up' needs for policy support towards a transition to CE in the sector. The case studies are focused on companies that produce innovative building components entirely made by secondary raw materials. The two cases allow for an in-depth understanding of the barriers the companies face in order to scale up their businesses, and what kind of policy interventions could be potentially helpful to their operations. The companies were selected as niche players in the field, and although they operate locally at the moment, both have identical aspirations of expanding their operations geographically by licencing their technology and establishing local units throughout Europe and beyond.

The two cases are based on company descriptions found online and in reports, combined with qualitative interviews conducted in June 2017. The interview guide included a set of questions related to the company, its growth plans, the main barriers for growing its business, and the main policy interventions that could be helpful for them. The findings of the interviews were further verified in the form of a survey run with the companies on business barriers and potential policy interventions. The companies were asked to grade the importance of the barriers and policies on a scale from 1 to 5, allocating the significance of perceived barriers and opportunities and enabling a meaningful analysis of the results.

4. THE TWO CASE STUDIES

In this section the two case studies will be analysed and a cross-case analysis will shed light into similarities and differences between the cases that will help us arrive to conclusions.

4.1 Company descriptions

4.1.1 Polyplank AB

Polyplank AB was established in 1994 in Sweden, and since its inception develops materials and products based on the philosophy of circular economy. Polyplank is a polymer-based fibre composite material made from wood fibres and recycled plastic. It is a very durable material and fully recyclable. The input raw materials for making polyplank are by-products from the wood and plastic industry (i.e. rest materials from industrial processes/pure waste stream). The company is sourcing its raw materials from the wood industry (for wood fibres) and through plastic recyclers (for plastic polymers). Although the material is categorised as a composite material, it is still 100% recyclable if collected separately in a clean stream, through the Polyplank manufacturing process. This means that the company needs to take back the material in order to recycle it, as the mainstream recyclers (plastic or wood recyclers) cannot process this material. The material is extremely durable and Polyplank is able to offer a 25 years warranty on purchase.

Currently the company employs 20 people. The company has a diverse portfolio of products and services targeting both construction and industrial applications. Since 2007, the building sector became the most important segment of Polyplank business activities, by providing products (e.g. balconies, fences, outdoor surfaces, noise barriers, etc.) and integrated solutions, such as the recently launched Poly Laundry System (PLS). Sales are dominated by building products (75%), while the rest of the production is used in the pulp and paper industry (25%) as core plugs for the paper rollers.

4.1.2 Noble Environmental

Noble Environmental Europe is a subsidiary company of Noble Environmental Technologies based in the USA. The European branch is based in the Netherlands with affiliates in Serbia and Turkey. Similarly with Polyplank in Sweden, Noble Environmental Europe (henceforth Noble Env.) bases its operations on the innovative material ECOR, which has been developed in USA since 2005. The European branch however, has only recently started its operations with a pilot production unit established in Serbia in 2014. Currently, Noble Env. employs 70 people in Europe.

ECOR is an advanced composite panel formed by the conversion of cellulose fibres, pressure, and heat. Fibres are sourced from old corrugated cardboard, old newspapers, office waste, forest waste, agricultural fibres, and even bovine process fibres. Evidently, ECOR can be produced from a wide variety of different secondary materials sources. It is 100% bio-based, comprised of recycled waste materials, and fully recyclable. Today, ECOR is available in a wide range of configurations from single and multi-ply panels to an extremely versatile range of three-dimensional assemblies (e.g. structure panels, partition panels, floorings, doors and (decorative) furnishings, etc., all applied both at the interior and exterior of buildings). In the European market, about 50% of ECOR product applications are in buildings.

The company is sourcing its raw materials mainly from two groups of actors. Firstly, the provider of the waste stream can be the off-taker of the products. For example, a company might provide raw material (e.g. bio-waste from an organic process) and receive back ECOR panels for use in construction or other functional applications. In this way, a fully closed loop can be observed, where the waste materials are transformed into products and used back by the same company in different ways. Secondly, the provider can be a waste management company, providing organic waste from public maintenance (e.g. grass, branches etc.), or residues from wastewater cleaning.

4.2 Interview findings on business barriers and policy interventions

The interviews with company representatives shed light to a variety of issues that small innovative firms are facing, especially in relation to 'circular' material products for use in buildings. The findings of the interviews will be discussed in the following sub-sections together with the results of the follow-up surveys which solidify the arguments and make a clear contribution to the

challenges addressed in this paper. Table 1 provides input from companies on the main barriers they face in their business operation at a scale from 1 to 5, where 1 stands for a very small barrier and 5 for a significantly high barrier.

Table 1 Barriers for scaling up the use of recycled building materials/components

Type of barrier	Barrier level for Polyplank	Barrier level for Noble Env.
Not enough access to markets to realise sufficient sales. It is difficult to penetrate through the conservative construction sector.	4	4
Not enough access to sufficient volumes of secondary materials	4	1
Time-consuming to establish relationships with suppliers of secondary material	3	2
Lack of criteria for participation in public tenders. Lack of specification in resource saving potential for new buildings or renovation of buildings.	4	3
Waste infrastructure is not well developed to recover clean fibre waste streams from commercial waste (municipal level? B2B?)	5	1
Lack of take-back systems (or development of) at company or association level within the sector	4	3
The design of products makes it difficult to recycle (residual substances in bio-waste, e.g. chemicals, adhesives, composites)	-	-
High tax on labour (affecting collection and recycling operations locally and/or abroad)	4	4
The price of products from virgin raw materials is cheaper than products from secondary materials	4	3
Organisations prefer products of virgin material origin vs. recycled	2	1
Consumers prefer products of virgin material origin vs. recycled	2	1
Consumers/organisations do not realise long-term benefits (e.g. durability, reduced environmental impact, resource saving potential, vs. cost of purchase)	4	2
Consumers/organisations do not realise that recycled products can be as good as similar ones from virgin raw materials	1	4
Environmental labels and certification systems have limited effect on purchase decisions	4	3
Lack of visions and political leadership from the public sector	3	2

Table 2 provides input from the companies on the desired policy interventions that would lift their main identified barriers, ranked at a scale from 1 to 5, where 1 signifies low importance of the policy measure and 5 represents an necessity for a transition to circular business operations.

Table 2 Policy interventions that could induce scaling up of recycled building materials/components

Potential policy	Importance for Polyplank	Importance for Noble Env.
Better waste infrastructure for collection for recycling	4	4
Make waste legislation less complex and reduce administration	4	2
Make eco and long-lasting design criteria more demanding for new buildings	5	4
Favour design of buildings for modularity, deconstruction and reuse/recycling at materials level	5	5

Potential policy	Importance for Polyplank	Importance for Noble Env.
Encourage the use of Environmental Product Declarations (EPDs) in order to facilitate the assessment of construction products and materials sustainability	4	4
Reduce the tax on labour	5	2
Reduce VAT for secondary/ recycled products	5	5
Increase prices on virgin raw materials (to favour recycled materials in the market)	2	4
More visions and leadership from politicians and the public sector	5	2
More ambitious targets (recycling/secondary material use) to promote recycled/recyclable goods	5	2
More information to citizens that recycled materials are good for the economy and for the environment	4	2
Make pre-demolition audits, selective demolition and post-demolition reporting compulsory	4	1
Make sorting on the construction site compulsory: improved separation of materials reveals a strong trend for higher levels of recovery	5	2
Develop building passports and material passports, along with design for deconstruction and building information modelling (BIM)	4	5
Enhance green public procurement through the introduction of mandatory percentages of recycled content in new building products	5	5

4.2.1 Polyplank AB

Polyplank AB is a small company which bases its expansion potential on the resource and environmental benefits of its product. However, due to its small size it faces typical problems of difficulty to access a wider market, also outside its geographic location. Therefore, the company faces a significant problem to access markets and to realise sufficient sales.

Certainly, the most critical barrier the company is facing is the access to sufficient and good quality secondary materials, and especially access to secondary plastic which forms a building block of the polyplank products. The company relates this critical issue to a 'waste infrastructure' problem, which ranks as the highest barrier in their business operations. However, the barrier of waste infrastructure is not perceived as a physical barrier (i.e. there is not enough collection and sorting facilities), rather than an organisational issue on how the recycling sector in Sweden works. There is only a few companies in Sweden that are active in the collection and distribution of recovered waste plastic, forming some kind of oligopoly that keeps other interested actors at bay. All B2B operations of collection and trading of waste materials go through one or two actors in the Swedish market. Municipal waste plastic is not reaching the company and if it happens, it is usually of inferior quality. As a result, if there is no good quality and/or enough material to buy, either from the waste management companies or municipal sources, then Polyplank is forced to buy virgin plastic. This goes against the established business model and creates a less attractive product in the sense of environmental performance.

In an effort to deal with this situation, Polyplank has worked to develop an industrial symbiosis system. However, this effort has been received with significant resistance from industry as well as waste management companies. This is because Polyplank is not in a position to commit to large contracts with an individual company for a fixed price and fixed amount (of waste), especially if the prices agreed do not reflect the market prices in the long run. On the other hand, traditional actors in waste management can commit in bulk volume long-term contracts and therefore become the preferred option for industrial partners.

A set of policy interventions, especially relevant to building codes and construction and demolition regulations, are seen very positively by the company. 'Building design for modularity, deconstruction and reuse/recycling', 'Compulsory sorting on construction site' and 'Durability criteria for building components' are deemed essential for boosting the reuse and eventual recycling of durable and recyclable materials like polyplank. All these rules can be easily integrated in existing building codes and be mandatory. For example, the energy efficiency regulation in buildings was absorbed very fast in Sweden. Thus, there is a good chance that something similar might happen to building materials as well. However, when it comes to materials in buildings, a strong opposition might be expected from the construction and demolition sectors, which have long-established practices in construction (also geographically influenced) and are particularly resistant to change (Adams et al., 2017; Deloitte, 2016).

Another way to boost the uptake of such a material is through public procurement requirements. At the moment, the criteria are not excluding the company; however, what the company sees missing from public tenders are the incentivising criteria that would favour better performing products to compete, despite price differences. Therefore, enhancing public tenders' criteria to include, for example durability and/or recyclability criteria, is considered a very positive measure.

4.2.2 Noble Environmental

Noble Env. similarly faces a significant obstacle for growing business operations in the limited access to wider markets for their products. Therefore, in order to expand, the domestic market is not the only outlet of production. Even though there is a really high traction for secondary materials in construction components in the Netherlands and other northern European markets, there is a critical barrier that prevents the scaling up of operations and expansion to several markets outside the Netherlands. This mainly refers to the different standards that the products need to acquire in different markets, even within the EU. Product requirements in the Netherlands fail in Germany, and therefore the company needs to go through a lengthy and costly process of standardisation and approval in order to be eligible for sale in the German market. Although belonging to the EU common market, many Member States have raised their own specific standards (in respect to building regulation and building materials) in a "protectionist" way in order to favour domestic manufacturing. It is evident that local conditions and building regulations play a critical deterring role in the upscale of 'new' building materials that seek to secure a share in the established building materials market.

Since the capital expenditure is relatively low for starting a new production unit for ECOR, and the raw material is waste –which usually is acquired for minimal or no cost–, the biggest cost for the company is labour. Labour costs are in turn significantly affected by high labour taxation (Eurostat, 2014). High labour costs due to taxation was identified as a major barrier in making ECOR more competitive and therefore more likely to proliferate in the market. Since raw material costs are minimal, ECOR would definitely gain a price advantage over any other mass produced good, based on the current linear production processes in Europe. Production from low labour cost countries though, would be harder to compete, unless other complementary measures are taken in conjunction with lower labour tax rates. Noble Env. recognises that it might be more feasible to expect a reduced VAT rate for recycled products, rather than an overall tax cut on labour.

One other issue identified, is the lack of awareness from consumers and involved actors in the construction sector that products from secondary raw material sources can be as good as similar products from virgin materials. A form of technical measure that can improve the knowledge of consumers, and increase their confidence in the secondary material products, is the development of the so-called 'material passports'. In this way, the properties of the product becomes evident and the consumer can confidently use the product in relation to the specific needs of a project, while making sure that it can be safely treated at the end-of-life.

Lastly, but most importantly, the company sees public procurement as the single most influential factor that can induce the uptake of recycled products that exhibit 'circular' properties and high environmental benefits. Carefully designed procurement criteria could critically turn the spotlight to innovative solutions that clearly benefit the environment, without necessarily being much more costly than the current business-as-usual alternatives.

4.3 Cross-case analysis

The two companies have similar perceptions on some drivers and barriers. Despite having slightly different business model configurations and addressing different geographical areas (within the confines of the EU common market), the study found out that there are several persistent barriers hindering the upscaling of 'circular' building products, irrespective of location and business operation. The access to market outlets that can secure sufficient sales, high taxes on labour and a general lack of knowledge among consumers that these products can be as good as virgin material based ones, with higher long-term benefits, are among the factors the companies agree upon.

There are also some differences in their answers concerning the most pressing barriers, which reflect major business model conceptual differences among the examined companies. The most obvious example here is the access to sufficient quantity (and quality) of secondary raw materials. Polyplank finds it very challenging to secure a steady flow of good quality secondary plastic, having to rely on waste companies. Noble Env., on the other hand, secures its raw materials by carefully selecting the location of production units and forming long term sourcing commitments, something that Polyplank is not doing at the moment.

Both companies favour a set of solutions that would facilitate the uptake of recyclable materials and boost their business operations, highlighting as the most important measure the effective use of public procurement. The companies wish that the public sector would catalyse change within a very traditional sector, such as construction, by stimulating the use of more efficient and effective solutions through public tender requirements. Another area, which both companies consider critical for inducing change in building practices and material use, is construction and demolitions rules and legislation. A set of measures, either voluntary or mandatory (depending on the nature of the measure and the willingness of the sector) can greatly influence the use of more durable and fully recyclable materials. Developing building passports and material passports, along with design for deconstruction, building modularity, durability and reuse/recycling at materials level, are considered the most important measures that can influence construction practices in the future and lead to better building materials selection and use in buildings. The concept of EPDs for building materials can be a complementary measure as well.

Lastly, both companies agree on the importance of economic incentives into shifting consumer behaviour towards more environmentally friendly and resource efficient products. Reducing VAT for secondary sourced manufactured products scores highly on the preference of both companies, while a general reduction in labour tax seems rather unrealistic at the moment.

5. CONCLUSIONS

This paper explores the existing barriers for increasing the uptake of building components based on a complete 'circular' approach –made by secondary raw materials and being fully recyclable at the end of life– and potential policy interventions that would tackle the barriers and incentivise such a development. Business barriers and policy drivers are exemplified through two company cases active in this sector. The cases complement previous research on barriers and policy interventions for CE (Adams et al., 2017; Westblom, 2015) and offer new knowledge on the construction materials sector, which has been under-researched thus far (Ness and Xing, 2017).

The main issues identified by examining the company cases include difficulties in accessing wider markets, high taxes on labour for recycling and manufacturing of products, and lack of consumer awareness and preference of such recyclable materials in construction. Moreover, access to secondary raw materials proved to be a significant challenge, with one company finding it as a major barrier, while the other circumvented the unstable sourcing of waste with flexibility in production and optimal localisation.

Concerning the need for policy support, both company cases emphasised the importance public procurement holds in promoting the use, reuse and recycling of innovative building materials, with one company underlining the significance of public leadership in driving change towards CE. Major revisions in building codes and regulations are considered essential for improving resource efficiency in buildings and a set of measures, as discussed above, are strongly supported by the

companies. Also, economic instruments are required in order to give clear signals to consumers, coupled with increased information and communication efforts by public and private actors. Companies' perceptions, however, constitute just one side of the coin as policies need to be carefully considered in design and scope so as to be fair and deliver the highest socio-economic benefit possible. Therefore, this paper provides a critical input from a business perspective and additional research would be required to complement the policy landscape for increasing the uptake of 'circular' building materials.

Finally, a holistic approach across the buildings' life cycle, including other actors within the buildings sector (i.e. from architects to construction contractors to demolishers etc.), is required in order to combine potential policy solutions (or policy mixes) that target not only building materials but also construction and demolition practices. This holistic view is necessary for a transition to a CE in the housing sector at large, and therefore this research would contribute the most if it is embedded in a larger perspective within the buildings' life cycle.

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