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POLISH CIRCULAR HOTSPOT

Circular construction in practice

Authors:
Hubert Bukowski
Wioletta Fabrycka

Collaboration:
Representatives of the organizations participating in the „Circular construction in practice" debates

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Partners:

Patronage:

Authors:
Hubert Bukowski
Wioletta Fabrycka

Collaboration:
Representatives of the organizations participating in the
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From debate to practical solutions

The construction sector is responsible for almost half of the global extraction of raw materials and for one third of global carbon dioxide emissions. While the relatively high level of construction waste recycling that is especially visible in developed countries, should be by and large described as downcycyling. At INNOWO we believe that it is necessary to transform this sector towards a circular model. This need is confirmed, i.a. by the above quoted indicators. That is why we have initiated the *„Circular construction in practice"* project.

The first outcome of this project is the report on practical aspects of implementing circular construction in Poland, which we present to you with great pleasure. This is one of the first studies on this subject on our market, I hope that it will contribute to the initiation of genuine changes in the construction sector and will be an inspiring material for decision-makers both in Poland and in the European Union.

The study was created as a result of eight-month consultations with a wide range of both Polish and foreign stakeholders. Throughout the project course INNOWO organized four workshops during which we discussed the opportunities, barriers and prospects for the development of sustainable construction. Each meeting was accompanied by engaging discussions, which proves that it is an important, though not easy, topic for the industry.

The beginnings were difficult. We met with comments and remarks full of doubts and suggestions that real change has no chance of success. These voices were supported by examples from the recent history of the construction industry, which in the last century was following an economically and ecologically irresponsible path. However, after months of work and discussion, we are sure that transformation towards circular economy in the built environment is possible. The report illustrates a number of possibilities for the construction sector to become more sustainable.

One of the important tools to support circular transformation is, for example, public procurement. This is one of the most important sources of innovation in developed countries, whereas, as demonstrated by the workshop conducted by INNOWO within the framework of the *„Circular construction in practice"* project, this role in the construction sector in Poland is only marginally fulfilled. As one of the incentives that could support innovation in construction, it is advisable to take into account the total life-cycle costs of building materials, or a performance-based specification. You can find more information on this subject inside the report, which I strongly encourage you to read.

At the same time, I would like to thank our partners who work towards making an authentic contribution to the development of the industry and are leaders in the field of sustainable development with vast awareness and understanding of corporate responsibility in this topic. My thanks go to Synthos, with particular emphasis on the role and expertise of Mr. Krzysztof Żarnotala, Armstrong, Forbo and EKOTECH Group. Special credit goes to Wiola Fabrycka, the good spirit of this project. We would like to thank all participants of the debates for the time devoted to this important topic, substantive input and suggestions for solving problems, that are the consequence of the linear construction model.

I hope that this is just the beginning and the report will be an opening for further work and wide-range stakeholder coalition building to support circular construction!

Dr Agnieszka Sznyk,

Director of the Board,,
Institute of Innovation and
Responsible Development

Contents

1. Introduction

In recent years, we have observed a significant increase in public interest in issues related to the climate, the natural environment and sustainable resource management. The discussion focuses on producers of plastics, food, and the transport industry. The influence of the construction sector on the condition of the economy, society and the environment is a relatively unnoticeable problem. However, official statistics say that construction uses the greatest amount of raw materials, emits the most greenhouse gases and produces the most waste among all sectors of the economy.

Of course, taking these indicators into account, we should not neglect the incredible benefits of the construction industry. Nevertheless, the basic finding is as follows - even small changes directing the construction sector towards a more sustainable path can bring radical benefits in global terms. Until now, this conclusion was absent or insufficiently emphasized in the public debate. Consequently, the implementation of specific measures introducing more sustainable construction in practice also did not take place. This report aims to change this situation.

The basic way in which the construction sector needs to be modified to optimize the benefits of construction, while limiting the associated problems is the transformation from a linear to a circular economic model. In layman terms, the circular model aims to maintain the goods in the economic cycle as long as possible while maximizing their economic value. This is a radically different vision from the standard product life-cycle in which, after obtaining the raw materials, the product is manufactured, distributed, used and disposed as waste. The construction sector is the ideal industry for introducing a closed-loop economic model. It is characterized by high durability of products, the possibility of repairs and adjustments as well as resale on the market. That is why we hope that this branch of the economy may be an ideal place to start the transition to the circular model in Poland. Furthermore the benefits of this transformation could be the greatest among all sectors.

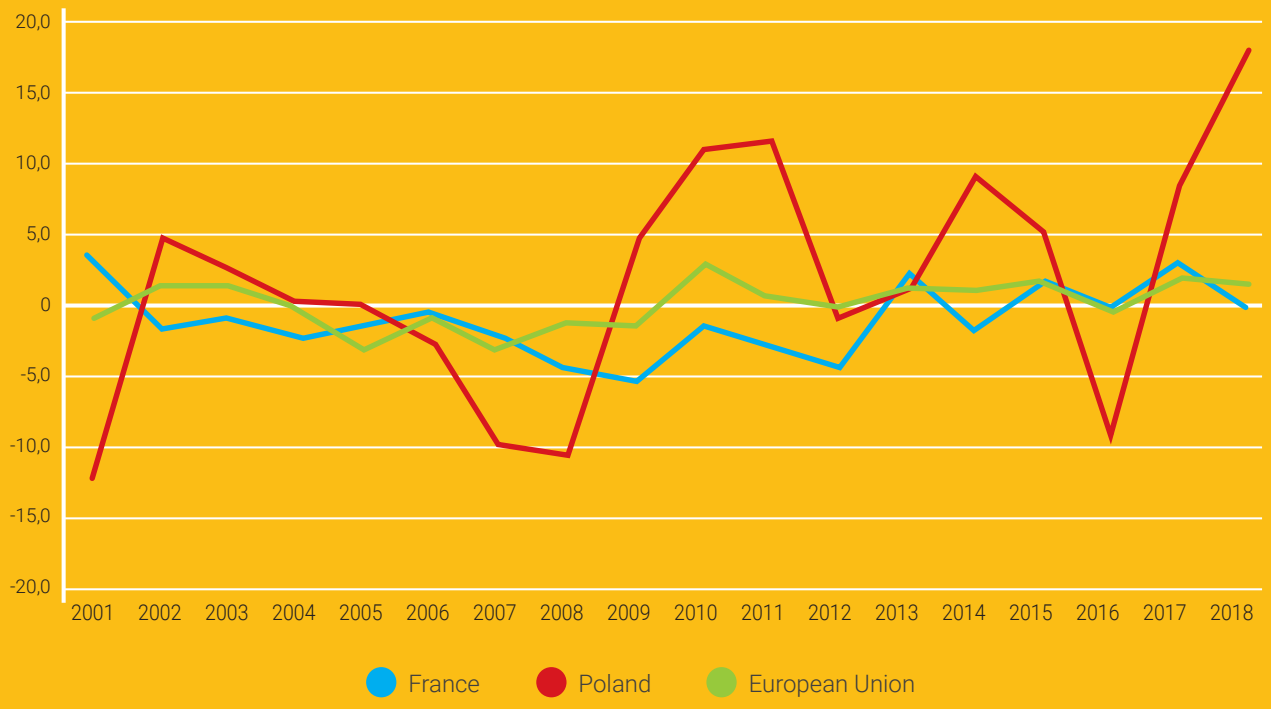
This report begins with a discussion of the need to adopt a circular model in construction. At the same time, it presents the latest history of construction industry's development directions, which explains built environment growing economic and ecological problems. The next chapter identifies barriers on the path towards circular construction, with particular emphasis on Polish conditions. On the basis of these considerations, the third chapter presents specific solutions that can contribute to a relatively quick and effective closure of economic loops. The last part addresses the topic of interesting, innovative technologies, the development of which makes the implementation of the circular model ever more likely.

The report could not have been produced without the participants of the *"Circular construction in practice"* debates. It is widely supported by quotes from discussions, statements of the debates' partners and presentations of already existing circular materials and technologies.

2. The necessity of transition from linear to circular model in the construction sector

Construction is widely regarded as an industry characterised by a slow pace of adaptations. In recent decades, there have been no landmark changes that would lead to significant sector development. As a result, also the productivity of the construction industry, both in the case of Poland and the European Union, did not improve significantly (in 2001-2017, the average annual growth equalled 0.7% and 0.2% respectively). In France, the country with the longest-running construction productivity statistics, there is a significant reduction in the growth rate of this indicator, from the average annual growth of 3.1% in 1951-1990 to a fall of 0.1% in 1991-2018 period.

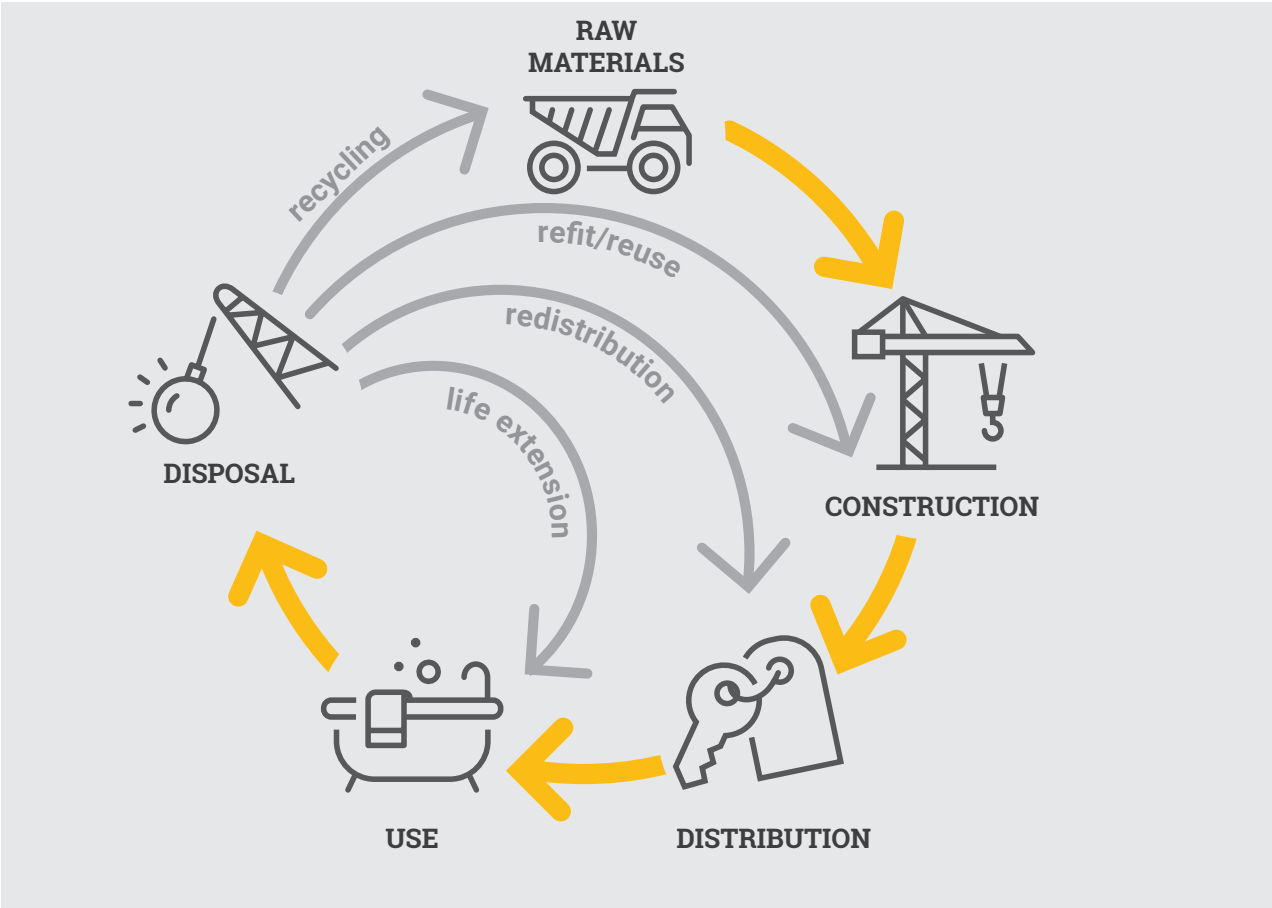
Figure 1
Change in gross value added per hour worked in construction sector (in %, constant prices)



Source: OECD

Because changes in the built environment, such as the implementation of new technologies or management methods, take place at an extremely slow pace, the industry in most cases continues to use solutions that appeared almost half a century ago. They were created at a time when externalities of economic activity were not taken into account, and resources were treated as practically inexhaustible. This does not mean, however, that the construction sector uses only a linear economic model.

Features of buildings and structures, such as durability, the possibility of modernization and reuse predispose them to apply circular concepts – closing economic loops, so that the goods circulate as long as possible with simultaneous value maximization. Repairs, real estate trade, sharing or renting rooms have been taking place for hundreds of years are all examples of applying the circular concept in real life.



However, the use of circular concepts occurs at most at earlier stages of the life-cycle of buildings (usually there is no key closure of the loop) and it is often a non-optimised process. Thus, the construction sector should be largely considered as a linear model. What's more, looking at the latest economic history (apart from the last decade, in which the closing of economic loops is slowly regaining popularity), there were tendencies to turn the construction industry away from circular concepts. This includes:

Lesser extent of material reusage.

For example, the use of lime mortar in the past has significantly contributed to the increased reuse of circular materials, such as bricks. This material has been used many times in the past[1], while the use of modern mortars drastically reduces the possibility of reusing bricks and thus limits their economic and ecological potential[2].

Decreasing the durability of buildings.

Technological changes that have taken place in the construction sector since the mid-twentieth century have meant that the construction time has been significantly reduced, which is directly related to the construction costs. The side effect of this process is the shorter overall durability of the structure. For some countries, the lifetime of buildings has reached levels unheard of in modern world history[3].

ca. 1945

Switch from steel and construction wood to concrete

ca. 1975

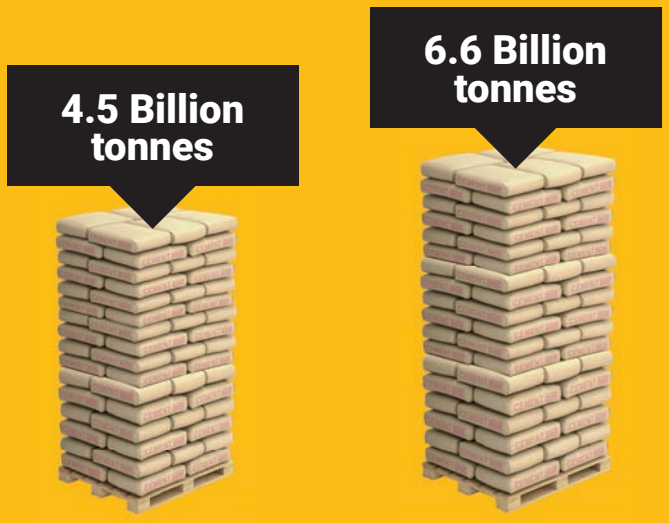
Modification in concrete composition that allows faster but less durable construction

Source: Author, based on Dias W.P.S.; Factors Influencing the Service Life of Buildings; Engineer; 2013.

Using non-renewable materials on an ever-growing scale.

The use of cement applied in the production of concrete, which despite the emergence of modern methods of recycling still is considered a non-renewable material, has grown radically. In China alone, within three years it was used to a greater extent than in the entire 20th century in the United States.

Figure 2
Cement usage



Source: United States Geological Survey

ca. 1990

Decreased renovation possibilities in result of hiding structural elements under panels or facades

The lack of circular concept implementation in the construction sector is even more puzzling considering its adoption would contribute to a significant improvement in the productivity of raw materials and work, as well as reduce the industry's negative impact on the natural environment.

1. Sims I.; Proceedings of the Institution of Civil Engineers - Construction Materials; Editorial; Institution of Civil Engineers; 2016.

2 Nordby A.S. et al.; Criteria for salvageability: the reuse of bricks; Building Research & Information; Volume 37, 1999.

3 Average building lifespan in China is 34 years compared with expected 50 years (Liu, G.; Xu, K.; Zhang, X.; Zhang, G. Factors influencing the service lifespan of buildings: An improved hedonic model. Habitat Int. 2014, 43, 274–282.)

2.1. Economic aspects

The aforementioned previous popularity of circular elements in the construction sector was the result of limited economic resources in the world. It was not until the 20th century that this barrier, due to a significant increase in economic prosperity, became less significant. This does not mean, however, that circular concepts have ceased to be economically justified. Unfavourable changes were only the result of distracting attention from long-term results in favour of short-term benefits of fast and mass construction. The focus on short-term aspects of construction activities is the result of separating the role of the long-term owner of the building and the original investor and contractor. As a result, the linear model, currently dominant in the construction sector, should be assessed as a consequence of the myopia of market entities.

Circular activities in construction have specific economic foundations. A number of circular tools aimed at maintaining the highest value of buildings and their parts and at attaining the most productive use of raw materials, can radically reduce the costs of the construction sector, and decrease the rate of decline in the value of assets.

According to some analyzes the effects of introducing a circular model in the construction sector in the European Union, which can be achieved by 2030, amount to over EUR 1 trillion in relation to the current state[4]. 29.7% of these benefits can be achieved thanks to savings in the use of raw materials, such as primary building materials, fossil fuels, land use and non-renewable electricity. Savings of building users and public authorities other than those resulting from the optimization of the use of raw materials will amount to 37.6% of the total sum. The remaining benefits are the monetary value of the external effects of the transformation towards the circular model.

However, additional cash outlays are necessary to realize these benefits. It is worth emphasizing that already at the beginning of this century, the initial costs of implementing circular solutions were lower than their benefits[5]. Furthermore, these costs fell significantly in the following years. For example, in France, the cost of a sustainable building's residential construction in 2003 was 10% higher than the standard building. This index fell to 1% ten years later[6]. The decrease in costs is mostly visible in the case of relatively less advanced sustainable construction solutions, while the most complex or avant-garde technologies remain relatively costly[7].

4 Growth Within: a Circular Economy Vision for a Competitive Europe; Ellen MacArthur Foundation; 2015.
5 Kats, G.H., Alevantis, L., Berman, A., Mills, A. and Perlman, J. (2003), The Costs and Financial Benefits of Green Buildings: a Report to California's Sustainable Building Task Force, Sustainable Building Task Force.
6 Ana Cunha Cribellier, Responsable du Développement International, QUALITEL - CERQUAL
7 Future of sustainable housing, BRE, 2013; website: https://www.bre.co.uk/filelibrary/pdf/casestudies/KN5211_-_Future_of_sustainable_buildings_finalsml.pdf

The Venlo City Hall in the Netherlands uses circular solutions which increased its construction costs by EUR 3.4 million. This investment will result in EUR 16.8 million savings

2.2. Ecological aspects

The direct effects of optimizing the natural resources acquisition and using them effectively, which is the basic assumption of the circular economy, are not only economic. Applying the concept results also in reducing the negative impact of the construction sector on the environment. In other words the departure from the circular model in the construction industry, which took place in the 20th century, also has no ecological justification. As a consequence of this transformation, the ecological burden of the construction sector increased significantly.

Impact of the construction sector on the environment in the European Union:

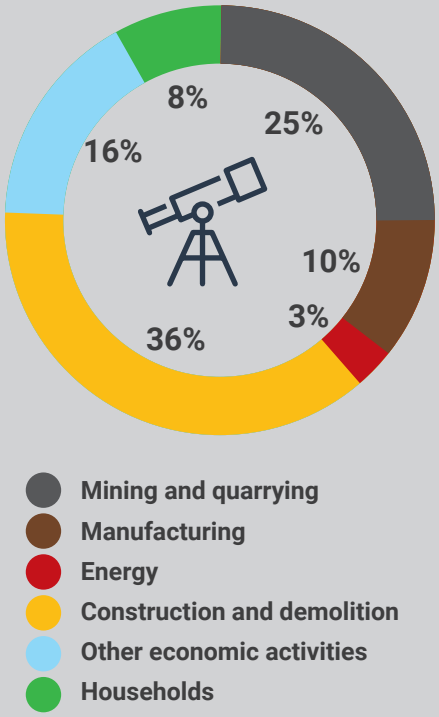
The construction industry uses directly **1.8 billion tons** of primary raw materials, which means it consumes **25% of the total demand for primary raw materials.**

It generates over **0.6 billion tonnes** of waste per year, **i.e. 36%** of the total amount of waste.

The construction industry uses directly or indirectly (mainly during the exploitation of buildings) **approx. 40% of generated energy**[8].

In result of energy demand, **36% of total CO_2 emissions** in the European Union are generated[9].

Figure 3
Sources of waste in the European Union in 2016.



Source: Eurostat

Taking into account all the mentioned indicators, it should be clearly stated that the construction sector is responsible for the greatest environmental damage among all branches of the economy. The scale of its negative impact has also been confirmed at the global level[10].

8. Energy Performance in Buildings Directive; press release 17/04/2018; European Comission.
9.Ibidem
10.Towards zero-emission, efficient and resilient buildings and construction sector; Global Status Report 2017; UN Environment; 2017.

Alicja Kuczera,
Polish Green Building Council PLGBC

Circular construction is ecological construction

The construction sector, the largest consumer of natural resources in the world, is beginning to implement the principles of circular economy. The application of the circular economy idea in the built environment will result in the buildings being designed, built and reused without wasting raw materials, environmental pollution and ecosystem degradation. Creating a circular building will essentially mean that no building material at the end of its life-cycle will become construction and demolition waste and will be incorporated into the supply chain again.

Sustainable construction assumes in particular aspects such as the life-cycle of the building, minimizing waste and recycling of raw materials. Hence the idea of circularity is rooted in green construction from the very beginning.

In the construction sector, the application of the principles of circular economy can be implemented in various areas, among others:

1. ***Circular materials***
   - *The use of new raw materials only in essential cases, with the principle that they are renewable.*
   - *Reuse of recovered items (remanufactured or original ones).*
   - *The use of toxic substances and materials that cannot be recycled is prohibited.*
2. ***Product – service system***
   The construction sector has been experimenting for years with different business models such as product-service solutions: this applies for example to lighting, lifts, photocopiers, but also floor coverings and equipment. The manufacturer may offer a product bundled with a service or a whole set of them, and in the most advanced form the producer remains the owner of the product and the user buys the possibility of using the service. This motivates manufacturers to design easily-repairable and long-lasting products.
3. ***Extending life***
   The concept incorporates both extending the life of materials and products used in the construction, but also the building as a whole, thanks to the "flexible" design of the building that allows cheaper and more resource-efficient functional modifications in the future. Applying this concept requires taking into account the total costs throughout the entire life-cycle of the building.
4. ***Exchange and sharing platforms***
   The sharing platforms have become widespread in our everyday life thanks to such concepts as, for example, Blablacar (the possibility of sharing a car) or Airbnb (sharing the flat). Other examples of this approach in the context of built environment are platforms for the exchange of construction machinery, as well as the provision of unused surfaces for multifunctional purposes.
5. ***Recovery***
   Using materials that have already completed their life-cycle in a particular building and are reused in another facility, striving to regain and use as many materials as possible in the demolition process.

3. Fundamental barriers on the path towards circular construction in Poland

Although the implementation of the circular model in construction is justified in economic and ecological terms, it encounters significant barriers. This chapter describes the most important barriers identified by the participants of the series of debates and workshops, grouped in four categories: financial, organizational, social and technological.

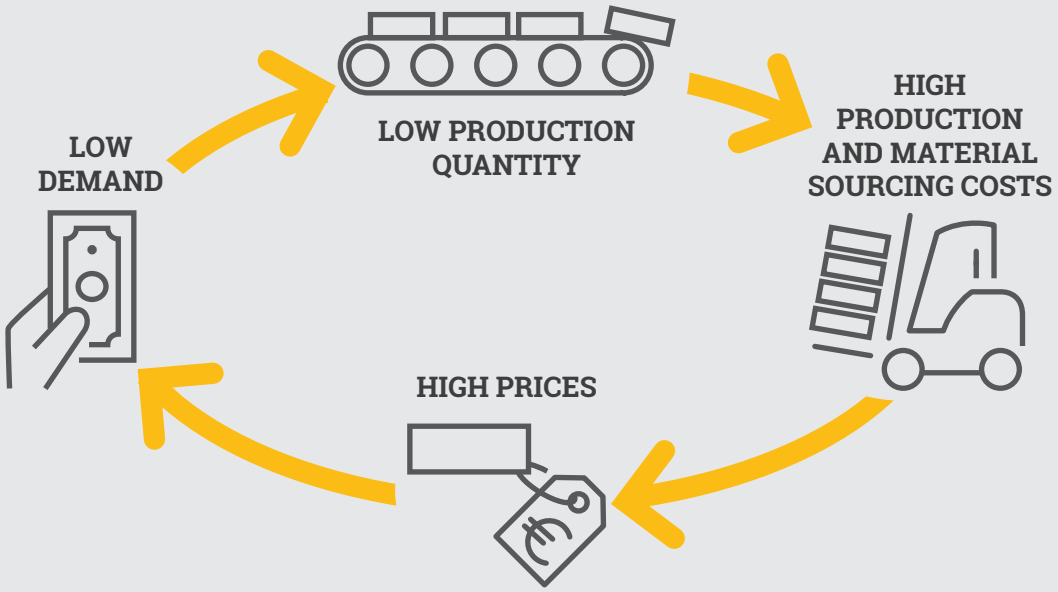
3.1. Financial barriers

3.1.1. Lack of economies of scale

The main barrier for closing economic loop in the construction sector is the relatively higher short-term costs of circular solutions. Although, as mentioned in the previous chapter, in recent years, most of these solutions have significantly reduced their prices the cost of purchase is higher than in the case of standard building materials or construction technologies. In a typical case where the investor and the long-term user are separate entities, investor has a tendency to pay attention to short-term expenses. This is how the preference for a linear model in construction appeared.

While the fight against short-term preferences in favour of long-term ones is possible, much faster results could be attained by lowering the price of circular products and construction materials to raise their competitiveness. Although the decline in their costs has been present for years, it seems that breaking the price dominance of standard products will not come either easily or quickly. The relatively higher price of circular products and materials is not due to their characteristics. On the contrary, these goods are often produced from used parts or waste, which is often considered worthless. Thus, they should be relatively cheap. The most important factor why this is not the case is the relatively small size of circular production, which does not allow economies of scale to be achieved. This creates a vicious circle that restricts the greater use of circular products and materials.

(...) ecological solutions are usually more expensive in the short term. However, one should take into account the longer perspective - to think about the next stages of the building life-cycle.. – Wioletta Fabrycka, A Propos

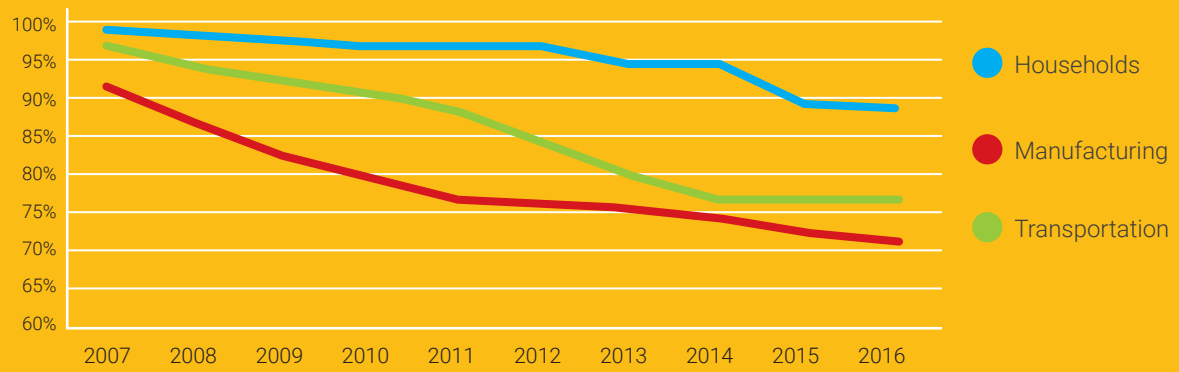


3.1.2. Unfavourable financing model

The current standard system of construction and use of buildings is a barrier to the introduction of the circular model in Poland, as well as in Europe. *The investor does not build for himself but considers how to sell the building even before the construction is completed.* - Ewa Kowalska-Ocneanu, WSP Poland. As a result, the price of the property becomes the decisive factor, instead of its total long-term costs. In result, the economic advantage of circular buildings over standard ones reduces its importance in consumer choices.

The advantage of energy efficiency of single-family housing over other types of buildings is a proof of the impact of ownership on the circularity of buildings. *(...) [single-family buildings] are the most energy-efficient, because they have a direct impact on the investor, who builds for himself. The bulk of the market concerns the construction of buildings used by other entities. This is not a ten-year or a century long perspective but a short term view.* - Maciej Mijakowski, Fundacja Poszanowania Energii. Probably the separation of the role of the investor and the owner is one of the reasons why the improvement of energy efficiency in recent years is the slowest in the household sector (it is worth adding that about 2/3 of energy consumption in this sector is used for heating real estate).

Figure 4
Energy efficiency ratio ODEX obtained by aggregating changes in unit energy consumption, observed at a given time at specific levels of end use (2006 = 100) Households, Manufacturing, Transportation



Source: Efektywność wykorzystania energii w latach 2006–2016; Główny Urząd Statystyczny; 2018.

3.2. Organizational barriers

3.2.1. De iure vs. de facto regulations

Despite the existence of regulations supporting the implementation of circular concepts in construction, in many cases they are not exercised. Participants of the debates have repeatedly mentioned that their use is limited.

- *Public procurement law provides, in addition to the price criterion, the criterion of the cost of a building throughout its whole life-cycle. In the last three years I have not seen any public contract that would take this into consideration.* - Wioletta Fabrycka, A Propos
- *Green procurement can be used but it is not necessary (...). If there are no mechanisms that enforce certain behaviours, the actions will not be altered.* - Bogdan Ślęk, Signify Poland
- *Appropriate regulations exist (...) we should finally start using it. (...) Entities should start to make use of these standards.* - Henryk Kwapisz, Saint Gobain Innovative Materials Polska

The lack of use of the circular regulatory options is illustrated by the statistics regarding their use in public procurement[11]. In 2017, 344 purchasers (out of 33 690) reported that they carried out 1212 public procurement processes taking into considerations environmental or innovative aspects. The share of green or innovative public procurement in the total number of public contracts awarded was less than 1% in quantity and about 2% in value, with environmental aspects usually only included in the description of the subject of the contract.

In 2017, the life-cycle assessment

was included in **17** cases out of **139133** public orders in total - i.e. they were applied in **0.01%** of procedures.

11 Stan Zrównoważonych Zamówień Publicznych w 2017 roku – raport; Urząd Zamówień Publicznych; 2018.

3.2.2. Precipitant regulations

In addition to the lack of applications of regulation, the basic problem in supporting circular concepts is rash, hasty legislation. The substantive support of the regulation is of particular importance, which should be supported by genuine consultations with all stakeholders. An example of regulations where the changes should be regarded as hasty is the radical reduction of maximal waste storage period from 3 years to 1 year[12], aimed at limiting the series of fires set to landfills in recent years, on the other hand significantly reducing the possibility of recycling solid waste, e.g. from construction and demolition.

The incompatibility of detailed regulations with strategic activities, such as the flagship provisions of the Circular Economy Package or the EU strategy for plastics may turn out to be a barrier to business tendencies in investing in new technologies. New recycling technologies are an example – they can make use of waste previously considered dangerous, and furthermore do it in an environmentally friendly manner, in effect maximizing the economic value of processed product. This example confirms that the law should be outcome-based. The fact that it is based on top-down, hasty and non-market-oriented prohibitions and orders as to the technologies and materials used may stand in the way of solutions consistent with the concept of circular economy.

The impact of regulation on various branches of the economy, including those unforeseen by the regulator, is a very important problem. This problem will increase, especially in the case of the introduction of circular economic model, characterized by increased interactions between seemingly unrelated industries. Hasty regulations, introduced with good intentions, may, for example, have positive effects on the packaging market while inhibiting the development of individual technologies, e.g. recycling in the area of construction. Therefore, it is particularly important to limit the multiplicity of legal interpretation and increase its factuality, so as to decrease the uncertainty of business activities, including investment and innovation, in various areas of the economy.

- *On one hand, regulators encouraged us to invest in circular concepts, while introducing further regulations limiting the recycling market. (...) They undercut the principle of investment certainty. (...) Discussion on regulations regarding the closed-loop economy (...) should be calm, not based on emotions, only on scientific, verifiable evidence.* - Krzysztof Żarnotal, Synthos.
- *(...) amendments to the Waste Act or other industry regulations create limitations that remove the possibility of using circular concepts and, consequently, the use of waste to reduce the costs of building facilities or the costs of the waste itself for the environment.* - Anna Frystacka, Tauron Polska Energia

12 Bill of 20th July 2018 r. „Ustawa o zmianie ustawy o odpadach oraz niektórych innych ustaw" (Dz. U. poz. 1592).

Krzysztof Żarnotal,
Synthos S.A.

The need for sound regulation at the national and supranational level

Synthos fully identifies itself with the assumptions of the Polish Circular Economy Road Map and the Circular Economy package as well as Sustainable Development Goals. Recognizing the importance of the idea of circular economy for shaping - in a long-term perspective - key aspects of economic growth in the European plastics industry - it fully supports the objectives of the European Plastics Strategy, which appreciates the economic and environmental qualities of plastics.

Synthos was and is an active partner of the European Commission in works and research aimed at regulating chemical and plastic industry. In the spirit of partnership, we also cooperate with other stakeholders.

Legal systems regarding circular economy should be prepared with particular considerations. Regulations should use unified and clear concepts. The debate on legal regulations concerning plastics should be scientific and based on facts and verifiable evidence. It should be accompanied by extensive consultations with all stakeholders. The life-cycle assessment (LCA) method is the best methodology for assessing the environmental footprint. LCA should be used to assess the entire life-cycle, and not only its end phase related to recycling. LCA includes more than just the material's ability to recycle. Entities positioning themselves as experts or advisory bodies to EU institutions and which influence the regulations concerning plastics should maintain impartiality. The existence of possible financial relations between advisory or expert entities with producers of certain plastics should in principle exclude the former from advisory bodies of EU institutions, or at least there should be a mechanism enforcing ex ante public disclosure of such relationships. Full transparency is needed here.

Low rates of plastic recycling efficiency in Europe, also in the construction sector, are not a derivative of their properties, but the result of the lack of an appropriate infrastructure and incentive system. Such a system should be created and implemented. To make a significant progress in the European approach to recycling plastics, we recommend:

- *putting emphasis on education and raising consumer awareness in order to increase the propensity and ability to collect and segregate plastic waste;*
- *supporting the continuity of developing innovative recycling and sorting techniques. Good examples can be observed in the Netherlands, Germany, Belgium, Norway and Spain. It is important that fees from non-discriminatory extended producer responsibility systems are directed to cover the costs of recycling infrastructure to reduce the environmental footprint;*
- *establishing a system of incentives for all stakeholders in the value chain to take responsible behaviour to increase plastic waste collection;*
- *the adoption of ambitious targets for the recycling of waste, as well as their implementation, should be enforced in all EU Member States.*

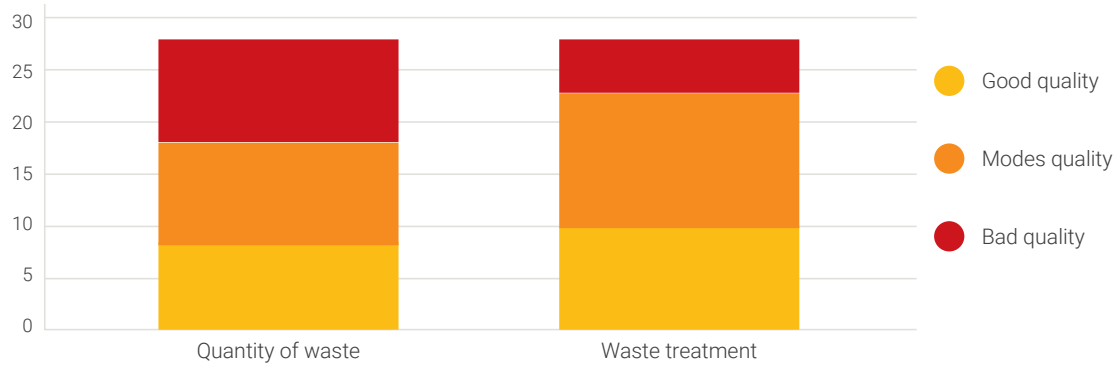
3.2.3. Not keeping proper track of construction waste

In order to ensure the proper functioning of the circular economy in Poland, system solutions are needed in the construction sector. There are many examples of companies that, despite being prepared to receive and manage materials at end-of-life of their product, encounter difficulties with redirecting the appropriate waste stream to their own facilities:

- *(...) products land on the landfill. Nobody is interested in giving this material to us as a producer. (...) construction waste is quite cheap when it comes to its utilization. The landfill will not use it properly, our company has such an option. (...) Given that approx. 40% of waste comes from construction, we have huge untapped potential in this industry.* - Maciej Rutkiewicz, Forbo
- *The loop in the construction sector is not being closed - particularly in the phase when the waste returns from the market. It is usually a mixed waste, not to mention the fact that the basic problem is that the traceability of these waste streams is very difficult.* - Bogdan Ślęk, Signify
- *Synthos technology deals with building waste [processing of expanded polystyrene, including its currently banned form with the addition of currently forbidden substances]. This technology effectively separates this harmful addition. The only problem is that we would like to be able to follow this waste stream.* - Krzysztof Żarnotal, Synthos.
- *Some consumers are able to pay more for sustainable products. We'll pay more but what will happen to the product next?* - Paulina Kot, Tarkett Polska

Statistics on construction waste depict the identified problem. Doubt concerning waste stream data quality is raised even in official publications[13].

Figure 5
Quality of data on construction and demolition waste in European Union



Source: Author, based on: Study on Resource Efficient Use of Mixed Wastes, Improving management of construction and demolition waste –Final Report; prepared for the European Commission, DG ENV; Deloitte; 2017.

13 Raw Materials Scoreboard – Construction and Demolition Waste; European Commission; 2018; website: http://rmis.jrc.ec.europa.eu/uploads/scoreboard2018/indicators/19._Construction_and_demolition_waste.pdf

This problem is particularly important as the lack of regulations regarding the tracking of construction waste, which already takes place in the case of electronics or cars, is not replaced by naturally developed market mechanisms. At present, it is not profitable to segregate individual elements and building materials, and then transfer them to the collection point or directly to the recycler. As long as the cost of transferring mixed up construction waste to landfills will be the cheapest option for getting rid of it, it will be virtually impossible to convince waste owners (both construction and demolition waste) to properly manage it without top-down regulation.

Maciej Kiepal,
Armstrong Building Products

Construction waste management in accordance with circular concepts - the role of awareness, information and regulation

The Polish real estate and construction market has been constantly developing for almost two decades. Every year in the largest cities, 200,000-300,000 square meters of new buildings is being developed in the office segment alone. With the development of the market, there is also a need to modernize buildings. This process is more and more visible in Poland. Many commercial buildings like offices or shopping centres handed over 10-15 years ago currently undergo modernizations. The need for refurbishment is not only a result of current expectations of tenants, it is also related to the response to current technical trends, including the adaptation of real estate to the trend of ecology and circular economy.

As one of the largest producers of acoustic suspended ceilings, we participate in the majority of office projects on the Polish market. We can see the changing proportions - the share of refurbished buildings is clearly increasing compared to equipping new buildings. On the British market, where Armstrong has been present for many years, the share of modernization in relation to new buildings is currently around 70% to 30% respectively. We expect similar proportions in a few years time in Poland. This means that each building will be a small construction waste factory. Ceilings during the renovation of one floor of offices - about 200 - 400 sq m. require few to a dozen containers of old ceiling tiles, which mostly go to landfills. Armstrong is one of the few manufacturers that run a ceiling recycling program. When our ceilings are assembled, we collect the old ones for free, and we send them to our facilities to be re-processed at the end of their life-cycle. Our company receives ceiling tiles also from competing companies. Tiles are transported to the Armstrong factory, where they are added as part of the raw material for the production of new ones. The program, being an example of circular economy in practice, helps to protect the environment and also contributes to obtaining more points in the process of green certification of buildings. In result of the Armstrong program, already 16 million sq m. of tiles have been processed and kept out of the garbage dumps.

The barriers we face in this area in Poland is the low awareness of the need to design, implement and operate buildings in the spirit of a circular economy - although the last year clearly shows that this trend is changing. Unclear and legal provisions that do not support such activities are also a hindrance. Current regulations do not keep up with the pace the market is changing. A comprehensive approach to the subject is necessary both at the central level and among local governments.

3.3. Social barriers

3.3.1. Perception of reuse of materials and building parts

The basic social barrier to the introduction of circular construction is the negative perception of the reuse of building materials and parts. In the study of basic barriers to the use of secondary materials in construction in the UK, it was shown that barriers directly or indirectly related to the perception of products from the so-called recycling are a fundamental problem limiting their prevalence. The problem is the uncertainty as to the durability and quality of the product, which means that this type of goods are not taken into account by architects, constructors and customers in the construction of the building.

Table 1
Barriers for reusing construction products made from reclaimed materials – UK survey results (barriers related to perception)

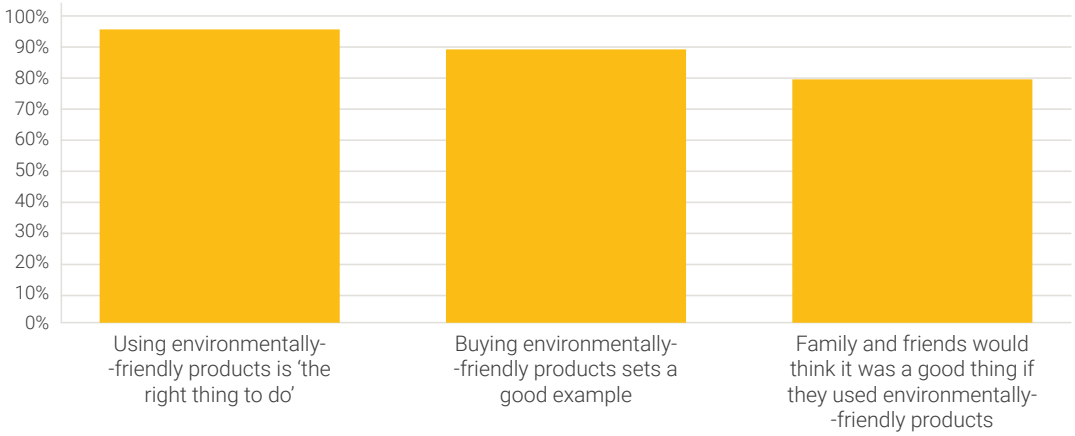
Ranking	Barrier
1	Architects and design engineers do not consider recycled materials and products during project design and specification
2	Lack of positive perception from clients who drive project process
3	Uncertainty on whole life durability of recycled materials and products
4	Materials selection and specification are influenced by cost rather than environmental benefits
5	Recycled Materials and products are more expensive than expected due to perceived environmental friendliness
6	Building control hindering the use of recycled materials
7	Suppliers' websites lack substantial product information
8	Recycled materials product information is difficult to find
9	Difficult to find suppliers of Recycled materials
10	There is inadequate education about recycled materials and products in schools
11	Samples of Recycled materials are difficult to obtain
12	Industry professionals are not versed enough on recycled materials and products
13	Recycled materials does not always meet projects needs and quality requirements
14	Supply of recycled materials is not always of the same quality
15	Market supply of recycled materials is not always reliable
16	There is a perceived culture among construction professionals that Recycled materials and products are inferior
17	Level of recycled contents in products is not always clear and easy to find
18	Legislation prevents the use of Recycled Products and Materials
19	Lack of tax breaks for contractors

Source: Oyedele L. et al. Use of recycled products in UK construction industry: An empirical investigation into critical impediments and strategies for improvement; Resources, Conservation and Recycling, Volume 93; 2014.

3.3.2. Declarations vs. practice

Despite the fact that declarations on ecological consumer choices in the European Union seem positive closing the loop for building products and materials requires increasing consumer awareness and, what is more important, putting it into practice.

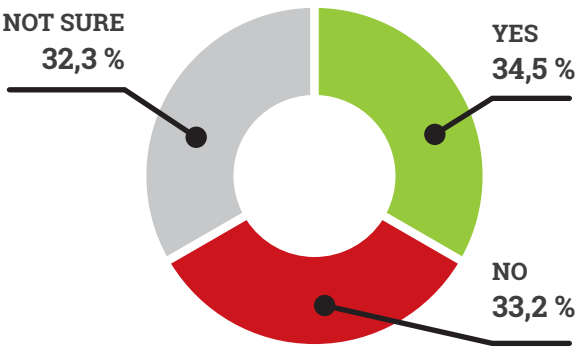
Figure 6
Positive answers of respondents in the EU countries to questions about the use of environmentally-friendly products



Source: Attitudes of European towards building the single market for green products; Flash Eurobarometer 367; European Commision, 2013.

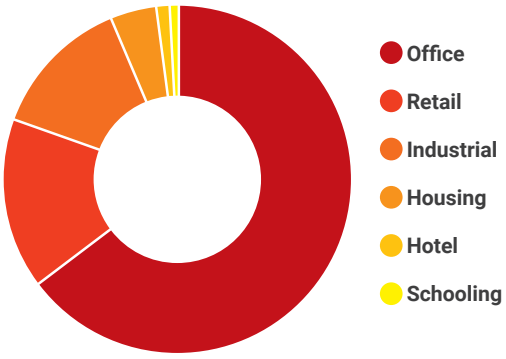
Considering the current state of consumption of environmentally-friendly products, the results on Europeans' attitudes towards green products should be interpreted only as consumers' tendency to use ecological solutions in the case of comparable purchase options for an alternative. Often, the European or Polish consumer is not aware of the long-term benefits and consequences of the specific materials and technologies used, which despite the declarations of positive preferences does not translate into consumer choices of circular goods[14]. An example confirming this thesis is the preference for the use of ecological materials in construction and their negligible translation into the supply of certified residential buildings (which is only a rough approximation for the number of sustainable or circular buildings).

Figure 7
Answers to the question: would the use of ecological materials in the construction of a flat or house make you pay more?



Source: OnBoard Think Kong, October 2018.

Figure 8
Buildings with green certificates in Poland (end of March 2019)



Source: Certyfikacja zielonych budynków w liczbach – Raport 2019; Polish Green Building Council; 2019.

14 The relationship between consumer choices and building sustainability exists in some European countries; see: Energy performance certificates in buildings and their impact on transaction prices and rents in selected EU countries; Final Report; European Commission, 2013.

- *Building consumers and managers awareness is a fundamental issue.* - Maciej Rutkiewicz, Forbo.

Low awareness also does not allow to close the loop for construction products, i.e., despite the purchase of a circular product, the consumer often does not know how to deal with it properly at particular stages of its life--cycle. These problems are in part a consequence of previously identified barriers - investors' short-sightedness and the current system of construction and use of buildings.

3.3.3. Investor's lack of knowledge and competences

The low level of knowledge and preparation to use circular solutions, both in the public and private sectors is a significant problem:

- *There is a great opportunity in education, raising awareness, and it is not just for a single official responsible for the procurement.* - Krystyna Wiaderny-Bidzińska, Ministry of Entrepreneurship and Technology
- *Officials themselves cannot, and it is not entirely in their interest, to impose additional requirements [consistent with circular concepts] (...). A top-down command is required to impose these requirements, although it complicates the entire public procurement process.* - Łukasz Sosnowski, GOZ.world
- *It is necessary for decision-makers to include specialists who understand circular concepts. (...) [Evaluation systems for building materials or buildings] should be simplified so that the person involved in the construction process (...) would have a chance to understand it.* - Maciej Kiepal, Armstrong Building Products
- *We should not (...) rely on building local knowledge only. It will have to take place, however developing individual standards for each project is not the way.* - Ewa Kowalska-Ocneanu, WSP Poland

The identified problem is directly related to currently accepted standards of investor activities. Therefore, apart from issues related to individual employees responsible for planning the construction of a building, the basic problem is the lack of behaviour patterns that take into account circular solutions that are beneficial for all stakeholders. It is precisely these types of barriers that concern in particular public officials who usually try to create public procurement in accordance with the legal provisions, but do not go beyond the already set standards.

3.4. Technological barriers

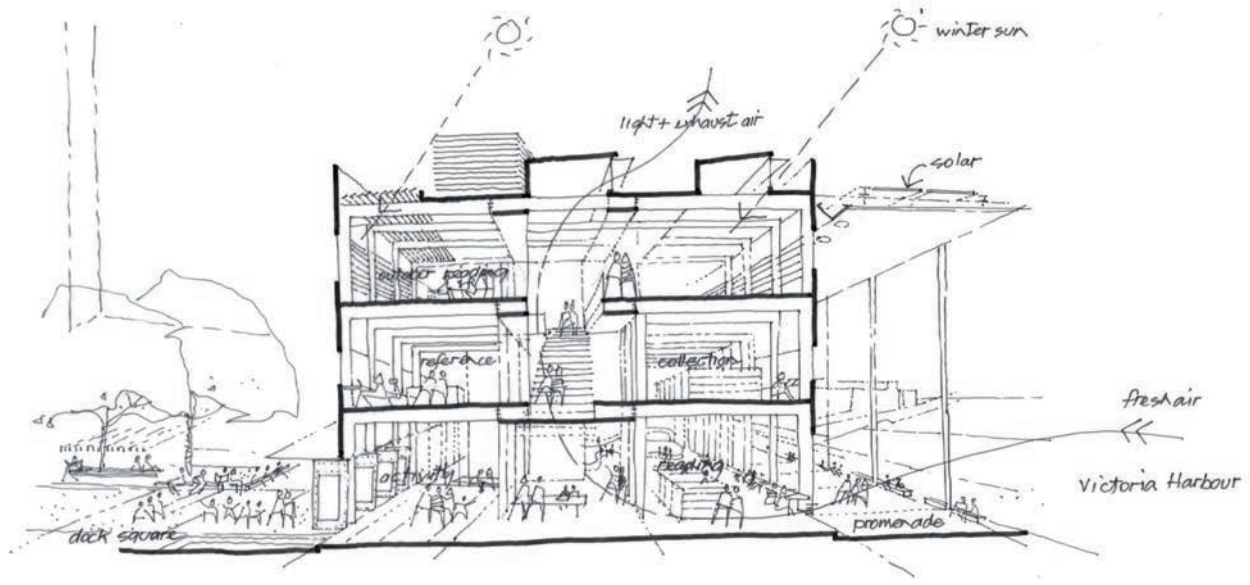
3.4.1. Limited possibilities of material recycling

Due to the characteristics of construction products, which in most cases are very durable, an often encountered problem is the recycling of materials from different periods, subject to different standards. In particular, this applies to the use of substances previously prohibited. As a result, recycling of such products requires significant changes in the technological process. In many cases, creating a dedicated technology is unprofitable. In such situations, products that have been released into the market before the introduction of specific bans is disposed of, which results in a loss of their remaining economic value? The same applies to products with uncertain production time (a relatively frequent case of not labelled building elements), which also precludes their recycling.

3.4.2. Pace and costs of construction and its circular characteristics

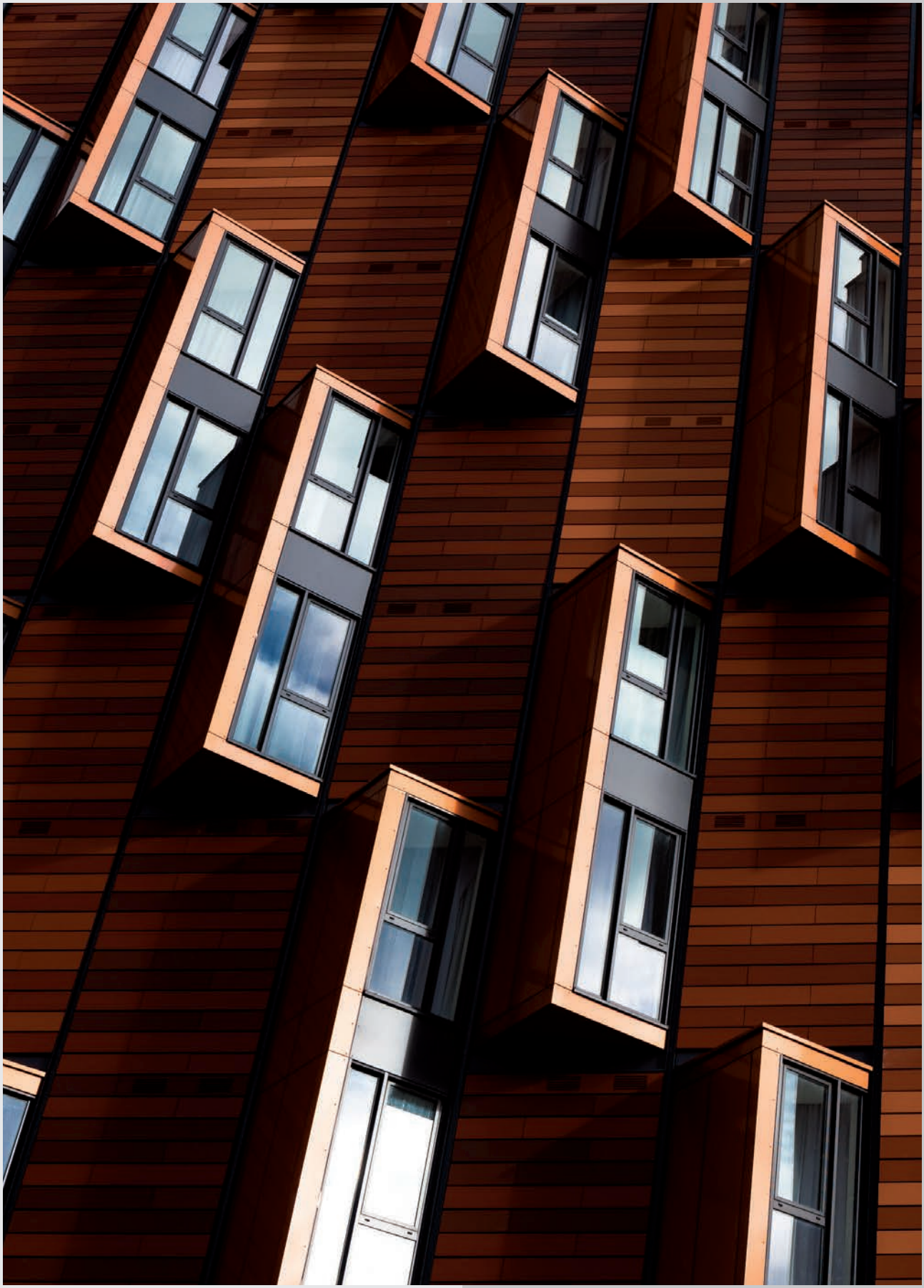
There are many examples confirming that the changes that the construction sector underwent in the 20th century were focused on the speed of construction. This modification is a consequence of i.a. separation of the role of the investor and the owner of the building. Unfortunately, technological changes that reduced the duration of the construction process (e.g. a higher proportion of alite in cement[15]) also resulted in lowering the durability of the building and decreased the possibility of reusing its parts and materials.

Despite the ever wider attempts to employ modular construction, which has not used common standards so far, and the reuse of already available parts (e.g. foundations), the quick and relatively cheap construction of a building that does not adversely affect its durability, modernization or reuse options remains an open problem.



15 Dias W.P.S.; Factors Influencing the Service Life of Buildings; Engineer; 2013.

By using lightweight materials and employing existing port areas as building foundations, the costs and environmental footprint of the Melbourne library were reduced.



4. Supporting circular solutions

4.1. Role of regulators

4.1.1. Standardization

Standardization of constructions in line with circular concepts is one of the basic solutions to the problem of the lack of appropriate behavioural patterns in the construction sector. There are many examples of positive results of such approach in a number of countries, most of them from the public sector.

In the case of new public buildings in the UK, energy efficiency certification is required. This resulted in the number of certified buildings being the largest in the world. However, it does not impose specific technological solutions, which is very important. - Ewa Kowalska-Ocneanu, WSP Poland

A standardized approach to sustainable construction brings many benefits. In the given example, 18.6 million buildings in England and Wales alone are certified (using the so-called Energy Performance Certificates), most of which, i.e. 17.8 million, are residential buildings[16] (in comparison housing stock in England is less than 24 million[17]). In order to fully implement the standardization in construction, it is most-importantly necessary to implement a coherent certification of buildings at the supranational level (for example the European Union), which could probably support the creation and closing of global value chains.

A positive example of the implementation of standardization in the construction industry is the integrated energy management service performed by CONSIP - the Italian National Public Procurement Agency. As part of it, suppliers were required to provide a minimum level of reduction for the basic energy consumption of the entire building / heating system. Suppliers were also required to provide evidence of the results obtained; the credibility has been confirmed by the Italian Regulatory Authority for Electricity and Gas. As a result, heating costs have been reduced in five thousand public buildings by as much as 27%[18].

16 Energy Performance of Buildings Certificates Statistical Release: Q2 2018: England and Wales; Ministry of Housing, Communities & Local Government; 2018,
17 Energy Performance of Buildings Certificates Statistical Release: Q2 2018: England and Wales; Ministry of Housing, Communities & Local Government; 2019. Website: https://www.gov.uk/government/statistical-data-sets/live-tables-on-dwelling-stock-including-vacants
18 Italian public buildings save with energy services framework; European Commission; 2011; website: http://ec.europa.eu/environment/gpp/pdf/news_alert/Issue11_Case_Study27_Consip_Energy.pdf

Piotr Bartkiewicz,
Go4Energy, Ogólnokrajowe Stowarzyszenie Wspierania Budownictwa Zarównoważonego (OSWBZ), Warsaw University of Technology

Certification as a support for the implementation of the circular model in construction

The implementation of new ideas in construction usually requires solid foundations. In addition to financial, legal and organizational tools that can support the implementation of the idea itself, pre-emptive activities such as informational and educational activities complemented by incentive mechanisms are necessary. This is the current stage of the "circular construction" concept. Discussions on the very definition of processes, scope of action, purpose and the way to achieve them are therefore indispensable. This debate should include the vastness of detailed issues related to construction in closed-loop model - legal, technical, formal as well as ethical and social ones. Already, it seems that adopting the main principles of circular construction will allow to redefine issues related to materials management, waste management, balance between energy and comfort, environmental quality, quality of indoor air, new forms of energy management in construction (including its storage) but also the behaviour of building users, their attitudes and habits.

For years, we have been observing an ever more complete implementation of the idea of sustainable development. In construction, it has received a number of practical implementations, as well as the entire assessment and certification system (BREEAM, LEED). As in the case of circular construction, it was initially perceived as an intellectual trick that hinders the traditionally perceived investment process. Currently, after years of educational and informational activities and then after collecting, processing and publishing practical implementations together with discussing the conclusions coming from them, we can conclude that it has permanently found its place in the real estate industry. We should take a similar path in the case of circular construction. That is why it is so important to reduce the asymmetry of knowledge and information between the parties of the investment process. An important moment for this process is when the paradigms of action change. I am convinced that in front of our eyes we begin to shift the accent from the building itself to the person for whom the building becomes the basic environment of life. A person for whom health, safety, comfort are increasingly important concepts. A person who noticing his place on earth, becomes aware of the impact of individual actions and decisions on the environment and climate in a broad sense. This is why the new certification systems (WELL, GBS) evaluate the building through the user's eyes. They evaluate solutions used in the design, construction and operation of a building that have a direct impact on quality of life, health and comfort. The inclusion of additional issues related to circular concept (materials, waste, air, water, energy, biophilia) in this catalogue allows us to use the proposed partial solutions that will form closed loops in the future. That is why building certification (WELL, BREEAM, LEED, GBS) becomes an additional, and importantly, an optional example of knowledge-raising in practice and a platform for information exchange. In addition, by incorporating it into marketing, promotional and PR processes, it becomes another form of reaching people who are not professionally connected with construction industry. People for whom buildings are created. This seems to be a perfect complement to the observed generational changes involving the transformation of the system of values, attitudes and behaviours among young people. I am convinced that in the face of current global changes, the issue of circular construction, and more broadly closing the loop of various processes may become a new, attractive and important challenge for the new generations. A challenge that also brings the potential to create new solutions, activities, products and services. Information, knowledge, education and exchange of experiences, including those resulting from the certification of buildings, may constitute an excellent first step in their creation.

4.1.2. Outcome-based specification

In order to support the circular concept, the regulator should not require particular construction technologies to be employed but base the specification on results. The use of specific and easily measurable indicators could significantly contribute to the implementation of circular economy in the built environment without the need to significantly increase knowledge of existing technologies of people responsible for conducting public procurement, but would not pose barriers to innovation. Such indicators could include energy efficiency, greenhouse gas emissions and the proportion of secondary raw materials used.

The regulation that managed to achieve a positive ecological effect, while not creating significant barriers to the implementation of new technologies, is the indicator of energy demand of the building proposed, i.a. in Norway[19], which takes into account the entire emission related to the maintenance of the building, but also its construction and demolition. This way, it is much more sensible to use the available structures, and not to create new buildings from scratch. In addition, to reducing the carbon footprint, it can result in increasing the amount of materials recovered on site.

The design of the new National Museum in Oslo in Norway is in line with the new regulation, which since 2017 require public constructions to limit environmental impact and promote climate-friendly solutions

19 Harkouss F.; Optimal design of net zero energy buildings under different climates; Mechanical engineering; Université Côte d'Azur, 2018.

4.2. Public authorities role

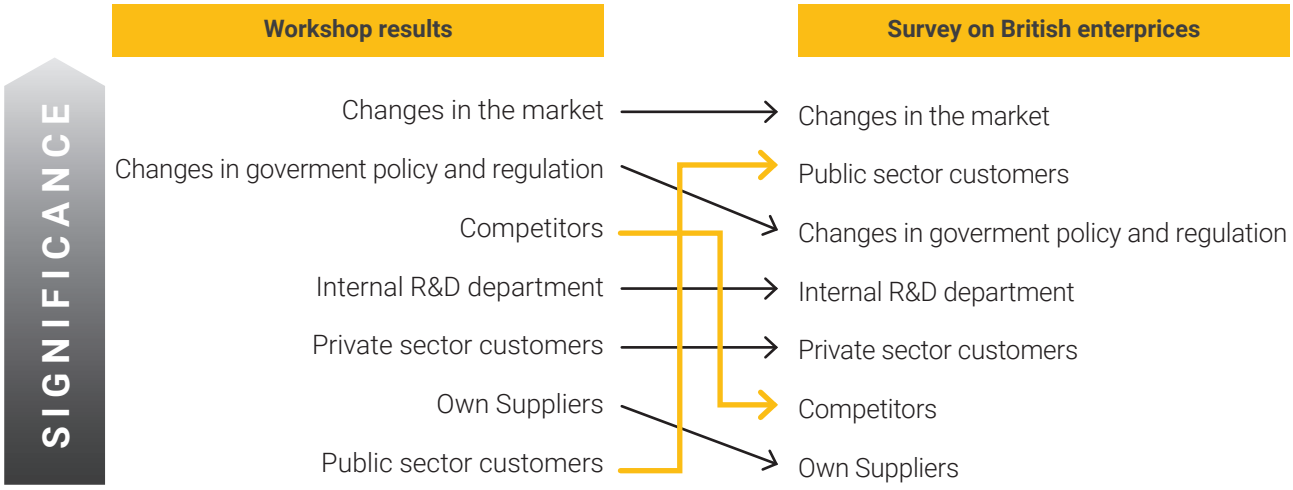
4.2.1. Public procurement support for construction innovation

The experience of other countries indicates the importance of supporting innovation through public procurement in the emergence of new technologies. In Finland, for example, almost half of the commercialized technologies (48%) in 1984-1998 were achieved through public procurement or regulations[20]. This is particularly important in the case of so-called adaptive innovations. In contrast to primary innovations, adaptive innovations are characterized by adaptation of existing solutions to local economic, social or regulatory conditions.

In order to analyze the importance of public procurement for innovations in construction in Poland, a short workshop was held. Participants of the meeting were asked to rank innovation sources supporting factors and barriers to innovation in construction sector in terms of their importance. The results of the workshop were then confronted with the results of a similar survey conducted among British companies (not limited, however, to the construction sector)[21].

In the case of innovation sources, market and regulatory changes were identified as the most important factors. Competition turned out to be a much more important stimulus in relation to the results of the British survey. Significant to the discussion held earlier is that the public sector clients placed last, in terms of the importance as sources of innovation in construction. This indicates the need for changes and improvements of the standards of public authorities' actions for innovation to the level already existing in other countries.

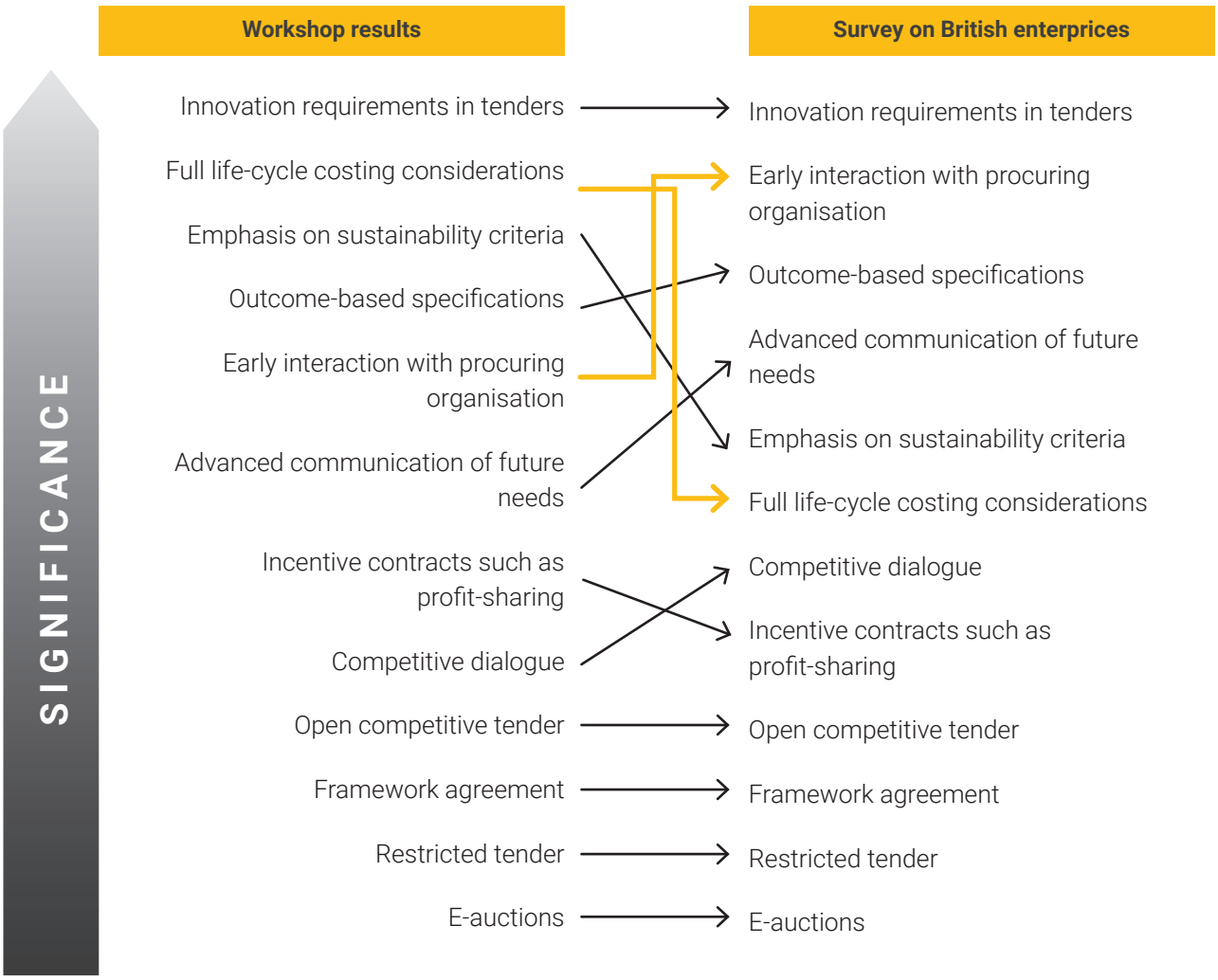
Figure 9
Sources of innovation in built environment



20 Saarinen, J. Innovations and industrial performance in Finland 1945–1998. W: Almqvist & Wicksell International, 2005.
21 L. Georghiou et al.; Policy instruments for public procurement of innovation: Choice, design and assessment; Technological Forecasting & Social Change, 86 (2014).

The most important factor supporting innovations in public procurement processes was the inclusion of technological advancements requirements and the inclusion of the full life-cycle costs. Polish law provides the possibility of considering them, however according to the Public Procurement Office, only 17 out of almost 140,000 public procurements procedures that took place in 2017 exercised it[22]. A positive conclusion from the analysis is the possibility of relatively early interaction with the ordering party regarding the public procurement in comparison to the results of the British survey.

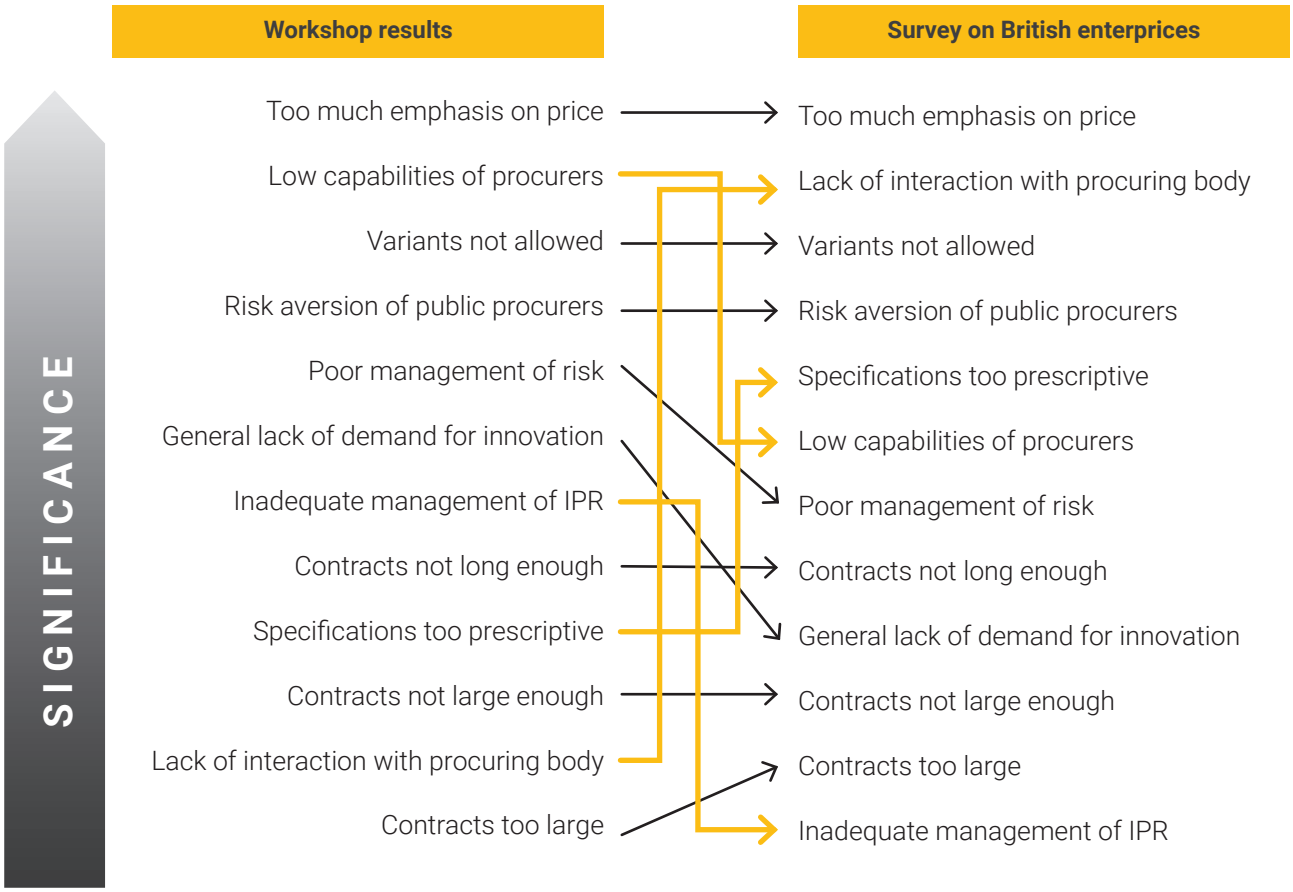
Figure 10
Construction innovation impact of procurement practices



The basic obstacle to innovation in construction sector is putting too much emphasis on the price in public procurement. The second most significant barrier is the low level of decision-making of people responsible for public procurement, which may result in, for example, prolonging the whole process, lack of willingness to use innovative technology, etc. Once again, it turns out that interaction with the ordering party is at a relatively high level in Poland.

22 Stan zrównoważonych zamówień publicznych w 2017 roku – raport; Urząd Zmówień Publicznych (2017). Website: https://www.uzp.gov.pl/__data/assets/pdf_file/0024/39255/Stan-zrownowazonych-zamowien-publicznych-w-2017-roku-raport.pdf

Figure 11
Barriers for innovation in the construction sectro, in the context of public procurement



4.2.2. Public procurement as a support for the scale of circular construction

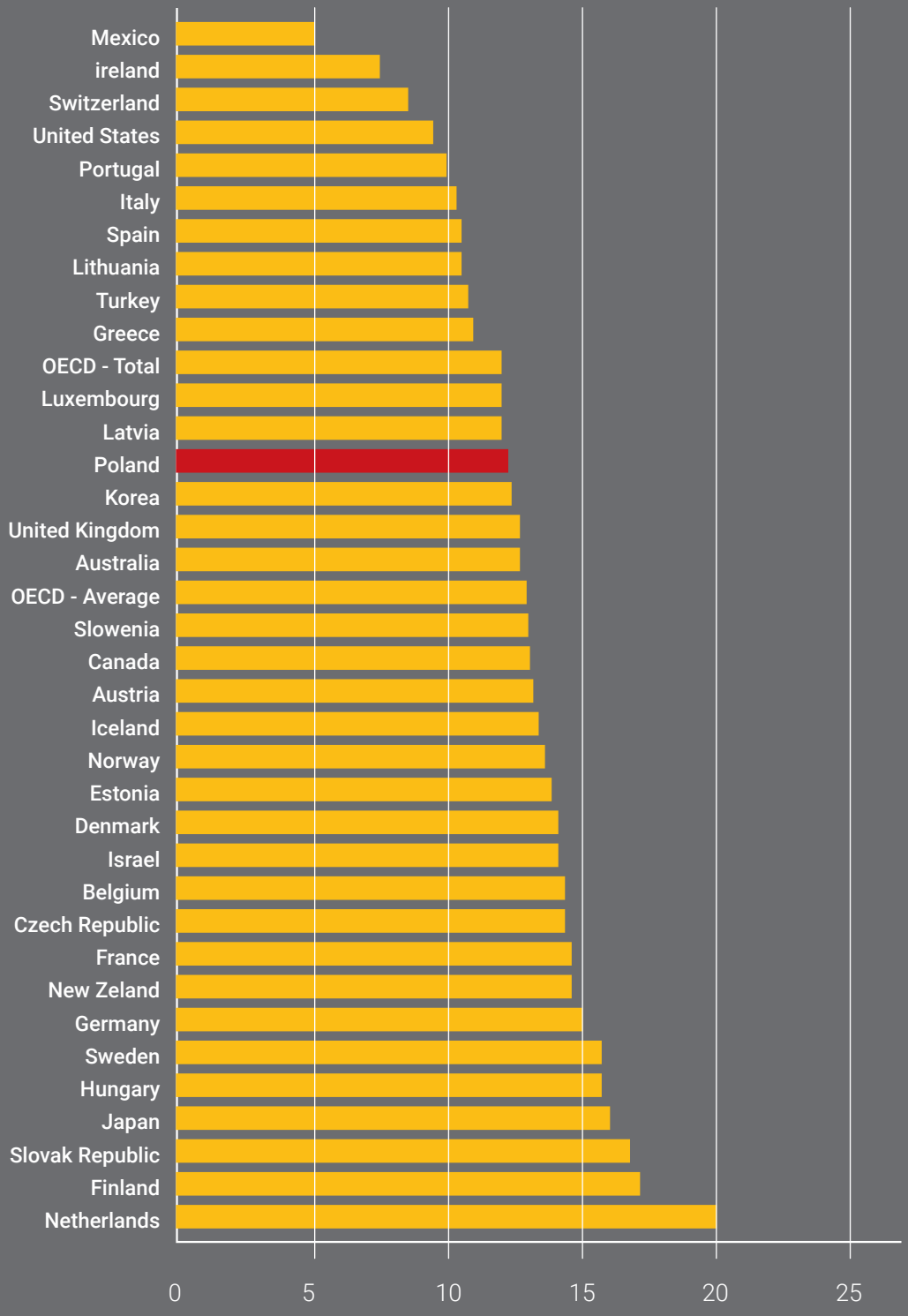
The support of circular construction with the help of economic stimuli is the basic tool that can enable circular construction to be universally adapted by helping to attain economies of scale. The basic tool in this context seems to be public procurement, value at over 12% of GDP in Poland (OECD data for 2015) and EUR 2 trillion in the European Union. A significant part of this expenditure is related to public construction.

The computer industry in the USA is an example of the positive effects of introducing circular concepts using public procurement. After a federal decision ordering public authorities to buy computers compliant with the Energy Star certificate, the demand for such models was so high that in a few years almost all products available on the market met these standards. The producers realized that it makes no sense to run parallel production lines[23].

23 www.energystar.gov

Figure 12

Public procurement in 2015 (in % of GDP)



Source: OECD

While the example does not affect the construction industry, it seems that the use of public procurement to implement circular concepts in this sector is fully economically justified.

- *A circular approach is particularly beneficial (...) if you are the owner and user of the facility, as is the case with public properties.* - Piotr Bartkiewicz, Go4Energy

4.2.3. Non-financial support

Another issue of how public authorities can support the implementation of a circular economy outside public procurement concerns the fact that many opportunities related to circular economy have a solid economic foundation, but often encounter non-financial barriers that limit their expansion or hinder the pace of development. For many small players, lack of clarity in getting the right permits, compliance with applicable laws or outdated perception of regulatory obstacles are also important obstacles to new projects.

In the Netherlands this problem was noticed and answered by creating a so-called 'Green Deal' programme. The programme is a joint initiative of the Ministries of Economy, Infrastructure and Environmental Protection as well as Internal Affairs, with a management board composed of representatives of enterprises, non-governmental organizations (NGOs) and the government. The government signs a Green Deal with the initiating organization to work with them for two to three years. The undertaking is subjected to an intensive legal assessment in relation to national and EU legislation. The proposed initiative must be in line with political objectives, be cost-effective (or be able to become financially-viable in the future), and it should be able to present the results within three years time frame.

A similar solution could be beneficial also in Poland, supporting the implementation of circular concepts on the Polish market. The advantage of this approach is, first of all, the lack of barriers to emerging technologies - the introduction of incentives, not necessarily regulatory, conducive to the implementation of this concept. In addition, these projects would act as positive examples.

- *(...) we should focus on non-legislative solutions other than those strictly legislative ones, concluded either in law or in the regulation. (...) the education, incentives to reuse building materials and their recycling are crucial.* - Łukasz Rymarz, Ministry of Investment and Development
- *There is a huge difference between investors: leaders are able to create a way of thinking, (...) and implement new ideas. (...) and perhaps these good practices are beginning to change awareness (...).* - Piotr Bartkiewicz, Go4energy
- *(...) good practices, should be popularized. Their financial profitability as well as the possibilities of their use and replication should be showcased.* - Elżbieta Szczygieł, Rzeszowska Agencja Rozwoju Regionalnego

Justyna Biernacka,
Association of Polish Architects SARP

Circular construction in modern urban concepts

Cities occupy only 3% of the surface of our beautiful planet, but like huge Tolkien trolls, they are extremely greedy: they consume 75% of world natural resources and produce 50% of global waste, while emitting 60% to 80% of greenhouse gases[24]. Activities conducted in cities can have a huge impact on the slowdown or deepening of global crises related to climate change, environmental pollution and growing social inequalities. The circular economy concept seems to offer excellent tools to get out of the impasse and provide cities with long-term sustainable development.

To imagine what a city's transformation towards circular model could look like, one should think about the city as an organism. At present, holding onto the Tolkien's metaphor, our troll cities operate based on a linear scheme to devour-digest-expel. Their crude diet means that cities cannot meet the needs of their growing bodies, in result they devastate the environment in search of next doses of energy and clutter it with products of their metabolism.

Today, instead of sluggishness, we expect the cities to be resilient and flexible as well as adaptable to rapidly changing external conditions. The troll diet must change. The city's organism must become more self-sufficient, using the unique conditions of its location and the resources it already has.

In cities transformation towards the circular model, the question that researchers from the Dutch Metabolic group, analyzing the spatial conditions of Amsterdam, have already asked themselves is: what should be the scale of loops in which the circular city functions[25]? Many years of experience in the implementation of sustainable buildings allow to build zero- and plus-energy buildings, in which the energy cycle closes thanks to their high energy efficiency and the use of renewable energy sources, e.g. sun, wind or thermal energy. It is obvious, however, that closure of energy, water, materials or ecosystem services loops within one construction or one building plot may not be possible in many cases, and if possible, it may not be necessarily the most effective approach. The location conditions, scale and individual needs of specific facilities may cause that if one of the resources - for example water - is deficient, they may offer their surpluses, for example, produced energy. The search for relations, synergies and exchange of "circular services" between areas with different characteristics, functions and typologies should become a new direction of urban and architectural thinking. The closure of the city's loops may take place in part within a building or housing estate, neighbourhood, district, entire city and even the region.

24. Ellen MacArthur Foundation, 2019. Circular Economy in Cities. Dostep online: https://www.ellenmacarthurfoundation.org/publications/circular-economy-in-cities-project-guide (dostęp z dnia 11.05.2019)
25. Metabolic, 2017. Circular Amsterdam: Spatial implications. Dostęp online: https://www.metabolic.nl/publications/circular-amsterdam-spatial-implications/ (dostęp z dnia 11.05.2019)

Transforming cities in a circular direction carries a number of benefits, not only environmental, but also social and economic. Particular attention should be paid to the potential of local urban areas and neighbourhoods, for which the circular economy can constitute a significant development impulse. The demands of sustainable low-emission mobility, promoting pedestrian traffic, cycling and public transport are conducive to the creation of urban polycentrism, where community life is centred around local hubs[26]where one can easily live, work, use recreational areas and participate in social life, educational and cultural activities.

The circular economy gives local life the necessary intensity by bringing back clean production, processing, craft work, as well as elements of sharing economy, such as local equipment rentals, repair cafes, exchangers, maker spaces, or FAB LABs for local DIY enthusiasts and innovators. These activities can be carried out both with existing functions - such as cafes, libraries, craft and schools as well as in newly designed buildings, taking into account the need to constantly change and adapt to emerging new needs. Multifunctionality is what allows society to intensively use the city space preventing its spilling, allows to create uniqueness using the potential of local talents. The closed circuit economy puts completely new design challenges for architects, at the same time preparing the field for innovative solutions and architectural creativity, as we have never seen before.

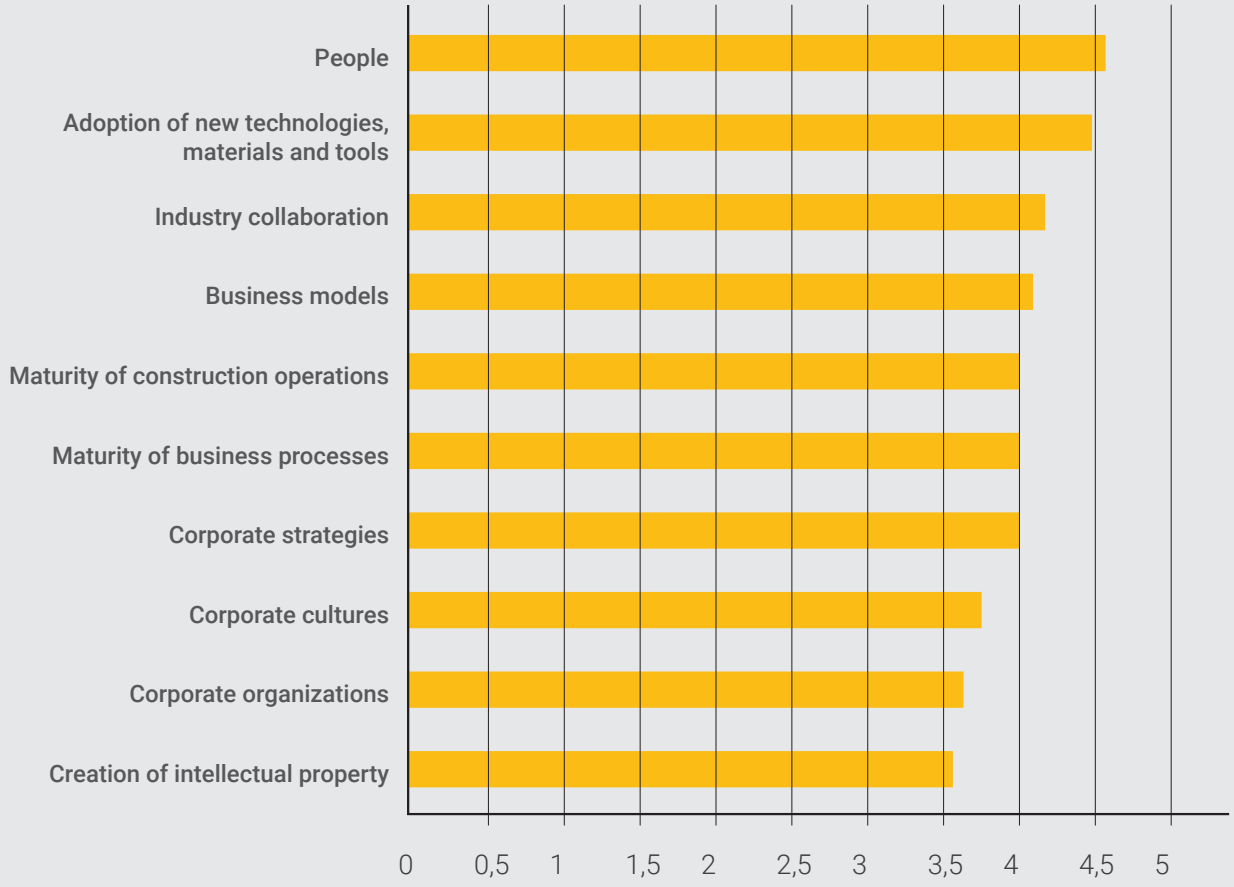
26. Happach, M., Sadowy, K. (red.), 2015. Centra Lokalne. Studium koncepcyjne dotyczące centrów lokalnych w Warszawie. Oddział Warszawski Stowarzyszenia Architektów Polskich, Warszawa.

4.3. The role of owners and users

The role of users and building owners is frequently emphasized as the most important area for the implementation of the circular model in the construction industry. Although, according to the current model of financing construction, often they are not responsible for the design and construction phase, the rest of the building's life-cycle depends on their decisions and behaviour.

Figure 13

Ares of transformation needed to implement circular construction (0 – trivial factor, 5 significant factor)



Source: Future of Construction Survey, appendix in: Shaping the Future of Construction a Breakthrough in Mindset, World Economic Forum; 2017.

Despite its perceived importance, the role of users and owners in the process of transformation towards a circular model in the built environment is often omitted. In order to reduce this gap, debates' participants discussed this problem and develop a set of tools that could help to encourage users and building owners to adapt the circular model in the construction sector. In this process a basic hierarchy of waste management was used[27]. To structure the selection of tools, separate types – including financial, non-financial, information and behavioural tools – were considered.

Table 2
Policy tools to influence individual behaviour

<table>
<tr><td rowspan="2">Regulation of the individual</td><td colspan="3">Fiscal measures directed at the individual</td><td colspan="4">Non-regulatory and non-fiscal measures with relation to the individual</td></tr>
<tr><td rowspan="2">Eliminate and restrict choice</td><td colspan="6">Guide and enable choice</td></tr>
<tr><td colspan="3">Incentives and information</td><td colspan="4">Nudging</td></tr>
<tr><td>Laws and regulations</td><td>Fiscal incentives</td><td>Non-fiscal incentives</td><td>Provision of information</td><td>Simplification and framing of information</td><td>Changes to physical environment</td><td>Changes to the default policy</td><td>Use of social norms</td></tr>
</table>

Source: House of Lords (2011), Behaviour Change, The House of Lords

4.3.1. Financial incentives

Among the financial incentives strong preferences of workshop participants for positive stimuli were visible. In this group the most popular suggestions were to:

- reduce taxes on certified[28] or energy efficient buildings,
- publically subsidise materials containing reclaimed resources,
- publically participate in the costs of obtaining certificates,
- cover recyclable waste collection costs,
- introduce tax breaks in connection to recycled waste.

Negative incentives, such as a tax imposed on materials that do not contain reclaimed resources, or penalties for the lack of recycling of waste, were not recommended. Participants pointed out the need for a cautious approach to the use of financial incentives, which may disrupt the natural market processes in a way that is not fully controlled.

27 Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives.
28. In Poland such tools are used for example in Szczecin; see: https://plgbc.org.pl/buduj-ekologicznie-w-szczecinie/

4.3.2. Non-financial incentives and information

In this set of tools, three basic subgroups have been distinguished, within which significant support for the transformation of the construction sector towards the circular model is possible. Factors associated with the product's life-cycle that reduce the asymmetry of information between investors and building users were distinguished:

- information on possible long-term savings on the product packaging,
- information on standard durability,
- creation of public platforms for trading materials and products.

Among the factors affecting the reduction of waste participants recommended:

- increasing the number of widely available collection points for building materials,
- requirement to report information on construction waste,
- the need to include repair instructions for building parts.

The last subgroup of tools were those that result in resource savings:

- obligatory labelling of energy efficiency,
- obligation to install energy meters.

4.3.3. Behavioural tools

The participants of the workshops proposed behavioural instruments that could help in the implementation of circular construction primarily through the simplification and so-called framing. Among these solutions were:

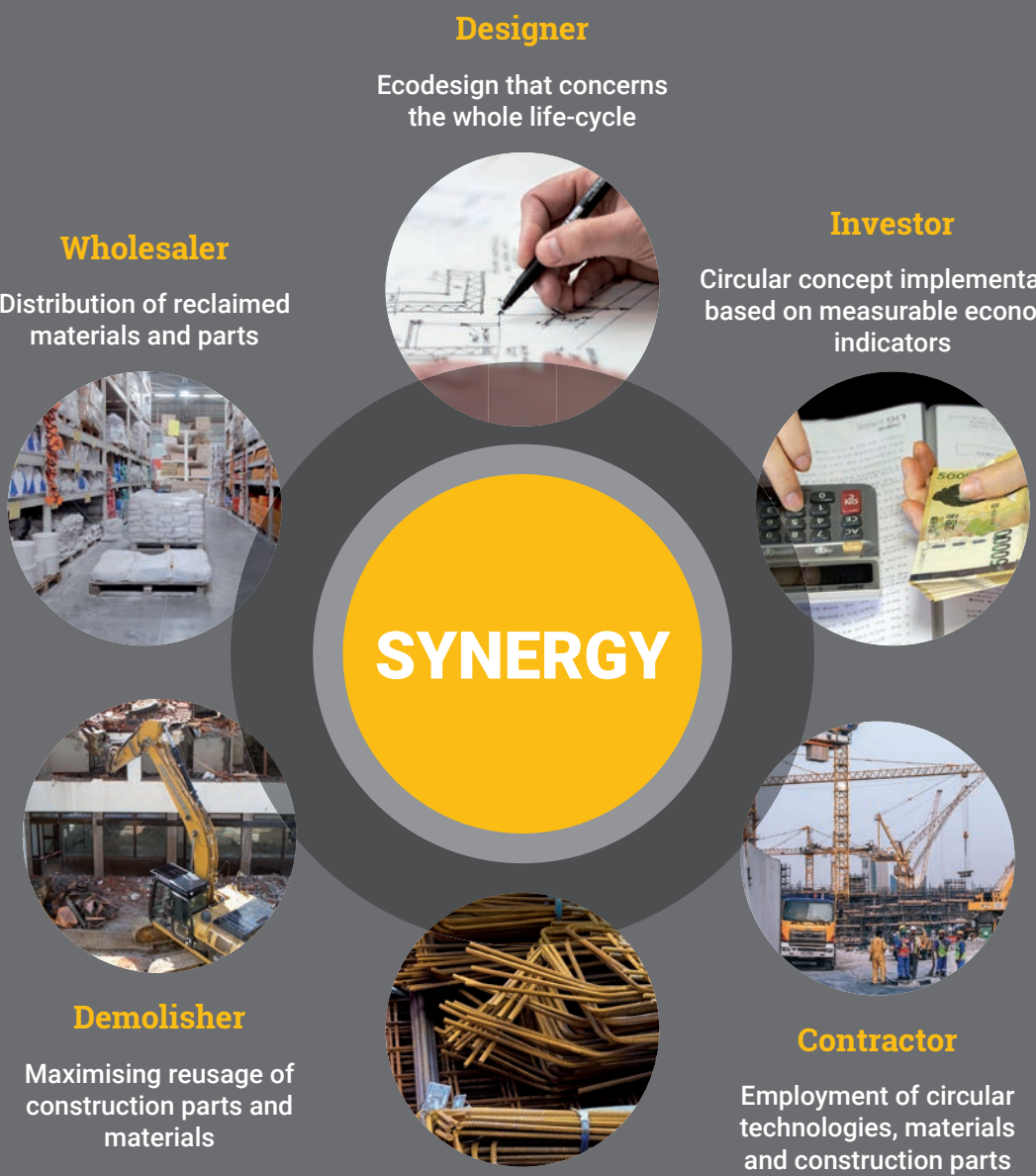
- clear-cut labelling of the product's environmental performance (e.g. traffic lights),
- possibility to add phrases such as "ecological", "sustainable" after meeting relevant requirements,
- the need to inform about the advantages of using ecological solutions,
- the need to inform about the negative consequences of using non-ecological building materials and parts.

Tools that use social standards, such as a public ranking of the most ecological buildings in the region, were less popular. Also changes in the default policy - the default option to re-certify the building after a specified time, or changes in the physical environment - preferential placement of ecological products and materials, were less popular as an effective measure for the implementation of circular construction in Poland.

- *Bearing in mind the circularity concept, we should expect the use of materials that will lead to circular circulation in the building's life-cycle.* - Maciej Rutkiewicz, Forbo

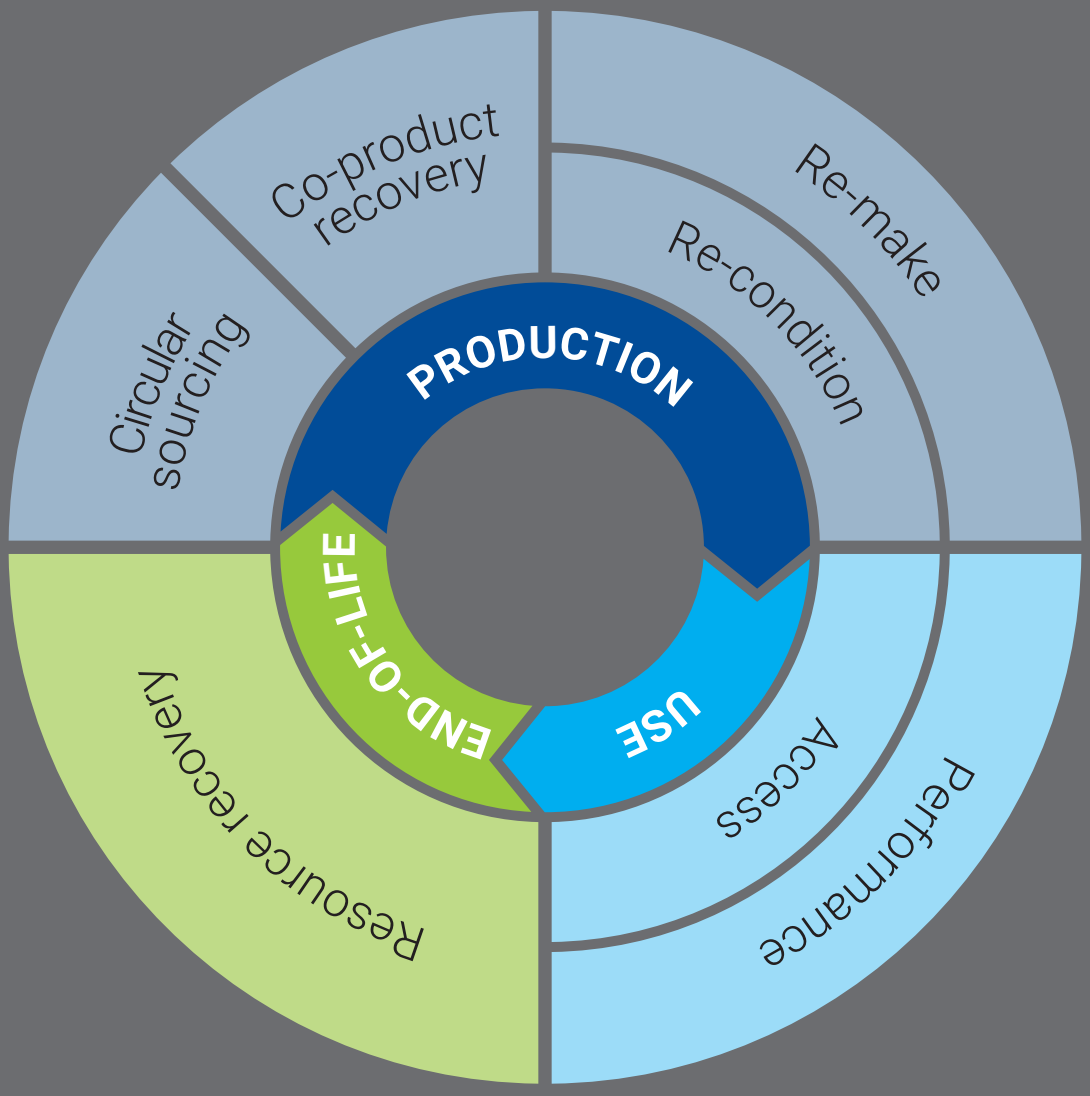
4.4. Synergy

Circular construction covers the entire supply chain. As a result, in order for this concept to fully demonstrate its advantages over linear economic model, it is necessary to involve all stakeholders in mutually beneficial cooperation.



The options for attaining synergy effects within the product life-cycle are numerous. For example, a demolition company may have an interest to disassembly the building without payment or pay for this opportunity after having familiarized themselves with the building material passport. Instead it will be able to make a profit by selling materials obtained from disassembly. At the same time, to make the profit higher, the demolisher can take on the role of the seller by directly supplying materials and parts to the contractor (bypassing the wholesaler and supplier of materials). These types of activities may increase the tendency of the investor, and thus also the designer to create buildings even easier to disassembly, which in result would increase their economic value.

This is just one of many examples of synergies that could be attained. Many of them are based on taking on new roles and tasks. In order to achieve these effects, one should mention once again the necessity of obtaining economical scale effects. This process may be additionally supported by regulators who, firstly, should remove legal barriers blocking the transformation of circular construction by limiting bureaucratic requirements for entities undertaking modifications in their activities. Secondly, if possible, actively support all entities that are interested in closing economic loops in construction, e.g. by improving international trade in used construction materials and parts.



Source: Smith-Gillespie A.; Defining the Concept of Circular Economy Business Model; R2Pi consortium; 2018

One of the basic issues necessary to achieve synergy effects, which stems directly from taking on new roles by market participants, is the introduction of circular business models (see figure above). Among these business models most of them have been used in the construction sector throughout history. However some options have not been employed, in particular servicising the products, e.g. providing lighting services instead of individual light bulbs[29]. This option results in suppliers having an additional incentive to create a product that is as durable as possible, which they can then rent multiple times. Another desirable business model is the creation of platforms for the exchange of parts and materials, or extending the life of individual parts (e.g. the so-called upcycling of once used bricks as a decorative material).

29 See Schiphol Airport in Amsterdam case: http://www.lighting.philips.com/main/cases/cases/airports/schiphol-airport

Maciej Rutkiewicz,
Forbo Flooring Polska

Circular activities throughout the product life-cycle

Forbo was one of the first companies in the world to appreciate the importance and responsibility of the industry for a common sustainable future. Our Life-Cycle Analysis (LCA) approach aimed at a continuous environmental improvement, sustainability programmes to minimize our environmental footprint, and our commitment to international organizations such as the World Green Building Council, Breeam and LEED are examples of taking on this responsibility. After the ratification of the Paris climate agreement and the publication of strategic development goals, we are now entering a new chapter of sustainable development, striving for a circular economy model.

The economy in a closed loop

The circular economy model is essentially a life-cycle system that takes the reuse of products and raw materials and the ability of natural resources to regenerate as a starting point. To further reduce the impact of floor systems on the environment, we transform our business model from a linear economic model into a circular one as a life-cycle system that takes the reuse of products and raw materials and the ability of natural resources to regenerate as a starting point. We strive to employ renewable energy to the biggest degree possible, in particular solar and wind energy.

We have already managed to begin our transition towards this concept. This concerns all groups of Forbo products (linoleum, PVC and carpet linings). Many of these improvements concern the composition of products and raw materials used, as well as internal reuse and recycling processes. One of the ways for Forbo to work on reducing its environmental footprint is the application of 4R principles: we reduce, reuse, renew and recycle. In some countries, such as the United Kingdom, Sweden, France and the Netherlands, we have introduced a post-installation, occasional consumer collection program for used items.

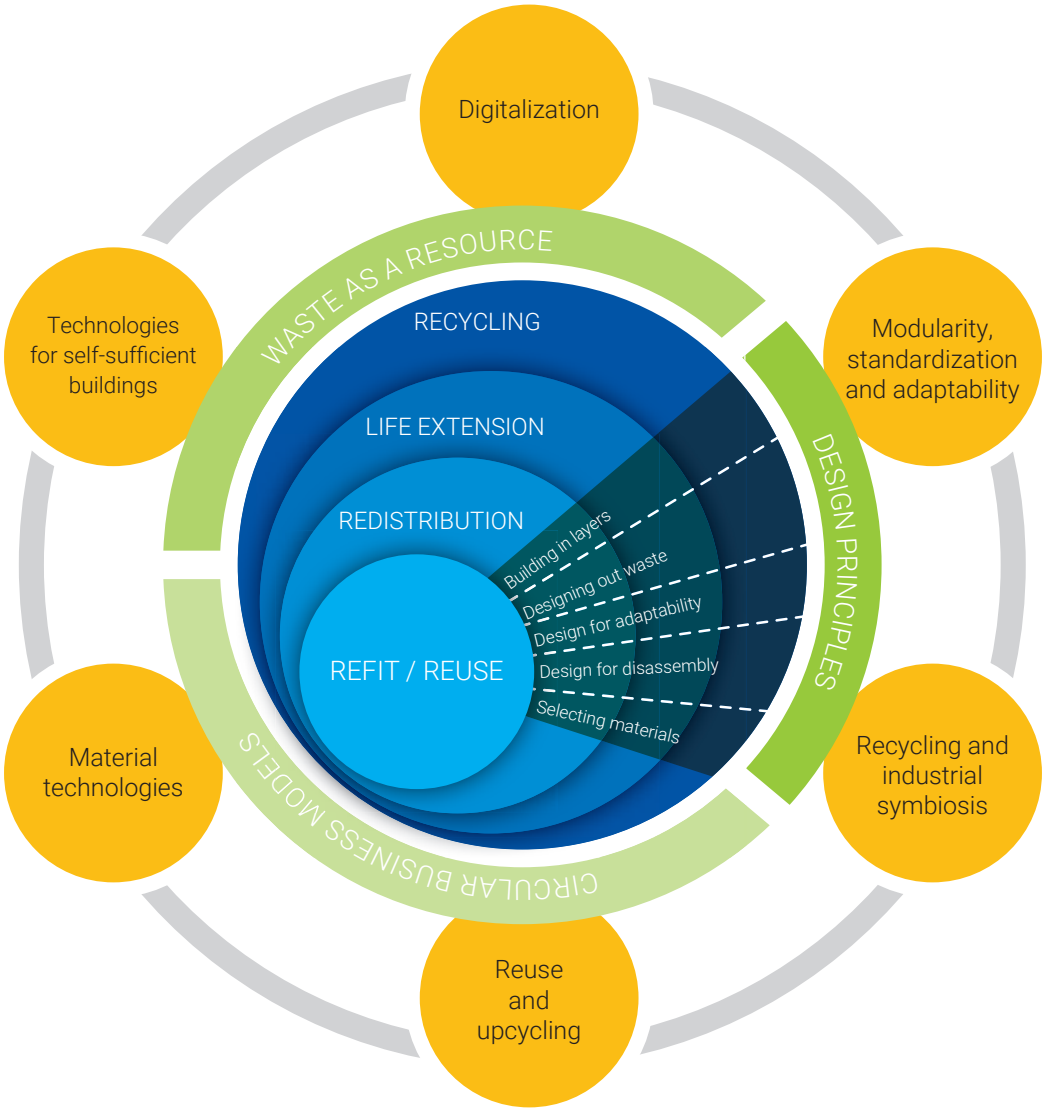
International cooperation

Taking a deeper look at the problem it becomes clear that this is a task that Forbo cannot face on its own, autonomously. Much wider cooperation, going beyond the flooring industry and covering the whole construction sector, as well as support from local and international authorities is required.

Collection of flooring materials from consumers is just one step, but a step necessary to close the economic loop. The waste received should be recycled or better yet reused. Forbo has joined initiatives that are currently being undertaken to make this a reality. ERFMI (European Resilient Floor Covering Manufacturers Institute), of which Forbo is a founding member, joined the European Floor Covering Association (EuFCA), promoting the interests of all European manufacturers of flooring materials.

5. Technologies enabling circular economy

The selection of appropriate technologies is a fundamental issue in the implementation of circular construction. The durability of the building, the possibility of managing its parts, or finally its total, long-term economic value is dependable on the technologies used. Circular technologies play a fundamental role at the design phase. During this process, basic design principles should be kept in line with the concepts of the circular economy. In addition, technologies give the possibility to use circular business models described in the previous chapter. Thirdly, they allow closing the loop, i.e. treating the waste as a resource. Therefore, technologies are a tool for implementing all elements of the circular economic model, in this case in the construction sector, although in many cases they have not been created with this concept in mind. This chapter presents basic groups of technologies that support the implementation of circular construction, along with the possible results of their application.



Source: Author, based on Cheshire D.; Circular Economy Buildings: Evolution or Revolution?; AECOM; 2018.

Kamil Szczygielski,
EKOTECH Group

Circular tools for the solution of waste problems - an example of mineral materials in construction.

When sustainable construction questions are raised in public debates, the issues of energy efficiency, water saving, or building and finishing materials are usually dominant. Green construction has a much wider context and concerns not only building construction, but also infrastructure construction, which we often forget about. The holistic way of looking at a particular investment determines the application of the right tools to implement the principles of circular economy. All elements of construction works affect each other and the environment, and the range of their impact can be considered in the micro and macro scale. By that I mean the creation of green infrastructure, but also the impact which the industry may have on the climate and natural resources.

The construction industry, both in the case of roads, railway lines and for large-surface investments, requires a stable foundation. Difficult soil conditions or high construction requirements are no longer obstacles for designers. The common denominator is the possibility of using anthropogenic minerals, which largely consist of fly ash from the energy industry. Used for the production of hydraulic binders, they significantly improve the properties of the soil, such as load-bearing capacity, compressive strength, homogeneity, resistance to water and frost, and reduction of plasticity. The largest skyscrapers are created thanks to the use of puculan concrete with the addition of ashes. These products potential to mitigate climate change is huge. The bottom line is the possibility of avoiding impressive amounts of CO_2 emissions.

If we look at the energy industry from a different perspective, we can see that it allows to generate electricity, heat and anthropogenic minerals, whose potential in the country is still undervalued. They are still treated as waste or by-product. And yet anthropogenic minerals can successfully replace natural resources. It is estimated that the annual global consumption of aggregates already exceeds 40 billion Mg. In the European Union alone, it is about 3 billion Mg. Polish mining accounts for over 7% of the total sum. Anthropogenic minerals, once again being put into circulation, instead of being landfilled, as previously, allow to implement sustainable development and circular economy concepts. Their dissemination in the economy reduces the carbon footprint of products and buildings. It is also one of the solutions limiting the excessive exploitation of sand and gravel - materials, the extraction of which has reached record levels.

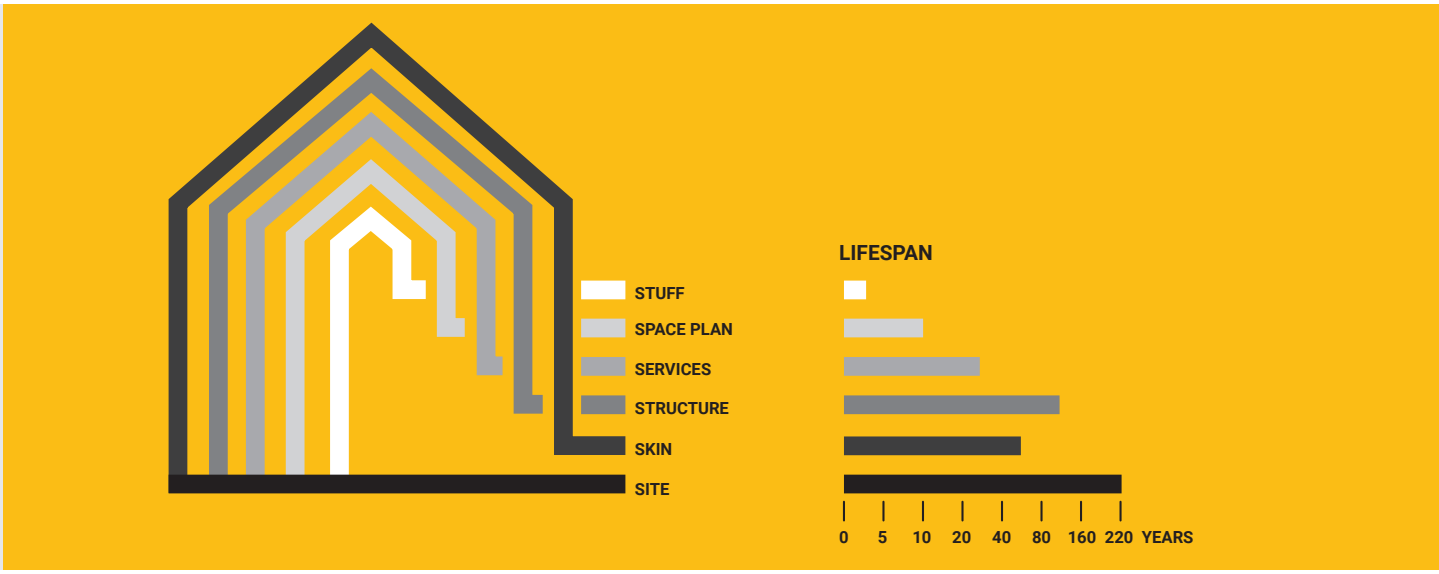
However, in order for activities related to the use of anthropogenic minerals to be undertaken on a wider scale, pressure from the market is also needed. The awareness of investors, designers and contractors is constantly growing. Let us hope that it is the deepening knowledge of market participants that will completely change the perception of by-products of combustion and the group of loyal clients of companies such as the EKOTECH Group will continue to grow.

5.1. Digitalization

Technologies that increase the amount and flow of information in the construction sector are the basis for the transition to the circular model. This applies above all to the permanent and more detailed knowledge of the elements and materials used in construction, from design to the end of its life-cycle. An example of such technologies is Building Information Modelling (BIM) - a digital record of the physical and functional properties of a construction. This technology is in line with the wider concept of material passports describing the material composition of the products and structures concerned. Storing such data in a digital repository allows for relatively easy management and access to all of them throughout the life-cycle of the building. Other information technologies that can support the implementation of circular construction are 3D printing, augmented and virtual reality that allow the design of buildings and its parts to be in line with the needs of customers and at the same time maintain circular principles.

- *Proposed solutions [material passports repository] will not be used only as a register that can be used in the future, but also as a motivation to make better construction decisions at the design stage of buildings.* - Rob Oomen, Madaster Foundation.

Digitalization of the construction sector brings many benefits. It allows the building to be treated as the sum of its layers, where each layer has its own function and lifetime. In addition to extending the durability of the building, it also allows for more economically efficient building management, repairs and modifications as well as a high level of adaptability. In addition, it can radically contribute to the simplicity of disassembly and optimal recovery of its economic value.



Source: Brand S.; How Buildings Learn: What Happens After They're Built; Viking Press; 1994 and Building Value: A pathway to circular construction finance; Circle Economy; 2019

It is also possible to significantly reduce the amount of waste. For example, detailed information obtained during the design of the building may allow for the purchase of strictly calculated quantities of materials. Another example is the possibility of limiting the amount of materials used during the production of building parts, thanks to computer modelling and 3D printing.

Rob Oomen,
Madaster

Digitization and data rich markets

Enabling new business models and a circular economy in the construction sector.

Digitization can take away the barriers of physical distance in trade and enables communication through one common language at a large scale. Generally speaking, the construction sector is still highly scattered geographically and operating offline. Every new project is regarded as a unique project, without much standardization in the building components, products and materials used among them. This results in a high level of waste, both in terms of materials and time, thus costs.

There are two main factors that could enable the sector to start standardizing and reducing the levels of waste (in time and materials): digitization and data rich industries. Additionally, this will open up the opportunity for new business models and a circular economy.

Digitization:

There are many information sources and processes that can be digitized and many ways to digitize them. In construction, the use of Building Information Models (BIM) is a comprehensive way to create an exact digital copy of a physical building. This enables one to detect clashes and design failures in the design phase, before the start of construction, reducing failure costs. It also makes it easier and cheaper to design the next projects, as one is gathering an increased set of data of all the buildings that have been constructed. An added benefit is that the BIM model can be used in the maintenance phase of a building and to create a material passport. This is where new business models and data rich industries kick in.

Data rich industries:

Aside from the fact that digitization and data can optimize existing processes, if done well, it opens up a new array of opportunities. In general, construction companies, only focus on constructing a building, having no interest in maintenance and extended client relationships whatsoever. Even worse, construction companies prefer not to have this extended client relationships because it extends their responsibility for what has been constructed. However, once construction companies digitize, design out waste, and have an exact digital overview of the building through BIM and a material passport, it becomes easier and less risky for to extend their involvement into the maintenance phase, creating new business models. Furthermore, it creates an incentive for the sector to build something of high quality and low maintenance at the start, reducing waste, and potentially enabling a circular economy.

Circular economy:

Once the construction industry has an incentive to maintain buildings and the inherent quality, the incentive for a circular economy, in which products and materials cycle as long as possible, grows inherently. In the Netherlands, the Madaster Foundation has set up an online register for products and materials in the built environment enabling its users to create material passports for real estate. This gives real estate owners an exact overview of the products and materials in their building, the level of circularity and financial value of these materials. A growing databank to enable a circular economy and to, amongst others, facilitate trade.

5.2. Modularization, standardization and prefabrication

Modular construction consists of creating building parts, which can then be relatively simply and quickly used to form a building. This process is characterized by a reduction in the amount of waste, primarily due to the standardized and refined production. Similar features are characterized by the prefabrication process, such as the production of concrete outside the construction site or prefabrication of metal elements in steel mills. Another example of similar technologies application are installations allowing for the unused concrete mix and its residues to be processed and returned to production, with a great deal of attention paid to the consumption of water.

As a result of these activities, in addition to the already mentioned reduction in the amount of construction waste (for example reducing the amount of waste on the construction site through appropriate construction preparation and avoiding repair works using mechanical hammers), the value of the building is maximized throughout its life-cycle. In result both modifications and disassembly becomes easier and depending on the durability of individual building parts, they can be reused in different projects.

5.3. Material technologies

Circular construction requires the use of appropriate materials. This does not mean, however, that they must be either complex or modern. Circularity is achieved primarily due to the simplicity of the materials, which allows their uncomplicated dismantling, increases possibility of recycling and reuse, and thus helps to maintain their value in the economic cycle. However lately a number of innovative materials have been created, which are characterized by certain advantages over the ones used so far and allow for a more complete implementation of the circular model in construction.

Among such materials are:

- flooring materials that have self-healing properties and are 100% recyclable;
- enhanced styropor, offering up to 20% efficiency improvement in insulation;
- organically coated steel that achieves 30-year guaranteed durability and does not contain genotoxic, hexavalent chromium;
- self-healing concrete, generated through the addition of bacterial spores, is estimated to reduce lifetime costs by up to 50%;
- rain-absorbing roof-mats, imitating the process of perspiration, considerably reduce air-conditioning costs.

Ecological and durable flooring

Forbo's Marmoleum is the most ecological flooring material in the world produced in 97% with natural resources, 72% of which are renewable (the process takes about 10 years).

The heart of Marmoleum is linen, from which the linseed oil is produced - the key raw material of linoleum. Marmoleum contains 43% recyclate, which reduces the need for natural resources.

The advantage of Marmoleum is its natural bacteriostaticity, ease of care and durability. Marmoleum has 30 times lower content of Volatile Organic Compounds than required by the European standard and zero CO_2 emissions. It is the only flexible floor covering on the market that has been approved by Allergy UK.

Marmoleum has been valued for years in health care, educational facilities, sports halls, but also in commercial outlets and offices.

5.4. Reuse and upcycling technologies

The reuse of buildings and their parts is crucial in the endeavour of implementing circular construction. In fact, this process has been taking place for hundreds of years, but it has been limited by construction technologies that appeared in the 20th century. The return to the reuse of parts is slowly gaining momentum. An example of such technology is the automated process of cleaning mortar bricks for reuse[30].

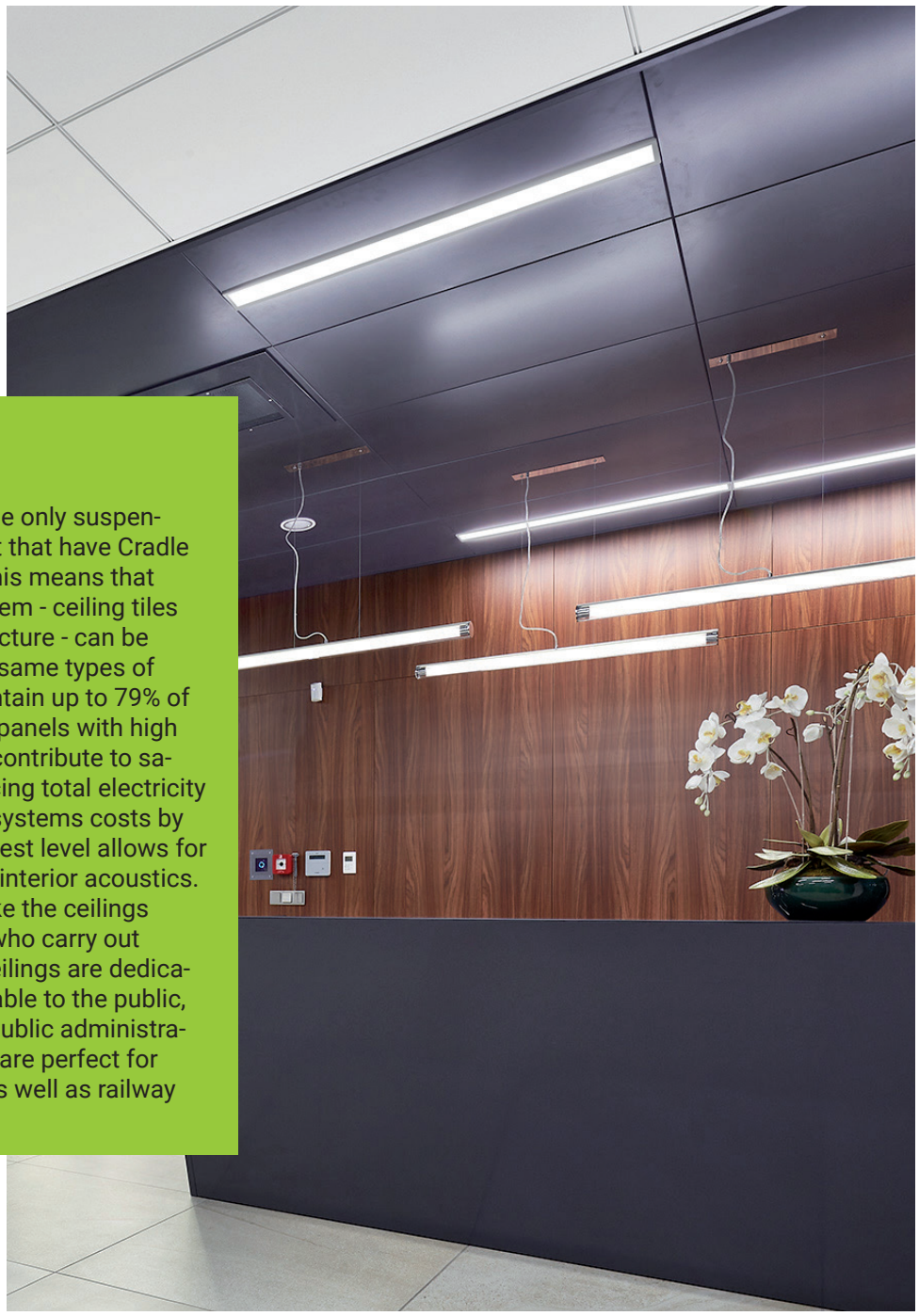
In combination with the modularity and standardization of buildings, as well as IT technologies, this gives a radical increase in the ability to adapt buildings to new needs, as well as to reuse its parts.

Veluvine in Nunspeet in the Netherlands is a multifunctional public building that is at the same time a school, theatre, cinema, sport arena, library and a cafe.

30 See: http://gamlemursten.eu/

5.5. Recycling technologies

In order to close the economic cycle in the construction sector, a recycling process is necessary. In the past, due to the relatively simple materials and building parts, such as stone, bricks, almost no recycling occurred. Instead, a process of reusing these raw materials, preferred in the waste management hierarchy, took place. Currently, together with the growing number of relatively complex building materials (e.g. reinforced concrete, plastics, cables made of various materials), a recycling process has become necessary to implement the circular model. Fortunately, in recent years, we have seen a significant increase in the number of these types of technologies.



Circular ceiling systems

Armstrong ceiling systems are the only suspended ceilings on the Polish market that have Cradle to Cradle® (C2C) certification. This means that the entire suspended ceiling system - ceiling tiles together with the supporting structure - can be recycled and entirely made from same types of reclaimed tiles. The products contain up to 79% of recycled material. White mineral panels with high light reflectance of approx. 85% contribute to saving electricity in buildings, reducing total electricity costs by up to 11%, and cooling systems costs by 7%. Sound absorption at the highest level allows for the development of user-friendly interior acoustics. These and other parameters make the ceilings highly popular among investors who carry out ecologically certified projects. Ceilings are dedicated to all types of buildings available to the public, in particular to offices, schools, public administrative centres, and the metal types are perfect for facilities from the retail market as well as railway stations and airports.

An example of recycling process with great potential could be the use of concrete and brick debris from demolition waste, not only as a secondary raw material for road foundation and soil reinforcement, but as a material for the production of a full-fledged component for new concrete. Recycling of boards from various types of polystyrene (PS, EPS, XPS), which as a nonmaterial is suitable for recycling, is also becoming more and more common.

Construction technologies using industrial symbiosis

The EKOTECH Group bases its operations on the principles of circular economy. This concept is implemented on many levels. The technology offered by the group that allows the production of low-emission geotechnical binders, which are based on ash from lignite, is not everything. We eliminate the element of ash storage, through their technical and economic use in geoengineering, minimizing the use of natural aggregates and extending the durability of the infrastructure. The circular principles can also be found in the order fulfilment process, in the form of a service on demand and production tailored to the needs of a specific projects and clients. Our installations are located in places of raw material production, which eliminates the necessity of its transportation. In turn, the implementation of custom-made services means no need for storage of adhesives, which are transported directly from the installation to the construction sites. We not only share the space for the installation, but also the transport fleet, minimizing the impact on the environment.

The EKOTECH Group is still investing in knowledge and innovation, taking care of its further development. It is thanks to the pursuit of technology improvement that the family of modern TEFRA® hydraulic binders that became the flagship product of our company was created. High-calcium fly ash with hydraulic properties is used for their production. They are substances registered in the European Chemicals Agency and are completely safe for the environment and living organisms. The products based on them are characterized not only by low carbon footprint but also by the highest level of environmental safety.

Recycling does not have to occur only within one branch of the economy. A great example of the so-called industrial symbiosis is the use of by-products of combustion in the building materials industry. This applies mainly, but not only to autoclaved aerated concrete, where ash accounts for approx. 70% of its content. In most cases the concrete plants are usually directly connected to the power plants with pneumatic transport lines. By-products of combustion are not only ashes, but also slags and post-reaction products from fuel desulfurization installations (also their mixtures), which can be used as a raw material for the production of hydraulic binder, mineral fillers, aggregates, etc.

Recycling of plastics, including construction

The pioneering implementation of circular economy is the PolyStyrene Loop Project (PSLoop). A demonstration PSLoop plant is being built in Terneuzen in the Netherlands. This innovative pan-European enterprise with the participation of Synthos allows recycling of construction waste with simultaneous separation of flame retardants used in EPS. It is also an example of a well-functioning partnership across the entire value chain - 70 entities from 14 EU countries participate in PSLoop. The European Commission (EC) recognized PSLoop as the best practice in the field of plastic recycling and the Basel Convention for the best flame retardant separation technology. The first PSLoop plant on an industrial scale will be built in Poland. Synthos works together with the Polish Academy of Sciences and the Cluster of Waste Management and Recycling on the concept of a waste collection system.

As part of another pan-European platform - Styrenics Circular Solution (SCS), a comprehensive package of breakthrough recycling technologies (mechanical, chemical, dissolution, depolymerization) of styrenes is being developed. This will allow for a return to the original monomer form and make styrene truly circular. SCS will increase the scale of implementation of recycling technologies and will deepen the recycling market.

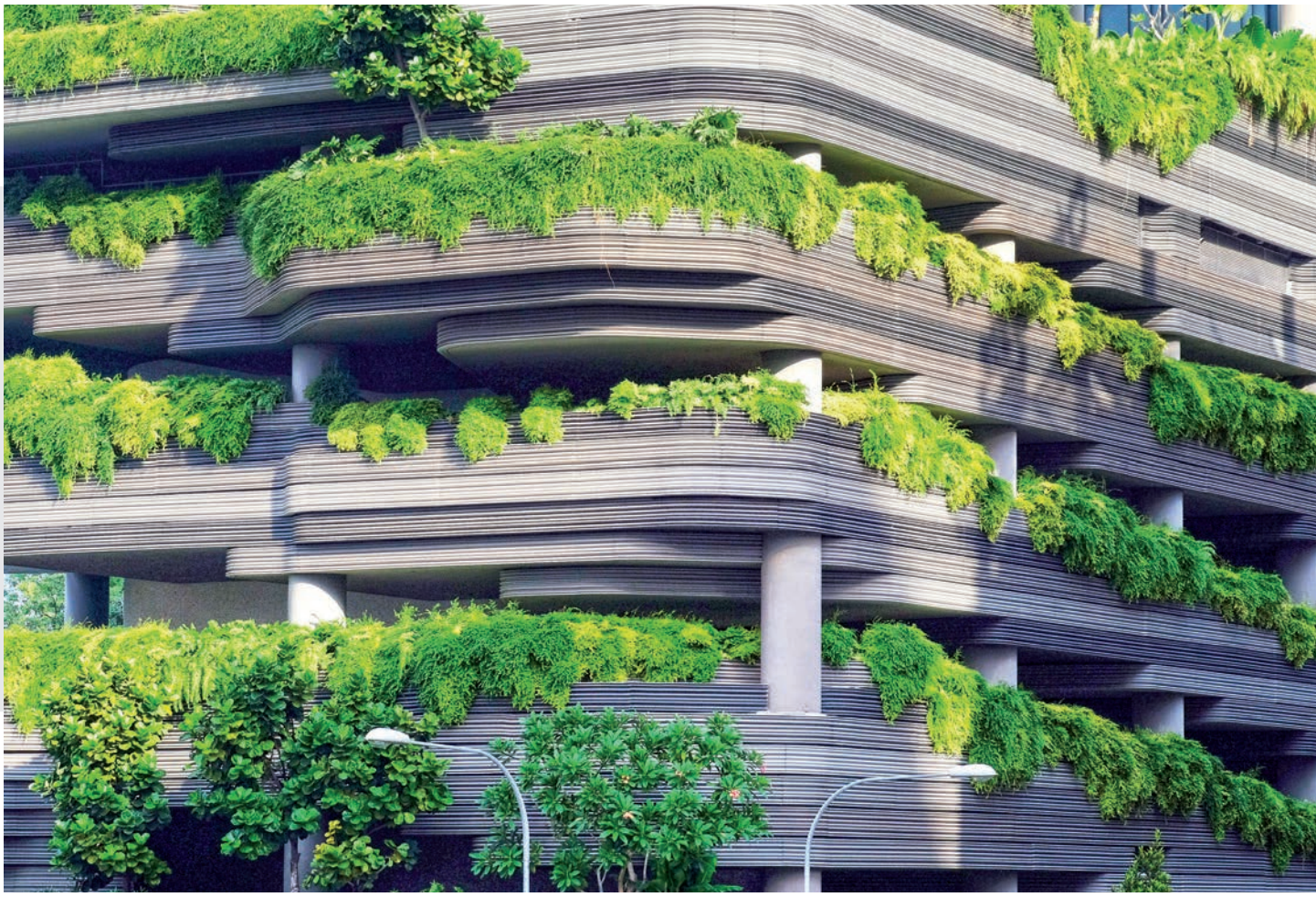
By 2030, we must achieve the targets set by the European Commission in the field of waste management (recycling of plastic at 55% level). Our entire sector took part in the campaign of voluntary commitments focused on the goals for 2025 (recycling of plastics - 50% and use of 10 million tons of recyclate), and now participates in the Circular Plastics Alliance established under the patronage of the European Commission.

5.6. Technologies ensuring self-sufficiency of the building

Circular construction is characterized by a low level of waste generation and low demand for raw materials not only at the design stage or at the end of the life-cycle, but above all during use. This is the stage of the building's life, which generates the largest costs for the natural environment, e.g. through greenhouse gas emissions or sewage production.

Among the technologies limiting the necessity of using raw materials during the use of buildings, the most attention is paid to the consumption of energy and its renewability. Examples of such technology are efficient, perovskite photovoltaic cells, windows producing electricity, heat pumps, but also entire cogeneration and trigeneration installations. These installations allow to produce not only electricity but also heat, or air-conditioning.

Although energy efficiency is often the first thing that comes to mind when thinking about building's sustainability, one of the most popular resource – water requires as much attention. Recycling of gray water from sinks and showers and rainwater recovery is recently gaining popularity. In both cases, we obtain colourless, odourless and hygienically safe water, which can be reused for flushing toilets, watering the greenery around the building or washing buildings and machines.



6. Summary

As modifications to the built environment, such as the implementation of new technologies or management methods, take place at an extremely slow pace, the industry in most cases continues to use solutions that appeared almost half a century ago. They were created at a time when external effects of economic activity were not taken into account and resources were treated as practically inexhaustible. What's more, when looking at the latest economic history, we observed a tendency to turn the construction industry away from the concept of using renewable materials, reusing them or extending the durability of buildings.

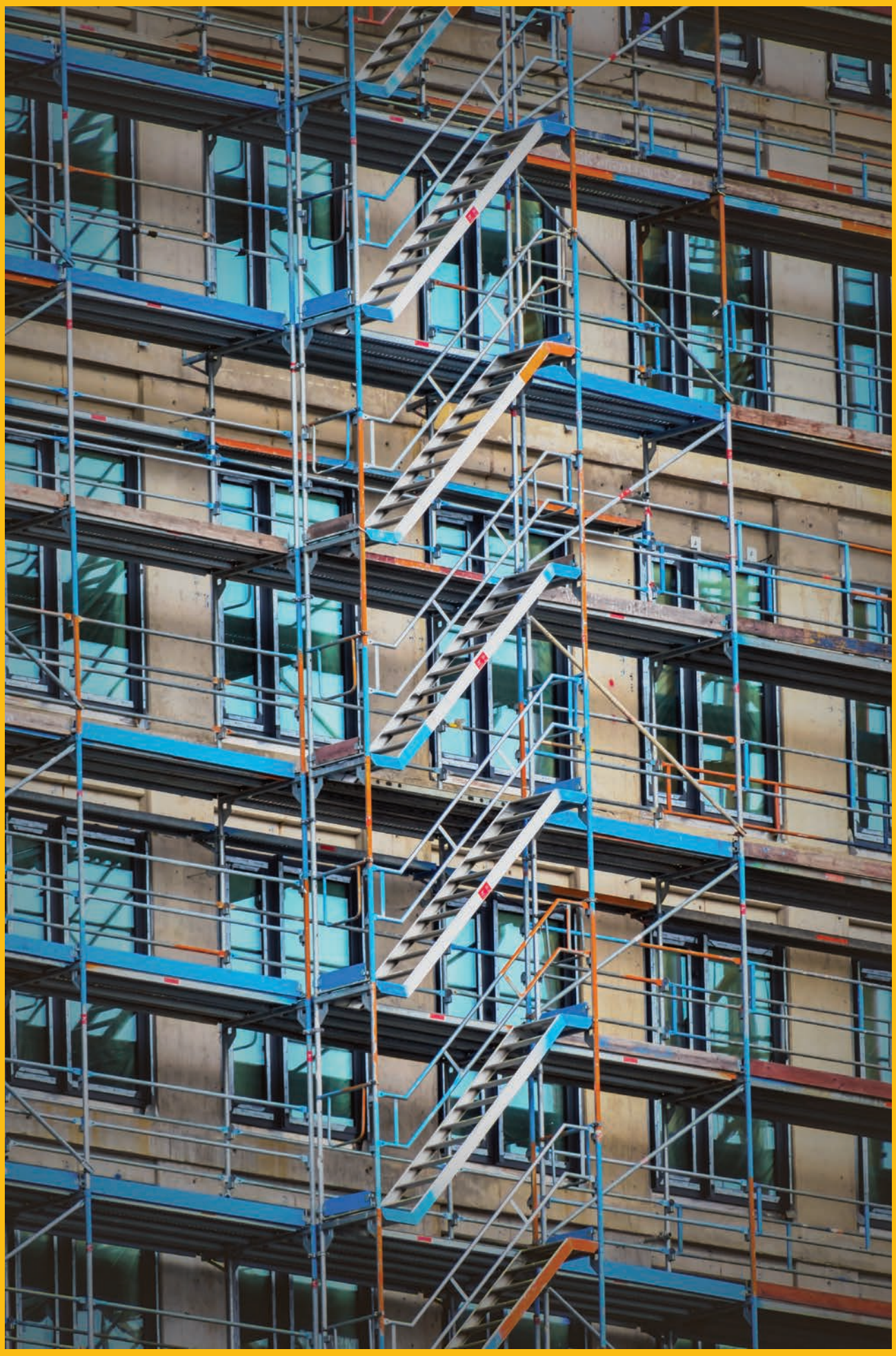
It is all the more puzzling that circular solutions have specific economic foundations. A number of circular tools aimed at maintaining the highest value of buildings and their parts in time as well as the most productive use of raw materials can bring economic benefits valued at EUR 1 trillion to 2030 in the European Union itself. At the same time, the negative impact on the natural environment of the construction sector, responsible for the largest environmental damage among all branches of the economy, would be significantly reduced.

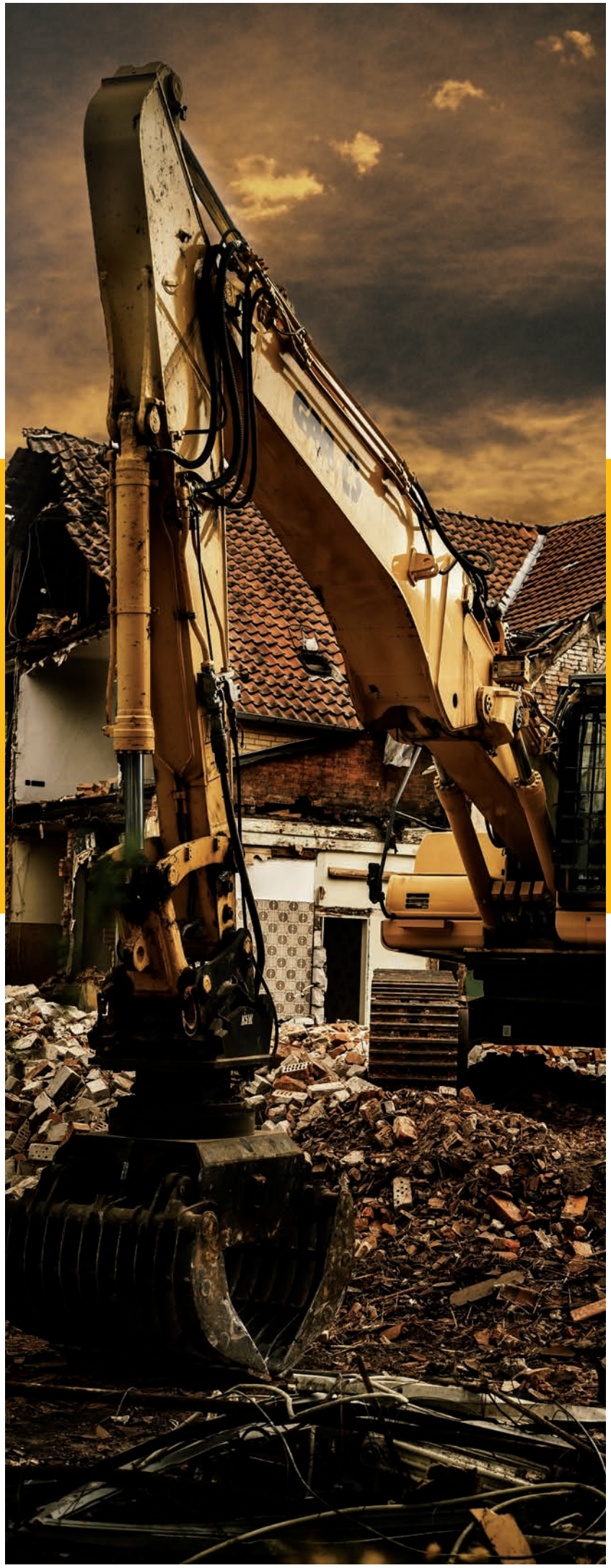
In order to implement circular construction, it is necessary to overcome identified barriers in the financial, organizational, social and technological areas. The basic ones concern the lack of economic scale effect for circular products, separation of the role of the investor and owner of the building, regulation and its actual enforcement, lack of tracking of construction waste streams, negative perception of reuse of materials and building parts, and low stakeholder awareness.

Public authorities have a fundamental role in overcoming these barriers. They should assume the role of a leader in the implementation of circular economy, also in the construction sector. To this end, it is necessary to use public procurement as a stimulus for innovation and to increase the scale of the circular production. At the same time, the regulator should not require specific construction technologies that should be used, as procurement process should be outcome-based. To this end well-designed standards of operations are a necessity. The users and building owners also play a significant role in the implementation of circular construction. One of the basic tools to transform linear construction into a circular one is to reduce the asymmetry of information between them and developers, suppliers of products and materials and realtors. Additionally, in order to achieve synergy effects in circular construction, it is also necessary to introduce circular business models, such as the servicisation of products.

Another issue in the implementation of circular construction are technologies that are a tool for implementing this economic model. The selection of appropriate technologies determines the later durability of the building, the possibility of managing its parts, or finally its total, long-term economic value. Circular technologies play a fundamental role at the building design stage. During this process, basic design principles should be kept in line with the concepts of the circular economy. In addition, technologies give the possibility of using circular business models. Thirdly, they allow closing the loop, i.e. treating the waste as a resource. We now see a series of technologies that could make all of this happen. This concerns in particular digitalization, modularization, prefabrication, new methods of recycling and reuse, innovative building materials and technologies limiting water and energy consumption.

Overcoming identified barriers using the proposed solutions and innovative technologies can lead to a more sustainable use of resources and bring long-term benefits not only for companies in the construction sector, but also for the environment and the general public. The transition to circular economic model in the built environment may bring the greatest benefits relative to other sectors of the economy, and prove to be comparatively easy due to the natural predispositions of the products of this branch of the economy.





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