Chapter 3

Buildings in Urban Regeneration

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Additional information is available at the end of the chapter

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Abstract

The number of people living in urban areas worldwide is constantly rising. This puts significant pressure on resources in general—leading to an urgent need for the radical improvement of local infrastructure, especially housing, food, water and waste. Managing urban areas is therefore one of the most important development challenges of the twenty-first century. The built environment is a key element in urban living. Significant investments in infrastructure and further development must be made to accommodate the increasing number of people moving to cities, thereby increasing the pressure on available resources and waste generated. Cities also face a huge energetic refurbishment task. These transformations of cities at the same time offer new opportunities: energetic refurbishment could bring multiple benefits to the citizens, and smart material loops can make the circular economy a reality. The design of and the material used for buildings also have a bearing on other important aspects of sustainability and urban life. They affect factors such as health, thermal comfort, acoustic performance and fire resilience. By taking a holistic approach, buildings have the potential to be a part of the solution of today's and tomorrow's challenges through the creation of sustainable cities. Cities have the power to act and make changes happen within their boundaries.

Keywords: energy renovation, urban regeneration, sustainable buildings, fire resilience, city lead, circular economy, resources, waste

1. Introduction

With around 1.5 million people moving to an urban area every week, the pressure on resources continues to increase and will drive the need to radically improve local infrastructures especially for housing, food, water and waste. Already today, cities are aggregators of materials and nutrients, accounting for 60–75% [1] of natural resource consumption, 50% of global waste production, and 60–80% of greenhouse gas emissions [2]. Managing the built environment is the key to securing a sustainable future. In the EU alone, buildings account for 40% of the final energy consumption, about 35% of greenhouse gas emissions, 50% of all extracted materials, 30% of water consumption and 35% of total generated waste [3].

People living in cities typically spend up to 90% of their time indoors—thus creating more demand for energy for heating and cooling of buildings. For households, this can be expensive—with energy expenditure accounting for up to 16% of an average household's total spending.

A key step to the sustainable design of buildings is to reduce the amount of energy needed in buildings to keep a comfortable indoor temperature throughout the entire year. Typically, 80% of the energy used in the building sector results from heating, cooling, hot water and lighting, while the remaining 20% is generated by construction materials, transport and demolition. So, while a low-energy design is essential, it's also important to design in a more comprehensive way and to consider how the building and its materials can be recycled and reused at the end of their life. The right design can make a building a 'material bank' for the future. Requiring deconstruction, selective demolition, sorting, increasing demand for recycled products and developing (digital) platforms for this will bring the circular economy in the built environment to the next level.

Many large cities host challenging neighbourhoods that are often characterised by multiple social problems, inadequate living conditions and bad reputations. These problems often reinforce each other in a vicious circle, causing a negative trend for the area. The buildings forming these areas are often 40–50 years old and were built at a time characterised by different societal ideals. Time has changed and so has our demand from the built environment. Most of these buildings are in dire need of an upgrade—to lower their energy consumption and improve thermal comfort and the health conditions of the people living in them, as well as to improve aesthetics of the neighbourhood. Urban regeneration is important because we need to ensure that our cities, living spaces and our working spaces are fit for the future and enable the citizens to live a sustainable lifestyle. Urban regeneration may be one of the main tasks for our societies to tackle, but it also provides an opportunity to create high-quality, affordable and sustainable buildings if we manage to upscale and replicate the lessons learned from the many pilot cases around the world.

Cities also face new risks due to climate change causing more extreme weather conditions. A higher frequency of disasters like flooding, hurricanes and fires poses new challenges to cities. Cities should be resilient to these risks too, preventing severe human, social and economic consequences. A resilient city will recover more easily after a disaster.

This chapter describes the results of various studies and publications on the role of buildings in cities to meet the challenges described above.

Section 2 explains the results of a recent European study on the challenges and opportunities of energy renovation in a city context, linking it to urban regeneration.

Section 3 goes into sustainable buildings and the challenges and opportunities for cities to get the built environment to become more circular, more resource-efficient and less wasteful. It provides an overview of available studies based on desk research.

Section 4 gives an introduction in generic terms on the theme of resilient buildings and the contribution of buildings to a more resilient city.

2. Energy renovation as a key element in urban regeneration

In June 2018, ROCKWOOL and the Building Performance Institute Europe, BPIE, published a report with a selection of successful urban regeneration projects and an analysis of the key elements in achieving successful urban regeneration [4]. The results of the study and subsequent use of its results in a paper from Copenhagen Economics [5] are described later.

Many large cities host run-down or challenging neighbourhoods, often characterised by multiple social problems, inadequate living conditions and bad reputations. These problems often reinforce each other in a vicious circle, causing a negative trend for the area (**Figure 1**).

Poor houses ➔ energy poverty ➔ social problems ➔ vandalism ➔ bad reputation ➔ lack of investments ➔ poor houses. The challenge to revitalise these areas is amplified by the fact that these neighbourhoods are often physically and socially detached from the rest of the city.

The buildings forming these areas are often 40–50 years old and were built at a time characterised by different societal ideals. During the 1960s and 1970s, there was a huge need for dwellings—resulting in most constructions being built quickly and on the idea of equality. Time has changed and so has our demand from the built environment. Most of these buildings are now in dire need of an upgrade to lower their energy consumption and improve their thermal comfort and the health conditions of the people living in them, as well as to upgrade

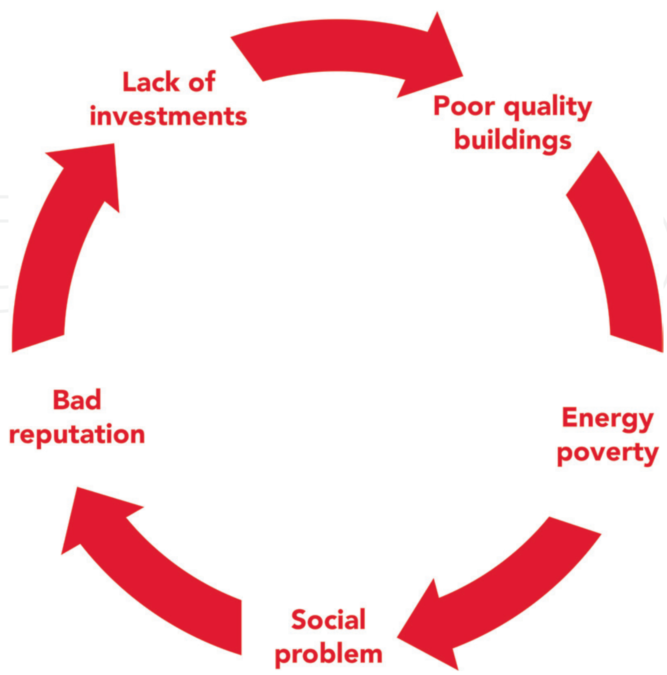

Figure 1. The vicious circle of poor housing in challenging neighbourhoods [4].

the whole neighbourhood that they are part of through the improvement of their aesthetic quality and that of the urban spaces.

Urban regeneration deserves additional attention as cities need to be transformed into living spaces and working spaces in a sustainable manner. Often, challenged urban areas especially need attention in creating resilient buildings as the combination of high-rise buildings and dense urban areas poses a higher risk for the built environment in case of fire or natural disasters. An upgraded building stock will also enable and induce the citizens to live a more sustainable lifestyle.

Many case projects around the world have shown that a comprehensive strategy comprising both physical and social initiatives can transform whole areas into attractive and liveable spaces as well as turn around the negative trend experienced in these neighbourhoods. Upscaling energy renovation of run-down or challenged urban areas is a key element, which can, if combined with other initiatives, not only improve the quality of life and enable citizens to live a sustainable lifestyle but also provide an opportunity to reduce social and health problems in society. Upscaling energy renovation should at the same time focus on creating new business models out of the challenges—focusing on the need for managing resources in the urban environment in a better way.

ROCKWOOL and BPIE describe a selection of successful urban regeneration projects in their study [4]. The key elements in achieving successful urban regeneration summarised later are the result of a review of successful cases combined with an interactive dialogue with leading experts in the field facilitated by ROCKWOOL and BPIE in 2018.

The key learnings identified are especially (see **Figure 2**):

- A strong long-term commitment of and an early engagement from the public authorities is necessary.
- A well-adjusted combination of social and physical measures needs to be considered—which also requires an early collaboration between multiple actors with different expertise.
- The involvement and empowerment of the people living in the area are crucial. Engaging residents in the renovation process, e.g. via ‘social contracts’, increases the support among residents and can help to give people a new start.

Key success factors which were identified for the building renovation projects were:

- A detailed assessment of renovation alternatives found that a deep renovation would be the cheapest option over a 30-year period.
- Improving the aesthetic quality of the areas combined with the use of long-lasting materials is cheaper in the long run and can attract new investments and new residents to the areas. Doing so can also be a tool to reduce crime and improve quality of life in the area as neighbourhoods that are in a poor state are perceived to be uncared for—resulting in the likelihood of crime going unchallenged [5].
- Building owners see an increased value of their properties while reducing operational and maintenance costs [5].

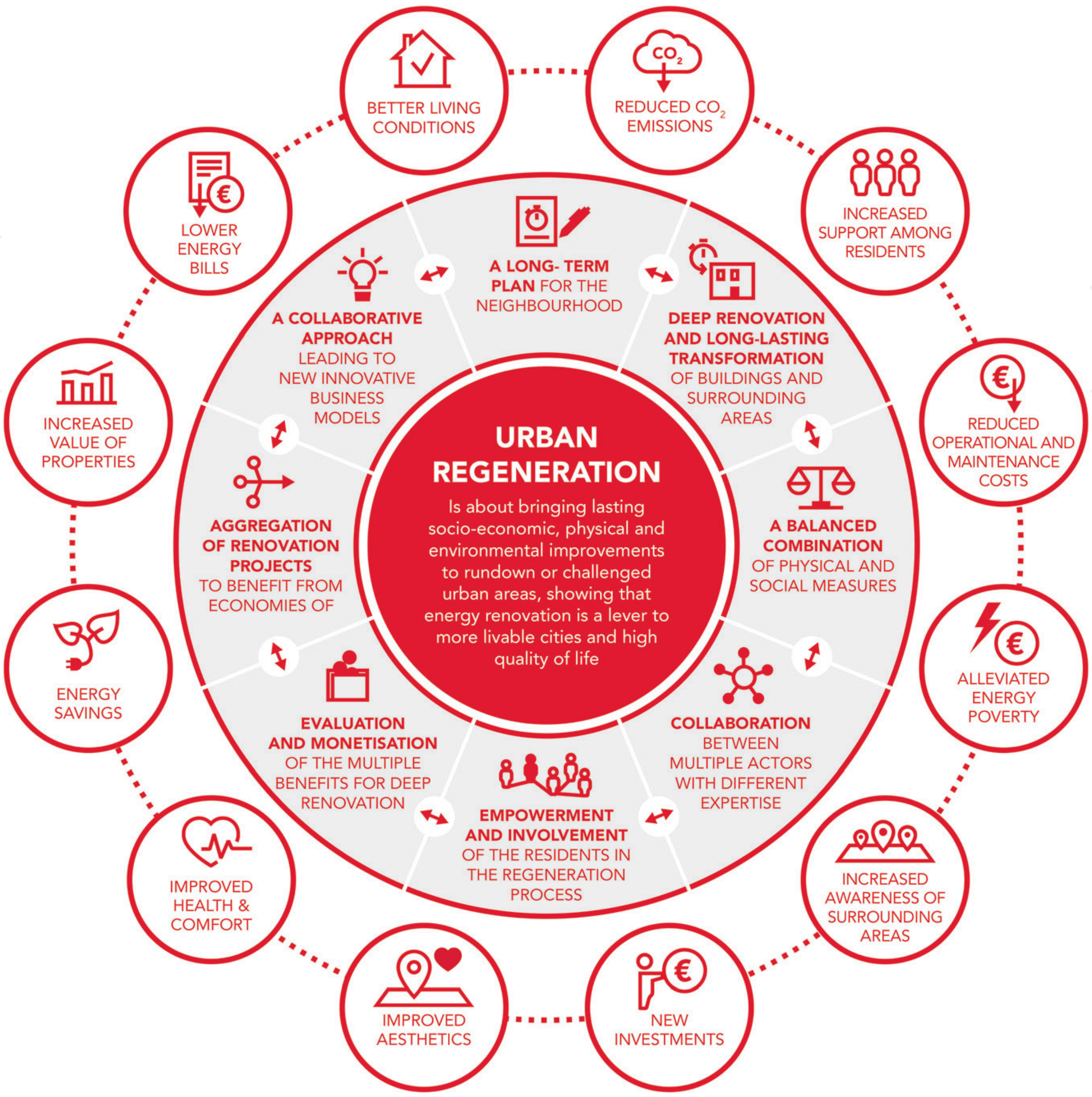

Figure 2. Key elements in achieving successful urban regeneration [4].

2.1. Key elements in achieving successful urban regeneration

One of the key learnings from the many existing urban regeneration projects is that people in general like their homes, want to be informed and involved in large-scale renovation projects and prefer to be given the opportunity to take individual choices.

A deeper dive into the findings provides the following insights.

Urban regeneration is not the same as gentrification. It is, therefore, important to **make sure the residents are involved and empowered in the regeneration process.** While many of the run-down or challenged areas would benefit from hosting a more mixed population, the means to achieve this cannot be to squeeze out certain groups. Extensive energy renovation will actually improve residents' ability to pay rent through lower energy bills. A successful urban regeneration process can therefore lift a whole neighbourhood including the people in it.

A successful urban regeneration strategy cannot be fulfilled without really knowing the needs of the residents. A **bottom-up approach where residents are involved can uncover**

new innovative solutions while giving the residents a sense of ownership of the process, thus increasing their willingness to participate. In other words, an urban regeneration strategy must build on the existing culture rather than building something new. Large-scale renovation projects can be tailored to the existing culture, e.g. by developing a catalogue of individual measures.

Look beyond the near-term period. **A long-term plan for the neighbourhood will increase the chances of a successful regeneration process.** The plan should incorporate the multiple benefits that a physical and social transformation will entail such as a higher living standard and improved health, the alleviation of energy poverty through lower energy bills, an increase in housing prices, the reduction of maintenance cost and the mitigation of the area's climate impact.

Furthermore, **the multiple benefits of deep renovation should be valued and monetized.** Research from Eurofound [6] shows that inadequate housing is linked with numerous societal costs ranging from health care expenses, higher policing and emergency costs to poor academic performance. Public authorities ought to incorporate these costs and benefits in their cost–benefit analysis.

The **physical transformation of a home and a neighbourhood can have a positive impact on people's perception and behaviour**. A balanced urban regeneration process needs to combine both physical and social measures in a harmonised manner. Physical and social measures are not two separate entities but are highly interlinked, as a new home is commonly associated to new beginnings.

The physical transformation of buildings should be long-lasting. It is evident that deep renovations using high-quality materials, combining the energy upgrade with an architectural upgrade, are the cheapest solution in the long run. Deep renovation guarantees a very low energy demand for the next 30 to 50 years. In addition, maintenance and administration costs are reduced as well. Past experience has shown that renovation projects that were quickly done using cheap materials had a short lifespan—thus requiring renovation again. In contrast, high-quality and durable materials guarantee that renovated buildings continue to look nice for many decades.

In all the cases investigated, the cities/municipalities have played a key role. **The authorities have been successful in driving transformation through public-private partnerships**, in which they safeguard the social aspects. Another key success factor is the breaking down of silos within the public governance, for example, by setting up a task group with various departments (energy, climate, social, budget, etc.) and involving solution providers early in the process. Scaling up deep renovation requires more collaboration between various stakeholders, assembling different skills and expertise.

Good planning can use the 'economies of scale' effect when renovating multiple identical buildings. The buildings **built during the 1960s and 1970s are especially suited to a more industrialised renovation approach**, which could reduce the time spent on site and cost. New business models (one-stop shops) and technologies should be supported and further explored.

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2.2. Moving forward

It is evident that extensive experience exists from individual case studies and within individual stakeholders. The existing experience must be scaled up—following the success factors from existing urban regeneration projects. Cities should be encouraged to develop their own urban regeneration path and to take responsibility for facilitating an early engagement with stakeholders covering all needed competences in a project.

3. Sustainable buildings as contributors to the circular economy in urban regeneration

The benefits of energy renovation in urban regeneration are not limited to energy savings alone. It is broadly recognised to also benefit people and the environment. Good indoor climate, thermal comfort, acoustic performance and daylight, for example, improve the health and wellbeing of inhabitants and positively affect the productivity in schools, hospitals and of workers in general [5]. Taking a life-cycle approach when considering the materials used in buildings can reduce the environmental impact of the buildings in a city. Moreover, valuing the potential for today and the future creates better economic value. Not surprisingly, there is clear trend towards a more sustainable design and renovation of buildings.

Urban centres are particularly impacted by waste from construction and demolition activities (CDW). The Ellen MacArthur Foundation has identified the built environment to be one of the key sectors of structural waste [2]. For example, in Europe, the average office is used only 35–50% of the time, even during working hours. The UN-IRP study called 'The Weight of Cities' [1] shows that the global 'domestic material consumption' (DMC) of raw materials (including sand, gravel, iron ore, coal and wood) is likely to be in the range of 8–17 tonnes per capita per year at 2050, assuming material use per capita will stabilise in developing countries at lower levels than today's developed countries. However, a DMC range of 6–8 tonnes per capita per year has been proposed as an indicative target for sustainable resource consumption [7]. In 2050, urban mining should be the main source of building materials in cities, with implications for storage, logistics and costs, while citizens will increasingly require a non-toxic environment.

Cities are well placed to tackle the resource and waste issues in the construction sector, with their high concentration of resources, capital, data, and talent over a small geographic territory. Closing the loop in the construction sector and improving design would lead to major benefits in sustainability and in quality of life. This could further support urban policymakers in achieving their objectives when it comes to carbon emissions, mobility, indoor air quality [2] and working towards a non-toxic environment. This transition towards a sustainable, low-carbon and resource-efficient economy—called a 'circular economy'—is considered vital to future-proofing cities and improving quality of life for citizens [8]. Our world economy is considered to be only 9.1% circular at the moment [37]. The Circle Economy states that 'Closing the circularity gap serves the higher objective of preventing further and accelerated environmental degradation and social inequality'—especially since housing and infrastructure needs represent the largest resource footprint [37]. They believe that a circular economy approach enables cities to take practical steps to help reduce emissions, create new jobs and strengthen industries and competitiveness, as well as enhance the health and wellbeing of its citizens. Sustainable buildings contribute to this transition.

3.1. Sustainable buildings

There is not one definition for 'sustainable buildings'. However, what all descriptions have in common is that a holistic approach is taken in the design, construction and demolition processes to minimise the buildings' impact on the environment, the occupants and the community and to maintain economic value. When it comes to the environmental aspect of sustainable buildings, the World Green Building Council describes a 'green' building as 'a building that, in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on our climate and natural environment. Green buildings preserve precious natural resources and improve our quality of life' [9].

There are several features that can make a building 'green' and additional features to make them more sustainable. Environmental features pertain to resources like materials, water and land and energy and carbon, as well as pollution of air, water and soil. Health-related features pertain to indoor climate, acoustic performance and thermal comfort. Additional features could be related to risks like earthquakes and fires—addressing the resources that the building represents.

Several tools and sustainable building rating schemes are in place to assess the sustainability of buildings. Examples of European-wide used commercial rating schemes are BREEAM, DGNB, HQE and LEED, but local schemes exist too. The European Commission recently launched a beta version of a framework for sustainable buildings called Level(s) [10], which describes the basic relevant features for the European housing stock. In the Netherlands [11] and France [12], building legislation is in place to assess environmental building features, and in Germany [13], a similar approach is taken for the Green Public Procurement of buildings.

The key step to a sustainable design is to reduce the amount of energy needed to operate a building. Typically, 80% of the energy used in a building results from heating, cooling, hot water and lighting, while the remaining 20% is used for construction materials, transport and demolition. However, moving towards a more energy-efficient building stock will change this ratio over time—putting more focus on the materials and the 'beyond energy' features of sustainability. Environmental assessments of buildings are therefore based on a life-cycle approach using various environmental indicators.

3.2. Buildings as Material Banks

Considering that a so-called circular economy is vital to future-proofing cities and improving the quality of life of citizens, according to [8], organisations need to stimulate the development of a circular economy by developing concepts for cities to become more circular. The Ellen MacArthur Foundation describes the built environment in 'circular cities' as 'designed in a modular and flexible manner, sourcing healthy materials that improve the life quality of the residents, and minimise virgin material use. It will be built using efficient construction techniques, and will be highly utilised thanks to shared, flexible and modular office spaces and housing. Components of buildings will be maintained and renewed when needed, while buildings will be used where possible to generate, rather than consume, power and food by facilitating closed loops of water, nutrients, materials, and energy, to mimic natural cycles' [2]. This description shows several aspects of buildings in circular cities, centred around the basic assumption that buildings are '*material banks*'.

Today, buildings are often created with only one function in mind, like being a school, an office or a multi-family home. When societal needs or user preferences change, these mono-functional buildings usually become outdated or even obsolete—resulting in a high rate of building vacancy and premature demolition. Those buildings, no longer suitable for use, are considered as waste and are thus treated as such. By applying circularity principles both to the existing building stock and to new buildings, the concept of waste can be eliminated.

This principle is elaborated in the European project Buildings as Material Banks (BAMB) [14]. According to the BAMB vision, the term 'Buildings as Material Banks' refers to a materialised investment: "the building itself is considered as a materialised savings account for material resources, through which building materials, products and components are temporarily 'deposited' into a functional element or part of the building. When socio-economic conditions are favourable, (a part of) the materials, products and components may be retrieved for another investment, that is: another building or another high-quality application. Seeing material resources as a temporary way of materialising investments opens the door to a wide range of circular business models, in which economic and environmental value is conserved and created through the reuse of materials, products, components and buildings, while (performance-based) services are provided to support the daily life of (end) users."

Three major systemic changes have been identified to support the BAMB vision:

- Change in design culture
- Change in value definition
- Change in collaboration across all actors

Both the existing building stock and the new buildings are interlinked in urban regeneration.

3.3. Resources from the existing building stock

The growing demand for and the scarcity of resources, less space for landfill and the challenges regarding the movement of resources through the city all create a push towards an approach of using the materials and products in existing buildings in the most optimal way. 'Urban mining' is mentioned in several sources as a necessary approach in circular cities [1, 15]. At the same time, it is identified that there are insufficient economic and regulatory incentives as well as a lack of trust in the quality and availability of secondary materials to create a market for recycled building materials [15, 16]. A lack of demand for reused or recycled products in combination with easy and cheap waste landfill and incineration hamper a sound business model throughout the construction chain.

The EU Construction and Demolition Waste Protocol [17] lists seven features for successful implementation of recycling:

1. Ban landfilling of construction and demolition waste.
2. Implement mandatory pre-demolition waste audits (identify quality and quantity).
3. Enforce traceability of waste to establish confidence (especially during transport).
4. Urban planning (recycling facilities within city limits).
5. Manage quality of recycled waste (same quality standards as virgin materials).
6. Environmental management along the entire value chain.
7. Create open markets through leading example of public procurement.

Below, possible measures are discussed to keep material resources from buildings in the loop, for both the end of the building's life and the production of new products.

3.3.1. Measures at the end of the life of a building

Upon demolition, budget constraints do not allow for (often more labour-intensive) the deconstruction of separate material fractions. The limited space for collection of many fractions is a further barrier in cities—requiring a more sophisticated after-sorting. Toxic legacy materials require specific attention if products must be reused or recycled. In many countries, landfill or incineration are still easily accessible and are too cheap to incentivise economically feasible alternatives. Separation and recycling only work business-wise in countries or regions with strict landfill bans for recyclable materials—like in Denmark or the Netherlands. This must be combined with (legal) requirements or incentives for buildings to be stripped before their frames can be demolished following an assessment (pre-demolition audit). This can create an entire service sector of SMEs with expertise in the removal of tiles, flooring, window frames, insulation material, sanitary items, lighting, etc. The Rotor in Flanders, Belgium, is an example of such a specialised company, as presented on the event from GLOBE-EU [15].

Cities can lead the way by discouraging landfill and incineration of construction and demolition waste and stimulating deconstruction, sorting and facilitate reuse platforms like Rotor. Local urban initiatives also contribute to social cohesion and job creation [8].

To facilitate this further, it is suggested to open up the European concept of waste [15, 18], in which 'preparing for reuse and recycling' is part of the waste definition, as shown in the left-hand side of **Figure 3**. On the right-hand side, an additional category is added between non-waste and waste (refuse), representing a situation in which secondary resources for reuse and recycling will not be regarded as waste to better fit the circular economy. Cities will have much more room for policies and experiments, if the European Commission would issue guidelines on the conditions to be fulfilled for recovered or reclaimed materials

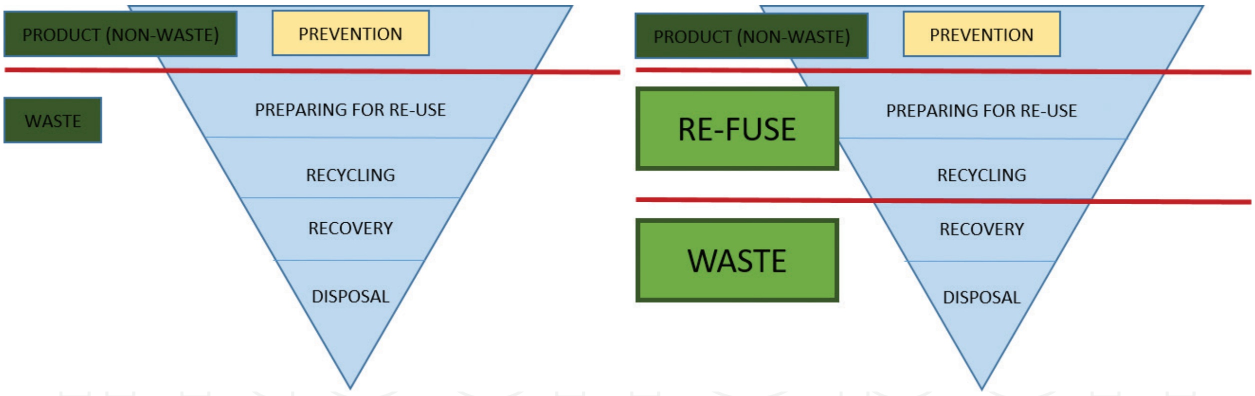

Figure 3. An illustration of the application of current definitions of waste [18].

to be considered a 'non-waste' while guaranteeing current levels of protection of public health and the environment. It could be similar to the conditions for by-products of manufacturing processes [15], so that materials, such as bricks, fittings, doors, window panes, beams, etc., can be transported, stored, processed, and sold as products provided these conditions are met.

3.3.2. Measures to stimulate the use of secondary materials

Closing the route towards landfill and incineration must go together with boosting demand for reused products and secondary materials. The market for secondary raw materials is still immature, and several policy choices exist to boost this market. The policy toolkit report from the Ellen MacArthur Foundation [38] explains it as follows: 'There are two broad, complementary policymaking strategies that can help accelerate the circular economy. The first is to focus on fixing market and regulatory failures. The second is to actively stimulate market activity by, for example, setting targets, changing public procurement policy, creating collaboration platforms and providing financial or technical support to businesses. These approaches are complementary and policymakers can determine where to put the emphasis, taking inspiration from the most applicable aspects of both approaches'.

Within public procurement, cities have the power to set high thresholds for recycled content in their public tenders and encourage the use of reusable and recyclable materials and products. Other suggestions are fast-tracked approval of construction permits, easier access to capital and stimulating new ownership models of buildings and constructions [15]. Creating platforms for collaboration and promoting value networks instead of value chains could also be a role for cities, as shown by the city of Brussels in the BAMB project [14] and the Dutch city of Almere in their UpCycle City contest [19]. A key takeaway from the Amsterdam Circular is to work closely together with the private sector and research institutes to find new business models in the context of existing strategies, such as green procurement.

Note that there is a growing belief that markets should be created without government interference like subsidies and levies on raw materials but much more by facilitating the emergence of business models that can work over time.

3.4. New buildings prepared for the future

New buildings can be requested to be designed and built in a 'circular' way. Better information about a building would help close the loop, and lower costs as worst-case scenarios in the future need no longer apply. Digital tools like BIM and cloud-based platforms of comprehensive data on buildings can already be used for today's buildings.

3.4.1. Reversible design and open building concept

Modularity and flexibility are mentioned by the Ellen MacArthur Foundation as key to circular buildings in cities [2]. A Dutch Architect Manifesto refers to both adaptability/flexibility and easy-to-dismantle construction [20]. Research on such reversible building designs is broadly available, as shown in the BAMB project [14] and the EU-based project [21], although it is not a common practice yet. The Flanders region in Belgium has applied these principles in their policy for 'Building for change', a policy that anticipates on future changes in building use, as presented in [15].

An 'open building' concept is based on similar principles, thereby taking the perspective of ownership. This seems especially interesting in the urban environment, with many rental buildings and apartment blocks. This concept suggests that buildings need to be looked at from the perspective of the owner (long-term client) and the tenant (short-term client), respectively. The diverging interests of these two owners make it important to treat them separately (two-step housing). Investors in real estate are interested in the 'shell' of a building, not the interior outfit, which is considered more of a liability. Cities in Japan are more advanced in the implementation of an open building concept which recognises that people need to adapt their living space according to changing circumstances. An entire industry sector has emerged around the remodelling of homes based on circularity principles: easy-to-remodel interiors, reuse of components and floor space tailored to family size [15, 22].

Encouraging innovation by adding reversible design to the conditions for competitive bidding on public works contracts and the development of EU-wide indicators and standards for reversible building design would go a long way towards more sustainable building design and use.

3.4.2. Information throughout the chain

Information on the materials in a building and on the building itself over time facilitates a building to be a material bank in future. The digitalisation of society will support this.

Material passports are based on the principle that one should know what type of materials is applied in the building. Information on content should reveal potential future legacies of hazardous materials that could hamper recycling. Further information, e.g. on recyclability, is suggested [14, 23]. It is likely that building information modelling (BIM) will also play a role in the transfer of environmental product information through the chain, as it already fulfils this role for technical characteristics.

Whereas material passports are typically connected to products and their manufacturers, building passports could play a role in city policies. Building passports provide information on the whole building design, its maintenance, refurbishments, etc. Building passports

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are not well defined yet and are suggested for different purposes, including renovation and circular economy, but they could also be a helpful tool for risk evaluation in case of, e.g. a fire or natural disaster. An example of a building passport in the context of the circular economy is Madaster [24]. It is Madaster's mission to eliminate waste by providing materials with an identity. The Madaster Platform facilitates the registration, organisation, storage and exchange of data of buildings over their lifespan, thereby becoming a public, online library of materials. The concept of building passports needs further development to be used in a consistent way on a large scale, but the principle clearly has a place when developing more circular buildings in an urban context.

3.4.3. What is a circular building?

It could be helpful in procurement and design processes if a definition of 'circular buildings' would exist. This is not the case, as the possibility of having a singular definition is being challenged, and the idea that 'circular buildings' are multidimensional is being considered.

Several suggestions have been made, for example in [2, 14, 20, 25]. Common themes in the descriptions of 'circular buildings' are energy efficiency, the materials applied in the building (their use of resources, reuse and recycling options and the waste they cause) and a design that enables long-term benefits from the building and its components.

Such a 'circular building' is not similar to a 'sustainable building': sustainability is to be assessed, but a circular building puts more focus on design and saving resources while not compromising sustainability. For the environmental assessment, an LCA approach as described before is indispensable. LCA reveals any trade-offs of specific measures targeting specific issues, like resources or waste in the circular economy. In this regard, it is important to remember that the circular economy and circular buildings target a goal—usually of reducing resource consumption and waste—*but 'circularity' is not a goal in itself*! Not all circular concepts will result in environmental benefits in the end. It can be questioned, for example, if materials should be recycled into products that are not recyclable anymore—a pitfall for some innovative products made from waste.

4. Resilient buildings

4.1. Resilience

The term resilience has been around for centuries and has been used in engineering, ecology and psychology before coming to civil protection and disaster risk reduction.

Several definitions of the concept of resilience can be found in the literature, for example, in publications from Timmerman [26] and Holling [27]. The UN Office for Disaster Risk Reduction came with the following definition in 2009:

> *"The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management." [28].*

Today, increased risk to hazards is manifested in cities. Climate change (flooding), earthquakes and terrorism, for example, pose new challenges to cities. Cities should be resilient to prevent social breakdown, physical collapse or economic deprivation. The Rockefeller Foundation report for the City Resilience Framework [29] describes city resilience as 'the capacity of cities to function, so that the people living and working in cities – particularly the poor and vulnerable – survive and thrive no matter what stresses or shocks they encounter'. It is stated that risk assessments and measures to reduce specific foreseeable risks will continue to play an important role in urban planning. Buildings also have an important role to play in this area. In land-scarce urban areas, more and more people are working and making their homes in high-rise buildings, which impose a challenge on safety issues if not well taken care of. If an earthquake or a fire strikes in a dense city, the consequences can be very serious. Energy efficiency and sustainability should—and can—go hand in hand with more resilient buildings.

4.2. Resilient and sustainable buildings

In resilient cities, man-made infrastructure and buildings are well-conceived, well-constructed and safeguarded against known hazards. Building codes and standards should promote long-term robustness, flexibility to adapt in the future and safe failure mechanisms in the event of a shock [28].

It has been argued that design for resilience is to design for sustainability to reduce the environmental impacts and societal consequences of post-hazard repairs [30] (as referenced in [31]). Conversely, design for sustainability is to design for resiliency to prevent that the unlikely extreme events may impact the urban communities [31]. This study shows such an integrated approach for a holistic building design, considering safety, resiliency and sustainability, based on multiple conflicting criteria. The US building assessment scheme RELI has its own system of not only assessing all types of risks related to resilient buildings but also starting from the sustainable building perspective [32].

It should be realised that building codes and standards often provide *minimum* requirements, focusing on safe escape of people. Standard EN 16309 for assessing sustainable constructions starts from this principle, by valuing 'above codes' performance as being more sustainable [33]. Accidental actions (earthquake, explosions, fire, traffic) are sustainable building aspects to assess. This shows once more the interlinkage of resilient and sustainable buildings.

The new EU Energy Performance of Buildings Directive (EPBD) from 2018 may lead to some improvements towards holistic building design, taking both energy performance and hazards into account. It requires for renovation projects to address fire safety and risks related to intense seismic activity affecting energy efficiency renovations and the lifetime of buildings, as well as the issue of healthy indoor climate conditions (Art.2a § 7 and Art.7 § 5).

4.3. Fire-resilient buildings

The above section clarifies that fire resilience also has a connection to sustainable buildings. The fire resilience of a building is often described as the ability of a building to withstand the effects of a fire, or it is often linked to the building's fire resistance properties. However, fire resilience covers more than the technical characteristic of being fire-resistant—it considers how the environment, the community and economy adapt and recover from a fire.

Fire can cause disturbance to a city's ability to deliver its service to the community. Especially in densely populated urban areas, the built environment is a crucial part of the city's infrastructure. In January 2018, a fire in a hospital in South Korea killed 37 people and injured over 100. All patients had to be evacuated and the hospital was immediately closed. This meant that this hospital was no longer able to serve the community, and the remaining patients had to be relocated somewhere else. To improve resilience, it is recommended to include property protection of critical infrastructure, in addition to the current requirements for life safety in case of fire [34].

Also, efforts to improve the sustainability of buildings often focus on increasing energy efficiency and reducing the embodied carbon. However, a fire could reduce the overall sustainability of a building through the release of pollutants and the subsequent rebuild. Furthermore, fires have a range of less immediate and obvious adverse consequences on the natural environment. These include air contamination (which is likely to also include land and water contamination), contamination from water runoff containing toxic products and other environmental releases from burned materials.

As stated earlier, there is a disconnection between sustainable building approaches and building regulations. When designing a sustainable and energy-efficient building, architects usually focus on elements such as using solar energy and promoting air circulation. In parallel, fire safety requires the respect of building codes and other specific national requirements focusing on other elements such as safe escape routes and optimal operating conditions for fire fighters.

Moreover, sustainable building assessments are based on a life-cycle description of buildings, which is scenario-based—scenarios that do not plan for fire. However, statistics show the scenario of a fire occurring during the lifetime of a building is a realistic scenario altogether. In the USA, for example, an estimated 380,200 residential building fires were reported to fire departments each year between 2013 and 2015 [35].

Therefore, methods that include quantitative risk assessment (QRA) for predicting fire spread to adjacent structures; life-cycle assessment (LCA) for estimating the environmental impact, the fire response and replacement of damaged materials; and cost–benefit analysis (CBA) for estimating the economic impact of the fire have been proposed to analyse optimal designs and environmental consequences [36]. These methods could be one solution to include fire resilience in sustainable building assessment.

In summary, fire safety, sustainability and energy efficiency should be assessed together. A risk assessment should be performed both when building new and when renovating as fire does not only have an impact on the structure of a building but also has societal, environmental and economic impacts that we should try to mitigate.

5. Conclusions

Managing urban areas and resources is one of the most important development challenges of the twenty-first century. Moreover, efficient and resilient buildings play a major role as part of the urban infrastructure.

The development in European legislation of buildings and several initiatives of cities themselves are going in the direction of a more holistic and integrated approach that includes accidental hazards like fire as an integral part of sustainable buildings and energy renovation approaches.

With an increasing demand for buildings in cities and an ageing and outdated building stock, there is a huge potential for urban regeneration to use the built environment as a key element towards achieving both environmental and social objectives.

Buildings have the potential to be part of the solution of today's and tomorrow's challenges in sustainable cities by taking a holistic approach. Extensive experience already exists across the world for how to build and renovate in a sustainable way to achieve high-quality, low-energy-consumption and resilient buildings. The main task is to find ways to scale the existing activities and to develop new and viable business models around the challenges faced in managing urban areas and resources.

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References

[1] UN Environment - IRP. Swilling M, Hajer M, Baynes T, Bergesen J, Labbé F, Musango JK, et al. The Weight of Cities: Resource Requirements of Future Urbanization. Report by the International Resource Panel. United Nations Environment Programme, Nairobi, Kenya. 2018. Available from: https://citiesipcc.org/wp-content/uploads/2018/03/Summary-for-Policymakers_Global-Weight-of-Cities-1.pdf [Accessed: Jun 30, 2018]

[2] Ellen MacArthur Foundation. Cities in the Circular Economy: An Initial Exploration. 2017. Available from: https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Cities-in-the-CE_An-Initial-Exploration.pdf [Accessed: Jun 30, 2018]

[3] European Commission (DG ENV), Biois, Arcadis, IEEP, A project under the Framework contract ENV.G.4/FRA/2008/0112 Service contract on management of construction and demolition waste – SR1, Final Report Task 2, February 2011. Available from: http://ec.europa.eu/environment/waste/pdf/2011_CDW_Report.pdf [Accessed: Jun 30, 2018] As referenced in the communication from the commission to the european parliament, the council, the European economic and social committee and the committee of the regions on resource efficiency opportunities in the building sector (2014) 445 final, p.2. Available from: http://ec.europa.eu/transparency/regdoc/rep/1/2014/EN/1-2014-445-EN-F1-1.Pdf [Accessed: Jun 30, 2018]

[4] ROCKWOOL, BPIE. Upscaling Urban Regeneration—European frontrunner cases are leading the way. 2018. Available from: http://www.ROCKWOOLgroup.com [Accessed: Sept 18, 2018]

[5] ROCKWOOL, Copenhagen Economics. Putting Renovation on the Agenda—Global perspectives of the value of renovation. Available from: www.ROCKWOOLgroup.com [Accessed: Sept 26, 2018]

[6] European Foundation for the Improvement of Living and Working Conditions, Inadequate Housing in Europe: Costs and Consequences. Available from: https://www.eurofound.europa.eu/sites/default/files/ef_publication/field_ef_document/ef1604en_0.pdf [Accessed: Jul 2, 2018]

[7] Fischer-Kowalski M, Swilling M, von Weizsäcker EU, Ren Y, Moriguchi Y, Crane W, et al. UNEP. Decoupling natural resource use and environmental impacts from economic growth. A Report of the Working Group on Decoupling to the International Resource Panel. 2011. ISBN: 978-92-807-3167-5

[8] Towards Circular Cities. 2017. Available from: www.eurocities.eu [Accessed: Feb 17, 2018]

[9] World Green Building Council. 2016-2018. Available from: http://www.worldgbc.org/what-greenbuilding [Accessed: Jul 5, 2018]

[10] European Commission. Level(s) Building Sustainability Performance. 2018. Available from: http://susproc.jrc.ec.europa.eu/Efficient_Buildings/docs/170816_Levels_EU_framework_of_building_indicators_Parts.pdf [Accessed: Jun 14, 2018]

[11] Stichting Bouwkwaliteit. Assessment Method Environmental Performance Construction and Civil Engineering Works. November 2014. Available from: https://www.milieudatabase.nl/imgcms/SBK_Assessment_method_version_2_0_TIC_versie.pdf [Accessed: Nov 12, 2015]. As referred to in Article 5.9 of the Dutch Building Decree 2012. Available from: https://www.bouwbesluitonline.nl/Inhoud/docs/wet/bb2012/hfd5 [Accessed: Jun 2, 2018]

[12] E+C− Building Regulation France. 2018. Available from: http://www.batiment-energiecarbone.fr/en/home/ [Accessed: Jul 5, 2018]

[13] UBA. July 23, 2010. Available from: https://www.nachhaltigesbauen.de/anerkannte-systeme-in-deutschland.html [Accessed: Jul 6, 2018]

[14] BAMB. Buildings as Material Banks. 2015. Available from: https://www.bamb2020.eu/ [Accessed: Jun 21, 2018]

[15] GLOBE EU. Recommendations from "Re-using the Rubble" Green Week 2018 Preconference, May 22, 2018. Available from: http://www.globe-eu.org/wp-content/uploads/GLOBE-EU-Recommendations_22052018.pdf and http://www.globe-eu.org/wp-content/uploads/GLOBE-EU-Background-Paper_22052018-.pdf [Accessed: Jun 4, 2018]

[16] European Commission, Com (2015) 614/2, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and

the Committee of the Regions. Closing the Loop—An EU Action Plan for the Circular Economy. Available from: https://ec.europa.eu/transparency/regdoc/rep/1/2015/EN/1-2015-614-EN-F1-1.PDF [Accessed: Jun 2, 2018]

[17] EU Construction and Demolition Waste Protocol. Sept 18, 2018. Available from: https://ec.europa.eu/growth/content/eu-construction-and-demolition-waste-protocol-0_el [Accessed: Jul 4,2018]

[18] Eurocities. Draft Action Plan 09.02.2018. Urban Agenda for the EU, Circular Economy. Available from: www.eurocities.eu [Accessed: Feb 17, 2018]

[19] Eurocities. Brochure Full Circle. Cities and the Circular Economy. Oct 2017. Available from: www.eurocities.eu [Accessed: Feb 17, 2018]

[20] BNA. Manifest Circulaire Architectuur. 2018. Available from: https://www.bna.nl/programmas/duurzame-ontwikkeling/wij-gaan-circulair/manifest-circulaire-architectuur/ [Accessed: Jan 31, 2018]

[21] Conception Construction Zéro Déchet. 2012. Available from: http://www.bazed.fr/ [Accessed: Nov 30, 2017]

[22] Zuidema R. The Elephant Rumbles through the Circular City. Jan 31, 2018. Available from: https://www.briqs.org/ [Accessed: Mar 21, 2018]

[23] Luscuere LM. EPEA Nederland, materials passports: Optimising value recovery from materials. In: Proceedings of the Institution of Civil Engineers Waste and Resource Management 170, February 2017 Issue WR1, ICE Proceedings. pp. 25-28. DOI: 10.1680/jwarm.16.00016 (Paper 1600016)

[24] Madaster. 2018. Available from: https://www.madaster.com/en [Accessed: Jul 4, 2018]

[25] WE Consultants. Circulair Bouwen is Meetbaar. Blog pril 12, 2017. Available from: https://www.w-e.nl/circulair-bouwen-is-meetbaar/ [Accessed: Jul 2, 2018]

[26] Timmerman P. Vulnerability, resilience and the collapse of society: A review of models and possible climatic applications. Environmental Monograph. 1981;**1**:1-45. DOI: 10.1002/joc.3370010412 [Accessed: Jul 3, 2018]

[27] Holling CS. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics. 1973;**4**:1-23

[28] UNISDR. Terminology. 2017. Available from: http://www.unisdr.org/we/inform/terminology [Accessed: Jul 2, 2018]

[29] Arup, the Rockefeller Foundation. City Resilience Framework. 2014 (Updated December 2015). Available from: https://assets.rockefellerfoundation.org/app/uploads/20140410162455/City-Resilience-Framework-2015.pdf [Accessed: Jul 5, 2018]

[30] Wei H, Shohet IM, Skibniewski M, et al. Assessing the lifecycle sustainability costs and benefits of seismic mitigations designs for buildings. Journal of Architectural Engineering. 2016. p. 22

[31] Alibrandi U, Mosalam KM. A Decision Support Tool for Sustainable and Resilient Building Design. Germany: Springer;

[32] Resilient Building Design—RELi. 2014. Available from: http://c3livingdesign.org/?page_id=13783 [Accessed: Jul 5, 2018]

[33] EN 16309:2014. Sustainability of construction works—Assessment of social performance of buildings—Calculation methodology. Available from: https://standards.cen.eu/dyn/www/f?p=204%3A110%3A0%3A%3A%3A%3AFSP_PROJECT%2CFSP_ORG_ID%3A58840%2C481830&cs=1EB6AC88BE9625D8C607EF660D11FEEB3 [Accessed: Jun 2, 2018]

[34] Gernay T et al. Urban infrastructure resilience to fire disaster: An overview. In: World Multidisciplinary Civil Engineering-Architecture-Urban Planning Symposium 2016, WMCAUS 2016. Procedia Engineering: Amsterdam, The Netherlands: Elsevier; 2016. pp. 1801-1805. Available from: https://www.sciencedirect.com/ [Accessed: Jul 4, 2018]

[35] FEMA, US Fire Administration, Residential Building Fires (2013-2015), Topical Fire Report Series. June 2017;**18**(1). Available from: https://www.usfa.fema.gov/downloads/pdf/statistics/v18i1.pdf [Accessed: Jul 5, 2018]

[36] Amon F et al. Development of an Environmental and Economic Assessment Tool (Enveco Tool) for Fire Events. Final Report. SP Technical Research Institute of Sweden; New York: Springer; 2016

[37] CircleEconomy. The Circularity GAP Report. 2018. Available from: https://www.circularity-gap.world/ [Accessed: Sep 18, 2018]

[38] Ellen MacArthur foundation. Delivering The Circular Economy. A Toolkit for Policymakers. 2015. p. 32. Available from: https://www.ellenmacarthurfoundation.org/assets/downloads/publications/EllenMacArthurFoundation_PolicymakerToolkit.pdf [Accessed: Sep 18, 2018]