Deliverable Proof – Reports resulting from the finalisation of a project task, work package, project stage, project as a whole - EIT-BP2018

Name of KIC project the report results from that contributed to/ resulted in the deliverable	Re-useable Buildings (RUBN) 2.1.7
Name of report	Final Report
Summary/brief description of report	This report summarises the outcomes and conclusions of the findings of the Re-useable Buildings project.
Date of report	31/12/2018

Supporting Documents: attach in pdf format

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Re-usable Buildings Pathfinder project

EIT Climate-KIC 2018 Reporting

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Contents

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Contributing Partners

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Climate KIC Partner:

LWARB
London Waste and Recycling Board

Other Contributing Partners:

ASBP The Alliance for Sustainable Building Products

Sustainable Development Foundation

FORUM FOR THE FUTURE

WHOLE LIFE LTD

Supplementary funding partners:

Cleveland Steel and Tube

Forum for the future foundation

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Re-usable Buildings Pathfinder project

Introduction

The built environment sector is responsible for 59% of UK waste and over half of London's waste, whilst consuming vast quantities of virgin raw materials. The tonnage of material re-use is on the decline. These materials are on average only used once at least in their high value form, resulting in significant wastage of materials and, as many of these are energy-intensive in their production, wastage of energy. In fact, material re-use tonnage declined by 25% between 1998 and 2007.

The circular economy looks to increase this material utilisation and develop products that are regenerative by design. There are exemplar projects in the built environment that have demonstrated what is possible, particularly technically, however the roll out and scaling up of new solutions remain inhibited by a host of external factors, particularly relating to defining the business case, a lack of demand, appropriate financing and validation, as well as more practical aspects such as testing/warranties and logistics. This project set out to explore the possibilities of addressing these factors, particularly those related to the business case by developing business models which can unlock the potential for a market for re-usable buildings and components.

There are questions throughout the report to provoke thought and discussion.

Re-imaging the industry: A Vision for re-useable buildings

We developed a vision for what the built environment could be like in the future if re-usable building business models were common place. Through this project this vision was further developed in consultation with some of the built environment industry. The vision is:

"The future of the building marketplace is one where traditional construction is a thing of the past, where reconstruction and redeployment are commonplace. A world where buildings can be flexibly changed, adapted, expanded and reduced according to demand or use.

Where a building built is not a capital cost but a future resource investment. Where the building and its components are rebuild-able, re-deployable, re-usable and resalable – retaining most of their original value.

This is a world where fleets of components, modules or whole buildings can be leased, then returned to the owner (developer, group of local authorities, etc) when they are no longer needed. A vibrant, competitive marketplace – where components from different providers are compatible, aligned to common standards.

Tenants and residents benefit from more buildings, at lower cost. As their spaces flex in line with their changing needs over time, families stay in the same homes longer, tenants in offices – avoiding the cost and disruption of multiple moves, while strengthening community bonds.

Meanwhile, tenants in short-term accommodation need can access safe, quality space.

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And all this at no extra cost."

This is a bold vision of the future, one which requires a different approach to construction to the one we currently have and ultimately requires different business models

In order to achieve this vision, system change will be needed to create a new market that will encourage the replication of successful practices and models. This is most likely to succeed by designing new buildings and components for re-use, deconstruction and re-deployment, given the added complexities of reclaiming and re-using products from existing demolition waste streams. However, creating such a market will require a critical mass of progressive building clients and investors, to generate sufficient demand to re-shape the supply chain and the supporting infrastructure (e.g. policy, finance, insurance) for re-usable buildings and components. The following report outlines the findings of this project, which looked to scope out the potential for this market based upon client benefits, develop capacity and interest in this area, and develop a roadmap for action.

What does this vision mean to you? Is there anything you would change?

The CO_2 benefits of re-use in the built environment.

Studies show that there is a large CO_2 benefit of reusing materials, products and buildings compared to new, as well as savings when compared to recycling. This is largely from the savings in retaining the embodied carbon within the materials, which on average accounts for around 25% of overall carbon usage.

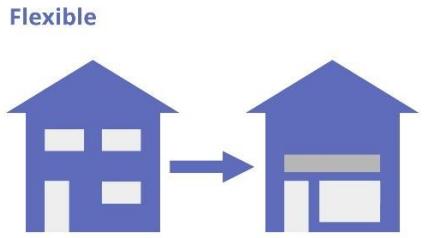
Studies show:

- 56% reduction in embodied carbon (700 tonnes CO_2e) from relocating a portal frame warehouse, rather than building new[1]
- Rebuilding a structure every 100 years and reusing the steel members can reduce the life cycle carbon by approximately 30%[2]
- 55% saving of environmental impacts from using a large proportion of re-used materials and components compared to new[3]
- Re-use of building materials commonly saves about 95 per cent of embodied energy that would otherwise be wasted[4]

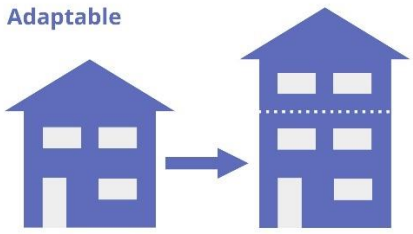
[1] https://asbp.org.uk/wp-content/uploads/2016/07/9-Cambridge-Avenue_as-built_040820141.pdf
[2] Yamada, T., Kurokawa, R., Aizawa, T., and Iwata, M., Evaluation of the Environmental Burden of Steel Building Structures Focused on Waste Weight and LCCO2. Trans AIJ J. Struct Constuct Engng, 2002, 554, 131 – 137.
3 C. Thormark Environmental analysis of a building with re-used building materials; International Journal of Low Energy and Sustainable Buildings, 1 (2000), pp. 1-18
4 S. Sattary, D. ThorpeOptimizing embodied energy of building construction through bioclimatic principles
Proc. 28th Annu. Conf. Assoc. Res. Constr. Manag. (ARCOM 2012) (2012)

Re-useable Business models

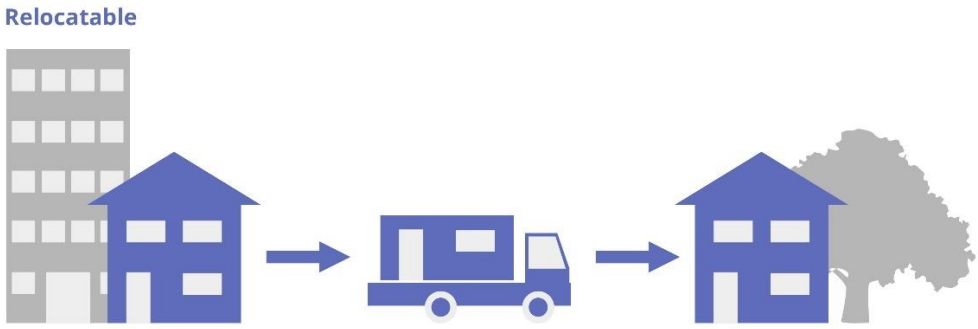
To realise our bold vision of the future, ultimately requires different but commonplace business models from what we have now; which are proposed as:



Flexible: Designed for 'in use' changes to meet needs from daily flexibility to a longer-term flexibility of internal layouts.



Adaptable: Readily transformable to meet longer term changes from adaptable expansion or changes of building use without significant building change. This could be in response to community needs or changes in demographics.



Relocatable: Fast deployment and redeployment, used for meanwhile spaces and urgent building needs such as changes in housing requirements or in office density.

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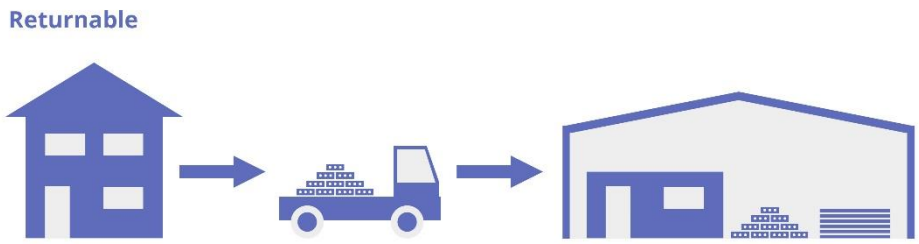
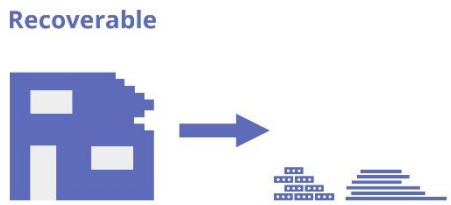


Returnable: Leasing of buildings (and components) for short term and/or one-off requirements, such as decanting of residents



Recoverable: Designed for deconstruction so residual value can be recovered at end of life at high value.

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Context

In developing the re-usable building models, it is important to understand the potential for their adoption, what has already been done, by whom and where the gaps are to enable further development and implementation. As such a literature review has been undertaken with the focus largely on the business case for adopting re-usable buildings and components, to demonstrate benefits to clients and the value of developing these models further, although other factors such as technical and social are noted. The literature review includes all the business models identified: flexible, adaptable, relocatable, returnable and recoverable. Presented in the next section is a summary of these findings. Further information, including the following sections can be found in Appendix 1:

- An overview of the circular economy within the building sector and benefits
- Re-usable buildings, which is mostly academic literature in the area of adaptability
- Re-usable components and the challenges and opportunities
- Case studies, which are largely from industrial sources.

Additionally, a stakeholder mapping exercise has been undertaken to establish who the key stakeholders are and what their influence is.

Summary of the Literature review

Whilst there are a number of studies showing the circular business models that can be adopted in the built environment, and some of the wider (macro) economic benefits that can be generated, there is little economic evidence of adopting circularity approaches at a building and product level and the financial benefit to each stakeholder. Whilst strategies such as whole life costing are recommended and considerations of how to value property, there is little in terms of 'hard' financial evidence. Most studies have focused on the technical and policy aspects of implementing a circular business model. Of the limited studies that have shown financial benefits from re-usable building models, mostly through scenarios, these rarely begin at day one, unless some form of leasing is undertaken. Most of the academic literature that does discuss the business case for re-usable buildings is focused on the flexible and adaptable business models for commercial buildings; the main findings are:

- The re-use of buildings is gaining more interest; with evidence showing that conversion (from one function to another) is increasing in inner urban areas
- The benefits and challenges for commercial re-usable buildings are well defined though not often quantified
- There is a clear distinction in the motivations between the different development models (develop to sell, manage or occupy), with owner-occupancy driving a greater interest in adaptability
- End-users preferences are for versatile and a refit ready building that provides fewer disruptions, improved service and better quality of space.

In terms of cost and savings, the main findings are:

- There remains a debate of the costs of re-use verses demolition and new build, though studies tend to show that it usually lower for the former. When considering re-use verses demolition of

commercial buildings, there are a number of diverse issues that need to be considered such as marketability, investment returns, productivity and ongoing costs

- Where buildings have not been designed for re-use, then the cost of adaption of existing buildings can be greater than building them from scratch. As such building adaptation is a higher cost process, when adaptable features are not incorporated with the initial design
- Cost is usually cited in the literature as the main obstacle to developing more adaptable (re-usable) buildings, with the assumption being that adaptability results in higher initial construction costs, though this is highly dependent on the solution adopted.
- Spending more on the initial construction costs of a building to make it more adaptable can only usually be justified if the adaptability is likely to generate some form of benefit or return on investment in the future. A life cycle approach is needed.
- Studies show that adaptable design solutions pay for themselves at the first adaptation cycle, generating, on average, a net saving equivalent to 2% of the initial construction cost. Other benefits include the reduction of time required to adapt the building (thereby reducing disruption to users) and easier access when maintaining the building
- Investments in the adaptability of buildings generate value in the long term because the needs of (future) users are more easily met. As such there is value though utility, though there is little empirical evidence to support this within the literature

In terms of costing and valuation techniques, the main findings are:

- Whole life costing is recommended to show payback, however there can be issues associated with discounting as the results are very sensitive to the rate used, the assumptions and risk factors used and how residual value is factored in (particularly from one building to another or one owner to another).
- There is a fundamental shortcoming in the current financing of buildings with the costs of demolition and recycling (as well as any residual value) at the end of its life not factored into business case (a side effect partly of discounting but also reflecting different contractual parties at the end of life)
- The value of real estate is currently linked mainly to the price of the location and the difference between rental income and operating costs. Often, the value of the raw materials in the building is of secondary importance.
- It is unclear if property valuations take into account any benefits from adaptability and 're-let ability' and how depreciation of assets is factored in.
- There is some institutional bias, whereby in the past the specification was promoted by property agents, who insisted that all new office developments should incorporate over-specified design features, to reduce the risk of depreciation, even though the specification did not bear any resemblance to what most occupiers actually needed from their office buildings—a case of exchange value prevailing over use value
- Banks such as ABN Ambro are investigating how to allow for higher investment costs which justify lower running costs and a higher final value of the building elements. This therefore means a relatively higher loan-to-value ratio for a project, and a relatively smaller amount of equity capital relative to the loan capital

Findings from the review of circular building case studies which are limited (some examples are shown below), show that the client is instrumental in driving the circular building forward, along with establishing the benefits to the end user.

PLACE Ladywell
- Deployable housing
- Volumetric construction
- Site vacant pending redevelopment
- Short-term solution (1-4 years)
- 24 homes + ground floor retail

Adaptable House
- Single-family detached home, Denmark
- Designed to adapt to changing needs of family
- Can be altered/ extended with reduced CO2 and materials use

ZedPods
- Designed for urban car parks, hard standings
- Assembled on ground or raised platforms
- High-performance, low-energy housing
- Delivered in a fraction of the usual time

Circle House
- 60 social housing units
- Townhouses & tower blocks
- 90% can be disassembled and reused – without losing significant value
- To be completed by 2020

Key points to note from these case studies are:

- Collaboration across the project stakeholders is key
- It can take time to build up the knowledge required for circular buildings
- There needs to be a clear vision and strategy for the building, with the client driving this forward
- The client is usually driven by their own values or work practices in wanting circular buildings
- Even though investment costs may be more initially, there is payback when residual value is factored in (the sooner they are achieved the shorter the payback period)
- As well as economic savings over the lifetime of a building, there are also likely to be carbon savings in the embodied impacts of new material use.
- The supply chain are willing to provide circular approaches and solutions, as long as they have commitment from the client. This is similar to offsite construction, whereby if different manufacturing systems are required, then a commitment is needed for long term volume and continuity
- It is important to agree which components of a building should be targeted for circularity
- With the right methodologies, issues relating to opex and capex, the splitting of benefits, discounting, and future residual values can be overcome.
- Some form of data collection and monitoring is required, through for example BIM and material passports
- Other schemes such as C2C and BREEAM can support circular buildings

When focusing on circular products, rather than buildings, the key findings are:

- Circular products tend to cost less over the lifetime/deployment cycles of the product
- More money may be required upfront (the capex stage), even though it may demonstrate operational savings in the maintenance stage, which companies may have issues with.
- Greater maintenance may be required for a 'second hand' product

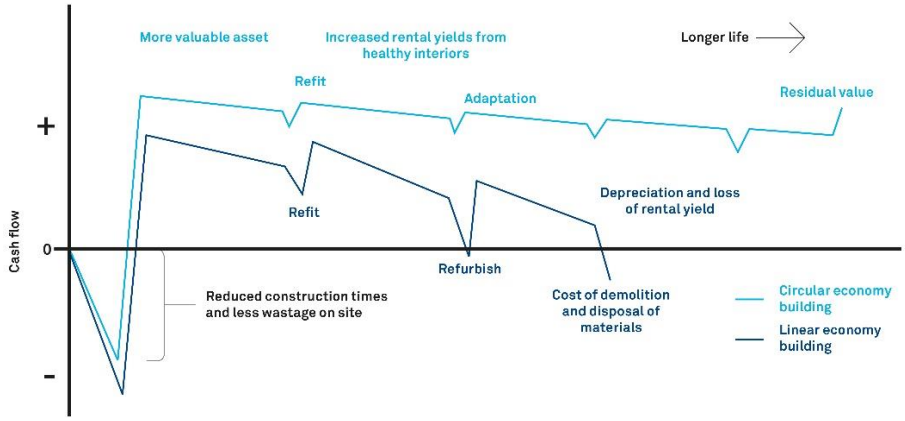
- There are many other benefits such as improved performance, better maintenance and for energy-using products, a reduction in energy usage
- There are benefits for the manufacturers to design products that are efficient and durable for multiple uses, such as customer loyalty, CSR, material supply and security
- In some cases (newer business models), it is difficult to know if the products will actually be re-used at the end of their life.

For re-usable components, the main challenges and opportunities are well known. Whilst there are a number of studies showing the technical potential of re-use, those showing the economic benefits are limited; however, those that are available, show either cost neutrality or a cost saving compared to using primary materials/products. There may be an issue of re-use, for products that are energy-using, though examples show that there is potential for the re-use of HVAC systems, as well as steel frames, carpet tiles, furniture and salvage items.

Business Benefits

As highlighted by the literature review, and much of our discussion, it is evident that the debate to date has focused largely upon the technical approaches to greater circularity, and its global resource impacts, with little consideration of the benefits to the building owner/user required to drive procurement of this approach.

David Cheshire in his book 'Building Revolutions' (RIBA, 2016), has started to look at these benefits, per the graph below, illustrating greater retention of building income and value through circular approaches, at various stages through building life.



Building Revolutions, David Cheshire, RIBA 2016

While the technical approaches to re-use (for the whole or part of a building) may be common to enabling all of the benefits above, our research suggests that there are a number of discrete approaches (i.e. the business models) to the use of circular enabled buildings, which will appeal to different sectors, who may respond to different business models.

To understand how these different business models could work in practice we have provided graphical representations of what could be typical whole life cost analysis of each model based on projections of changing needs over time. The following graphs illustrate a possible cost model for each over 3 building lifetimes (20 years each) mapped against a "business as usual" building. In each life cycle a minor and major refurbishment cycle where required was assumed.

The five business models (Flexible, Adaptable, Relocatable, Returnable and Recoverable) are illustrated below and are viewed from the perspective of cost to provide the building service (i.e. they do not presume to estimate net benefit of income less the costs). Further, sector specific, research would most certainly yield a greater understanding of the utility of each to specific sectors, and the business model most likely to accelerate take-up and optimal use of the supply chain.

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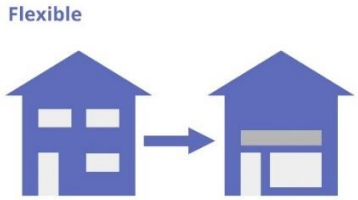
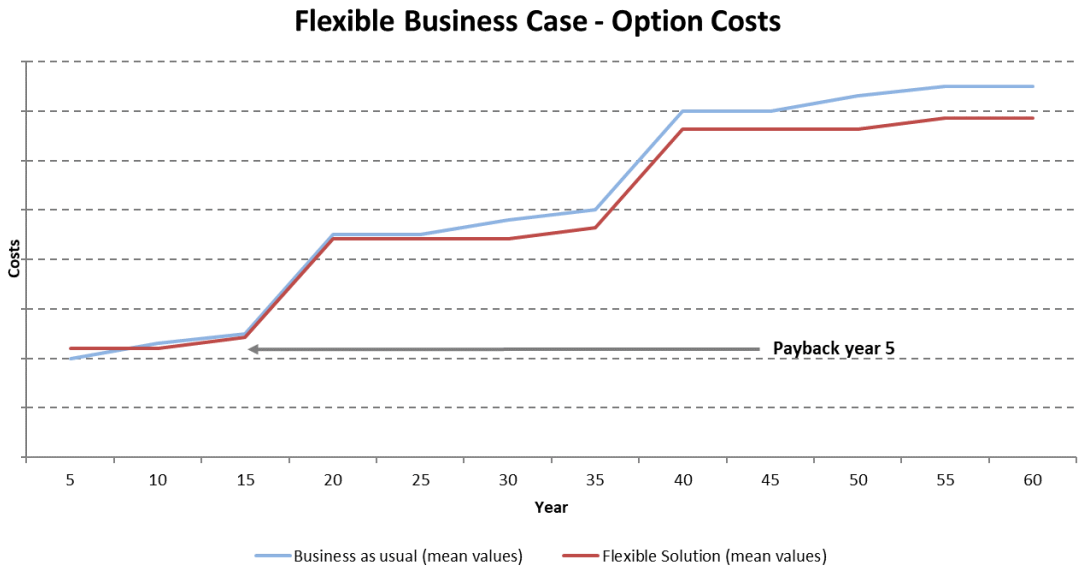
Flexibility (in Use)





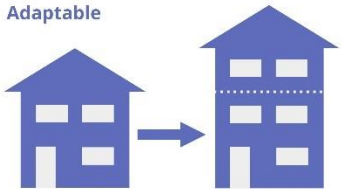
This business case reflects the increased flexibility, in short term use, conferred upon buildings designed for deconstruction and re-use. It is, in effect, an extension of the benefits of flexible partitioning etc which allows use for a number of purposes (and minor upgrading/re-configuration) over short time frames. This opens up opportunities for more varied revenue streams (not reflected here) and reduces cost of each cycle of use or minor refurbishment.

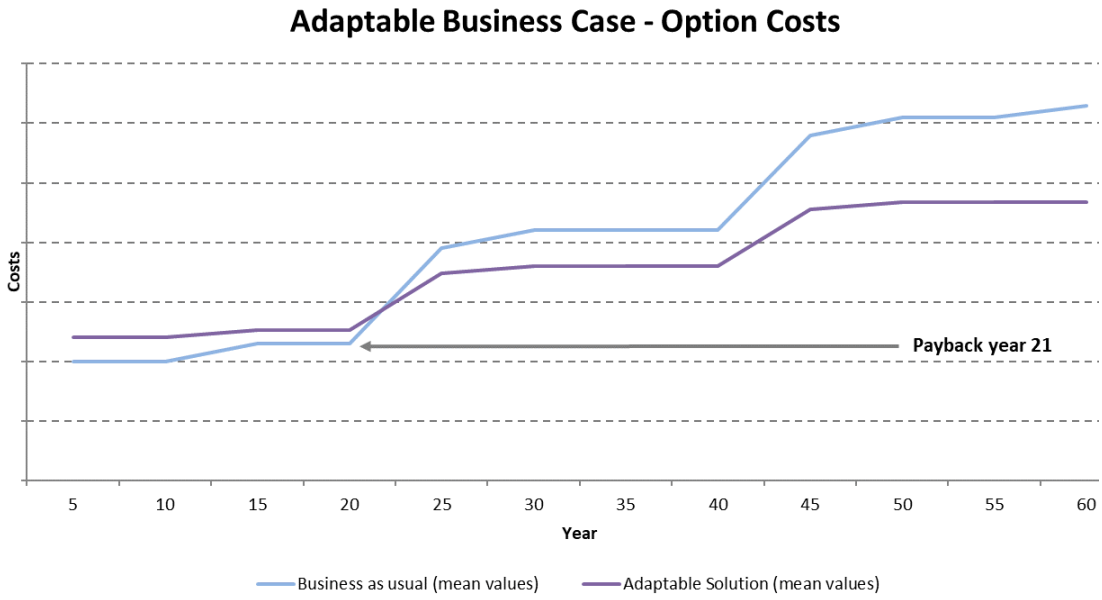
Although the direct costs benefits might be small there are significant direct cost savings on disruption, churn and in use construction costs. It is also in effect an additional benefit (at no additional cost) to deploying for any of the other benefits below. It offers however the potential for a low payback period as it requires relatively little upfront investment and potentially rapid payback depending on whether the sector has relatively frequent reorganisation of space to meet required function. Typically for example commercial buildings might have space reorganised on a 3 to 5 year cycle, with associated (churn) costs that are rarely considered at the initial capital investment stage. Similar costs are incurred in the retail sector but are more directly linked to income generation and are likely to be even more frequent.

It also serves to address the significant wastage seen as buildings, offices in particular, get refurbished to 'refresh' or change how a space is used. Flexible design can allow this at no additional cost over the life of a building and drastically reduced material wastage.

The trends of the graph illustrate that with a small increase in initial investment to design for flexibility, refurbishment and flexibility over the life can be done at little or no extra cost, recouping the initial investment.

Adaptability





This business case reflects a desire to allow for significant changes in the scale or nature of use of a building through design for adaption and re-use. This may be due to anticipated change (spreading capital cost over periods of real demand), or to mitigate future costs in the case of future uncertainty.

The key benefit is reduced cost (at the time) of accommodating adaptation (including major upgrades) but it also reduces the upfront cost of allowing for uncertain future needs. The economic business case for this is directly dependent on the perception of the need and associated "disbenefits" (which might not be financial) of the foreseeable needs for adaptation.

The trends of the graph show that with a small increase in initial investment to design for adaptability this facilitates reduced costs in minor and major refurbishment and results in the building asset being appropriate for use and utilised for longer in its current or adapted form.

The housing sector generally has done considerable analysis to encourage "lifetime homes" already[5]. The intermingling of social benefits and cost benefits and links to policy are key messages in respect of

[5]for example, BRE/ Habinteg Homes Lifetime Homes Design Guide and associated assessment of health cost savings and cost of provision of homes suitable to adapt to changing mobility

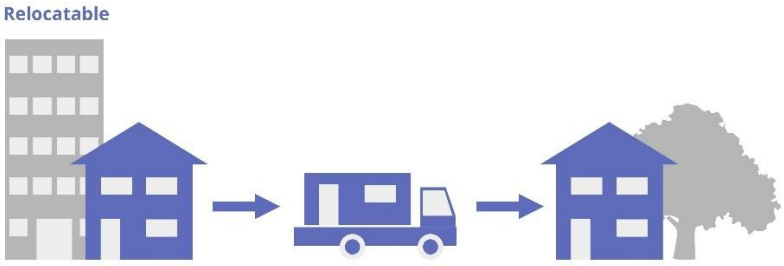
making the economic business case for adaptability. Cost Benefit Analysis (CBA) is an established economic technique particularly for the public sector to assess this type of business case.

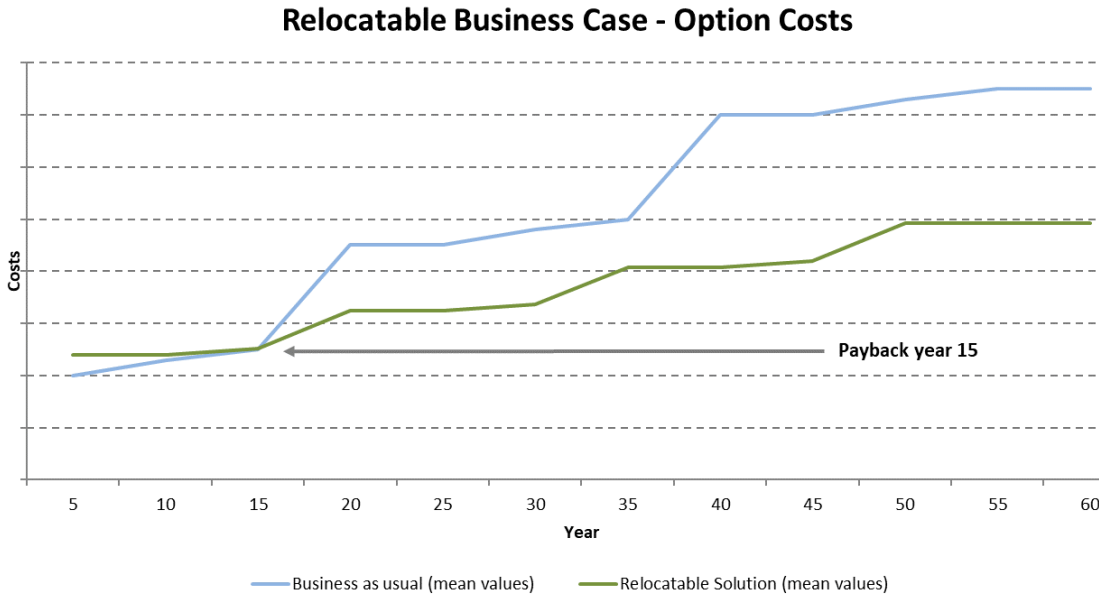
In terms of other sectors, it is already clear that the education sector prioritises adaptability and flexibility in use, but may struggle to finance it within capital cost constraints. Similar issues may arise in respect of other sectors unless the costs / income associated can be clearly quantified as part of the business case. This might be easiest in respect of retail, but real benefits to leaseholders on commercial space could also be clearly quantified. Fit out specialists might be the clearest source of cost and benefit. Drivers in the commercial sector would also include reinstatement requirements. However, capital tax allowances might positively encourage repeated fit outs rather than building in flexibility in advance (up to 80% allowances currently available on office refurbishments and 95% on retail and leisure, while enhanced capital allowances are available for energy efficient investments). This does however provide an indicator of a potential route to encourage upfront investment.

A new Structures and Buildings capital allowance[6] has just been introduced (2018) for non-residential buildings which provides a two percent allowance p.a. over 50 years regardless of ownership changes, but the claimant must have an interest in the land on which the building is erected. Capital expenditure on renovation will also qualify. Ready built assets are covered as are leases but there is a proposal to allocate allowances between lessor and lessee. This allowance does not apply to housing of any sort (e.g. school, student or prison accommodation). This might encourage investment in longer term, more durable buildings but the implications of the new allowance have not been considered in detail.

[6] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/752092/Capital_allowances_for_structures_and_buildings_technical_note.pdf

Relocation





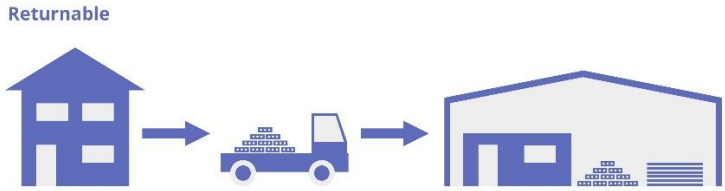
This approach again reflects both elective and risk management options. In the case of "meantime space", circular approaches can allow multiple deployments of buildings to permanent quality standards. Compared to a traditional fixed build, cost benefits accrue to the lower cost of removal and each new deployment, with cumulative benefits over a number of deployments representing probably the most significant saving versus business as usual. Where limited time availability of land is known to apply, this will often represent the only practical solution, given the cost of fixed build and quality constraints on some temporary solutions. It also guards against future changes to demand which might otherwise require premature demolition or relocation.

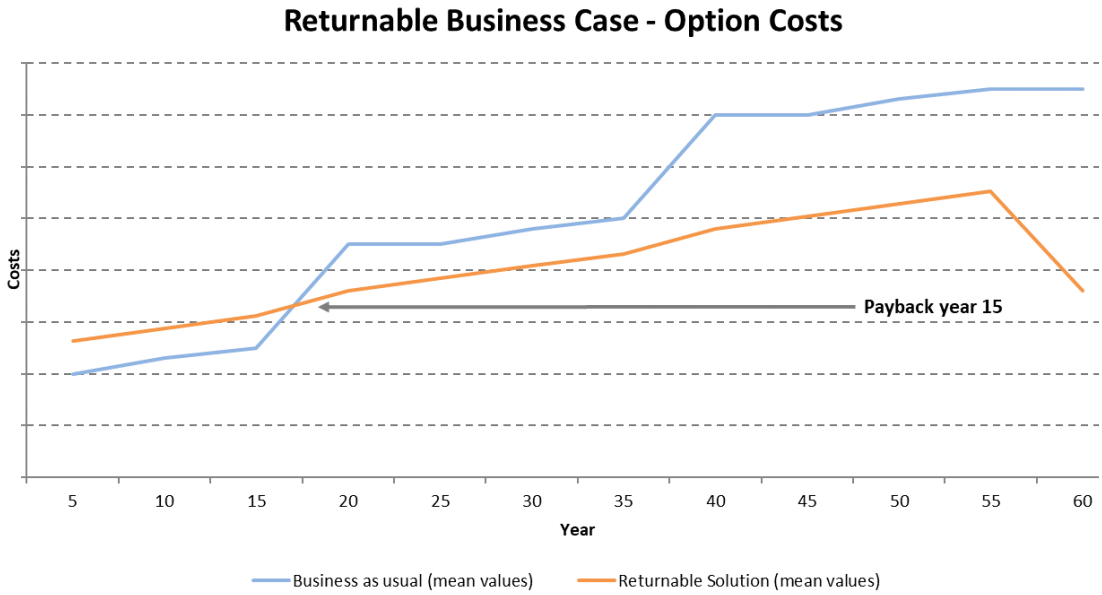
The trends shown in the graph illustrate that instead of building and rebuilding a similar 'asset' in multiple locations, a re-deployable asset only incurs the cost of relocation between sites. A client then retains the value of the building asset to deploy where it is required as well as the land.

This approach will benefit specific clients within various sectors who have a portfolio of land and a changing profile of requirements and particularly those who have a high need for decanting space. Therefore, those who have a rolling programme of renewals or refurbishment might be interested in spreading the cost over several capital projects. Currently both education and leisure might be good candidates, along with other public sector client groups such as health trusts or universities. However, it is likely that it will also be associated with suppliers who fund the upfront investment and lease out

space to occupiers in a similar way to the returnable business model but over a time period rather than for a single use.

Returnable

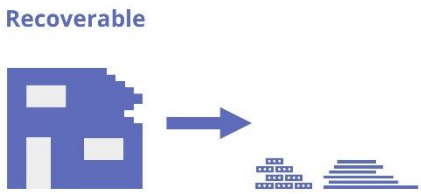


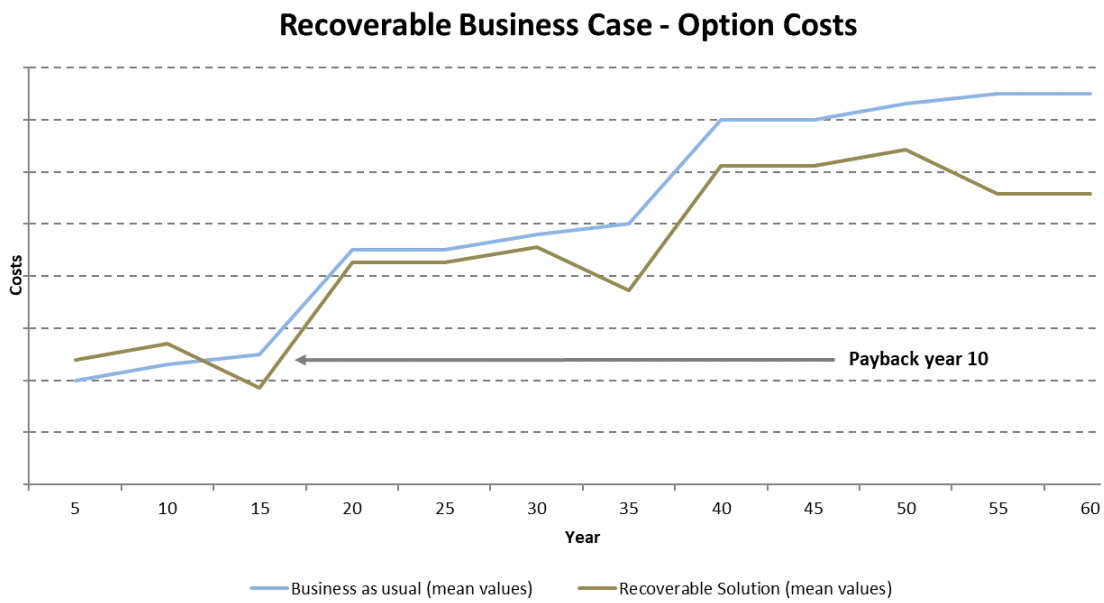


This approach might also be applied to the meanwhile space or unexpected change, as for redeployment (above) or for use of temporary systems/buildings, such as pop up type units. In this approach however, the building is returned to the provider when changes of demand or location bring an end to the initial deployment. In this case, which will require new business approaches (leasing or shared fleets), the user only pays for the building when needed and does not need to find alternative uses subsequently. The cost of this approach is mitigated by lower cost of removal, and over a limited lifetime (planned or otherwise) will be significantly below the cost of a fixed building.

The graph shows an example model of a 'leased' building for which the cost of redeployment and maintenance or degradation is covered in an on-going leasing cost. After three 'life-times' the building is given back, and the residual value of the asset re-funded against the initial outlay (i.e. there is an income stream which is revenue and a capital income at handback). This is just an example model and others could be developed to achieve the same end. Additionally, this type of model could also be used at a component/system level e.g. façade, lighting, flooring etc.

Recoverability





The adaptable and flexible building scenarios describe long term building provision, where circumstances dictate change in usage or location, planned or otherwise. There may of course be situations where a building requirement, originally expected to be temporary, is extended over a longer period. In this case, the quality of the “temporary” building might require multiple rebuilds/replacements, compared to a circular building which has the potential to extend life in one deployment. We have not modelled this counterfactual, as it is both situation specific and retrospective.

The graph takes a simpler view, comparing whole life performance of traditional and circular buildings. The key benefits flow from ease of regular refurbishment (per the examples above), but uniquely to this approach, additional value recovery (resource and financial) at the end of full building design life.

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As noted at the beginning of this section, all the illustrations are based upon existing “standard cost” and viewed purely from a cost to the provider basis. We have not sought to recognise income, although there is some evidence that premiums may be available for certain elements of utility delivered by flexible or adaptable building. Nor have we modelled the differences in operational value for different sectors, where we expect that health, education and retail sectors might value adaptability, with the logistics and defence sectors utilising redeployment to enhance building utility. We are also aware that there may be different tax treatments for demountable buildings than for buildings viewed as permanent.

Most notably, all of the illustrations demonstrate a degree of business benefit to the building operator, albeit in varying degrees, as a future benefit against current cost. The scope for business models to deliver prompt, and recurrent, financial benefit, while providing adequate returns to the provider (and critical mass for technical provision) is likely to be a key element of delivering the system change envisaged in our road map, below.

Stakeholder mapping

The built environment can be broken down into a number of sectors. For this project we identified sectors associated with different building use types. These could be from the following:

- Commercial - Typical offices or commercial environments
- Retail – Shops or restaurants
- Social housing – Housing provision owned (and potentially operated) by local councils or large social housing providers
- Private Residential – Homes for individual owners
- Education – Schools or research facilities
- Health care – Hospitals or similar facilities
- Other – i.e. hotels or transport facilities

Our stakeholder focus

For the purposes of this project we focussed on 3 sectors, commercial, retail and social housing, by undertaking a number of interviews. This is due to the applicability to the London context and also the opportunities for owner occupiers for the business cases mentioned.

This project further focused on the social housing sector due to interest and appetite to explore different models and also the non-competitive collaborative possibilities. Some actors in this sector were invited for a collaborative workshop session to explore the concepts in more detail.

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Table 1 Stakeholders' indicative involvement and influence in a project's life-cycle

	Inception	Feasibility appraisals	Plan and design	Construct and handover	Operate and maintain	Decommission and renewal
Public and private sector commissioning clients and developers	***	***	**	**	*	**
Users' groups	***	**	*	*	***	*
Occupiers	**	*	*	*	***	*
Policy-makers and planners	***	**	*	*	*	**
Procurement advisers and managers	***	***	***	**	**	*
Funders, financiers and bankers	**	**	*	*	*	**
Insurers	**	*	*	*	**	**
Quantity surveyors	***	***	**	**	*	**
Specifiers, designers and engineers	**	***	***	***	**	**
Construction project managers	**	**	**	***	**	***
Contractors (main and specialists)	**	**	**	***	**	***
Materials suppliers	**	*	**	***	***	*
Asset managers and asset maintenance professionals	***	**	**	**	***	**

Stakeholders' level of influence and involvement for achieving WLV: *** high influence and involvement; ** medium influence and involvement; * low influence and involvement

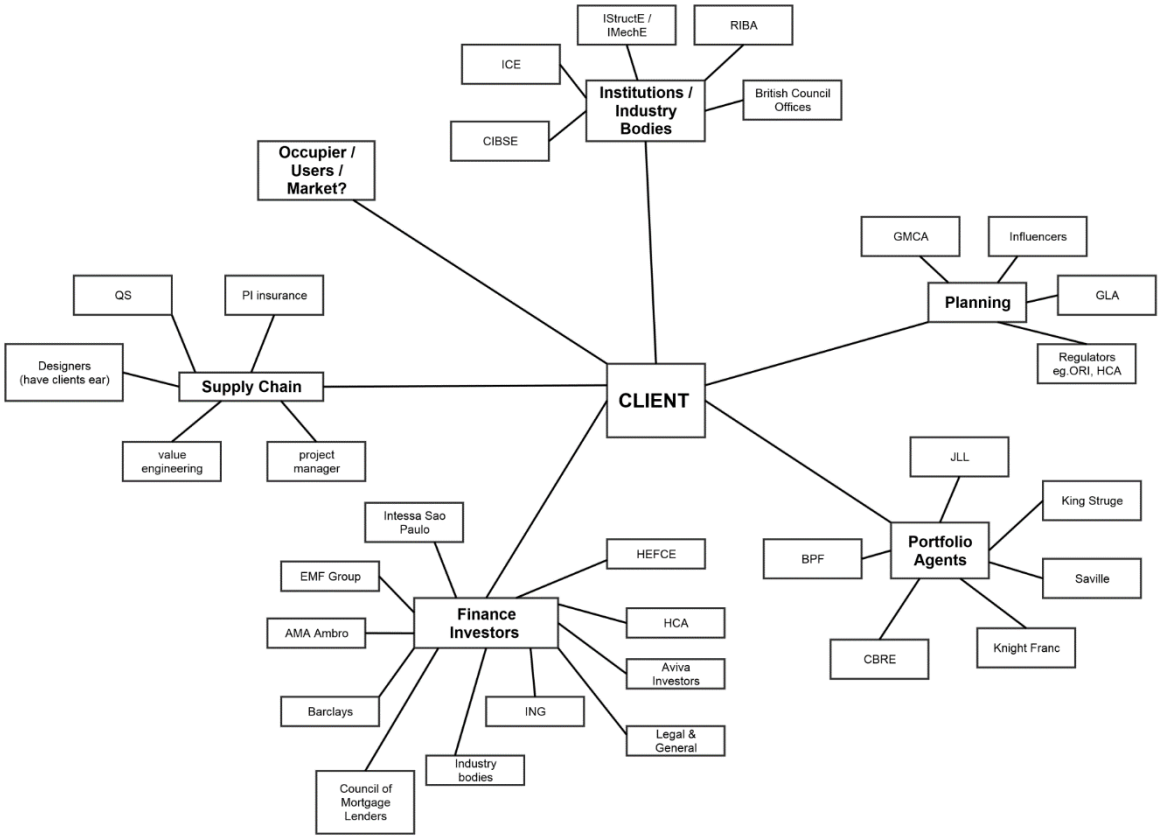
BRE Report 476 Achieving Whole Life Value in infrastructure and buildings

The table above highlights that different stakeholders have different levels of involvement and influence at different stages of procurement.

There are some key observations with regard to stakeholder influence and involvement over a project's life cycle, e.g. occupiers don't have much influence until the in-use phase of the life cycle, whereas funders tend to have a lot of influence up front, which then tails off. Developers tend to have relatively small influence / involvement during the in-use phase. This therefore has an impact on the re-useable building business case as they need to reflect both the influence (e.g. of funders, who can influence availability of finance for long term savings) and the activity in the project procurement at key stages. For example, if material suppliers are needed to make a business case add up, they need to be involved at feasibility / planning stage. The project procurement life cycle currently over-emphasises the upfront activities, which tends to reduce the perception of the importance of who's aware of / involved in the in-use phase of the life cycle.

As part of the stakeholder mapping an exercise to show potential industry influencers was made. Different sectors and businesses would be affected by varying degrees to the influencers mapped below.

Influencers map:



Interviews

A series of interviews were carried out with members of the building and property industry across different sectors. A total of 11 interviews were carried out. Whilst this is by no means conclusive It gives an indication of the range of views and common challenges of some of the industry.

Interviewers range from landowners to developers and operators.

Business Models

Through these interviews we asked which of the business models would be of most interest. The results below show that flexibility and adaptability overall were of most interest to most of the sectors, with social housing favouring returnable or relocatable housing solutions.

The table below shows the interest in each of the business models, overall sectors and for each main sector. The total number of interviews in each category are indicated below, percentages relate to the percentage interest out of the number of interviews undertaken.

	All interviews	Commercial	Retail	Social housing
Recoverable	9%	0%	0%	20%
Flexible	55%	88%	100%	10%
Adaptable	55%	88%	50%	30%
Returnable*	45%	50%	0%	60%
Relocatable	27%	0%	0%	60%
No. of interviews	11	4	2	5

Note: most organisations interviewed also provide private residential alongside their other primary sector.

*20% of the total interviewees interested in returnable buildings were specifically interested in short-term temporary uses, i.e. for decanting.

Additionally, two fund management investors were also interviewed. The key points raised from their perspective included:

- The business case needs to become more obvious by undertaking detailed cost exercises
- An increasing number of funds are requiring environmental and social factors, but circular economy is not yet within this
- Level of interest depends on the fund and how long the fund holds onto the asset

- There is likely to be more opportunity with assets that are held for a longer period; a challenge is the short payback period for some assets
- Even though re-usable building models haven't been thoroughly costed, they are unlikely to be detrimental to the investment value
- Due to variety of assets owned by funds (scale, type, longevity), different circular economy strategies will be needed.
- There is an inherent value from adaptability and flexibility, driven by market demand
- Impact investing could act as lever, as could the requirements from BREEAM and LEED
- Uncertain if demolition costs are included in the overall investment value

Other conclusions and trends

For all the businesses interviewed, sustainability was a driver in decision-making but with the business case or economic model being the greater factor; however, the majority admitted that their cost and valuation models did not consider 're-usability' in any detail. Common to the literature review findings, those clients that regularly bought and sold buildings, were sceptical that anything that was viewed as a long-term benefit would be implementable. This was particularly the case for the 'recoverable' business model, with few showing interest.

Some of the commercial clients' business models were based on buying existing buildings and then depending on lots of different factors, either refurbishing and selling or keeping hold of it. Whilst this may be viewed as a type of re-usable building model i.e. adaptability and change of use, there was little evidence that this was being undertaken in a circular manner. The same can also be said for flexibility, which was seen as standard by the office clients.

From the retail clients there was a drive to be able to gain additional value from the land they may own; so being able to have relocatable buildings was of interest as was the need for flexibility in their building space due to the ever-increasing demands of the retail environment. Most were unconvinced of a returnable (leasing) model for components due to factors including adding to the debt ratio, uncertainty in business continuity (for those providing the lease), too long lease agreements and the uncertainty of the cost benefits of this approach versus the purchase price.

Has your organization considered / piloted / investigated issues of circular economy already – if so, what was the outcome?

Would your organisation be willing to consider re-usable building solutions such as the five models outlined in this report?

What would be the arguments which might persuade you?

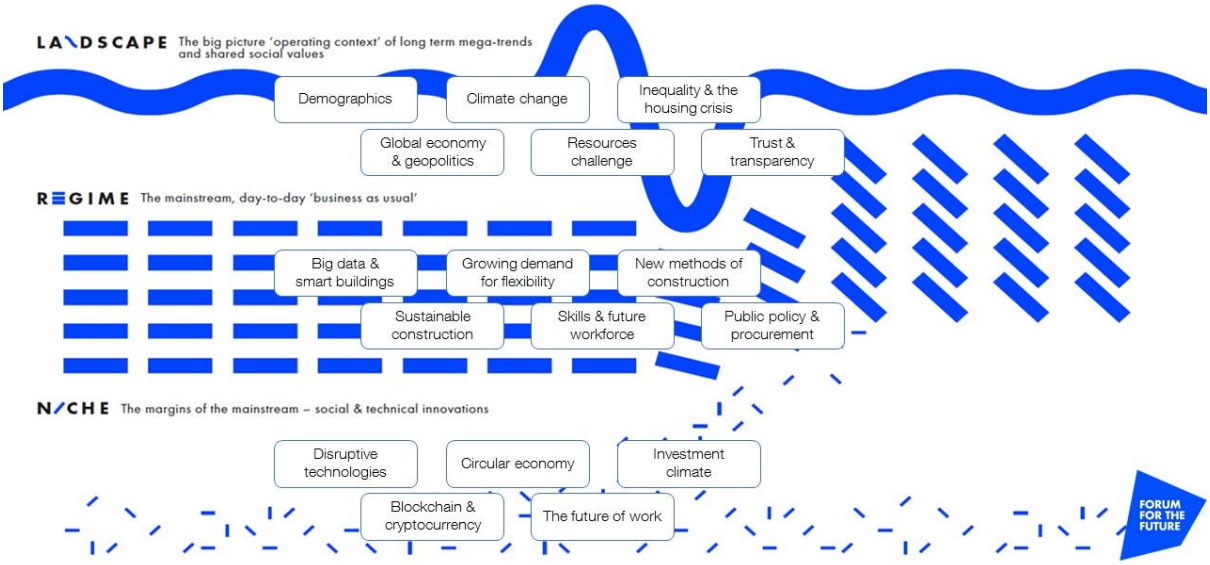
Workshop input

The following sections were developed as a result of consultation with industry representatives in a half day social housing workshop held on the 31st October attended by 9 organisations. The workshop considered trends of global and local systems, exploring the case for action, then development of the vision for the built environment of re-usable buildings, before exploring some of the business models and business cases in more detail. The results are described below.

These results were also used to inform the following roadmap and next steps.

System diagnosis & case for action

The project partners identified a number of trends that are being observed today, which are likely to shape the future (social) housing market in general, and the market for re-usable buildings specifically. These were mapped using the multi-level perspective, which illustrates how trends occur and interact in the landscape, regime and niche.



For example:

Inequality & the housing crisis

The richest 10% own nearly half the country's wealth – more than the bottom 80% put together. Inequality is linked to property ownership. In response we are starting to see discussion of alternative models for both housing and capital ownership. Signals of change include: developers are exploring modular and micro-homes as possible solutions to the housing crisis; the number of shared ownership home purchases in the UK rose by more than 130% from 2010 to 2016; co-working company WeWork has created the co-living concept WeLive, based on the philosophy of shared space, services, community and social interaction.

Circular economy

A growing 'distaste for waste' is creating momentum for a shift from linear value chains to cradle-to-cradle production systems and an efficiency mindset. The application of circular economy principles to the built environment could radically change the way we value and invest, design and deliver. Signals of change include: Group Machiels aims to mine Remo, Europe's largest landfill site with 18 million tonnes of waste, recovering half for building materials and half as energy; Park 20|20: an Amsterdam business park, claims to be the world's first cradle to cradle business community, with a focus on design for disassembly, material banking for each building, and leasing of products.

New methods of construction

Construction techniques such as modular building, offsite manufacture and 3D printing have the potential to transform the sector. With low margins, a growing skills shortage and pressing housing needs, companies are increasingly looking to modern methods of construction to save time, materials and labour. Signals of change include: Legal & General launched its modular housing factory in 2016, aiming to reduce building time on-site; Dubai-based construction company Cazza has committed to building an 80-storey skyscraper with 3D printing by 2020; Amazon has invested in US homebuilding start-up Plant Prefab, marking its first investment in the space.

Participants in the social housing workshop spent time exploring these in groups – deprioritising, adding to and/or clustering the trends as they felt appropriate. Following the workshop, these were combined into a single set of trend clusters, shown below:

Needs of building users	Macro-level economic & policy drivers	Market expectations & innovation concepts	Tech enablers	Workforce available
Demographics	Climate change	Investment climate	New methods of construction	Skills & future workforce
Growing demand for flexibility	Resource challenge	Public policy & procurement	Disruptive technologies	The future of work
Inequality & the housing crisis	Global economy & geopolitics	Trust & transparency	Big data & smart buildings	
	Placemaking & community	Sustainable construction	Blockchain & cryptocurrency	
	Governance	Circular economy		

These trends and drivers of change provide the basis through which to consider a re-usable building market place and how the different re-usable building business models might be affected by them. These trends also affect and inform a future vision for the sector.

What trends and drivers of change do think will have significant impact the industry and your sector? (across Landscape, regime or niche as diagram above)

Vision for a Re-usable Buildings sector

A draft vision statement for 2030 was presented to the participants. The draft vision described a future where traditional construction is a thing of the past, where reconstruction and redeployment are commonplace, and the use and purpose of buildings could be changed easily. In this world, buildings would be considered not a capital cost, but a future resource investment.

Before being presented with the draft vision, participants in the workshop were invited to suggest what characteristics an effective vision would have. Their suggestions included:

- Positive, inspiring
- Stretching, but plausible
- Gives a sense of scale
- Provides illustrative examples
- Logical, practical, pragmatic
- Has broad ownership and support (is popular among users)

Participants were then presented with the draft vision and invited to give feedback. Their key comments were:

- One of the sentences was considered unclear: “A world where you can lease a building or parts of it, rather than buy it outright, like you do with scaffold or an electrical load bank.” It was felt that this needed explaining further; it was suggested that an analogy with car leasing would be more straightforward, and easier to understand.
- The future market must be competitive, with many different providers – but also compatible, so that components from different manufacturers can be used interchangeably.
- The vision should show empathy with the end users – highlighting the benefits for tenants and their wider communities.

These comments were taken on board by the project team, and an amended vision agreed:

The future social housing marketplace is one where traditional construction is a thing of the past, where **reconstruction and redeployment** are commonplace. A world where buildings can be flexibly changed, adapted, expanded and reduced according to demand or use.

Where a building built is not a capital cost but a **future resource investment**. Where the building and its components are re-buildable, re-deployable, re-usable and resalable – retaining most of their original value.

This is a world where fleets of components, modules or whole buildings can be leased, then returned to the owner (developer, group of local authorities, etc) when they are no longer needed. A vibrant, competitive marketplace – where components from different providers are **compatible, aligned** to common standards.

Tenants and residents benefit from **more housing, at lower cost**. As their homes flex in line with their changing needs over time, families stay in the same homes longer – avoiding the cost and disruption of multiple moves, while strengthening **community bonds**.

Meanwhile, tenants in short-term housing need can access **safe, quality accommodation**.

And all this at **no extra cost**.

Business cases and business models

The social housing sector is itself undergoing change, with mergers and diversification leading to fewer, larger providers. With social housing providers now able to invest in future stock, re-usable buildings provide an opportunity to de-risk, for example by procuring via revenue payments rather than major capital payments, or by rapidly securing viable 'flexible' homes for meanwhile spaces.

The following models were considered as part of the workshop with the social housing industry. Flexibility was not deemed a significant driver within the social housing sector, so wasn't covered as a separate model, although some of the potential was considered with the adaptable model.

Re-usable building model	**Drivers**
Relocatable	Fast deployment and redeployment, used for meanwhile spaces and urgent housing issues
Adaptable	Readily transformable to meet changing family needs and demographics
Returnable	Leasing of buildings (and components) for short term and/or one-off requirements, such as decanting of residents
Recoverable	Residual value at end of life

Mainstreaming re-usable buildings in social housing

Participants in the social housing workshop were asked to explore the four business models in turn, highlighting for each: potential benefits for social housing providers and their users; likely barriers and enablers to mainstreaming; and key actors who could influence its development and growth. A table setting out all the points raised is included in the appendix.

In summary, perceived **benefits** included:

- Ability to adapt to long-term changes in the needs of clients, provider and users – mitigating the risk of not knowing the building's future purpose, requirements of future legislation, or shifting patterns of demand as demographics and the economy change.

- Easy and quick adaptation/deployment to meet the needs of different user groups, such as those with disabilities or temporary housing needs, including the homeless or those who need to be decanted during redevelopment of permanent sites.

- A permanent quality solution to gain economic and social value from meanwhile spaces (e.g. changing land banks) or difficult-to-develop land.

- Lower cost/risk over whole life, with resources/components being retained and re-used.

Some of the key **barriers** flagged by participants were:

- Identification of suitable sites – local authorities are often not aware of meanwhile sites that they own, or there may be competing priorities for different uses e.g. infrastructure.
- While the whole life cost is lower, increased upfront costs for re-usable buildings may present a challenge to procurers and organisations using traditional financial models. Uncertainties regarding time, cost and risk are likely to discourage some partners.
- Planning system constraints and a conservative culture among planners could make it difficult for those wishing to take a lead to do so.
- With many partners needing to be involved, there is potential for confusion regarding who is responsible for what.

The key **enablers** to mainstreaming were:

- Clients understanding the extended value and utility of re-usable buildings over their whole life – with concerted efforts to raise awareness with politicians and planners, adapt planning requirements, and further embed social value in procurement.
- Examples of success, to demonstrate what is feasible and effective. This requires being prepared to trial and test new approaches and develop commercially viable business models, so that providers/commissioners can invest with confidence.
- Availability of suitable, standardised components as the market matures.
- Shared intelligence, with clear capabilities and ownership across different partners and sectors.

A wide range of actors were considered significant in driving the development of a market for re-usable buildings, from social housing providers, their suppliers and industry bodies, to investors, policymakers and thought leaders. We provide recommendations for each of these groups in the form of a roadmap in the following section.

Organisational considerations

There may be a number of organisational considerations for introduction re-usable buildings and components. This includes using appropriate financial modelling (capex v opex) and consideration of how assets are treated on the balance sheet, tax implications and possibly savings through temporary uses, costing over more than one life cycle, development of knowledge and practicalities of further re-use and deployment. For example, communication of benefits across a range of internal stakeholders, with differing priorities and metrics, was seen as a key issue.

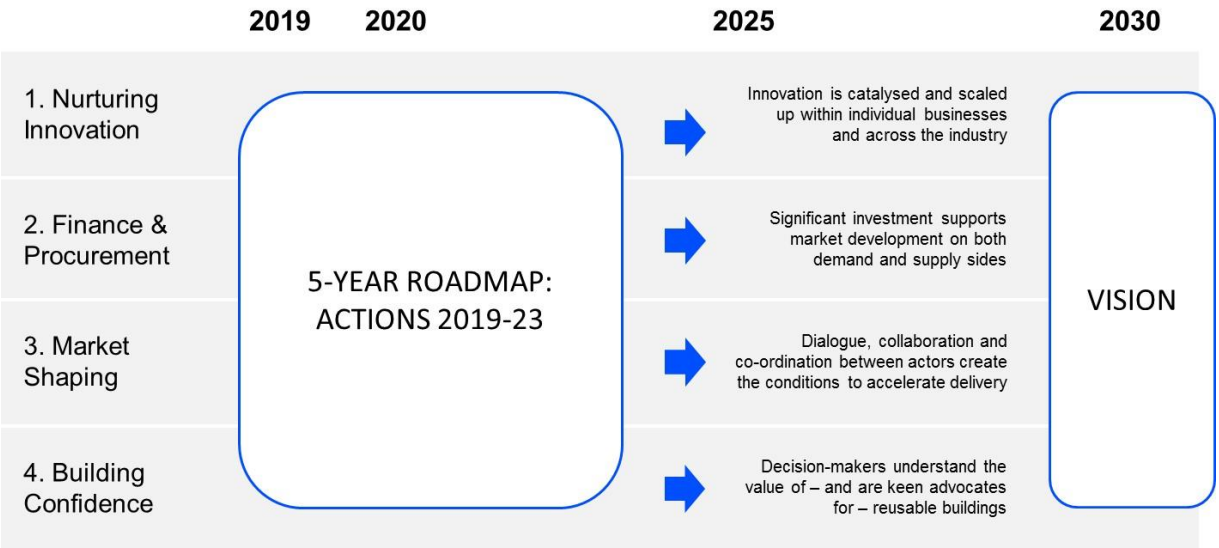
Road map and next steps

An internal road mapping session was conducted, using outputs from the social housing workshop to plot a series of high-level actions that would help to shift the market towards the vision; feedback was then provided on this roadmap, based upon discussions with industry participants. Whilst the roadmap is based on information from the social housing sector, it is seen to be applicable to all sectors, in enabling them to adopt re-usable building models.

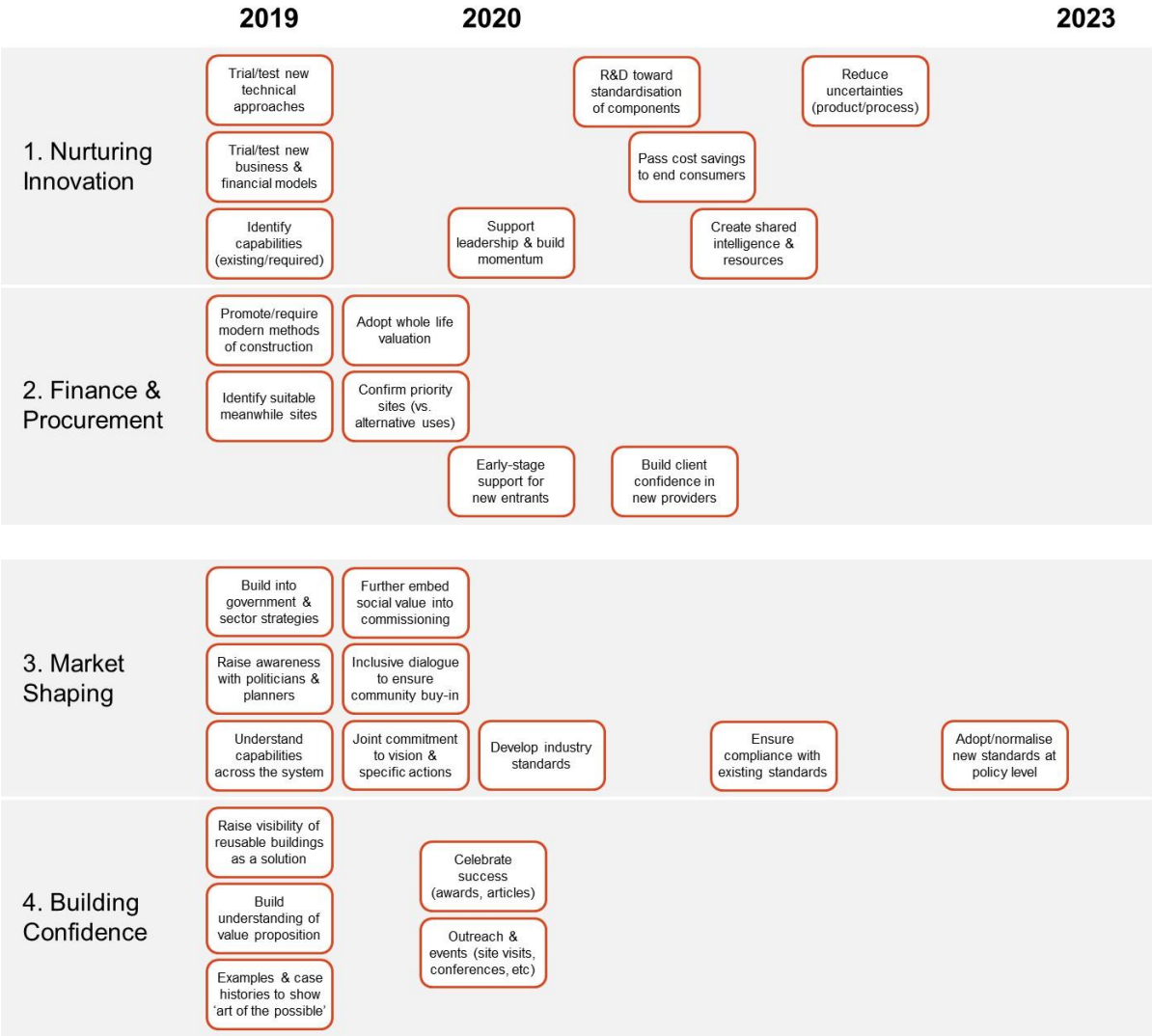
The time horizon for the vision developed earlier in the project was 2030 – to stretch participants' thinking beyond what is immediately possible, to that which is desirable in the long run. However, in the interests of practicality and actionability, the roadmap focuses on the next five years, 2019-23.

Actions in the roadmap are divided into four key themes or tracks – nurturing innovation; finance and procurement; market shaping; and building confidence. These themes are not specific to any one stakeholder group – they are cross-cutting.

The overview image below shows how the actions in the roadmap are designed to lead to four 'big shifts' or high-level outcomes, which would help to make the vision a reality by 2030.



The image below provides the detail of the roadmap, setting out key initiatives or areas of focus to be delivered under each track. It is anticipated that these initiatives will be further developed, from involvement and collaboration with key stakeholders and as such their timescales and scheduling may be subject to alteration and therefore the roadmap may undergo several iterations.



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Recommendations

In delivering the roadmap, every stakeholder group will have a different focus and role, drawing on their unique capabilities, resources and networks. As a starting point, we recommend the following:

Social housing providers

Local authorities, ALMOs, housing associations, private developers

- Encourage circular business models and modern methods of construction
- Trial new approaches with the supply chain and adopt whole life valuation
- Collaborate with suppliers, peers and the wider industry e.g. share what works
- Pass cost savings to end users

Supply chain

Designers/architects, developers, contractors, manufacturers

- Build an innovation culture: invest in R&D, trial and test new approaches and business models
- Collaborate with customers, peers and the wider industry e.g. developing standardised components
- Pass cost savings to commissioners

Industry & collaboration bodies

Industry associations (e.g. UKGBC), CE initiatives (e.g. Ellen MacArthur Foundation)

- Convene dialogue and collaboration, including shared understanding of capabilities and shared commitments
- Develop industry standards
- Build understanding of value proposition
- Demonstrate the art of the possible with demonstration projects and case studies

Finance community

Banks, insurers, venture capital, innovation funders (e.g. Innovate UK), finance professionals, buyers:

- Nurture innovation by providing seed funding for demonstration projects and new entrants/potential disruptors
- Provide patient capital to allow innovators to establish sustainable business models
- Adopt whole-life valuation models

Policymakers & regulators

Central government (e.g. BEIS, Treasury), lobby groups (e.g. NHF, ASBP), local authority planners

- Build into government and sector strategies and unlock additional support
- Change procurement rules, e.g. enhanced social value, whole life valuation
- Identify and prioritise suitable sites
- Increase awareness within this group

Thought leaders & influencers

Academia, industry/general media, NGOs, advocacy/campaign groups, award schemes (e.g. businessGreen):

- Build understanding of value proposition with detailed analyses and evaluations
- Demonstrate the art of the possible with case studies and examples
- Celebrate success through awards, events and outreach

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Next steps

For the social housing sector

From the roadmap, we can identify a few immediate priorities:

1. Led by industry bodies, stakeholders should come together to **map capabilities and resources** across the sector and develop a set of joint commitments.

2. Each sub-sector, profession group and/or organisation should explore what the roadmap will mean for it in practice – and agree their own, more **detailed action plans** to help deliver it.

3. A number of specific **collaboration initiatives** or pilots should be established, bringing stakeholder groups together to accelerate outcomes under the four tracks, e.g. availability of seed funding, policy change, or demonstration projects.

For other sectors

While this vision and roadmap were developed specifically in the context of social housing, we believe they contain a number of transferrable lessons that would be applicable to other sectors. We invite other sectors (commercial property, education, etc) to convene and deliver similar explorations to that delivered by the re-usable buildings project team.

We recommend using the following challenges/discussion points to help guide the process:

1. **What are the external trends/factors** that may drive the need for re-usable buildings in your sector over the next 10-12 years? Consider the demand and supply sides, and different types of trends – landscape/long-term, industry/mainstream, and niche/disruptive.

2. **What would an ideal outcome/vision look like** for your sector by 2030? How have the fundamentals changed? How do key stakeholder groups benefit? Consider taking the vision for social housing as a starting point – how would it differ for your sector?

3. **Which of the five business models would be most suitable/viable** for your sector – flexible redeployment, adaptable, returnable and/or recoverable? Which would be less suitable, or not suitable at all? Why is that – what are the potential benefits, or disadvantages?

4. **What changes are needed to deliver those business models** in your sector? What are the current barriers, what would enable change, and who would be responsible for driving that change? Can you summarise all this in a roadmap, with clear roles and responsibilities?

5. **What are the immediate priorities?** Which are the key actions and collaboration opportunities that would kick-start progress, build momentum for further action, and reorient the sector towards delivering a thriving market for re-usable buildings?

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What is the next step your business could take? Where is your business or sector positioned on the roadmap? Are there any missing steps?

Conclusion

The built environment sector is responsible for 59% of UK waste and over half of London's waste, whilst consuming vast quantities of virgin raw materials. The tonnage of material re-use is on the decline. These materials are on average only used once at least in their high value form, resulting in significant wastage of materials and, as many of these are energy-intensive in their production, wastage of energy. In fact, material re-use tonnage declined by 25% between 1998 and 2007.

This poses a significant challenge for the built environment. We believe that some of the answers to address this are not solely in technical solutions (many of which exist) but in innovations in business models and approach to building value and costing. This project has looked at alternative approaches and business models in order to address these challenges and unlock not only better resource use but greater economic value too.

This project has outlined five possible broad business models and how the business case for each might work:

- **Flexible:** Designed for 'in use' changes to meet needs from daily flexibility to a longer-term flexibility of internal layouts.
- **Adaptable:** Readily transformable to meet longer term changes from adaptable expansion or changes of building use without significant building change. This could be in response to community needs or changes in demographics.
- **Relocatable:** Fast deployment and redeployment, used for meanwhile spaces and urgent building needs such as changes in housing requirements or in office density.
- **Returnable:** Leasing of buildings (and components) for short term and/or one-off requirements, such as decanting of residents.
- **Recoverable:** Designed for deconstruction so residual value can be recovered at end of life at high value.

We have found that there is interest from a number of stakeholders and clients across many different sectors with particular interest from the social housing sector.

With a group of interested stakeholders we have explored the global and local trends and drivers for change influencing the sector, the business cases and how they could address some of these trends, set out a future vision and developed a road map of how to get there. The aim of this project was to start this process but further input and development from further stakeholders to incorporate and test these principles and approaches within their projects, developments and businesses is required to move this important agenda forward.

Appendix 1: Stakeholder feedback: mainstreaming re-usable buildings in the social housing sector

Benefits	Barriers	Enablers
• Permanent approach to meanwhile sites • Better solution for homeless people • Lower cost than alternatives • Allows for re-planning of sites: plan regeneration • Allows decanting • Testing a concept – advocating disruption • Meet changing needs of client, provider & users – thereby saving money & resources • Easy adaptation to support users with disabilities • Mitigate risk in not knowing what the building will need to do in the future + future legislation • Adapt to changes in economy, the way we live & changing needs/expectations of households • All resources/components retained & re-used • Lower cost over whole life	• Identification of suitable meanwhile sites – boroughs often not aware of what they own • Competing priorities for sites e.g. big infrastructure • Scaling/procurement – additional upfront cost • Must be viable for the location & community • Time, money & risk – process & product are uncertain • Out-of-the-box for many planners (cultural shift) • Planning system constraints • How do buildings meet acoustic & fire requirements? Need to consider building regulations • Nobody 'grasping the nettle', taking the lead • Understanding who is responsible for what – quality/risk assurance needed • Property/housing doesn't lose value as cars do – often increases over time, thus reducing incentives	• Raise awareness of opportunity with politicians, planners → accelerated process, flexibility requirements • Be prepared to trial/test a new approach • Market provision – provider confidence in new entrants • Availability of commercially viable business model • Examples to demonstrate what's possible • Commissioners further embed social value • Cost savings passed on to end users e.g. Common Home – 2-bed homes in London for sale at £250k • Market demonstrating possibilities – who will be first? • Availability of suitable, standardised components • Clients understand extended value/utility over whole life • Community sitting at the table when decisions are made • Single point of ownership • Share intelligence • Clear capabilities

Appendix 2: Literature Review

Introduction

A literature review has been undertaken of academic journal articles, Government and industry publications, focusing on re-usable buildings and components, which are a vital part of the applying circular economy thinking within the building sector. The main aim of the literature review is to understand the outcomes of previous work and where there are gaps to inform the Climate-KIC project on re-useable buildings. The focus of the literature review is largely on the business case for adopting re-usable buildings and components and to demonstrate benefits to clients and the value of developing this further, although other considerations such as technical and social are noted. The literature review includes all the business models identified: flexible, adaptable, relocatable, returnable and recoverable. It includes the following sections:

- A summary of key findings
- An overview of the circular economy within the building sector and benefits
- Re-usable buildings, which is mostly academic literature in the area of adaptability
- Re-usable components and the challenges and opportunities
- Case studies, which are largely from industrial sources.

Summary of key findings

- The reuse of buildings is gaining more interest; with evidence showing that conversion (from one function to another) is increasing in inner urban areas
- The benefits and challenges for commercial Re-usable buildings are well defined though not often quantified
- There is a clear distinction in the motivations between the different development models (develop to sell, manage or occupy), with owner-occupancy driving a greater interest in adaptability
- End-users preferences are for versatile and a refit ready building that provides fewer disruptions, improved service and better quality of space.

In terms of cost and savings, the main findings are:

- There remain as a debate of the costs of reuse verses demolition and new build, though studies tend to show that it usually lower for the former. When considering reuse verses demolition of commercial buildings, there are a number of diverse issues that need to be considered such as marketability, investment returns, productivity and ongoing costs

- Where building have not been designed for reuse, then the cost of adaption of existing buildings can be greater than building them from scratch. As such building adaptation is a higher cost process, when adaptable features are not incorporated with the initial design

- Cost is usually cited in the literature as the main obstacle to developing more adaptable (Re-usable) buildings, with the assumption being that adaptability results in higher initial construction costs. Though this is highly dependent on the solution adopted.

- Spending more on the initial construction costs of a building to make it more adaptable can only usually be justified if the adaptability is likely to generate some form of benefit or return on investment in the future. A life cycle approach is needed.

- Studies show that adaptable design solutions pay for themselves at the first adaptation cycle, generating, on average, a net saving equivalent to 2% of the initial construction cost. Other benefits include the reduction of time required to adapt the building (thereby reducing disruption to users) and easier access when maintaining the building

- Investments in the adaptability of buildings generate value in the long term because the needs of (future) users are more easily met, as such there is value though utility, though there is little empirical evidence to support this within the literature

In terms of costing and valuation techniques, the main findings are:

- Whole life costing is recommended to show payback, however there can be issues in its use from discounting as the results are very sensitive to the rate used, the assumptions and risk factors used and how residual value is factored in (particularly from one building to another or one owner to another).

- There is a fundamental shortcoming in the current financing of buildings with the costs of demolition and recycling (as well as any residual value) at the end of its life not factored into business case (a side effect partly of discounting but also reflecting different contractual parties at the end of life)

- The value of real estate is currently linked mainly to the price of the location and the difference between rental income and operating costs. Often, the value of the raw materials in the building is of secondary importance.

- It is unclear if property valuations consider any benefits from adaptability and 're-let ability' and how depreciation of assets is factored in.

- There is some institutional bias, whereby in the past, the specification was promoted by property agents, who insisted that all new office developments should incorporate over-specified design features, to reduce the risk of depreciation even though the specification did not bear any resemblance to what most occupiers actually needed from their office buildings—a case of exchange value prevailing over use value

- Banks such as ABN Ambro are investigating how to allow for higher investment costs which justify lower running costs and a higher final value of the building elements. This therefore means a

relatively higher loan-to-value ratio for a project, and a relatively smaller amount of equity capital relative to the loan capital

Findings from the review of circular building case studies which are limited (some examples are shown below), show that the client is instrumental in driving the circular building forward, along with establishing the benefits to the end user. Key points to note from these case studies are:

- Collaboration across the project stakeholders is key
- It can take time to build up the knowledge required for circular buildings
- There needs to be a clear vision and strategy for the building, with the client driving this forward
- The client is usually driven by their own values or work practices in wanting circular buildings
- Even though investment costs may be more initially, there is payback when residual value is factored in (the sooner they are achieved the shorter the payback period)
- As well as economic savings over the lifetime of a building, there are also likely to be carbon savings in the embodied impacts of new material use.
- The supply chain is willing to provide circular approaches and solutions, as long as they have commitment from the client. This is similar to offsite construction, whereby if different manufacturing systems are required, then a commitment is needed for long term volume and continuity
- It is important to agree which components of a building should be targeted for circularity
- With the right methodologies, issues relating to opex and capex, the splitting of benefits, discounting, future residual values can be overcome.
- Some form or data collection and monitoring is required, through for example BIM and material passports
- Other schemes such as C2C and BREEAM can support circular buildings

When focusing on circular products, rather than buildings, the key findings are:

- Circular products tend to cost less over the lifetime/deployment cycles of the product
- More money may be required upfront (the capex stage), even though it may demonstrate operational savings operational (maintenance) stage which companies may have issues with.
- Greater maintenance may be required for a 'second hand' product
- There are many other benefits such as improved performance, better maintenance and for energy-using products, a reduction in energy usage

- There are benefits for the manufacturers to design products that are efficient and durable for multiple uses such as customer loyalty, CSR, material supply and security

- In some cases (newer business models), it is difficult to know if the products will actually be reused at the end of their life.

For Re-usable components, the main challenges and opportunities are well known. Whilst there are a number of studies showing the technical potential of reuse, those showing the economic benefits are limited; however, those that are available, show either cost neutrality or a cost saving compared to using primary materials/products. There may be an issue of reuse, for products that are energy-using, though examples show that there is potential for the reuse of HVAC systems, as well as steel frames, carpet tiles, furniture and salvage items.

Circular economy within the building sector

There are a number of industry studies that have looked at how circular economy can be applied in the building sector, such as those by Arup[7], Ellen MacArthur Foundation[8], Horizon 2020 Building As Material Bank Project[9] and a number of international studies, predominately Dutch[10]. These studies mostly describe the different business models that could be applied, together with some of the challenges and opportunities, though they are lacking in actual costs. The role of stakeholders is also presented, which differs depending on their viewpoint and the impact of business models. A few of these studies define, what a circular economy in the built environment would look like and the macro-economic benefits (at a region or Country level). For example, Ellen MacArthur Foundation, 2015considers the *'built environment based on circular economy principles would reclaim the inner-city land unlocked by a circular mobility system to create high-quality spaces where people would live, work, and play. The system would integrate green infrastructure (e.g. parks) with durable, mixed-use buildings designed in a modular way and constructed with looped and non-toxic materials. Buildings would generate, rather than consume, power and food. They would have fully closed water, nutrition, material, and energy loops. They would be highly utilised, thanks to shared and flexible office spaces and flexible, smart, and modular homes'.*

Based on this definition, they propose that there is a reduction in the cost per m^2 of more than 30% today and an estimated £300 billion of savings from primary resource benefits, including energy by 2030 in Europe. An example provided focusing solely on deconstruction and social and economic benefits, estimated that If deconstruction were fully integrated into the U.S. demolition industry, which takes down about 200,000 buildings annually, the equivalent of 200,000 jobs would be created (Ellen MacArthur Foundation, 2013).

A study for Amsterdam estimates that circular building chain can lead to 3% increase in productivity growth worth € 85 million/year which is realised in part by value retention due to material reuse and efficiency improvements as well as increased employment opportunities; over time, about 700 (1%)

[7] https://www.arup.com/perspectives/publications/research/section/circular-economy-in-the-built-environment
[8] https://www.ellenmacarthurfoundation.org/
[9] https://www.bamb2020.eu/
[10] For example work by: https://www.circle-economy.com/ and https://www.tudelft.nl/en/architecture-and-the-built-environment/research/research-themes/circular-built-environment/

additional low to medium skilled jobs can be created. The reuse of materials leads to material savings of 500,000 tonnes, which is significant when compared to the current annual import of 1.5 million tonnes of materials. This study also shows the effect on greenhouse gas emissions which are estimated to decrease by 500,000 tonnes of CO_2 per year equivalent to 2.5% of the current annual CO2 emissions of the city of Amsterdam (Circle Economy, 2016).

The academic papers focus largely on the policy or technical aspects of circular economy, with a large number emanating from China, on recycling and industrial symbiosis. There are few that relate solely to the built environment. There is more literature available on adaptable buildings and the reuse of buildings, though this tends to be older than the industrial studies. Examples of circular economy implemented to building projects as a whole are scarce and those that do propose to be fully or part 'circular' are mostly in relation to the use of materials, such as using Cradle to Cradle certified. Often clients looking for circular solutions just ask tenderers for a vision as precedents on alternatives are lacking, as often is the knowledge of clients, as well as the industry, on how exactly to define a circular economy building.

At the micro (business level), there is little economic information available within the literature on the financial benefits or costs for undertaking circular business models, such as Re-usable buildings. Indeed, research by (Adams *et al.*, 2017) found that one of the largest challenges for adopting circularity in the built environment is the unclear financial case, particularly for the whole life of a product/building which ranked number one for the majority of stakeholders; having a clear business case was the most important enabler. There remains an underlying question on how to develop a clear economic case for circularity in the built environment, including re-useable buildings and how to motivate change in the key players, Common issues include:

- A large amount of uncertainty on material resource prices into the future, resulting in the difficulty to predict the potential value of materials at the end of life, particularly for long-lived products; though it should be noted that material prices have mostly increased in the last 20 years.
- Many construction products designed and manufactured now at their end of life at today's prices are low in value, making it uneconomical to reuse
- Keeping upfront (capital) costs low remains an issue in construction, which may negate any future value
- Short-termism of many clients
- The initial investor may not benefit directly from circular economy approaches, as the benefits may fall to the final owner
- A lack of understanding of the cost benefit of applying circular economy principles to each party involved due to the current ownership models
- How building and material assets are currently valued may also provide disincentives for their future use
- Cost and associated profit is still largely the dominant factor in any decision-making process

<u>Re-usable buildings</u>

The reuse of buildings is attracting more interest; one of the key drivers identified within the literature is that of obsolescence which affects every building to some degree at some stage during its lifecycle (Douglas, 2006). As buildings age, the rate of decay increases and the decline in building condition escalates unless regular maintenance and upkeep is undertaken. There are 6 principal types of obsolescence; economic, functional, social, legal, physical and aesthetic (Barras and Clark, 1996). As such, when a certain level of obsolescence is reached, a building may require adaptation in some form.

Conversion (changing use or sometimes known as adaptive reuse), is a growing strategy for dealing with vacant buildings such as offices. Indeed, a study in Liverpool showed that more than 60% of buildings have changed their original use during their life cycle and around 10% of them have changed their use frequently (every six year) during the last 20 years thereby signalling an increase in the rate of change (Manewa *et al.*, 2016). Developers, investors and housing associations have a choice of converting for sale or for the rental market. However, the property market can be segregated and for example, office investors are not always keen on investing in the housing market. The high asking price for vacant office buildings can be an obstacle for conversions. In locations with high housing demand and low office space demand, residential conversion is especially interesting. Housing and inner-city locations have a positive influence on the conversion potential. A study of 15 cases in the Netherlands displayed the following success factors: low purchase price, an adaptable floor plan, government subsidy, or clients with long- term investment scenarios (housing associations) (Remöy and Voordt, 2014). According to Bullen, 2007,. there are numerous benefits arising from reusing and adapting buildings including:

- reducing resource consumption, energy use and emissions;
- extending the useful life of buildings;
- less disruption than building new
- being more cost effective than demolition and rebuilding;
- reclaiming embodied energy over a greater time frame;
- creating valuable community resources from unproductive property;
- revitalising existing neighbourhoods;
- reducing land consumption and urban sprawl; .
- enhancing the aesthetic appeal of the built environment;
- increasing the demand for retained existing buildings;
- retaining streetscapes that maintain sense of place;
- and retaining visual amenity and cultural heritage

However according to Bullen, 2007, there are also a number of challenges such as (Bullen, 2007):

- only being viable where the costs and benefits are factored in over the life of the building;
- building owners may see no economic benefit in reuse;

- older buildings may require extensive and costly refurbishment;
- inability to match the performance of a new building;
- ongoing maintenance costs may be higher than a new building;
- older buildings may be unable to meet current sustainability standards;
- availability and price of matching existing materials may create problems; and
- maintaining the structural integrity of older buildings may be difficult

Reuse v demolition

There is a debate of the costs of reuse verses demolition and new build, though studies tend to show that it usually lower for the former. For example, it is potentially cheaper to adapt than to demolish and rebuild, in as much as the structural components already exist and the cost of borrowing is reduced, as contract periods are typically shorter (Shipley et al., 2006). This is also likely to be the case if the building is designed for adaptation and re-use. Buildings are generally demolished because they are perceived to no longer have any value (Kohler and Yang, 2007). In most cases, it is the market that sets this value, even though such an assessment may be based on incomplete information with no consideration given toward externalities. According to Ball (2002), it is generally preferable to repair a building than replace it because the value of the location and quality of a new building is not necessarily better than the old one. In contrast, O'Donnell (2004) suggests that an adapted building will not completely match a new building in terms of operational energy performance, but the shortfall should be balanced against gains in social value. Certainly, the life cycle expectancy of the materials in an older building may well fall short of those in a new building. The age of materials will also directly affect the on-going maintenance costs of an adapted building, which, as a result, may well be higher than those for a new building. Bullen and Love, 2010 identified that there are a diverse set of issues that organisations need to consider when comparing the option to demolish or reuse a commercial building which include:

- ability to attract tenants
- investment returns
- meeting employee needs
- marketability
- maintenance and repair costs
- operating costs
- productivity levels
- employee retention rates

A study by Aude11, looked at the legacy of 1960's office and higher education buildings and examined the factors in determining whether to rebuild or refurbish, including economics, energy efficiency potential, adaptability to current requirements, functionality, compliance etc. It also developed a tool to help make the decision, and which also analysed what made 1960s buildings more or less re-usable in situ.

Stakeholders

Studies have been undertaken on stakeholder's views on adaptable and Re-usable buildings (an example is provided in Figure 1). In a survey of high profile UK property developers and agents, 94% saw the need for an adaptable building solution providing associated capital cost increases were minimised (Gregory, 2004). Workshops undertaken in the UK (Pinder, Schmidt and Saker, 2013) for adaptability suggested that:

- For developers that are procuring buildings to sell, more adaptable buildings will only be worth investing in if they are easier to sell and/or command a premium over less adaptable buildings, which in turn will be dependent on them being more attractive to investors and/or occupiers.
- For developers that are procuring buildings to sell, the incentives to develop more adaptable buildings are less clear, because responsibility for adapting the buildings in the future will fall on another party, who will reap the benefit of the initial investment though this is linked to being able to command a premium (above point)
- For owner-occupiers, institutional investors or developers with a longer-term interest in buildings, investing in adaptable design strategies can sometimes be justified because they may recoup the benefits in the future, for instance through lower rates of depreciation.
- Funders have a desire for simplicity and the use of traditional construction methods to reduce risk, costs and tenant churn.
- Owners are driven by a desire to minimise risk and initial capital expenditure, while being able to sell or lease the building was a key motivator for applying any type of adaptability.
- There was also a clear distinction in the motivations between the different development models (develop to sell, manage or occupy), with owner-occupancy driving a greater interest in adaptability.
- This was complimented by end-user preferences for a versatile and refittable building that provides fewer disruptions, improved service and better quality of space.

[11] See http://www.sustainabilityexchange.ac.uk/legacy-of-1960s-buildings-aude-research-project and https://www.aude.ac.uk/search?s=1960s

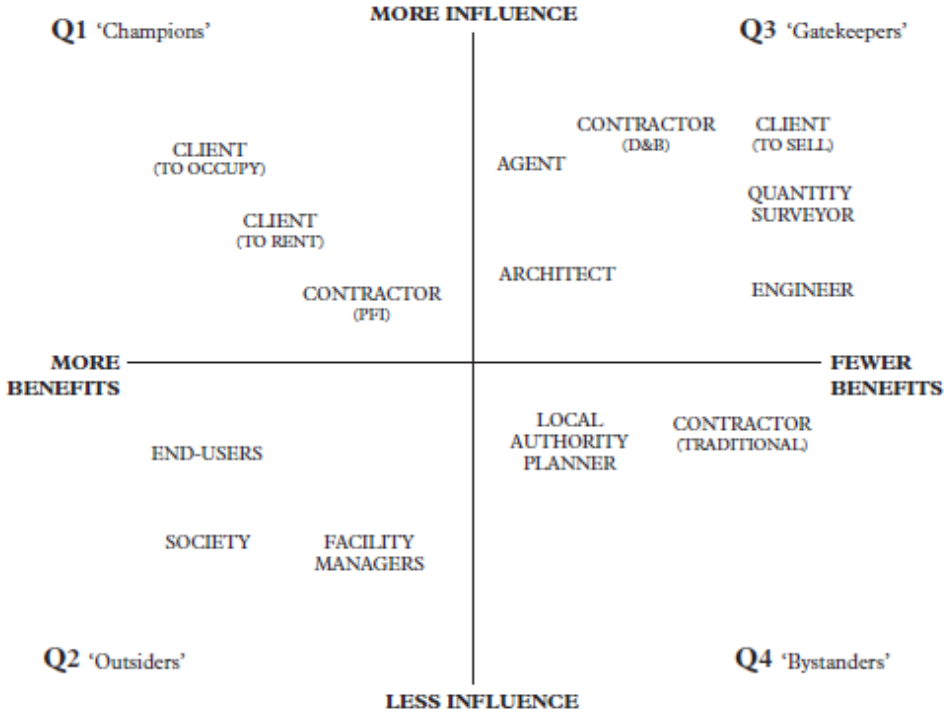


Figure 1: Stakeholder influence for designing adaptable (Re-usable) buildings (Pinder, Schmidt and Saker, 2013)

Costs

Where building have not been designed for reuse, then the cost of adaption of existing buildings can be greater than building them from scratch. As such building adaptation is a higher cost process, when adaptable features are not incorporated with the initial design. Therefore, there is an immediate benefit to integrating an appropriate level of adaptable features within new construction.

Cost is usually cited in the literature as the main obstacle to developing more adaptable (Re-usable) buildings, with the assumption being that adaptability results in higher initial construction costs. For example, studies have shown that using solutions such as higher floor-to-ceiling heights, system walls and soundproof suspended ceilings, could increase initial construction costs by approximately 20–25% (Arge and Landstad, 2002). However, other adaptable design solutions, such as easily divisible building forms and floor plans, were found to be cost neutral (see Figure 2). Other studies found that on average, the design strategies employed resulted in a 1% increase in initial construction costs when compared with conventional (less adaptable) designs; one-third of the strategies resulted in longer initial construction times. Though, the use of offsite approaches, is likely to reduce construction times on site.

In the UK the notion that more adaptable (re-useable) buildings cost more to construct has, to some extent, been fuelled by past attempts at 'future-proofing' buildings. Guy (1998) explains how, during the 1980s and 1990s, institutional investors' desire to reduce the risk of depreciation associated with changing occupier requirements led to the emergence of an institutional specification that involved over-specifying, among other things, floor loadings, small-power provision and comfort cooling services. This institutional specification was promoted by property agents, who insisted that all new office developments should incorporate these over-specified design features, even though the specification

did not bear any resemblance to what most occupiers actually needed from their office buildings—a case of exchange value prevailing over use value.

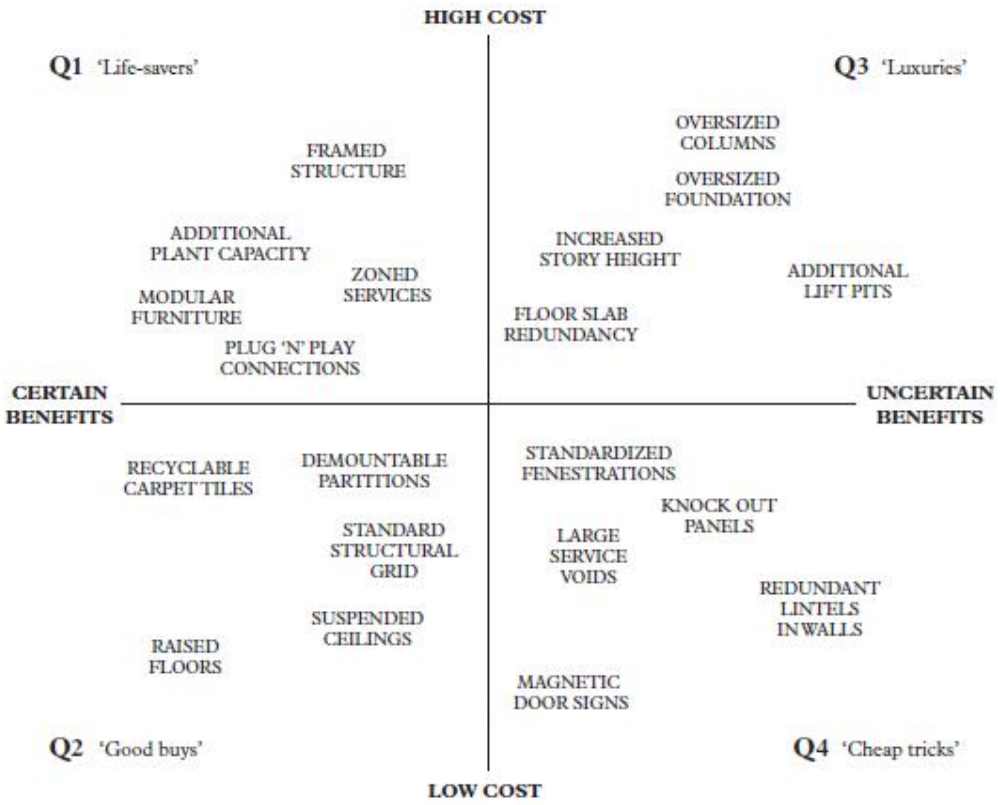


Figure 1 Examples of the interplay between cost and uncertainty when developing more adaptable buildings (sourced from case study buildings)

Figure 2: Cost and uncertainty in designing adaptable (Re-usable) buildings (Pinder, Schmidt and Saker, 2013)

Spending more on the initial construction costs of a building to make it more adaptable can only usually be justified if the adaptability is likely to generate some form of benefit or return on investment in the future. Slaughter (2001) estimated that all but one of the adaptable design solutions in her study would pay for themselves at the first adaptation cycle, generating, on average, a net saving equivalent to 2% of the initial construction cost. She found that three-quarters of the adaptable design strategies reduced the time required to adapt the building (thereby reducing disruption to users) and allowed for easier access when maintaining the building.

Whole life costing

A critical component to aid Re-usable buildings is the use of whole-life costing (WLC), when all the costs and benefits are factored in over the projected lifecycle of the building which includes the cost of the demolished building. WLC can be used as a forecasting tool to evaluate alternative planned capital expenditures with the aim of ensuring the optimum value from capital assets considering all future costs

and benefits in present day values. An example is shown in Figure 3 of the difference in cash flow over the lifecycle of the building based on adaptable and standard design. However, the ultimate answer (for linear and circular buildings) depends on future assumptions which may involve high risk and uncertainty (which are likely to be less in the 'business as usual case' and the hidden costs/benefits associated with social and environmental issues remain untapped.

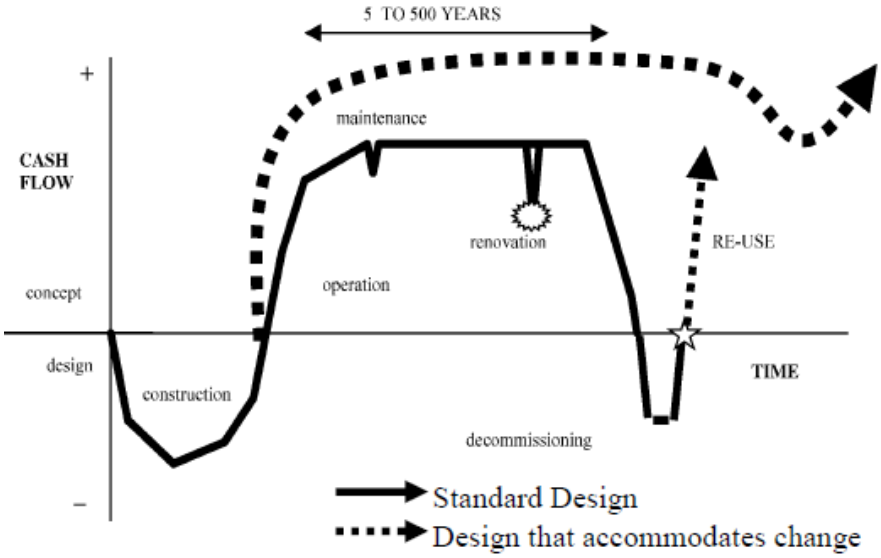


Figure 3: Illustrative Life cycle costs of standard design versus adaptable design (Manewa *et al.*, 2016)

Discounting is commonly used in WLC and is based on the concept of time preference: the tendency for people to attach more value to a benefit received today than to the same benefit received in the future. The choice of discount rate is important in the context of reuse as high discount rates give little weight to more distant entries in the cash flow and place great emphasis on the early years, thus favouring a short-term approach and the minimisation of capital investment. As such it is important to develop an economic model for circular buildings that allows the investor to benefit from day one.

BRE is also looking at how whole life cycle costing can be used within a circular building assessment methodology for the BAMB[12] project. A number of modelling scenarios have been undertaken, and the key findings are that whilst the methodology can show benefits over one lifecycle (through adaptation), taking into account residual value within the current building is difficult, as is applying value from other building cycles. The model (similarly to life cycle assessment), is based on one building, and as such limits the opportunity to transfer value. Discounting as already recognised above, also presents issues.

Financing

Studies have shown that there is a fundamental shortcoming in the current financing of buildings (Circle Economy and ABN AMRO, 2017) . Commonly, a bank issues a loan (mortgage) to buy a building, including the land on which it is built. However, the costs of demolition and recycling (as well as any residual value) at the end of its life are not part of the financing. The result is that it can be cheaper to leave a building vacant or not be incentivised to realise any value from the material within the building. In addition, the building and land are viewed as part of the same asset, if these were separated,

[12] https://www.bamb2020.eu/

financing may be easier or at least more flexible. There could be a benefit from having land that is easier to access as buildings can be dismantled quickly and reused elsewhere.

Moving towards circular buildings requires an alliance of parties that collaborate to deliver services. To do so, material reuse has to be the starting point, both during renovation (interior and exterior) and at the end of the lifecycle. This new chain is also based on an integrated lifecycle approach to investment decisions and design. The producer or financer remains the owner of the resources and is responsible for the residual value. The residual value of materials remains on the balance sheet and can be estimated using resource model predictions. Building in such a way that materials have a residual value instead of a negative value (disposal costs) makes investing in circular design useful. The customer pays for the performance of the building or a section of road, instead of the function. This shifts the responsibility for good maintenance and management from the customer to the owner of the materials. Investments in the adaptability of buildings generate value in the long term because the needs of (future) users are more easily met, as such there is value though utility, though there is little empirical evidence to support this within the literature.

Banks such as ABN Ambro are investigating how to allow for higher investment costs which justify lower running costs and a higher final value of the building elements. This therefore means a relatively higher loan-to-value ratio for a project, and a relatively smaller amount of equity capital relative to the loan capital. More (hybrid) financing products can further facilitate the financing. These could be equity, risk funds or other forms of financing besides bank financing. (Circle Economy and ABN AMRO, 2017)

Valuation

A building constructed according to a circular method has added value for investors. The value of real estate is currently linked mainly to the price of the location and the difference between rental income and operating costs. Often, the value of the raw materials in the building is of secondary importance. This view will change fundamentally in the transition from a linear to a circular economy. In addition, the purpose for which buildings are used changes with increasing regularity. A building that can be converted easily and inexpensively to another function has more potential future value than a one-purpose building. As a result, the investor knows that when the current tenant's lease is terminated, it will be relatively easy to re-let the building, possibly for a different use. However, current investors' relatively short-term investment visions of between five and ten years and the highly limited or total absence of appreciation of this added value by surveyors often forms a barrier. Research by Ellison et al., (2007) suggested that only a very limited interpretation of adaptability, relating primarily to the flexibility of internal spaces, was currently factored into commercial property valuations. Consequently, valuations fail to reflect other forms of adaptability, such as the ability to accommodate changes of use. Ellison et al (2007) concluded that:

"An appraisal that fails to reflect a property's potential to adapt is likely to be proved erroneous over time by not accurately reflecting the extent to which one property may represent a higher risk in terms of depreciation than another. This is of growing importance to investors as lease lengths shorten, making re-lettability a more critical issue, and as discount rates fall, increasing the significance of cash flow over the lifetime of the asset."

McAllister (2009) suggests that property valuations play an important role in the property market by acting as a surrogate for prices, but he also argues that '… there is some anecdotal evidence to suggest that valuation can act as an impediment to innovation in property markets. This is because property values tend to be based on information from past transactions; in other words, if there is no evidence that a design attribute has added value to a building in the past, then valuers will not ascribe any

additional value to those attributes in the present. This can result in a vicious circle, whereby developers will not include a particular design attribute in their buildings because valuers do not consider that it adds value, and valuers do not consider that it adds value because developers do not include it in their buildings.(Pinder, Schmidt and Saker, 2013)

One of the few empirical studies to (inadvertently) provide an insight into the relationship between adaptability and rental values was undertaken by Baum (1994). Baum was interested in understanding why some buildings experience higher rates of depreciation than others, so he explored this by statistically analysing the relationship between building characteristics and rental values, using data from 125 office buildings in the City of London. He found that internal configuration (floor to ceiling height and floor layout) and internal specification (quality of finishes and services) were the most important determinants of depreciation in the sample buildings. Baum suggested that because demand for these characteristics would change over time (due to changes in working practices, fashions, etc.) property investors should look to purchase buildings that were flexible, in terms of their configuration and internal specification. He concluded that 'Flexibility reduces the risk of an irreversible and major reduction in the market value of a building'.

Re-usable components

Construction materials have been reused and remanufactured in the UK since at least Roman times. There are many examples from the past of the reuse of materials. The Anglo-Saxons used reclaimed Roman bricks to rebuild the abbey of St Albans, followed by the Normans who reused old Roman masonry in many of their buildings. In 1928, when McAlpines built the new Dorchester Hotel in Park Lane, London, they ordered that bricks from the demolition of the former Georgian mansion on the site, Dorchester House, should be reclaimed and reused in the building of council housing in outlying estates in north London. Reuse was a natural first choice for any materials arising from demolition. However, in the last twenty years there has been a shift away from reuse towards recycling, and latterly towards energy from waste. This was confirmed by two recent BigREc surveys, which show that 25% less material was being reclaimed in 2007 than in 1998, and that reclamation was becoming more difficult. Overall the reclamation trade in 2007 shows a large increase in value of sales but a general decrease (25% less in 2007 than 1998) in the volumes of materials salvaged, with the demand for reclaimed products increasing (Kay and Essex, 2012). It should also be noted that the charitable status and reliance on volunteers for community reuse has tended to make re-use rather local and low key[13].

There are many examples are found in the literature of beneficial reuse of standardized, unpowered products and components, and reusing an item is always found to be less energy intensive than new production or re-processing. There are some immediate opportunities, posing few technical challenges, to reuse energy-intensive unpowered products. If the product is powered, the environmental impact of the use phase is often dominant. In this case, it is important that short-lived products are fully restored to their original efficiencies. For longer-lived products, there is the possibility that more-efficient, new products now exist, and unless an upgrade to modern efficiency levels is possible, it may be better to replace the old product and pursue reuse of its components. When new product efficiency trends can be predicted with some confidence, it appears that designers can justify adding material in the production stage (increasing durability, standardization, or modularity) to facilitate reuse end of life.

13 https://www.ciwm.co.uk/ciwm/news/2016/ciwm%20report%20proposes%20collaborative%20approach%20to%20support%20the%20future%20of%20reuse.aspx

There are a number of challenges affecting reuse, which are based on the current model of business and the lack of design of products and buildings for end of life considerations. These all have the potential to be reduced going forward if design for deconstruction becomes commonplace. Depending on national and local circumstances, these can include:

- Mismatch of supply and demand –both in terms of quantity and quality. If heavy materials need to be moved long distances to reach their markets, this can increase costs and environmental impact significantly.

- Insufficient time allowed for deconstruction and careful packing of Re-usable items –the length of time needed to deconstruct can be unappealing where extra costs are incurred through having a building (such as local property taxes) or loss of revenue on a replacement building owing to an extended scheduling of works. There can also be a time constraint linked to planning permission expiration.

- Lack of facilities locally –some countries, such as the UK, have a good spread of reclamation facilities, although space is limited and expensive in highly built up areas. This can cause a disparity between the location of the stocks of reclaimed items and the market for such items. The third-party costs will need to be added to the purchase price, which can diminish the attractiveness of reclaimed products compared to new. This is particularly key when matched against possible risks associated with reuse.

- Reluctance to use products without certification of tested performance is one of the biggest barriers to reuse, particularly in a structural capacity. Often there is very little information on where the product has come from and its length of use in a particular application. This means that the 'worst case scenario' is normally applied to the potential reuse applications. Testing of performance can be expensive and require destruction of samples to mitigate possible risks of further use. These costs will be added to the cost of the product/material and may override savings from reuse.

- Health and safety risks of manual deconstruction are considered to be a key reason for the move to mechanical demolition techniques. Whilst these risks can be mitigated through improved data on the building design and composition, such information is often not available.

- Building technology is a mixture of traditional and rapidly changing techniques. Both can cause challenges in further reuse, such as cement mortar used in brick and block construction, through to rapid fix, prefabricated panelised systems which are multi-material composites.

- Value of products and materials can be an opportunity or a barrier. In case of low value/cheap products and materials, the incentive to reuse versus the cost of careful removal can be low or negative.

To overcome some of these challenges, several opportunities are identified:

- Reuse of offcuts and surplus materials within the construction project (or exchanged with nearby projects)

- Design for deconstruction and adaptability

- Pre-demolition audits, on-site sorting and separate collection

- Waste exchanges and industrial symbiosis
- Standards and testing of products to promote reuse
- Planning and procurement practices which promote incorporation of reclaimed products and materials
- Involvement of the community sector to maximize local benefits

There have been studies undertaken estimating the reuse potential of certain construction products, largely from a technical viewpoint (see Figure 4) and various authors (for example Iacovidou & Purnell 2016) have developed typologies for the reuse of products, again based largely on technical criteria.

Reuse potential rates of a range of construction components.

No potential (0%)	Low (<50%)	Medium (~50%)	High (>50%)
Clay bricks (cement-based mortar)[a,f]	Mineral wool[b,e]	Steel cladding (buildings)[c]	Clay bricks (lime-based mortar)[a,h,f,o]
Steel rebar (buildings)[c]	Gypsum wallboard[a,h,e,g]	Steel cold formed sections (buildings)[c]	Structural timber[h,e,f,g,l,l]
Steel rebar (other infrastructure)[c,i]	Steel rebar in pre-cast concrete (buildings)[c]	Steel pipes (buildings)[c]	Structural steel (buildings)[c,f,j,m]
Steel connections[c,f]	Structural steel (infrastructure)[c,h]	Pre-cast concrete[a,m]	Concrete building blocks (with lime mortar)[a,f]
Structural concrete (buildings)[d,e,f,g,i,l]	Timber trusses[m]	Slate tiles[p]	Concrete paving slabs and crash barriers[j]
Asphalt (other infrastructure)[d,g,i]	Concrete in-situ[a,j,k,l,n]	Timber floorboards[p]	Clay roof tiles[j,l]
Asphalt roof shingles[e,m]	Concrete fencing, cladding, staircases and stair units[f]		Concrete roof tiles[j,l]
Plastic pipes (water and sewage), roof sheets, floor mats, electric-cable insulation, plastic windows[n]	Glass components (e.g. windows)[d]		Stone paving[f,j,p]
Concrete pipes and drainage, water treatment and storage tanks and sea and river defence units[j]			
Non-ferrous metal components (aluminium window frames, curtain walling, cladding, copper pipes, zinc sheets for roof cladding)[a,i,n]			Stone walling[f,j,p]

Figure 4: Example of reuse potential for construction products

There is little reference to the economic considerations , and/or motivations i.e. the potential benefits for reuse and to whom they flow to although recent studies for structural steel have shown this to be cost neutral (depending on the price of new steel) (Dunant *et al.*, 2018), and studies from the likes of BedZed, have shown that reclaimed structural steel and timber are available cheaper than new and offer 96% and 83% savings in environmental impact (Lazarus, 2005)(see Figure 5). There are also guides available showing the cost differences of reclaimed and new products such as the WRAP and Salvo Guide[14].

[14] http://www.wrap.org.uk/sites/files/wrap/Reclaimed%20building%20products%20guide.pdf

Material	Off-the-shelf product	Achieved on BedZED	Easy	Cost implications
Reclaimed steel	x	✓	Fairly Easy	Neutral
Reclaimed timber for internal studwork	x	✓	Fairly Easy	Saving
Reclaimed timber for external studwork	x	x (small quantity)	Difficult	Cost Premium
Reclaimed floorboards	x	✓	Easy	Saving
Reclaimed bollards	✓	✓	Easy	
Recycled aggregate	✓	✓	Fairly Easy	Saving
Recycled crushed green glass sand	✓	✓	Easy	Saving
Reclaimed doors	x	x	Difficult	Cheaper than equal quality but more expensive than B&Q
Reclaimed paving slabs	x	x	Difficult	Neutral (with storage space)
Reclaimed shuttering ply	x	✓	Easy	Saving
Re-used sub-grade fill	-	✓	Easy	Saving

Figure 5: Summary of reuse of products on BedZed development (Lazarus, 2005)

An example is provided of the potential for reuse for building services

Building services

For building services, by utilising Re-usable services components, facilities managers may be able to increase the adaptability of both new and existing buildings and reduce the financial impact of change. With an anticipated future increase in the frequency of building adaptation the likelihood is that more services components will become functionally - rather than economically or physically - redundant corresponding with a reduction in the duration of their application. These functionally redundant components retain a significant residual physical life and potential for future use. Due to their embodied residual physical life and un-depreciated capital investment the potential value of such components, if recovered for reuse, is likely to be substantially higher than if they are disposed of as scrap (Webb, Kelly and Thomson, 1997). However, to enable reuse, they are likely to have been regularly maintained during their prior installation. Such maintenance minimises the extent of reconditioning or overhauling required before reuse. The need to accommodate rigorous maintenance requirements necessitates that these components types are physically durable and, consequentially, they tend to be of long life. In addition, these component types can be readily identified within and isolated from their surrounding installation (i.e. they are non-bespoke in nature). Compared with services installation elements such as pipework and ductwork runs, the ease of physically relocating these components is apparent (Thomson, Kelly and Webb, 1998).

Some figures are available when focusing on remanufacture of compressors within (HVAC) systems. Remanufacture of HVAC units is limited almost exclusively to the larger plant (> 50 kW) because the lower power markets are dominated by low price competition. Low capacity compressors are also hermetically sealed making remanufacture more difficult; in essence, these units are designed to be thrown away at the end of their useful life. Although cost is the primary reason for remanufacturing, other factors are also important. Company lease agreements may require that at the end of the tender the building is handed back with working air conditioning. To achieve this, the company can use

remanufacturing to significantly increase the lifetime of the air conditioning without requiring a new installation. Another issue with cost is not simply the capital investment in plant, which will only make up approximately 50 % of the overall cost of a new unit; there are significant consultancy fees for recommending new equipment and installation cost can be extremely high. The logistics of installing bulky, heavy equipment on the roof of a working building can lead to prohibitive costs. In addition to these costs is the (less quantifiable) cost of disruption to the workforce occupying the building while the installation is being performed. This makes the remanufacturing option more attractive. However, refurbishing a compressor can be a costly option. For instance, the value of remanufactured compressors is 75 % of a new unit. Only compressors of over £1,000 are considered for remanufacture. Therefore, general maintenance - such as repairs and replacement of components - is more common in order to maximise a compressor's lifespan before considering end-of-life options: refurbishment or new purchase (The Scottish Government, 2015).

Case studies

A number of case studies are highlighted below for circular buildings and products which have either cost information or have embarked on circularity.

Park 2020 (Netherlands) (Leising, Quist and Bocken, 2018)

Park2020 is an office area which is based on the Cradle to Cradle (C2C) philosophy, with closed cycles of water, waste and energy. The most innovative element is the inclusion of end-of-use options for buildings right from the start and the application of 'material passports, which allows for tracking of materials and their corresponding residual value along the lifecycle of a building. Where possible, suppliers retain ownership of their materials, urging them to come up with solutions that can be disassembled easily to regain material value at the building's end-of-life. Examples are components such as the LED light system, solar panels and office equipment. The process for Park2020 was initiated by developer Delta Development Group (DDG) in close collaboration with architect and C2C founder William McDonough. The project was led by a dedicated construction team that included a developer, an architect, a general contractor, a building installations advisor, interior designer(s) and an installation company. The 'construction team model' is a multidisciplinary collaboration model where participants collectively work on the preparation of a building project while retaining their autonomy and responsibility. It is a bilateral agreement between the commissioning company (in this case DDG) and the general contractor. For each office building, a six weeks workshop series was held with its tenants and clients. The aim was not only to get to know clients and their requirements, but also to get clients acquainted with C2C principles. This is an important change in the building process, where a common language between client and construction team was established.

Alliander Headquarters (Netherlands) (Leising, Quist and Bocken, 2018)

Alliander is a Dutch energy grid operator who wanted to create an iconic project and revealed high sustainability ambitions for the renovation of its office in Duiven. This resulted in a project in which five existing office buildings were transformed into one sustainable building. Materials were reused as much as possible. Take back management of the materials was put in place via 'material passports'. The process started in 2010 when Alliander redeveloped its real estate strategy and implemented a novel way of assigning a building project. Instead of specifying requirements, needs were the starting point allowing for innovation in both the building itself and the building process. Alliander summarized its needs and ambitions in a strategy document. This included a C2C building and a positive energy balance, as well as social ambitions, such as the creation of a pleasant working environment, a collaborative building process, and combining functions of the building with its surrounding area (e.g. combining work

and leisure activities). This strategy document was used in the tender phase when Alliander asked consortia of building parties for a vision meeting their ambitions, instead of an initial design for the building. The winning consortium, led by the general contractor and the architect, turned the vision into an actual plan for the renovation. The most important design characteristic was the glass atrium connecting the five existing buildings. This atrium creates space and improves the energy performance of the building, because large parts of former outer-walls would become inner-walls. The atrium is made of a steel structure realized by a rollercoaster construction. Rollercoasters are pre-eminently built for disassembly, using as little material as possible. The process can be described as a co-creation between the consortium involving different building disciplines and Alliander as instance, the supplier retains ownership of the elevator and its materials.

Venlo Town Hall (Netherlands)[15]

At the start of the project, the municipality concentrated on creating a design team in the Netherlands with the right mind set with regard to sustainability, by asking architects to present a vision, with special attention to C2C; then selection criteria were used. The target was to construct a building using only Re-usable materials that generates energy, purifies water and improves air quality. The building was only needed for 20 years as such they agreed with several suppliers that they would be willing to buy back their materials (for example furniture) after some years at pre-set prices. This creates a continuous cycle of resources. To achieve this, almost everything can be dismantled. There are several cycles in the building. The south façade is constructed using aluminium and is fully Re-usable without losing any of its value. The biological north façade consists largely of plants and greenery. In terms of the business case, then an additional investment of €3.4 million, will bring a net result of €16.9 million, after a defined use time of 40 years, with a ROI of 11.5%.

SEGRO Relocation (UK)[16]

SEGRO dismantled an office and warehouse space (3180m^2) and re-erected at 9 Cambridge Avenue (around a mile away), reusing existing building's components wherever feasible. Sturgis Carbon Profiling was commissioned by SEGRO plc to assess the Whole Life Carbon impact of this in order to understand any potential carbon savings compared to a new build; and identify options that could reduce its embodied carbon impacts further. The key achievements included

- 56 % lower embodied carbon at practical completion compared to a comparative new build
- 25% saving in costs compared to a comparative new build
- 6% lower whole Life Carbon Footprint compared to a comparative New Build
- The re-use and recycling of building components also allowed a saving of 25% in costs of materials for the building compared to a comparative new build. A large proportion of the saving comes from reusing the superstructure components.

[15] https://www.circulareconomyclub.com/listings/research/circular-cities-circular-buildings-new-guidance/
[16] https://asbp.org.uk/wp-content/uploads/2016/07/9-Cambridge-Avenue_as-built_040820141.pdf

The savings could have been further extended had the other components also been re-usable, and the superstructure been designed for dismantling and reuse from the outset.

Circular Building (UK)[17]

Developed by Arup, Frener & Reifer, BAM Construction and The Built Environment Trust the circular building is a prototype which is designed for all the elements to be dis-assembled and re-used. This full-scale prototype is intelligently designed and constructed with materials that can be removed with minimum damage, helping each component to retain its value. Digital technology is used to 'tag' all items, including everything from window frames to individual fixings, each with a unique QR code containing information allowing it to be reused. All the data collected from the build can be viewed using a Building Information Model, as a virtual 'Materials Database'. A high percentage of materials and products sourced with a C2C design ethos have been donated by a number of partners, collaborating on this prototype.

Land Rover Ben Ainslie Racing Building (UK)[18]

In line with its commitment to becoming the most sustainable sports team in the UK, Land Rover BAR created a headquarters that showcases all that is sustainable. Designed by HGP Architects and built by Allied Developments, the innovative building saw sustainability embedded from the outset with 98% of all demolition, excavation and construction waste diverted from landfill and 100% of the demolition concrete reused in the foundations as secondary materials. BIM enabled the design team to undertake life cycle analysis of the design choices whilst providing informed options for in-use performance monitoring. This encouraged circular thinking about procurement of construction materials and products – how they will perform in-use and what options are available at the end of their life in terms of reuse or recycling.

The Ark Building (UK) (WRAP, no date)

Located in Hammersmith, West London, the Ark Building was acquired by General Electric (GE) Capital Real Estate and O&H Properties for £49.5 million in 2006. An additional £20 million has subsequently been spent on a major refurbishment programme which focused on optimising the use of space while providing 360- degree natural lighting and retaining the building's iconic features such as the cathedral-like atrium. A full pre- refurbishment audit of all existing spaces was undertaken to determine what materials could be retained, and what should be replaced. As a consequence, certain areas, such as toilet facilities, were retained and upgraded. The reuse of existing materials was also prioritised over purchasing new materials which helped to avoid producing unnecessary waste and saved a total of £1,010,000 for the project as a whole:

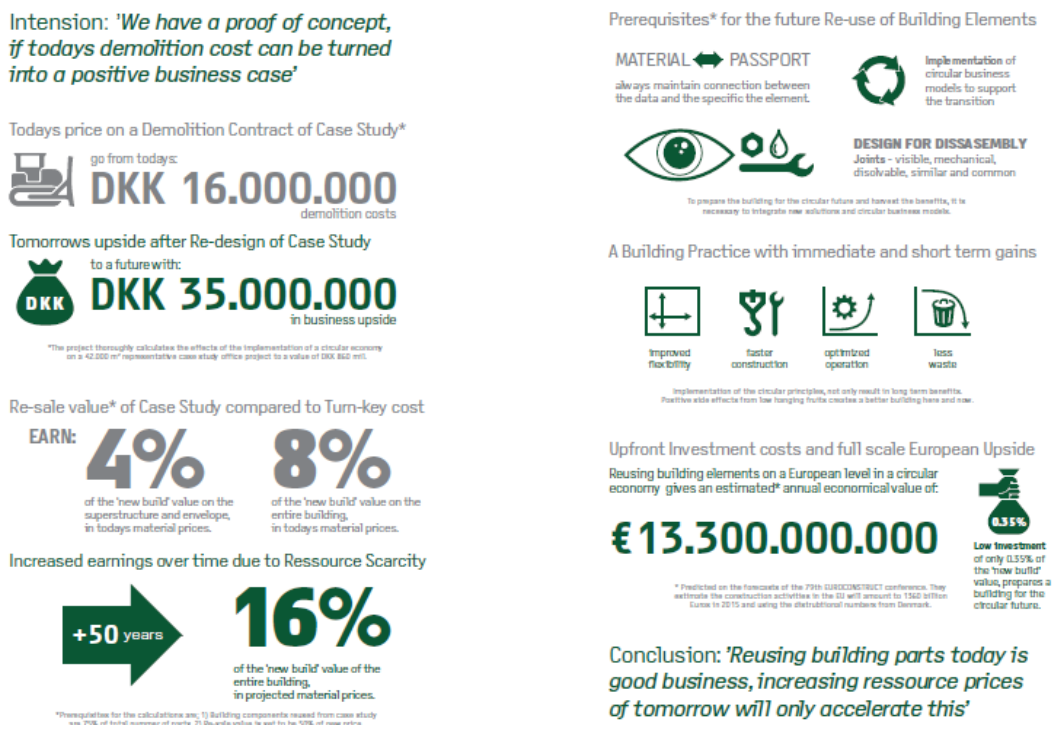
- 100% of existing ceiling tiles were reused and set into a replacement ceiling grid (80% of the total). This saved £490,000 across all floors.

- 100% (4,861m2) of the raised floor access was reused. It was taken up to allow access to M&E services and then re-laid. This saved a total of £505,000

3XN Project (Denmark) (Danish Environmental Protection Agency,, 2015)

[17] http://circularbuilding.arup.com/
[18] https://www.breeam.com/case-studies/mixed-use/land-rover-bar/

Based on a specific 3XN project and existing construction practice at MT Højgaard, the project partners developed and tested a business case based on the project's strategies. This is a 42,000 m^2 office building with 'design for disassembly', a 'material passport' that documents what exactly comprises each element and a description of how the individual parts of a building can be recycled and returned to the circular economy. The financial result is a profit of €4.7 million compared to traditional demolition of a building built for the cost of €115.6 million. The total potential for the whole building, calculated in projected material prices, is estimated to be up to 16% of the total construction cost. By incorporating dismantling and new circular strategies from the start of construction, it is proven that there is an economic incentive and a positive business case (see Figure below).



<u>Bedzed (UK) (use of reclaimed materials)</u> (Lazarus, 2005)

BedZED sourced 3,404 tonnes of reclaimed and recycled materials, 15% of the total materials. All of the recycled and reclaimed materials used were either cheaper than the conventional option or the same price, even after additional staff time was spent on sourcing the material. On BedZED, using reclaimed steel was 4% cheaper than using new. The cost average was £300/tonne, although this price varied considerably according to the source. The comparative tender price for new steel was £313/tonne. The cost of additional staff time in sourcing reclaimed steel and the visual inspection has been estimated at £1,000, making the use of reclaimed steel effectively cost neutral. Key findings included: high grade reclaimed materials such as doors or structural steel are not off-the-shelf products and there needs to be a willingness to work at securing a reliable supply of materials. Long lead times and storage space are particularly helpful in making reclaimed and recycled materials possible.

District Court of Amsterdam[19]

The recently delivered building for the District Court of Amsterdam has a contract period of five years after which the building had to be removed. The architecture firm, an SME which also delivered engineering and contracting services, designed a rather traditional building which however can be easily de-mounted and re-mounted at another site. The residual value of the materials was translated into a reduction of the clients' investment. This shows that shortening the life span, doesn't necessarily reduce sustainability as long as multi cyclic behaviour is modelled, from a circular perspective.

Housing (reuse) (Chini, 2003)

Six one- and two-story houses representing typical South-eastern United States wood-framed residential construction were deconstructed to examine the cost-effectiveness of deconstruction and salvage when compared with traditional demolition. Over 500 pieces of salvaged timber were graded visually to understand the damage resulting from use and the deconstruction process on and the potential reuse for structural applications. The study concluded that deconstruction can be more cost-effective than demolition when considering the reduction in landfill disposal costs and the revenues from salvage. Although the cost of the deconstruction process was on average 21% higher than demolition, the net cost of deconstruction after factoring in the revenue from sales was 37% lower than demolition.

Other housing examples

These include PLACE Ladywell[20], which used redeployed housing for a short-term solution, ZedPods which can be built over car parks and moved as required[21], the Circle House[22] showing high levels of reuse and the Adaptable House[23], feature adaptable design solutions.

PLACE Ladywell
- Deployable housing
- Volumetric construction
- Site vacant pending redevelopment
- Short-term solution (1-4 years)
- 24 homes + ground floor retail

Adaptable House
- Single-family detached home, Denmark
- Designed to adapt to changing needs of family
- Can be altered/ extended with reduced CO2 and materials use

ZedPods
- Designed for urban car parks, hard standings
- Assembled on ground or raised platforms
- High-performance, low-energy housing
- Delivered in a fraction of the usual time

Circle House
- 60 social housing units
- Townhouses & tower blocks
- 90% can be disassembled and reused – without losing significant value
- To be completed by 2020

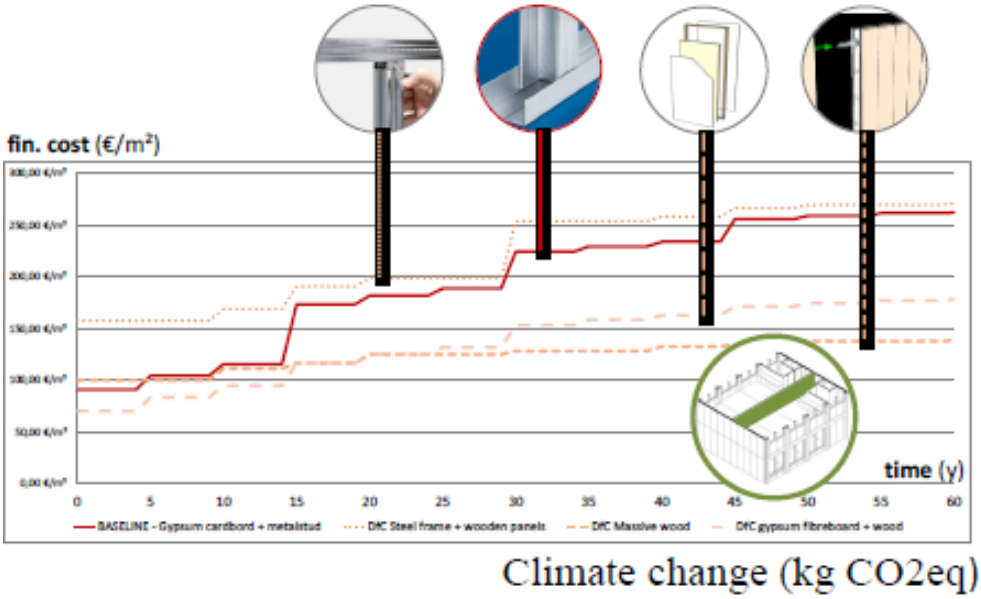
[19] https://www.circle-economy.com/wp-content/uploads/2016/04/Circular-Amsterdam-EN-small-210316.pdf
[20] https://asbp.org.uk/case-studies/placeladywell
[21] https://zedpods.com/
[22] https://urbannext.net/circle-house/
[23] https://www.archdaily.com/546890/adaptable-house-henning-larsen-architects-gxn

Circular Pavilion , Amsterdam[24]

Circl, a new pavilion in Amsterdam's Zuidas district which has been created by the bank ABN AMRO to share knowledge it has gained about circularity and advise its clients effectively about that issue. It is designed and constructed according to sustainable and circular principles. Circl has been created to be energy efficient and easy to disassemble, with many of the raw materials being circular. ABN Ambro took a very active role in the design and construction, and at one point stopped the construction process, in effect to start again, to ensure that circularity was embedded on all design and operational aspects.

BAMB Pilots[25]

The BAMB project, has a number of pilot projects where they are testing some of the outputs from the BAMB project, to provide a feedback loop. This includes undertaking economic and environment assessments for some of the circular designs. This includes a wall system, which shows that whilst there are higher initial financial costs for the reversible interior wall solutions, they pay back, once the transformation (either first or second) has taken place, and there are lower refurbishment and disassembly costs, as shown on the following graph:



Reuse on the London 2012 Olympics[26]

[24] https://www.abnamro.com/en/about-abnamro/in-society/sustainability/our-focal-points/circular-economy/circular-construction/index.html
[25] https://www.bamb2020.eu/
26 https://www.bioregional.com/wp-content/uploads/2015/05/Reuse-and-recycling-on-London-2012-olympic-park-Oct-2011.pdf

There was some reuse on the London 2012 Olympics which included the reuse of 7 steel portal frame buildings re-erected elsewhere, as well as some of the event components. However, a key failing for more reuse, was the lack of a separate target; it was included with recycling. An economic analysis of the opportunities for reuse and reuse of bricks was undertaken.

Historic buildings

There are some examples of analysis of the reuse of historic buildings (in situ) rather than demolition, which includes estimates that its saves 23% energy, and would take 40-65 years to recoup the wasted embodied energy of the existing building[27]. Other studies show the value and impact of heritage on community, economy[28].

Adaptable Buildings

There are a number of case studies, which show how buildings can be adapted throughout their lifetime, including those from Adaptable Futures (http://adaptablefutures.com/); however there is little information in relation to the financial cost and benefits with the case studies largely focusing on the technical aspects of the design.

Products

There are an increasing number of products that are being marketed as circular from a technical perspective – for example they may have high amounts of recycled content, be remanufactured or from natural materials. The examples chosen below to illustrate some of the business models that sit behind a number of circular product offerings, rather than focusing on the technical aspects.

Phillips Lighting[29]

Perhaps the best known, circular business model is that of Philips Lighting, who have developed a "Pay-per-lux" intelligent lighting system. Several features on the system lead to a 55% reduction in total energy consumption including the installation of LED lights, a focus on natural sunlight and a sensor to dim or brighten the artificial light depending on how much natural daylight is entering the building. The lighting system is provided as a service to the customer, with Philips Lighting retaining ownership of the assets and providing maintenance, upgrades and end of life recovery. This has been used in the office refurbishment of National Union of Students (NUS), whereby they provided £120,000 of LED lighting, along with controls, instead of less efficient T5 lamps that the NUS would have installed with its original budget of £40,000. The NUS pay a quarterly rental payment, if the energy use exceeds the figure that was agreed for energy consumption, then they pay less rent.

Mitsubishi Elevator Europe (ING, 2017).

Mitsubishi Elevator Europe provides a service model for lifts with its M-Use®. In the concept, Mitsubishi continues to own the lift system and provides support to the end user. This is a deviation from the maintenance model in which the lift is purchased in combination with maintenance. M-Use® provides 'vertical mobility'. Result agreements regarding the service are easy to make for the lift based on the

[27] https://sheffieldtimewalk.wordpress.com/2015/08/12/the-economics-of-reuse-vs-demolition-and-rebuild/
[28] https://historicengland.org.uk/research/heritage-counts/.
[29] http://www.lighting.philips.co.uk/cases/cases/education/national-union-of-students

maximum number of failures (one a year) and number of hours the lift is out of operation (15.5 a year). Lifts are relatively complex products meaning that Mitsubishi as supplier can exploit its knowledge advantage over other (maintenance) companies and is able to offer maintenance efficiently. Through the use of sensors, Mitsubishi knows exactly how often the lifts are used and through remote monitoring, it coordinates the maintenance programme perfectly with this actual use. While at the same time, the life span of the product is increased. Mitsubishi is a keen supporter of the reuse of lift parts and the recycling of materials to promote more circularity. For the financing the user still pays the system costs at the start, but these are much lower (up to half) than for traditional purchase. Additionally, the user pays an annual amount

Interface[30]

For the past decade, Interface has worked particularly hard on developing a design technology which could facilitate the debonding of carpet and allow for the remanufacture of this product. Through ReEntry 2.0 both yarn to yarn, and backing to backing recycling can successfully take place. One of Interface's biggest challenges with the remanufacturing of carpet continues to be the return of the end-of-life product to its remanufacturing facilities. Due to the longevity of carpet, the original purchaser of the carpet may not be able to have influence over its disposal. Additionally, many consumers are unaware of where to return the product or simply do not recognise the carpet as valuable enough to return to a manufacturer. The relatively low cost of disposal for carpet in the UK has meant that there is little incentive to look for alternatives to landfill. In an attempt to tackle this issue, Interface has developed a business model, known as Evergreen which leases carpet tiles instead of selling them, allowing the company to maintain ownership of the product and ensure it returns to Interface at its end-of-life stage. Interface produces, installs, cleans, maintains and replaces the carpets for customers, shifting the carpet cost to the consumer from a capital to a maintenance cost. However, this model has faced constant challenges, as it can often be difficult for the costs to be off-set from a one-time expense to a facilities budget.

Premier Sustain[31]

Premier Sustain has developed its business around the difficult logistical issues related to the return of office furniture for remanufacture. Along with providing remanufacturing services, they also organise all logistical issues around collecting furniture and supplying their Renew Centre where components are remanufactured and returned to the customer. A remanufactured desk will typically cost the consumer around £50 and with delivery costs at around £80 the desk can still be up to 50% cheaper than the cost of a new desk (circa £200-300).

Paint[32]

Water based paint constitutes 80% of all paint circulated in the UK and is recognised as relatively non-toxic in comparison to solvent-based paint and has been identified as very easy to remanufacture. Remanufacturing in this industry, however, continues to be hindered by the large volume of paint which remains unused all over the UK, particularly in households where paint is opened, used, stored and often never reused. The British Coating Federation (BCF) estimates that approximately 10% (or 50 million litres) of all paint bought each year in the UK remains unused. According to the BCF

[30] https://www.interface.com/IN/en-IN/about/mission/ReEntry-en_IN
[31] https://www.premierworkplaceservices.co.uk/knowledge-centre-articles/integrating-reuse-recycling-office-refurbishment/
[32] http://www.remanufacturing.org.uk/pdf/story/2p650.pdf

remanufactured paint has a carbon footprint which is 50% lower than virgin manufactured paint. Increasing the use of chemical and paint leasing schemes would boost the paint remanufacturing industry. Chemical leasing comprises of selling chemicals on their functionality rather than their volume. For example, with a chemical leasing model, paints could be sold by coverage rather than by volume. This is already taking place in the chemical industry where some solvents and catalysts are 'leased' and the waste materials are returned to the provider for reprocessing or recycling. Leasing paints would mean that more paints are returned to the original manufacturer allowing for paint remanufacturing to be scaled up and possibly even automated.

Facades[33]

Façade leasing relies on recent technical innovation in the form of multifunctional façades results in building envelopes which have the potential of delivering an ongoing indoor comfort service. This can be done through the use of decentralized, façade-integrated building support systems which replace the traditional installations running through the ceilings and hallways of traditional constructions. This can facilitate their maintenance and replacement, enhances the capacity of the façade to not simply protect the indoor spaces from the weather, but actively generate the energy required to control and monitor the indoor comfort conditions which it also provides. It also relies on innovation in business and management practices, which include new methods of financing, contracting, and operating these new and highly complex building systems. Firstly, it would support the initial design and engineering of components which can be more easily maintained and replaced. Secondly, it would promote high-quality production, based on durability and performance rather than lowest initial cost. Last and foremost, it would enhance the operation and reprocessing of components, incentivising a long-term, ongoing collaboration between the suppliers of building technologies and the clients and users whose spaces are conditioned by the formers' systems.

In September 2016 a consortium of companies, ranging from component suppliers to façade fabricators, installed a pilot project temporarily replacing a section of the façade on the low-rise building of the Faculty of Electrical Engineering, Mathematics and Computer Sciences at TU Delft, commonly known as the EWI building. This pilot project demonstrated the state-of-the-art in façade-integrated technologies and acted as anchor point and collaboration catalyst to further develop the complex system of contracts, financing structures, and operational services required to turn the façade leasing research project into a feasible and implementable proposition. In early 2018 the project consortium has received further funding for the upscaling of this research pilot project to a large-scale practical demonstrator case-study. This demonstrator case-study brings together architects, builders, developers, and managers of buildings, as well as lawyers, financiers, scientists, and business developers, to produce the first practical example of a Façade-as-a-Service performance contract.

[33] https://www.tudelft.nl/en/architecture-and-the-built-environment/research/projects/green-building-innovation/facade-leasing/facade-leasing-pilot-project-at-tu-delft/

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WRAP (no date) 'Fit out of a central London office block'. Banbury: WRAP.

Appendix 3: Stakeholder interview questions

Name:

Organisation / Contact details (consent to use them for this project):

Job Title or department in the organization represented (e.g. finance, development, sustainability…)

1. **Has your organization considered / piloted / investigated issues of circular economy already – if so what was the outcome?** (WRAP definition of a circular economy "A circular economy is an alternative to a traditional linear economy (make, use, dispose) in which we keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life".)

2. **Would your organisation be willing to consider reusable building solutions such as those below? What would be the arguments which might persuade you?** (these might be financial, time, social, allowing use of marginal sites if that is an issue for them)

The focus of this project is on the re-use aspects of CE - specifically 4 potential business cases:

a. '**Deconstructable** ' - where refurbishment or demolition and re-use have been facilitated by design

b. **'Flexible'** - would allow fast delivery, deployment and re-deployment – e.g. if demographic changes mean that location no longer requires that building function, or less e.g. a social housing "fleet" for London.

c. '**Adaptable' -** where change of use is anticipated in initial design (e.g. repurposing Olympic Park athletes accommodation to become classic apartments through anticipating need for kitchens at design stage. This can also allow "for now" uses or enhanced ability to upgrade / retrofit and therefore life extension.

d. '**Returnable ' -** where the use is foreseeable for a limited period, and the functional elements are rented and returned when no longer required. This might be at building or at element / system level (e.g. rainscreen cladding panels with incorporated PV's or solar heating). There is a parallel to "software as a service" in IT solutions.

Note: in discussion with many stakeholders these models were developed into the 5 business models shown in this report.

3. **Would you be willing to take part in our follow up to this initial interview (e.g. short day facilitated workshop with other clients representatives) or would you just like a summary of our report once we have completed the feasibility stage?**

4. **Please answer these about your organization.**

   a. **What type of newbuild or major refurbishment developments do you currently undertake?** (e.g. which sectors, which areas / regions, are they speculative or for identified clients, any minimum / maximum size of developments in area or cost, how frequently do they undertake developments, how experienced are they, why do they prefer one or the other?)

   b. **Do you currently own land for development, or is it bought at the time of development – do you have land that is hard to develop currently?** (e.g. narrow / small / inaccessible sites can be difficult to develop but also how do they choose the land for development – are they rejecting sites because they don't think they can be effectively developed traditionally.)

   c. **Who are the key decision makers in your development choices?** (these could be internal or external influencers, e.g. funders or regulators for public sector or particular departments / Board reporting lines) *Try also to identify whether there are specific relevant documents stating mandatory requirements, e.g room data sheets, standard specifications, BCO Best Practice Guides, Costa standard formats / sizes.*

   d. **How is sustainability incorporated into decision-making, and how importantly is it viewed? How do you engage with your end users and ascertain the market offer in respect of building sustainability?** (e.g. do you have a statement of environmental policy, do you consider stakeholder value to be the only key issue, do you have a corporate social responsibility commitment, is it 'bottom line' finances only or is long term cost / income considered? Do you see these aspects as near future or medium or distant future? Are there threats as well as opportunities?

Appendix 3: Stakeholders interviewed

Below are the clients and developers that were interviewed as part of this project.

Commercial	Retail	Social housing
Argent	Marks & Spencer	Lewisham
Derwent	John Lewis	Tower Hamlets
Great Portland Estate		PLACE
Crown Estate		Clarion
		Telford Homes

A couple of other conversations were had with investors.

Investors
Hermes Investment
Aberdeen Standard Investments

Workshop attendees:

There were representatives from the following present at the workshop.

Businesses Present
Lewisham
Telford Homes
PLACE Ltd
Tower Hamlets
London Councils
Sixty Bricks
London Borough of Wandsworth
www.freeliveproject.com
Clarion

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Appendix 4: Workshop output

Reusable Buildings Network

Working session to explore potential within the social housing sector – write-up

November 2018

FORUM FOR THE FUTURE

1. Purpose

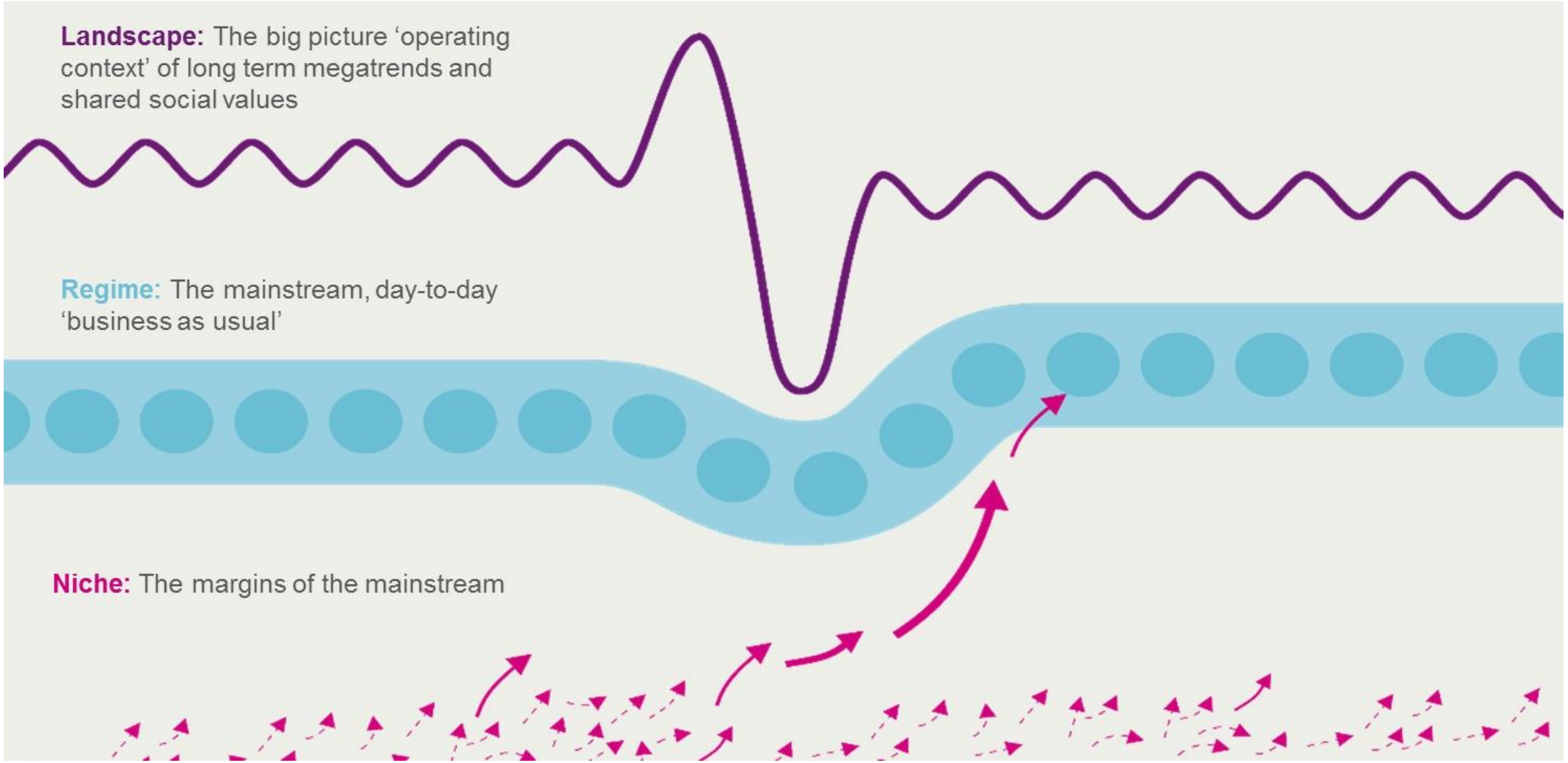
Purpose of the RUBN project:

- Develop and articulate the business case for Reusable Buildings, focusing on the demand side (clients)

Purpose of the workshop (31 Oct.):

- Explore drivers of change for the built environment
- Test and develop a future vision and scenario/business models
- Identify barriers, enablers and key actors (to inform a roadmap)

2. Exploring future trends – how systems change



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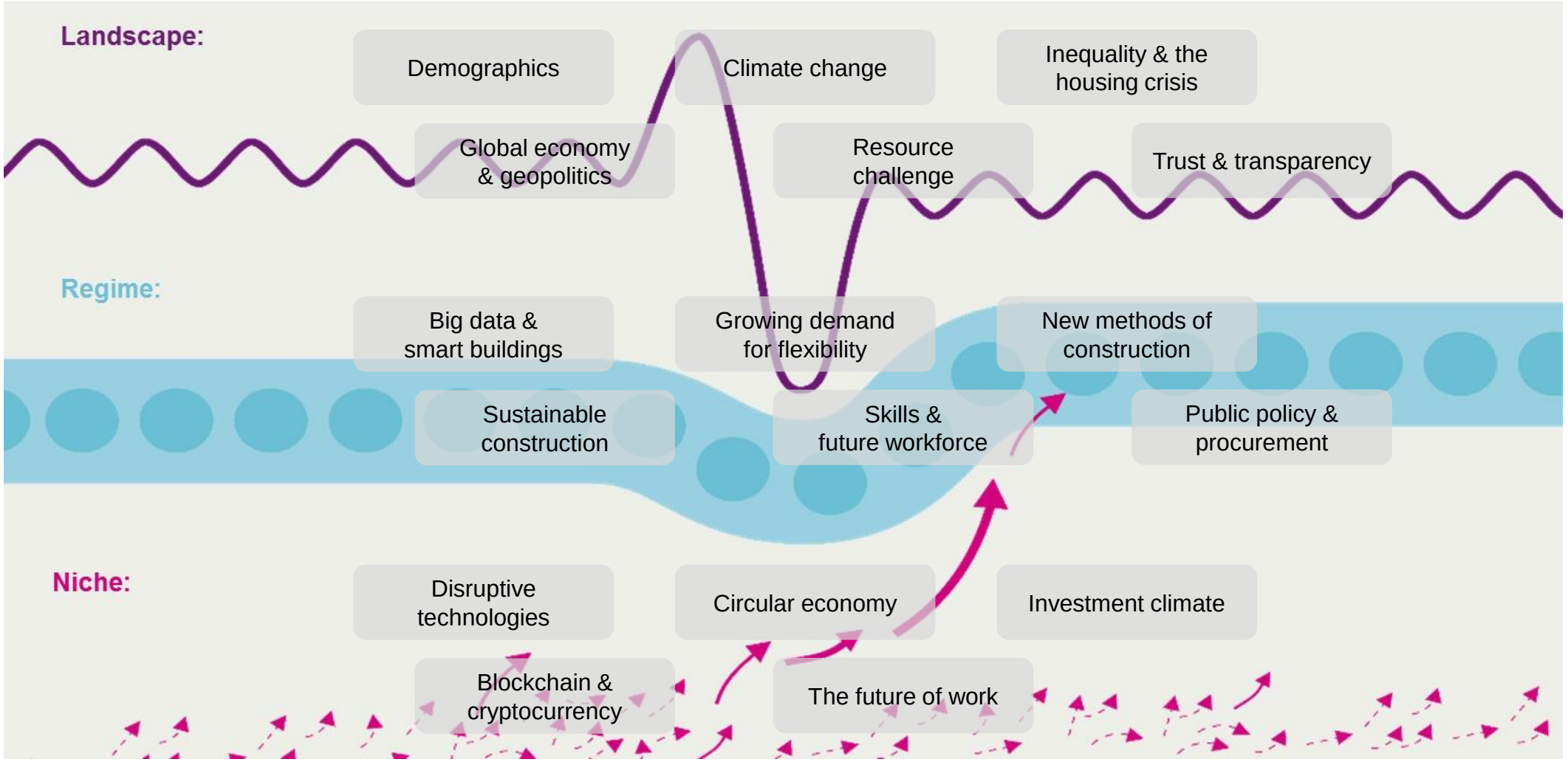
2. Exploring future trends – social housing marketplace



2. Exploring future trends – trend clusters (group 1)

Market drivers

- Investment climate
- Trust & transparency
- Global economy & geopolitics
- Public policy & procurement

Demand & expectations

- Demographics
- Growing demand for flexibility
- Inequality & the housing crisis
- Sustainable construction

Workforce available

- The future of work
- Skills & future workforce

Tech enablers

- Big data & smart buildings
- Disruptive technologies
- Circular economy
- Blockchain & cryptocurrency
- New methods of construction

Unstable environment

- Climate change
- Resource challenge

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2. Exploring future trends – trend clusters (group 2)

Quality of place

- Climate change
- Global economy & geopolitics
- Resource challenge
- Placemaking & community
- Governance

Market drivers

- Trust & transparency
- Sustainable construction
- Public policy & procurement
- Investment climate

Market innovation

- Circular economy

Tech enablers

- New methods of construction
- Disruptive technologies
- Big data & smart buildings
- Blockchain & cryptocurrency

People & users

- The future of work
- Growing demand for flexibility
- Demographics
- Skills & future workforce
- Inequality & the housing crisis

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3. Characteristics of a Reusable Buildings market

Characteristics of an effective future **vision**…

- Positive, inspiring
- Stretching, but plausible
- Sense of scale
- Illustrative examples
- Logical, practical, pragmatic
- Broad ownership & support (popular among users)

…and the supporting **roadmap**

- Shows the transition process
- Clear on whether *regime or niche* accelerates the change

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3. Characteristics of a Reusable Buildings market

Feedback on original vision

- Point about leasing needs clarifying
- Market must be competitive – many different providers – but compatible
- Show empathy – what's in it for tenants, communities?

3. Characteristics of a Reusable Buildings market

Revised vision

The future social housing marketplace is one where traditional construction is a thing of the past, where reconstruction and redeployment are commonplace. A world where buildings can be flexibly changed, adapted, expanded and reduced according to demand or use.

Where a building built is not a capital cost but a future resource investment. Where the building and its components are rebuild-able, re-deployable, re-usable and resalable – retaining most of their original value.

This is a world where fleets of components, modules or whole buildings can be leased, then returned to the owner (developer, group of local authorities, etc) when they are no longer needed. A vibrant, competitive marketplace – where components from different providers are compatible, aligned to common standards.

Tenants and residents benefit from more housing, at lower cost. As their homes flex in line with their changing needs over time, families stay in the same homes longer – avoiding the cost and disruption of multiple moves, while strengthening community bonds.

Meanwhile, tenants in short-term housing need can access safe, quality accommodation.

And all this at no extra cost.

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4. Future scenario for social housing – examples

PLACE Ladywell

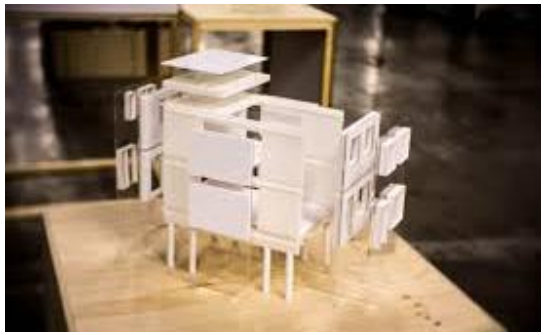
- Deployable housing
- Volumetric construction
- Site vacant pending redevelopment
- Short-term solution (1-4 years)
- 24 homes + ground floor retail

Adaptable House

- Single-family detached home, Denmark
- Designed to adapt to changing needs of family
- Can be altered/ extended with reduced CO2 and materials use

ZedPods

- Designed for urban car parks, hard standings
- Assembled on ground or raised platforms
- High-performance, low-energy housing
- Delivered in a fraction of the usual time



Circle House

- 60 social housing units
- Townhouses & tower blocks
- 90% can be disassembled and reused – without losing significant value
- To be completed by 2020

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4. Future scenario for social housing – part 1

The following business models are now commonplace:

Flexible redeployment

- For housing in meanwhile spaces, or to address urgent/short-term housing needs
- Can be quickly redeployed, multiple times, to different locations
- Initial build cost slightly higher than business-as-usual
- Minor refurb & redeployment >50% cheaper than new build, with zero cost of demolition

Adaptable buildings

- To meet changing family needs and demographics
- Can be subject to multiple significant changes in type and use
- Initial build cost slightly higher than business-as-usual
- Major & minor refurb/repurposing >50% cheaper than new build, with zero cost of demolition

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4. Future scenario for social housing – part 1

FLEXIBLE REDEPLOYMENT

What **benefits** does this model provide?

- Permanent approach to meanwhile sites
- Better solution for homeless people
- Lower cost than alternatives
- Allows for re-planning of sites: plan regeneration
- Allows decanting
- Testing a concept – advocating disruption

What are the **barriers** to this mainstreaming?

- Identification of suitable meanwhile sites – boroughs often not aware of what they own
- Competing priorities for sites e.g. big infrastructure
- Scaling/procurement – additional upfront cost
- Must be viable for the location & community
- Time, money & risk – process & product are uncertain
- Out-of-the-box for many planners (cultural shift)

What are the key **enablers** for mainstreaming?

- Raise awareness of opportunity with politicians, planners → accelerated process, flexibility requirements
- Be prepared to trial/test a new approach
- Market provision – provider confidence in new entrants
- Availability of commercially viable business model
- Examples to demonstrate what's possible
- Commissioners further embed social value

Who are the key **actors & influencers**?

- Planners
- Policymakers (local plan, London Plan)
- Central government – finance, use of MMC (modern methods), industrial plan for construction
- Developers providing solutions
- New entrants – innovators/disruptors

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4. Future scenario for social housing – part 1

ADAPTABLE

What **benefits** does this model provide?

- Meet changing needs of client, provider & users – thereby saving money & resources
- Easy adaptation to support users with disabilities
- Mitigate risk in not knowing what the building will need to do in the future + future legislation
- Adapt to changes in economy, the way we live & changing needs/expectations of households

What are the **barriers** to this mainstreaming?

- Scaling/procurement – additional upfront cost
- Planning system constraints
- How do buildings meet acoustic & fire requirements? Need to consider building regulations

What are the key **enablers** for mainstreaming?

- Cost savings passed on to end users e.g. Common Home – 2-bed homes in London for sale at £250k
- Market demonstrating possibilities – who will be first?
- Raise awareness of opportunity with politicians, planners → accelerated process, flexibility requirements
- Commissioners further embed social value

Who are the key **actors & influencers**?

- Standards bodies e.g. Shelter, British Gas & Ipsos Mori developed the Living Home Standard – develop standard/assurances for adaptable homes
- Construction Leadership Council
- Minister for Communities, Homes & Local Government
- Industry associations
- Developers & architects

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4. Future scenario for social housing – part 2

These business models are also more widely available, albeit to a lesser extent:

Returnable buildings & components

- For short-term or one-off requirements, e.g. decanting residents during redevelopment
- Buildings (and components) are leased from the provider (developer, leasing company, local authorities' shared fleet) and returned after a number of years
- Initial build cost slightly higher than business-as-usual
- Redeployment >50% cheaper than new build, with zero cost of demolition

Deconstructable buildings

- Where refurbishment, deconstruction and re-use are facilitated by design
- Building components are recovered to provider's 'fleet', esp. at early end-of-life
- Initial build cost slightly higher than business-as-usual
- Income/residual value captured through reuse of components is worth several times more than the cost of deconstruction

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4. Future scenario for social housing – part 2

RETURNABLE

DECONSTRUCTABLE

What **benefits** does this model provide?

- All resources/components retained & reused
- Lower cost over whole life

What are the **barriers** to this mainstreaming?

- Nobody 'grasping the nettle', taking the lead
- Understanding who is responsible for what – quality/risk assurance needed
- Property/housing doesn't lose value as cars do – often increases over time, thus reducing incentives

What are the key **enablers** for mainstreaming?

- Availability of suitable, standardised components
- Clients understand extended value/utility over whole life
- Community sitting at the table when decisions are made
- Single point of ownership
- Share intelligence
- Clear capabilities

Who are the key **actors & influencers**?

- Government – national, local
- Government-affiliated agencies e.g. Big Society Capital
- Communities & users
- Developers

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4. Future scenario for social housing – overall benefits

To clients/providers

- Reduction in overall cost, when reused more than once or adapted
- Reduction in time and cost required for maintenance and adaptation
- High durability and long-lasting – can be reused a number of times
- Can be deployed quickly and ease pressures on housing requirements
- Fits with model of offsite construction, for modular buildings
- Increased residual value in the building and its components
- Enhanced reputation by supplying houses that meet the needs of residents, which can be adaptable, flexible and long-lasting

To society

- Increase the economic value of meanwhile space (e.g. land banks) or difficult-to-develop land, by deploying temporary reusable buildings
- Enhance social value by providing housing solutions that are cost-effective, quick to deploy and adaptable to suit people's needs
- Reduce environmental impact through more efficient use of materials and decreased waste generation
- Align with external needs (for flexibility, adaptability, etc) and standards such as Lifetime Homes and Home Quality Mark

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5. Summary & next steps

Key insights from the workshop:

- Address the structure of the market as a whole – incentives etc.
- Business models are desirable, but not easy to get to
- Collaboration and coordination are needed to activate multiple enablers simultaneously

Next steps for this project:

- Revised vision + roadmap
- Findings incorporated into social housing scenario & business models
- Small-group explorations of scenarios for other sectors
- Share insights with Climate-KIC and stakeholders

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Reinventing the way the world works

Accelerating the **big shift** to a sustainable future

Appendix 5: Trend Cards

Demographics

Graphic shows the proportion of the UK workforce over 60

The UK's population is both growing and ageing.

This has impacts in several key areas:

- T**he composition of the workforce** – by 2020, one third of the nation's workforce will be over 50. This will proportion will be even higher in construction.
- **Services and living arrangements will need to adapt** – a quarter of the entire population will be over 65 by 2030. **Social security provision and practical care** – puts increasing pressure on the working population. There is growing concern about a 'family care gap' as the number of older people in need of care outstrips the number of children able to provide it.

What does this mean for buildings in the UK?
New approaches will be needed to accommodate both **ageing construction workers and end users. What processes and technologies** will be needed to make manual work easier? How will the **design of developments** need to change?

Signals of change:

- **BMW** has adapted sections of its factories in Germany to make it easier for older employees to work
- **Germany** is also developing federally funded 'multigenerational houses' – co-housing with mixed age groups that support older residents.
- Contractor **Willmott Dixon** are trialling the use of an upper body exoskeleton, which aims to reducing the risk of fatigue and injury during heavy lifting or continuous repetitive tasks.
- **Japan** is moving towards fully automated construction, in part due to its demographics (world's fastest ageing country)

Global economy & geopolitics

The era of Western-led globalisation seems to be ending and political systems are in flux. Historically, times of flux are dangerous as new players make bids for power and try to reshape systems. ‘Strong-man’ politics is in the ascendant worldwide. We’re already seeing increased Russian adventurism. China continues to grow in power, whilst President Trump is pushing protectionist policies. Britain’s withdrawal from the EU is likely to have wide ranging impacts on our politics, society, national identity and economy.

What does this mean for buildings in the UK?
Increased uncertainty around supply chains, key markets, workforce availability, due both to Brexit and the changing global context.

The nature of **competition** is changing and we may see more foreign entrants into various property and construction sectors.

Signals of change:

- The **China National Building Material Company** is currently building 6 pre-fab factories in the UK, to build 25,000 pre-fabricated homes in 5 years.
- As part of **China’s ‘One Belt, One Road’** initiative, they have invested $40bn into ‘silk road’ infrastructure to connect them to the Eurasian continent.
- **President Trump** signed off 25% tariffs on steel and aluminium imports in March 2018, and since then has been engaged in an escalating “tit for tat” trade dispute with China. This could result in a full blown trade war involving the two largest economies.

Climate change

A two degree world will be radically different. Coastal cities like Miami and Shanghai will be inundated. Low lying areas of the UK will also be vulnerable. Above 2 degrees, chances sharply increase of dangerous tipping points with severe impact on global natural, industrial and agricultural systems.

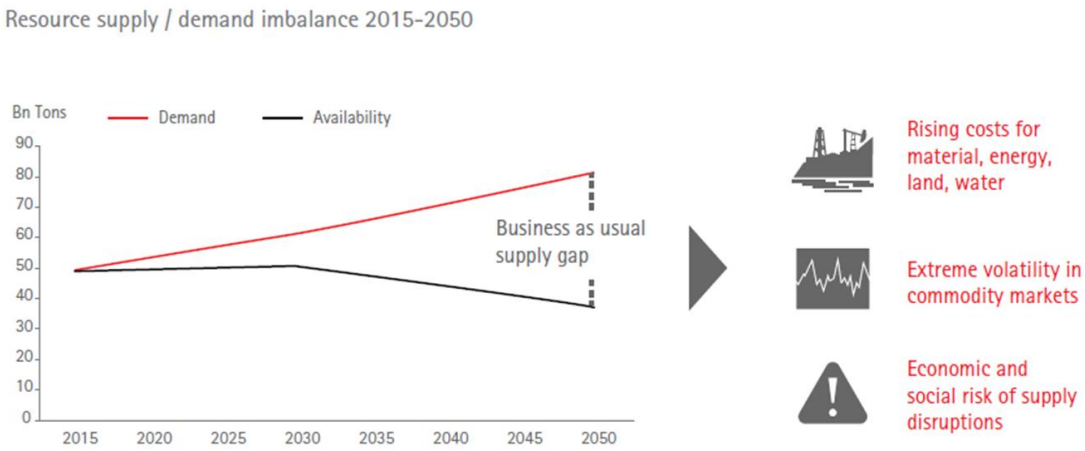
We are currently on course for more than 3 degrees of warming, and could exceed 1.5 degrees in the next five years. In October 2018, the IPCC warned that radical decarbonisation and the deployment of carbon capture technologies are required to limit warming to 1.5 degrees. A level of change in our climate is now unavoidable

What does this mean for buildings in the UK?
Adaptation will include addressing overheating and cooling needs, improving storm resilience of buildings, etc. **Mitigation** requires fast decarbonisation – considering energy sources, materials, embodied carbon, and lifetime use. **We are likely to see a strong policy and investor response – and the later it is, the more radical it will have to be.**

Signals of change:

- 2015, 2016 and 2017 were the hottest three years in recorded history.
- UK Government figures state that 2000 deaths are already caused by overheating every year due to poor design. Heat-related mortality is expected to increase significantly to 2050, due to climate change.
- In 2018, **Legal and General**, who manages over $1.2 trillion in assets, said it will pull its investment from all companies who it perceives as failing to act on climate change**.**

Resource challenge



Graphic source: Mackinsey 2015

The resource challenge is tied to global demographics. The global population is projected to rise to over 8.5 billion by 2030 - that's another billion people over the next 12 years. The global middle class is projected to more than double (from 2bn to 5bn) – with implications for consumption.

A serious resource supply / demand imbalance is looming, which will stimulate demand for alternative materials, more efficient, flexible portfolios and highly adaptable buildings.

What does this mean for buildings in the UK?
Traditional approaches to the sourcing of materials and use of supply chains will be increasingly challenged. The concept of the circular economy is gaining traction and will become a strategic issue.

Signals of change:

- The use of **timber frame technology in mid-rise and taller buildings** is rapidly increasing in some markets – due to advances in structural strength, fire resistance, green credentials.
- **Machiels** aims to **mine Remo,** Europe's largest landfill with 18M tonnes of waste, recovering half for building materials and half as energy.
- **Park 20|20**: a Dutch business park, claims to be the **world's first cradle to cradle business community**, with a focus on design for disassembly; material banking for each individual building: and leasing of products.

Inequality & the housing crisis

The richest 10% own nearly half the country's wealth - more than the bottom 80% put together. Inequality is linked to property ownership and the housing crisis - the UK has an economy biased towards capital ownership - more national income is going towards the owners of capital, rather than to workers.

In response we are starting to see discussion of alternative models for both housing and capital ownership. Public ownership is back on the political agenda and common ownership (such as co-housing) is another idea aimed at democratising wealth.

What does this mean for buildings in the UK?
This debate is likely to refract most strongly through attempts to address the causes of the housing crisis.

Signals of change:

- The Government is scrapping the **cap on how much councils can borrow** to build new homes.
- Developers are beginning to explore **modular and micro-home**s as possible solutions to the housing crisis. The image shows the iKozie pod installed by the Homeless Foundation.
- The number of **Shared Ownership** home purchases rose by more than 130% from 2010 - 2016
- Co-working company **WeWork** has created the co-living concept **WeLive**, based on the philosophy of shared space, services, community and social interaction

Trust & transparency

Trust in business is at a new low in the wake of high profile scandals ranging from Dieselgate to the Carillion collapse. But the last few years have seen declining trust in all institutions, and with recent scandals in the charity sector, no organisations are guaranteed the level of trust they once were.

Corporate accountability is being accelerated by technology, with openness increasingly expected. Connectedness is driving transparency, from an increasing ability to investigate the validity of corporate reporting and supply chain management. Data practices are also in the limelight with the dawn of GDPR, hacking scandals, and the surveillance state.

What does this mean for buildings in the UK?
Public scrutiny of major incidents like Grenfell and Carillion have shone a light on a fragmented construction sector that is dominated by low margins, a lack of trust or true collaboration. Many people question whether the current culture and operating practices can change sufficiently to deliver the innovative buildings and business models we need in many sectors.

Signals of change:

- The Carillion collapse and subsequent inquiry has challenged the traditional contracting model and openly questioned its ability to deliver the future public infrastructure we need.
- The BuyPartisan app scans a product's barcode and tells the consumer the company's political donations.
- NGO Skytruth is using remote sensing to expose the damage caused by mining, gas drilling, deforestation, fishing and other human activities.

Big data & smart buildings

As the Internet of Things develops, its becoming all about the data. There is a massive opportunity to optimise operations. For example, venture capital investment into prop tech has rocketed in the last couple of years. The opportunity is seen to be around radically reducing building inefficiency.

There is also increasing risk for incumbent businesses. Large tech companies will be able to create considerable value from data as buildings become ‘smart’. With significant capital, they could enter certain markets quite quickly.

What does this mean for buildings in the UK?
A diverse range of technologies is now steadily transforming cities into “open-air computers.” How can procurers and managers of buildings derive benefit from this? Who should they consider partnering with?

Signals of change:

- **Google’s subsidiary Sidewalk Labs** is developing ‘Quayside’ in Toronto, a 12 acre area which will be ‘the world’s first neighbourhood built from the internet up. The project aims to reimagine urban life in terms of housing, energy, mobility, social services, and shared public spaces.
- **Amazon** recently invested in prefabricated housing start-up Plant Prefab. Plant Prefab focuses on building new, prefabricated, single- and multi-family homes. It claims it can build faster and with less waste than traditional methods.

Sustainable construction

The sustainable construction agenda has moved on from simply low carbon, low waste. It's also about putting the user at the centre, addressing issues like affordability and wellbeing. Wellbeing is an important adoption factor in the commercial sector with growing evidence that sustainable buildings also enhance creativity and clarity of thought. For example, research has found that workers who can see a green environment from their desks experience 23% less time off sick and also report greater job satisfaction.

What does this mean for buildings in the UK?
Globally sustainable construction continues to move on and UK businesses could get left behind if they rely solely on government policy to drive innovation.

Signals of change:

- **Synapse Development Group** is aiming to be 'the Tesla of housing', bringing Passivhaus standards into the mainstream; Their Brooklyn development 'Perch' centred around superior user wellbeing as well as eco credentials.
- **The Well Building Standard** is seeing growing adoption by commercial property clients
- **Pasona Group in Tokyo** integrates an urban farm in its office space, with tomato vines above conference tables and lettuces in meeting rooms.
- Clare Cousins Architects in Australia recently developed **an affordable carbon-positive house**, built along circular principles and at no extra building cost.

Growing demand for flexibility

For many property investors and clients, flexibility in the design and use of assets is becoming increasingly important. In response to significant disruption in areas like **retail** and **commercial office space**, property developers are going to have to respond with a more flexible proposition – be that in leasing arrangements, or in the physical spaces they provide.

In addition, local authorities are seeking to use all the land at their disposal efficiently, including the creative use of "meanwhile land" for the deployment of social housing.

What does this mean for buildings in the UK?
Flexibility and adaptability will be critical criteria for property projects in the future – to both avoid "stranded assets" and extend the building life and value of buildings through repurposing.

Signals of change:

- **PLACE Ladywell in Lewisham** is a pioneering housing project looking to address local housing needs on a "meantime" site.
- **Flexible office demand across the UK's regional cities doubled in 2017**, according to Savills.
- Since launching in London in 2014, **WeWork** now houses 26,000 tenants from start ups and entrepreneurs to major global companies.
- **HeadBox** is an easy-to-use online platform allows users to rent under-used spaces for meetings, conferences and workshops.

Skills & future workforce

The UK building industry remains vulnerable to **significant labour and skills shortages**, partly because of an ageing workforce and an inability to attract and retain talent in the numbers required. There remains underinvestment in training, innovation, and raising productivity.

Increasing the diversity of the workforce is critical if the industry is to prosper, although the emergence of automation, offsite manufacture and robotics may offset challenges in certain professions and sectors.

What does this mean for buildings in the UK?

Improving the attractiveness and appeal of the industry is critical. And will the emergence of new digital technologies, higher levels of automation and offsite methods of construction help?

Signals of change:

- According to the Farmer Review, based purely on existing workforce age and current levels of new entrant attraction, UK construction could see a 20-25% decline in the available labour force within a decade.
- Despite a shrinking workforce, the city of Tokyo is still able to build nearly the same number of homes per year that the UK delivers nationally This is partly because of mass market cultural acceptance of pre-manufactured modular housing, as well as increasing use of robotics.

New methods of construction

Construction techniques such as modular building, off-site manufacture and 3D printing have the potential to transform the sector.

Technological innovations are changing the nature of the construction industry. With low margins, a growing skills shortage and pressing housing needs, companies are increasingly looking to off-site manufacture and 3D printing to save time, materials and human labour. However, moving to such a model takes significant capital expenditure, and few industry players want to be first movers.

What does this mean for buildings in the UK?
The recent Construction Sector Deal sets goals for the sector to deliver – which include producing better-performing buildings that are built more quickly and at a lower cost, and reducing energy use. Scaling up offsite manufacturing and digitization are seen as critical to delivering this.

Signals of change:

- In 2016 Legal & General launched its modular housing factory, aiming to reduce building time on-site, as well as the overall embodied carbon footprint.
- Dubai-based construction company Cazza has committed to building an 80-storey skyscraper with 3D printing by 2020, using what they are calling ‘crane printing’.
- Amazon has invested in US homebuilding start-up Plant Prefab, marking its first investment in the space. Plant Prefab builds prefabricated, custom single- and multifamily homes.

Public policy & procurement

The construction & property sectors remain heavily regulated, and the health of its key markets subject to political ideology and regulatory risk.

In a policy climate defined by austerity and a desire to deregulate, demand for sustainable, healthy buildings is largely driven by individual clients. However, regulatory and procurement expectations may change significantly in response to the housing shortfall, and major incidents like the Grenfell disaster and Carillion collapse.

What does this mean for buildings in the UK?
For many commercial and public sector clients, there is a concerted effort to leverage greater value from existing and new assets, as well as the land upon which they sit.

Signals of change:

- The London Plan requires an average of 42,000 net additional homes every year across the capital.
- Adopted in 2008, the Code for Sustainable Homes was scrapped in 2014.
- Feed in Tariffs for renewables were cut significantly in 2016.
- Local authorities in England lost 27 per cent of their spending power between 2010 and 2016 in real terms. Some services, such as planning, have seen cumulative cuts to the order of 45%.
- In 2018, the government scrapped the cap on how much councils can borrow to build new homes.

Disruptive technologies

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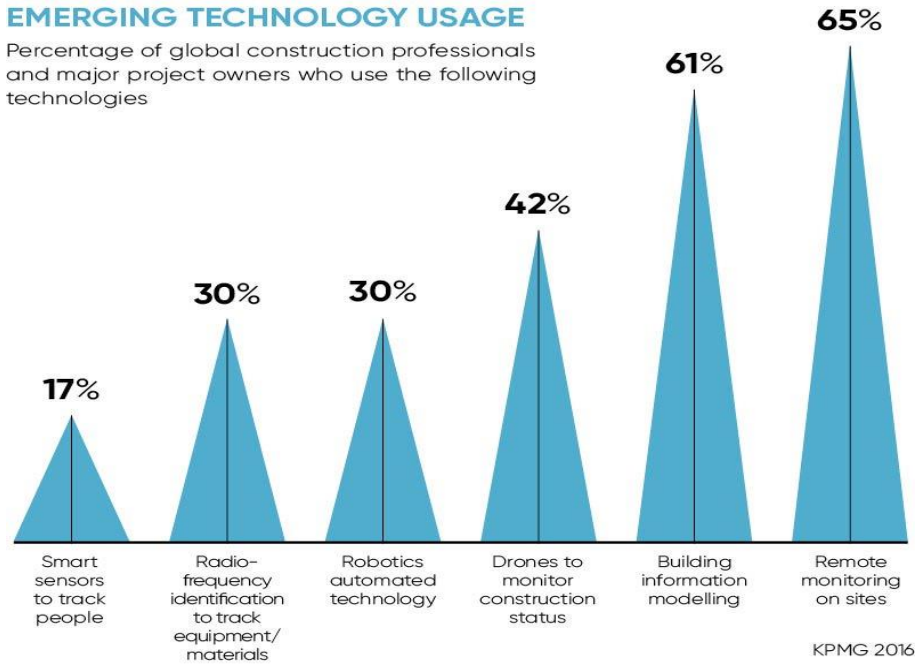

AI, Robotics, 3D printing, and biotech are rapidly developing technologies that are also known collectively as the 4th industrial revolution. 2017 research from Mace found that the widespread adoption of AI and robotics in construction has strong potential to boost the sector's productivity. Mark Farmer, author of the Farmer Review, agreed with the findings, saying "technology will bring a step change to construction, which has remained artisan-based for decades".

What does this mean for buildings in the UK?
New skills and new ways of working are required. The current challenges in construction might drive much greater adoption of automation and 3D printing than currently anticipated.

Signals of change:

- Chinese contractors **Win Sun** 3D printed 10 homes in one day at a cost of just $5000 each (from 'inks' made of 100% recycled material). Customers include the governments of Dubai and Egypt
- **Construction sites in Japan** are experiencing a wave of automation, including robots to assist in heavy and drones to collect real time data.
- **Willmott Dixon** is trialling the use of a robotic exoskeleton to aid operatives in heavy lifting.
- **Construction Robotics** has developed **SAM100**, a masonry robot that can lay 350 bricks per hour, and has been used by **Clark Construction** and **Wasco.**

The future of work

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Developments in technology and generational shifts are bringing rapid change. Automation is changing the nature of work by automating some tasks and making it much easier to co-ordinate and crowdsource others. Many millennials – who will be 75% of the global workforce by 2025 – prioritise flexible working and self-direction.

Enabled by technology, new organisational models are emerging. But the flipside of this flexibility and automation is the gig economy, and very real concerns around exploitation and underemployment.

What does this mean for buildings in the UK?
The property and buildings sectors need to consider the impact of increasing automation and technologies on their ways of working, and how they might compete for, and attract the best talent amongst the next generation.

Signals of change:

- 2017 research from **Mace** predicted that **600,000 UK construction jobs could be automated** over the next 2 decades. The remaining workers will need to have different skills, in order to work effectively with new organisational models, and new technologies.
- **Smarties** is 'uberising' knowledge work by breaking up complex projects into discrete tasks that can be done remotely at times that suit workers - a distributed, scalable and on-demand network.
- **Colony** is another start-up that is using blockchain to build a radically decentralised collaboration platform.

Blockchain & cryptocurrency

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Both **blockchain and cryptocurrency** have the potential to improve construction in many areas. Blockchain can make all transactions open, tracked and transparent through the core of a digital ledger.

When combined with the Internet of Things it can give full transparency through supply chains, as well as enable decisions to be made by decentralised robotic systems. Smart contracts (self-executing automated contracts) can minimise disputes, reduce need for intermediaries, verify supply chains and provide new payment mechanisms.

What does this mean for buildings in the UK?
Building applications are just emerging, but imagine if all materials on-site could be tracked on a transparent, immutable database? Imagine sensors monitoring performance triggering smart contracts that pay contractors based on performance over the life cycle of the building.

Signals of change:

- The Construction Blockchain Consortium (CBC) is a construction industries knowledge transfer consortium that tracks and tests blockchain proof-of-concepts in the construction industry
- PropertyShare is providing fractional ownership opportunity for small ticket investments into large-scale development projects using blockchain. Investors can earn up to 9% in rental yields per month.
- Dubai plans to have all its documents on a blockchain by the year 2020, claiming that adopting blockchain technology stands to unlock 5.5 billion dirham in savings p.a.

Circular economy

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Increasing recognition of **planetary boundaries** is contributing to a growing 'distaste for waste'. Planned obsolescence and the linear value chain could be superseded by **cradle-to-cradle production systems** and an **efficiency mind-set**. Consumers and clients will be looking to companies to demonstrate how their propositions reflect this. Pioneers are beginning to make strides in remanufacturing and recycling end of life products, laggards risk seeing their business models and value chains radically disrupted.

What does this mean for buildings in the UK?

The application of circular economy principles to the built environment could radically change the way we value and invest, design and deliver, as well as the end of life infrastructure and new markets that evolve.

Signals of change:

- Group Machiels aims to mine Remo, Europe's largest landfill site with 18 million tonnes of waste, recovering half for building materials and half as energy.
- IKEA is pioneering a circular business model, creating upcycled products and supporting customers to repair, rent, share resell and return them.
- Park 20|20: an Amsterdam business park, claims to be the world's first cradle to cradle business community, with a focus on design for disassembly; material banking for each individual building: and leasing of products.

Investment climate

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Large investors have signalled rising expectations of companies regarding their management of environmental, social and governance (ESG) risks. Divestment from dirty assets is gaining momentum, while good sustainability management or organisations and projects is increasingly expected as standard.

At the same time, new financing mechanisms and digital technologies such as crowdfunding have mainstreamed and are facilitating different ways of raising capital, allowing communities and individuals greater visibility and control over how and where to invest their money.

What does this mean for buildings in the UK?

New sources of finance for new build and repurposing may emerge. Clients and investors are increasingly aware of the need to futureproof portfolios and mitigate risks associated with inflexible or “stranded” assets.

Signals of change:

- In 2016, equity raised from crowdfunding passed venture capital funding for the first time. By 2025, the World Bank estimates that global investment through crowdfunding will reach $93 billion.
- Community energy cooperatives were successful in more than 90% of bids in a German wind power auction. There are nearly 300 community energy organisations across the UK.
- By 2018, nearly 1,000 institutional investors, with $6.24tr in assets, have committed to divest from fossil fuels, a rise from $52bn in 2014. This increase come from traditionally conservative investors such as insurers, and pension funds.