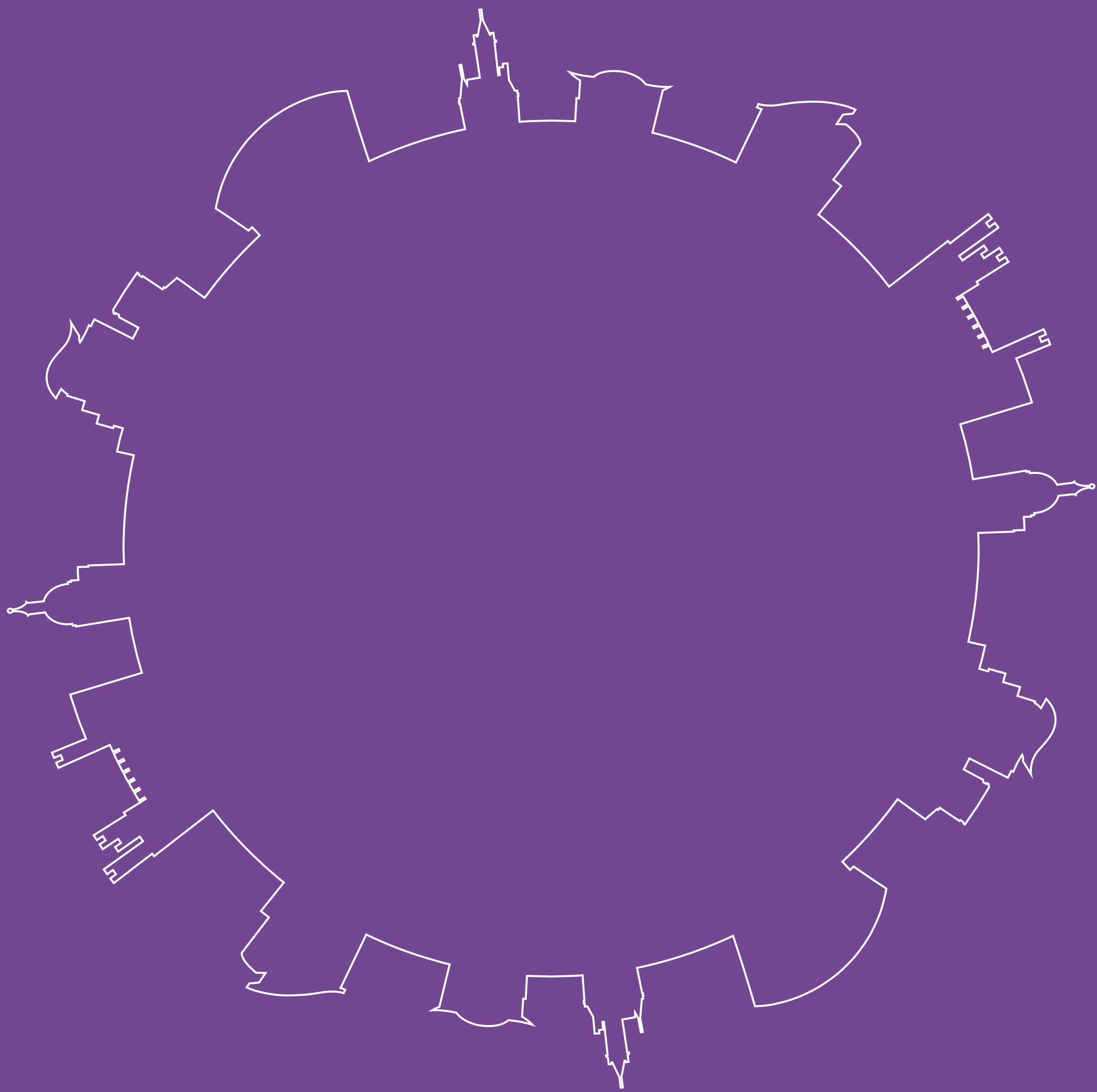
ADEILADU ARBENIGRWYDD YNG NGHYMRU

CONSTRUCTING EXCELLENCE IN WALES

Closing the circle

Circular economy: Opportunity for the welsh built environment



Contents

Foreword

When the Well-being of Future Generations Act was passed in 2015, the United Nations said that they hoped 'what Wales was doing today, the world would do tomorrow'[01]. The legislation is both internationally ground-breaking and game-changing, and the world's eyes are on us now to not only talk the talk of the Act but walk the walk. It is central for Welsh construction to play a role in the delivery of that walk.

After the UN's comment, the second, less quoted part of that speech is that 'actions more than words, is the hope for future generations', and that is where I see the challenge for the built environment; building today for the Wales we want tomorrow, and for future generations to come. It will be your actions, and the lead that you take throughout the construction sector, to embed the spirit of the Well-being of Future Generations Act, through the reduction in raw material consumption, waste production, of moving us towards a low-carbon, resilient society, of providing secure and well-paid jobs, and of building well-connected environments for everyone in Wales that improves our lives and enhances our well-being.

The Act defines sustainable development as 'improving the way we achieve our economic, social, environmental and cultural well-being.' I have been very clear that this is not just another piece of legislation – that this is the catalyst for culture change, throughout the public sector and for everything we do here in Wales.

We examine how the sector is performing and look to address activities that are not delivering across the seven well-being goals. The five ways of working offer a mechanism to begin to consider how changes can be made.

Using resources more efficiently in a loop, where they can be returned to use and their value retained will become an important economic consideration. Innovating in this manner to develop better ways of working that enable economic prosperity with positive impacts on the environmental and social well-being of Wales will be key to the successful delivery of the Act.

Construction has a key role to play in building environments that reflect the reality of the lives that people lead, and communities that enhance the lives and well-being of everyone here in Wales, today and for future generations.

Sophie Howe
Future Generations Commissioner for Wales

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Executive summary

The value creation opportunity from the circular economy has been clearly demonstrated. As the biggest consumer of raw materials (EEA, 2011), with eighty per cent of all materials produced used in the built environment, the scale of the opportunity for the sector and Wales is significant.

This report outlines a model demonstrating how circular economy principles may be applied to the built environment, the size of the economic opportunity, material priorities, challenges and recommendations to how the principles could be implemented across the sector to realise the benefit.

Our current linear "take-make-dispose" practices rely on large quantities of easily accessible materials, energy and landfill and it is reaching its physical limits. Notably in Wales the sector is the largest producer of controlled waste (EAW Survey, 2005).

The concept of a circular economy was inspired by the functioning of natural ecosystems where "nothing is lost and everything transformed". It is a development strategy that enables economic growth while optimising consumption and resources. The circular economy is one that is restorative and regenerative by design and aims to keep products, components and materials at their highest utility and value at all times. It aims to decouple economic development from resource consumption, whilst enabling key policy objectives such as generating economic growth, creating jobs, and reducing environmental impacts, including carbon emissions. Our model demonstrates how the principles of the circular economy can be applied to the sector to realise the potential benefits turning theory in practical application.

Our research has demonstrated a potential economic opportunity of an additional £1 billion per annum by 2035[2]. This is an increase of 12.5 per cent in the turnover of the Welsh built environment sector[3] and generating 7,300 jobs (gross). This figure is consistent with a growing body of research that identifies the economic opportunity and the importance of the sector in delivering. The built environment sector has a high environmental impact, retained financial value and potential for reuse[4].

The EU Exit provides an opportunity to move away from EU classifications of waste and develop national strategy to decouple waste generation from economic growth and accelerate a transition to a circular economy.

Focus is needed to develop the right conditions to enable Wales to make the most of the opportunity presented. Key to making the transition between linear and circular economies will be the ability of the sector to collaborate and innovate within its supply chain and across other industry sectors, working to design out waste at all construction stages, redefine waste as a resource and integrate circular economy principles into practice.

[2] Amec Foster Wheeler
[3] In 2015, 91,900 people employed in 46,220 enterprises with a turnover of £8 billion, Welsh Government
[4] LWARB, London: The Circular Economy Capital

Sections 1-3

The circular economy

1. Background

The Welsh Government has established sustainable development as its central organizing principle, the Well-being of Future Generations (Wales) Act 2015 and the Environment (Wales) Act 2016 provide a new sustainable development framework for Wales.

The development of policy therefore should contribute to the sustainable management of natural resources[5] (SMNR) (as provided by Part 1 of the Environment Act) which in turn contributes to the delivery of the seven well-being goals[6].

SMNR requires that any use (direct or indirect) of and actions on natural resources is undertaken in such a way that does not reduce the ability of ecosystems to continue to deliver the multiple services (supporting, regulating, provisional and cultural) they provide in the short, medium and long term.

Resource efficiency defined by the EU as 'using the Earth's limited resources in a sustainable manner while minimising impacts on the environment'[7] is therefore a key element of SMNR to reduce:

- the amount of natural resources used in the first instance;
- the impact of waste treatment processes on the health and functioning of ecosystems; and
- the impact of end-disposal on the health and functioning of ecosystems.

Construction is the biggest consumer of raw materials (EEA, 2011), with eighty per cent of all materials produced used in the built environment. Moving towards an economic model that delivers an efficient, resilient, innovative approach is in the best interests of the sector.

Established in 2002, Constructing Excellence in Wales (CEW) is the single organisation charged with driving change within construction. CEW is working to help the Welsh Government and the industry to make the changes necessary to move the industry towards a more circular approach making construction more efficient and effective, ensuring that the industry is able to deliver the best value built environment for Wales.

2. Aim

The aim of this report is to apply circular economy principles to the built environment sector moving theoretical concepts to demonstrable best practice.

As part of this approach, CEW has modelled what is required to achieve a "circular built environment" further highlighting the economic opportunity and the strategy necessary for the built environment in Wales to move away from a linear economy. In this new approach resources are not simply extracted, used and disposed of, but are put back in the loop so they can stay in use and retain value for longer. This work has been developed in accordance with the SMNR approach developed by Welsh Government.

In applying the circular economy to the sector and in accordance with the welsh context it is key that any methodology demonstrate:

- a "whole life approach";
- circular economy principles;
- value opportunities; and
- the inter-relationships between the built environment, other sectors and the natural environment

[5] Environment (Wales) Act 2016, s 3
[6] Well-being of Future Generations (Wales) Act 2015, s 4
[7] http://ec.europa.eu/environment/resource_efficiency/

3. The circular economy

The concept of a circular economy was inspired by the functioning of natural ecosystems where "nothing is lost, everything is transformed", the concept of circular economy has emerged in a context where it becomes increasingly more important for all economic actors to improve the management and efficiency of resources and to secure their long-term supply, by moving away from a linear supply chain, i.e. from a 'take-make-dispose' economic model[8].

3.1 Definition of circular economy[9]

Circular economy represents a development strategy that enables economic growth while optimising consumption of resources, deeply transforms production chains and consumption patterns, and redesigns industrial systems at the system level.

The circular economy aims to keep the value added in products for as long as possible and to cut residual waste close to zero. It could therefore be considered as a regenerative system, which retains the resources within the economy in contrast to the currently prevailing 'linear' model of extraction, manufacturing, consumption and disposal.

Moving to a circular economy requires changes in all parts of the value-chain, from consumer demand, through product design, new business models and new ways of turning waste into a resource. It implies a fully systemic change, affecting all stakeholders in the value chain.

Innovation, in all its forms – technological, organisational, and social – is one of the main drivers of the circular economy. A circular economy closes 'resource loops' in all economic activities in a sense that there is no 'end' within a circular economy, but a 'reconnection to the top of the chain and to various activity nodes in between'.

The circular economy is restorative, with materials designed to circulate at high quality with their economic value preserved or enhanced[10]. It is important to note that a circular economy goes beyond the pursuit of waste prevention and waste reduction to encourage technological, organisational and social innovation across and within value chains[11].

3.2 A whole life approach

This considers the impact of buildings and the products within them over their entire life-cycle. For buildings this includes from concept, design, construction, use, maintenance to demolition. For products this includes from extraction, production and transport, to performance in use, maintenance and final recycling or re-use.

Materials can have an impact on the environment in a range of different ways and at different times during their life cycles. For example, the extraction, transportation, processing and/or manufacturing of a raw material consumes energy and produces carbon. The longer the material is kept within the system means that these negative impacts are reduced over its life cycle.

For the model to reflect a 'whole life approach', it should demonstrate the relationship between the different construction phases but also the life cycle of products within a building. This is key if we are to understand and obtain true value from each phase and element.

For example, in relation to construction phases, design decisions will influence not only the choice of materials used but also whether or not those materials can be reused more efficiently for a longer period of time. Decisions at the design stage can determine the longevity of retaining value within the life cycle not only of the structures but also of the materials and goods used in buildings.

Life cycle assessment is a method to measure and evaluate the environmental impacts associated with a product, system or activity, by assessing the energy and materials used and released to the environment over the life cycle. This guides decision making and enables distinctions to be made between products/systems/activities on the basis of environmental impacts over the whole life.

[8] EU Commission, Scoping study to identify economic actions, priority sectors, material flows and value chains, 2014, Annex I, p 11
[9] Ibid, Annex II, p 12
[10] Aldersgate Group, Resilience in the Round: Seizing the Growth Opportunities of a Circular Economy, 2012
[11] EU Commission, Scoping study to identify economic actions, priority sectors, material flows and value chains, 2014, p 3

Another factor to be considered in the circular economy is the embodied impacts of a material or product, which are assessed through a lifecycle assessment and can be categorised into five stages[12].

- mining/extraction;
- manufacture;
- construction;
- operation and maintenance; and
- demolition

A holistic approach to embodied impacts should be used as for instance, transporting large quantities of heavy recycled materials over long distances may be more damaging than using locally sourced virgin materials.

3.3 Principles of the circular economy[13]

- **Maintain and enhance resilience of ecosystems** - by using in a way and at rate that controls finite stocks and balances renewable resource flows.

  Key elements:
  - Not to overuse valuable finite resources;
  - Not to overuse renewable resources at a rate which jeopardises their ability to renew and impacts on ecosystem resilience;
  - Use reused, recycled materials;
  - Using the most appropriate resources;
  - Use energy from renewable sources;
  - Consider embodied impacts e.g. is transportation of recycled materials have more or less impact on ecosystem resilience than the use of virgin materials

- **Optimise resource yields** - by circulating products, components, and materials at the highest utility at all times in both technical (non-renewable) and biological (renewable) cycles.

  Key elements:
  - Designing for product remanufacturing, refurbishing and recycling (disassembly) and asset deconstruction/reconstruction. In effect this seeks to design out any potential opportunities for waste;
  - To maintain life by continued application within the cycle, In a circular economy, the goal for durable components (such as metals and most plastics) is to reuse or upgrade them for other productive applications through as many cycles as possible.

- **Foster system effectiveness** - by revealing and designing out negative externalities. In effect this aims to ensure that resilience is built into the system. Key elements:
  - Reducing negative impacts on natural resources;
  - Ensuring continued provision of ecosystem services.

These are the principles for taking action, the following are the characteristics of a circular economy:

- Designing out waste - to enable this, biological materials are non-toxic so that they can be returned to the soil by composting or anaerobic digestion. Technical materials –polymers, alloys, and other man-made materials – are designed to be recovered, refreshed and upgraded, minimising the energy input required;
- Designing in reused elements, wastes, secondary materials and by-products – to retain resource in use
- Building resilience through diversity – in relation to ecosystems this includes both bio- and geo-diversity;
- Using energy from renewable sources - energy required to fuel the circular economy should be renewable by nature, in order to decrease resource dependence and increase systems resilience;
- Thinking in 'systems' - businesses, people or plants, are part of complex systems where different parts are strongly linked to each other.

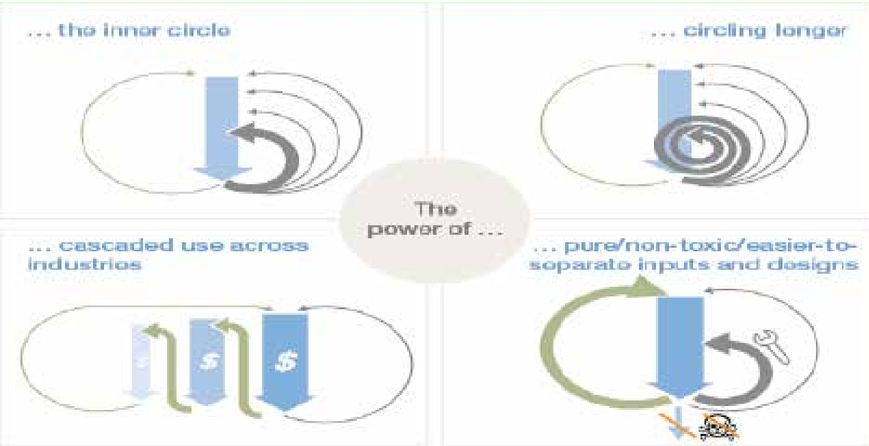
All of these are compatible with SMNR if not all explicitly stated. SMNR with its objective of maintaining and enhancing the resilience of ecosystems and the benefits they provide is based on a natural systems approach. As ecosystems are made up of both biotic and abiotic components, resilience is reliant on diversity of both. It therefore includes both renewable and non-renewable components.

Limiting waste and using renewable energy, are also important to achieve the above objective as these limit the negative impacts on the SMNR objective and are consistent with forthcoming carbon budgets.

[12] CPA, A Guide to understanding the embodied impacts of construction products,
[13] Ellen MacArthur Foundation, Towards a Circular Economy: Business Rationale for an accelerated transition, Nov 2015

3.4 Value opportunities

Figure 1: Sources of value creation for the circular economy[14]



Inner Circle: reflects the advantages of direct reuse, e.g. reusing packaging rather than recycling. This not only reduces the need to use raw natural resources but also reduces any negative impacts on natural resources from transportation and processing that may be associated with recycling. Associated construction activities include:
- Design for disassembly;
- Refurbishment of assets;
- Reclamation led deconstruction.

Circling longer: this involves maximizing the number of consecutive cycles (be it repair, reuse, or full remanufacturing) and/or the time in each cycle. Associated construction activities include:
- Easy disassembly for reuse or refurbishment;
- Design for multiple uses;
- Design for easy up-grade.

Cascaded use: this relates to diversifying reuse and involves enabling a material to be used multiple times for a variety of different purposes across multiple industry sectors. For the construction sector cascading could be about reusing a material from another source, for example secondary, by-products or recycled materials or where the primary use is in a construction project and it can be reused subsequently.

For example, in Wales there are large quantities of aggregates generated as by-products from other industries, for example steel slag, PFA, IBA. These materials may be used as alternatives to virgin aggregates within construction projects.

Associated construction activities include:
- Separate collections and treatment for bio-waste and waste oils to reduce contamination and enable reuse;
- Reduction use of hazardous materials in biomass products to enable reuse;
- Reusing e.g. wood from another source.

Pure inputs: this involves the reduction of the use of harmful substances as their presence reduces the opportunities to undertake the three other value approaches. Associated construction activities include:

3.5. Inter-relationships

The circular economy is a complex concept encompassing a range of materials, products and actors, different stages in product and value chains, with varying potential for circularity across different sectors, products and value chains.

Within the built environment sector there are both internal and external relationships:

Internal:
- Between each of the phases of a construction project, e.g.:
  - Design connects to construction and deconstruction;
  - Construction connects use, refurbishment and to deconstruction;
- Architects and designers;
- Between each of the disciplines e.g. engineers, builders, construction and demolition companies.

External:
- Extraction industry for the raw materials needed not only to build but also for the raw materials for e.g. fittings and fixtures;
- Electronic & electrical (machinery & tools, long-term lighting & energy-use design);
- Manufacturers, suppliers and retailers;
- Public sector clients;
- Private sector clients;
- Waste management companies.

It is important that consideration is given to these relationships

[14] Ellen MacArthur Foundation, Towards a Circular Economy: Business Rationale for an accelerated transition, Nov 2015

Sections 4-7

Circular economy model for the built environment

4. CE model for the built environment

A simple model representing the circular economy (CE) is presented at Figure 2. There are a number of challenges in applying the principles of CE to the built environment and translating this into a creating a CE model.

Figure 2: Simplified illustration of the use of resources in circular economy[15]

Circular economy models in general have looked at production processes for a product. Within the built environment a project will comprise of numerous materials/products which make up the whole. Therefore consideration needs to be given to examining the whole project as one and understanding how the numerous elements interact and co-exist with each other over time.

As such, the 'product' is the asset and various construction materials are the 'components'. When an asset is no longer required, it may be dismantled and its components (e.g. bricks, blocks, concrete) can be seen as a source of raw materials for re-use.

The ultimate aim is to preserve the value of these components through either direct re-use in another project or by 'up-cycling', retaining or even increasing their initial value. On construction and demolition sites this requires careful segregation of construction material components to avoid contamination, and identifying markets (e.g. contactors or component manufacturers) to re-use or up-cycle the components.

However, the construction is only one phase within a project as there are a number of inter-connected stages, these include concept, design, occupation and deconstruction/demolition. These phases are linear in process but circular due to the inter-relationships between decisions and actions at one stage impacting further along the process.

Assets are also used for a number of different purposes from commercial, public to private use. The use will impact upon its application for circular economy.

There are also a number of different disciplines and industrial sectors involved in the built environment, from extraction companies, to architects, designers, builders, manufacturers and reclamation/demolition companies.

In addition, the construction sector's role in a circular economy should include:

- Reuse of materials, components (reuse) or by-products, secondary materials and recycled products;
- To ensure that any primary use of components or products can subsequently enter the CE to be reused, recycled, remanufactured.

All of these factors make a single built environment model very complex, however the opportunities are vast and significant.

4.1 Why is a circular economy model required?

The following are some reasons as to why a CE model for the built environment is required:

- Resource and energy use;
- Rising commodity prices;
- Resource constraints (especially wood & timber);
- Stricter landfill requirements;
- Higher energy efficiency targets/standards for buildings; and
- Competing uses/priorities for materials.

[15] European Commission COM(2014) 398

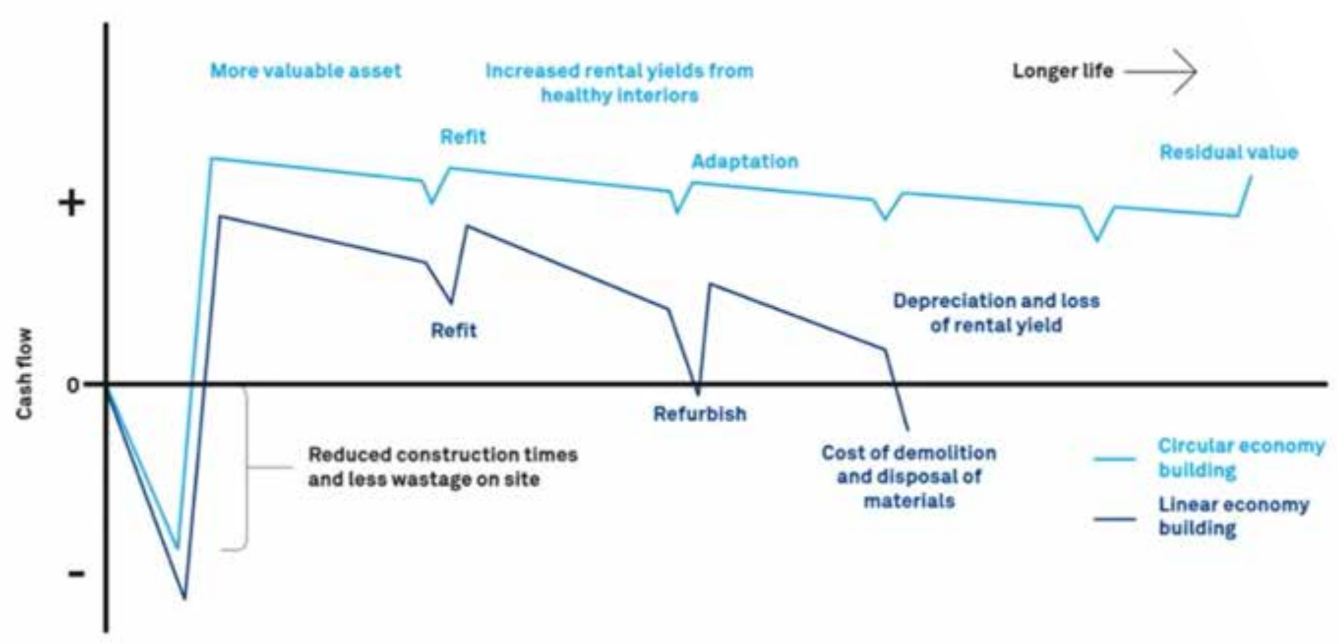
In developing a model it is important that it considers and delivers a SMNR approach working to achieve the goals of WFG and Environment Act. If the theory can be put into practice and a transition made the model offers a substantial mechanism for maximising the prosperity and resilience of Wales.

4.1.1 Identified benefits of circular economy approach

A circular approach has been demonstrated to offer multiple benefits, these include warding against increasing material prices, conserving embodied carbon and adding value to end of life.

David Cheshire, AECOM within Building Revolutions has prepared an illustrative comparison of circular economy buildings and conventional building. The graph is based on ideas from Coert Zachariassee and research from Loughborough University.

Figure 3: Benefits of circular economy buildings



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AECOM

In adopting a more adaptable approach to building design, where disassembly and reuse are considered it is possible to achieve a positive residual value. The graph above compares a traditional approach to building, highlighting where circular economy building can reduce construction and refurbishment time and associated costs, maintaining the value of the asset whilst protecting the rental yield.

We recognize that in order to realise the benefits the sector will need to embrace a different approach to its delivery. It will be necessary to move towards a more collaborative approach to working across the supply chain in an earlier and more integrated manner than is currently commonplace.

4.2 Circular Economy Model & Construction Phases

Table 1 outlines the different types of CE actions that can be taken at each phase of a construction project and provides, where relevant an outline of some of the potential barriers to its implementation.

The table has been drafted as the basis to the development of a model that outlines the key circular economy methods identified by phase. In its scoping study, the EU has identified a number of priority materials[16] for consideration in a circular economy, where appropriate, these have been identified in the table.

In addition, these have been referenced to those critical and essential materials identified in the Welsh Government's 'Mapping critical resources for Wales' report. Detailed consideration of the critical resources for the Welsh built environment is provided in section 9.

Table 1: Cicular economy actions against construction phase

Phase	CE Actions	Links to other phases	Potential Barriers
Concept Preparation Initialisation RIBA stages 0-2	**1. Reuse** **2. Refurb** **3. New build** Determine whether to refurbish or reuse an existing asset – would reusing or refurbishing have a lower lifecycle impact than a new build?	Design Construction Demolition/Deconstruction	- Awareness and information - Lack of demand (client) - Leadership - Perceived costs - Foresight – paying at capital for savings in operational stages - Skills
Design RIBA stages 2-4	**1. Design for durability and reuse** **2. Eco-design** **3. Design for disassembly** **4. Design for deconstruction** **Key actions asset:** - asset designed for longevity including reuse (e.g.) easy to convert from commercial to domestic - easier to disassemble to recover valuable materials and components at any stage in the lifecycle of the building **Key action Components:** - products more durable for longer life; - easier to repair, upgrade or remanufacture - easier to disassemble to recover valuable components to enable reuse, recycling, remanufacture; - designed without hazardous materials or where necessary designed to enable ease of removal without contaminating product	Pre-construction Construction Use Refurbishment Demolition/Deconstruction	- Insufficient skills and investment in circular product design and production which could facilitate greater re-use, remanufacture, repair and recycling - Lack of infrastructure for the segregating of biological from technical nutrients and phasing out toxic materials - No adequate means to account for the extent to which a product embraces circular economy principles - Renewable Energy Directive encourages use of biogas - Awareness and information - Planning legislation - Lack of demand (client)
Planning RIBA stage 3	**Reuse** - Working to achieve cut and fill balance - Consider soil creation opportunities - Import of reused, recycled, secondary and by-product materials as first choice		

[16] EU Commission, Scoping study to identify economic actions, priority sectors, material flows and value chains, 2014, p vi

Pre-construction RIBA stages 4-5	- Stimulate CE requirements - Identify requirements to reduce use of hazardous materials	Tender/contract Design Construction	- Awareness and information
Tender/ contract RIBA stage 5	- Stimulate CE requirements - Identify CE opportunities, sources;	Design Construction	- Make the true cost of resources known (inclusive of externalities - Awareness and information - Cultural and consumer awareness - Procurement to consider CE principles
Construction RIBA stage 5	**1. Use reused, recycled or refurbished components** **2. Use materials that can be disassembled for easy reuse, recycling and refurbishing** **3. Use materials which do no have hazardous substances for easy disassembly** **5. Use materials that can be reused, recycled after deconstruction**		
Site setup/ initialisation/ enabling works RIBA stage 5		Demolition/Deconstruction Sub-structure	- EU waste legislation – classification of waste[17] - Awareness and information - Cultural and consumer awareness - Building Regulations
Ground-works/ drainage RIBA stage 5	Site clearance; removal of soil, of buildings, On-site segregation to identify materials that can be reused on site or for reuse, recycling off-site		- EU waste legislation – classification of waste - Awareness and information - Cultural and consumer awareness
Sub-structure RIBA stage 5	**Priority products – metal** Use of existing materials from previous phases Use of recycled materials	Use Occupancy Refurbishment Demolition/Deconstruction	- Access to secondary materials market - EU waste legislation – classification of waste - Awareness and information - Cultural and consumer awareness
Super structure RIBA stage 5	**Priority products – metal, wood, plastic** Reduce use of hazardous materials Take into account the efficiency of the recycling of raw materials Choose products designed for disassembly Choose produces with little negative environmental impact	Use Occupancy Refurbishment Demolition/Deconstruction	- Access to secondary materials market - Volatile resource prices - EU waste legislation – classification of waste - Lack of information about green suppliers - Uncertainty over recycling market as investment opportunity - Absence of a widely recognized, independent organization to award certification on resource efficiency or a CE - Awareness and information - Cultural and consumer awareness - No adequate means to account for the extent to which a product embraces circular economy principles - Health and safety - Quality assurance & traceability - Recognition of material characteristics e.g. steel strength
Fit-out RIBA stage 5	**Priority products – metal, wood, plastic** Sourcing of products which: - are more durable or easier to repair, upgrade or remanufacture -can recover valuable materials and components - include reduced use of hazardous materials Choose products designed for disassembly Choose produces with little negative environmental impact	Use Occupancy Refurbishment Demolition/Deconstruction	- Limited information, know-how and economic incentives for key elements in the supply and maintenance chain, e.g. for repair and reuse, on chemical composition of certain products such as substances in electronic devices - EU waste legislation – classification of waste - Lack of information about green suppliers - Awareness and information - Cultural and consumer awareness - Building Control Regulations - Composite/difficult materials

[17] The EU Commission scoping study identified EU waste legislation and the definition of waste as a potential barrier to a circular economy approach. See EU Commission, Scoping study to identify economic actions, priority sectors, material flows and value chains, 2014, p viii

Dry trades RIBA stage 5	**Priority products – metals, woods, plastic** Reuse products Use recycled products Choose produces with little negative environmental impact Use energy efficient products	Use Occupancy Refurbishment Demolition/Deconstruction	- EU waste legislation – classification of waste[16] - Lack of information about green suppliers - Awareness and information - Cultural and consumer awareness - Composite/difficult materials
Wet trades RIBA stage 5	**Priority products – plastic** Reuse products Use recycled products Choose produces with little negative environmental impact Use energy efficient products	Use Occupancy Refurbishment Demolition/Deconstruction	- EU waste legislation – classification of waste - Lack of information about green suppliers - Awareness and information - Cultural and consumer awareness - Composite/difficult materials
External works/ landscaping RIBA stage 5	Opportunities to introduce biodiversity		- EU waste legislation – classification of waste - Awareness and information - Cultural and consumer awareness
Finishing RIBA stages 5-6	Use non-hazardous materials Reuse materials Recycle		- Lack of information about green suppliers - Awareness and information - Cultural and consumer awareness - Composite/difficult materials
Occupancy/Use RIBA stage 7	**1. Maintain** **2. Reuse** **3. Refurbish/recycle** Buy energy efficiency products Recycle		- Awareness and information - Cultural and consumer awareness
Refurbish/Reuse	Choose products designed for disassembly Choose produces with little negative environmental impact	Demolition/Deconstruction	- Widespread planned obsolescence in products - Awareness and information - Cultural and consumer awareness - Composite/difficult materials
Demolition/ Deconstruction	**1. Reuse** **2. Redurbish** **3. Recycle** **4. Reclamation**	Construction	- EU waste legislation – classification of waste - Awareness and information - Cost (implications of H&S) - Availability & storage - Lack of demand for deconstruction/extraction - Quality assurance & traceability - Lack of supply chain integration (esp. demolition & design)

5. Circular economy model for built environment by construction phase

We have an uncertain future, we take a finite number of resources, make something out of them and ultimately at the end of their life throw them away.

The wasteful approach we have applied to natural resources in construction is not compatible with the well-being of future generations. In a circular economy resources are kept in use and their value retained.

We have worked to develop a model, an illustrative representation and associated animation to demonstrate how the circular economy applies to the built environment. The model has been developed to reflect:

1. The key phases in a construction project and how they connect to one another. e.g. design links to:

a. Construction;
b.How the property will be used;
c. Demolition/Deconstruction; and
d. In reverse to the concept which can impact on what sort of design is required

2. Each phase is represented by its own circular hierarchy reflecting the key components within a circular economy approach, for example, for construction this shows:

a. Electing to use reused, recycled materials;
b. Using materials that can be disassembled (so linking to demolition/deconstruction);
c. Using non-hazardous materials, which enable disassembly and therefore further reuse or recycling;
d. Using materials (where primary materials) that can be reused, recycled or remanufactured

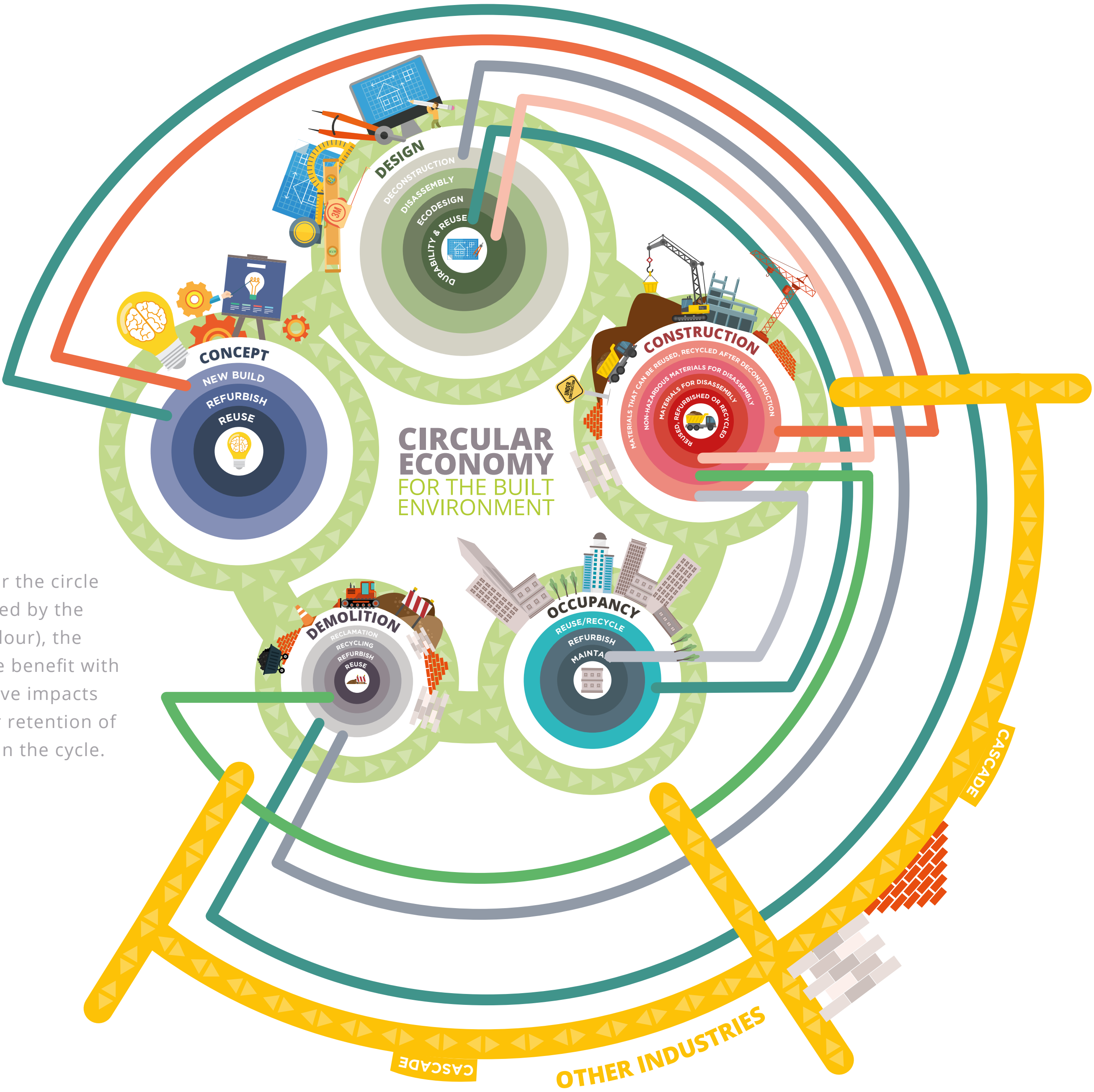
3. External connection to cascading, identifying opportunities for inter-linkages between other sectors/ resources/materials from other sectors, where:

a. Construction projects can use cascaded materials (e.g. aggregates); or
b. Can send materials into the cycle to be reused (e.g. wood, metal).

This ensures that products and materials are retained within the lifecycle of a building for as long as possible and that products and components are designed in such a way to ensure that they can be disassembled for reuse, recycling or remanufactured (if technical materials) or reclaimed (e.g. through extraction, anaerobic digestion) if biological material.

To achieve circularity no phase can work in isolation. The sustainable management of natural resources will require industry to capitalise upon opportunities offered by other sectors.

Circular economy model for built evironment by phase



The smaller the circle (represented by the darkest colour), the greater the benefit with less negative impacts and longer retention of value within the cycle.

5.1 Application of the model

The model has been applied to the construction process by phase. Detailed below is an outline of the methodology and actions that need to be considered at each construction phase.

The smaller the circle represented by the darkest colour the greater the circular economy benefit with the least negative impact and longest retention of value.

5.2 Concept

The concept stage establishes the basis for a project. Decisions made at this stage will have repercussions throughout and will impact the project's ability to work in a circular fashion.

To establish a position of lowest impact, projects should consider if there is the opportunity to reuse or refurbish an existing building. This typically has a smaller impact than a new build. The smaller the circles represented here, the lower the impact.

5.2.1 Prevention

To be most effective prevention of waste must begin at the initial concept stage. At this stage opportunities and options to prevent wastage should be most easily identifiable, such as cut imbalances. At this early stage they can be dealt with most effectively and cheaply, with time to consider innovative alternatives or solutions. Client engagement on the issue of wastage should be raised early in the concept stage. Clients are often unaware of how their decisions affect wastage, so project design and construction teams should spend time highlighting these types of issues.

Actions to consider

- Development of resource management plans
- Clear planning policy
- Explicit prevention targets at concept/design stage

5.2.2 Reuse

Proposed sites often have existing structures or resources which can be reused when constructing a new asset. For example, if there are existing structures or utilities on the site. Aligning the conceptual design to connect with existing drainage, saves time, money and materials used to remove / cap any existing and replace with new. For example, at Aberystwyth Fire Station the existing telecoms routes were tapped into rather than installing new.

Actions to consider

- Requiring the use of pre-demolition surveys would be an effective tool in identify opportunities for reuse.
- Material information – technical information such as chemical properties, strength
- Clear BIM policy, facilitating sharing of information on materials used within

5.2.3 Refurbish

Is there scope within the pre-existing asset for refurbishment to meet the use of the proposed new build? Refurbishment can achieve the same aims as a new build at lower cost and with lower impact and wastage, prolonging the value life of the materials in the existing asset.
At the concept stage of a new asset future refurbishment should be considered, such as conversion of offices into flats or retail space. Flexibility in systems, such as ventilation and heating, need to be built into the design from the beginning to allow for anticipated change of use driving by socio-economic change or climate change. Asset owners / commissioners will benefit from the flexibility / ability to diversify, maintaining income streams / versatility.

CASE STUDY: Public Health Wales

Public Health Wales brought together multiple sites to a single office location in Cardiff, as part of the procurement a contract was awarded to an SME consortia to repair and refurbish office furniture from the multiple sites to produce a fit for purpose unified and coordinated office furniture for use at the new site. Approaching the contract in this way identified financial savings, environmental and social benefits.

Actions to consider

- Procurement guidance
- Tax incentives for reuse/refurbishment
- R&D support to develop skills in design for adaptability/reuse/refurbishment

5.2.4 New Build

Constructing a new build using modular systems or pre-fabricated components reduces waste. Prefabricated components are produced in controlled, factory environments where wastage can be controlled through quality control systems. Any wastage that is produced may then be captured, potentially put back into the manufacturing process.

Modular components now commonly used include:

- Entire bathrooms – eg hotels, student accommodation
- Wall systems with pre-installed electrics / services

CASE STUDY: Celtic Manor Resort, Newport

As part of the construction of the 334 bedroom Celtic Manor resort off site construction techniques were used to manufacture complete bathroom pods which were craned into the site, ready for plumbing and electrical connection.

5.3 Design

Design offers the biggest opportunity to deliver a circular economy approach. Around 80% of a product/building's environmental impact is determined by decisions made at the design stage (Environmental Change Institute, 40% House, 2005). Decisions made at the design stage impact upon the value retained within a structure and material's life cycle.

Time spend in planning is never wasted. "Design represents minute proportion of the lifetime cost of a building – less than one percent – but done well it has a disproportionate impact on how well the building and its surroundings perform" NAO[18]

Projects need to design for reuse with durability in mind, making it easier to repair or upgrade, reuse, recycle or recover at end of the life.

Design principles for a circular economy include building in layers; designing out waste; designing for adaptability; designing for disassembly/deconstruction and the selection of materials for circularity.

> ### CASE STUDY:
> ### Bryn Ivor Lodge Care Home, Newport
>
> The original location, and level, of the Bryn Ivor Lodge care home would have involved the removal of 4,550m^3 of soil. Analysis of alternate location options showed that by raising the building by 500mm and moving it 3m a cut and fill soil balance could be achieved. Preventing the removal of excavated materials from site saved £96,460 in waste management costs, not including associated costs, such as labour, plant hire and fuel. This would have been nearly five and a half times the actual waste management cost. This is all detailed in the report which can be found at http://www.cewales.org.uk/files/7014/9071/0362/EZW_Bryn_Ivor_Report_English_-_use.pdf

5.3.1 Prevention

The design stage is where the majority of a construction project's waste will be determined. Consideration at the earliest opportunity is necessary to design waste out of a project. For example, material standard sizes can help to prevent wastage i.e. room dimensions to standard plasterboard widths or brick dimensions to minimise the amount of wastage produced through offcuts.

Design complexity is a common reason for wastage; producing small, unusable offcuts. Designers should consider how their decisions, and design details, could generate waste through offcuts or damage. BIM is a useful tool here. It allows for the full visualisation of the design, and then assessment, in 3D.

The BIM process eases identifying clashes which prevents waste caused by abortive and / or restorative works on site. For the Bryn Ivor Lodge, Castleoak's timber frame designers used specialist software to design the roof structure. The software produces 2D outputs, there were no 3D outputs. 3D modelling would have highlighted issues with the design earlier, such as:

- Rafters extending beyond soffits
- Discontinuity of rafter geometry

Accurate modelling of the roof structure is important when it comes to installation of M&E systems. Ventilation, plumbing and electrical systems are well known for causing delays on site due to clashes. Designers aim to limit this by providing more than adequate space in roof/ceiling voids. But to avoid wasting time, materials and workmanship M&E systems can be checked for clashes against the architectural design within BIM. This ensures the use of optimal routes and economic layouts.

BIM also makes it easier to make small changes to designs to experiment with room dimensions and layouts with a view to preventing waste. This can be achieved by considering standard material sizes when deciding on room dimensions.

Actions to consider

- Design review
- Early engagement with supply chain
- Use of BIM

5.3.2 Durability

How the asset will be used should be considered at the design stage, especially when choosing products for use in the asset. For example, carpet may need replacing on a regular basis in heavily trafficked areas. A more expensive tilling solution may have a higher capital investment cost, but over an asset's lifespan may have a lower operational cost, since it is harder wearing. This can be applied to all aspects of an asset e.g. renders, roofing materials, hardscaping surfaces, barriers etc.

Actions to consider

- Formulating an asset management plan at an early stage allows for assessment of whole life costs for the asset. Providing clients with a full understanding of the longer term impact of capital investment decisions.

[18] National Audit Office (2004), Getting value for money from construction projects through design

5.3.3 Reuse

There are two parts to reuse at the design stage;

i. Using Reusable Materials

Design for the inclusion of reused materials and components which may be available. Detailed consideration should be given to how to use onsite resources, such as:

- crushing existing blockwork for fill material (down cycling)
- utilising existing assets, for example; roads, utilities and services
- processing of excavated sub-soils to produce a topsoil (upcycling)
- allowance for secondary materials/by-products in the designers specification

CASE STUDY:
Ysgol Y Ffwrnes, Llanelli

CASE STUDY: Llanelli School reworded to CEW worked with WRW and WRAP to bring PAS 100 compost to manufacture top soil for large scale urban landscaping of amenity and wildflower grasses. The manufacture top soils offered nutrient benefits together with cost savings of between 15 -20% based on the import of top soil. Further information can be found at https://www.youtube.com/watch?v=gcMO5OlQW2w

Actions to consider

- Development of resource management plans at earliest stage to facilitate site reuse
- R&D to facilitate the innovation of products/assets designed with reused materials

ii. Designing for Material Reuse

Designing for reuse requires consideration of how the components of an asset may be reused and designing to facilitate that. For example, a steel frame structure could see some reuse of its steel beams or columns if the design allows for easy disassembly without damage to the steelwork. Designing for extraction/future reuse helps to retain value of material.

Manufacturers are beginning to recognise the potential of reuse through material leasing. Assets would lease components like the steel from manufacturers who then reclaim it on disassembly. Leasing allows for the resource to be returned to the manufacturer for assessment and reuse or inclusion in their manufacturing process. Consideration for material leasing is needed at the design stage to ensure design for efficiency and deconstruction.

CASE STUDY:
Ice Arena Wales, Cardiff

As part of the development of the Enabling Zero Waste project at Ice Arena Wales, analysis has been conducted on the steel work, highlighting which elements will be fit for reuse at deconstruction and which will require processing or recycling, see BIM diagram at http://www.cewales.org.uk/current-programme/enabling-zero-waste/

Actions to consider

- Material leasing schemes
- Design for reuse at earliest opportunity
- Consideration within planning/building control policy

5.3.4 Ecodesign

Design can be considerate of the environmental impact of building materials. By choosing "eco" materials the asset can act as a material / "resource" store rather than an end user. This can be through the use of materials, such as;

- natural materials which sequester carbon-dioxide eg timber
- artificial materials which capture and sequester carbon eg Carbon8
- cradle to cradle (C2C) materials

Material choices such as these are at the foundation of the circular economy approach in the construction industry. With various certificates and measures, it can be complicated making effective and considerate decisions with regard to; lifespan, chemical content, reuse and disassembly.

Actions to consider

- A focus is needed on procurement and the examination of information on the material content of materials and components. Doing so is worthwhile. It allows built assets to be material / resource stores which future generations can salvage from for sale, or for new projects / designs.
- Clear direction towards a circular approach within planning policy and Building Standards/Regulations

5.3.5 Disassembly

Designing for disassembly involves designing an asset with full consideration of how it would be taken apart in a way which maintains maximum resource value. Assets should be designed with thought given to what happens to the constituent parts at the end-of-life eg. plant, cladding, internal partitions, structural elements. Products should be designed and optimised for a cycle of use, disassembly and reuse.

Actions to consider
Demolition contractors have highlighted it would be beneficial for designers to consider;

- reversible (ie not chemical) or mechanical connections
- ease of access to connections
- independent and separable asset elements eg structure, envelope, services
- no use of resins or coatings on components
- not using products which become difficult demolition wastes eg. polymer composites

5.3.6 Deconstruction

Deconstruction is an essential piece of the circular economy puzzle and it is made possible by design for deconstruction (D4D). Consideration of D4D principles should allow for a more focused deconstruction compared to a traditional demolition. Buildings could be considered as material banks where the materials and resources are assets which have been stored in the building and whose value can be released for use elsewhere.

Government Soft Landings (GSL) is about adopting a mind-set and a process to align design and construction with operational asset management and purpose. Designers and contractors will be involved with the building beyond its construction completion to ensure that handover becomes a smooth process, operators are trained, and optimum performance outcomes become a focus of the whole team[19]. Consideration could be given to expanding this to include not just the end user but the end use and ultimately the building's deconstruction.

Actions for consideration

- Designing in such a way that components can be separated for easy reuse and recycling. This means using composite products which have been design for separation. Avoiding the use of composite materials.
- Modular construction offers the opportunity to deploy assets temporarily, allows for easier deconstruction or part demolition. For example, modular site offices / cabins able to expand / reduce as needs onsite change
- Pre-selling of materials before demolition to incentivise best practice by deconstruction contractors

5.4 Construction

The construction phase has the ability to either enhance or inhibit the delivery of the design brief. Decisions made about the method of construction; material choice; site management and build quality impacts at future stages.

Actions to consider

- Recycled materials should be used intelligently. High recycled content does not necessarily mean lower impact and the product itself may not be recyclable.
- Materials should be reused or recycled after disassembly and deconstruction and should not contain hazardous substances.
- Good site management helps to retain the value of materials both on and off-site.

5.4.1 Prevention

Prevention of waste at the construction phase requires thorough planning by site teams. Planning helps to highlight waste as an issue, which if poorly managed poses a potential source of extra cost. Effective planning and scheduling is at the core of waste prevention. Reducing double jobbing or material movements which produce wastage through damage.

Early engagement and planning allows for the prefabrication of asset elements or the use of modular construction systems. Offsite preparation means construction elements can be produced in a controlled, factory environment, where waste can be monitored and processed effectively.

BIM can play a key part when preventing waste during the construction of an asset. Full visualisation helps detection of clashes, which are well known for producing waste due to abortive/restorative works. Augmented reality offers a practical way for those working on site to see where components should go, what components have gone before and what components will come afterward. Removing the existing culture of making an issue the next tradesman's problem.

BIM can also prevent waste by allowing accurate quantity surveying, removing an aspect of traditional over ordering. Accidental, unavoidable breakage on site may still occur but QSs will be able to order exactly what is needed for building.

> **CASE STUDY: Glynn Vivian, Swansea**
>
> The augmented reality approach has been used for the Glynn Vivian Art Gallery in Swansea. Scans of services were taken before they were covered and these scans have been incorporated into a 3D model. Glynn Vivian staff will be able to use augmented reality to assess a section of wall for services and then place new artwork with confidence that they won't hit hidden services

Actions to consider

- Early engagement with the supply chain
- Use of design review/BIM to identify potential errors and clashes
- Development of a resource management plan, this will facilitate the identification of possible wastes and enable early intervention to prevent waste occuring

5.4.2 Reuse

Reuse is common on sites and often goes unrecorded. Timber makes an excellent case study. Much of the timber that ends up in the skip on a construction site has been used a handful of times after its original use. For example, Enabling Zero Waste projects have used timbers to baton

[19] http://www.bimtaskgroup.org/gsl-faqs/

down plastic sheeting, which have then been used to build access ramps and then been used build protection for pipe manifolds.

Temporary site infrastructure is often reused. Occasionally disposal is seen as an easier option than transport to another site or short term storage. Reused infrastructure includes:

- Hoardings/fencing (posts and boards) are often taken on to the next site. Public facing sites tend to use branded hoardings using them as an advertising opportunity
- Shuttering (either timber or metal) is reused
- Scaffolding
- Protection – eg correx sheets, foam protection

Actions to consider

- Planning for reuse, including provision for storage to facilitate multiple uses
- Monitoring to increase visibility of reuse and assist in management and identification of opportunities
- Thinking for the long term and Investing in products designed for multiple uses, such as metal hoarding

5.4.3 Refurb

During construction contractors should consider how their decisions will affect the refurbishment of the asset. Using products which save time or money in the short-term may have longer-term impacts on the flexibility of the asset for refurbishment or adaptability. For example, limited patressing only in necessary locations when the design may specify pattressing for all stud walls. Patressing throughout would allow for a variety of alterations from wall shelving to toilet locations. Additional investment of time and money during construction can see an improvement in the value life of the asset.

Actions to consider

- Consideration of future adaptability with scenario modelling to consider how well an asset may adapt to future refurbishment and reuse
- Development of business case for adaptable solutions to support decision making

5.4.4 Use of recycled materials/By-products/ Secondary materials

Recycled materials/by-products, and secondary materials provide lower impact alternatives to virgin raw natural resources. Through cascades it is possible to introduce materials from other sectors and industries that meet the necessary technical specification. The cascade of resources between sectors maximises the value and use of these materials. With value, products and materials are more likely to be retained in use, this may be multiple times for a variety of different purposes across numerous industry sectors.

The use of recycled materials in construction should be encouraged. They should be used intelligently, as high recycled content does not necessarily mean the product is recyclable itself.

CASE STUDY: Eastern Bay Link Road, Cardiff

Dawnus, as part of the East Bay Link road in Cardiff Bay utilised steel slag produced in the neighbouring Celsa steel works as aggregate fill material. Over the course of the project 60,000 tonnes of steel slag was used as 6F2, replacing virgin material. This reduced the requirement for virgin quarried materials, significantly reducing the environmental impact by using an alternative source and significantly reduced transport distances, along with the associated CO_2 emissions.

Actions to consider

- Consideration of recycled materials/by-products/ secondary materials as first choice materials

5.4.5 Use of non-toxic materials

Toxic material usage creates hazardous waste which have to be disposed in accordance with hazardous waste regulations. Construction teams should give serious consideration to how to eliminate the need to use these products. This may mean alteration of the program, for example, to allow screed to fully dry before laying flooring without a damp proof coating. These coatings often come as a two-part epoxy resin with all the containers being deemed hazardous waste.

Actions to consider

- Consider use of cradle to cradle certified products
- Where there are no alternatives available, address packaging, for example mastics etc can be purchased in cardboard tubes greatly reducing the volume for hazardous disposal

5.4.6 Use of materials/components for disassembly

The use of elements capable of being easily disassembled and repaired or replaced extends the life, retaining value and reducing the impact. However, products/ elements designed for disassembly are at risk of being "value engineered" out of an asset by contactors aiming to save on the capital cost of building the asset. "Value engineering" does not take into account the effect of decisions on the long-term value of the whole asset, often it favours materials which have a lower capital cost and are not easily repaired, replaced and recoverable at end of life.

Actions to consider

- Choice of fixings, some prohibit refurbishment and repair, such as high strength adhesives, reversible fittings are available
- Most products are capable of being refurbished/ remanufactured, do new products need to be purchased, could savings be made from reuse of existing?

5.4.7 Use of materials which can be reused or recycled after deconstruction

During construction it can be tempting to revert back to well-known / traditional methods or products to save time or money in the short-term. Often these methods have long-term impacts on the asset's flexibility during use and then value at deconstruction. Binding materials together in ways which make disassembly difficult or impossible is a major issue. Contractors should be aware of how to assemble an asset using reversible processes. Use of powerful adhesives should be discouraged.

5.5 Occupancy

The built environment should be considered an endowment for future generations, however, it can become a liability that has to be demolished at cost.

Appropriate management and maintenance will help extend the use into the long term. Consideration must be given to the impact of any alteration on the ability of the structure to be reused, refurbished or recycled at end of life.

Actions to consider

- Use and update BIM models to reflect changes made during occupancy to provide the best information at end of life
- Consider repair/refurbishment ahead of new items, these approaches bring environmental and cost savings

5.5.1 Plan & Prevention

Effective asset management is at the core of effective and efficient use of an asset. At the beginning of the assets life a comprehensive asset management plan should be laid out for the lifespan of the asset. This boosts the value life of the asset and its components.

An asset management plan would detail all layers of the asset, specifying how regularly each will need maintenance or replacement. These can be classified as;

- Set; day to day - consumable components (eg carpets, furniture, equipment)
- Scenery; 5-10 year - replacement components (eg modular components, built-in furniture, movable partitions)
- Services; 15-20 year - replacement components. Building services (eg heating / ventilating) which may require replacement to maintain efficiency
- Shell; 50-75 year - the main fabric of the asset (eg SIPs or masonry for example) will require repair or replacement over a longer time scale.

Planning in this way maintains a long-term vision for the asset all the way to value extraction at deconstruction. It also prevents double jobbing, maintaining or replacing in line with the plan. BIM could prove an essential tool to maintenance staff. Bringing material lists and specification together in one place, allowing for assessment of a model for detailed understanding.

Augmented reality will be a next step, presenting this information to maintenance staff as they work, when they need it. It would highlight;

- what asset elements are
- where they are if behind other elements (X-ray vision)
- what the maintenance plan for the elements are
- disposal options; suggesting reuse and recycling options for components

The augmented reality approach has been used for the Glynn Vivian Art Gallery in Swansea. Scans of services were taken before they were covered and these scans have been incorporated into a 3D model. Glynn Vivian staff will be able to use augmented reality to assess a section of wall for services and then place new artwork with confidence that they won't hit hidden services.

Actions to consider

- With a BIM models consider investing in GPS locators to enable models to be used in live environments to track services etc encouraging regular use
- Preparation of asset management plans for short, medium and long term
- If no digital modelling is available consider retrospective scanning, model will prove invaluable for management and at end of life

5.5.2 Refurbishment

Refurbishment of assets often requires reconfiguring the makeup of an asset to suit a change of use, or to allow modernisation to allow for development in the current use. Hopefully, refurbishment will have been considered at the design stage, making the process straight forward and efficient.

Assets which had no consideration of refurbishment at the design stage, significant work may be required. These works may produce significant quantities of waste. Ideally refurbishments should be undertaken in a well-planned, staged manner with similar wastes being produced from different parts of the asset at the same time. Doing so eases waste segregation and planning for material reuse and recycling.

Any refurbishment works would ideally be undertaken with a view to aiding any potential future refurbishment and deconstruction.

Actions to consider

- Pre-refurbishment survey
- Asset schedules
- Consider refurbishment of fixtures and fittings

5.6 Demolition/Deconstruction

The opportunity to reuse or refurbish a structure should always be considered ahead of demolition. Conversion can often be a more cost effective alternative and could lead to significant savings.

At the end of an asset's life, careful planning and a reclamation based approach can assist in turning a negative end of life value into a positive. Deconstruction can result in added benefit from the extraction of value items. Leasing or the presale of resources by the owner may encourage careful extraction of resources to retain value. Steps can be taken to prevent waste generation, with materials in the existing asset being of use for a variety of purposes.

Actions to consider

- Pre-demolition surveys can help identify components or resources of use
- Timescales, the more time that can be given to planning and advertising available items the greater the chance of diverting from waste streams

5.6.1 Reuse/Reclamation

Demolition is an industry which sees significant added benefit from the extraction of value items from the asset. As part of the process best practice will involve the identification of what can be reclaimed. Presale of some materials / resources by the asset owner may encourage quality removal of resources.

Actions to consider

- Key to reuse/reclamation is understanding what materials you may have and what is of value, for example bricks have increased in price 24% recently
- Careful choice of demolition contractors, look for deconstruction/reclamation led approaches
- Consider how deconstruction/demolition is undertaken as some items will need to be removed correctly to retain value

5.6.2 Recycling

To aid effective recycling of materials demolition contractors should develop detailed, staged plans for the demolition. Different types of waste should be removed at different times / stages allowing for consistent segregation of that waste type. With circular economy principles in mind this would go;

1. Set – eg consumable products such as carpets, furnishings and plant. Frameworks have been developed for the distribution of unwanted furniture

2. Scenery – eg partitions, modular components, built in furniture. Modular components, such as hotel bathrooms, could be disconnect and removed for upcycling / refurbishment

3. Services – eg heating, ventilating, electrical services. In an ideal circular economy future, the services will be easily demountable and have been leased by the manufacture. The manufacturer will then retake possession of their product for recycling / refurbishment

4. Shell – eg the main fabric of the asset; masonry, SIPs. Disassembly of SIPs is possible while masonry walls may be deconstructed carefully with second hand bricks often in demand

Actions to consider

- Choice of demolition contractor, look at recycling rates achieved
- Timescales, recovery rates are highest where sufficient time is given to plan
- Is there need of material at the site, for example could inert materials be processed on site for future use?

5.6.3 Waste

Some wastes may prove difficult to dispose of through reuse / reclamation networks. Disposing of waste in skips should be done responsibly with waste being segregated into separate skips for inert, timber, metal wastes for example. This makes the job of the waste management company much easier and they pass on this saving to their clients, offering lower rate for segregated skips vs. mixed skips.

Actions to consider

- Choice of waste management contractor, look carefully at recovery rates achieved and for what materials
- Plan site waste areas, ensuring segregated skips are closer than mixed options

6. Circular economy model by project

This model guides the decision making process for a project example. A project can be any type and in any stage in the construction lifecycle for example housing, a school, hospital or road and at any stage of the lifecycle, for example during construction, demolition or design.

Opportunities closest to the project provide the highest value least impact option where materials are retained for the same purpose within the same state.

The model helps to demonstrate how materials can be retained in circulatory and the resource recovery process.

It reflects:

1. A value chain by focusing firstly on on-site reuse, refurbishment or recycling opportunities;
2. Closed Loop - Connection to external collections and the ability of products, components or parts to be able to be entered back into the cycle through reuse, refurbishment or recycling and this returning back into the construction cycle by the user;
3. Open Loop - Extraction of biomass components back into the system

The start of the chain focusses on on-site activities such as reuse, refurbishment and recycling. These opportunities all help to contribute to the extended use of materials and are the preferred activities as they result in higher resource value. Segregation of materials on site helps to encourage material reuse and higher quality recycling opportunities. Environmental impact is minimised and value highest when materials are used for their original purpose. As materials are repurposed by altering their physical state or original use the amount of input increases therefore increasing cost which may impact on their value.

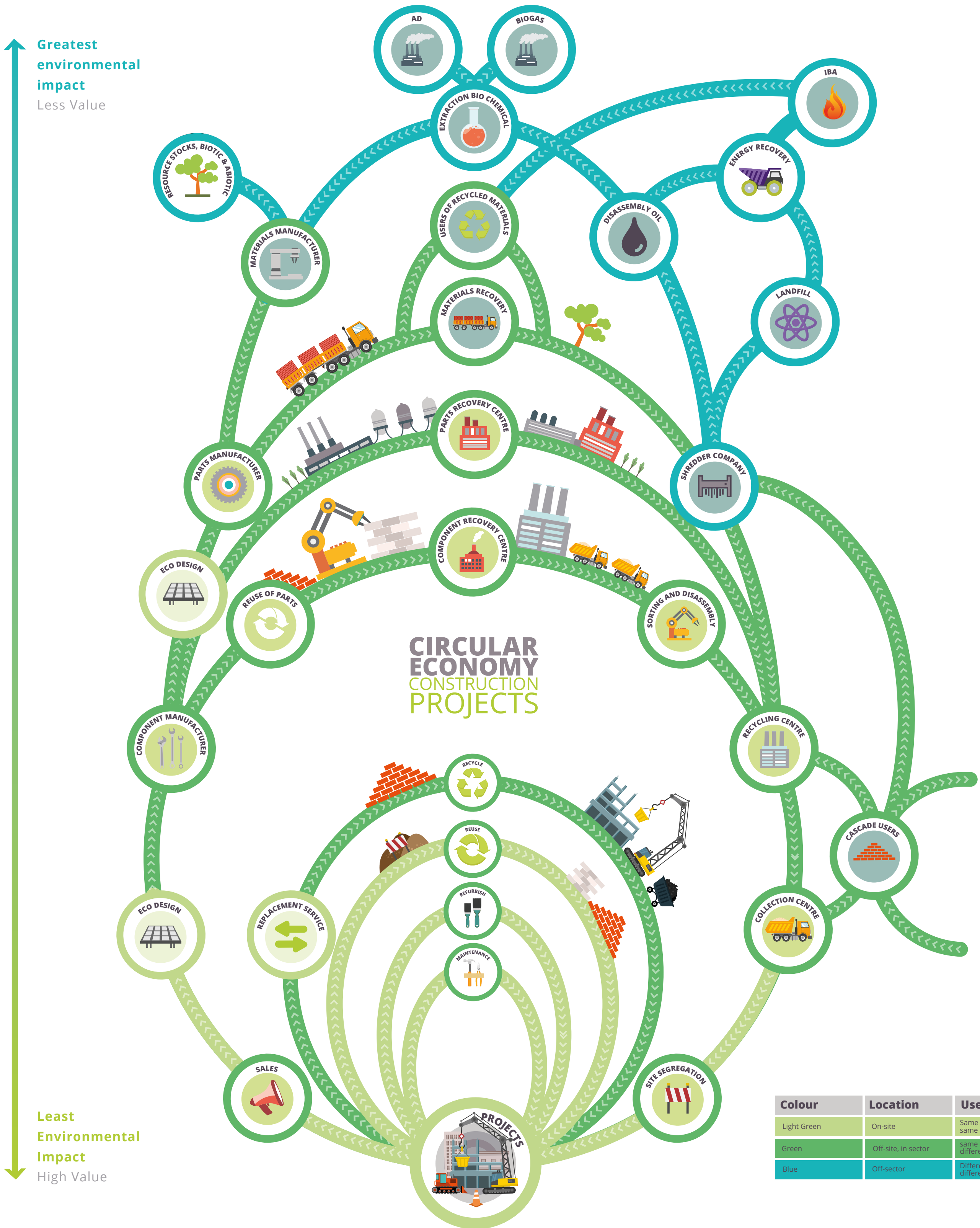
The wasteful approach we have applied to natural resources in construction is not compatible with the well-being of future generations. In a circular economy resources are kept in use and their value retained.

The model has been developed to reflect:

1. **the key phases in a construction project and how they connect to one another. e.g. design links to:**
   a. Construction;
   b.How the property will be used;
   c. Demolition/Deconstruction; and
   d. In reverse to the concept which can impact on what sort of design is required

2. **Each phase is represented by its own circular hierarchy reflecting the key components within a circular economy approach, for example, for construction this shows:**
   a. Electing to use reused, recycled materials;
   b. Using materials that can be disassembled (so linking to demolition/deconstruction);
   c. Using non-hazardous materials, which enable disassembly and therefore further reuse or recycling;
   d. Using materials (where primary materials) that can be reused, recycled or remanufactured

Circular economy model for built environment (on decision basis) by project



Colour	Location	Use
Light Green	On-site	Same purpose, same state
Green	Off-site, in sector	same state, different purpose
Blue	Off-sector	Different state, different purpose

7. Indicators of circular economy

To demonstrate how effective the transition is from linear to circular economy there will be a need to develop a set of indicators to monitor progress and evaluate the change in process.

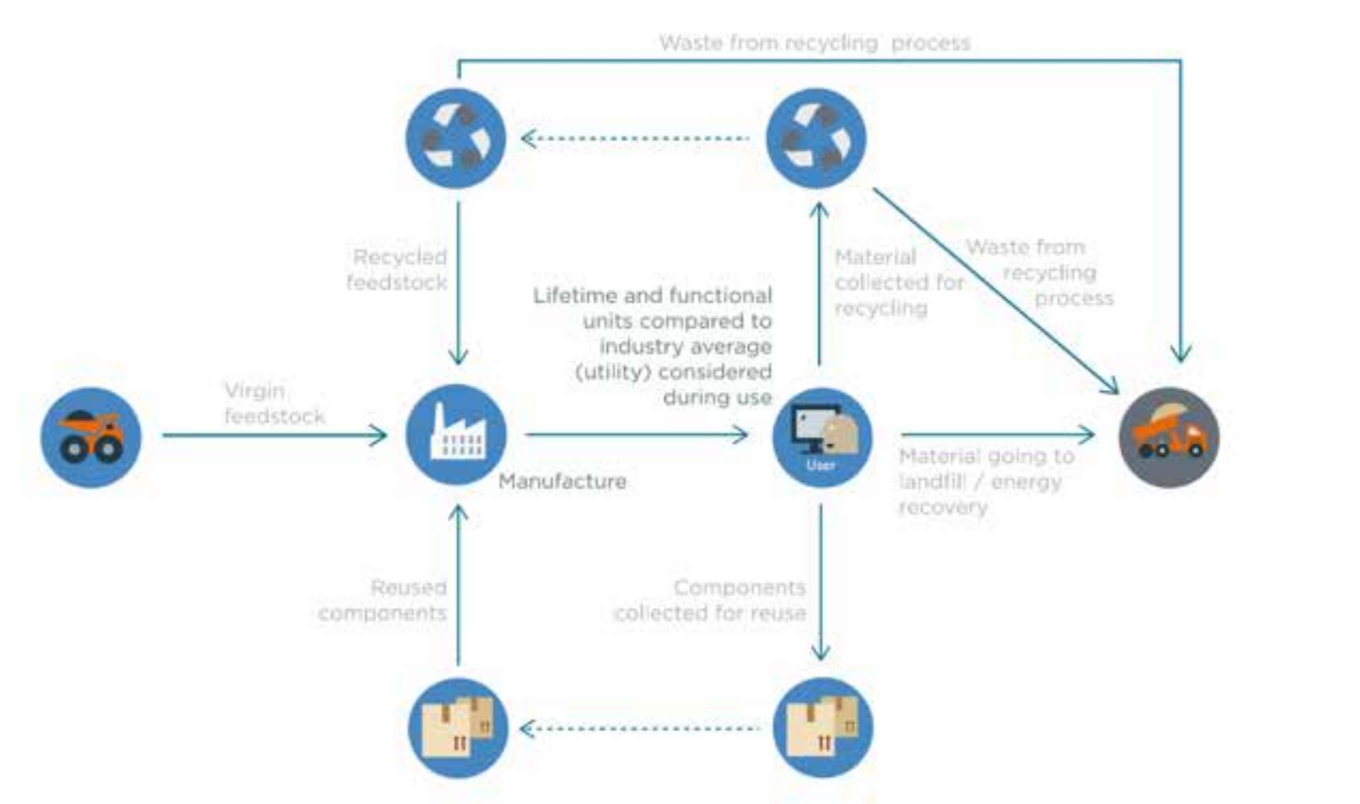
The indicators will need to map the transition from a linear economy where a project/product uses virgin materials and ends up in landfill at the end of its life to true circularity where a project/product contains no virgin feedstock and is completely collected for recycling or reuse, and where recycling can be considered one hundred per cent efficient can be considered a fully circular project/product.

The Ellen MacArthur Foundation as part of the Circularity Indicators Project[20] developed the material circularity indicator (MCI) to demonstrate how restorative material flows are within a product lifecycle.

There will be a need for a combination of indicators to capture material flows through the process as well as wider indicators that would capture the achievement of the economic opportunities and associated ecological footprint and carbon savings.

CEW propose that a series of indicators are developed to manage and monitor progress. Practically these indicators need to be integrated with wider industry and project funding requirements, such as those identified within Towards Zero Waste and 21st Century Schools Framework.

Figure 4: Circularity indicators



Source: Ellen MacArthur Foundation, Circularity Indicators: An approach to measuring circularity

[20] Ellen MacArthur Foundation: Circularity Indicators Project, https://www.ellenmacarthurfoundation.org/programmes/insight/circularity-indicators
[21] The ecological footprint methodology calculates the land area needed to feed, provide resource, produce energy and absorb the pollution (and waste) generated by our supply chains. Definition from Towards Zero Waste: The Overarching Waste Strategy for Wales
[22] Greenfield Resource Management Hierarchy of http://www.mrw.co.uk/opinion/merging-the-circular-economy-and-waste-hierarchy/8654179

7.1 Material flow indicators

The following material flow indicators have been identified, these have been divided between project phase.

1. Concept/Design
    - Waste prevented
    - Percentage recycled/secondary/by-product content*
    - Percentage reuse content

2. Construction
    - Percentage waste to landfill – 0%
    - Percentage waste incineration/energy recovery 0%
    - Percentage waste reused/recycled*

3. Occupancy
    - Percentage waste to landfill – 0%
    - Percentage waste incineration/energy recovery 0%
    - Reuse/repair/Refurbish/Adaptability
    - Utilisation rate

4. Demolition
    - Percentage waste to landfill – 0%
    - Percentage waste reused/recycled*

*Need to factor the efficiency of recycling processes

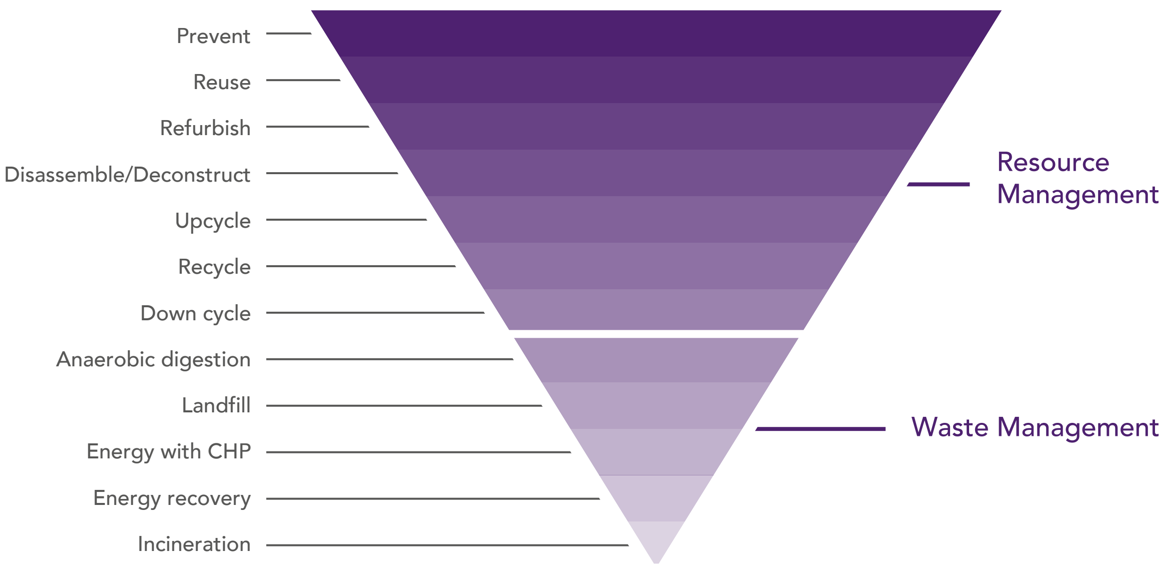
To demonstrate the achievement of the economic opportunities we would need to capture the amount of waste generated for the sector per unit of GVA (gross value added).

- Carbon savings / carbon budgeting
- Ecological footprint[21]

7.2 Resource hierarchy

To encourage industry to guide more circular decision making, a revision to the waste hierarchy may help to facilitate the process. The waste hierarchy or Lansink's ladder was originally developed by the Dutch politician Ad Lansink. It has been introduced as part of the European Union's Waste Framework Directive (1975/442/EEC). It provides a simple guide to the preference of of waste management options. A revised resource management hierarchy was suggested in 2013 within the Greenfield Resource Management Hierarchy[22], which began to introduce concepts of circularity adding closed loop recycling, anaerobic digestion and energy with CHP to the original pyramid. In revising the hierarchy within a built environment context it is suggested that refurbishment and disassembly be added, recycling be expanded upon to prioritise value generating options over down cycling. With landfill and incineration be reordered to take into account the potential for resource recovery through landfill mining.

Figure 5: Alternative waste hierarchy



Section 8-9
Economic potential

8. What does the circular economy mean for the built environment in Wales: value of economic opportunity

amec foster wheeler

Amec Foster Wheeler were commissoned by CEW to analyse the value of the economic opportunity from the circular economy for the built environment. The aim of this research is to build upon work developed by CEW by identifying the net benefits to Wales of adopting a circular economy approach in the built environment. While requiring a number of assumptions, an estimate of net benefits provides a quantitative measure in monetary and economic terms which sets the overall scale of impacts in context and can be used to prioritise practical steps towards changes in design and operational practices.

8.1 Characteristics of Wales important to transition to a circular economy

8.1.1 The Welsh economy

Wales has a history of resource production and resource intensive manufacturing, with coal mining, metal-working and other mining and heavy industries in the North-East and the South dominating the Welsh economy since the 18th century. However, these core industries declined significantly in the 20th century, leading to mass unemployment and emigration, but also attempts to diversify the economy[23].

Today, Wales remains a lagging region within the wider United Kingdom economy. Gross Value Added (GVA) per head for Wales is 71% of the UK average the lowest of any other UK region or country[24]. Mining and quarrying now makes up less than 1% of Wales' GVA. Manufacturing still accounts for 16% (compared to 10% in the UK), with basic metals and metal products still the largest manufacturing industry (2%)[25]. Therefore, the traditional manufacturing base and the associated skills are still an important factor in the Welsh economy and thus for its transformation to a more circular economy, as pointed out by the Ellen MacArthur Foundation, WRAP and Welsh Government report "Wales and the Circular Economy"[26].

With 6% of Wales' GVA (the same share as UK-wide)[27], construction is an important sector for the Welsh economy. The Construction and Demolition Sector Plan of Towards Zero Waste[28] stresses the potential to drive change in the built environment and the people that use it, with particular regard to sustainable development. The Ellen MacArthur Foundation points out the built environment as one of its three key areas for the transition to a circular economy in its "Growth Within" report[29]. Services account for most of the rest (about 75%) of Welsh GVA[30].

The strategy for the future development of the economy of Wales, as reflected in Economic Renewal[31], Science for Wales[32] and Innovation Wales[33], has identified a number of key areas in the Welsh economy with existing strengths and economic opportunities. Many of these areas are also key areas for a transition to the circular economy: low carbon energy and environment, advanced engineering

[23] BBC: A history of Wales. Chapters 15, 20 and 21. http://www.bbc.co.uk/wales/history/sites/themes/guide.shtml
[24] http://gov.wales/statistics-and-research/economic-indicators/output?slideId=0&lang=en
[25] Office for National Statistics: Regional Gross Value Added (Income Approach) NUTS1 Tables.
[26] http://www.wrap.org.uk/sites/files/wrap/Wales_and_the_Circular_Economy_Final_Report.pdf
[27] Office for National Statistics: Regional Gross Value Added (Income Approach) NUTS1 Tables.
[28] Welsh Government: Construction and Demolition Sector Plan. Towards Zero Waste One Wales: One Planet. November 2012. http://gov.wales/docs/desh/publications/130301construction-demolition-waste-plan-en.pdf
[29] Ellen MacArthur Foundation, Stiftungsfonds für Umweltökonomie und Nachhaltigkeit, McKinsey Center for Business and Environment: Growth Within: A Circular Economy Vision for a Competitive Europe. 2015. https://www.ellenmacarthurfoundation.org/publications/growth-within-a-circular-economy-vision-for-a-competitive-europe
[30] Office for National Statistics: Regional Gross Value Added (Income Approach) NUTS1 Tables.
[31] Welsh Assembly Government: Economic Renewal: a new direction. July 2010. http://www.wlga.gov.uk/publications-environment-and-regeneration/economic-renewal-a-new-direction-welsh-assembly-government/
[32] Welsh Government: Science for Wales A strategic agenda for science and innovation in Wales. 2012. http://gov.wales/docs/det/publications/120306scienceen.pdf
[33] Welsh Government: Innovation Wales. 2014. http://gov.wales/docs/det/publications/140313innovationstrategyen.pdf

and materials, as well as ICT and the digital economy (among others as enabler for the sharing economy, reducing resource consumption). Other areas identified in the strategy are life sciences and health, creative industries and financial and professional services.

There are strong regional disparities in the Welsh economy, as workplace based NUTS2 estimates for 2014 show GVA per head in East Wales at 84% of the UK average and West Wales and the Valleys at 64%. Most economic activity is concentrated in the South of Wales, where also the highest GVA per capita is generated. Cardiff and the Vale of Glamorgan was ranked the highest NUTS3 area in Wales at 90%[34]. The Welsh economy has strong ties with the rest of the UK, notably Cardiff and the South with the Greater Bristol area, the M4 corridor and even London, and the North-East with Chester, Cheshire, Merseyside and Manchester[35]. This means that resource flows and supply chains are very likely to extend beyond the borders of Wales. This is true of course for the economy of any region or country and includes every other region or country with which it trades. However, it appears likely the transition to a more circular economy in Wales influences and is influenced by circular economy activities in the English areas to which it was traditionally linked.

8.1.2 Political support and institutions in Wales

The political support as well as the presence of innovative institutions are important factors influencing the transition to a more circular economy, because they can create the right enabling conditions and set the direction for unlocking the benefits from this transition[36].

The institutional environment and especially the political support for a transition to the circular economy both in general and for the built environment sector is particularly strong in Wales. This supports an ambitious transition scenario for the estimation of benefits from the implementation of CE in Wales.

8.2 Current CE practice in Wales (from recent case studies)

CEW has monitored a number of projects optimising construction and minimising waste arising from the built environment. These are effectively pilot projects for CE in the built environment in Wales and provide possible pre-cursors for wider implementation of new practices. Case study documents have been developed by CEW to document and analyse these projects.14 case study documents were reviewed with regards to evidence that can be used to estimate the benefits of implementing CE in the built environment in Wales.

- **One case study, Bryn Ivor Lodge care home[37] , identified cost savings attributed to consideration of the waste hierarchy and effective waste management of over £170,000, equivalent to over 2% of the project budget.** This gives a direct indication of the magnitude of savings that can be incurred in Wales if the applied circular economy practices are implemented. It is worth noting that the construction in this project was executed by Castleoak, a Welsh company leading to a greater likelihood that a greater proportion of benefits being retained in Wales.

- **Two other case studies[38] quantify cost savings for niche applications** that seem less reasonable to extrapolate to all of Wales. While the other case studies do not provide evidence that could be readily used for the quantitative estimation of benefits, they illustrate that early adopters of CE practices in the built environment are present in Wales.

An overview of all case studies reviewed, as well as conclusions regarding the use of case study statistics for the estimation of net benefits is presented in the Annex.

[34] http://gov.wales/statistics-and-research/regional-gross-value-added-sub-regional-gross-value-added/?lang=en
[35] Welsh Assembly Government: Wales: A Vibrant Economy. The Welsh Assembly Government's Strategic Framework for Economic Development. Consultation document November 2005.
[36] Compare for instance: Ellen MacArthur Foundation, McKinsey Center for Business and Environment, Danish Business Authority, Danish Protection Agency, NERA Economic Consulting: Delivering the Circular Economy – A Toolkit for Policymakers. Page 13. 2015.
[37] http://www.cewales.org.uk/files/6114/7730/1938/Bryn_Ivor_Lodge_Castleton.pdf
[38] Aberystwyth fire station and Millbank primary school (the reviewed reports were not yet published at the time of writing)

8.3 Data required to assess potential for CE for all of Wales

A literature and data review has been conducted to determine the availability of appropriate data for the assessment of the circular economy benefits in the built environment in Wales. The information is reviewed against the main factors characterising the built environment including:

- the housing stock,
- the developers and constructors,
- the users, and
- the materials of the built environment in Wales.

The table below briefly presents the results of this review and the possible use of datasets available for each of these factors.

Table 2: Systematic overview of data identified

Factors characterising the built environment	Data identified
Stock of the built environment: Current and future (new build) stock of housing and other buildings	• Data for new construction is available from measures of turnover in the construction industry in the national accounts (Welsh national accounts and statistics); this also indicates the level of construction activity undertaken using current practices. It provides a basis for bottom-up (activity-based) estimation of new CE benefits compared to current building practices (see Section 4.1). • The existing stock of houses and building is an important determinant of CE potential. However, data is disparate and would require more collation before it could be used for estimation. At a more detailed level, further research could investigate the implication of the different types of housing stock on CE implementation.
Developers and constructors of the built environment: The construction industry	• The methods the developers and constructors choose directly affects the implementation of certain CE activities. Construction GVA (related to construction industry turnover) is used as summary measure of the scope for new CE construction practice but information on industry opinion of feasible changes in building practices would provide more accuracy. • The CEW case studies are used as a qualitative indicator of the readiness and willingness of the industry to implement CE. While CE practices are not commonplace, the presence of early movers suggests further implementation of CE is possible and likely.
The users of the built environment: Population, businesses	• Estimates are based on summary comparison with other European countries because there was no readily usable information on patterns of use (e.g. more working from home) for Wales. Further research could investigate the readiness and willingness of the Welsh users to implement CE practices.
Materials of the built environment: Material flows and construction waste	• The Welsh construction and demolition sectors generate an estimated 3.4 million tonnes of waste (2012)[39]. The source of these statistics is regular reporting from the waste industry. Additional waste composition monitoring helps understand current behaviours. New monitoring systems may allow measurable (accountable) basis for implementing financial incentives and support mechanisms. • The value of these waste flows is also high. The Welsh construction sector generates over £1,000 per tonne of waste[40], which is higher than the UK average of £845[41], suggesting an already slightly more advanced position on waste prevention in the sector Wales compared to the UK average. • The average cost of the waste materials in a construction site skip is between £1,300 and £1,500[42]. However, construction site skips make up only a small share of construction waste[43]. Hence this information is not adequate for a high-level estimate of potential savings from reducing construction waste. More in-depth case studies could further investigate the valuation of avoided construction waste to generate bottom-up benefit estimates for specific applications. • Beyond the above, no readily usable information relating to material flows has been identified.

Source: Amec Foster Wheeler 2016

[39] Natural Resources Wales: Survey of Construction & Demolition Waste Generated in Wales 2012. https://naturalresources.wales/media/1988/survey-of-construction-an-demolition-waste-wales-2012.pdf
[40] Based on £3.5bn construction sector GVA in Wales (Source: Welsh Government: Regional Gross Value Added by industry)
[41] Department for Environment, Food & Rural Affairs: Digest of Waste and Resource Statistics – 2015 Edition. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/482255/Digest_of_waste_England_-_finalv3.pdf
[42] Welsh Government: Towards Zero Waste C&D sector plan. http://gov.wales/docs/desh/publications/130301construction-demolition-waste-plan-en.pdf
[43] Less than 1% according to the Towards Zero Waste C&D sector plan

8.4 Key sources of evidence for CE and the built environment

Two sources have been identified which quantify the benefits of implementing CE in the built environment. Both are recent reports from the Ellen MacArthur Foundation. In the following, the benefit estimates from these sources are briefly presented along with the key assumptions they are based on.

8.4.1 Growth within[44]

In this source, the implementation of six CE levers in the built environment[45] by 2030 would produce resource savings that could generate total benefits of approximately €360 billion of additional Gross Domestic Product (GDP) compared to a business as usual scenario in the EU. The six levers are:

- Industrial production and 3D-printing
- Energy generation and use
- Shared residential space
- Shared and virtual office space
- Modularity and durability
- Urban planning

Note that energy generation and use is considered out of scope in this study. Hence, any estimate based on Growth Within overestimates the benefits of CE to the built environment in Wales as defined for the purpose of this study, unless energy generation and use are excluded from the estimate.

The total benefits are based on economic modelling across all sectors, implying that CE is adopted in all sectors. Implementation in all sectors leads to a set of direct changes in market demand, supply responses and associated prices. These changes are fed into a macroeconomic model that attempts to predict all economic effects throughout the whole economy. Benefits are net compared to a business-as-usual scenario (BAU scenario). This is mostly achieved through adoption rates (i.e. an adoption rate of 20% means that with the implementation of CE, the adoption of the changes will be 20% higher than in BAU).

8.4.2 Toolkit for policymakers[46]

The Policy Toolkit includes a case study assessing the economic benefits of prioritised circular economy opportunities in Denmark. In the built environment, the prioritised opportunities and estimates of the savings they incur compared to a business as usual scenario (using net adoption rates as above) by 2035 are:

- Industrialised production and 3D printing of building modules: €600m p.a.
- Reuse and high-value recycling of components and materials: €150m p.a.
- Sharing and multi-purposing of buildings by 2035: €450m p.a.

The above estimates are based on a range of assumptions, the main ones of which are the following:

- Construction costs consist of 35% material, 20% labour, 20% other operating expenditure (opex) and 25% costs not related to the actual building
- Industrialised production and 3D printing:
- industrialised (non-3D printing) production of modular building components: 50% adoption (compared with 5% in BAU), leading to 15% material savings, 5% labour savings and 5% additional capex/opex savings
- 3D printing: 25% adoption (2% in BAU). leading to 25% material savings, 40% labour savings and 10% additional capex/opex savings
- Reuse and high-value recycling:
- looping of materials increased to 15% by weight (2% in BAU)
- resulting in 30% material cost savings (adding 5% additional labour cost)
- Sharing and multi-purposing:
- increased overall utilisation of buildings from 39% (current) to 63% (46% in BAU)
- leading to a reduced demand of 39% (17% in BAU) of new buildings
- adopted by 25% of all new buildings
- Result: reduced demand for new buildings by 9–10%

[44] Ellen MacArthur Foundation, Stiftungsfonds für Umweltökonomie und Nachhaltigkeit, McKinsey Center for Business and Environment: Growth Within: A Circular Economy Vision for a Competitive Europe. 2015.

[45] Industrial production and 3D-printing, Energy generation and use, Shared residential space, Shared and virtual office space, Modularity and durability, Urban planning

[46] Ellen MacArthur Foundation, McKinsey Center for Business and Environment, Danish Business Authority, Danish Protection Agency, NERA Economic Consulting: Delivering the Circular Economy – A Toolkit for Policymakers. 2015.

8.5 The benefits from circular economy

8.5.1 Methodology

The methodology used below combines both top down and bottom-up approaches, the second typically giving small value as it does not include representation of linkages to other parts of the economy. The different estimates are compared in the Table 4.2 which presents estimates which include different elements of the circular economy as well as different methodologies. This range of estimates provides a more comprehensive picture of how circular economy benefits arise.

The methodology for the calculation of each estimate is presented below. In addition, an estimate for the overall net benefit of implementing CE in the built environment in Wales is made combining all the calculated benefit figures and the qualitative evidence reviewed. This is discussed in the section on results and discussion.

Top-down estimates, mainly based on evidence from integrated assessments in other study regions

The extrapolation from Growth Within and the Policy Toolkit is based on the use of 2014 Construction GVA[47] as a scaling factor to reflect as closely as possible Wales' share of the impact of implementing CE in Europe/Denmark in the built environment sector. This implies several assumptions, which are discussed below.

As discussed in Section 8.4.1, Growth Within estimates a GDP impact of implementing CE. This impact is the result of a chain of effects and interrelations that can only be reasonably estimated using a model of the overall economy. It is assumed that the chain of effects and interrelations modelled by the Ellen MacArthur Foundation for the EU also applies to similar activities in Wales. This implies among other things a similar make-up of the sector in Wales as in the EU, and that CE activity outside Wales is sufficient to support CE in Wales where necessary, most importantly in the English regions with which Wales has strong economic ties, as discussed in Section 8.1. The benefit estimates from the Policy Toolkit are also based on a set of assumptions, which are presented in Section 8.4.2 as well. It is assumed that these also apply to Wales in a similar fashion, which implies once again a similar make-up of the sectors in Wales that support the transformation to CE and a resulting realisation of benefits to a similar degree.

The characterisation of Wales relevant to CE assessment (Section 8.1) indicates that Wales can use its economic structure as an advantage in the transformation to a more circular economy and that there is strong government support to create the right environment and guide this transition. This suggests that Wales is likely to be able to support a similar transformation and realisation of benefits as assessed in the above Ellen MacArthur Foundation studies.

Besides a geographic extrapolation from the two study areas to Wales, impacts predicted for 2030 (Growth Within) to 2035 (Policy Toolkit) are extrapolated to 2020/2035/2050 under the assumption that the percentage of GDP added or savings from implementing CE grow at a constant average yearly rate.

Bottom-up estimates, using Welsh case study data

As presented in Section 8.2, the Bryn Ivor Lodge care home[48] case study in the Welsh built environment sector identified cost savings attributed to consideration of the waste hierarchy and effective waste management of over £170,000, equivalent to over 2% of the project budget. The estimate assumes the practices adopted in this case study can be implemented on a larger scale and result in savings of a similar share in all construction projects. Specifically, it is assumed that by 2020 the practices are adopted to a similar degree by the majority of projects, leading to savings of 2%. Further introduction of circular economy is expected to increase the level of savings as principles and practices are replicated into new areas and themselves benefit from previous improvements.

Table 3 shows a forecast based on estimated rates and the most recent data on construction output per year in Wales (all new work) which is currently running at about £3.6bn annually[49]. Construction output is also likely to grow in the future, which would increase the potential savings. However, in the absence of a robust forecast, constant yearly construction output is conservatively assumed.

Table 3: Bottom-up benefit estimation: Cost savings attributed to CE practices of consideration of the waste hierarchy and effective waste management

Year:	2020	2035	2050
Assumption: % of project budget cost savings	2%	5%	8%
Result: Total cost savings (£m)	70	180	290

Figures are rounded to the closest £10m.
Source: Amec Foster Wheeler 2016 based on data from CEW and ONS.

[47] Wales: Welsh Government: Regional Gross Value Added by industry. 2014.
EU and Denmark: Eurostat: National Accounts aggregates by industry (up to NACE A*64) [nama_10_a64]. 2016.
[48] http://www.cewales.org.uk/files/6114/7730/1938/Bryn_Ivor_Lodge_Castleton.pdf
[49] Office for National Statistics: Output in the Construction Industry. July 2016.

8.6 Results and conclusion

The resulting calculated estimates are presented in Table 4. The first column indicates the main source used as the basis for the estimate. The second column specifies what kind of benefit is estimated, i.e. a positive impact on GDP or an annual saving. The difference between the two is discussed below. The third column describes the kind of CE activity that is considered in the respective estimate.

Table 4: Overview of calculated net benefit estimates (£m)

Source	Category	CE model/measure	2020	2035	2050
Growth Within	GDP added	6 levers ("Growth Within")	600	2,500	4,400
EMF Denmark case study	p.a. savings	Industrialised production and 3D printing of building modules	50	210	360
EMF Denmark case study	p.a. savings	Reuse and high-value recycling of components and materials	10	50	90
EMF Denmark case study	p.a. savings	Sharing and multi-purposing of buildings	40	150	270
CEW case study	p.a. savings	Consideration of the waste hierarchy and effective waste management	70	180	290

Figures are rounded to the closest £10m.
Source: Amec Foster Wheeler 2016 based on data from the Ellen MacArthur Foundation, CEW, Eurostat and the Welsh Government.

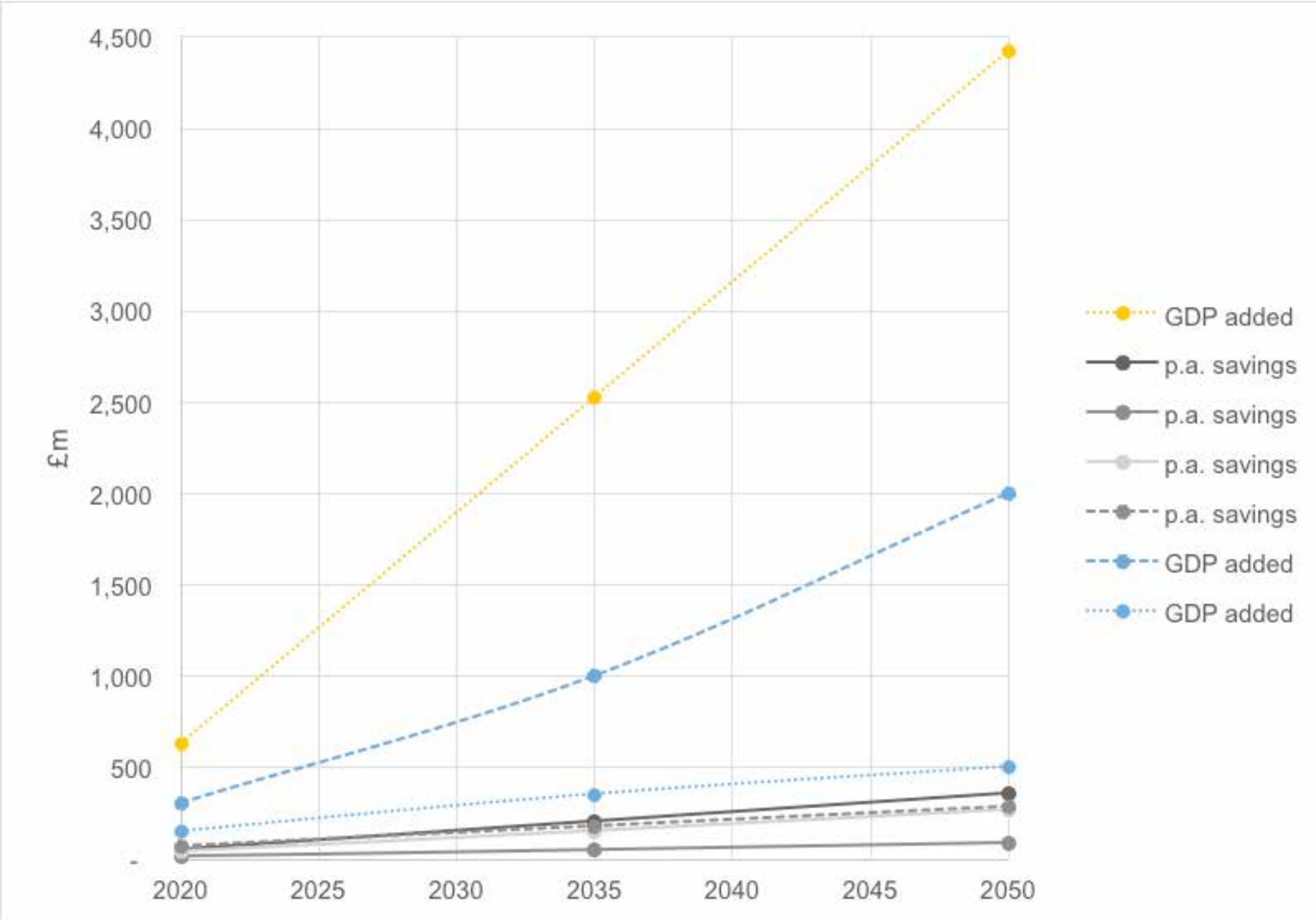
The GDP estimate reflects the full value of net benefits, as it includes the wider economic effects (linkages) achieved by implementing CE in the built environment. However, it also includes energy, which is out of scope in this assessment which leads to overestimation. As it is based on EU-wide modelling, it also leads to further overestimation if other countries than Wales lag in their development of the circular economy.

The annual savings calculated in the other estimates represent fractions of the overall net benefit. Note that they are not strictly additive, as some of the benefits they represent may overlap, but there are other CE activities yielding benefits which have not been assessed, and the overall net benefit will almost certainly be greater than the sum of the savings quantified here. The direct effect of the quantified savings on GDP is often negative (e.g. as sales of raw materials fall), but there are offsetting positive indirect effects on GDP through its transformation of the whole economy. Modelling by, among others, TNO, the Club of Rome and the Ellen MacArthur Foundation[50] has shown that despite the initial contraction in consumption, GDP increases in the long run.

In conclusion, it is estimated that the true overall net benefit of implementing CE in the built environment in Wales is clearly higher than the calculated savings from individual activities, but lower than the scaled macro-economic GDP estimate. In combination with the qualitative evidence presented in this report, an indicative range of the true overall net benefit is estimated, subject to relatively high certainty in the short-run and higher uncertainty further in long-run (see Table 4). A central estimate reflecting the midpoint of the upper and lower estimates indicates around £700m will be achieved in 2035 and around £1.2bn in 2050. We estimate that adopting circular economy practices in the construction and built environment sectors in Wales could lead to a benefit in the region of £1 billion annually from 2035.

[50] TNO: Opportunities for a circular economy in the Netherlands (2013); Club of Rome: The Circular Economy and Benefits for Society (2015); Ellen MacArthur Foundation, Stiftungsfonds für Umweltökonomie und Nachhaltigkeit, McKinsey Center for Business and Environment: Growth Within: A Circular Economy Vision for a Competitive Europe (2015).

Figure 6: Overview of calculated net benefit estimates and estimated total impact (£m)



Source: Amec Foster Wheeler 2016 based on data from the Ellen MacArthur Foundation, CEW, Eurostat and the Welsh Government

9. Material security in the built environment: critical and essential materials for construction

The Ecodesign Centre Wales were commissoned to analyse the material security within the built environment. The following is an extract taken from a wider report into material security wihtin Wales.

As discussed in Section 3.3, amongst the guiding principles of the circular economy is maintaining and enhancing the resilience of ecosystems by using materials in a way and at a rate that controls finite stocks and balances renewable resource flows.[51] Two key principles in achieving this are: not overusing valuable finite resources; and not overusing renewable resources at a rate that jeopardises their ability to renew. Whilst these principles should be borne in mind for all materials in a building project, there are two classes of materials where their application is particularly important: the so-called 'critical resources' and essential resources for the industry.

9.1 What are critical resources?

A critical resource is one which demonstrates both high risk to supply and the vulnerability of the user to supply constraints.[52] As such, critical resources are highly context-dependent. Whilst supply risks are similar for companies in a particular geographical region, vulnerability to supply shock can be very different.

Supply risks for materials may result from one or more of the following factors:

a. The available reserve of a material

The available reserve of a material is defined as "that part of the reserve base which could be economically extracted at the time of determination".[53] Materials are rarely fully exhausted from the earth's crust; it is more likely that the cost of extraction becomes too great for companies to bear. Some materials are by-products from the mining of other metals (for example, indium is a by-product of zinc mining) and their available reserve is strongly linked to the markets for those materials. A surplus of zinc on the market may lead to a reduction in the available reserve of indium.[54]

b. Standards and regulations

National and international standards can affect the supply of materials. For example, BS 8902 2009: Responsible sourcing sector certification schemes for construction products - specification discourages the use of conflict resources - those materials that are extracted in a conflict zone and may be sold to finance the fighting.[55] Conflict resources include casserite (the primary ore of tin), wolframite (for tungsten) and coltan (for tantalum).

Due diligence for conflict resources are also considered in the US Dodd-Frank Act and a proposed EU regulation that will be voted on in the European Parliament in 2017.[56] Other regulations that affect the supply risk of materials include the Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). Phthalate plasticisers for PVC are currently on the REACH list of Substances of Very High Concern

[51] Ellen MacArthur Foundation (2015). Towards a Circular Economy: Business rationale for an accelerated transition.
[52] Ecodesign Centre (2014). Mapping Critical Resources for Wales. A report for Welsh Government.
[53] USGS (2010). Minerals Yearbook. Available from: http://minerals.usgs.gov/minerals/pubs/commodity/myb
[54] Defra (2010). Review of the Future Resource Risks Faced by UK Business and an Assessment of Future Viability. AEA Technology plc., London.
[55] BRE (2013). Critical Materials and Materials Security in the Construction Industry and Its Supply Chains. Available from: https:/www.brebookshop.com
[56] Global Compliance News (2017). Final Text of the EU Conflict Minerals Regulation. Available from: https://globalcompliancenews.com/eu-conflict-materials-regulation-20170208

(SVHCs) and will be progressively phased out over time, and there are a number of other chemicals of importance to the construction industry that feature on the list.[57] The imminent EU exit will impact the degree of risk, changes to regulations can create supply risks.

c. Geopolitics

Some materials are extracted predominantly in one location. For example, China currently controls over 90% of rare earth elements (REEs). In 2006, quotas were introduced on for the export of REEs and, in 2010, the quotas were slashed by 40%, rocketing prices on the global markets.[58] Whilst REE export restrictions were lifted by China in 2015, this illustrates how material monopolies can introduce supply risk. The concern over conflict resources also highlights the role of geopolitics in supply risk. A number of important raw material sources are located in locations that either do not have market-based systems, or are economically or politically unstable.

It is not straightforward to precisely calculate the supply risk for a material. However, the EU has identified thirty-five materials of importance to EU industry and Table 1 shows the supply risk values calculated for the 'EU 35' materials during The Mapping Critical Resources for Wales project in 2014.[59] It is important to note that supply risks can change rapidly and these values are only given for illustration.

Table 5: Supply risk values for materials relevant to Welsh industry calculated for 2014

Material	Supply risk value	Material	Supply risk value	Material	Supply risk value	Material	Supply risk value	Material	Supply risk value
Antimony	7.5	Cobalt	6.6	Indium	6.8	Niobium	6.5	Silicon metal	6.2
Arsenic	6.4	Coking coal	5.8	Lead	5.4	Phosphate rock	5.9	Silver	5.4
Barytes	6	Copper	4.3	Lithium	5.6	Platinum group metals	6.4	Strontium	7
Beryllium	6.5	Fluorspar	6.1	Magnesite	6.3	Rare earths (heavy)	9.5	Tantalum	5.9
Borates	5.3	Gallium	6.3	Magnesium	6.3	Rare earths (light)	8.4	Tellurium	5.3
Carbon/ graphite	6.5	Germanium	6.8	Manganese	5.2	Rhenium	5.7	Tin	5.7
Chromium	5.5	Gold	5	Mercury	7	Selenium	5.8	Tungsten	7.6

Factors that affect a company's vulnerability to materials supply restrictions are affected by:

i. Importance

The importance of a material to a company is determined as the importance to strategy, revenue impact and the ability to which a company can cope with price rises[60].

ii. Substitutability

Some materials with high supply risk are relatively easy to substitute in specific applications. For example, fluorspar is considered to have high supply risks by the European Union due to geopolitical factors. About 25% of fluorspar is used in the production of steel, where it is added as flux to open hearth oxygen and electric arc furnaces. In this application, fluorspar can be readily substituted by aluminium smelting dross, borax, calcium chloride, iron oxides, manganese ore, silica sand and titanium oxide. In contrast, there is limited opportunity for its substitution in aluminium manufacture.[61]

iii. Innovative capacity

A company's ability to react and change a process or supply chain in response to a supply risk influences the criticality of a material.

iv. Susceptibility

The extent to which a company is reliant on imported materials affects their vulnerability to material supply restrictions.

[57] BRE (2013). Critical Materials and Materials Security in the Construction Industry and Its Supply Chains. Available from: https:/www.brebookshop.com
[58] Foresight, Government Office for Science: The Future Impact of Materials Security on the UK Manufacturing Industry: Future of Manufacturing Project Evidence Paper 27. Available from:https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/283901/ep27-material-security-impact-uk-manufacturing.pdf
[59] Ecodesign Centre (2014). Mapping Critical Resources for Wales. A report for Welsh Government.
[60] Graedel, T. E., Barr, R., Chandler, C., Chase, T., Choi, J., Christoffersen, L. & Zhu, C. (2012). Methodology of Metal Criticality Determination. Environmental Science and Technology, 46 (2), 1063 - 70.
[61] CRM_InnoNet (2013). Critical Raw Materials Substitution Profiles, September 2013.

Whilst it is possible to create critical materials profiles at national and sectoral level based on supply risk factors and economic value indicators (gross value added, number of people employed and business population)[62], these are of limited value at company level; a material that is critical for an individual company may not register on national profiles and vice versa. Therefore, companies wishing to develop a strategy to ensure their material security would be well advised to carry out an internal criticality assessment.

9.2 What are essential materials?

Essential resources are defined as those that have a high importance to an organisation, but not the global supply risks that warrant them being described as critical. In the construction industry, aggregates may be considered to be an example of an essential material. Whilst aggregates have high global availability, there are particular local issues that might affect their supply. In 2010, a study conducted on behalf of Defra identified that restricted access to local reserves of aggregates as a result of local planning constraints, coupled with high transportation costs were a significant and ongoing risk to the construction supply chain.[63]

9.2.1 Examples of critical and essential material impacts on the construction supply chain and mitigation strategies

Most, if not all, of the materials listed in Table 1 will rarely feature on the bill-of-materials for a building project. However, they may still impact on day-to-day business activities of the construction sector. Table 2 provides examples of common construction materials that may be affected by reliance on high supply risk (or critical to some businesses) materials, and measures that companies may consider to mitigate them. The list illustrates how supply risks may be 'hidden' in the construction industry's long, complex supply chains. Materials are listed in alphabetical order.

Table 6: Examples of construction materials affected by high supply risk

Construction material	Associated supply risk material	Type of supply risk	Rationale for risk	Potential mitigating strategies
Aggregates	Aggregates	Regulation/ standards	UK planning regimes leading to limited availability and associated price rises. [64]	• Use industry by-products (PFA, steel slag, IBA) as total/partial substitutes where possible • Use crushed recycled glass and demolition rubble in backfill applications
Aluminium	Fluorspar; magnesium	Geopolitical	Fluorspar is used as a source of cryolite for the aluminium electrolysis process. Magnesium is used in 5000 series alloys. Both materials are produced predominantly in China.	• Use recycled aluminium wherever possible • Design buildings to enable recovery of aluminium at end-of-life • Where possible, substitute 5000 series alloys with 3000 series alloys or ultra high-strength steel.[65]
Architectural glass	Indium; tin	Available reserves; geopolitical; regulation	Indium-tin-oxide (ITO) layers are used on glass as low-emissivity coatings. Indium is a by-product of zinc production and is dependent on zinc markets. It is also widely used in high-technology markets, leading to competition for materials. The primary ore of tin is identified as a potential 'conflict material'	• Where possible, replace ITO layers with fluorine-doped tin oxide • Practice responsible sourcing of materials

[62] Ecodesign Centre (2014). Mapping Critical Resources for Wales. A report for Welsh Government.
[63] Defra (2010). Review of the Future Resource Risks Faced by UK Business and an Assessment of Future Viability. AEA Technology plc., London.
[64] BRE (2013). Critical Materials and Materials Security in the Construction Industry and Its Supply Chains. Available from: https:/www.brebookshop.com
[65] CRM_InnoNet (2013). Critical Raw Materials Substitution Profiles, September 2013.

Cutting tools	Tungsten; cobalt	Geopolitical; regulation	Tungsten is used in cemented carbides for cutting tools. It is predominantly extracted in China but has also been identified as a potential 'conflict material' in other extraction locations. Cobalt is a binder phase for cemented carbides and is identified as a potential 'conflict mineral'	• Consider lease/access business models for cutting tools • Refurbish exhausted cutting blades with carbide metal powders, rather than replacing blades/ buying new tools • Practice responsible sourcing of materials
Fibre-optic services	Germanium	Available reserves	Germanium is used as a dopant in fibre-optics for telecommunication and internet applications. It s a by-product of the zinc mining process.	• Design buildings to enable disassembly of telecommunications systems at end-of-life • Negotiate lease/access business models with suppliers
Flame retardants	Antimony	Regulations/ standards; geopolitical	Antimony is used as a flame retardant material in cable coatings, wall coverings and building panels. It is on the REACH SVHC list and is largely produced in China	• Explore the appropriateness of alternative flame retardants (e.g. hydrated aluminium oxide).
LED lighting systems	Gallium; indium;	Available reserves; geopolitical	Gallium and indium compounds may be used in LEDs. Both are by-products of other metal extraction processes. Extraction of gallium is primarily in China, Kazakhstan and Ukraine.	• Keep up-to-date on innovation in the sector (organic LEDs, zinc oxide-based LEDS) • Replacement of LEDs with fluorescent or incandescent light bulbs introduces other material security and environmental issues. Instead, negotiate lease/access business models with suppliers to ensure appropriate material stewardship at end-of-life[66]
Solar panels	Gallium; germanium; indium	Available reserves; geopolitical	Gallium, germanium and indium may all be used in solar panel applications. All are by-products and mined in a small number of locations.	• Keep informed about developments in the field; alternative low-cost abundant materials are in early stage commercialisation • Consider lease/access models to allow good material stewardship • Consider how solar panels are integrated into building projects to ensure recovery is possible at panel end-of-life
Steel	Fluorspar; natural graphite; niobium; rare earth elements; tungsten	Available reserves; geopolitical; regulation	Fluorspar and graphite are used in the steel production process; niobium, rare earth metals and tungstens may all be used in construction steel alloys. The materials are variously potential 'conflict minerals', by-products and extracted in limited locations	• Practice responsible sourcing • Source steel that is produced without the use of fluorspar (substitutes include aluminium smelting dross and calcium chloride)[67] • Design buildings for simple recovery of steel where possible • Only use steel alloyed with high risk materials where it is unavoidable • Use recycled steel wherever possible
Timber	Timber	Essential material factors	Increasing global demand and increasing import prices affect the markets for timber[68]	• Practice responsible sourcing to ensure renewable supplies of timber in the long-term • Use reclaimed timber where possible • Reuse timber within different phases of a project

[66] The National Union of Students has negotiated a 'Pay-per-lux' access-based lighting system with Phillips that sees Phillips retaining responsibility for the LED after a fifteen-year lifespan. The business model incentivises Phillips to provide high-efficiency lighting. See http://theenergyst.com/philips-delivers-cradle-cradle-lighting/

[67] CRM_InnoNet (2013). Critical Raw Materials Substitution Profiles, September 2013.

[68] BRE (2013). Critical Materials and Materials Security in the Construction Industry and Its Supply Chains. Available from: https:/www.brebookshop.com

9.3 Understanding material security within a company

Material security is complex and it can be difficult for companies to fully understand how their supply chains may be affected by shortages. However, there are a number of ways in which companies can manage the impact of material security.

a. Know your materials

Understanding the supply chains for the products that a company uses in day-to-day business is essential if strategies are to be put in place that can manage material security. Developing and extending responsible sourcing strategies can increase knowledge of materials vulnerabilities within a company. BS 6001: Responsible Sourcing of Construction Materials provides a framework for companies to develop responsible sourcing strategies. High supply risk materials should be a specific consideration in a sourcing policy. A responsible sourcing strategy that takes into account the environmental and health impacts of materials can also protect companies against future resource risks arising from standards and regulations.

b. Make your own criticality matrix

Companies can only know if materials are critical to them if they assess them within the context of the organisation. Plotting materials supply risk (values for 2014 are given in Table 1 and the European Commission publish periodic updates to the risk values) against economic value to the company and/or proportion of supply chain affected by supply disruption can identify the most critical materials and help companies to set priorities for a materials security plan

c. Keep abreast of developments for high supply risk materials

It is important to note that materials criticality is not absolute. External factors (for example, the opening of a new mine in a new location, technology changes in other markets for a material) can rapidly change the criticality of a material. Update the internal criticality matrix at least once a year to reflect changes in material criticality and the impact of internal material security actions.

d. Be innovative in identifying material security strategies - make a materials security plan

Mitigation of material security issues can be conducted in any number of ways. Substitution of materials, new business models, application of new technologies and new design methodologies are just some of the ways in which companies can protect their business from resource shocks.

e. Be aware some materials security actions may only be useful in the short-term

As well as reviewing the criticality matrix, materials security plans should be reviewed regularly, as actions may also be affected by external factors. For example, use of pulverised fuel ash (PFA) is a potential mitigation strategy for ongoing aggregate issues. However, the move away from coal-fired power stations in the UK and across Europe will significantly impact on the availability of PFA in the longer-term.

f. Be more circular

Materials security is the fundamental underlying principle of the circular economy. Following best circular practice as explored within this document will improve a company's material security; widescale adoption will ensure that critical and essential resource risks are minimised across the sector.

Sections 10-12

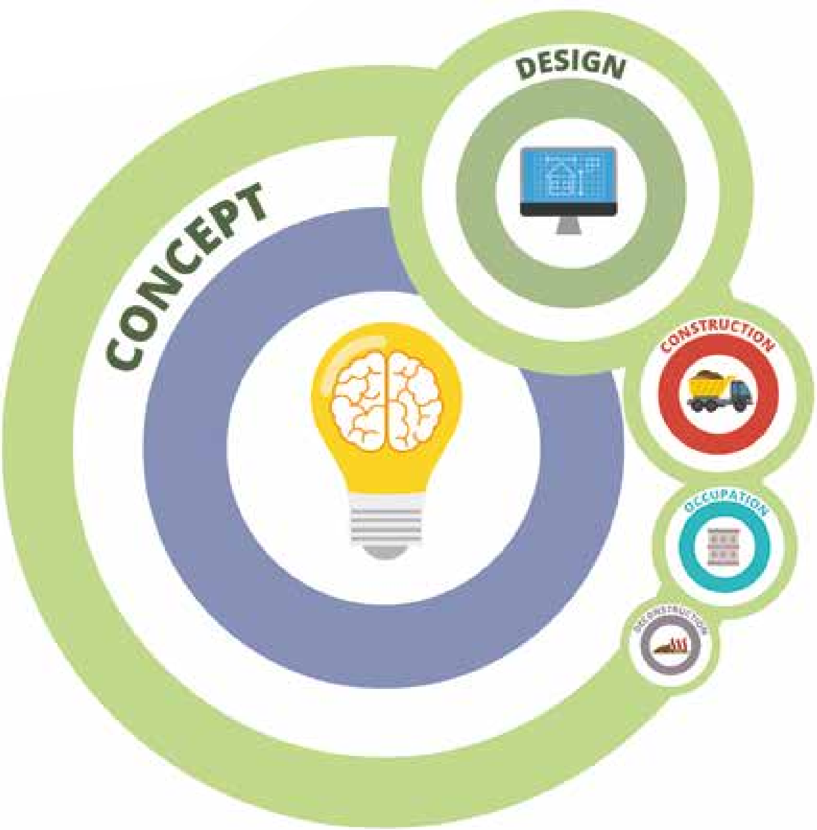
Conclusions

10. Challenges/opportunities

To deliver the opportunities afforded by the circular economy there will be a need to address the identified challenges/barriers to implementation.

Within figure 7 the circles have been scaled using data gathered as part of research into the circular economy in Wales. The size of the circle represents the size of the economic opportunity by the construction phase. The data indicates that the concept/design stage offers the greatest opportunity, the potential at design stage is ten times that of construction, with the opportunity at the occupation stage approximately half that of the construction phase. This provides a clear indication of where the biggest opportunities lie and how actions may be prioritised.

Figure 7 Wales circular economy, scale of economy benefit for built environment



10.1 Challenges

The transition to a circular economy will require a change in process, this will bring significant challenges within all phases of construction. Key challenges to transitioning include:

Transforming mindsets

A lack of client awareness/demand and/or associated negative perception is a big risk to the successful implementation of circular economy principles within the sector. A change in economic model may be perceived as risky, with associated costs and benefits that are realized in the future. This will require a strong business case for change to be demonstrated.

Legislative barriers

The unintended consequences of the existing waste regulatory framework, for example definitions act as a barrier hindering trade and transportation of resources/products for reuse/remanufacturing. These may be addressed with the exit from the EU, however, this brings its own uncertainty and legislative challenge.

Infrastructure constraints

There needs to be investment made to ensure there is the infrastructure in place to enable products to be recycled/recovered. This needs to include physical infrastructure to ensure good quality reused and recycled materials as well as generating markets for recyclates, secondary materials and by-products. Uncertainty over recyclates markets will not encourage their use.

In addition, work will need to be undertaken to ensure products are capable of being reused, remanufactured, recovered, and recycled. It is common place for buildings to be constructed with design lives beyond 2050 using materials and products that are not able to be reused or recovered and whose only end of life option is landfill.

Supply chain

Currently there is limited information, knowledge and economic incentive for key elements in the supply and maintenance chain e.g. chemical composition and strength. This makes it difficult to repair, refurbish and/or recycle materials, reducing the value and recovery opportunities. In addition, a lack of supply chain integration means that often decisions are made in isolation with little consideration for the wider impact.

Products

Products/components are currently on the market that are unable to be disassembled/repaired/replaced. A lack of quality assurance, traceability and the absence of certification means that even products/components that are capable of being recovered are often not identified and segregated making it very difficult. There exists a widespread planned obsolescence in products, limiting reuse, repair, refurbishment and recovery opportunities.

10.2 Opportunities

The following identified opportunities would support and accelerate a transition towards a circular economy and its development. These include:

10.2.1 Government policy

The Welsh Government has chosen sustainable development as its central organizing principle, this has established a framework providing a clear direction. The 2016-2021 programme for Government 'Taking Wales Forward' outlines as part of it's business support the need to promote and invest in a green economy for growth.

Building upon this, the introduction of the Well-being of Future Generations Act and the Environment Act put in place the legislation needed to plan and manage Wales' resources in a more sustainable, joined up way. The recent Natural Resource Policy Consultation highlights opportunities to accelerate green growth by increasing resource efficiency, renewable energy and supporting innovation towards a more circular economy.

As a devolved power planning and tax raising provide opportunities to encourage the conditions necessary for a circular economy. Planning and building regulations could actively encourage development to maximise resource use, supporting the use of recycled/secondary materials and by products. Newly acquired tax raising powers could be used to increase the levy applied to virgin aggregates to favour recycled alternatives. A coordinated UK approach could look to lower VAT applied to products containing recycled content to incentivise their use.

The UK's exit from the EU and Wales' role within this may offer opportunities to address legislative challenges associated with the classification of waste and introduce more proactive resource based legislation.

10.2.2 Role of the public sector

The public sector spends nearly half of its budget on construction. This makes procurement to consider circular economy principles a significant opportunity. The education of the public sector client is key to bringing about change within our economic approach. Procurement can be used to influence the construction outcome through placing circular economy requirements on the supply chain.

Within Wales the public sector estate is large, it is believed the annual cost of maintaining unused public sector buildings is in excess of £12million. The circular economy offers a viable method of transforming these buildings into functional use. Models include the use of innovative products and business models including reusable steel, pay per lux, leasing components and eco-design.

10.2.3 Resource availability

Current research indicates that resource costs are likely to increase due to volatile markets and demand pressures. Within Wales there is a large volume of secondary materials and by-products, generated in large part from steel and power generation activities. The utilization of these materials would provide volume aggregate materials bringing a positive environmental impact, reducing the carbon footprint and addressing material legacies.

10.2.4 Realisation of multiple benefits

The application of the circular economy to buildings generates a multitude of benefits, that may not be realised elsewhere. Advantages include: reduced use of natural resources, mitigation against material prices, land savings, resource efficiency, reduced greenhouse gas emissions and energy consumption during the construction, use and demolition of buildings. Making an important contribution towards delivering in accordance with the Well-being of Future Generations Act.

10.2.5 Economics

Adopting circular economy practices makes economic sense. Achieving Growth Within[69] identifies a total economic benefit of up to €135 billion by 2030 in reduced utility, repair and maintenance cost, in addition to a €105 billion investment opportunity between now and 2025.

Arup[70] have identified that designing steel for reuse could generate high potential value for building owners, estimating savings of 6-7% for a warehouse, 9-43% for an office, and 2-10% for a whole building, with up to an additional 25% savings on materials. Working with Arup and Kier at the design and construction of the Ice Arena Wales, CEW have prepared a report identifying and grading the steel frame for future use, reuse, and recycling. Through the use of the building information model a colour coded animation was prepared, colour coding the various steel values and virtually deconstructing the building, all prior to its physical completion. The model is available at https://youtu.be/GQESvkJ8oBU

10.2.6 Changing the way we use our built environment

We need to change the way we think about how we use our built environment. We currently under occupy our buildings, typically 35-40% of offices in Europe are occupied , the same report identified that within UK homes 49% are under occupied. The advent of the driverless car could change the way we use roads, enabling vehicle spacing distances to be reduced. The UK Government has allowed trials of driverless cars on public roads since 2014.

[69]Ellen MacArthur Foundation, Achieving Growth Within: A €320 billion circular economy investment opportunity available to Europe up to 2025, 2017
[70]Arup, Circular Economy in the Built Environment, 1996

11. Recommendations/actions

This report outlines a model for how the circular economy may be applied to the built environment, the size of the economic opportunity and how the principles could be implemented across the sector to realise the benefit.

The recommendations included are consistent with and intended to build upon the framework established by the Well-being of Future Generations Act, Environment Act, and Wales' Waste Strategy Towards Zero Waste. It is important to note that Wales is the only nation to establish waste prevention targets. These elements form the foundations of a positive policy basis in which Wales can transition towards a circular economy.

The Ellen MacArthur Foundation identified key enablers to assist in the delivery of a circular approach, namely:

- Collaboration
- Rethinking incentives
- Providing suitable environmental rules
- Leading by example & driving up scale fast
- Access to financing
- Early adoption

Many of these enablers link to the Rethinking Principles identified by the Egan and Latham reports. Constructing Excellence in Wales have been working to demonstrate, these actively compliment the ways of working identified with the Well-being of Future Generations Act. For Wales, the key drivers of delivering a circular approach include:

- Collaboration
- Innovation
- Thinking for the long term
- Taking a preventative approach

From the research undertaken in the development of this report, CEW has identified the following as being key to achieving circularity within the built environment, these are:

- Design out waste at all stages e.g. design, construction/ manufacture, end of life
- Products designed to be reused/remanufactured/ reassembled/biological basis
- Waste redefined as resource
- Working across the supply chain/across the sector

It has been noted[71] that making small, incremental changes towards resource efficiency could drive up capital costs and/ or design fees, this is difficult to defend against lowest-cost tendering and value engineering. Developing a whole circular economy narrative, with collaboration across the entire supply chain and the ability to design for the whole life, including the end of life is necessary to fully realize an economic return.

- To truly evolve into a circular industry there will be a need to bring together the process start and end, aligning design and demolition to remove the current disconnect. Design practices will need to consider what and how materials are used, are extracted and reused within the built environment, with demolition removing materials to protect the reuse value.

11.1 Industry focus

The actions of industry will be key to the success and speed of implementation towards circularity. CEW has identified some early industry lead instances of best practice from these Welsh examples the following actions are considered key elements to delivering and necessary for best practice to become mainstream practice.

a. Materials selection

Materials will need to be selected with consideration given to their end of life, there are numerous commonly used building materials that have no alternative recovery option other than landfill.

b. Standardised components

There is a need to look towards manufacturing principles, such as component standardisation to deliver efficiencies including enhanced time in use, extended life, facility to repair/refurbish

c. Design for circularity, principles include:

- Design for flexibility/adaptability to extend life
- Design for deconstruction – requirement to consider end of life in current design – especially important for assets with design lives beyond 2050 (zero waste to landfill target)
- Design for disassembly/deconstruction and reuse of asset/elements

d. Product design

Design for longevity – eliminate current practice to design planned obsolescence within asset and products

- Design for separation/on site management/demolition
- Design for reuse/site management/demolition
- Buildings as materials banks

[71] David Cheshire (2016) Building Revolutions: Applying the Circular Economy to the Built Environment, RIBA

e. Building core competencies to facilitate:
Product reuse, Recycling, Cascading - Requires advanced skills sets/information sets/working methods

11.2 Policy focus

Industry will require policy support to deliver effective action, the following are considered key areas for government policy development:

a. Market development: Quality supply and demand
There is much to be done to support the development of markets for the large quantities of by-products, secondary materials and waste, such as IBA, PFA and steel slags. Many of these legacy materials need assistance to develop markets and routes to market for the type and volumes of these high quality by-products/secondary materials and recyclates.

b. Sector support
The construction sector is fragmented, this is true across the industry and government. This does not provide a solid basis for end of life material extraction. There is a need for a cohesive construction strategy to be developed to provide clear direction and remove barriers to scalability and applicability.

c. Development of Infrastructure
The sector consumes and generates large volumes of materials. There will be a need to develop cost efficient, better quality collection and treatment systems and effective segmentation of end of life. Without this investment the leakage of materials out of the system will continue, undermining development towards circular economy.

d. Role of the public sector client
The public sector client is responsible of between 45 – 55% of annual construction spend, therefore the role of the sector as a construction client is significant. The development of consistent approaches to the design, build and deconstruction of public funded construction with consideration of circular economy principles would provide clear direction creating stable investment and development platform for green growth.

e. Alignment of capital and revenue funding
Current public funding differentiates between monies available for capital and revenue elements. This often results in decisions made at design and build stages funded by capital budgets negatively impacting on future decision making and longer term revenue funds. The Well-being of Future Generations Act provides a useful basis to resolve these issues and develop coherent strategies for decision making. With an alignment of capex and opex budgets in a more totex approach circular thinking can be embedded and opportunities realised, such as products as services.

Following the UK Sustainable Development Strategy developed approach table 7 outlines key actions across a range of options, primarily aimed at the development of policy to support a transition to a circular economy.

Table 7: Policy Actions to support a transition to a circular economy

	Concept	Design	Construction	Occupancy	Deconstruction
Enforce	Planning policy/ requirements Waste Regulation - development of resource framework	Prevention targets Policy/requirements	Targets Building standards/ requirements	Targets	Buiding standards favouring deconstruction
BIM Policy					
Encourage	Tax advantages	Skills R&D Support Tax advantages for CE materials Voluntary schemes	Tax advantages for CE materials Skills	Tax advantages reuse/remanufacture Skills R&D Support	Tax advantages for CE materials Skills
Enable		Sector guidance Standard designs/ details	Sector guidance Labelling	Labelling	Labelling
Exemplify	Government funded demonstrators				
	Public sector procurement to favour CE/ requirements in favour of CE	Public sector procurement to favour CE/ requirements in favour of CE			
Engage	Awareness raising/information				

12. Conclusions

The circular economy presents a significant opportunity, delivering multiple benefits across multiple platforms/portfolios/agendas.

Wales, through its sustainable development commitment has put in place a framework which establishes many areas identified as key for a transition to a circular economy, such as low carbon energy and environment, advanced engineering and materials, ICT and the digital economy. It is considered that the institutional environment, together with the political support for a transition to the circular economy in general and for the built environment is strong in Wales. This supports the potential for an ambitious transition scenario, and with focus the right conditions can be developed to enable Wales to make the most of the opportunity presented.

As demonstrated within our models working across the supply chain throughout projects and between sectors will be key to the success of a transition between linear and circular economies.

Our research has demonstrated a potential economic opportunity of an additional £1 billion per annum by 2035. This is an increase of 12.5 per cent in the turnover of the welsh built environment sector and generate 7,300 jobs (gross). It is important to acknowledge that these economic gains can only be achieved working across the supply chain. Making small incremental changes towards resource efficiency could drive up capital costs and/or design fees, this becomes difficult to defend against lowest-cost tendering and value engineering.

We need to redefine waste as a resource, if we continue to define material surplus as waste we will struggle to close resource loop and retain value. EU exit brings the potential for legislative change to address issues with the classification of waste in EU definitions, develop a more Wales specific approach.

Key to the application of the approach will be design, influencing at the earliest possible opportunity. It is at the design stage that decisions are made that impact 80% of the waste generated on a project. Adopting circular design will require the sector to embrace new ways of working, collaborating at earliest possible stages across the supply chain, thinking for the long term and embracing innovation in product and process.

CEW are working across its programmes to demonstrate how the theories described can become best practice examples delivering transformational change across Wales. The built environment sector is seen as key to the delivery of a circular economy. The Ellen MacArthur Foundation has identified the built environment sector as key to the delivery of a circular environment.

Sections 13-14

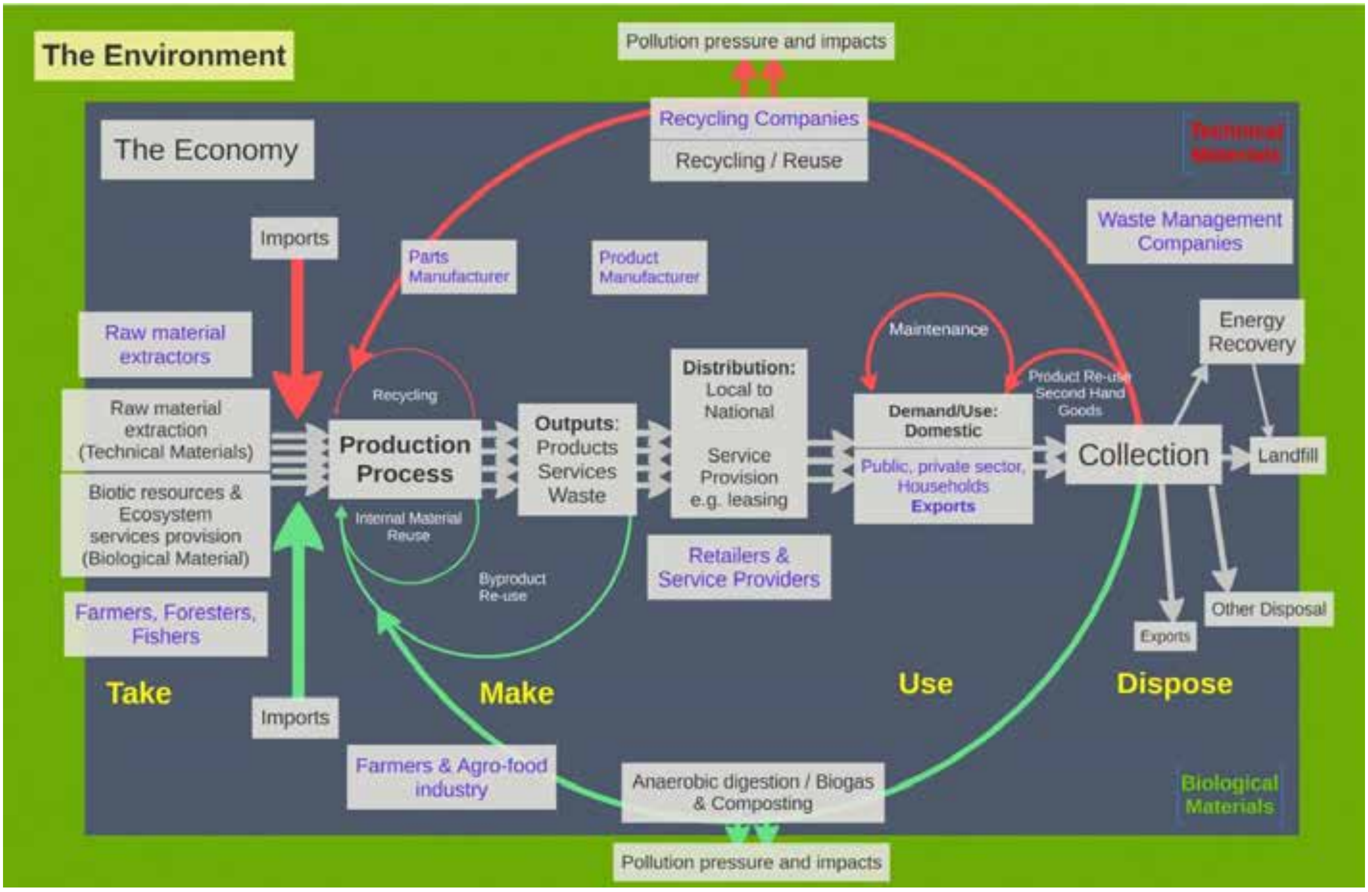
Appendices

13. Appendices

Review of Existing Models for a Circular Economy and their application to the Built Environment

The current linear model (take, make, use and dispose) has not incorporated the value of natural systems into decision making. It has resulted in a loss of natural resources as well as their value in value chains and has not properly valuing the impact of our society on the environment. Whilst there are some examples of a circular approach in the linear model such as recycling and composting it is still very limited. The model below provides an example of a linear model.

Model 1: The Linear Model

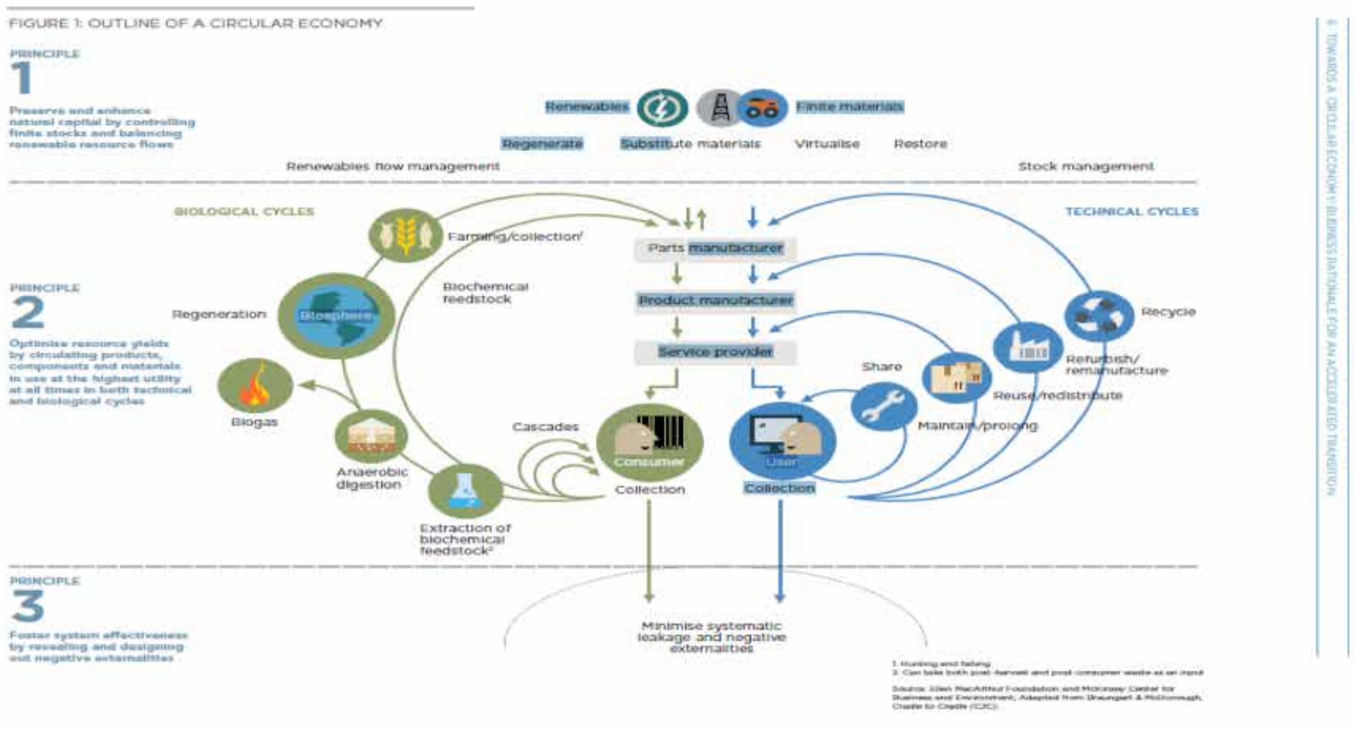


Source: P ten Brink, P Razzini, S. Withana and E. van Dijl (IEEP), 2014

Circular models

The Ellen MacArthur Foundation produced a circular economy model, which really looks at the consumer goods sector.

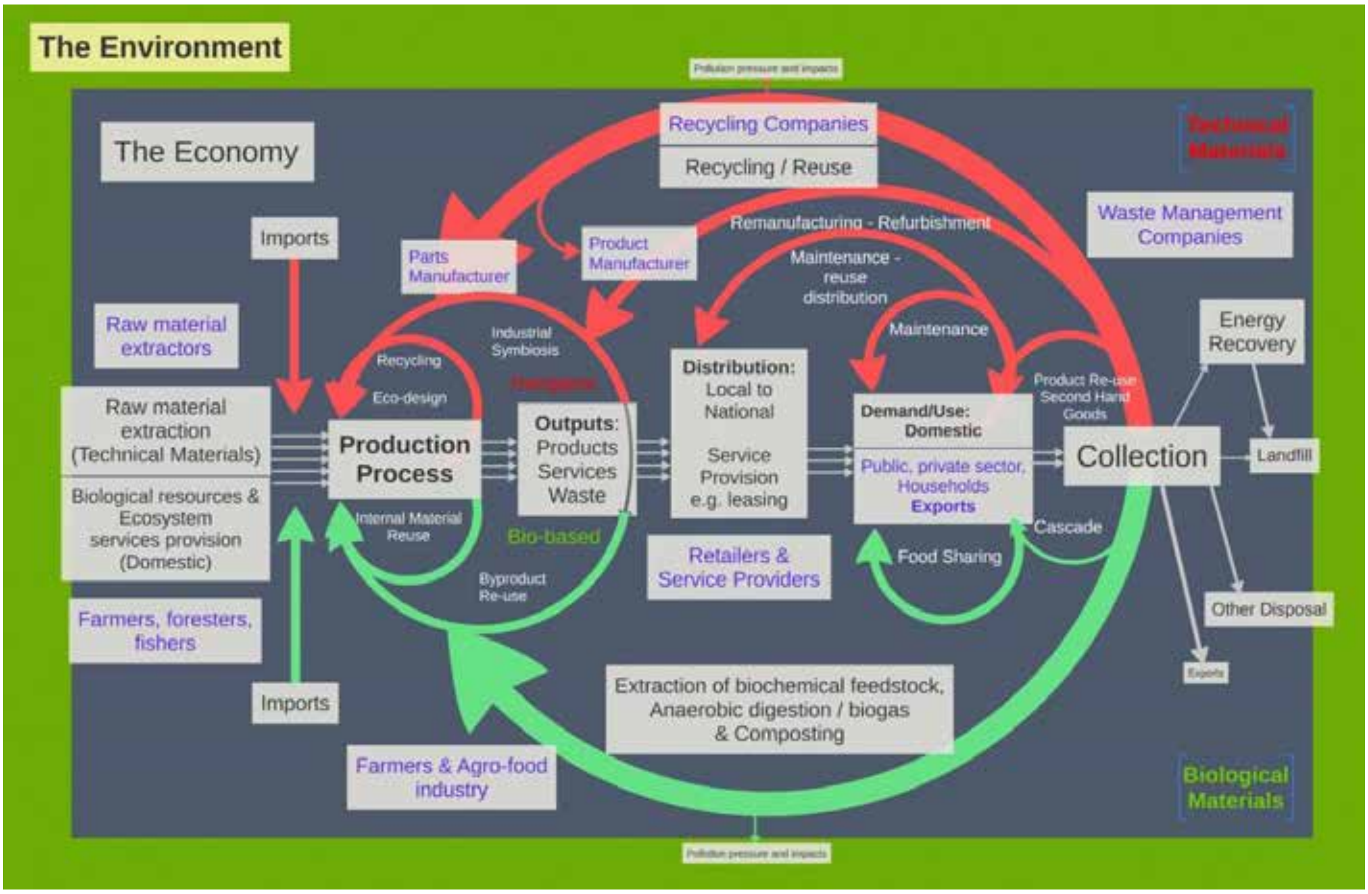
Model 2: CE Model - Products



The model could be misconstrued, as it identifies an end-user (or consumer). This end-user is the purchaser of the goods produced. However, each actor in this cycle is a user of natural resources and the model should reflect early on in the cycle, the need for all users to be applying a circular economy approach.

IEEP have also produced a simplified circular economy model for an EU study, building on its simplified linear model.

Model 3: CE Model

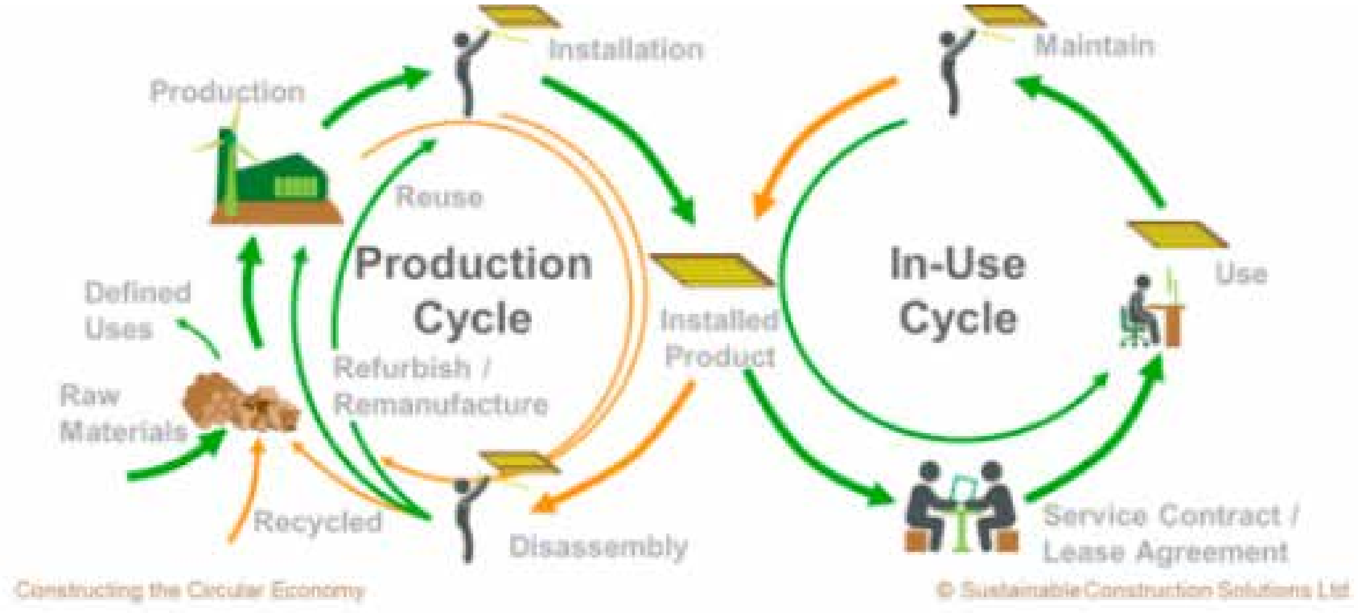


However, this still sees cycle from a waste perspective. It also needs to be clearer that collection is not something that occurs at the end of the cycle but throughout the cycle and needs to be clearer on the inter-relationships with other sectors. For example energy sources may be coming from the anaerobic digestion of resource sources from other sectors.

Construction production cycle

A simplified model has also been produced to by Sustainable Constructions Solutions.

Model 4: Simplified construction production cycle



This simplified model does not reflect the inter-relationship between the different phases within a construction cycle or the necessary long-term values of resources as it focuses more on recycling and excludes reuse.

14. Glossary

Asset	element of built environment infrastructure, for example building, road, sewer
Biodiversity	the variety of plant and animal life in the world or in a particular habitat, a high level of which is usually considered to be important and desirable (Oxford Dictionaries)
Carbon budget	a carbon budget places a restriction on the total amount of greenhouse gases that Wales/UK can emit over a defined period
Cascade	a process whereby something, in the case of circular economy a material, is successively passed on. Enabling the material to be used multiple times for a variety of purposes across multiple industry sectors
Circular economy	represents a development strategy that enables economic growth while optimizing consumption of resources, deeply transforms production chains and consumption patterns, and redesigns industrial systems at the system level (EU Commission, Scoping study to identify economic actions priority sectors, material flows and value chains, 2014, Annex I, p11)
Circular hierarchy	adaptation of the waste hierarchy to give consideration of priniciples of circular economy
Deconstruction	the extraction of materials contained within an asset to retain value for future use
Direct reuse	reuse without alteration/processing for original purpose/intent
Down cycling	the recycling of waste where the recycled material is of lower quality and functionality than the original material
Ecodesign	is an approach to designing products with special consideration for the environmental impacts of the product during its whole lifecycle.
Embodied energy	the sum of the energy requirements associated, directly or indirectly, with the delivery of a good or service (Cleveland & Morris, 2009)
Externality	the cost or benefit that affects a party who did not choose to incur that cost or benefit
Geo-diversity	the variety of rocks, minerals, fossils, landforms, sediments and soils in an area, together with natural processes, such as erosion and landslips, that may still be active (Scottish Natural Heritage)
Inter-relationships	the way in which each of two or more things is related to the other or others (Oxford Dictionaries)
Life cycle assessment	a systematic set of procedures for compiling and examining the inputs and outputs of materials and energy and the associated environmental impacts directly attributable to the functioning of a product or service system throughout its life cycle (ISO14040:2006).
Prosperous	bringing wealth and success (Oxford Dictionaries)
Sustainable development	development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland Commission)

Sustainable management of natural resources (SMNR)
SMNR means:
a. Using natural resources in a way and at a rate that promotes achievement of ecosystem resilience
b. Taking other action that promotes achievement of that objective, and
c. Not taking action that hinders achievement of that objective (Environment (Wales) Act 2016)

Recycling
is the process of converting waste materials into reusable materials and objects.

Resilient
able to withstand or recover quickly from difficult conditions (Oxford Dictionaries)

Resource efficiency
using the Earth's limited resources in a sustainable manner while minimising impacts on the environment (European Commission)

Reuse
use again or more than once (Oxford Dictioanries)

Upcycling
reusing unwanted items/materials by converting them into something of greater value

Waste hierarchy
the "waste hierarchy" ranks waste management options according to what is best for the environment (DEFRA)

Well-being
the state of being comfortable, healthy, or happy (Oxford Dictionaries)

Whole life costing
the systematic consideration of all relevant costs and revenues associated with the ownership of an asset nCRISP

Value chain
the process or activities by which a company adds value to an article, including production, marketing, and the provision of after-sales service (Oxford Dictionaries)

15. Constructing Excellence in Wales

Established in 2002, Constructing Excellence in Wales (CEW) is the single organisation charged with driving change within construction. Established by Welsh Government (WG) it is CEW's role to help deliver WG's commitment to a collaborative, integrated industry, based on innovation and extended markets, supporting economic, environmental and social well-being in Wales.

Constructing Excellence in Wales (CEW) is working to help the Welsh Government turn these commitments into actions. CEW works across the industry to make construction more effective, ensuring that the industry is able to deliver the best value for built environment for Wales.

All our actions are focused on working to achieve better value (Be Valuable), with less long term impact (Whole Life Costing) delivered in a more efficient way (Circular Economy for the Built Environment).

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