Accelerating the transition to a circular economy (CE) through exchange of excess materials: A conceptual framework for an excess materials exchange (EME) for the public sector, built environment in Ireland.

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Submitted in partial fulfilment of the requirements of: *Master of Science in Circular Economy Leadership for the Built Environment*

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Submitted to: Atlantic Technological University September 2023

ACKNOWLEDGEMENTS

I would like to thank the following people for guidance, assistance, and support during this study towards the Masters in Circular Economy Leadership of the Built Environment.

Thank you to Dr John Scahill, my thesis supervisor, for his support and guidance towards completion of this study.

Dr Martin Taggart, Dr Mark Kelly, and Dr Shane Newell for their support during the early phases of this study.

I would like to also thank the interviewee panel who gave of their time to contribute to this research.

Lastly, I would like to thank my partner, friends, and my family for their support throughout this journey.

PLAGIARISM DECLARATION

This dissertation and its contents, including all text, graphs, figures and/or infographics used in the body of the report are identified as solely the author's work except where noted, referenced, italicised, and cited as the work of others. No part of this dissertation has been accepted for any degree or other award previously and is not concurrently submitted for any other degree or award.

I declare that this dissertation is my original work except where stated and duly acknowledged.

David Whelan

September 2023

ABSTRACT

The research examines the viability of accelerating the transition to a circular economy (CE) in Ireland through the exchange of excess materials from the public sector, built environment.

This study uses Design Science Research (DSR) as described in Hevner et al. (2004) as its primary methodological approach. The research process consisted of problem identification and the motivation for the project, defining objectives for a solution and the results needed, and the creation of an innovative artefact.

The study begins with a comprehensive literature review which examines the current state of the CE, and specifically the contribution of the built environment to material resource depletion globally, and nationally. A model was developed from the literature and was further refined using data from the primary research, consisting of a series of interviews with twelve (*n=12*) industry experts with expertise in economic and social research, procurement, design, and public policy areas. The results of the interview process identified several key factors which further influenced the development of the conceptual framework for excess materials exchange (EME). The main research findings were the following: a) the definition of excess materials must include a broad category of descriptors to reach scale, b) mandatory legislation, specifically through the mechanism of circular public procurement would enable adoption of an EME framework across the public sector, c) a carbon tax or allowance could incentivise the use of circular materials, and d) an EME should be regulated and governed by a commercial state agency, successful examples of which already exist within the Irish state.

The conceptual framework for excess materials exchange is offered as a proposed solution to the problem of material and energy value loss, specifically as it concerns construction and demolition (C&D) waste. In Ireland C&D waste accounts for *8.2m tonnes* in 2020 (EPA, 2023). Ireland's circular material use rate is *1.6%* which compares unfavourably with the EU circular material use rate average of *11.9%* (Eurostat, 2023). The low circular materials use rate in Ireland suggests

that a significant percentage of C&D waste could be reused, but it will require efficient systems and mechanisms to recover, categorise, certify, and manage materials along the value chain.

The conceptual framework also proposes that incentivisation and mandatory legislation could increase adoption of an EME framework and accelerate the transition to the circular economy.

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LIST OF ACRONYMS

AI	Artificial Intelligence	**EU**	European Union
AFLU	Agriculture, Forestry, and other Land Use	**GDP**	Gross Domestic Product
AR	Action Research	**GHG**	Green House Gas
BE	Built Environment	**GPP**	Green Public Procurement
CAP	Climate Action Plan	**HLCF**	High Level Construction Forum
CBAM	Carbon Border Adjustment Mechanism	**IoT**	Internet of Things
C&D	Construction & Demolition	**IPPU**	Industrial Processes and Product Use
CE	Circular Economy	**LCA**	Life Cycle Assessment
CEAP	Circular Economy Action Plan	**LCC**	Life Cycle Costing
CESM	Circular Economy Structural Mechanism	**MCS**	Material Classification System
CPP	Circular Public Procurement	**NAP**	Needs Assessment Phase
CPV	Common Procurement Vocabulary	**NFT**	Non-Fungible Token
CRMA	Critical Raw Materials Alliance	**OECD**	Organisation for Economic Cooperation and Development
DSR	Design Science Research	**OGP**	Office of Government Procurement
DT	Design Thinking	**PESTLE**	Political, Economic, Social, Technological, Legal, Environmental
EC	European Commission	**PSO**	Public Service Organisation
EDEN	Environmental Data Exchange Network	**PSP**	Public Service Platform
EME	Excess Materials Exchange	**SDG**	Sustainable Development Goals
EMF	Ellen MacArthur Foundation	**SPP**	Strategic Public Procurement
EOL	End-of-Life	**SWD**	Staff Working Document
EOSL	End-of-Service-Life	**SWOT**	Strengths, Weaknesses, Opportunities, Threats
EPA	Environmental Protection Agency	**UN**	United Nations
EPD	Environmental Product Declaration	**UNEP**	United Nations Environment Programme
ERMA	European Raw Materials Alliance	**UNFCCC**	United Nations Framework Convention on Climate Change
ERP	Enterprise Resource Planning	**WEEE**	Waste Electrical and Electronic Equipment
ETS	Emissions Trading System	**WEF**	World Economic Forum

NOTE ON TEXT: Main text in Calibri (Body) Font Size 12. Tables and Figures Calibri (Body) Font Size 11.

1 INTRODUCTION

This chapter provides an overview of existing challenges, risks and opportunities facing the global economy under problem definition, specifically as it refers to current resource usage and depletion, the built environment, and the public sector opportunity. It includes a definition for excess materials exchange in the context of the research undertaken. The chapter also outlines the aim and objectives of the study and describes the challenges involved in researching a new and nascent technology, and its implications for the public sector, and for the transition to the CE more generally. Finally, the chapter also includes an outline of the publication schema for the research approach adopted.

1.1 Problem Definition

A report by the World Economic Forum (WEF, 2023) identifies the Top 10 Risks to the world over the next ten years (APPENDIX A). Each risk is, in one way or another, linked to the way we, as humans, have attempted to harness and capitalise on the earth's resources to build our societies, and to develop and prosper.

Societies become more vulnerable to collapse when the supply of raw materials, on which they subsist, become scarce. However, the global demand for materials continues to grow, increasing from 27 billion Gigatonnes (Gt) in 1970 to 89 billion Gt in 2017, and is projected, in the absence of new policy interventions, to rise to 167 Gt in 2060 (OECD, 2019).

Governments worldwide have reached a critical inflection point in how to balance continued economic growth with the carrying capacity of the planet (World Population, 2023) . The question arises whether this can be achieved without a fundamental restructuring of capitalism itself. Such a radical societal shift will need to be achieved 'in a way that is inclusive, sustainable, and driven by innovation' (Mazzucato, 2020, p. 244).

To date there has been a limited appetite for the transformation required to bring societies back within the planetary boundaries, as described in (Figure 1).

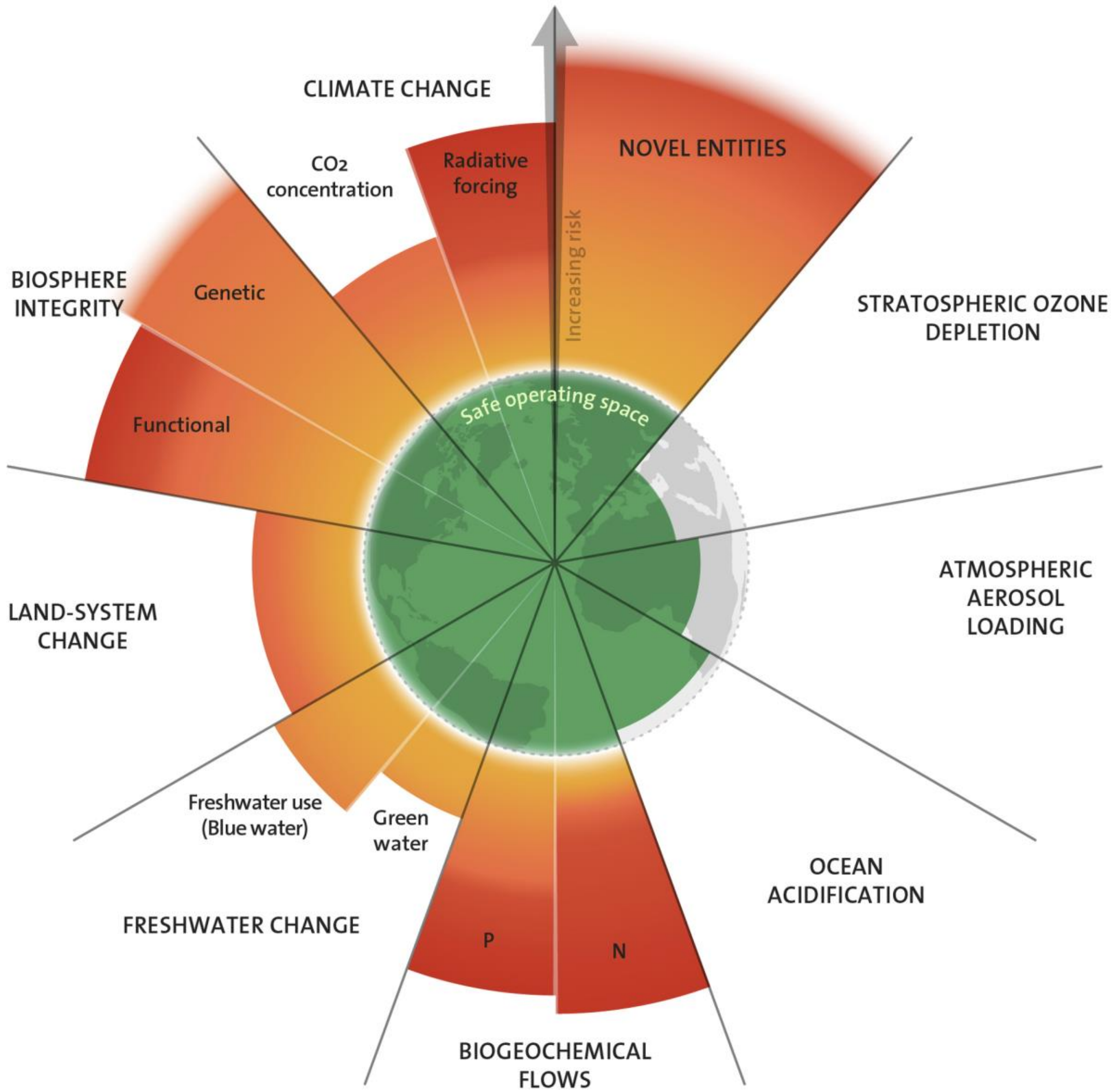


Figure 1: Planetary Boundaries (Source: J. Lokrantz/Azote based on Steffen et al. 2015)

A future, where the competition for resources and raw materials becomes more intense, is also a future where the possibility of conflict increases. The war in Ukraine is one such example. Ukraine produces 5% of the world's Gallium and 7% of the world's Scandium, both of which are critical raw materials for Europe's proposed renewable energy future (APPENDIX B).

In addition, The Circularity Gap Reporting Initiative (2023) projects a material extraction rate of 184 Gt by 2050 if a business-as-usual scenario prevails. The timeline of global material extraction is presented in (Figure *2*).

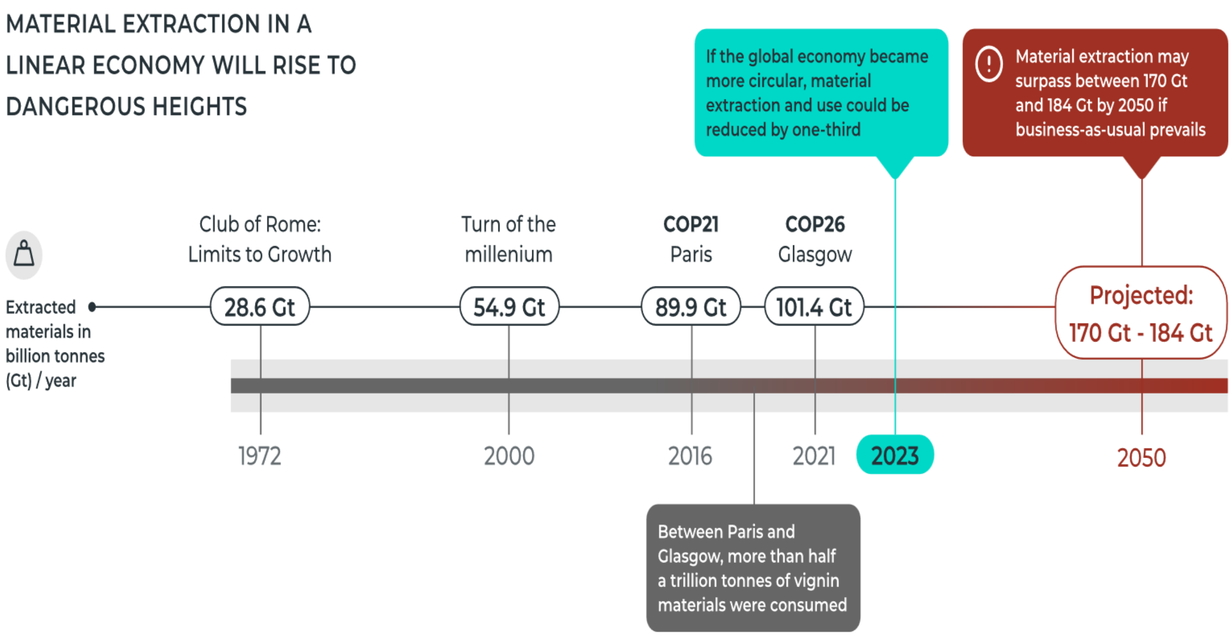


Figure 2: Timeline of Global Material Extraction Rate in a Linear Economy (Source: Circularity Gap Reporting Initiative 2023, p. 21)

According to the United Nations Environment Programme (UNEP) global greenhouse gas (GHG) emissions for 2021, excluding land use, land-use change, and forestry (LULUCF), are estimated at *52.8 GtCO2e*, continuing the growth trajectory established over the previous ten years (UNEP, 2022).

The sectors designated by the Inter-governmental Panel on Climate Change (IPCC) (Calvo Buendia; Peru et al., 2019) as primarily responsible for global greenhouse gas (GHG) emissions are, *Energy*, *Industrial Processes and Product Use* (IPPU), *Agriculture*, *Forestry*, *and other Land Use* (AFLU), and *Waste*. It is thought that the Built Environment (BE) accounts for approximately 30-40% of anthropogenic greenhouse gas emissions (i.e., emissions resulting from human activities) (O'Hegarty and Kinnane, 2022).

According to a report from the World Economic Forum (WEF) 30% of global greenhouse gas (GHG) emissions can be attributed to buildings alone (WEF, 2016). The International Energy Agency (IEA) estimates that building stock are on track to double by 2050 (IEA, 2019). As resources become scarce, harder to extract, and more expensive to process, the circular economy will become a more attractive option for all stakeholders in the value chain for construction and infrastructure projects.

1.2 Definition of the Topic

An excess materials exchange is a digital marketplace or public service platform (PSP) where materials which have reached their end-of-life in one use phase can be exchanged between different actors in the exchange and find a new use value. The goal of an excess materials exchange is to keep materials in circulation for as long as possible and create the conditions for optimal and/or alternative material choices to be made.

Different material choices can be made through a step-by-step workflow embedded in the system. For example, in some scenarios it may be possible to reduce the need for new products or virgin raw material use by opting for a recycle, repurposed, or remanufactured material instead.

1.3 Aim & Objectives of Study

The Aim of this study is to develop a conceptual framework for an excess material exchange for the public sector in Ireland. In so doing I attempt to provide a solution for how excess materials can be effectively and efficiently exchanged across a peer-peer network, or public sector digital marketplace. I also conceptualise how the EME is governed, monitored, and regulated, using current public procurement legislation, and identify the stage of the public procurement process at which the EME can be introduced.

There are four objectives to the study:

1. Determine, through rigorous primary and secondary research, the essential characteristics of a public sector focused excess materials exchange (EME).
2. Determine, through rigorous primary and secondary research, how the public sector can be incentivised to use an excess materials exchange platform and what form incentives would take.
3. Determine, through rigorous primary and secondary research, the benefits/challenges to implementing a public sector excess materials exchange (EME).
4. Determine, through rigorous primary and secondary research, where system ownership of a public sector EME resides.

1.4 Parameters of Study

The EME framework under consideration, while developed initially for application in the public sector, built environment, will have multi-sectoral application. Given the linkages between industry and state-run enterprises the EME should find proponents for its rapid implementation across both public and private sectors in equal measure.

1.5 Limitations

The research was undertaken in partial fulfilment of a post-graduate programme at master level in circular economy leadership for the built environment. The programme had pre-defined start and finish dates, bounded by the academic calendar, and time spent on literature review, data gathering, data analysis and dissertation write-up was determined by this set schedule, on which a comprehensive work breakdown structure was developed.

While twelve (*n=12*) interviews were completed it may have been beneficial from the perspective of research validity to have completed a larger sampling of industry stakeholders. It may also have been beneficial to the research if additional data gathering methods, such as surveys and questionnaires, were employed. In addition, further research opportunities exist to understand more clearly, the connections between carbon as an incentivisation measure, and its implementation within the public sector environment.

1.6 Research Methods Overview

The study adopts Design Science Research (DSR) as its primary methodological approach described in (Hevner et al., 2004). DSR is an important approach in the creation of successful artifacts (Peffers, Tuunanen and Niehaves, 2018). The DSR approach was deemed to be the most practically suitable to achieving the aim of the study, however, given the lack of authoritative consensus on DSR as a research methodology, and the complex nature of the project under consideration, it was also useful to draw from the Design Thinking (DT) methodology, as described by (The Double Diamond - Design Council, 2023).

A series of twenty questions were developed which covered the relevant topics under consideration, and twelve (*n=12*) interviews in total were completed. The questions were constructed to address both technical and business process-related routes of inquiry, and to provide context and overview of the sectoral and professional backgrounds of the subject-matter experts interviewed.

Detail on the questions and interview format can be found in *Chapter Three*. An analysis of the qualitative data collated from the interview process is described in *Chapter Four*.

1.7 Structure of Thesis

A publication schema was adopted which was based on an interpretation of the Design Science Research framework described by Gregor & Hevner (2013 p. 350) see Table 1 below.

Chapter 1 defines what I mean by excess materials and outlines the aim and objectives of the study. The chapter describes the parameters and limitations of the research. It also outlines research methods used and structure of the thesis as well as the publication schema.

Chapter 2 includes a Literature Review, which provides a global context and the rationale for transitioning to a CE. The chapter also examines the current thinking on the CE as it pertains to the built environment and outlines the challenges which exist in transitioning to a circular economy. The Literature Review also describes the landscape for the public sector as, both an agent of positive change in terms of proactive environmental policy, and as a significant lever to influence the market towards a CE through mandatory policy measures. Lastly, the Literature Review examines best available technologies and the applicability of incentives (specifically carbon measures) to garner support for public sector adoption of excess materials exchange platforms.

Chapter 3 introduces the research methodology used, and the rationale for employing the methodology as the basis for the research.

Chapter 4 describes the data collection and analysis and a description and evaluation of the final artefact.

Chapter 5 provides a discussion on the findings and an interpretation of the results.

Chapter 6 provides conclusions and recommendations and summarises the findings. It outlines the importance of the research in adding to the knowledge base. The chapter also includes recommendations for further research.

Table 1: Publication Schema for a Design Science Research (DSR) Study

Section	Contents
1. Introduction	*Problem definition, problem significance/motivation, introduction to key concepts, research questions/objectives, scope of study, overview of methods and findings, theoretical and practical significance, structure of remainder of paper.* For DSR, the contents are similar, but the problem definition and research objectives should specify the ***goals*** that are required of the artifact to be developed.
2. Literature Review	*Prior work that is relevant to the study, including theories, empirical research studies and findings/reports from practice.* For DSR work, the prior literature surveyed should include any prior design theory/knowledge relating to the class of problems to be addressed, including artifacts that have already been developed to solve similar problems.
3. Method	*The research approach that was employed.* For DSR work, the specific DSR approach adopted should be explained with reference to existing authorities.
4. Artifact Description	A concise description of the artifact at the appropriate level of abstraction to make a new contribution to the knowledge base. This section (or sections) should occupy the major part of the paper. The format is likely to be variable but should include at least the description of the designed artifact and, perhaps, the design search process.
5. Evaluation	Evidence that the artifact is useful. The artifact is evaluated to demonstrate its worth with evidence addressing criteria such as validity, utility, quality, and efficacy.
6. Discussion	*Interpretation of the results: what the results mean and how they relate back to the objectives stated in the Introduction section. Can include: summary of what was learned, comparison with prior work, limitations, theoretical significance, practical significance,* and *areas requiring further work.* Research contributions are highlighted and the broad implications of the paper's results to research and practice are discussed.
7. Conclusions	*Concluding paragraphs that restate the important findings of the work.* Restates the main ideas in the contribution and why they are important.

(Source: Gregor & Hevner 2013, p. 350)

1.8 Summary

In *Chapter 1* I have defined the topic under consideration. I have also outlined the aim and objectives of the research and the parameters under which that research was undertaken. I describe the limitations of the research and the research methods used, as well as the overall structure of the thesis. In the following chapter I describe the secondary research undertaken as part of the comprehensive literature review and data gathering exercise.

2 LITERATURE REVIEW

2.1 Introduction

A comprehensive literature survey was undertaken to develop an understanding of the extant knowledge and ascertain the supporting evidence for the conceptual framework. Topics were chosen based on their relevance to the research problem, to define objectives for a solution, create an innovative artefact, and to add to the knowledge base.

The approach to the Literature Review is consistent with the methodology used in the Design Science Research (DSR) model discussed in *Chapter 3* and as described by (Hevner et al., 2004).

Chapter 2 also provides an overview of the existing challenges in accelerating the transition to a CE, across both the public and private sector, and a rationale for the proposed solution (artefact). The section headings were chosen based on their relevance to the topic and to provide supporting evidence for the development of a conceptual framework for a peer-peer excess materials exchange for the public sector, built environment.

The Literature Review includes the following section headings:

- European Context & Opportunities
- The Circular Economy (CE)
- The Built Environment (BE)
- The Public Sector
- Excess Materials Exchange
- Carbon as Incentivisation Measure to CE-adoption

2.2 European Context & Opportunities

Europe (EU-27) features in the top seven emitters of greenhouse gases with emissions per capita in 2020 at 7.2 tonnes of CO2 equivalent (tCO2e) (India by comparison is 2.3 tCO2e emissions per capita in the same period) (WEF, 2023). The European Union (EU) has set out an objective to be a climate neutral economy by 2050. The EU has determined, for geo-political, economic, and environmental reasons, and as part of the European Green Deal and other policy imperatives, that localisation of industry and critical raw materials is in the best interest of the union (European Commission, 2019). To support the ambitions of the European Green Deal, the European Commission (EC) has drafted a Critical Raw Material List and created the European Raw Materials Alliance (ERMA), seeking to *build more resilience* internal to the European market, *create more local jobs* and opportunities, and *enable more resilient value chains*, while simultaneously decoupling the EU's exposure to external suppliers of critical raw materials, and reducing pressures on natural resources.

2.2.1 Circular Economy Action Plan (CEAP)

The Circular Economy Action Plan (CEAP) is an attempt to decouple economic growth from resource use, by reducing the EU's material consumption footprint, while doubling the circular material use rate (European Commission, 2020). There are several specific objectives within the plan, such as: *to enable a healthier planet, reduce pollution, emissions, and pressures on natural resources, create local jobs and businesses,* and *enable more resilient value chains.*

2.2.2 Carbon Border Adjustment Mechanism (CBAM)

In addition to both the European Green Deal and Circular Economy Action Plan, the EU has adopted amendments to the Carbon Border Adjustment Mechanism (CBAM) (European

Commission, 2022). The CBAM will have a specific impact on heavy industry, as it pertains to both finished goods and raw materials passing into the European Union and will affect the construction sector and materials critical to construction sector disproportionately more than other sectors, given the carbon-intensive nature of commonly used materials, such as steel, concrete, aluminium, and glass.

2.2.3 European Critical Raw Materials Alliance (CRMA)

The Circular Economy Action Plan and European Green Deal lean heavily on supply chain localisation, or the shortening of supply chains to provide positive socio-economic results, and as a de-risking strategy - a European Commission (EC) Staff Working Document (SWD 2020) identifies that access to materials represents a 'strategic security risk to the European Union' (European Commission, 2020). As part of the CRMA roadmap towards a more resilient, secure, and stable supply chain for critical raw materials a mapping exercise will be undertaken to determine the 'potential supply of secondary raw materials' and 'viable recovery projects' (APPENDIX C). This is of relevance to the scaling of a circular economy within the borders of the European Union through dematerialisation.

2.2.4 Ireland

Ireland is a Party to the United Nations Framework Convention on Climate Change (UNFCCC), and the Paris Agreement (UNFCCC, 2015). Ireland also participates in the EU Emissions Trading System (2023) and is legally bound by the Effort Sharing Regulation (EU, 2018). Ireland has a commitment to a 30% reduction in non-Emissions Trading System (ETS) emissions by 2030, and net zero by 2050.

Ireland's circular material use rate however is 1.6%. This compares unfavourably with the EU circular material use rate average of 11.9%. If Ireland is to achieve any of the goals set out by the Climate Action Plan (2023), the Waste Action Plan for a Circular Economy (2021) and the European Green Deal (2023), it will be necessary to accelerate the transition to the circular economy. That accelerated transition could be facilitated through the exchange of excess publicly owned materials through a public sector marketplace. We refer to that public sector marketplace as an Excess Materials Exchange (EME).

2.3 The Circular Economy (CE)

2.3.1 Introduction to the Circular Economy

The Circular Economy (CE) is an evolving field of study and research. The subject incorporates industrial, ecological, socio-economic, and technological systems, and has long established roots in ecological and environmental economics and industrial ecology (Ghisellini, Cialani and Ulgiati, 2016). This is also a view held in (Chizaryfard, Trucco and Nuur, 2021). The CE is 'entangled' with several overlapping concepts, including, cradle to cradle, biomimicry, natural capitalism, and regenerative design (Lazarevic and Valve, 2017). It has also been proposed that the CE has origins in the work of Rachel Carson's book, *Silent Spring* published in 1962 and *Limits to Growth* from the Club of Rome, published in 1972 (Silent Spring | Rachel Carson's Environmental Classic | Britannica, 2023; The Limits to Growth - Club of Rome, 2023), amongst others (Winans, Kendall and Deng, 2017). Or that the CE has its origins in *systems theory*, and *industrial ecology* (Ghisellini, Cialani and Ulgiati, 2016).

2.3.2 Defining the CE

The definition for the CE as described in Hartley, van Santen and Kirchherr (2020, p. 2) is, '[CE is] an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling, and recovering materials in production/distribution and consumption processes.' According to the Ellen MacArthur Foundation the goal of the CE, is to 'circulate products and materials' (at their highest value), 'eliminate waste', and 'regenerate nature' (EMF, 2023).

The European Union state that in a CE 'the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste is minimized' (Circular economy, 2023). And the United Nations Conference on Trade and Development (UNCTAD) the CE as 'entails markets that give incentives to reusing products, rather than scrapping them and then extracting new resources' (UNCTAD, 2023). The CE has also been described as 'a concept that articulates a socio-technological future radically different from the one existing today', and a response to the conventional economic model of 'take-make-consume-dispose' (Lazarevic and Valve, 2017).

Reike, Vermeulen and Witjes (2018) offer a further interpretation of the CE through their R-Hierarchy of material retention options (RO's) and unified 10R typology (Figure 3). The 10R hierarchy is the most comprehensive interpretation of material value retention options reviewed as part of the secondary research and is suggested *here* as a useful mechanism to aid in the understanding of material pathways for an EME.

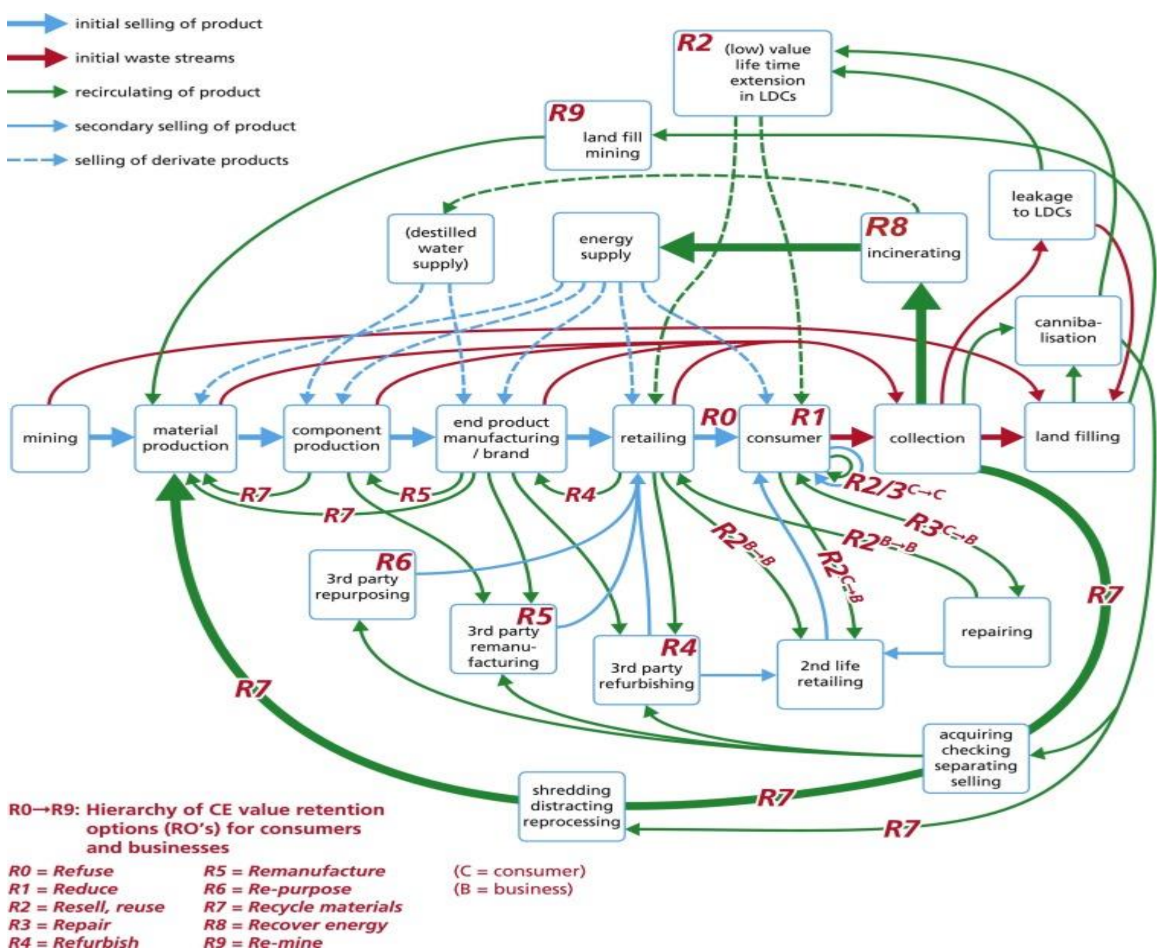


Figure 3: Mapping Circular Economy Retention Options: The Produce and Use Life Cycle (Source: Reike, Vermeulen and Witjes, 2018, p. 258)

For the purposes of this study a distinction is made between the CE and resource efficiency. Resource efficiency, as defined by the European Commission, *Roadmap to a Resource Efficient Europe* includes efficiencies in energy, transport, and buildings, coupled with potential savings from more efficient waste management and prevention strategies (European Commission, 2011).

Pratt, Lenaghan and Mitchard (2016) further explore the differences between the CE and resource efficiency, explaining that the CE 'considers dematerialisation strategies across all stages of the lifecycle, including those related to production, manufacturing, and end of life'.

Kirchherr, Reike and Hekkert (2017, p. 224) conclude that, 'A circular economy describes an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations.'

2.3.3 Economic de-growth and the CE

The CE has often been associated with the concept of 'post-growth circularity' (Kirchherr, 2022, p. 2). It has also been described through the lens of 'green growth' by Bauwens (2021, p. 1) as 'decoupling economic growth from the ecological impacts associated with economic activities'. This has led to the concept of a CE that grows, because only in a growth scenario will circular economy business models compete with, and substitute for, their linear economy equivalents.

Bauwens (2021, p. 2) argues for a 'post-growth' era, 'one in which macroeconomic goals are reoriented towards equitable downscaling of production and consumption and wellbeing enhancement.' O'Neill et al. (2018) estimate that, based on the current relationship between Gross Domestic Product (GDP) and resource consumption – to meet only the basic needs of individuals and simultaneously strive to achieve 95% of the target of net zero emissions by 2050

– resources will still need to be used at 2-6 times the sustainable level. Ward et al. (2016) argue: 'If GDP growth as a societal goal is unsustainable, then it is ultimately necessary for nations and the world to transition to a steady or declining GDP scenario.'

The CE also offers a potential solution to the seemingly contradictory demands of economic growth and environmental conservation (Pomponi and Moncaster, 2016). Blomsma and Brennan (2017, p. 609) 'the CE articulates (more clearly) the capacity to extend the productive life of resources as a means to create value and reduce value destruction.'

Chizaryfard, Trucco and Nuur (2021) suggest that an evolutionary view of industrial transformation must be taken to mitigate against climate change, claiming that there is consensus that neo-liberal economic thinking, and its inherent models of globalised supply chains, is unsustainable. This is a view shared by many proponents of the CE, who consider the CE as a strategy which involves 'socio-industrial transformation' towards closed-loop systems for materials and energy.

The design intent of circulating material and closed-loop systems also finds commonality with the ideas of 'social metabolism' developed by Savini (2023) and with industrial symbiosis (IS), that is 'the sharing of a by-product or service that would otherwise have been disposed of to minimise waste and maximise the utility of resources' as described by (Napp et al., 2014, p. 635).

While the concept of economic degrowth, post growth circularity, and a steady or declining GDP scenario should be considered as part of the wider conversation around decoupling economic growth from ecological impact, further investigation is beyond the scope of this research at this point.

2.3.4 Challenges to the CE transition

Bianchi and Cordella (2023) for example, argue that it is still unclear whether the CE mitigates against virgin material resource extraction. With a particular focus on the EU-28 (EU-27 & UK), they ask whether CE initiatives, and specifically secondary material use (material finding another use after its designed end-of-lie), mitigate against the extraction of virgin raw material. In the absence of mitigation, a question arises as to whether the CE therefore helps, or hinders, the efforts to combat climate change.

Chizaryfard, Trucco and Nuur (2021) suggest that the transition to the CE is inhibited by little understanding of the 'structural tensions' which exist in the current economic system and that in a scenario where products are designed for 'long life' rather than designed for obsolescence, it is possible that consumers will make savings based on not having to buy new products but that any savings made might not be invested in sustainable products and services. This leads to a 'circular economy rebound' effect (Zink and Geyer, 2017).

Bianchi and Cordella (2023b) conclude that the CE might remain a technical tool which does not alter the current trajectory of unsustainable development, and that a decoupling, or change in contemporary consumption patterns, can influence the viability of the CE.

2.3.5 Opportunities for the CE

Husgafvel et al. (2022, p. 227) maintain that 'CE and sustainable development goals are intertwined and sustainability management and assessment encompassing economic, social, and environmental dimensions are essential focus areas.'

According to the Ellen MacArthur Foundation (2023), the CE meets 12 of the 17 United Nations Sustainable Development Goals (UN, 2023). Hartley, van Santen and Kirchherr (2020, p. 155) propose that: 'environmental sustainability, economic prosperity and social equity are valid objectives' as it pertains to the CE.

European Commission (2020) provide a useful summation of creating advantage through a CE (Figure 4). Where resources, lifecycles, embedded values, and capacity are wasted, and where the objective is to eliminate waste where possible, the CE can be part of the solution, creating advantage across the value chain when applied on business models, technologies, and capabilities.

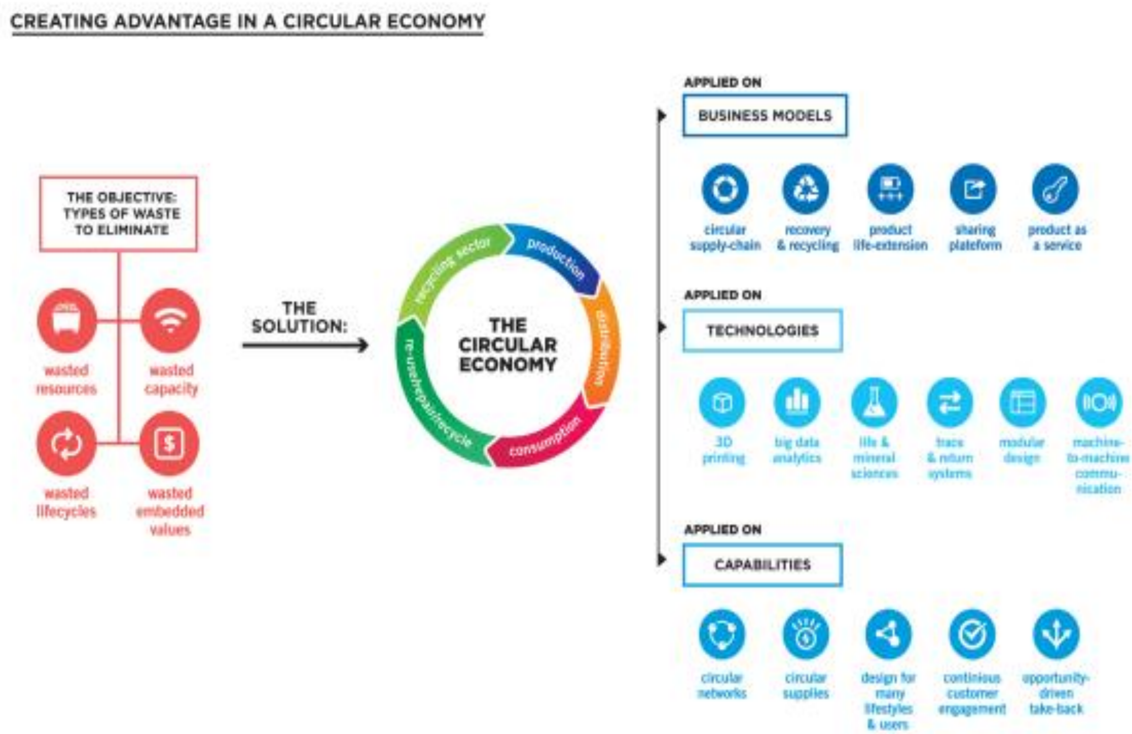


Figure 4: Creating Advantage in a Circular Economy (Source: European Commission 2020, p. 17)

Farrant, Olsen and Wangel (2021, pp. 726-736) outline five opportunities of a CE, including, '*making better use of finite resources*, *reducing greenhouse gas emissions*, *boosting economies*, and *creating more and better jobs*'. Opportunities to achieve circular objectives are presented in (Circularity Gap Reporting Initiative, 2023). The four flows of *Make Clean*, *Use Again*, *Use Less* and *Use Longer* summarised in (Figure 5) are a useful shorthand in considering the challenges and opportunities available to the CE in the Built Environment.

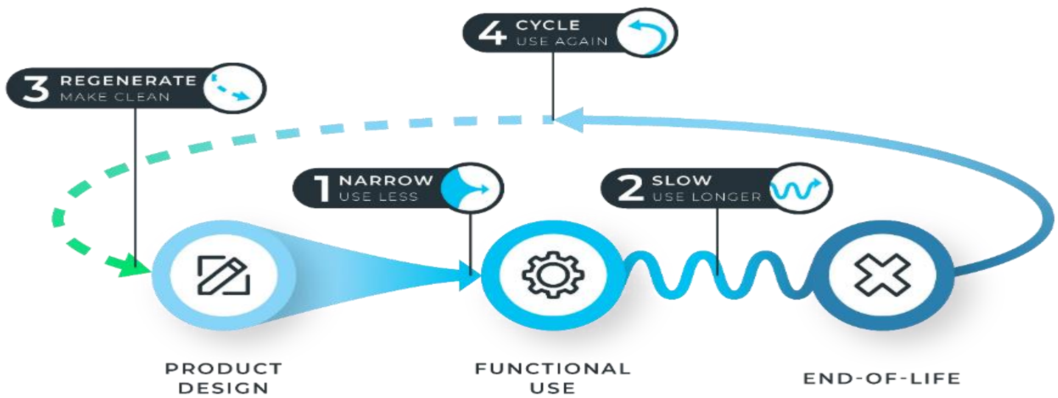


Figure 5: Four flows to achieve circular objectives (Source: Circularity Gap Reporting Initiative 2023, p. 21 *based on* Bocken et al., 2016)

2.4 The Built Environment (BE)

2.4.1 Introduction to the Built Environment

The sectors designated by the Inter-governmental Panel on Climate Change (Calvo Buendia; Peru, Guendehou and Tanabe, 2019) as primarily responsible for global greenhouse gas (GHG) emissions are, *Energy*, *Industrial Processes and Product Use* (IPPU), *Agriculture*, *Forestry*, *and other Land Use* (AFLU), and *Waste*. It is thought that the BE accounts for approximately 30-40% of anthropogenic greenhouse gas emissions (i.e., emissions resulting from human activities) (O'Hegarty and Kinnane, 2022). According to a report from the World Economic Forum (WEF) 30% of global greenhouse gas (GHG) emissions can be attributed to buildings alone (WEF, 2016). The International Energy Agency (IEA) estimates that building stock are on track to double by 2050 (IEA, 2019) .

2.4.2 Defining the Built Environment

UNESCO defines the built environment (BE) as: 'the human-made environment that provides the setting for human activity, ranging in scale from buildings to cities and beyond' (UNESCO, 2021). The United States Environmental Protection Agency (US EPA) define the BE as: '… the man-made or modified structures that provide people with living, working, and recreational spaces' (US EPA, 2023).

However, the BE does not sit neatly within the taxonomy of the commonly understood IPCC inventory categories (O'Hegarty and Kinnane, 2022). According to the United Nations Environment Programme (UNEP) global greenhouse gas (GHG) emissions for 2021, excluding land use, land-use change, and forestry (LULUCF), are estimated at *52.8 GtCO2e*, continuing the growth trajectory established over the previous ten years (UNEP, 2022).

According to the UNEP report, the buildings and construction sector contributes approximately *'37% of global operational energy and process-related CO_2 emissions'*. Built environment operational energy use, at the global level, grew by 4% from 2020 levels, with carbon dioxide (CO_2) emissions increasing to approximately *10Gt CO_2* (UNEP, 2022, p. 42).

According to the World Building Council on Sustainable Development (WBCSD, 2021) we can separate the carbon impact of a building into two categories, *operational carbon* (OC) and *embodied carbon* (EC) (Figure 6).

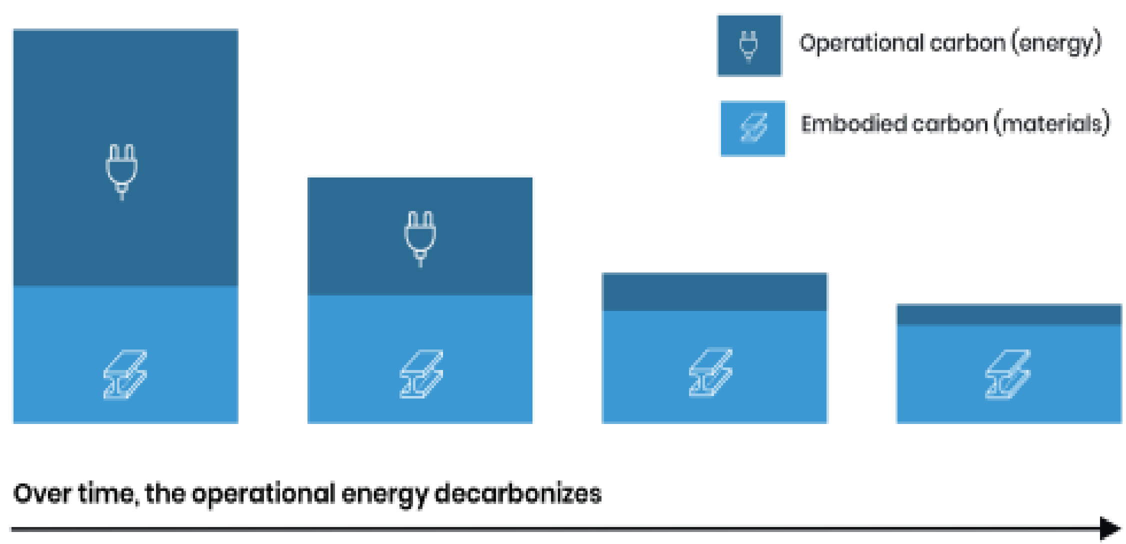


Figure 6: Proportional increase in embodied carbon increase as energy demand decreases and energy sources are decarbonised (Source: WBCSD, 2021, p. 9)

Operational carbon (OC), the energy used during a buildings operational phase, such as the energy required for, lighting, air conditioning, heating etc., accounts for 80% of a building's total carbon emissions, while the remaining 20% is attributed to a building's embodied carbon (EC), i.e., the carbon associated with extraction, processing, manufacturing, and transportation of a building's components, and its assembly and construction phases (Iacovidou and Purnell, 2016).

For building stock, which has reached its end-of-service-life (EoSL) – a building which might be due for demolition for example – a cost/benefit analysis would need to be undertaken to understand the resource inputs that would be required to recover materials. According (IPCC, 2022) efficiency gains in the construction sector from improvements in materials and processes have been largely offset by an overall increase in floor area per capita and an increase in global population since 2020 (APPENDIX D).

Ness and Xing (2017) developed a conceptual model for a resource efficient built environment using the key strategic drivers of *Systems Innovation*, *Performance Management* and *Resource Efficiency* and the use of CE systems and arguing for more to be done with less (Figure 7). The conceptual model illustrates the complexities, synergies, and interdependencies of the many stakeholders and, processes involved in achieving a resource efficient built environment.

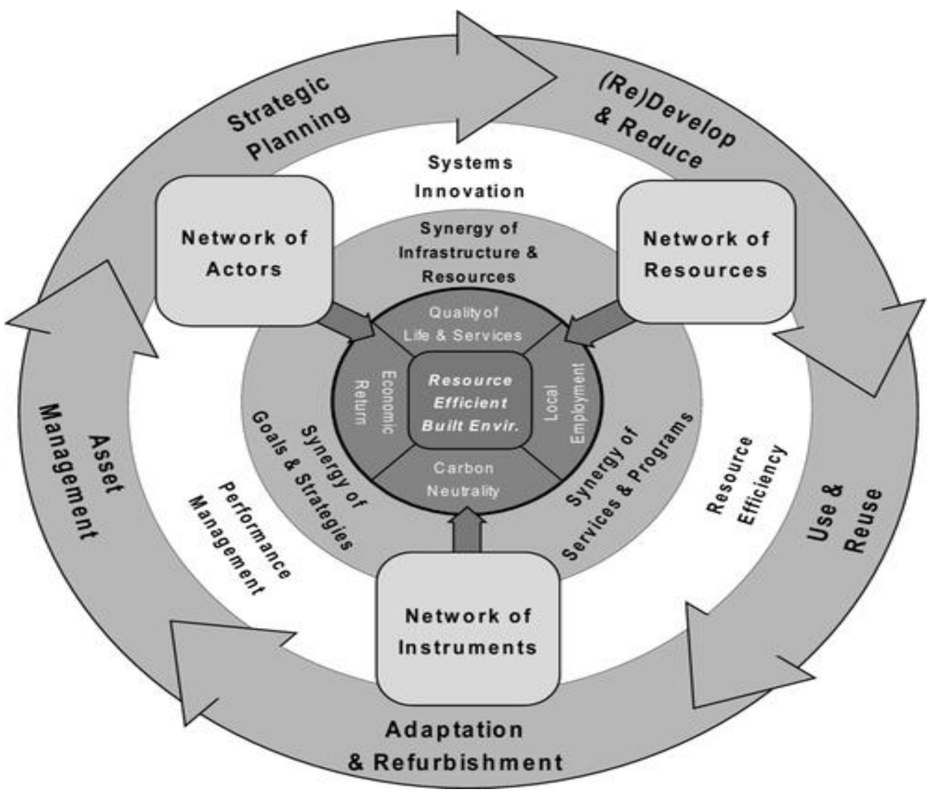


Figure 7: Conceptual model for a resource efficient built environment (Source: Ness and Xing 2017, p. 584)

Gallego-Schmid et al. (2020) find that for the built environment, *closing resource solutions* (i.e., minimising waste and keeping materials in circulation for longer) is dependent on the efficiencies of both the *recycling* and *transportation processes*.

2.4.3 Construction

At some point in the future, based on the *rate of global resource depletion*, buildings and other infrastructure will become material and product banks providing rich sources of high-value materials. This scenario will encourage localisation of materials for further *use and reuse*, and will, according to Hopkinson et al. (2018) *'create value, promote innovation and attract investment'*. As resources become scarce, harder to extract, and more expensive to process, the circular economy will become a more attractive option for all stakeholders in the value chain for construction and infrastructure projects.

A recent report from the High-Level Construction Forum (HLCF) of the European Commission (2021) recommended five key steps for the construction industry in its transition to lowering whole life cycle greenhouse gas emissions across the sector:

1) *carbon budgets*
2) *transition roadmaps*
3) *standard tools and methodologies*
4) *rewarding of circularity approaches*
5) *the importance of material and technology neutrality*

These are combined with recommendations to develop decarbonisation targets in line with the *Net Zero by 2050* vision (European Climate Foundation, 2020), implementation of *circularity targets* as they pertain to the Energy Performance in Buildings Directive (EPBD, 2018) improving the public tendering process through *sustainable procurement* (currently a voluntary mechanism), and finally improved measures around *sustainable finance*: taxonomy and access.

From a European perspective Gallego-Schmid et al. (2020) contend that construction is a particular priority of the European Green Deal and the Circular Economy Action Plan (CEAP). This focus is attributed to the scale of both waste and greenhouse gas emissions emanating from the sector. The European Union (EU-28 including the UK) alone contributes to nearly *one billion tonnes* of construction and demolition (C&D) waste annually (Gallego-Schmid *et al.*, 2020).

Bianchi and Cordella (2023) observe that net material accumulation across the EU-28 amounts to *3.13 Gt per year*; exceeding what could be recycled in any given year (European Commission, 2018) . This is due in part to *in-use stocks* (buildings and infrastructure) which due to their long lifetimes are not recycled at the same rate as other materials. As a result, virgin raw material extraction, or direct extraction, will almost always exceed the *rate of recycling*, offsetting some of the perceived benefits of the CE in reducing raw material inflows.

There are additional challenges, including that materials degrade each time they are recycled. This results in in higher energy inputs with each cycle, and higher costs (Bauwens, 2021).

To get a better understanding of the scale of materials available for recovery and reuse in Europe and Ireland the study examines the area of waste, and specifically construction and demolition (C&D) waste.

2.4.4 Waste

Waste is defined as *'any substance or object which the holder disposes of or is required to dispose of pursuant to the provisions of national law in force'* (Eurostat, 2023). The disposal of waste, in regulated environments, is complex and involves collection, sorting, transportation, storage, and treatment. Transformation of waste can include recovering, recycling, and reusing of materials which would otherwise be sent to landfill or incinerated. Once a material is classified as *waste* it cannot be reclassified as anything other than *waste*. This poses difficulties for its reuse, particularly in highly regulated industries, such as construction, pharmaceuticals, and electronics, where materials adhere to a technical specification. The European Union has developed a waste hierarchy with a view to minimising the number of materials going to disposal (Figure 8).

Figure 8: Waste Hierarchy (Source: European Commission 2023)

In 2020 Europe exported more than 33 million tonnes of waste annually and imported more than 16 million tonnes (Figure 9).

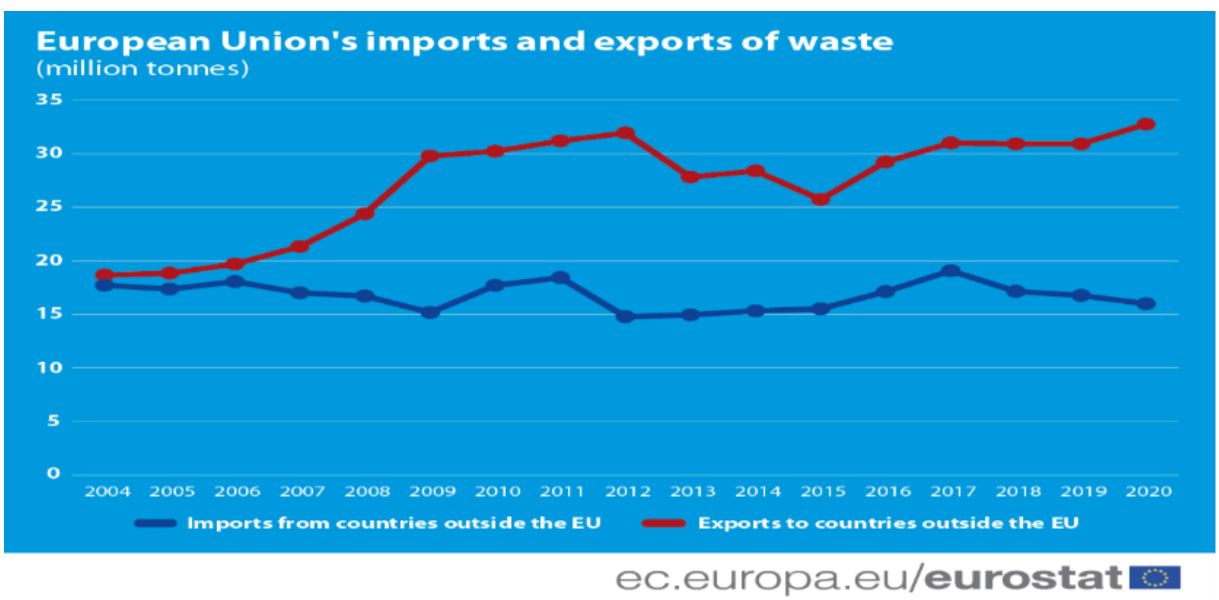


Figure 9: European Union's imports and exports of waste (Source: Eurostat 2021)

The vast bulk of both exported and imported waste consists of iron and steel materials, 17.4 million tonnes (Figure 10). Precious metals accounted for 0.1 million tonnes, bringing the entire metals scorecard to 17.5 million tonnes in 2020.

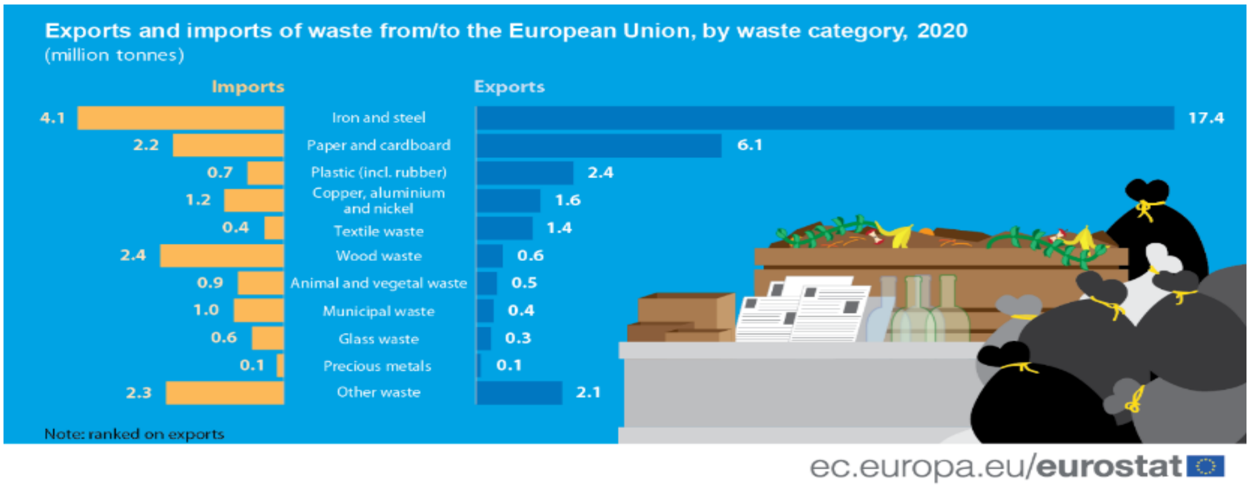


Figure 10: Where does EU waste go? (Source: Eurostat 2021)

As one example of how this volume of waste metals can be reduced Ness et al. (2015) argue for the concept of smart steel, enabling the digital tracking and modelling of steel to encourage reuse. The authors cite the use of Radio Frequency Identification (RFID) and Building Information Modelling (BIM) as technology interventions and argue for the growth in new business opportunities for steel 'resellers'.

2.4.4.1 End of Waste

The End-of-waste criteria under *Article 6* of the Waste Framework Directive (European Commission, 2008) seeks to reclassify materials as *product* or *secondary raw materials* under certain conditions:

1. *The substance or object is commonly used for specific purposes.*
2. *A market or demand exists for such a substance or object.*

3. *The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products.*
4. *Use of the substance or object will not lead to overall adverse environmental or human health impacts.*

Source: European Commission (2023)

The EU has identified the following *priority* waste streams, which are of *specific relevance* in the context of the built environment.

- *Iron, Steel & Aluminium scrap* (Council Regulation (EU) N° 333/2011)
- *Glass cullet* (Commission Regulation (EU) N° 1179/2012)
- *Copper scrap* (Commission Regulation (EU) N° 715/2013)

In Ireland the End-of-Waste criteria (*Article 28*) legislation aims to achieve '*end-of-waste status* for *recovered waste materials* to *divert waste from landfill*', helping to '*keep those materials in the economy as a resource*', the result of which is, a '*lower environmental impact from waste management'* (Environmental Protection Agency, 2023).

2.4.4.2 By-product

A by-product is *'a substance or object, resulting from a production process, the primary aim of which is not the production of that item'* (European Commission, 2008). A material is classified as a by-product if it meets *all four* of the following conditions:

1. *Further use of the material is certain.*
2. *The material can be used directly without any further processing other than normal industrial practice.*
3. *The material is produced as an integral part of the production process.*

4. *Further use is lawful, in that the substance or object fulfils all relevant product, environmental and health protection requirements for the specific use and will not lead to overall adverse environmental or human health impacts.*

Source: Environmental Protection Agency (2020)

The Environmental Protection Agency (EPA) is a key stakeholder and gatekeeper in the regulation of By-Products in Ireland. The By-Product Notification (APPENDIX F) process is described below (Figure 11).

Figure 11: By-Product Notification process (Source: Environmental Protection Agency 2023)

*EDEN: Environmental Data Exchange Network Welcome - EDEN PORTAL (edenireland.ie)

2.4.5 Construction and Demolition (C&D) Waste Europe

López Ruiz, Roca Ramón and Gassó Domingo (2020) contend that construction and demolition waste (C&D) is a priority for policy makers, given the significant volume of C&D waste produced annually worldwide, and the inadequacy in its management – only *20-30%* of C&D waste is recovered annually and much of the C&D waste recovered is downcycled material of *inferior value*, *quality*, and *functionality* (Tebbatt et al., 2017).

The Waste Framework Directive 2008/98/EC carries specific provisions for how C&D waste is handled. The primary goal of the Directive is to ensure the proper disposal of both non-hazardous and hazardous waste. Construction waste tends to be less contaminated and less mixed than demolition waste, which is more difficult to recover. Construction waste offers the greatest potential for reuse; however, demolition waste is a larger percentage of the overall C&D waste category.

The European Environment Agency (EEA) offers some solutions for circular actions which can be taken to improve the management of C&D waste including; Design for Disassembly, Higher grade products with high grade recycle content, Material Passports, Extension of construction life, and Selective Demolition (APPENDIX E) and (Table 2).

Table 2: Benefits and Challenges of C&D waste management actions

ACTION	BENEFITS	CHALLENGES
Design for Disassembly	- Reuse is part of waste prevention - Separation of components makes recycling easier	- Higher complexity of disassembly - Potential for conflict with other legislation - Lack of knowledge and information - Long time-delay before implementation and results
Higher Grade Products	- Prolong construction lifespan - Increase quality of recycling	- Lower price of virgin materials - Doubts on quality of recyclables
Material Passports	- Facilitate source separation of end-of-life materials	- Information and data management over a long period - Cost of data gathering and storage
Extended Construction Life	- Implementation of waste prevention - Avoidance of new construction environmental impacts	- Energy inefficient buildings also extend their lifespan - Risk from presence of inferior materials - High labour costs - Changes in architectural preferences
Selective Demolition	- Increase quantity and quality of recycling	- More time consuming - More costly - Lack of traceability - Complexity of buildings and construction materials

(Source: EEA 2023)

2.4.6 Construction and Demolition (C&D) Waste Ireland

The EPA National Waste Statistics Summary 2020 shows that C&D waste is approximately *8.2m tonnes* in 2020 down by *0.6m tonnes* on the previous year due to the reduction in construction activity during the Covid pandemic. Soil and stone represent *82%* of the C&D waste stream. Metals account for approximately *2%* (Figure 12) or *199,392 tonnes* of the total C&D waste with 100% of the metals being recycled.

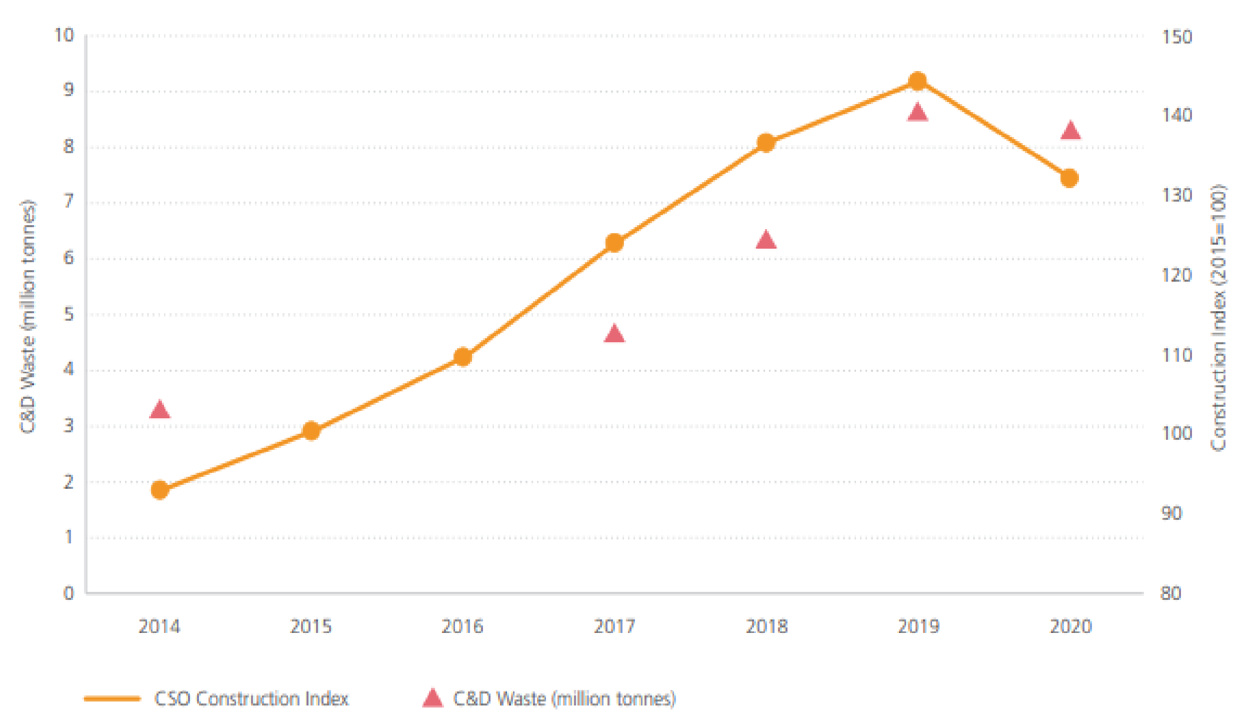


Figure 12: Quantity of construction waste managed in Ireland, compared with CSO construction index 2014-2020 (Source: Environmental Protection Agency 2020)

There is no determination of the contribution of the public sector-built environment to the waste statistics primarily because C&D waste collection is contracted out to third parties through the tendering process with no specific requirement on those contracting entities to declare the percentage of materials collected and disposed of by public or private sector material codes. An opportunity exists to capture this additional data with the purpose of determining public sector contributions to both overall waste statistics, and to material category statistics.

2.4.6.1 Case Study: Steel as component of C&D waste

Council Regulation (EU) N° 333/2011 specifically references steel as a priority material. For the purposes of this research, I am limiting this brief evaluation to steel to demonstrate the relative opportunity available to retain material and energy value in the system. Across the EU the steel industry is responsible for circa *5%* of CO_2 emissions and *7%* globally (IEA, 2020) .

Steel is extensively used in construction and the built environment more generally. It has a relatively high embodied carbon impact compared to other materials, and it is very suitable to both recovery, recycling, and reuse, however in composite construction - where steel is combined with another material, concrete – it can be a barrier to ease of deconstruction (Hopkinson *et al.*, 2018; ARUP, 2023). The reliance of the Irish construction and manufacturing sectors on imports of steel is both a strategic risk, and an opportunity. Given that metals account for almost *200,000* tonnes in C&D waste annually (Figure 12), it suggests that there is an opportunity to retain a percentage of that material and energy value through a circular economy for metals.

Additionally, given that Ireland imports large quantities of steel for use in manufacturing, construction, and the built environment, an opportunity could exist to substitute a percentage of those material imports with recovered materials from C&D waste. This could help reduce Ireland's strategic material requirements and lower its climate risk through a reduction in the carbon footprint of imported materials.

The analysis of Pratt, Lenaghan and Mitchard (2016) provides a useful guide to possible alternatives for Ireland's transition to a CE in this regard. Several lessons can be taken from the example from Scotland as it concerns Ireland's dependency on steel imports and balancing those imports against more circular actions, such as reuse of materials and localisation of steel processing etc.

2.4.7 Material Recovery Tools & Methods

To this point in our literature review, I have described the macro and global context in terms of the need to build a circular economy. There is a need to balance the needs of a growing world population and manage resources in a more environmentally sustainable way to stay within planetary boundaries and to mitigate against raw material resource exhaustion, biodiversity collapse and the negative impacts of the climate crisis, and other human-created environmental, social, and economic challenges. I have investigated the meaning and definition of the circular economy (CE) to better understand its benefits to society in the 21st century and have outlined the challenges which exist to its universal adoption. I have described Europe and Ireland's waste statistics, circularity rates, and focused in on the C&D waste category to get a better idea of the scale, quantity, and quality of materials available within the built environment.

In *Section 2.4.7.* I investigate best available enabling technologies and innovations which could accelerate the transition to a CE and highlight opportunities to further develop the conceptual framework for the EME within the context of the built environment in Ireland, and the public sector-built environment more specifically. I review Urban Mining (UM), and discover how Blockchain, the Internet of Things (IoT), and Artificial Intelligence (AI) in conjunction with Material Passports and Building as Material Banks (BAMB) can help facilitate that transition.

2.4.7.1 Urban Mining

Urban mining (UM) is defined as 'recovering and recycling critical materials from end-of-life clean energy technology products' (Carrera et al., 2023, p. 1). UM 'de-notes the systematic reuse of anthropogenic materials from urban areas' (Brunner, 2011, p. 339). When referring to urban mining (van Oorschot *et al.*, 2023) use the analogy of *materials hibernating*, waiting for a new lease of life. Access, Markopoulou and Taut (2023, p. 8) maintain that '… urban mining in the context of the built environment offers the possibility for bridging the gap between the circular production of materials and the urban system as a complex multidimensional locus both for the sourcing and the destination of its products.'

A study by Koutamanis, Van Reijn and Van Bueren (2018) which was motivated by the increasing prices for metals suggest lack of accurate information on the material content in buildings and C&D waste figures could be a problem and claims that resource recovery from buildings is already as high as it can get, are exaggerated. According to the authors of the study UM, originally thought of primarily as a concept for the recycling of electrical and electronic waste, is gaining wider acceptance across the built environment for the recovery of materials other than electrical and electronic components. As resources become scarcer and more expensive UM will move from the fringe to the mainstream and introduce new and innovative ways of recovering and reusing precious materials. Ingenuity through necessity will drive the rapid adoption of urban mining to conserve energy and keep materials in circulation for longer as part of the circular economy of the 21st century.

Arora et al (2017) claim that urban mining has relevance in the context of sustainable cities, drawing from work by Baccini and Brunner (2012, p. 180) in defining urban mining as 'all the activities and processes of reclaiming compounds, energy, and elements from products, buildings, and waste generated from urban catabolism.'

Tesfaye et al. (2017) in their study on e-waste suggest UM linkages to pre-processing and separation on site with one potential solution offered as being a technical, administrative, and economic alternative being the use of mobile processing units, versus stationary recycling plants (Ulubeyli, Kazaz and Arslan, 2017).

Çetin et al. (2023) suggest demolishers of buildings will become harvesters of materials instead. In a study of the Dutch residential building sector Yang et al. (2022, p. 1) conclude that urban mining 'cannot meet future material demand due to the new construction caused by population increase and its limited ability to supply the required kinds and amounts of materials' and suggest that urban mining will be concentrated in cities, citing The Hague, Rotterdam, and Amsterdam as examples. In the Dutch example the study concludes that urban mining as a single strategy does not offer significant GHG emission reduction and should be undertaken in conjunction with the scaling up of renewable energy related projects to realise real benefits. While UM is an important consideration in terms of the structural, technical, administrative, and economic justifications for the EME it must be viewed in conjunction with aligned technologies and processes which will facilitate a more efficient transition to the CE more broadly.

2.4.7.2 Material Passports

Material Passports (MPs), also known as *product passports* or *circularity passports* contain information on material or product component characteristics, and their potential for reuse (BAMB, 2016). An MP is 'an instrument providing digitised qualitative and quantitative life cycle information on the characteristics of a product to enable circular principles of narrow, slow, close, and regenerate' (Çetin et al., 2023, pp. 422-423) . Other examples used across industry are Digital Product Passports (European Commission, 2022b). And Digital Building Logbooks (European Commission, 2020). Çetin et al. (2023) have produced a table to help clarify the distinctions between the various terminologies and their applications (Table 3).

Table 3: Differences and similarities between digital product passports, material passports, and digital building logbooks

	Digital Product Passports	Material Passports	Digital Building Logbooks
Scale	Product	Area; Complex; Building; Element; Product; Material; Raw material	Building
Industry	Cross-industry	(Mainly) Built environment	Built environment
Regulation	EU Ecodesign Directive	-	EU-wide Framework for a Digital Building Logbook

(Source: Çetin et al. 2023, p. 424)

Material passports can be digitised with the 'transferring of the material properties among the stakeholders involved in the value chain' (Figure 13) with each stakeholder updating the MP along the material lifecycle (Panza, Bruno and Lombardi, 2022, p. 1492). Haas et al. (2015) estimate that globally processed material stocks account for *62 Gigatonnes* annually while *4 Gigatonnes* of waste are recycled annually. With stocks increasing at *17 Gigatonnes* annually Honic, Kovacic and Rechberger (2019, p. 788) advocate for MP as means of effectively capturing 'detailed knowledge about the material composition of buildings' and reducing embodied energy and primary material use.

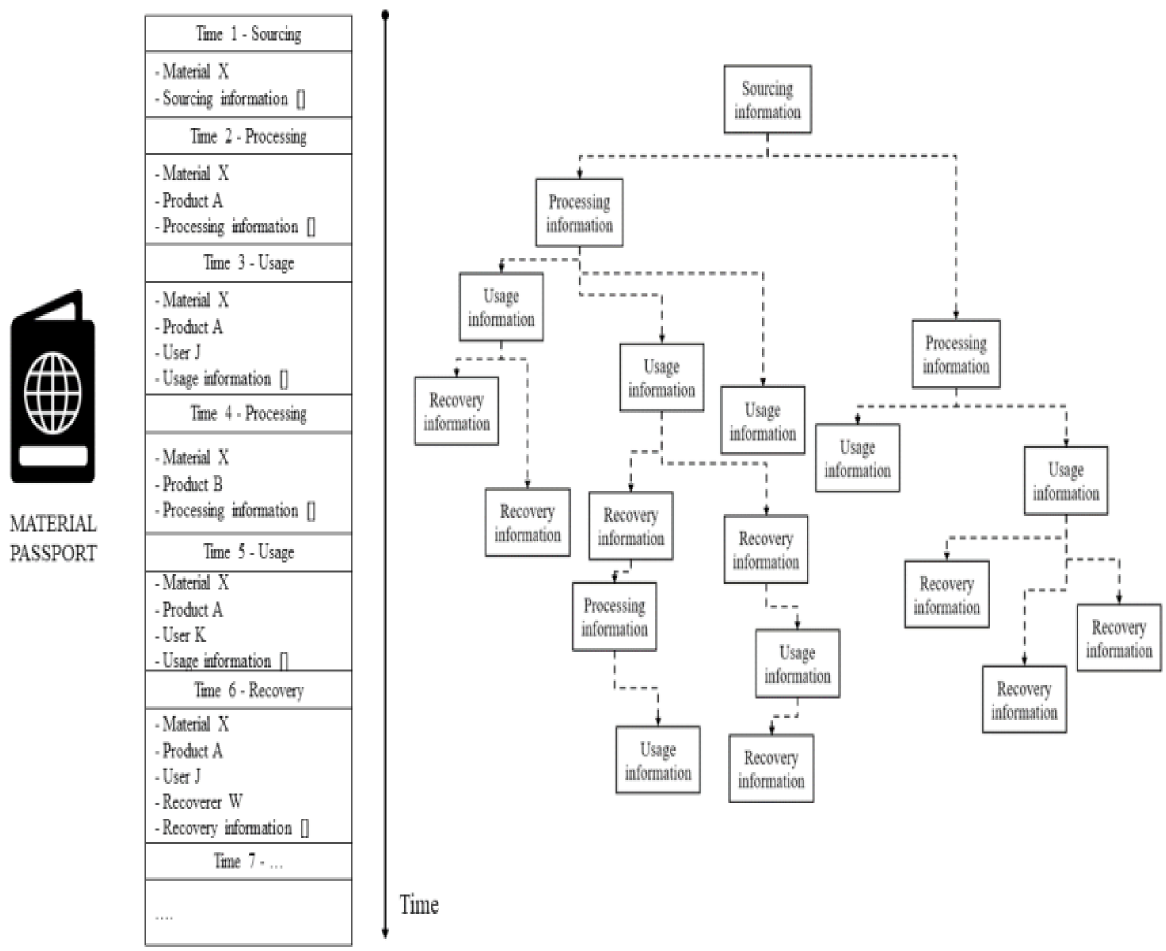


Figure 13: Generation and incremental update of material passport through the material lifecycle (Source: Panza, Bruno and Lombardi 2022, p. 1493)

2.4.8 Building as Material Banks (BAMB)

The purpose of Building as Material Banks (BAMB, 2016) is to enable *'a systemic shift in the building sector by creating circular solutions'* with buildings functioning as *'banks of valuable materials'.* BAMB was launched in 2015 and is a critically important area of work, more applicable to the future built environment. It does not substantially address the case of building stocks already in existence prior to 2015. In Honic, Kovacic and Rechberger (2019) an existing building could be in-situ for 30 years or longer, and design approaches, methods of construction, and materials have changed radically over the years. The authors of the study examine the case of existing buildings and determine that greater challenges exist in obtaining accurate information for existing buildings versus buildings yet to be designed and constructed. Some of those challenges relate to the absence and inaccuracy in information regarding methods of construction and materials used. (Figure 13) provides an outline of the proposed solution as it relates to the Building Information Modelling (BIM)-MP using geometry acquisition, demolition acquisition (DA) and urban mining assessment (UMA).

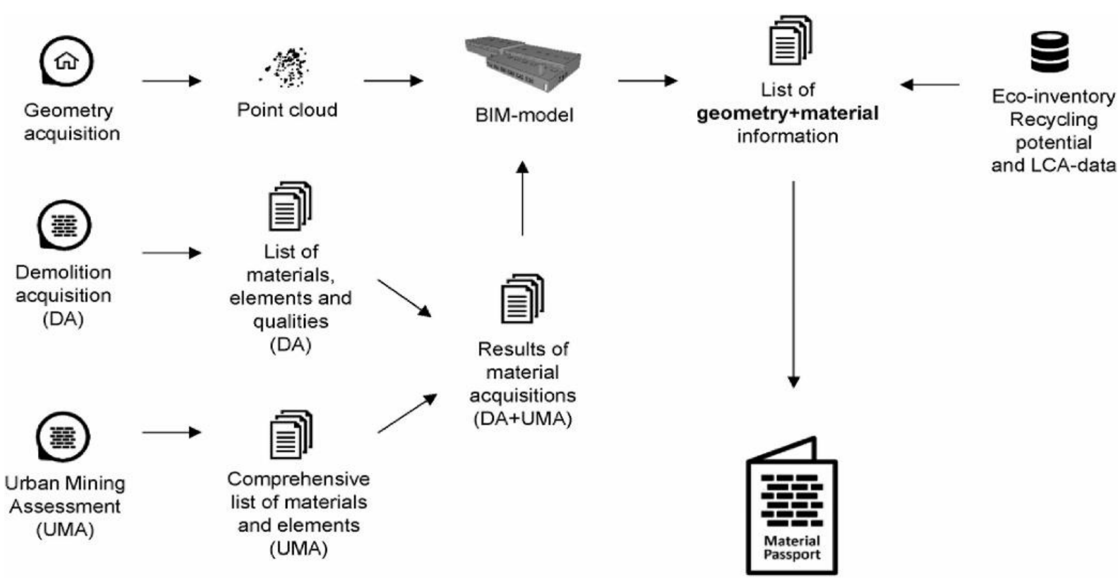


Figure 14: Workflow for the compilation of the BIM-based MP for the end-of-life stage (Source: Honic, Kovacic and Rechberger 2021, p. 3)

The applicability of the approach in Honic, Kovacic and Rechberger (2021) is important to the conceptualisation of an EME framework given the challenges of acquiring relevant information to validate the reuse of materials from the built environment and specifically as it relates to existing buildings and infrastructure which would otherwise be condemned to landfill and/or other waste management processes.

2.4.8.1 AI

Artificial Intelligence (AI) is becoming increasingly important enabler in the transition to the CE (Andoni *et al.*, 2019). Oluleye, Chan and Antwi-Afari (2023, p. 521) examines the role of AI in enabling circularity in the building construction industry (BCI) and concludes that 'AI models could enable the CE in various dimensions along a building's lifecycle'. AI 'has several key components, including machine learning and the ability to process unstructured data' (Wilson, Paschen and Pitt, 2022, p. 15).

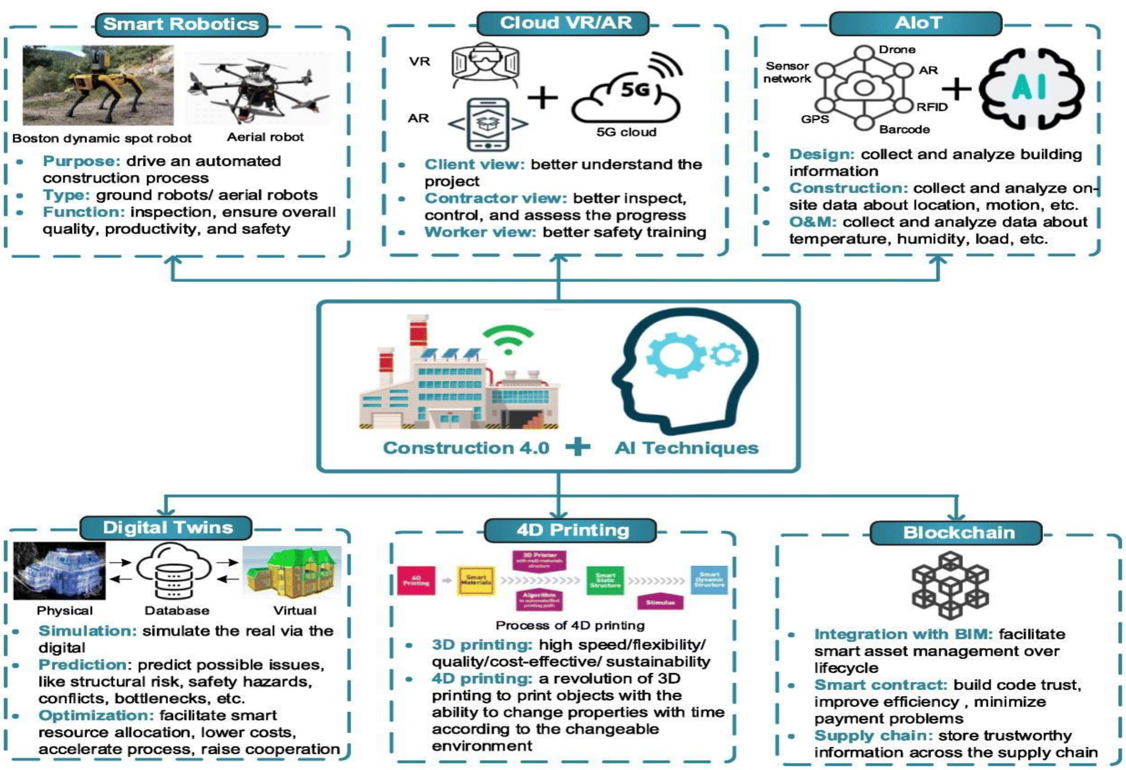


Figure 15: Future directions of AI in CEM (Source: Pan and Zhang 2021, p. 13)

Pan and Zhang (2021) offer the following summary for the interface of construction and engineering management (CEM) with AI in the future (Figure 14). It is useful to note that except for references to integration with Blockchain and effective resource allocation the graphic (Figure 14) neglects to specifically reference the role of the CE in this future paradigm. The omission does not negate the relevance or complexity of integrating *Construction 4.0* and *AI* as described. By extension AI can also have a significant impact on how materials are recovered, assigned, verified, validated, and quality assured, and as such the technology cannot be ignored in the development of an EME framework.

2.4.8.2 Distributed Ledger Technology (DLT) and Blockchain

Distributed Ledger Technology (DLT) is described as a 'technical infrastructure and protocol that allows simultaneous access, verification, and updating of records in an irreversible manner over a network spanning multiple entities or locations' (Garg, 2023, p. 2). A blockchain is a 'digital data structure, a shared and distributed database that contains a continuously expanding log of transactions and their chronological order' and allows for 'a fast, secure, and accessible information network by providing a decentralized ledger where materials and products can be traced to their sources' (Andoni et al., 2019, p. 145; Shojaei et al., 2021, p. 1). Blockchain can also be described as 'designed to ensure the data is stored and updated in a secure, tamper-proof and irreversible way' (Upadhyay et al., 2021, p. 1). Narayan and Tidström (2020, p. 4) see opportunities for blockchain through incentives for cooperation and coopetition to create CE ecosystems and 'new ways of coordinating economic activity'. Blockchain is a 'critical enabler for accelerating the transition towards the CE' (Rejeb et al., 2023, p. 1).

(Schulz and Feist, 2021, p. 3) 'Emerging DLTs hold the possibility to facilitate innovative forms of climate finance by enabling decentralized forms of cooperation between stakeholders, and by fostering trust based on transparent, automated, and standardized transactions'. Both DLT and blockchain are important technological considerations in the development of an EME due to critical necessity for verified and verifiable data as well as the creation of incentivisation structures for all stakeholders.

2.4.8.3 The Internet of Things (IoT)

European Commission (2020, p. 16) examines the role of IoT as an enabler of the CE and describe it as the 'democratisation of automation technologies' allowing components and 'assets to communicate with each other' (Figure 15). Rejeb et al. (2022, p. 2) see the IoT as the 'inter-networking of physical devices through electronics and sensors used to collect and exchange data' and technology as a prerequisite for scaling up the CE.

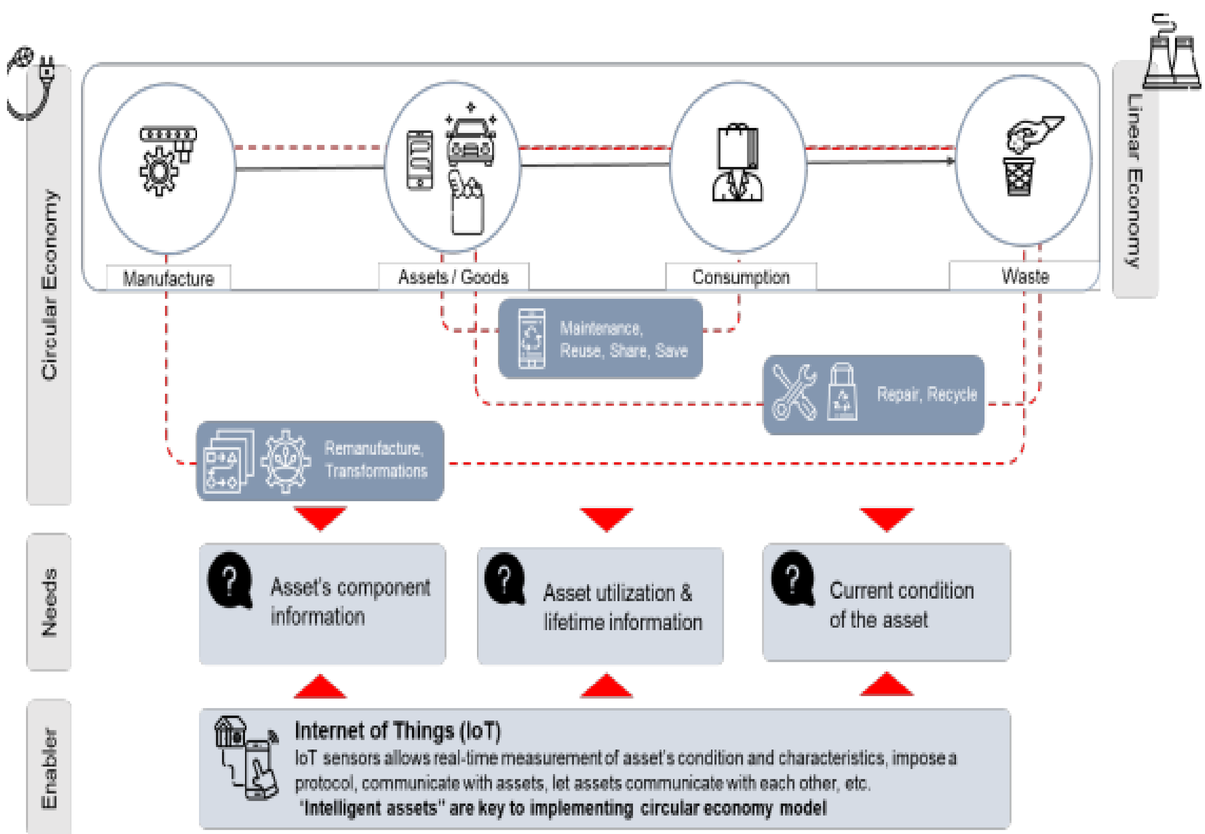


Figure 16: Business models for interplay of circular economy with IoT (Source: European Commission 2020, p. 20)

2.4.8.4 Non-Fungible Tokens

Wu et al. (2023) investigate the idea of non-fungible tokens (NFT's), to enable the cross-jurisdictional trading of C&D waste. NFT's are a unique digital identifier embedded in a blockchain. The NFT, the authors argue, will ensure authenticity, transparency, and ownership, attributes desirable in peer-peer network transactions, such as across an EME platform.

2.5 The Public Sector

2.5.1 Introduction

The public sector offers an opportunity to positively change the narrative for the CE. It does this because of its position in the marketplace, the need to implement public policy and regulation (the European Green Deal and Circular Economy Action Plan as examples), and its ability to absorb risk (both resource and reputational). The public sector, according to Mariana Mazzucato in her book, *The Entrepreneurial State (Debunking Public vs Private Sector Myths)*, can 'create markets' and 'think big again' (Mazzucato, 2013, p. 237).

Additionally, the European Commission (EC) estimate that over *250,000* public authorities across the EU-27 spend approximately 14%, or €2 trillion, on goods, works and services annually (European Commission, 2023). As such, the public sector can have an important influence on internal (EU-27), and external markets (rest of the world), in driving research, innovation, and the creation of alternative market structures across all sectors of industry and society. It is from the perspectives of scale, risk taking, risk absorption, policy, and rapid transition that the public sector has a significantly important role to play in the development and implementation of the excess materials exchange concept.

2.5.2 Public Procurement

The Public Sector, through public procurement, has a significant role to play in the transition to the CE (Rainville, 2021). Due to the magnitude of public spending (14% of EU GDP), public procurement can be a crucial instrument to achieve policy delivery and optimum outcomes for the citizenry of the EU, through more sustainable economic growth, a fairer society, sustainable public finances, wider market participation (including in the areas of smart and clean technologies), and crucially better environmental outcomes (including where it pertains to having a positive climate impact and the circular economy).

Public procurement is defined as ‘the process by which public authorities, such as government departments or local authorities, purchase work, goods, or services from companies’ (European Commission, 2023). Public procurement seeks to achieve a market that is open, competitive, and well regulated. The 2014 Public Procurement Directives govern public procurement across the EU the core principles of which are; transparency, equal treatment, open competition, and sound procedural management. According to the report, ‘*Making Public Procurement work for and in Europe*’, public procurement is regarded therefore as a ‘powerful tool for spending public money in an efficient, sustainable and strategic manner’ and a strategic tool which ‘can also support the transition to a resource-efficient, energy-efficient and circular economy’ (EU, 2014, p. 2).

The public procurement process begins with a *Needs Assessment* and *Market Analysis*. These are arguably the most important phases of the tendering process from a CE perspective given they are the stages where those requiring a specific product or service must outline their rationale for that need and must determine if the market has capacity to meet the need. It is also, crucially, the stage of the process at which alternatives can be introduced, such as design options which demand a circular economy (CE) approach, and the stage where the public authority issuing the tender can test the market capacity to provide a desired outcome, or solution. Sustainable and circular economy-oriented public procurement of construction and buildings are one of the key areas to investigate in the future (Husgafvel *et al.*, 2022).

According to the Commission, 55% of public procurement procedures are awarded based on lowest price or Most Economically Advantageous Tender (M.E.A.T.), to the exclusion of other considerations, indicating that public buyers are not ‘paying enough attention to’ sustainability, quality, and innovation criteria in their final decision- making process. A report on Strategic Public Procurement (SPP) states that an ‘increasing number of public tenders continue to see only one bid due in part to the perception that the public tendering process is seen as onerous, overly complex, and time consuming’(European Commission, 2023).

The European Commission (EC) is resolved to achieve the most optimum outcomes from public procurement and strategic procurement is viewed as playing a very important role, and achieved through systematic application of strategic criteria, enabled by, dissemination of standards, a library of good practice, and extensive practical support, amongst other measures. Socially Responsible Public Procurement (SRPP) is defined by the European Commission as the following: 'Socially responsible public procurement (SRPP) implements social considerations in public contracts to achieve positive social outcomes' (European Commission, 2021).

Directive 2014/24/EU, Article 2 (22) defines innovation as: 'the implementation of a new or significantly improved product, service or process, including but not limited to production, building or construction processes, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations inter alia with the purpose of helping to solve societal challenges or to support the Europe 2020 strategy for smart, sustainable, and inclusive growth.' And by extension, Innovation Procurement is defined by the European Commission as the following: 'Buying the process of innovation – research and development services – with (partial) outcomes … buying the outcomes of innovation' (European Commission, 2023). Green Public Procurement (GPP) is 'a process whereby public and semi-public authorities meet their needs for goods, services, works and utilities by choosing solutions that have a reduced impact on the environment throughout their life cycle, as compared to alternative products/solutions' (Environmental Protection Agency, 2021) (Figure 16).

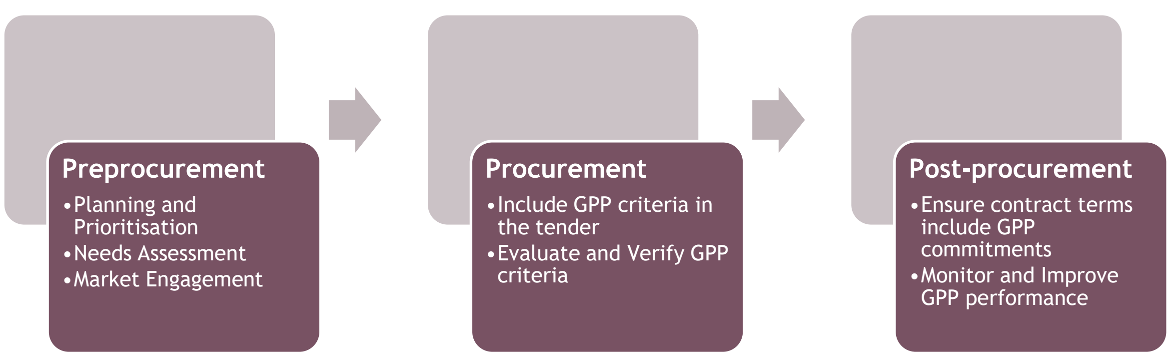


Figure 17: Incorporating GPP into the procurement cycle (Modified from Source: Environmental Protection Agency 2021)

Circular Public Procurement is defined as 'the process in which a product, a service or a project is purchased according to the principles of a circular economy. In this process the technical aspects of the product are as circular as possible, taking maintenance and return policies at the end of the use period into account, as well as including financial incentives to guarantee circular use' (European Commission, 2023).

The Ellen MacArthur Foundation (Circular Procurement for Cities, 2022) summarises the benefits of CPP as; 'Maximising value for money, Optimising resource efficiency, Supporting climate change targets, Protecting biodiversity, Promoting innovation, and Promoting circular jobs and skills' and defines the CE intervention points along the procurement journey as in (Figure 17).

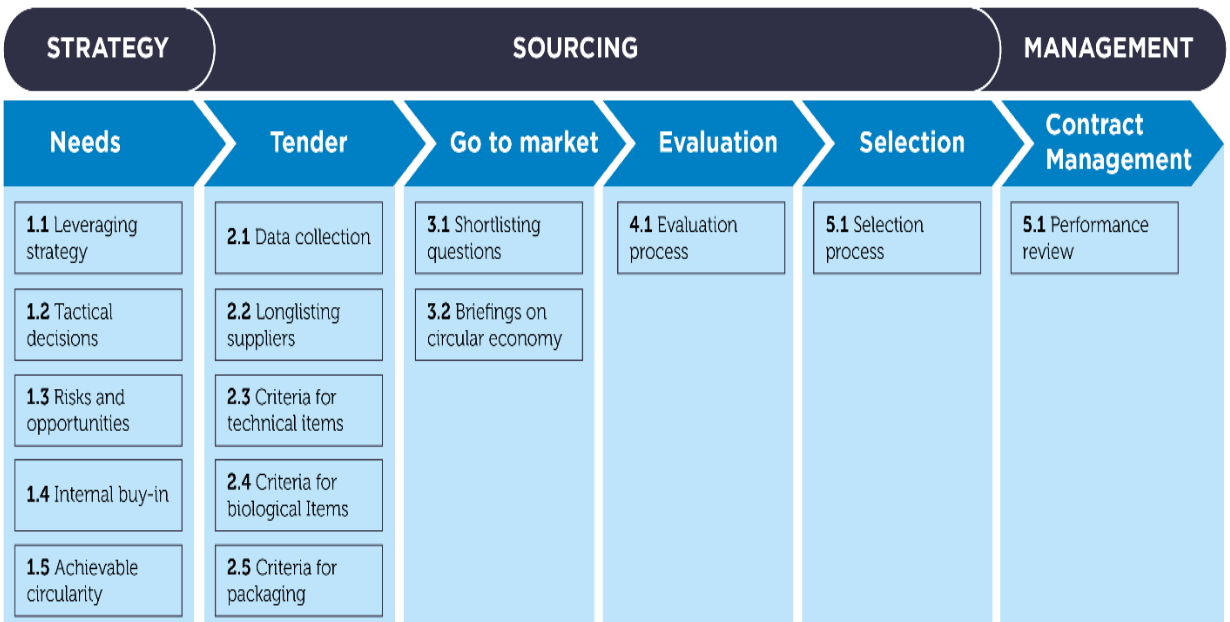


Figure 17: Circular economy procurement framework overview (Source: Ellen MacArthur Foundation, 2023)

Qazi and Appolloni (2022) identified many barriers and enablers to adopting circular procurement policies under the headings of; sourcing strategy, specifications and requirements of material, identification of material, cost, reverse logistics, resource constraints or availability (such as financial resources), knowledge & expertise, management constraints, organizational culture and flexibility, and external environment (preferential tax policies for CP and weak government policies as examples).

Rainville (2021, p. 1) found the role of intermediaries to be of importance by ‘1) coordinating government and industry through aligning project goals’, ‘2) facilitating cooperation of industry players to stimulate new business relationships’, and ‘3) collaborating with the buyer to push for higher post-consumer recycled material in the final tender.’

Mandatory CPP for governments in the EU is the view of European Economic and Social Committee (2021, p. 3) who argue that ‘circular public procurement will allow administrations to move beyond the lowest price criterion at the time of purchase.’

The Synthesis Report from the OECD (2020, p. 1) on the Circular Economy in Cities and Regions also makes the point that ‘a legislative framework conducive to the circular economy should incentivise circular business models and practices across the economy, so that circularity becomes the norm while making linear models increasingly unattractive economically.’

2.6 Excess Materials Exchange

2.6.1 Introduction

For the purposes of developing the conceptual framework excess materials are defined as; end of life (EoL) materials which have been *recovered* and are deemed to have a *material retention* and *reuse value*. Excess Materials Exchange (EME) is an all-encompassing terminology used to describe a digital marketplace, or technology platform, where materials which have reached their end-of-life (EoL) in one use phase can be exchanged between different actors on the exchange and find a new use value. The goal of an excess materials exchange is to keep materials in circulation for as long as possible and create the conditions for optimal and/or alternative material choices to be made.

2.6.2 Review of Best Available Technologies (BAT)

The digital marketplace under consideration in this study is a public service platform (PSP), enabling and accelerating the transition to the CE for the public sector. Due to the specificity of the public sector EME conceptual framework to publicly owned materials no equivalence has been found during this research, except as it concerns the generalised approach to circulating materials irrespective of source, and/or design intent. While several established private companies use a brand name equivalence, for example Excess Materials Exchange, and/or its derivatives CMEx and Emenz, the terminology itself is not commonly used across industry, or in the literature. Nor has the technology been specifically adopted for public sector use. [1,2,3]Circular

[1] Excess Materials Exchange

[2] CMEx – Construction Materials Exchange

[3] Emenz – Excess Materials Exchange (NZ)

materials platforms are becoming more common, however. Circular Materials, Floow2 and WasteBase are examples of material sharing platforms, and additionally circular collaboration using blockchain technologies, such as, Circular in Motion, are now available. (4,5,6,7)

While many of the sites researched for this study had attributes which were desirable for inclusion in the conceptual framework, several omissions were evident, including; lack of carbon-based incentivisation and connection to public procurement mechanisms. The waste material recycling and exchange network (WMREN) developed by Huang, Zhen and Yin (2020) for the purpose of recycling by-product serves as another useful example of the theoretical model under consideration for development of the public sector EME conceptual framework. In the excess materials exchange the public sector organisation (PSO) can be substituted for the *I-J type nodes* as described in (Figure 18).

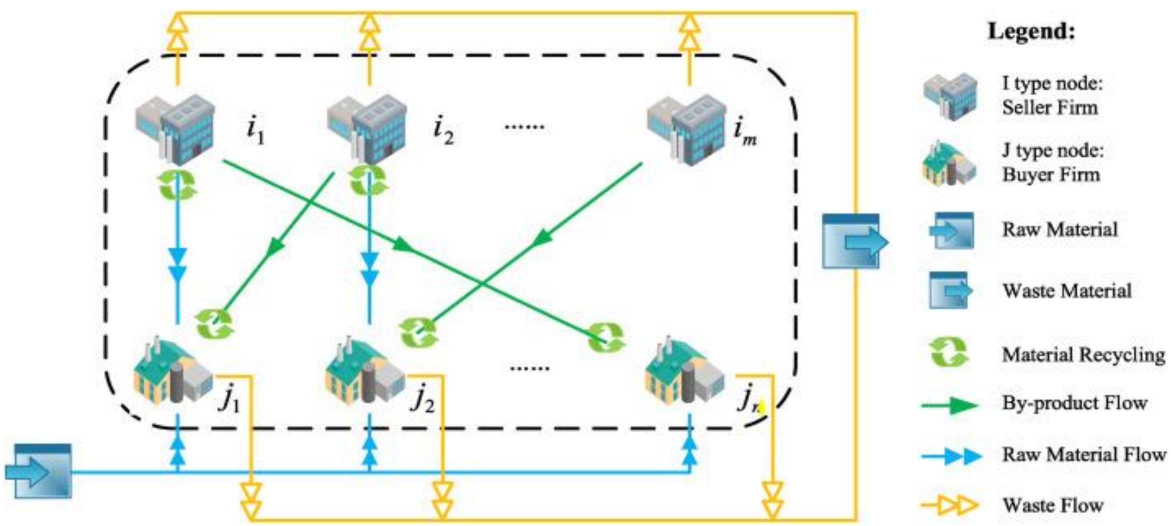


Figure 18: Input/output of by-product exchange among firms of the proposed WMREN model (Source: Huang, Zhen and Yin 2020, p. 4)

[4] Circular Materials

[5] Floow2

[6] WasteBase

[7] Circular in Motion

Upcyclea offers another interesting solution for the CE of building materials. In addition to some of the attributes mentioned Upcyclea offers a certified Cradle-Cradle Products Library and establishes automatic matches between needs and material deposits, among other services.

The European Cement Association (CEMBUREAU, 2023) has also investigated Alternative Raw Materials (ARM) and Supplementary Cementitious Materials (SCMs) as well as other initiatives to support the transition to circularity in construction for cement and associated products. To ensure a robust solution for secondary materials and the accelerated transition to a CE, the inclusion of a digital marketplace in the service offering could prove to be beneficial.

As part of the Literature Review of Best Available Technologies I have also searched through the European Circular Economy Stakeholder Platform: A joint initiative by the European Commission and the European Economic and Social Committee. After an exhaustive trawl through the available documentation, using search terms such as 'innovation', 'construction', 'economic instruments', 'procurement' etc., I was unable to find additional technologies under development or in practice which fit the description of Excess Materials Exchange, despite many articles and documentation which included references to the CE more broadly (European Circular Economy Stakeholder Platform, 2019)

A practical example of a digital marketplace for the exchange of circular materials is Concular an AI-driven platform, matching buyers, and sellers of circular materials. It uses the concept of urban mining (UM) previously discussed (*Section 2.4.7.1*) and material passports (MPs), or Digital Building Resource Passport (DBRP).

The DBRP includes a Circularity Performance Index (CPX), Life Cycle Passport, Material Categorisation Module, and Life Cycle Assessment Tool. The pre-demolition audit methodology used is compliant under the DIN specification 91484-2023-09. [(8)]

[8] Concular - Circular construction for future-proof real estate

Conceptually Concular resembles the EME conceptual framework under development in this study, with some possible exceptions. Concular does not make provision for carbon-based incentivisation mechanisms, and it does not have the public sector as its primary marketplace, both of which are objectives of the EME conceptual framework.

For Concular and for the EME conceptual framework under development here, primary outputs are, reductions in GHG emissions, to keep materials in circulation for longer, reduce waste, ensure costs and risk are minimised, and that materials can move between buyers and sellers seamlessly.

Rotor is another project model which has been considered as part of the review.[9] While Concular focuses on the digital marketplace, Rotor is a cooperative which concentrates on management of the material environment.

Interestingly Rotor was involved with (WPLT, 2022) an analysis of digital trading platforms for construction products in North-Western Europe. The Rotor study identifies the following key attributes of a ‘good’ digital platform.

- *A well-populated catalogue.*
- *A good network of actors (buyers-sellers) and other stakeholders.*
- *A professional and user-friendly interface.*
- *A filtering process to eliminate redundancies.*
- *A showcase or window to the organisation’s expertise.*

The study introduces the concept of a *meta-platform*, a tool which operates between actors on a material exchange, helping to improve collaboration, enable better sharing of material catalogues, and minimise resistance to adopting the technology.

[9] Rotor

The authors of the study usefully summarise the Strengths, Weaknesses, Opportunities, and Threats of the market and the various platforms reviewed (Figure 19).

Strengths	Weaknesses
- Managing multi-locations stocks - Fluidifying logistics and optimizing storage spaces - Offering guarantees - Working as a network of actors	- Digital platform as an auxiliary activity - Avoiding the all-digital - Non coordinated cross-publications
Opportunities	**Threats**
- An entry door to other services - Favorable context to circular economy	- Too many sollicitations - A fluctuating market not mature enough - Keeping a physical contact

Figure 19: SWOT Matrix and Insights (Modified from Source: WPLT 2022, p. 12)

2.7 Carbon as Incentivisation Measure to CE-adoption

2.7.1 Introduction

Another novel aspect of the conceptual framework proposed, in addition to its applicability to the public sector-built environment through utilisation of best available technologies and methodologies, concerns the use of carbon as an incentivisation mechanism in scaling and accelerating the transition to the CE for the public sector. In this section I investigate carbon (allowances and taxes) as incentivisation mechanisms and their applicability, or not, to the conceptual framework for excess materials exchange.

2.7.2 Carbon Allowances

The connection between the carbon footprint of a product derived from the extraction of virgin raw materials versus the carbon footprint of a recovered-recycled-reused material is not always straight forward (Pratt, Lenaghan and Mitchard, 2016; Zink and Geyer, 2017; Bianchi and Cordella, 2023b). In many cases LCA and LCC modelling can produce relatively accurate answers to individual scenarios, however for the purposes of our discussion here, carbon can also be utilised as a form of incentivisation. The Emissions Trading System (ETS) is one such example (Readiness and Partnership, 2021).

Under the ETS (EU ETS, 2003) allowances are allocated to companies participating in the scheme, with limits decreasing for some industries on each subsequent year of participation. The allocations cover four primary benchmarks, product (approximately *75%* of eligible emissions), heat (approximately *20%* of eligible emissions) fuel (approximately *5%* of eligible emissions), and process (approximately *1%* of eligible emissions). '*In 2020, the EU ETS accounted for almost 90% of the global carbon market value*' (EMA, 2021).

According to Ecocore (2023) a carbon allowance could be applied to every product and service in the economy and would operate under a dual currency system of carbon tokens and cash (Figure 20).

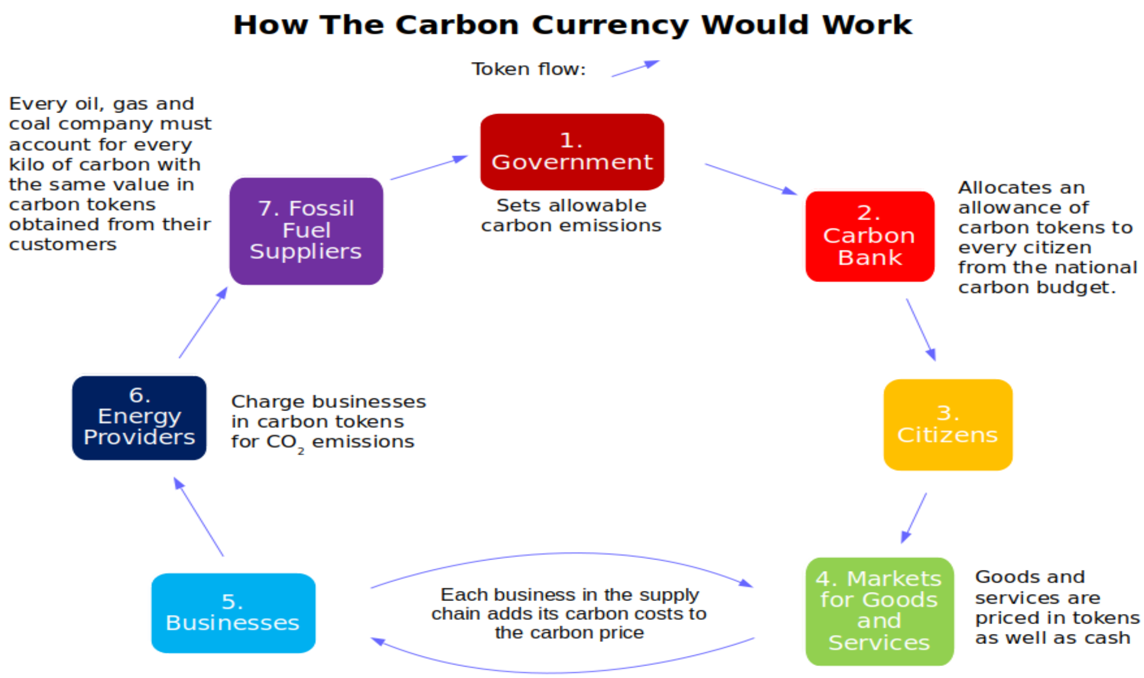


Figure 20: How the carbon currency would work (Source: Ecocore 2023)

EcoCore imagines a system where the government sets allowable carbon emissions and then allocates a carbon token to every citizen from a national carbon budget. This is not unlike the conceptual framework as envisaged for the EME, except in the EME example government sets allowable carbon emissions for each Public Sector Organisation (PSO) from a national carbon budget and allows trading of carbon tokens on a peer-peer basis.

2.7.3 Carbon Tax

While the EU ETS is one mechanism for incentivising change, another is carbon tax. The Ex'tax Project proposes '*shifting the tax burden from labour to pollution and resource use*' (The Ex'tax

Project, 2023). This burden shifting could result in a decoupling of Gross Domestic Product (GDP) from CO_2 emissions and hasten the transition to the CE.

This strategy aligns with EU policy as outlined in European Commission (2023):

> ‘LOWER LABOUR TAXES NEED TO BE COMPENSATED BY INCREASES IN OTHER SOURCES OF REVENUE TAXES THAT ARE LESS DETRIMENTAL TO GROWTH, SUCH AS TAXES ON CONSUMPTION, RECURRENT TAXES ON IMMOVABLE PROPERTY, AND ENVIRONMENTAL TAXES OR BY A REDUCTION IN PUBLIC SPENDING.’

Carbon taxes are a way to incentivise the reuse of materials and accelerate the transition to a CE. A report on Ireland from the Ex’Tax Project sees the burden of taxation shift from labour to natural resource consumption (Figure 21) in a revenue neutral scenario (The Ex’tax Project, 2023).

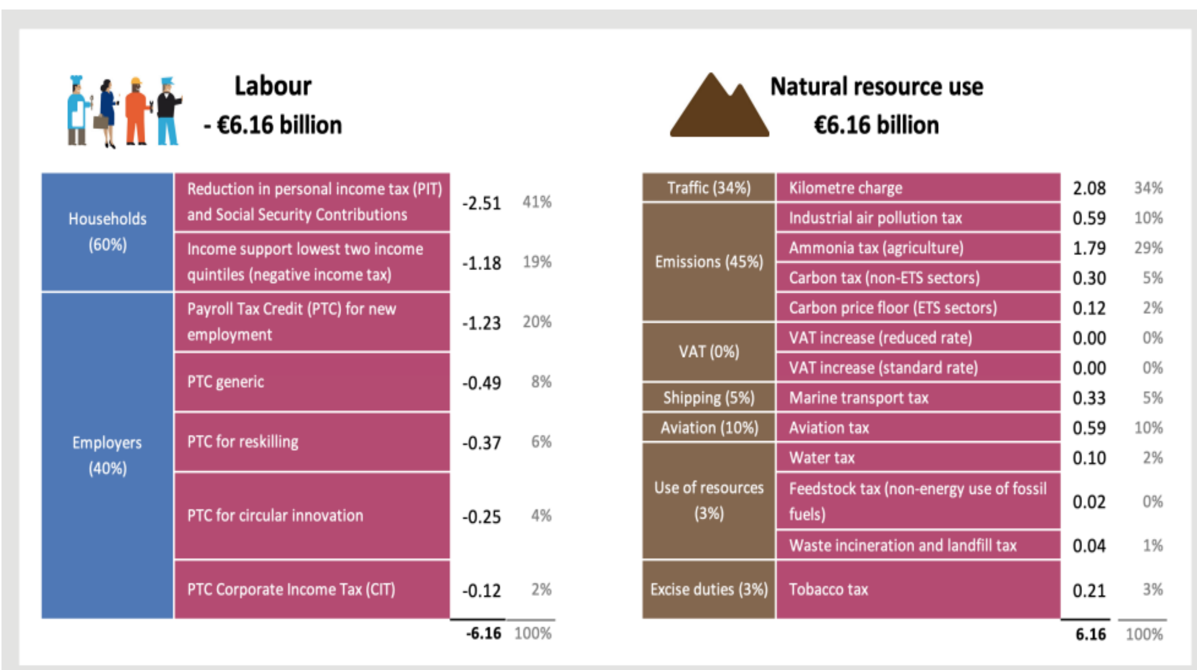


Figure 21: Tax Shift Scenario under review – Ireland (Source: The Ex’tax Project 2023, p. 36)

The David Suzuki Foundation (2023) suggest that carbon taxes have one big advantage over cap-and-trade, in that they are easier to implement. The International Monetary Fund (IMF, 2019) agree, arguing that carbon taxes can also play a part in countries meeting their obligations. However, *t*he World Bank (2022) argues that a carbon tax has a disproportionate effect on the welfare state. Since the European Commission published the Carbon Border Adjustment Mechanism (CBAM), to mirror the ETS, and issue certificates, it would suggest that the direction of travel is for carbon taxation to become a more widely used tool to realise EU policy.

2.8 Summary

In this Chapter I have explored the current thinking and best available research as it pertains to the Circular Economy, Built Environment, Public Sector, Excess Materials Exchange, and Carbon-based Incentivisation Mechanisms. There is quite a distance to travel if the CE is to gain both universal acceptability, and impact. An EME framework can capture material and energy value retention from the built environment, and by extension across other areas of the public sector, which can operate on a peer-peer basis, and is transparent, trustworthy, and incentivised can be a workable solution.

3 RESEARCH METHDOLOGY

3.1 Introduction

The research methodology is outlined below. This includes the basis for the theory, methods and phases of the research undertaken. The methodological approach consisted of:

- Literature review
- Development of a conceptual framework (artefact)
- Research questions
- Research ethics
    - Confidentiality and Anonymity
- Participant selection
- Research Interviews
    - Rigour
    - Standardisation
    - Interview Format
- Software Tools
- Data collection & presentation
- Data analysis

3.2 Methodology Design

This study adopts Design Science Research (DSR) as its primary methodological approach (Figure 22), described in Hevner et al., 2004). Design science is used to solve practical problems (Bider, Johannesson and Perjons, 2013). While DSR is an important approach in the creation of successful artifacts (Peffers, Tuunanen and Niehaves, 2018) full consensus on the methodology of DSR has yet to be achieved (Muntean, Danaiata and Hurbean, 2021). The DSR process consists of problem identification (which also identifies the motivation for the project), defining objectives for a solution and the results needed, or desired goals (Design Knowledge), and the creation of an innovative artefact.

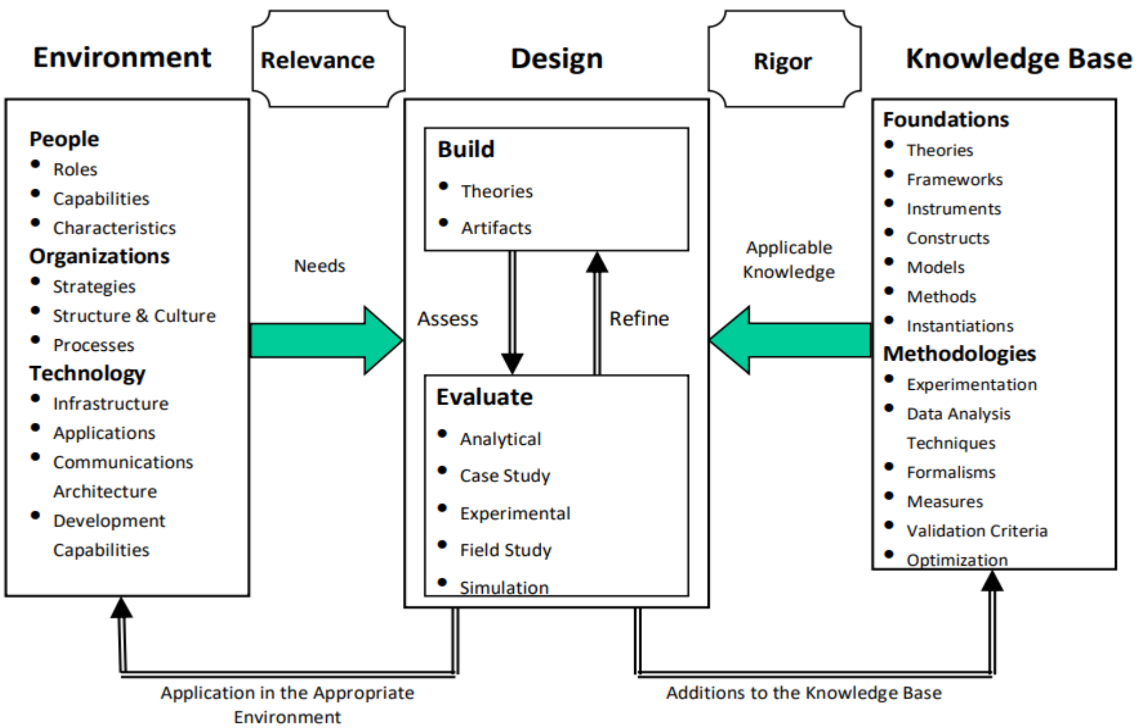


Figure 22: DSR Model (Source: Hevner et al. 2004, p. 80)

'Environment' in (Figure 22), refers to the problem space, organisational needs, and the needs of the organisation relative to the best available technology. *'Knowledge Base'* consists of extant knowledge (knowledge available from prior research and results), and methodologies, to ensure

that the research is evaluated with rigour and adds to the knowledge base. Finally, in the *'Design Space'*, the build and evaluation of the artefact is undertaken.

The core aim of this research is the development of a conceptual framework (artefact). The DS approach was deemed to be the most practically suitable to achieving this aim, however, given the lack of authoritative consensus on DS as a research methodology, and the complex nature of the project under consideration, it was also useful to draw from different methodological approaches in parallel. This included the approach taken in Design Thinking (DT). The first three phases of the DT process were of specific relevance to this research, that is the, *Discover*, *Define* and *Develop* phases as outlined in (Figure 23) as adapted from The Double Diamond - Design Council (2023).

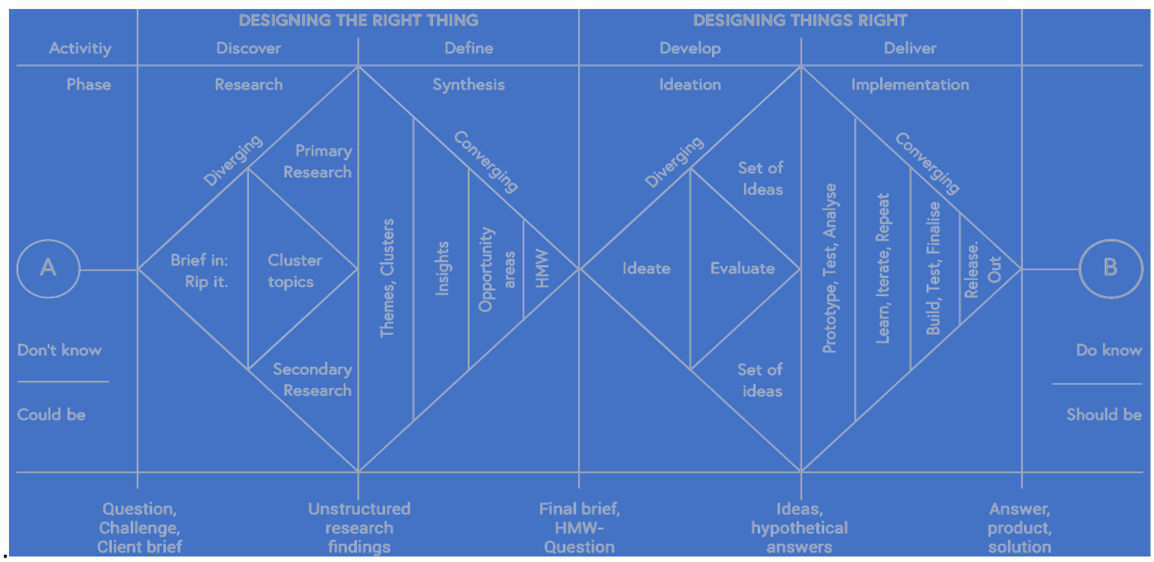


Figure 23: Double Diamond illustration of Design Thinking process (Source: The Double Diamond - Design Council 2023)

In the *Discover* phase the problem was presented, i.e., how best to accelerate the transition to the CE for the public sector through the exchange of excess materials. Certain assumptions were made at this point, including that the solution, 1) must work in conjunction with existing public sector legislative and regulatory frameworks, 2) would involve existing and future technologies,

3) would require an incentivisation mechanism, and 4) would be cost-neutral. The Discover phase was a phase of high activity, given the unknown, and unforeseen challenges which existed in the original conceptual appreciation. The *Discovery* phase involved both primary and secondary research. In the secondary research a comprehensive literature survey was undertaken to ascertain the supporting evidence for the conceptual framework (a similar approach to that taken in DS). This was then, further supported through the primary research, which in the case of this study, involved a range of one-one semi-structured interviews with industry and policy experts across the public and private sector. In the *Define* phase of the process, the research findings were collated into thematic areas, allowing insights to evolve, and potential opportunities to be identified. The conceptual model (artefact) was developed as an *improvement* on existing solutions, and as an *exaptation*, extending a known solution, i.e., exchange of materials, to a new problem, exchange of materials across the public sector, built environment (Figure 24).

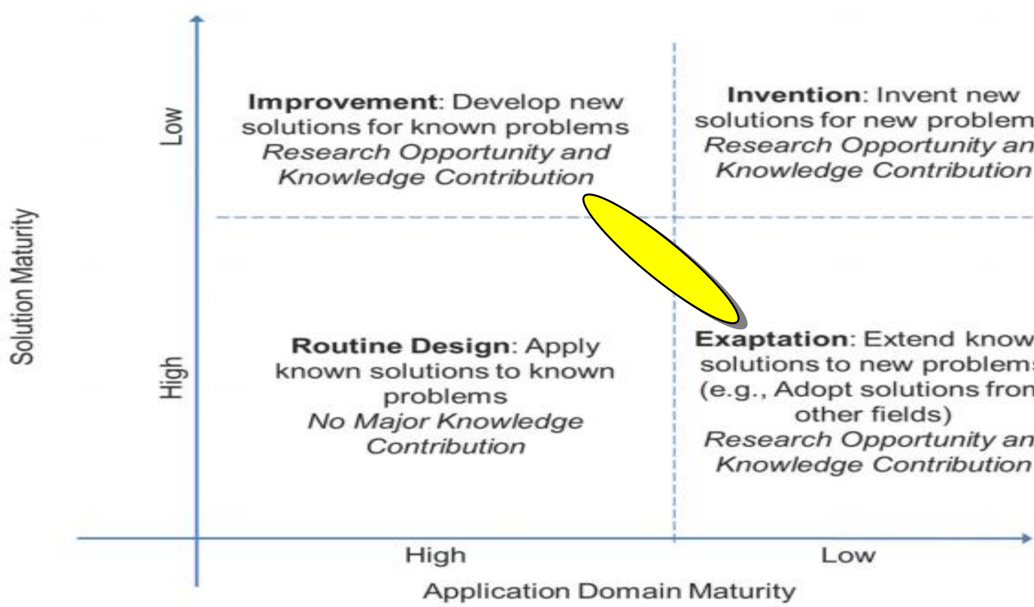


Figure 24: Solution Maturity vs Application Domain Maturity (Source: Gregor & Hevner 2013, p. 348)

The *Development* phase allowed for further idea creation, or ideation, and evaluation of different concepts and models resulting in the production of a revised conceptual framework. The DS and DT processes were used in the development of, and improvement upon, the conceptual framework. The conceptual framework (artefact) is, in this instance, akin to the prototype system produced through the DT process. The final artefact is developed in Chapter 4 and refined and expanded upon in Chapter 5.

3.3 Literature Review

A comprehensive literature survey was undertaken to develop an understanding of the extant knowledge and ascertain the supporting evidence for the conceptual framework. Topics were chosen based on relevance to the research. The Literature Review followed a process, of evaluation, search, locating and finally writing. The Literature Review was undertaken using a variety of information resources, including; books, scholarly and research journals, industry policy papers, websites, and online databases such as; ScienceDirect, Springer Open, Taylor & Francis, Web of Science, JSTOR, EBSCOhost, and Wiley Online. The information search strategy included the following elements, as described by (Rowley and Slack, 2004, pp. 35-36).

1st stage:

- *citation pearl growing (using search terms and one or more starting documents to retrieve other documents)*
- *brief searches (using internet search engines to generate leads to further documents)*

2nd stage:

- *building blocks (using synonyms and related terminology to create a comprehensive set of documents)*
- *successive fractions (searching within a larger set of documents to eliminate less relevant documentation)*

Based on the comprehensive literature review undertaken an artefact was developed. This approach is consistent with the methodology used in the DSR Model as described by (Hevner et al., 2004). The literature review takes a similar methodological approach to that taken by (Pomponi and Moncaster, 2017, p. 711):

i) *critical review of CE framing*
ii) *examination of the fundamental dimensions of the CE*

iii) *building a framework for CE research on the built environment, public sector, excess materials exchange, and carbon incentivization mechanisms*

iv) *identifying challenges in the research*.

A qualitative literature review was undertaken using a variety of information resources, including the online databases mentioned above. I used a keyword Boolean search with 'circular economy' AND 'built environment' OR 'public sector'. I further refined our search using 'circular economy' AND 'carbon' OR 'public procurement'. I identified the most relevant scholarly and research journals, articles, and books as it related to the Boolean search terms. I combined the results from all the databases and excluded duplicates where necessary to arrive at 350 unique items. 143 items are specifically referenced throughout this study. The publication dates of the materials used in this research ranges from 2004-2023 with 75% of the analysed papers, journals, articles, and books published in the last five years. This is possibly indicative of an increased academic interest around the circular economy in recent years.

3.4 Development of a conceptual framework (artefact)

The development of the conceptual framework went through two iterations. The first iteration was based on key themes reviewed as part of the comprehensive literature review (Chapter 2) as being essential to the development of a public sector EME. The second iteration was arrived at based on an analysis of the interview data. The methodological approach is also consistent with the DSR process of building an artefact using the foundational theories and frameworks already in existence from the knowledge base; assessing and refining through analysis and evaluation, in combination with an understanding of the relevant characteristics, organisational constructs and available, or predicted, technological infrastructure, to establish both *Rigour* and *Relevance* in the research.

This methodological strategy is consistent with the DT processes of *Research*, *Synthesis*, *Ideation* and finally, *Implementation*. This approach to conceptual framework design and development ensured a robust final artefact as discussed in Chapter 5.

3.5 Interview Questions

As a result of information discovered in the literature review the following topics were considered of importance in the further development of the EME:

- Political, legislative and governance opportunities and impediments of EME implementation.
- Technological capabilities supporting or impeding rapid transition to the CE.
- Economic viability and incentivisation structures for the promotion of circular materials and the EME.
- Environmental constraints on existing resource and supply chain systems.
- Social conditions and industry acceptance of the need for the CE.
- Material and energy retention value opportunities in the built environment, specifically as they relate to the C&D waste stream.

As can be seen from (Table 4) snapshot of responses to *Q1*, *Q2* And *Q3*, the data was tabulated by interviewee number (*P1, P2* etc.) and interviewee response. See (APPENDIX G) for complete tabulation. This approach was taken to simplify the process of data analysis and for ease of identification of trends and patterns in the data. In the first series of questions interviewees were asked to pick from three options to describe the industry sector in which they were primarily involved: private sector, public sector, not-for-profit/social enterprise. In the case where no options were provided interviewee responses were based on subjective experience or opinion. As such the range of interview responses and terminology varied. It was necessary in to extract a common terminology which best reflected interviewees intentions.

Table 4: Selection of tabulated interview data

INTERVIEW DATA	Q1. HOW WOULD YOU DEFINE YOUR ORGANISATION?	Q2. WHICH INDUSTRY SECTOR BEST DESCRIBES YOUR ORGANISATION?	Q3. WHAT IS YOUR EXPERIENCE/KNOWLEDGE OF THE CIRCULAR ECONOMY (CE)?
P 1	PRIVATE SECTOR	PROFESSIONAL SERVICES	INTERMEDIATE
P 2	NOT-FOR-PROFIT	RESEARCH ORGANISATION	NONE

In *Question 2* as an example, interviewees were asked to describe their industry sector or organisation. In this instance a selection of options was not presented, and the interviewee responses varied according to their respective definitions, understanding of their industry, and subjective opinions. For consistency therefore responses were presented in terminology which was both indicative of the intended meaning and in a language which could be easily understood by academic, industry, and non-industry reviewers of the data.

3.6 Research ethics

This study has been the subject of a formal ethics application to the Atlantic Technological University (Galway-Mayo), School of Engineering ethics committee. As part of the ethical approval for the study it is a requirement that participants must formally state that they are partaking freely and that they have been advised of their rights to terminate their involvement. The ethics application is appended in APPENDIX J.

3.6.1 Confidentiality and Anonymity

All interviews were recorded and transcribed through Microsoft Teams, with the resulting recording automatically uploaded to the ATU One Drive facility. A record of all documentation relating to individual interviews is stored, for data management purposes, on the ATU server.

All responses given in the interviews are confidential and data is stored only on the ATU (Galway-Mayo) encrypted file server. All data used was fully anonymised for the purposes of the publication of the thesis document and all interview data are set to be deleted/destroyed as soon as practicable after the fulfilment of the degree requirements are met.

To protect individual's identities, interviewees were anonymised as *P1* to *P12* in chronological order per their actual interview date and time. Where interviewees are quoted in the text, or their comments have been paraphrased for the purposes of emphasis, or to expand upon a line of investigation, they are referred to as the anonymised version of their names. Each interviewee (*P1-12*) received four documents prior to their scheduled interview:

- Participant Consent Form
- Interview Questions
- Participant Information Sheet
- Participant Invitation and Information Sheet

A copy of the documentation templates is attached in Appendices G-K.

3.7 Research Interviews

The primary research involved semi-structured interviews with twelve (*n=12*) interviewees. Semi-structured interviews are conducted conversationally using open-ended and closed-ended questioning techniques, sometimes mixed with follow up questioning to allow the interviewer to consider avenues of inquiry that might not have been immediately identified using an original line of questioning, but which subsequently emerge because of the interviewing process. The semi-structured interview approach was ultimately chosen for the qualitative research because the technique allows more latitude for *discovery* and *space to expand* upon individual questions and answers, and for topics to be investigated in more detail, when it is deemed relevant to the area of research (Magaldi and Berler, 2020). Table 5 offers a *quick visual* representation of how semi-structured interviewing compares with focus groups, structured and unstructured interviews.

Table 5: Quick visual of Interview Types

	Structured interview	Semi-structured interview	Unstructured interview	Focus group
Fixed questions	✔	✔	✘	✔
Fixed order of questions	✔	✘	✘	✘
Fixed number of questions	✔	✘	✘	✘
Option to ask additional questions	✘	✔	✔	✔

(Source: Scribbr.com 2023)

3.7.1 Rigour

To enhance rigour in the interviewing and data gathering process, a series of twenty (*n=20*) questions were developed. The questions were constructed to solicit precise feedback regarding the EME conceptual framework. The questions sought answers to specific routes of inquiry regarding the structural, technical, and policy requirements of the EME, and clarify the challenges which may exist to its practical implementation. In addition, the questions sought to highlight the sectoral representation of the individual interviewees, and their knowledge and expertise as it pertains to the workings of the CE.

3.7.2 Standardisation

To ensure standardisation in the process the list of questions was submitted to each interviewee in advance (usually at the time of issuance of the interview invite) of the scheduled interview, allowing the interviewee adequate time to submit questions, or concerns, to the interviewer, prior to the scheduled interview time. To add rigour to the research process, a copy of the interview transcript was emailed to interviewees post-interview inquiring if there were any additional comments or corrections. Several responses were received in support of the research but no corrections to the transcripts were received prior to publication of the thesis.

3.7.3 Interview format

The interview format consisted of one-one conversations, conducted using Microsoft Teams. The interviews were scheduled to suit the interviewees time constraints and were normally no longer than one hour in duration. Interviews began on April 17th, 2023, and all interviews were completed by May 9th, 2023. During the interview process clarification was requested, on occasion, by interviewees, either to repeat a question, or elaborate on a line of questioning. This was especially relevant where the interviewee had little experience or knowledge on a specific topic under consideration in a question. Interviewees were also invited and encouraged during the interview process to give their opinion and general insights into the subject matter.

3.7.4 Participant selection

Interview participants were chosen to reflect a broad spectrum of stakeholders across the public and private sector in Ireland. More than twenty (*n=20*) invitations were issued to participate in the interview process, of which twelve (*p=12*) individuals eventually agreed to participate. Interviewees represented a broad range of specialisations and industry sectors, including professional services, public sector procurement, architecture, social sciences, and policy development. It was deemed important to include representation from individuals who are positioned at the interface of the public and private sector given the dependencies involved between the two, including public sector spending and outsourcing of goods, works and services requirements to the private sector. It was also important to obtain objective opinion from both the public and private sector of their perceptions of excess materials exchange opportunities and challenges and the impediments to a more rapid transition to the CE in Ireland.

3.8 Software Tools

Microsoft Teams – Microsoft Teams was used to facilitate online meetings between tutoring staff, thesis supervisors, and for the purposes of research interviews. The latest Microsoft Teams app, available through ATU's intranet, consists of both audio, video, and transcription functions. All interview dialogue was transcribed with applicable time stamps to indicate date and time of interview, and the transcription was then downloaded from the Teams platform to a Microsoft Word document and analysed for content.

Microsoft Excel – Microsoft Excel is part of the Microsoft Office 365 suite of products used to tabulate data collected from the interview transcription process and to auto-populate charts and tables.

Miro – the Miro Mind Map and Whiteboard template was used to visually illustrate the EME concept, and to provide better understanding to the researcher of the dynamics and synergies involved at both a macro and micro level.

Microsoft Office 365 – the Microsoft Office suite including Excel, Word, PowerPoint, Teams, and Outlook were used to collect, communicate, and collaborate during the research project.

Moodle – Moodle was used to access course content and upload assignments, including the dissertation proposal, and final dissertation draft.

Mendeley Reference Manager – Mendeley was used to facilitate citation and referencing. The Mendeley reference management system collects, stores, and inserts citations, references, and other document information, using applicable formatting, and was compatible with Microsoft Office software.

3.9 Data collection & presentation

The question format (Table 6) was split into five main areas of investigation:

- General questions (*Q1-Q2*): related to the interviewees background, and area of expertise, to determine demographic spread.
- Circular economy (*Q3-Q6*): to determine if the interviewee is involved in CE-related activities, or projects in their respective organisations.
- Excess Materials Exchange (*Q7-Q16*): to develop an understanding of the interviewees level of knowledge pertaining to EME, gather insights on what the interviewees viewed as the most important challenges and perceived benefits were, to the deployment of an EME across the public sector and attempt to understand the role of incentivisation in enabling the transition to an EME.
- Incentivisation (*Q17-Q19*): examines the area of incentivisation, specifically through the medium of carbon quotas and/or credits, and participant's familiarity with current carbon trading systems.
- Gaps in the Knowledge (*Q20*): the final question asks participants for their thoughts on any areas of the topic of excess materials exchange which they felt was not covered during the interview, or if they had any additional comments on topics which were addressed during the interview.

Table 6: Interview Questions

1. How would you define your organisation?
2. Which industry sector best describes your organisation?
3. What is your experience/knowledge of the Circular Economy (CE)?
4. How would you define the Circular Economy as it pertains to your organisation or industry sector?
5. Are you involved in CE-related activities or projects in your organisation?
6. In your opinion which of the following areas could help scale the Circular Economy: Material passports - Artificial Intelligence - Blockchain Technology - Carbon taxes - Carbon Allowances
7. Are you familiar with Excess Materials Exchange platforms?
8. What do you understand an EME to be?
9. What, in your opinion, are the benefits of Excess Materials Exchange platforms?
10. How, in your opinion, could an excess materials exchange be optimally applied for the public sector?
11. Are you familiar with the circular economy procurement framework?
12. At which stage of the circular economy procurement framework would you envisage an Excess Materials Exchange being most effectively introduced?
13. In your opinion, which of the following incentives would increase engagement with CE principles across the public sector?
14. Which of the following, in your opinion, would be the key attributes of an EME platform for your organisation, or industry sector?
15. What, in your opinion, are the principal barriers to adoption of excess materials exchange platforms in your organisation, or industry sector?
16. What, in your opinion, is the correlation between a circular material and its carbon footprint?
17. Are you familiar with the concept, and role, of carbon caps (limits)?
18. How would carbon caps (limits) if applied to your organisation, or industry sector, impact your organisation’s transition to a CE?
19. In an ideal world, where would the ownership for a public-sector EME lie?
20. Are there any other aspects of the concept of an EME that you would like to expand upon?

3.10 Data Analysis

Semi-structured interviews are conducted conversationally using open-ended and closed-ended questioning techniques (Magaldi and Berler, 2020). Semi-structured interviews contribute to trustworthiness and objectivity (Kallio *et al.*, 2016). MS Teams transcription service was used, and interview text was collated into paragraphs of text tabulated by question and participant number, snapshot provided in (Table 7). The MS Teams transcript was then copied into MS Word, where additional formatting and notation could be undertaken, before the paragraphs of text were pasted into an MS Excel spreadsheet. As an example, *Question 2* asked participants to describe their industry sector. While there was some commonality between interviewees, for example, professional services, there was also a broad spectrum of industries and sectors represented from public, private, and third sector.

Table 7: Snapshot of Interview Questions (Row 1) vs. Participant (P1-3) Response (Row 2-4)

	Q1. How would you define your organisation?	**Q2. Which industry sector best describes your organisation?**	**Q3. What is your experience/knowledge of the Circular Economy (CE)?**
P 1	PRIVATE SECTOR	PROFESSIONAL SERVICES	INTERMEDIATE
P 2	NOT-FOR-PROFIT	RESEARCH ORGANISATION	NONE
P 3	PRIVATE SECTOR	PROFESSIONAL SERVICES	BASIC

Additionally, it was extremely beneficial to this interviewer to review each transcript directly after an interview had been completed to integrate any additional manual notation and comments into the MS Word transcript while it was fresh in the mind, before proceeding to transfer the text to the MS Excel spreadsheet. From the Excel spreadsheet a series to pivot tables and graphs were developed which better illustrated trends and patterns in the data. Given the volume of text involved in each interview transcript it was necessary to identify common themes and patterns using an *inductive* coding technique. Concise terminology was arrived at, after several transcript re-reads, using an *axia*l, or *focused* coding technique, to explain a participant's specific response more succinctly to each open-ended question. This was deemed the most efficient methodology for analysis of the data given the variety of terminologies and opinions provided by each interview participant.

3.11 Summary

In this section I have described the research methodology followed including; Literature Review, Development of the Conceptual Framework, Research Questions, Research Ethics, Software Tools, Data Collection and Data Analysis.

4 DATA PRESENTATION, ANALYSIS & RESULTS

Introduction

In this chapter I develop the conceptual framework (artefact) for the Excess Materials Exchange (EME). I begin by mapping the framework to determine dependencies and critical attributes of the EME. I proceed from the initial concept mapping exercise to develop the system architecture and technical requirements of the EME. I have embedded the Design Thinking ideation and synthesis process as described in Section 3.2 into the development and design of the conceptual framework. An artefact was developed which was based on material gathered during the Literature Review. The artefact gave due consideration to the macro-level CE environment and the desired functional attributes of a public sector EME.

4.1 Conceptual Framework (Artefact)

In the first stage of developing a conceptual framework I created a concept map of the Political, Economic, Social, Technological, Legal, and Environmental (PESTLE) considerations with a view to developing a broad canvas of the macro-dynamics involved in, and supporting, the transition to a CE (Figure 25).

Figure 25: PESTLE Map of EME

The socio-economic and political conditions necessary for the CE are supported by the European Green Deal, Circular Economy Action Plan, Critical Raw Materials Act, and EU Climate Action Plan. Based on the initial concept mapping exercise a system architecture was developed (Figure 26). The *User* is defined as all public sector organisations (PSO's).

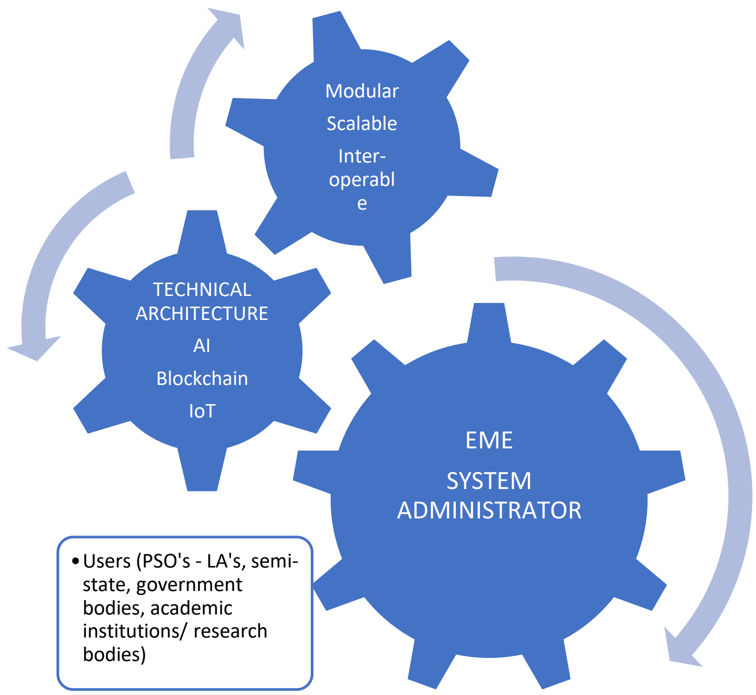


Figure 26: Technical Requirements for Excess Materials Exchange (EME)

An *EME Systems Administrator* is defined as an arbiter of the exchange, determining which materials can enter and leave the system – this could be a publicly-owned materials management organisation. The *material input process steps* for the EME are described in (Figure 27). This is described as the Material Classification System A (MCS-A) concept. The first phase of MCS-A is the *Recovery Phase*, where *waste* materials are recovered from a previous use-stage. The recovered material will then be classified depending on its *reuse value*. These initial stages of the process of material discovery, recovery and assignment will be enabled using a combination of existing and future management information system and data storage technologies, such as; Blockchain, IoT, AI, and Material Passports, as described in more detail in Section 2.4.7.

In Section 2.4.4.1 Ness et al. (2015) argue for the use of RFID and BIM in the tracking of materials for reuse, specifically as it applied to steel reuse. Steel has a high reuse value due to its robustness and durability. This paradigm does not apply to all materials equally. However, a material tracking and designation system will be required to ensure the proper functioning of the EME. Designated waste materials will continue through an established waste management process as described in Section 2.4.4. *Recovered* materials will be assigned an *R-number*, as described by the framework developed by (Reike, Vermeulen and Witjes, 2018). The R-number will determine the material's next use stage. Assignment of the R-number will be the responsibility of the EME System Administrator facilitated by a material passport provided by the *pre-owners* – the public sector organisation (PSO) which supplies material to the exchange. The EME Systems Administrator will assign a material category and R-number based on the information on the material passport before allowing the materials to be available through the EME to a new user.

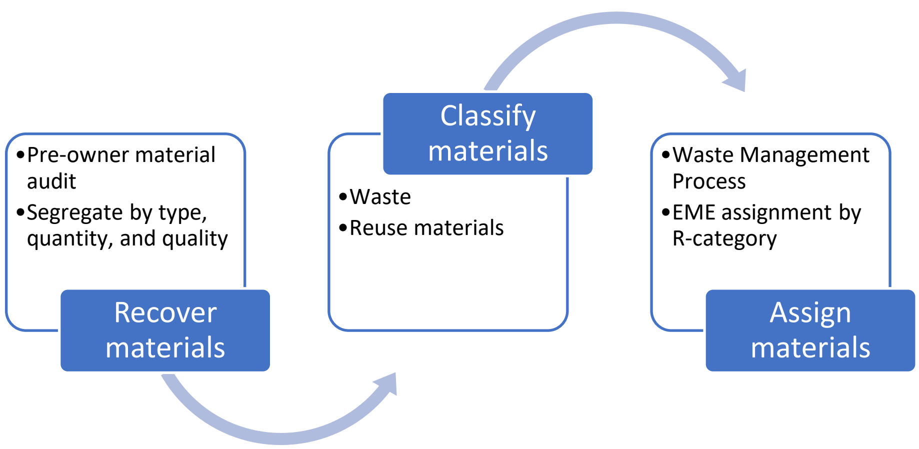


Figure 27: Material Classification System A (MCS-A)

Certain assumptions are made but not explicitly described, such as, the requirement for transportation, storage, administration, and other logistics which will also form part of the chain of custody for materials enabled by management information systems such as IoT, Blockchain and AI, as mentioned previously in Section 2.4.7, and developing on the conceptual framework (Figure 28) as presented by (Panza, Bruno and Lombardi, 2022).

Based on the concept described in (Figure 13) a Digital Material Passport (DMP) could be developed which could help establish a chain of custody (Figure 28) for pre-used materials.

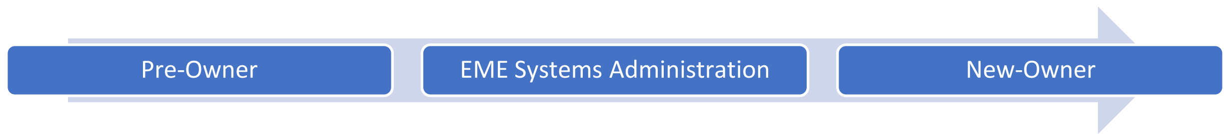


Figure 28: Chain of Custody Model for Pre-Used Materials

Under a typical *use scenario*, a PSO will determine a specific need, such as a requirement for goods, works, or services. Once the *need is assessed*, an approval is required, and the procurement process moves to the next stage. Under a normal procurement process a *market sounding exercise* is undertaken but under a Circular Public Procurement (CPP) process the buyer would check the EME for material availability before proceeding to the next stage of the procurement process. The EME becomes a new stage of the process for procuring *recovered materials*. The option to proceed with new material acquisition is still available, however, a lifecycle analysis (LCA) and lifecycle costing (LCC) exercise should be undertaken to determine *achievable circularity* of both pre-used and new material before an ultimate procurement decision is arrived at. A System Workflow for the Needs Assessment Phase (NAP) of the CPP process is developed in (Figure 298) below.

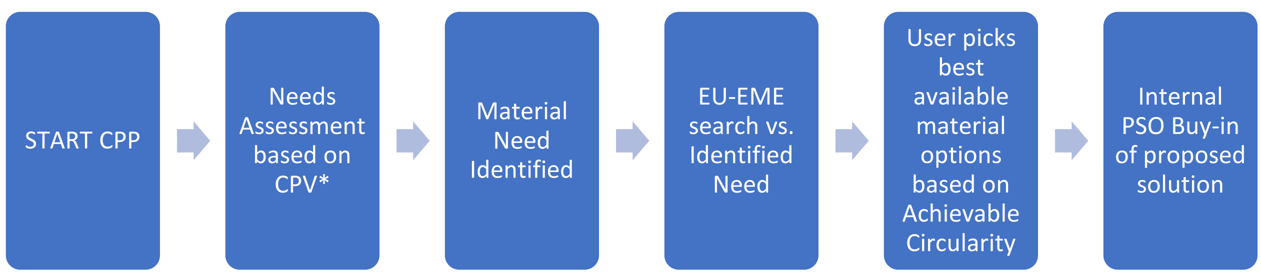


Figure 29: System Workflow for Needs Assessment Phase of CPP Framework (NAP)

*CPV (Common Procurement Vocabulary) relates to the EU CPV Code which ensures a common approach by procurement professionals when creating tender documents on the EU Tenders platform.

If, based on *achievable circularity*, calculated using Life Cycle Analysis (LCA) and Life Cycle Costing (LCC), a PSO decides to avail of materials in the EME, a system workflow such as that in (Figure 30), is initiated. A recovered material request is generated. The recovered material request is reviewed by the EME System Admin, and based on review approval, a recovered material order is created. Once materials have been issued, EME inventory levels are adjusted, and a Carbon Token Request (CTR) is sent to the PSO.

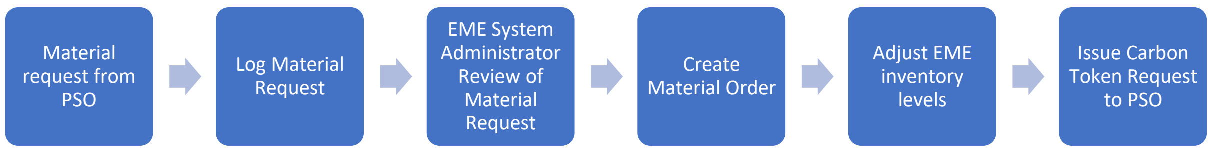


Figure 30: System Workflow for EME Material Request (EME-MR)

A workflow was also developed to illustrate how materials can be added to the EME. This is referred to as EME-MT. If a PSO has recovered materials which it wants to send to the EME it will, according to the EME-MT workflow described in (Figure 31), be required to create a Material Transfer Request (MTR). The EME System Administrator will require material specifications – a material passport to accompany the MTR. Based on information on the material passport a material categorisation will be assigned. Material will be classified by applicable standards. Once material is accepted, EME inventory levels will be adjusted, and a carbon credit issued to the PSO calculated based on the material embodied carbon.

Figure 31: System Workflow for EME Material Transfer (EME-MT)

4.2 Incentivisation Mechanism

To incentivise the various actors in the exchange it is proposed that a system of carbon swaps be developed. The carbon value is based on the embodied carbon of the transferred and allocated materials. For example, *one metric tonne of steel* produces on average *1.8 metric tonnes of CO_{2e}* (McKinsey & Company, 2022). 1.8 metric tonnes CO_{2e} avoided could be credited to the EME and carbon credits allocated based on a proportion of the savings to both PSO's. The carbon credits could be in the form of tokens which can be used on the EME for other available materials or added to a carbon ledger. It is anticipated, based on this EME framework modelling, that a system of carbon budgets will be in operation at some point in the future. The carbon budget will be allocated on a country basis, and divided between public sector organisations, at a national, regional, and local level. Designing and developing such as system will be a highly complex undertaking and beyond the scope of this study, however a *carbon-based incentivisation mechanism*, could resemble (Figure 32).

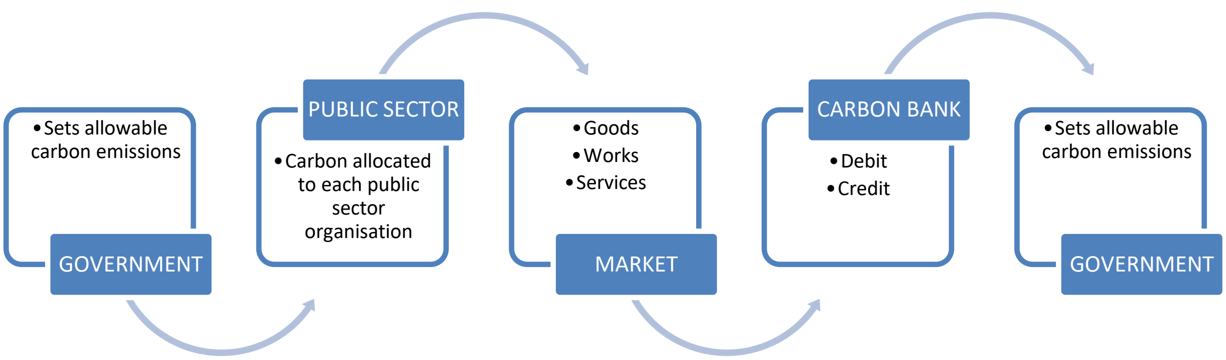


Figure 32: EME Incentivisation Cycle (EME-IC)

Inspiration for the EME-IC was drawn from the *10 Steps for ETS Design* (International Carbon Action Partnership, 2021) (APPENDIX K). The preliminary rationale applied is that an ETS correlates energy use with GHGs, hence carbon, and that a corollary could be developed between materials and carbon for the purposes of building an excess materials exchange. A more detailed description of carbon-based models is described in Section 2.7.

4.3 CESM

The next step in the development process involved connecting the various system functionalities (Figure 33), referred to *here* as the Circular Economy Structural Mechanism (CESM). The CESM is in essence a *meta-platform*, a concept introduced in Section 2.6 as part of the review of the analysis of digital trading platforms for construction products in North-Western Europe (WPLT, 2022). Just as in the meta-platform concept, an excess materials exchange cannot function independently, but must be connected to the public procurement system, specifically through CPP, and to buyers and sellers, in this case PSO's, and with the aid of an incentivisation and governance mechanism.

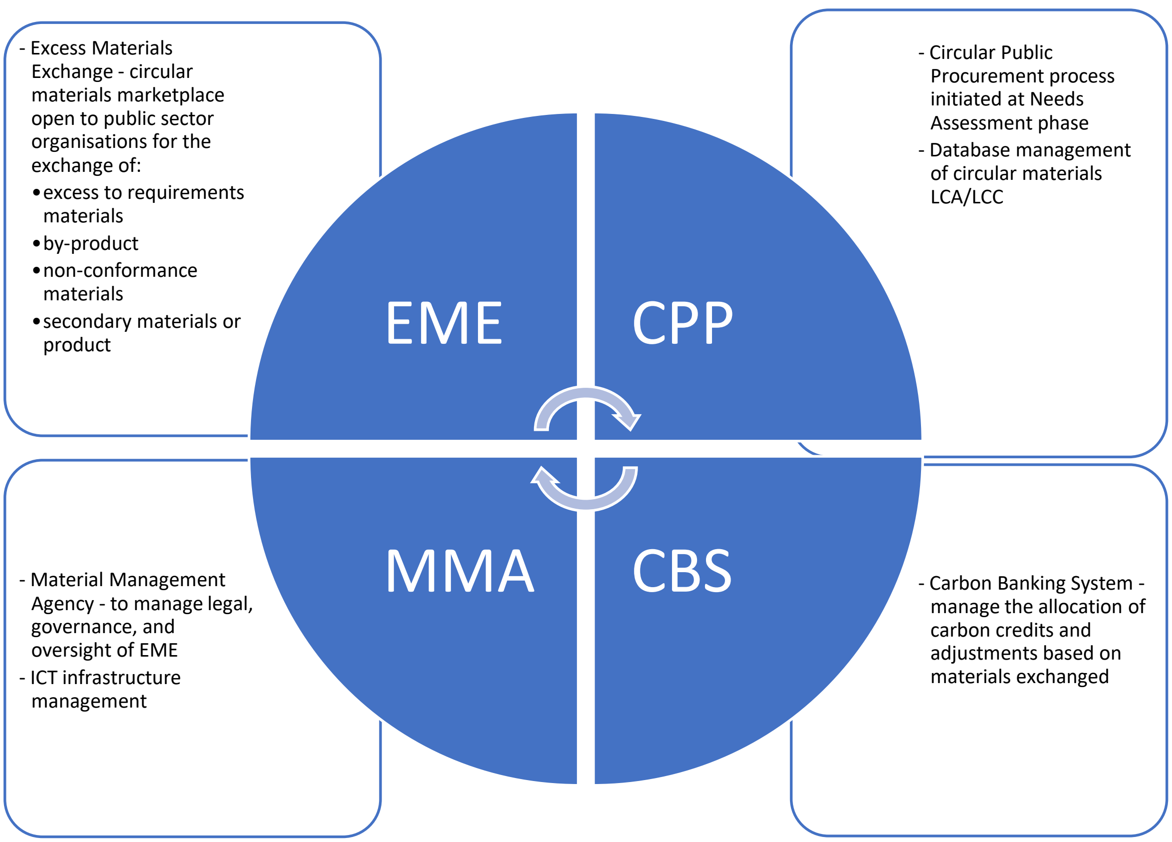


Figure 28: Circular Economy Structural Mechanism (CESM)

A Carbon Budgeting System (CBS) would need to operate in tandem with both the EME and CPP. Lastly, a Materials Management Agency (MMA), would administer, govern, and regulate the overall system. The CESM constitutes the conceptual framework for an EME for the public sector. The conceptual framework which was developed has highlighted the dependency of an EME framework on a broader system architecture (CESM) with three essential components:

- Availability of materials
- A mandatory circular public procurement mechanism (CPP)
- An incentivisation mechanism (CBS)
- An administration and governance mechanism (MMA)

4.3.1 Summary

Based on the CESM model as developed a series of twenty (n=20) questions were designed to solicit further information to substantiate the conceptual framework from Section 4.2.1 to Section 4.2.3 in this chapter and advance the model to the next iteration.

4.4 Data

4.4.1 Introduction

This section describes the question format and presents the data collected. For ease of review, coding, and analysis, each interview participant was anonymised and designated as (P1-P12). The questions were designed to solicit more information and further develop upon the key thematic areas investigated in the Literature Review, with a view to advancing the conceptual framework.

Semi-structured interviews were conducted conversationally using open-ended and closed-ended questioning techniques. MS Teams transcription service was used, and interview text was collated into paragraphs of text tabulated by question and participant number. The MS Teams transcript was then copied into MS Word, where additional formatting and notation could be undertaken, before the paragraphs of text were pasted into an MS Excel spreadsheet. Given the volume of text involved in each interview transcript it was necessary to identify common themes and patterns.

Concise terminology was arrived at which succinctly explained a participant's specific response to each open-ended question. This was deemed the most efficient methodology for analysis of the data given the variety of terminologies and opinions provided by each interview participant. The terminology which was arrived at was included in an Excel spreadsheet and presented in the format of pivot tables, bar charts, or data tables for ease of data analysis. In *Section 4.4* we will analyse the data for patterns and trends.

4.4.2 Interview Data

Question 1* asks the interviewee to describe their industry.** Of *12 participants* interviewed*, six (50%)* represented the public sector, *four (35%)* represented the private sector, and the remaining two (15%) represented a not-for-profit or social enterprise, (Table 8). ***Question 2* expands on the theme from *Question 1 and reveals that the interviewees also represent a broad range of disciplines and subject matter areas, with Professional Services (consulting, contract management, design etc.) representing the largest proportion of sectors *(*Table 9*).*

Table 8: Distribution of respondents vs. Sector

Q1. How would you define your organisation?	
PUBLIC SECTOR	6
PRIVATE SECTOR	4
NOT-FOR-PROFIT/SOCIAL ENTERPRISE	2
TOTAL RESPONSES	**12**

Table 9: Distribution of respondents vs. Area of Knowledge

Q2. Which industry sector best describes your organisation?	
ACADEMIC INSTITUTION	1
COMMERCIAL SEMI-STATE (TELECOMMUNICATIONS SECTOR)	1
COMMERCIAL SEMI-STATE (TRANSPORT SECTOR)	1
PROFESSIONAL SERVICES	5
PUBLIC SECTOR ORGANISATION (GRANT AID + POLICY)	1
PUBLIC SECTOR ORGANISATION (RESEARCH FUNDING)	1
REPRESENTATIVE BODY	1
RESEARCH ORGANISATION	1
TOTAL RESPONSES	**12**

***Questions 3-6* deal with the Circular Economy at a general level.** While four (*n=4*) of the *participants* claimed to have basic or no understanding or knowledge of the circular economy, eight (*n=8*) of the twelve participants had intermediate knowledge of the circular economy, as it concerned their industry sector (Table 10).

Table 10: Range of Interviewees experience/knowledge of the Circular Economy

Q3. What is your experience/knowledge of the Circular Economy (CE)?	
INTERMEDIATE	8
NONE	3
BASIC	1
TOTAL RESPONSES	**12**

***Question 4* asks the interviewees to define the CE as it pertains to their organisation or industry sector.** *50% of participants* identified that the CE represents an opportunity to retain material value (keep materials in circulation). *Two participants* (*n=2*) identified material substitution opportunities (where recycled material can be used as a substitute for new materials). *One participant* (*n=1*) responded that the CE represents an opportunity for further business. *Three participants* (*n=3*) with basic or no CE experience answered as 'Don't Know', or N/A (not applicable) (Table 11).

Table 11: Relevance of the CE to interviewees' organisation or industry sector

Q4. How would you define the Circular Economy as it pertains to your organisation or industry sector?	
MATERIAL VALUE RETENTION OPPORTUNITIES	6
DON'T KNOW	2
MATERIAL SUBSTITUTION OPPORTUNITIES	2
N/A	1
CAN HAVE AN IMPACT THROUGH TRAINING AND CONSULTING WORK	1
TOTAL RESPONSES	**12**

75% of the interview participants however, defined the CE through the following lens, maintaining materials in circulation for longer, substituting existing materials for more circular materials, building knowledge capacity on the CE through consulting and training work.

***Question 5* asks interviewees if they are involved in CE-related activities or projects in their organisations.** Three (*n=3*) of the interviewees, responded that they were not involved in CE-related activities or projects in their organisation (Table 12).

Table 12: Participant involvement with CE-related projects in their organisation

Q5. Are you involved in CE-related activities or projects in your organisation?	
NO	3
THE COMPANY PROVIDES BEST-PRACTICE ADVICE TO CLIENTS IN THE PUBLIC SECTOR (NOT NECESSARILY CE-SPECIFIC)	2
RESEARCH PROJECTS (INVOLVED IN PROJECTS THAT HAVE SOME CE-RELATIONSHIPS)	1
WORKING ON EXCESS MATERIALS EXCHANGE PILOT PROJECT (CE-SPECIFIC)	1
END-OF-WASTE CRITERIA (A CE-ACCELERATING POLICY MECHANISM)	1
REFURB PROJECTS (CE-SPECIFIC BUT SMALL SCALE)	1
MATERIAL SUBSTITUTION FOR LOWER IMPACT (IMPLEMENTING CE-REDESIGN)	1
CIRCULAR DESIGN (IMPLEMENTING CE-DESIGN)	1
CE IS A SET OF PRINCIPLES AND ACTIONS (CE-POLICY DRAFTING)	1
TOTAL RESPONSES	**12**

While it was difficult to find a common thread between the remaining interview responses to *Question 5* the variety of the responses would indicate that the CE has a broad reach across organisations and industry sectors, with CE projects ranging from small scale refurbishments to policy implementation and development, and industry research projects.

Question 6 asks participants for their opinion on what areas from a selection provided could help scale the Circular Economy. Four (n=4) participants (Table 13) agreed that **Materials Passports was the most important scale multiplier** from the list below, however carbon taxes and carbon allowance feature prominently too. This is an important area of consideration for the research given that incentivisation is integral to the successful development and implementation of an EME.

Table 13: Participant opinion of CE-scaling factors

Q6. In your opinion which of the following areas could help scale the Circular Economy:	
MATERIAL PASSPORTS	4
CARBON TAXES	3
ALL	2
DON'T KNOW	2
CARBON ALLOWANCES	1
TOTAL RESPONSES	**12**

From the data it was found that *material passports* were the most significant factor, from the options available, to scale the CE, followed closely in preference by, carbon taxes. Two interview participants did not have an opinion, while two other interview participants choose *all categories* as being relevant to scaling the CE.

***Questions 7-16* address the concept of excess materials exchange.** *Question 7* asks if participants were familiar with EME platforms (Table 14). Eight (n=8) responded that they were familiar with EME platforms, while *33%* responded that they were not familiar with the EME platforms.

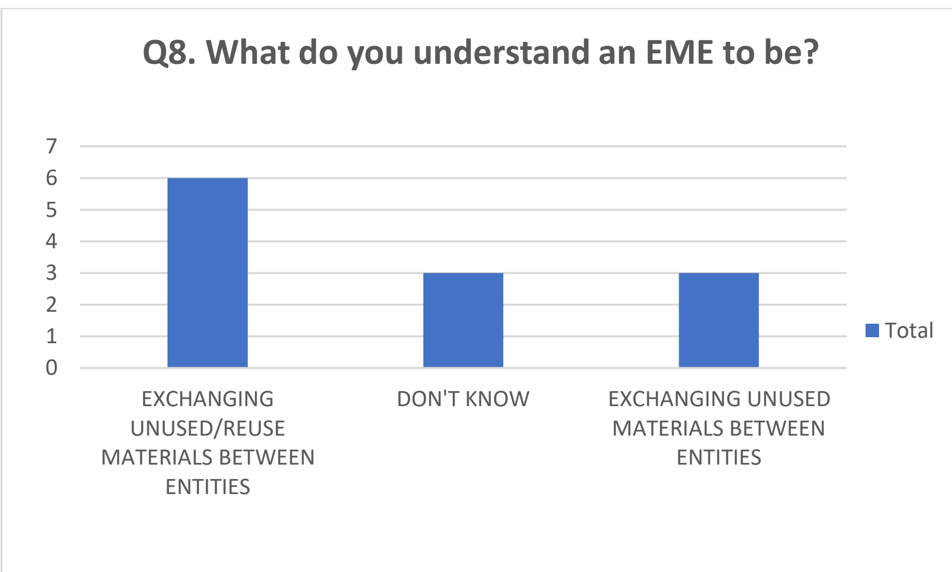
Of the 8 respondents who had heard of Excess Materials Exchange, only one participant of the eight had practical working knowledge of how the system worked. Given that there are very few examples of EME's in practice in the EU this finding is unsurprising.

Table 14: Participants familiarity with Excess Materials Exchange platforms

Q7. Are you familiar with Excess Materials Exchange platforms?	
YES	**8**
NO	4
TOTAL RESPONSES	**12**

Question 8 **asks participants about their understanding of EME's.** Interviewee responses depended primarily on their familiarity with Excess Materials Exchange. Eight (n=8) of respondents answered that an EME Is a marketplace where unused/reuse materials could be exchanged (Table 15). The term 'entities' was used in the descriptor to reflect a wide range of responses ranging from 'organisation', 'stakeholder', 'companies', and 'local authorities'.

Table 15: Participants description of an Excess Materials Exchange



Question 9 asks participants what they view as benefits of Excess Materials Exchange platforms. All twelve (*n=12*) participants responded that the principal benefits an EME platforms is to minimise waste. With specific reference to EME implementation within the public sector participants were asked in *Question 10* **how EME's could be optimally applied**. Participants provided a range of responses (Table 16) but six (n=6) responses included references to *building greater knowledge capacity* around the CE across both the public and private sector.

Table 16: Optimal application of EME to Public Sector

1. ADDRESSING MATERIAL QUALITY AND REGULATORY CONCERNS
2. NEED TO TAKE A SECTORAL APPROACH
3. NEED TO REACH ECONOMIES OF SCALE
4. REQUIRES A BY-PRODUCT MANAGEMENT PLAN TO AVOID THE WASTE MANAGEMENT PROCESS
5. CAPTURE MATERIALS THAT ARE IN-SITU BUT ARE REMOVED DUE TO CHANGE IN SPECIFICATION
6. ENSURE IT IS COMPATIBLE WITH, OR LOOKS LIKE, E-TENDERS
7. MUST SEAMLESSLY FEED INTO THE PUBLIC PROCUREMENT SYSTEM
8. BUILD KNOWLEDGE CAPACITY
9. MATERIAL PASSPORTS

***Question 11* asked participants if they were familiar with the Circular Economy Procurement Framework (CEPF)**, as described below (Figure 34). Seven (n=7) of the *twelve* participants were familiar with the CEPF (Table 17). Three (n=3) of the remaining *five* participants were familiar with public procurement procedures more generally.

Figure 29: Circular economy procurement framework overview (Source: Ellen MacArthur Foundation 2023)

From the data provided five participants were unfamiliar with the CEPF. The responses align with data from Question 3 (p. 68) which indicate respondents overall familiarity and working knowledge of the CE.

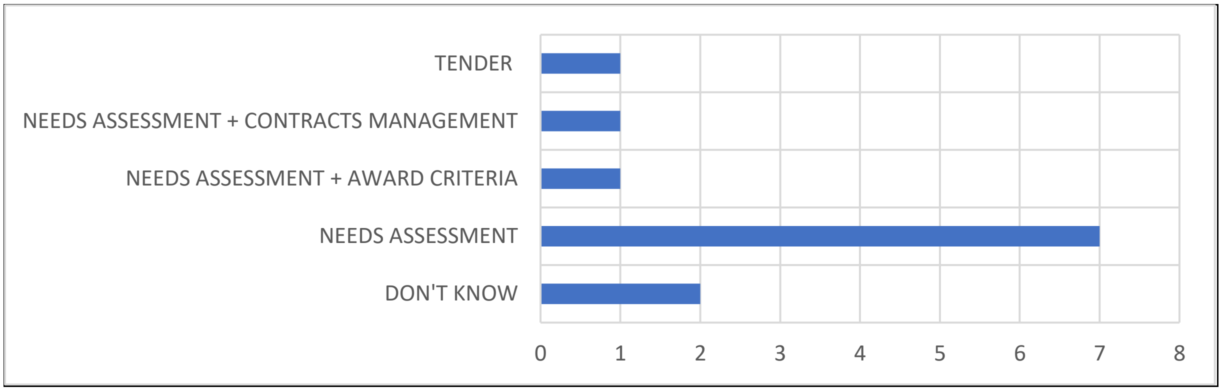
Table 17: Range of participants familiar with the circular economy procurement framework

Q11. Are you familiar with the circular economy procurement framework?	
YES	7
NO	5
TOTAL RESPONSES	**12**

Based on participants knowledge of procurement within the public sector ten participants gave their opinion on where an EME would be most effectively introduced (Table 18). Nine (n=9) of the twelve respondents to *Question 12* indicated that *Needs Assessment*, or a combination of

Needs Assessment, *Contracts*, or *Award Criteria*, was the optimal stage at which to introduce the EME, while one indicated at *Tender*, and two participants responded *Don't Know*.

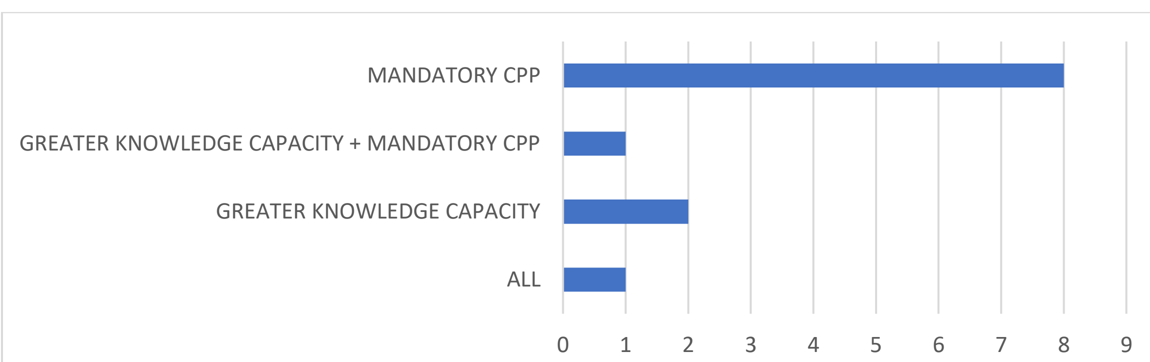
Table 18: Optimal stage to introduce the EME in the Public Procurement process



Where respondents were unfamiliar with public procurement processes, they deduced from the options available that the most logical stage to introduce an EME would be as early as possible in the process, given the added complexities of adding new information later in the process.

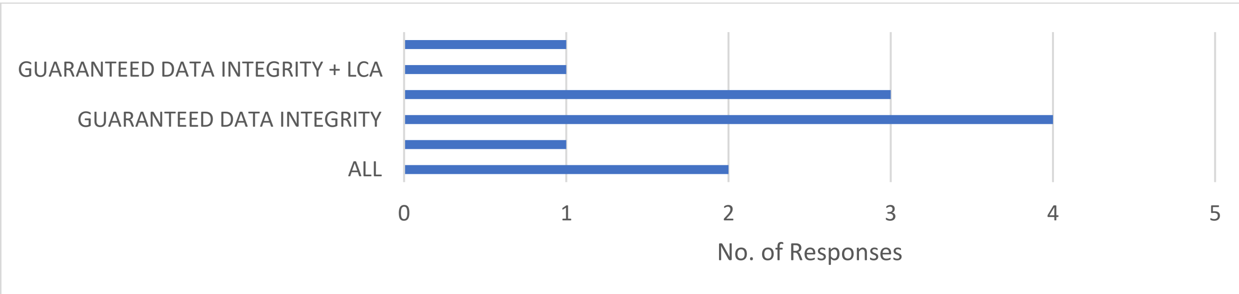
Question 13 asks participants to select from the following on which would increase engagement with the circular economy across the public sector:*75% of respondents* indicated that a Mandatory Circular Public Procurement process would increase engagement with CE principles across the public sector (Table 19).

Table 19: Factors which would increase public sector engagement with CE



Question 14 asks respondents to choose from the following list of **key EME attributes** which would be most relevant to their organisation or industry sector. *>80% of participants* identified *Guaranteed Data Integrity* as their top choice, however, some participants also indicated that the other factors were also relevant considerations (Table 20).

Table 20: Key EME attributes as identified by participants



Question 15 asks participants for their opinion on the principal barriers to adoption of excess materials exchange platforms in their organisation, or industry sector (Table 21).

Table 21: Principal Barriers to Adoption of an EME

Categories	# Responses
RECERTIFICATION OF USED MATERIALS	1
TRANSACTION FEES	1
SYSTEM MANAGEMENT	1
BUILDING KNOWLEDGE CAPACITY	3
PROXIMITY PRINCIPLE	1
DEVELOPING TRUST	1
REGULATION	1
EDUCATION & TRAINING	1
THE PUBLIC PROCUREMENT PROCESS	2
LACK OF MANDATORY REGULATIONS	3
ACCESS TO EME SYSTEM	1
OVERCOMING PUBLIC SECTOR RISK AVERSION	2
Total Categories	**18**

Question 16 asks participants if they were aware of the correlation between a circular material and its carbon footprint. All participants (100%) responded that the *carbon footprint of a circular material is dependent on its next use stage*.

Question 17 asks participants if they were aware of the concept and role of Carbon Caps, or Limits. The purpose of the question was to ascertain if participants could identify a correlation between carbon emissions and industrial activity (Table 22).

Table 22: Participants familiarity with the concept, and role, of Carbon Caps (Limits)

Q17. Are you familiar with the concept, and role, of Carbon Caps (Limits)?	
YES	10
NO	2
TOTAL RESPONSES	**12**

Question 18 asks how Carbon Caps (Limits) if applied to an organisation, or industry sector, would impact the transition to the CE. Six (n=6) respondents (Table 23) indicated that a carbon price would incentivise the transition or encourage change.

Table 23: Impact of Carbon Caps on Transition to a CE

Q18. How would Carbon Caps (Limits) if applied to your organisation, or industry sector, impact your organisation's transition to a CE?	
CARBON PRICE WOULD INCENTIVISE CHANGE	6
COLLABORATION ACROSS VALUE CHAIN	2
SET SECTORAL BUDGETS AT A LOCAL AUTHORITY LEVEL	1
DON'T KNOW	1
ACCELERATE THE TRANSITION	1
AVAILABILITY OF DATA	1
TOTAL RESPONSES	**12**

Question 19 asks where EME ownership lies. (Table 24) indicates that 75% of participants believe the ownership resides with a third sector commercial semi-state agency. This is distinct from a third sector academic institution such as a university, or research institute. A third sector is also not a private sector entity, but is normally referred to as a public sector body with a commercial objective/s.

Table 24: Participants choice of EME ownership

Q19. In an ideal world, where would the ownership for a public-sector EME lie?	
THIRD SECTOR (COMMERCIAL STATE AGENCY)	9
PUBLIC SECTOR	2
THIRD SECTOR (ACADEMIC INSTITUTION)	1
TOTAL RESPONSES	**12**

Question 20 asks participants to expand on any areas they feel were not covered in the previous questions, or to expand on an answer they had previously provided. There were a wide range of responses to *Question 20*, with the topics highlighted in bold in (Table 25) being of particular significance.

Table 25: Participants overall opinion on practical implementation in the marketplace

Q20. Are there any other aspects of the concept of an EME that you would like to expand upon?	
PUBLIC SECTOR IS RISK AVERSE	**2**
TRANSACTION FEES	1
REGULATION IS KEY	**1**
WOULD VIEW CE AS 2ND ONLY TO ELECTRIFICATION AS PRIMARY DRIVER OF DECARBONISATION	**1**
CARBON CAPPING THE CONSTRUCTION INDUSTRY	1
SET UP A NEW STATE AGENCY TO RUN IT. A LARGE INVESTMENT REQUIRED.	**1**
COULD WORK FOR SMALL SCALE INITIATIVES	1
WITHOUT INCENTIVES IT WILL BE DIFFICULT TO BUILD A USER BASE	**1**
IN PRACTICAL TERMS THE CE IS 10-15 YEARS FROM REALISATION	1
BUILD SUPPLY CHAIN CAPACITY	1
BEHAVIOURAL NUDGING	1
TOTAL RESPONSES	**12**

4.4.3 Summary

The data gathering exercise consisted of a series of twelve (*n=12*) interviews with a variety of experts from across industry, academia and third sector institutions. In this chapter the data from the twenty (*n=20*) interview questions was collated and presented in tabular format (Table 9 – 25) for ease of explanation.

4.5 Data Analysis

4.5.1 Introduction

This section presents a rigorous analysis of the qualitative data and discusses its *relevance* and *validity*. The data analysis helps to build a logical chain of evidence, establish relationships, and identify *plausible* patterns and trends, as well as identifying and interpreting *outliers* in the data to derive a *theoretical coherence*. The interview participants were assigned a reference number (P1-P12) for ease of coding and analysis of the audio transcriptions.

The interview data produced many themes and areas of inquiry. However, four main thematic areas emerged which are of particular importance to the development of the conceptual framework for the EME. The four main themes can be summarised as:

1. The need for a *clearer definition* of what is understood as 'excess materials'.
2. Implementation of *mandatory circular public procurement* legislation, *material passports*, and addressing *quality and data integrity* concerns related to circular materials could accelerate the transition to the CE for the public sector.
3. *Ownership & governance* of the EME through a commercial state agency could enable and accelerate, through systems and processes, the transition to the CE for the public sector.
4. *Carbon taxation or credits* could incentivise the adoption of an EME across the public sector.

4.5.2 Definition of *'excess materials'*

There is no consensus on an exact description of a CE, with six (n=6) respondents (Table 11) stating that the CE offers material value retention or substitution opportunities, as defined by opportunities for reducing, reusing, and recycling. This was the most common reference point used across the interviews, with participants describing their understanding of the CE via the *3R's – Reduce, Reuse and Recycle*. This finding correlates closely with an observation by (Klein, Ramos and Deutz, 2020). In their study on advancing the CE in public sector organisations (PSO's) the authors discovered that public sector employees view the CE through the lens of public procurement, and material value retention opportunities and through the 3R's philosophy, as distinct from the expanded lens of *Resell, Repurpose, Remanufacturer*, taken by (Reike, Vermeulen and Witjes, 2018b).

Implementation of circular public procurement legislation (OECD, 2020), and the Circular Economy Procurement Framework (CEPF) as presented to interviewees, are emerging topics and have not, at the time of writing, gained enough traction to influence public procurement decision making one way or the other. It was accepted however, based on the responses from those interviewees with responsibility for procurement, and those interviewees with contributions along the public procurement value chain, that an EME must be *deployed as early in the procurement process* as possible to enable optimal circularity decision making. Mandatory CPP measures would increase engagement with the CE across the public sector (European Economic and Social Committee, 2021), leading to the conclusion that a process must include legislative measures to encourage engagement with an EME and that option must occur as early in the public procurement journey as possible.

4.5.3 Ownership & governance of the EME

Awareness of the EME concept

Interview participants fell into three broad categories in respect to knowledge of the CE; 1) no CE-knowledge, 2) basic CE-knowledge, and 3) a working (intermediate) knowledge of the CE. This indicates a potential challenge to EME adoption. In the absence of CE-knowledge, and a lack of awareness of the potential benefits of transitioning to a CE, it may be difficult to convince public and private sector stakeholders of the overall benefits of adopting an EME framework.

Lack of familiarity with the EME also suggest that there is more work to be done to *increase the visibility of EME's* in every day practical use and application. The data would suggest that there is an opportunity to build knowledge capacity around the functions of an EME while also expanding the range of terminology used to describe materials exchange but, from the data presented, this must be done in conjunction with building knowledge capacity around the CE more generally. All interviewees agreed that their *perception of the benefits* of an EME were that it would help *minimise waste*, facilitating one of the key objectives of building a CE.

Attributes of an EME

This leads to the question of key EME attributes. The data supports the need for *guaranteed data integrity* as a key attribute of an EME framework (Question 14, Table 14). A concern expressed by all interviewees on the topic of EME attributes concerned trustworthiness, robustness, validity, and availability of data as it related to the operability of the EME.

To overcome barriers to EME adoption in the public sector, three main factors were identified; mandatory Circular Public Procurement legislation is required (Table 19), minimisation of risk factors associated with decision making processes, i.e., guaranteed data integrity (Table 20), and building knowledge capacity around the benefits of the EME, and the CE more generally, a conclusion arrived at based on the data presented in (Table 21) and further commentary related to this interviewer during discussions on *Question 20*.

The data revealed that there is a *strong aversion to placing ownership of an EME in the private sector*, and a preference for retaining ownership of an EME which trades in public materials, in state hands, through a commercial semi-state company, or agency. The data supports therefore, state ownership of a public sector EME (Table 24).

In interviews participants expressed an opinion that EME materials are publicly owned and therefore socio-economic benefits should accrue to the taxpayer, and not the private sector. Additional rationale provided concerned the integration of existing procurement and data management systems within a novel EME framework. Comparisons were drawn, by interviewees, with existing semi-state and commercial state agencies, such as, *EirGrid*, *Bord na Mona*, and *Coillte*, and how public materials could be managed. The conclusions arrived at during the interview process resembled the initial concept mapping for a Materials Management Agency (MMA) as outlined in Section 4.3.

It was difficult to determine a common theme, however, among the answers provided to Question 20 leading this researcher to conclude that the practical deployment of a public sector focused EME is a highly complex undertaking which will face many obstacles to its implementation.

4.5.4 Carbon-based Incentivisation Mechanisms

The second choice of many interviewees was for the implementation of carbon taxation or allowances to incentivise the transition to a CE.

There are several reasons cited by interviewees as to why carbon taxation and/or allowances were chosen from the list of available options, most notably that, 1) carbon taxation is a *commonly used terminology* in the lexicon of environmental-related policy measures, 2) that the nature of taxation is to *nudge behaviour* in a specific direction, 3) there was an accepted recognition amongst the interviewees that *mandatory policy measures* are more effective than voluntary measures in incentivising change.

From Question 16-18 (p. 86) the data also indicates that there is a general familiarity around carbon and its association with industrial activity. There is also a recognition that a *carbon price* at a sufficient level would incentivise the pace of transition to a CE further validating the data from (Table 23) regarding *carbon taxation/allowances*. A carbon price and method of taxation (or allowances) is relevant to the discussion on the EME conceptual framework. It is the direction of travel for EU policy (European Commission, 2023).

4.6 Summary

The research data would suggest that a significant gap exists in the knowledge of the CE across the public and private sector, and this has a limiting effect on the understanding of broader CE-related concepts, such as excess materials exchange. There also appears to be a limited amount of CE-activity in practice across all sectors researched as part of the interview process. This appears to correlate to the data on circularity in Ireland (1.6% compared to the EU average of 11.9%). The data further identified that excess materials exchange has a role to play in the future landscape of the CE. However, the data also identifies that many challenges remain before a system can be implemented which meets the myriad of requirements to justify its implementation and enduring utilisation.

The key thematic areas which can be arrived at from the data are the requirements for:

- A *clearer definition* of 'excess materials' is required to enable use of a broader range of materials.
- *Mandatory legislation* governing circular public procurement related practices is essential.
- A commercially minded and *state-run materials management agency* is preferred over publicly or privately owned equivalents.
- An *incentivisation measure* consistent with a system of carbon taxes or allowances would nudge behaviours towards more circular materials and practices.

5 DISCUSSION

5.1 Introduction

In this section I discuss the conceptual framework from Section 4.2. The second iteration of the conceptual framework is arrived at based on an analysis of the interview data in conjunction with the literature reviewed. The interview data identified the key thematic areas below:

- A *clearer definition* of 'excess materials' is required to enable use of a broader range of materials.
- *Mandatory legislation* governing circular public procurement related practices is essential.
- A commercially minded and *state-run materials management agency* is preferred over publicly or privately owned equivalents.
- An *incentivisation measure* consistent with a system of carbon taxes or allowances would nudge behaviours towards more circular materials and practices.

This approach to conceptual framework design and development enhances the final artefact which is supported by foundational theories and evidential data and is compatible with the DSR approach of iterative concept development (Hevner *et al.*, 2004b).

5.2 Excess materials

A key theme arose during the interviews concerning the definition of the term, *excess materials*. A central assumption made, during the initial conceptualising of an EME, was that the term *'excess materials'* referred to End-of-Life recovered materials. Based on conversations with interview participants it became clear that individual understanding of excess materials differed, and the definition of excess materials could be expanded to include *Excess to requirements, Non-conforming materials* and *Recovered materials*.

'Excess to Requirements' Materials

- **excess to requirements materials** arise in scenarios where extra materials are procured but remain unused, for example (*2x Qty. procured*, *1x Qty. used, leaving 1x Qty excess*). The extra materials are normally added to existing inventory, incurring additional administrative costs in the process.
- However, if excess materials are instead made available to an exchange, the transfer of material could reduce the requirement to, and cost of, procuring new material in another part of the public sector, with resultant reductions in GHGs emissions across the value chain.

'Non-conformance' Materials

- **non-conformance materials**, do not non-conform to their intended specification, or application. For example, a 10mm screw received into inventory versus a 12mm screw required per design specification. If the cost of returning the screw to the supplier exceeds the cost of adding the 10mm screw to inventory, then the stock of 10mm screws could instead be added to the materials exchange. In a well-publicised example, 7,500 electronic voting machines were purchased by the Irish government in 2002 at a cost of €51m (not including storage costs over the proceeding years), only to be sold again for scrap in 2012 for €70,267. (10)

[10] €54m voting machines scrapped for €9 each | Independent.ie

- In many cases however a non-conforming material may be the wrong size, material type, colour etc., but also defective.

i) *In the case of defective material, it may be possible to return the material to its place of manufacture in exchange for a non-defective material*.

ii) *Where non-conformance material cannot be returned to its place of origin then the non-conforming material could be made available to the excess material exchange, notifying the exchange of the specific non-conformance, for example, 10 tonnes of 10mm stone delivered, 10 tonnes of 12mm stone required by specification.*

'Recovered' Materials

Section 2.4.4.1 discusses several alternatives concerning materials which were previously designated as waste. These materials can now instead be described as *Waste, Secondary raw materials and products, and By-product*. Secondary raw materials and products, and by-product, offer unique opportunities for material and energy value retention. The revised designations have resulted in an iteration Material Classification System A (MCS-A) as described in Section 4.1. A more comprehensive definition of excess materials has produced Material Classification System B (MCS-B). MCS-B includes a provision for *secondary raw materials and products*, *by-product*, *non-conformance,* and *excess to requirements* material categories (Figure 35).

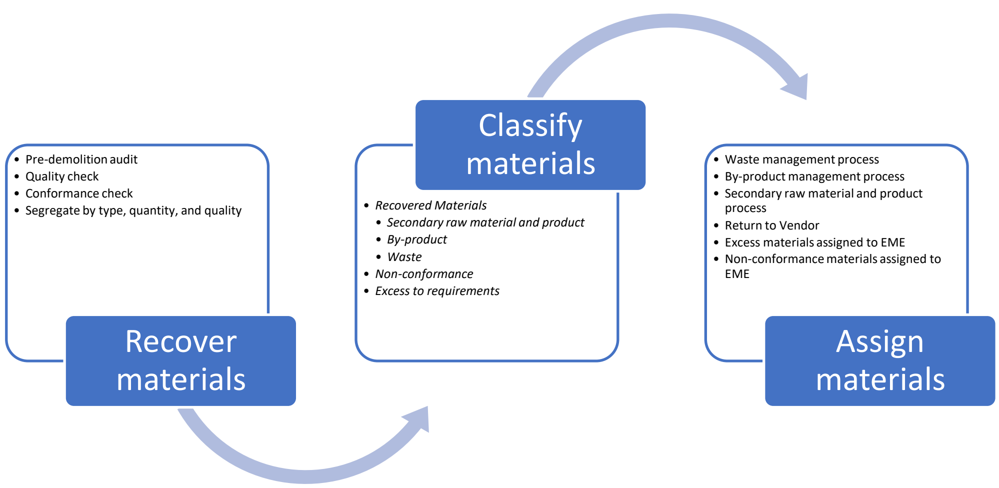


Figure 30: Material Classification System B (MCS-B)

5.3 Mandatory CPP to enable Excess Materials Exchange

There is a broad recognition, expressed by all interviewees during the interview process, that there should be a mandatory policy instrument in place to incentivise the transition to the CE. Given that public procurement is the mechanism used for procuring goods, works, and services, across the public sector, mandatory CPP would seem to be the most appropriate vehicle. Mandatory CPP would also necessitate the use of validation and certification instruments, such as, Material Passports, and reinforce trust, integrity, and robustness of the EME. Mandatory CPP is the view of (European Economic and Social Committee, 2021).

The Synthesis Report from the OECD (2020) on the Circular Economy in Cities and Regions also makes the point that 'a legislative framework conducive to the circular economy should incentivise circular business models and practices across the economy, so that circularity becomes the norm while making linear models increasingly unattractive economically.' Given the scale of public procurement across the EU (14% of GDP) it seems logical that a shift to mandatory CPP would also bring an acceleration of the transition to the CE.

The EME is most applicable to materials which are durable, for example, metals, and less applicable to materials which must undergo a more complex *repurposing* or *remanufacturing* process, or which have degraded during their first use phase, for example, plastics.

Specific regulations exist, for example in the WEEE Directive (WEEE, 2012) where recovered electrical and electronic materials cannot be immediately reused and must be broken down into individual components and elements before another use is found. This negates many of the life cycle cost benefits, and GHG emission reductions, achieved in material recovery and reuse. It is proposed that EME materials will be regulated according to the following:

- Waste (Waste Framework Directive, 2019)
- Secondary Raw Material and Product (End of waste criteria in Ireland | Environmental Protection Agency, 2023)
- By-product (By-products Regulation 27 | Environmental Protection Agency, 2023)

- Non-conformance (Standardisation in Europe, 2023)
- Excess to requirements (Managed by individual public sector entities inventory and enterprise resource planning (ERP) systems)

5.4 EME Governance, Regulation, and Adjudication

One of the key findings in the research concerned the issue of EME ownership. From Section 4.4.2 over three quarter of individuals interviewed for this study stated a preference for a third-sector or commercial state-agency approach to the governance, regulation, and adjudication of an EME. The interview data confirmed the need for a statutory body to oversee the governance, regulation, and adjudication of the EME.

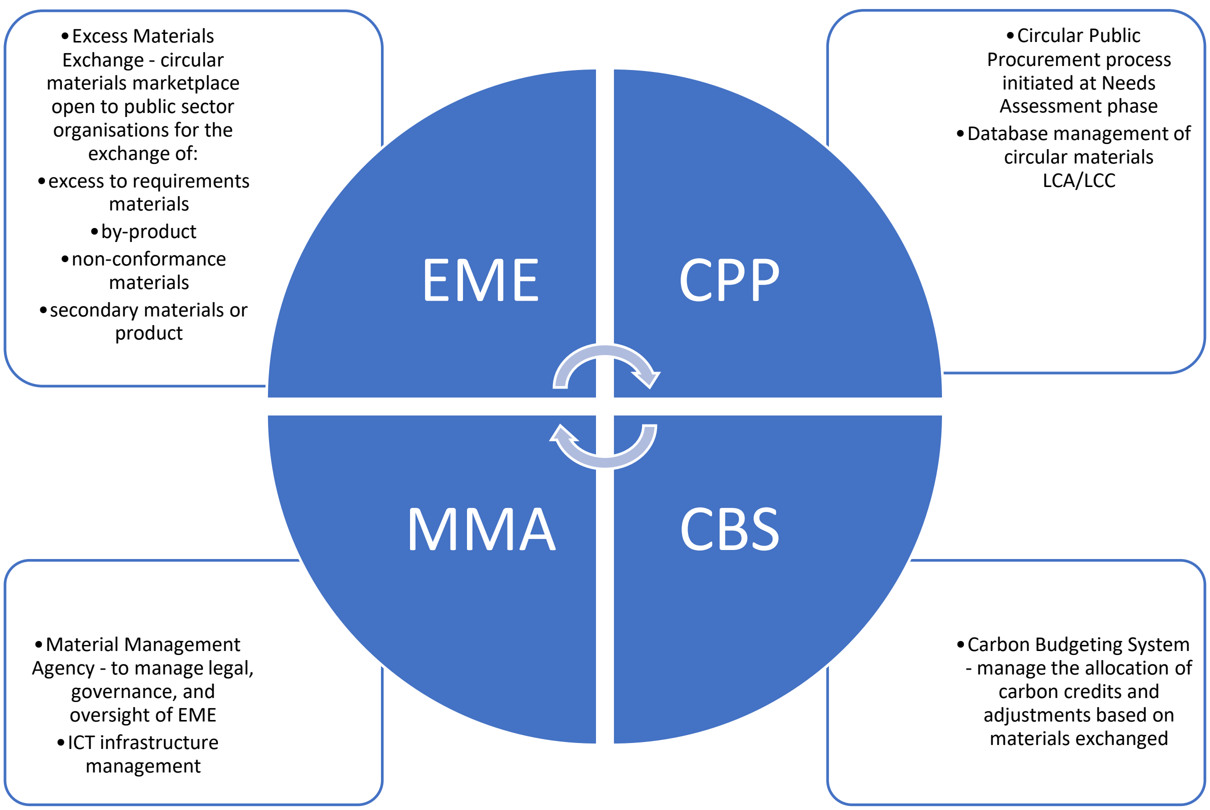


Figure 31: Circular Economy Structural Mechanism (CESM)

The EME interacts with the Circular Public Procurement (CPP) and Carbon Budgeting System (CBS) processes and is managed by a Material Management Agency (MMA). An MMA would act as an arbiter of transactions and material flows. This third-sector approach could be run on a commercial, or not-for-profit basis, though it is essential that it operate on a cost neutral or cost positive basis. For the purposes of simplifying the four interlinked systems the term, Circular Economy Structural Mechanism (CESM) has been derived.

Additionally, a CESM can be scaled up to include an EU-wide public sector as shown in (Figure 37). The EU-CESM (Figure 37) could, based on an efficiently designed technical and structural architecture, help Ireland, and the EU, accelerate the transition to a CE.

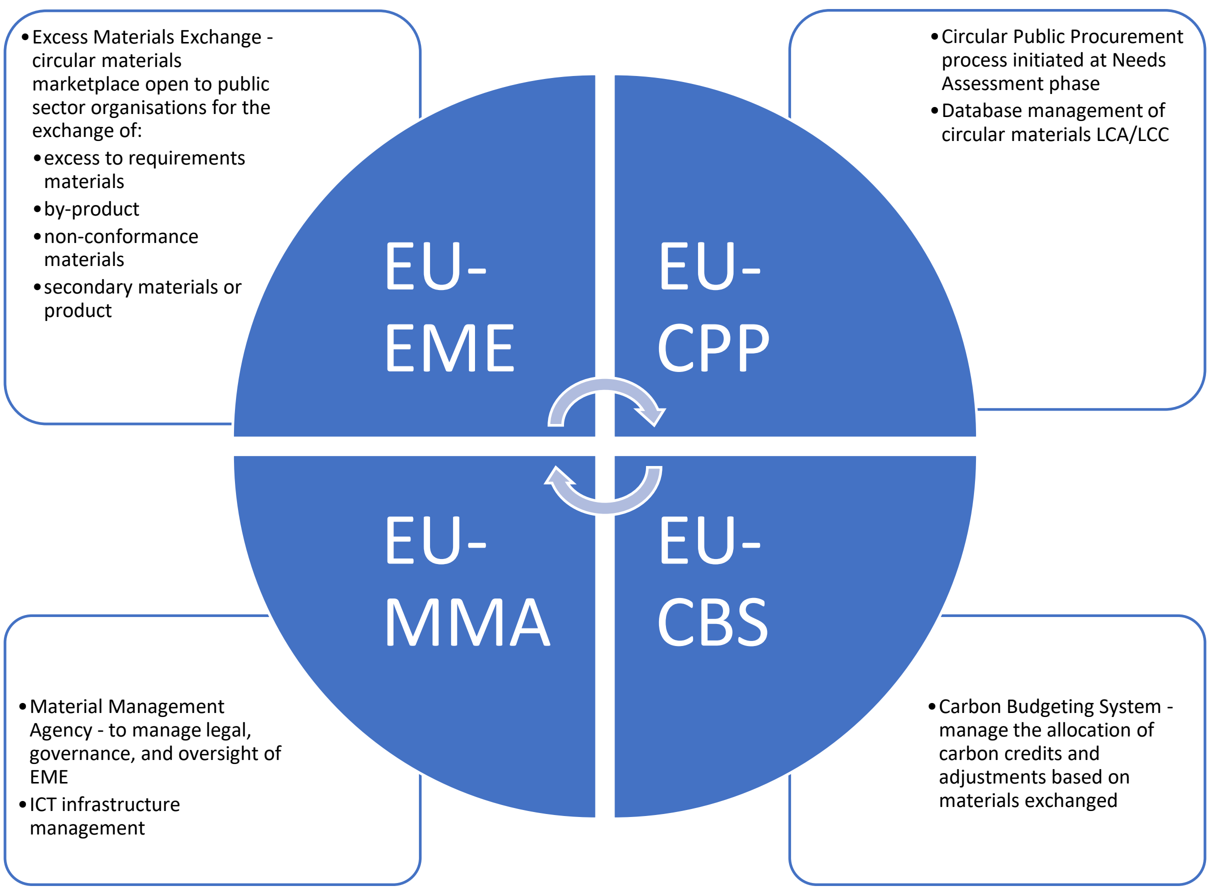


Figure 32: EU Circular Economy Structural Mechanism (EU-CESM)

The EU-CESM would have a mandate to maximise environmental, social, and economic returns in three principal ways:

- Keeping materials in circulation in the public sector (at their highest value) for as long as possible
- Regenerating nature across the EU-27
- Eliminating waste and pollution across the EU-27

$$CESM_{(state)} \times 27 = CESM_{(Europe)}$$

5.5 Carbon-based incentivisation

Opportunities exist to embrace some form of carbon-based incentivisation, either in the form of taxes or allowances described in Section 2.7. The Emissions Trading System (ETS) is a relevant example of how carbon allowances can be used to encourage change towards reduced GHG emissions. Additionally, carbon taxes are used to encourage consumer behaviours towards greener alternatives. The mechanisms are already in place, both at an individual and industry level, and either system could be adopted to incentivise the EME. Indeed, from above, the literature supports this thesis. The interview data also supports adoption of carbon-based incentivisation. Further work is required to understand which system of carbon-based incentives works best for reducing material use and/or promoting circular materials.

5.6 Summary

In this section I have examined, and developed upon, the conceptual framework from *Chapter 4, Section 4.2*. The second iteration of the conceptual framework was arrived at based on an analysis of the interview data and in conjunction with the reviewed literature. This approach to conceptual framework design and development ensured a robust final artefact supported by evidential data and is compatible with the DSR and DT models of iterative concept development.

The interview data suggested that a gap exists in the knowledge of the CE across the public and private sector, and this may have had a detrimental effect on the understanding of broader CE-related concepts, such as excess materials exchange. Many of the discoveries made, from both the primary and secondary research, will require further investigation.

6 CONCLUSIONS & RECOMMENDATIONS

6.1 Introduction

There were four objectives to the study:

1. Determine, through rigorous primary and secondary research, the essential characteristics of a public sector focused excess materials exchange (EME).
2. Determine, through rigorous primary and secondary research, how the public sector can be incentivised to use an excess materials exchange platform and what form incentives would take.
3. Determine, through rigorous primary and secondary research, the benefits/challenges to implementing a public sector excess materials exchange (EME).
4. Determine, through rigorous primary and secondary research, where system ownership of a public sector EME resides.

To achieve the project's objectives, primary research in the form of interviews, data collection, and data analysis was undertaken in addition to secondary research. In this chapter I present our conclusions, the impact and limitations of the research, and opportunities for further research.

6.2 Main Research Findings

In relation to the primary and secondary research undertaken the following discoveries were made:

- A *clearer definition* of 'excess materials' is required to enable use of a broader range of materials on the exchange. With a broader inventory categorisation, a greater volume of materials becomes available and further incentivises use of the exchange.

- *Mandatory legislation* governing circular public procurement related practices is essential to incentivise use of the EME by the public sector. Voluntary public procurement measures, as was the case with GPP, have proven to be ineffective in the past. Most economically advantageous tendering (M.E.A.T.) continues to be the default option in public tenders. To increase the inertia towards more circular public procurement (CPP) and hence circular materials, products, and services, mandatory CPP legislation must be enacted to incentivise change.
- A commercially minded and *state-run materials management agency* is preferred over publicly or privately owned equivalents. Many examples currently exist within the Irish state on which a Materials Management Agency (MMA) could be based. An MMA could be cost neutral to the taxpayer, and reinvest any profits or savings made from the EME and CPP-based practices back into the exchequer.
- An *incentivisation measure* consistent with a system of carbon taxes or allowances would nudge behaviours towards more circular materials and practices. The EU-ETS is an example of how carbon allowances are effectively deployed to incentivise change. Similarly, carbon taxes have been proved to nudge consumer behaviour towards better environmental outcomes.

6.3 Contribution to Practice

Based on the research it seems inevitable that excess materials exchange (EME) will transition from being a *business exception* to a *business process norm*. Additionally, given the scale of public sector spending on products, services, and works, it also seems feasible that the private sector will be incentivised to adopt circular practices to ensure competitive bidding for public tenders. This virtuous cycle of public-private sector incentivisation can accelerate the transition to the CE, but only if the public sector is incentivised as the primary market mover. Through the implementation of mandatory circular public procurement policies and practices the public sector will be legally obliged to scale and accelerate CE-related business practices. Additionally, internal carbon-based budgeting systems, based on carbon taxation or carbon allowances, can further incentivise the public sector to act to reduce GHG emissions from their business practices.

It is worth mentioning however that a comprehensive material flow accounting exercise undertaken in Scotland highlights, some challenges which exist in recovering materials and building a value chain which is economically, socially, and technologically feasible (Pratt, Lenaghan and Mitchard, 2016). In the study the authors found that the CE can help countries achieve their GHG emissions targets without sacrificing economic growth – a desired result for most economic policy makers – however this is dependent on many factors, including; specific national dematerialisation priorities, scaling up of indigenous high-tech recycling industries, and a system of consumption-based carbon accounting.

6.4 Contribution to Theory

The research has added to the body of knowledge on the CE in the following ways. Excess materials exchange has been identified as a key component in the acceleration of the transition to the CE for the public sector, built environment. Circularity, from the perspective of material and energy value retention has been studied comprehensively in the literature. However, the connection between the broader definition of excess materials discovered during this study (i.e., by-product, non-conformance, excess to requirements etc.) is less commonly known.

Additionally, the connection between public sector material and energy value retention opportunities and mandatory circular public procurement mechanisms, highlighted in this study, is also less understood in the literature. New technologies are emerging, such as, Blockchain, AI, and NFT's, which will enable the CE, and each of those subject areas are comprehensively covered in the literature, however, the intersection between public sector procurement policies, emerging enabling technologies, and the CE is less studied.

Lastly, the literature is also less detailed on the opportunities which exist to connect circular material use in the public sector with carbon-based incentivisation mechanisms, either through carbon taxation, or carbon allowances. This study has highlighted that knowledge gap and laid some of the groundwork for future investigations.

6.5 Limitations of the Research

The research was limited by available resources, timeframe, and interview schedule. Given a longer interview timeline it may have been possible to increase the number of interview participants. The number of available interview participants was also limited by individual calendar and work-related commitments, and delays in response time after initial invitation to interview had been sent. A larger interview sampling size and additional data gathering using surveys or questionnaires may have been beneficial to the study results.

6.6 Opportunities for future research

The secondary research highlighted that a significant number of challenges exist to the transition from a linear economy to a CE. Those challenges are accentuated for the public sector-built environment, due in part to the scale and complexity of the transition required, and to the well-established dominance of the linear economy model of doing business in the construction sector and its value chain. This was evidenced from conversations with industry representatives during the interview process, and from research undertaken as part of the literature survey, however it is not conclusive evidence of a sectoral resistance to circular economy transition and further study and analysis would need to be undertaken to arrive at a more in-depth understanding of the various dynamics retarding the rate of conversion to the CE across the sector.

The research produced four important findings, as outlined above. Each of the findings should be considered for further investigation. The primary research identified a gap between policy aspirations and policy reality. Industry is not moving at a pace necessary for transformational change to have a desired impact, on climate and resource depletion. A wider study of the construction industry is necessitated to understand effective incentivisation of the sector in the direction of the CE. This would involve a larger interview sampling size, surveys, questionnaires, and stakeholder assemblies. Such an undertaking would also involve a longer timescale and more resources.

Classification of materials is of utmost importance in the implementation of an excess materials exchange platform. Once a material is classified as waste, it must, proceed through a highly regulated, waste management process. Trust, material quality, integrity of the data and data verification were major concerns which were expressed as they relate to the reuse of circular materials. Additionally, the subject of material classification was also confirmed as a topic requiring deeper inquiry, during the interview phase of the primary research.

Legislation in the form of mandatory CPP was one of the main findings of this research and further investigation of mandatory CPP could help determine at which phase of the procurement process an EME framework could be best utilised.

A system of governance must be in place to adjudicate and regulate the EME for the public sector. From the research a third party, or commercial semi-state agency was proposed. However, further research is required to determine a best practice model for a commercial semi-state materials trading agency.

Lastly, both the primary and secondary research indicated that carbon would become a more prevalent policy measure. The EME conceptual framework envisages a carbon-based incentivisation mechanism for use in the public sector however, a conclusion was not reached as to what form that incentivisation would take, i.e., carbon taxation, or carbon allowances, or a carbon ration. The utilisation of a system of carbon taxes or allowances to incentivise adoption of CE-related practices deserves further inquiry. Carbon incentives have not been expansively researched as an incentivisation mechanism to accelerate the transition to the CE.

6.7 Summary

There were four objectives to the research; identify the essential characteristics of a public sector focused excess materials exchange (EME) and determine how the public sector can be incentivised to use an excess materials exchange platform and what form incentives would take, the benefits/challenges to implementing a public sector excess materials exchange (EME) and finally, where system ownership of a public sector EME resides. In this chapter I have discussed the main research findings as it pertains to the objectives as outlined above and have identified the impact of the research on both industry and academia, and the limitations to the research, and opportunities for future research.

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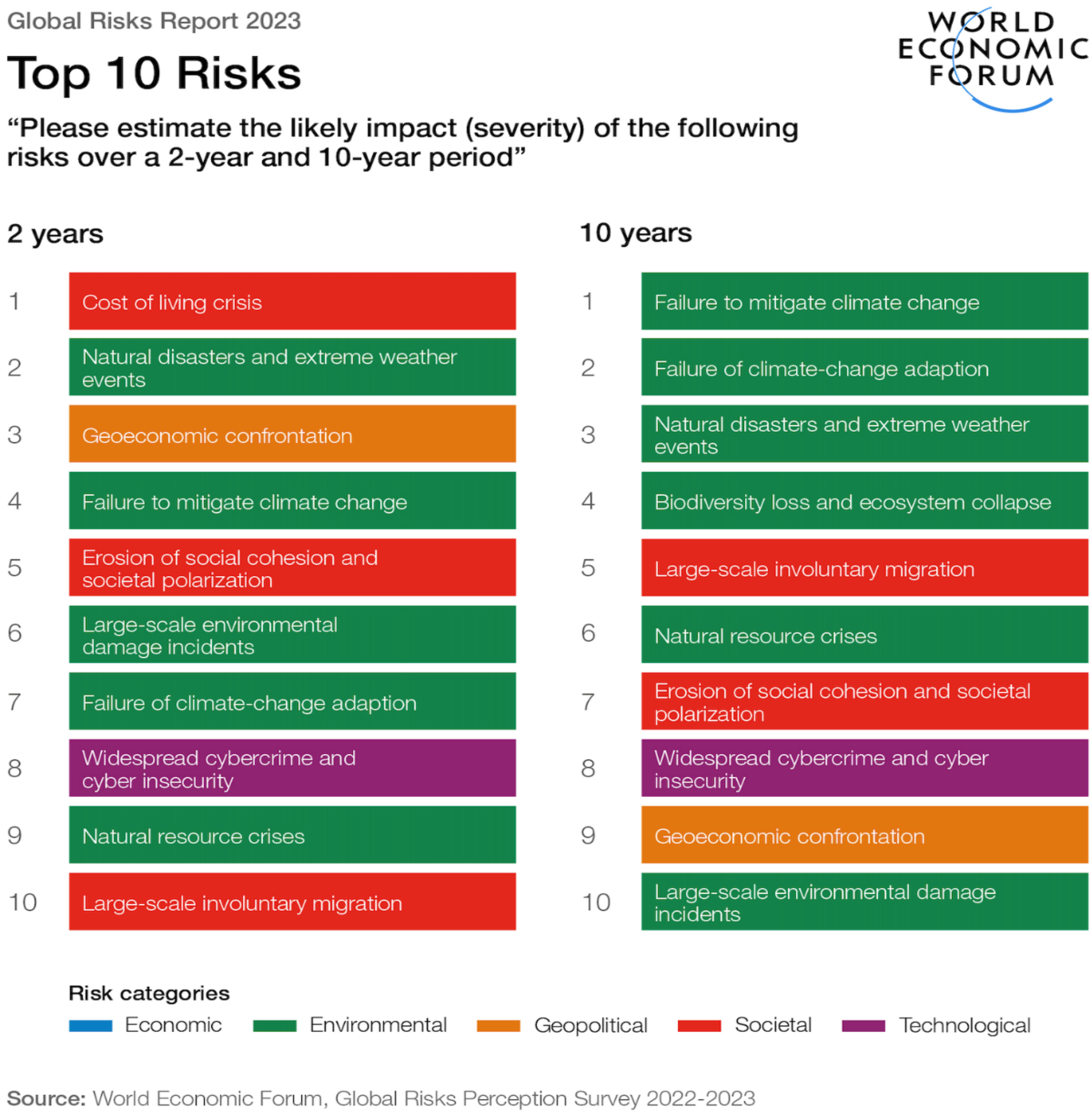
APPENDIX A:



Global Risks Report 2023

Source: WEF (2023)

APPENDIX B:

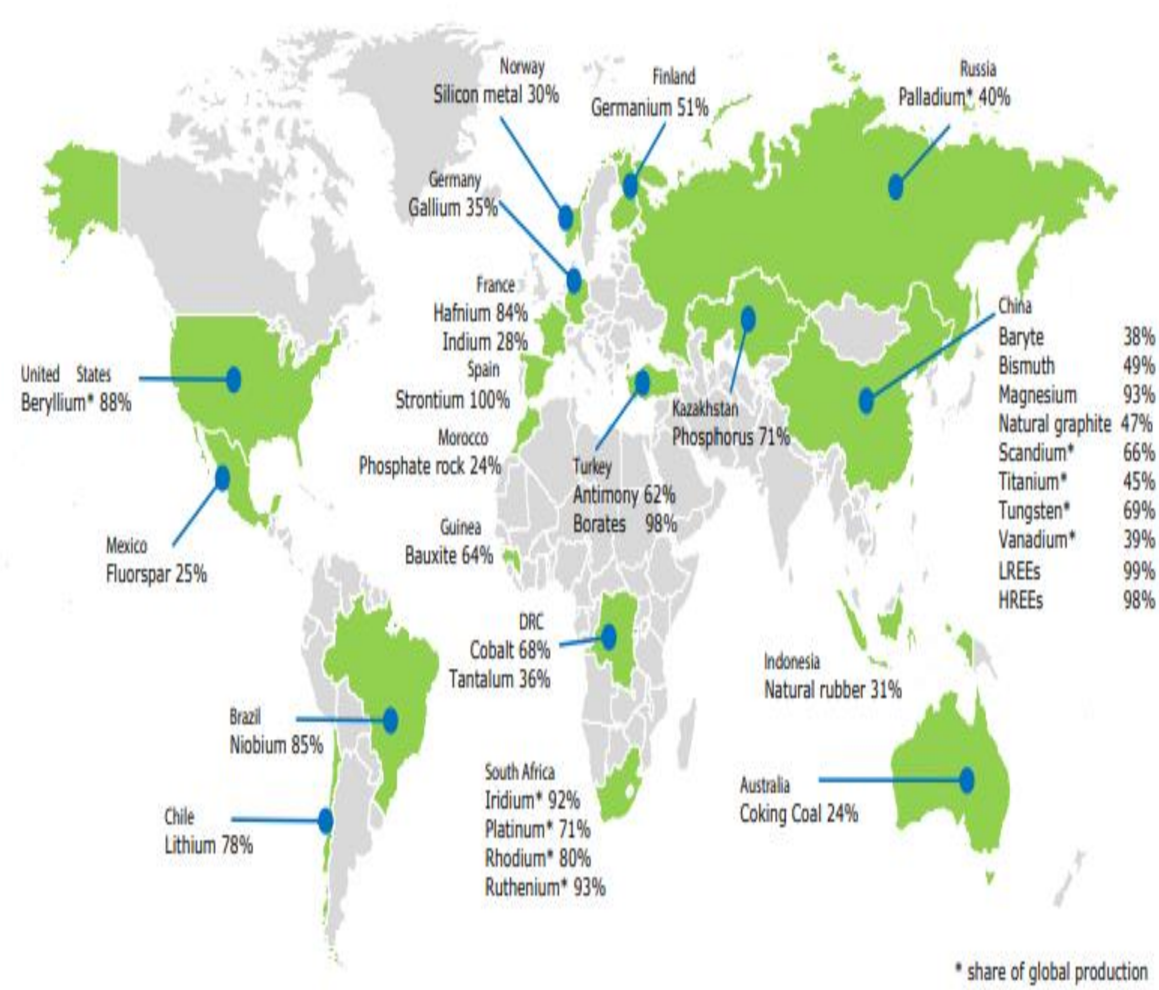
Annex 2: Relevance of Critical Raw Materials for industrial ecosystems

	Aerospace/ defence	Textiles	Electronics	Mobility/ Automotive	Energy-intensive industries	Renewable energy	Agri-food	Health	Digital	Constructi on	Retai l	Proximity / social economy	Tourism	Creative/ cultural industries
Antimony	✓	✓		✓						✓				
Baryte				✓	✓			✓		✓				
Bauxite	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
Beryllium	✓		✓	✓		✓			✓					
Bismuth	✓		✓		✓			✓	✓	✓				
Borate	✓		✓	✓	✓	✓	✓		✓	✓				
Cobalt	✓	✓	✓	✓	✓	✓			✓					
Coking coal				✓	✓	✓								
Fluorspar					✓		✓				✓			
Gallium	✓		✓	✓		✓			✓	✓				
Germanium	✓		✓		✓	✓								
Hafnium	✓		✓		✓	✓			✓					
Indium	✓		✓			✓			✓					
Lithium	✓		✓	✓	✓	✓		✓	✓					
Magnesium	✓		✓	✓	✓				✓	✓				
Natural graphite	✓		✓	✓	✓	✓			✓	✓				
Natural Rubber	✓	✓		✓				✓						
Niobium	✓		✓	✓	✓			✓		✓				
Phosphate rock					✓		✓							
Phosphorus	✓				✓		✓							
Scandium	✓			✓		✓								
Silicon metal	✓	✓	✓	✓	✓	✓		✓		✓				
Strontium	✓		✓		✓			✓		✓				
Tantalum	✓		✓		✓	✓			✓					
Titanium	✓		✓	✓	✓			✓		✓				
Tungsten	✓		✓	✓	✓			✓						
Vanadium	✓			✓	✓	✓		✓		✓				
PGM	✓		✓	✓	✓	✓		✓						
HREE	✓		✓	✓	✓	✓		✓		✓				
LREE	✓		✓	✓	✓	✓		✓		✓				

Relevance of Critical Raw Materials for industrial ecosystems

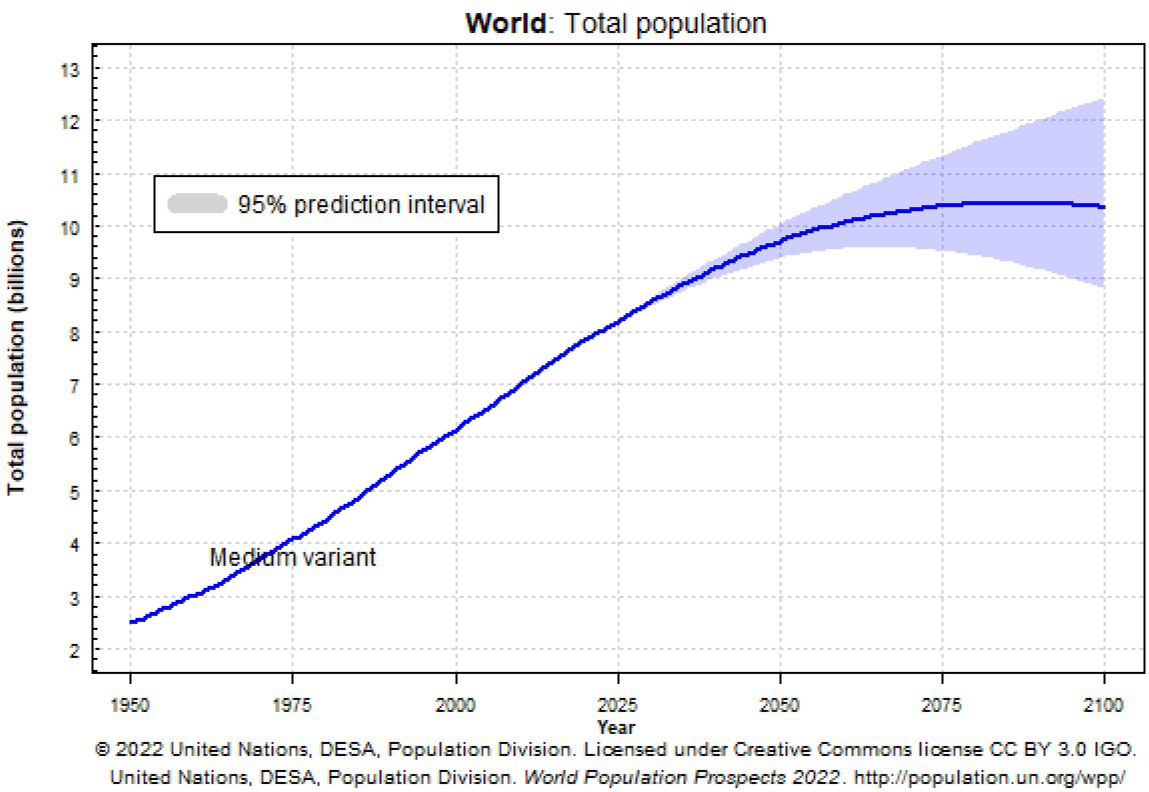
Source: European Commission (2020)

APPENDIX C:



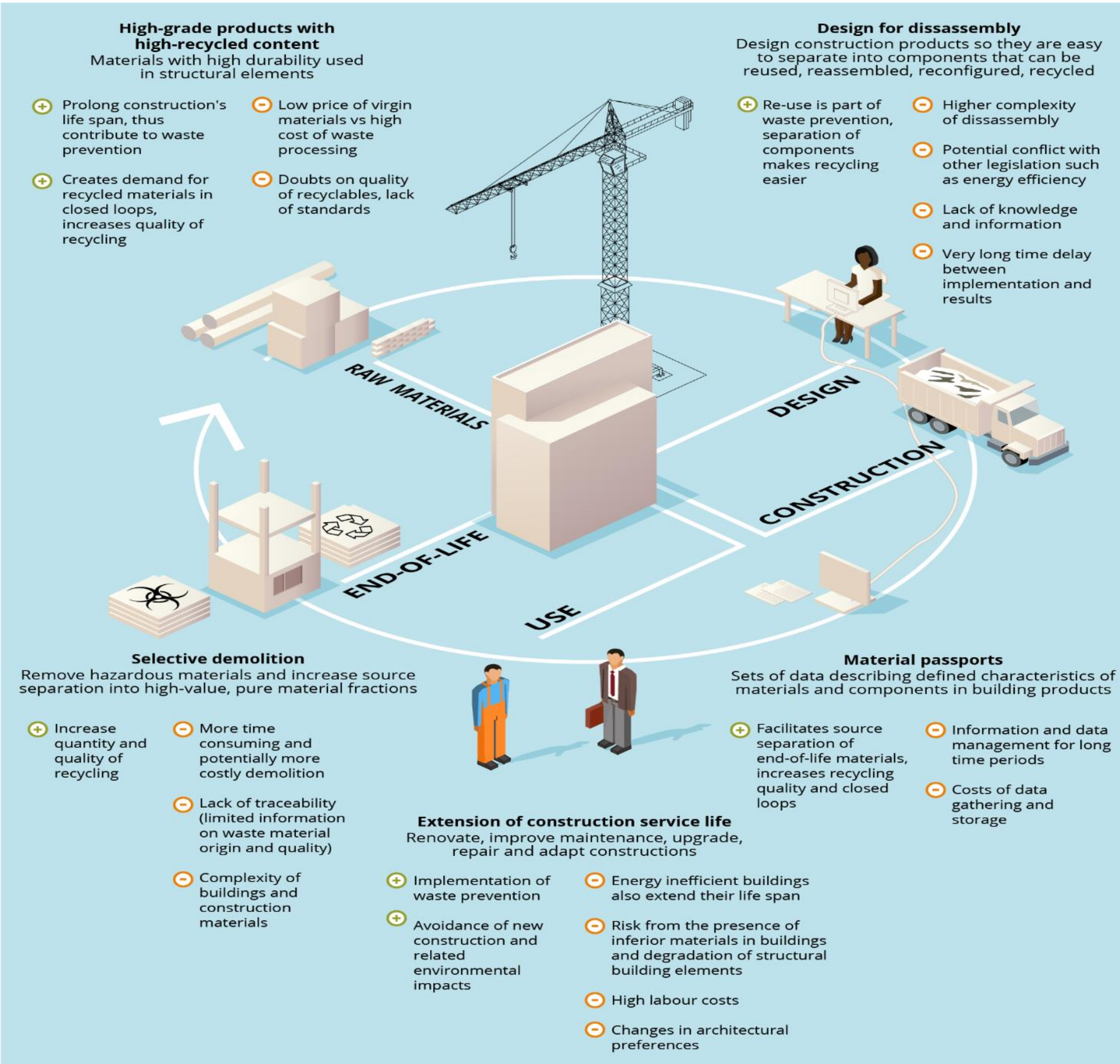
Source: European Commission (2020)

APPENDIX D



Source: World Population Prospects - Population Division - United Nations (2022)

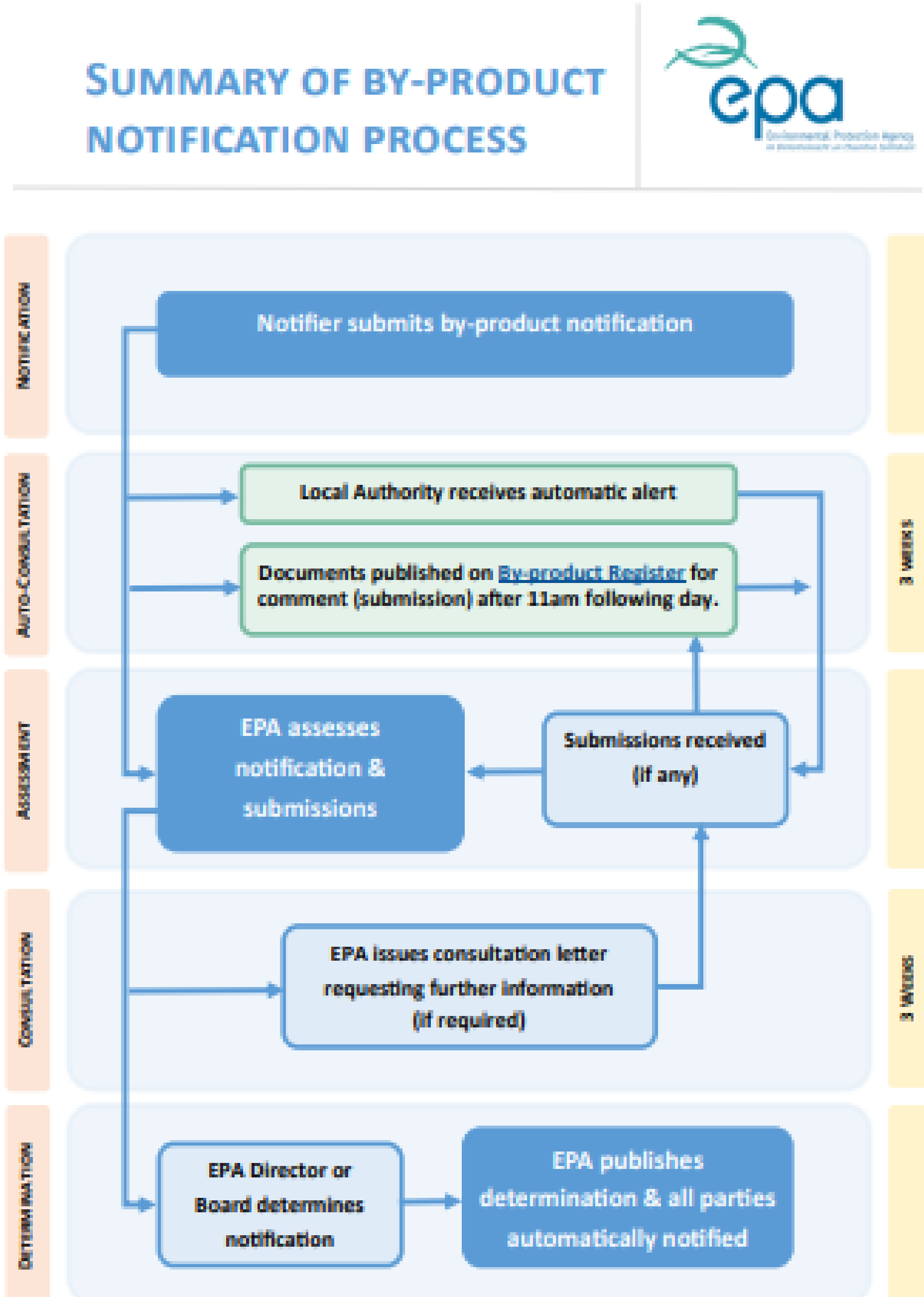
APPENDIX E



Examples of Circular Economy Actions that improve the management of construction and demolition waste

Source: European Environment Agency (2023)

APPENDIX F



By-product Notification Process

Source: gov.ie - Waste Action Plan for a Circular Economy (2020)

APPENDIX G

Interview Data

	Q1. How would you define your organisation?	Q2. Which industry sector best describes your organisation?	Q3. What is your experience/knowledge of the Circular Economy (CE)?	Q4. How would you define the Circular Economy as it pertains to your organisation or industry sector?	Q5. Are you involved in CE-related activities or projects in your organisation?	Q6. In your opinion which of the following areas could help scale the Circular Economy:	Q7. Are you familiar with Excess Materials Exchange platforms?	Q8. What do you understand an EME to be?	Q9. What, in your opinion, are the benefits of Excess Materials Exchange platforms?	Q10. How, in your opinion, could an excess materials exchange be optimally applied for the public sector?
P 1	PRIVATE SECTOR	PROFESSIONAL SERVICES	INTERMEDIATE	MATERIAL VALUE RETENTION OPPORTUNITIES	THE COMPANY PROVIDES BEST-PRACTICE ADVICE TO CLIENTS IN THE PUBLIC SECTOR	ALL	YES	EXCHANGING UNUSED MATERIALS BETWEEN ENTITIES	MINIMISING WASTE	ADDRESSING MATERIAL QUALITY AND REGULATORY CONCERNS
P 2	NOT-FOR-PROFIT	RESEARCH ORGANISATION	NONE	N/A	NO	CARBON TAXES	NO	DON'T KNOW	MINIMISING WASTE	SECTORAL APPROACH
P 3	PRIVATE SECTOR	PROFESSIONAL SERVICES	BASIC	CAN HAVE AN IMPACT THROUGH TRAINING AND CONSULTING WORK	THE COMPANY PROVIDES BEST-PRACTICE ADVICE TO CLIENTS IN THE PUBLIC SECTOR	MATERIAL PASSPORTS	YES	EXCHANGING UNUSED/REUSE MATERIALS BETWEEN ENTITIES	MINIMISING WASTE	SECTORAL APPROACH
P 4	NOT-FOR-PROFIT	REPRESENTATIVE BODY	INTERMEDIATE	MATERIAL VALUE RETENTION OPPORTUNITIES	WORKING ON EXCESS MATERIALS EXCHANGE PILOT PROJECT	ALL	YES	EXCHANGING UNUSED/REUSE MATERIALS BETWEEN ENTITIES	MINIMISING WASTE	REACH ECONOMIES OF SCALE
P 5	PUBLIC SECTOR	PROFESSIONAL SERVICES	INTERMEDIATE	MATERIAL VALUE RETENTION OPPORTUNITIES	SMALL SCALE REFURB PROJECTS	CARBON TAXES	YES	EXCHANGING UNUSED/REUSE MATERIALS BETWEEN ENTITIES	MINIMISING WASTE	ADDRESSING MATERIAL QUALITY AND REGULATORY CONCERNS
P 6	PUBLIC SECTOR	PUBLIC SECTOR ORGANISATION (PROVIDES RESEARCH FUNDING)	INTERMEDIATE	MATERIAL VALUE RETENTION OPPORTUNITIES	END-OF-WASTE CRITERIA	CARBON TAXES	YES	EXCHANGING UNUSED/REUSE MATERIALS BETWEEN ENTITIES	MINIMISING WASTE	REQUIRES A BY-PRODUCT MANAGEMENT PLAN TO AVOID THE WASTE MANAGEMENT PROCESS
P 7	PRIVATE SECTOR	PROFESSIONAL SERVICES	INTERMEDIATE	MATERIAL VALUE RETENTION OPPORTUNITIES	CIRCULAR DESIGN	MATERIAL PASSPORTS	NO	EXCHANGING UNUSED/REUSE MATERIALS BETWEEN ENTITIES	MINIMISING WASTE	CAPTURE MATERIALS THAT ARE IN-SITU BUT ARE REMOVED DUE TO CHANGE IN SPECIFICATION
P 8	PUBLIC SECTOR	COMMERCIAL SEMI-STATE (TRANSPORT SECTOR)	NONE	DON'T KNOW	NO	DON'T KNOW	NO	DON'T KNOW	DON'T KNOW	ENSURE IT IS COMPATIBLE WITH, OR LOOKS LIKE, E-TENDERS
P 9	PUBLIC SECTOR	ACADEMIC INSTITUTION	INTERMEDIATE	MATERIAL SUBSTITUTION OPPORTUNITIES	RESEARCH PROJECTS	MATERIAL PASSPORTS	YES	EXCHANGING UNUSED/REUSE MATERIALS BETWEEN ENTITIES	MINIMISING WASTE	MUST SEAMLESSLY FEED INTO THE PUBLIC PROCUREMENT SYSTEM
P 10	PRIVATE SECTOR	PROFESSIONAL SERVICES	NONE	DON'T KNOW	NO	CARBON ALLOWANCES	NO	DON'T KNOW	MINIMISING WASTE	BUILD KNOWLEDGE
P 11	PUBLIC SECTOR	PUBLIC SECTOR ORGANISATION (GRANT AID + POLICY)	INTERMEDIATE	MATERIAL SUBSTITUTION OPPORTUNITIES	CE IS A SET OF PRINCIPLES AND ACTIONS	MATERIAL PASSPORTS	YES	EXCHANGING UNUSED MATERIALS BETWEEN ENTITIES	MINIMISING WASTE	MATERIAL PASSPORTS
P 12	PUBLIC SECTOR	COMMERCIAL SEMI-STATE (TELECOMMUNICATIONS SECTOR)	INTERMEDIATE	MATERIAL VALUE RETENTION OPPORTUNITIES	MATERIAL SUBSTITUTION FOR LOWER IMPACT	DON'T KNOW	YES	EXCHANGING UNUSED MATERIALS BETWEEN ENTITIES	MINIMISING WASTE	BUILD KNOWLEDGE CAPACITY

Interview Data (Cont'd.)

Q11. Are you familiar with the circular economy procurement framework (see Figure 1)?	Q12. At which stage of the circular economy procurement framework would you envisage an Excess Materials Exchange being most effectively introduced?	Q13. In your opinion, which of the following incentives would increase engagement with CE principles across the public sector?	Q14. Which of the following, in your opinion, would be the key attributes of an EME platform for your organisation, or industry sector? (Check all that apply)	Q15. What, in your opinion, are the principal barriers to adoption of excess materials exchange platforms in your organisation, or industry sector?	Q16. What, in your opinion, is the correlation between a circular material and its carbon footprint?	Q17. Are you familiar with the concept, and role, of carbon caps (limits)?	Q18. How would carbon caps (limits) if applied to your organisation, or industry sector, impact your organisation's transition to a CE?	Q19. In an ideal world, where would the ownership for a public-sector EME lie?	Q20. Are there any other aspects of the concept of an EME that you would like to expand upon?	
YES	NEEDS ASSESSMENT + AWARD CRITERIA	MANDATORY CPP	GUARANTEED DATA INTEGRITY	OVERCOMING PUBLIC SECTOR RISK AVERSION	CARBON FOOTPRINT IS DEPENDENT ON NEXT USE STAGE	YES	CARBON PRICE WOULD INCENTIVISE CHANGE	THIRD SECTOR (COMMERCIAL STATE AGENCY)	PUBLIC SECTOR IS RISK AVERSE	PROCUREMENT TRAINING & CONSULTING
NO	DON'T KNOW	GREATER KNOWLEDGE CAPACITY	GUARANTEED DATA INTEGRITY	THE PUBLIC PROCUREMENT PROCESS	CARBON FOOTPRINT IS DEPENDENT ON NEXT USE STAGE	YES	SET SECTORAL BUDGETS AT A LOCAL AUTHORITY LEVEL	THIRD SECTOR (COMMERCIAL STATE AGENCY)	BEHAVIOURAL NUDGING	ECONOMIC AND SOCIAL RESEARCH
YES	NEEDS ASSESSMENT + CONTRACTS MANAGEMENT	GREATER KNOWLEDGE CAPACITY + MANDATORY CPP	ALL	SCALING/DEVELOPING TRUST	CARBON FOOTPRINT IS DEPENDENT ON NEXT USE STAGE	YES	CARBON PRICE WOULD INCENTIVISE CHANGE	THIRD SECTOR (COMMERCIAL STATE AGENCY)	SET UP A NEW STATE AGENCY TO RUN IT. A LARGE INVESTMENT REQUIRED.	PROCUREMENT TRAINING & CONSULTING
YES	NEEDS ASSESSMENT	ALL	GUARANTEED DATA INTEGRITY	OVERCOMING PUBLIC SECTOR RISK AVERSION	CARBON FOOTPRINT IS DEPENDENT ON NEXT USE STAGE	YES	CARBON PRICE WOULD INCENTIVISE CHANGE	THIRD SECTOR (COMMERCIAL STATE AGENCY)	PUBLIC SECTOR IS RISK AVERSE	INDUSTRY EDUCATION
YES	NEEDS ASSESSMENT	MANDATORY CPP	COMPATIBILITY WITH PUBLIC PROCUREMENT PROCESS	BUILDING KNOWLEDGE CAPACITY	CARBON FOOTPRINT IS DEPENDENT ON NEXT USE STAGE	YES	CARBON PRICE WOULD INCENTIVISE CHANGE	THIRD SECTOR (COMMERCIAL STATE AGENCY)	COULD WORK FOR SMALL SCALE INITIATIVES	STATE DEVELOPMENT
YES	NEEDS ASSESSMENT	MANDATORY CPP	MATERIAL AVAILABILITY	REGULATION + PROXIMITY PRINCIPLE	CARBON FOOTPRINT IS DEPENDENT ON NEXT USE STAGE	YES	AVAILABILITY OF DATA	PUBLIC SECTOR	REGULATION IS KEY	STATE DEVELOPMENT
NO	NEEDS ASSESSMENT	MANDATORY CPP	GUARANTEED DATA INTEGRITY + LCA	RECERTIFICATION OF USED MATERIALS	CARBON FOOTPRINT IS DEPENDENT ON NEXT USE STAGE	YES	CARBON PRICE WOULD INCENTIVISE CHANGE	THIRD SECTOR (COMMERCIAL STATE AGENCY)	CARBON CAPPING THE CONSTRUCTION INDUSTRY	ARCHITECTURE
NO	NEEDS ASSESSMENT	MANDATORY CPP	GUARANTEED DATA INTEGRITY + COMPATIBILITY WITH PUBLIC PROCUREMENT PROCESS	BUILDING KNOWLEDGE CAPACITY	CARBON FOOTPRINT IS DEPENDENT ON NEXT USE STAGE	NO	CARBON PRICE WOULD INCENTIVISE CHANGE	PUBLIC SECTOR	IN PRACTICAL TERMS THE CE IS 10-15 YEARS FROM REALISATION	TRANSPORT
NO	TENDER	MANDATORY CPP	ALL	REGULATION + PROXIMITY PRINCIPLE	CARBON FOOTPRINT IS DEPENDENT ON NEXT USE STAGE	YES	COLLABORATION ACROSS VALUE CHAIN	THIRD SECTOR (COMMERCIAL STATE AGENCY)	WITHOUT INCENTIVES IT WILL BE DIFFICULT TO BUILD A USER BASE	EDUCATION
NO	DON'T KNOW	MANDATORY CPP	GUARANTEED DATA INTEGRITY	MADATORY REGULATIONS	CARBON FOOTPRINT IS DEPENDENT ON NEXT USE STAGE	NO	DON'T KNOW	THIRD SECTOR (COMMERCIAL STATE AGENCY)	BUILD SUPPLY CHAIN CAPACITY	CONTRACT MANAGEMENT
YES	NEEDS ASSESSMENT	MANDATORY CPP	GUARANTEED DATA INTEGRITY + COMPATIBILITY WITH PUBLIC PROCUREMENT PROCESS	MADATORY REGULATIONS	CARBON FOOTPRINT IS DEPENDENT ON NEXT USE STAGE	YES	COLLABORATION ACROSS VALUE CHAIN	THIRD SECTOR (COMMERCIAL STATE AGENCY)	WOULD VIEW CE AS 2ND ONLY TO ELECTRIFICATION AS PRIMARY DRIVER OF DECARBONISATION	GOVERNMENT POLICY
YES	NEEDS ASSESSMENT	GREATER KNOWLEDGE CAPACITY	GUARANTEED DATA INTEGRITY + COMPATIBILITY WITH PUBLIC PROCUREMENT PROCESS	TRANSACTION FEES, EDUCATION & TRAINING, SYSTEM MANAGEMENT, BUY-IN, ACCESS	CARBON FOOTPRINT IS DEPENDENT ON NEXT USE STAGE	YES	ACCELERATE THE TRANSITION	THIRD SECTOR (ACADEMIC INSTITUTION)	TRANSACTION FEES	TELECOMMUNICATIONS

APPENDIX H

Participant Information Sheet

STUDENT NAME: DAVID WHELAN

CONTACT DETAILS: DAVID.WHELAN@research.atu.ie

MOBILE: 085 1069414

STUDY OVERVIEW

This study forms part of the dissertation undertaken by David Whelan for the award of MSc. Circular Economy Leadership at Atlantic Technological University.

The aim of this study is to develop a conceptual framework for a peer-peer excess materials exchange for the public sector, the goal of which is to accelerate that transition to a circular economy (CE). There is a particular focus in the development of the exchange on the use of carbon-based incentivisation mechanisms and its application to the built environment, with particular emphasis on construction and demolition waste streams (given the scale of C&D waste across the EU). The interview process is designed to solicit feedback from experts on the viability of an excess materials exchange, the possible challenges to wider scale adoption of the exchange, the opportunities to link adoption of the exchange across the public sector with an incentivisation structure based on carbon allowances, and lastly to help identify the best available technologies and processes to accelerate more rapid adoption of the excess materials exchange.

The output of the study is to demonstrate the viability, or otherwise, of excess materials exchange across the public sector-built environment and determine if incentivisation structures can be put in place to encourage increased public sector participation. Lastly, the study examines whether increased adoption of excess materials exchange can accelerate the transition to a Circular Economy.

All responses to the following questions are confidential and anonymised for the purposes of publication of the final dissertation document.

APPENDIX I

Participant invitation and information sheet

Dear …,

I would like to invite you to partake in a research interview as part of my research work to develop a conceptual framework for a peer-peer excess materials exchange for the public sector. This research is important in helping position Ireland towards meeting its obligations to develop a more circular economy which will reduce waste and emissions.

The research is being conducted in fulfilment of the requirements of the of M.Sc. in Circular Economy Leadership for the Built Environment at Atlantic Technological University (Galway-Mayo). The output from the study will be a thesis and associated research paper(s).

STUDENT NAME: DAVID WHELAN

CONTACT EMAIL: DAVID.WHELAN@research.atu.ie

MOBILE NUMBER: 085-1069414

RESEARCH SUPERVISOR: Dr John Scahill

CONTACT EMAIL: john.scahill@atu.ie

STUDY OVERVIEW.

The aim of this study is to develop a conceptual framework for a peer-peer excess materials exchange for the public sector, the goal of which is to accelerate that transition to a circular economy (CE). There is a particular focus in the development of the exchange on the use of carbon-based incentivisation mechanisms and its application to the built environment, with particular emphasis on construction and demolition waste streams (given the scale of C&D waste across the EU). The interview process is designed to solicit feedback from experts on the viability of an excess materials exchange, the possible challenges to wider scale adoption of the exchange, the opportunities to link adoption of the exchange across the public sector with an incentivisation structure based on carbon allowances, and lastly to help identify the best available technologies and processes to accelerate more rapid adoption of the excess materials exchange.

The output of the study is to demonstrate the viability, or otherwise, of excess materials exchange across the public sector-built environment and determine if incentivisation structures can be put in place to encourage increased public sector participation. Lastly, the study examines whether increased adoption of excess materials exchange can accelerate the transition to a Circular Economy.

Confidentiality and anonymity

All responses given in the interviews are held confidential and data will be stored only on an official ATU (Galway-Mayo) encrypted file server. All data used will be fully anonymised for the purposes of publication of the final thesis document and associated research paper(s). All interview data will be deleted/destroyed as soon as practicable after the fulfilment of the degree requirements have been met.

Interview format

The interview will be semi-structured in nature using a template of questions that have been developed from an in-depth study of literature published in this area. You are of course also invited and encouraged to give your wider/general insights into the subject matter.

Ethical approach

This study has been the subject of a formal ethics application to the Atlantic Technological University (Galway-Mayo), School of Engineering ethics committee. As part of the ethical approval for the study it is a requirement that participants must formally state that they are partaking freely and that they have been advised of their rights to terminate their involvement. A participant agreement form is thus attached for your signature.

May I offer my sincere thanks for your agreement to take part in my study.

Kind regards.

David Whelan

APPENDIX J

Ollscoil Teicneolaíochta an Atlantaigh
Atlantic Technological University

Participant consent form for research interviews

STUDENT NAME: DAVID WHELAN

CONTACT DETAILS: DAVID.WHELAN@RESEARCH.ATU.IE

RESEARCH SUPERVISOR: DR JOHN SCAHILL

CONTACT DETAILS: JOHN.SCAHILL@ATU.IE

Programme Details.

This research is being undertaken as part of the M.Sc. degree in Circular Economy Leadership for the Built Environment Programme at Atlantic Technological University (Galway-Mayo). Data collected in this study will only be used for publication of a thesis and associated research paper(s) which are in fulfilment of the degree requirements.

Title of research study.

Accelerating the transition to a circular economy (CE) for the public sector through exchange of excess materials: A conceptual framework for a carbon-indexed excess materials exchange based on a preliminary analysis of the potential material retention and energy savings available from the construction and demolition (C&D) waste stream.

Study Overview.

The aim of this study is to develop a conceptual framework for a peer-peer excess materials exchange for the public sector, the goal of which is to accelerate that transition to a circular economy (CE). There is a particular focus in the development of the exchange on the use of carbon-based incentivisation mechanisms and its application to the built environment, with particular emphasis on construction and demolition waste streams (given the scale of C&D waste across the EU). The interview process is designed to solicit feedback from experts on the viability of an excess materials exchange, the possible challenges to wider scale adoption of the exchange, the opportunities to link adoption of the exchange across the public sector with an incentivisation structure based on carbon allowances, and lastly to help identify the best available technologies and processes to accelerate more rapid adoption of the excess materials exchange. The output of the study is intended to demonstrate the viability, or otherwise, of excess materials exchange across the public sector-built environment and determine if incentivisation structures can be put in place to encourage increased public sector participation. Lastly, the study examines whether increased adoption of excess materials exchange can accelerate the transition to a Circular Economy.

Confidentiality and anonymity.

All responses given in the interviews are held confidential and data will be stored only on an official ATU (Galway-Mayo) encrypted file server. All data used will be fully anonymised for the purposes of publication of the final thesis document and associated research paper(s). All interview data will be deleted/destroyed as soon as practicable after the fulfilment of the degree requirements have been met.

Note: Participants who wish to withdraw their consent should do so via email to David Whelan and Dr John Scahill.

Participant Declaration

Please agree to the following statements

(1) I have read, or have had read to me, the Participant Information Sheet, and I understand the contents

☐ Yes ☐ No

(2) I have been given an opportunity to ask questions and am satisfied with all the answers I was given

☐ Yes ☐ No

(3) I consent to take part in the study

☐ Yes ☐ No

(4) I understand that participation is voluntary and that I can withdraw at any time

☐ Yes ☐ No

(5) I understand that withdrawal will not affect my access to services or legal rights

☐ Yes ☐ No

(6) I consent to possible publication of findings in management, scientific or research journals. Any publication will be strictly anonymous and free from identifying data.

☐ Yes ☐ No

(7) I give my permission to use the data obtained from me in other future studies without the need for additional consent

☐ Yes ☐ No

Participant's Statement:

I have read, or have had read to me, this consent form. I have had the opportunity to ask questions and all my questions have been answered to my satisfaction. I freely and voluntarily agree to be part of this research study, thought without prejudice to my legal and ethical rights. I understand that I may withdraw from the study at any time.

Name:

____

____

Contact Details (Preferred method of being contacted, could be email or phone etc.)

By checking this box, I give my consent. (You must be 18 years or over to participate in this study.)

☐ I consent

APPENDIX K

Dissertation Research Questions

STUDENT NAME: DAVID WHELAN

CONTACT DETAILS: DAVID.WHELAN@RESEARCH.ATU.IE

RESEARCH SUPERVISOR: DR JOHN SCAHILL

CONTACT DETAILS: JOHN.SCAHILL@ATU.IE

Programme Details.

This research is being undertaken as part of the M.Sc. degree in Circular Economy Leadership for the Built Environment Programme at Atlantic Technological University (Galway-Mayo). Data collected in this study will only be used for publication of a thesis and associated research paper(s) which are in fulfilment of the degree requirements.

General

1. How would you define your organisation?

- Public sector
- Private Sector
- Not-for-Profit/Social Enterprise

2. Which industry sector best describes your organisation?

- Professional Services
- Academic Institution
- Research organisation
- Public Sector Organisation (PSO)
- Other (please explain)

Note: If Public Sector Organisation (PSO), which department?

Circular Economy

3. What is your experience/knowledge of the Circular Economy (CE)?

Please explain …

4. **How would you define the Circular Economy as it pertains to your organisation or industry sector?**

Please explain …

5. **Are you involved in CE-related activities or projects in your organisation?**

(Yes/No)

If Y*es,* please explain….

If *No,* are there any plans to initiate CE-related projects in the future?

Built Environment

6. **In your opinion which of the following areas could help scale the Circular Economy:**

- Material passports
- Artificial Intelligence
- Blockchain Technology
- Carbon taxes

- Carbon Allowances

Please explain your reasoning …

Excess Materials Exchange

7. **Are you familiar with Excess Materials Exchange platforms?**

Please explain …

8. **What do you understand an EME to be?**

Please explain …

9. **What, in your opinion, are the benefits of Excess Materials Exchange platforms?**

Please explain …

10. **How, in your opinion, could an excess materials exchange be optimally applied for the public sector?**

Please explain …

11. **Are you familiar with the circular economy procurement framework (see Figure 1)?**

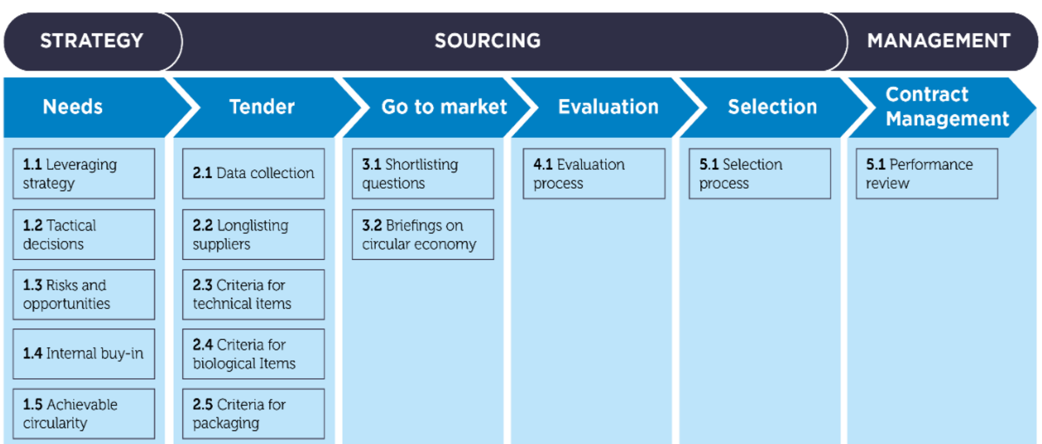


Figure 1: Circular economy procurement framework overview

Source: Ellen MacArthur Foundation

12. **At which stage of the circular economy procurement framework would you envisage an Excess Materials Exchange being most effectively introduced?**

Please explain your reasoning ...

13. **In your opinion, which of the following incentives would increase engagement with CE principles across the public sector?**

- Greater knowledge capacity around the CE
- Better data flow internal to your organisation
- Mandatory Circular Public Procurement procedures

Are there other initiatives that you think might increase uptake?

14. **Which of the following, in your opinion, would be the key attributes of an EME platform for your organisation, or industry sector? (Check all that apply)**

- Flexibility of the system for different material codes
- Data availability
- Guaranteed data integrity (Accuracy and trustworthiness)
- Compatibility with public procurement process
- Cost/Benefit Analysis (LCC) capability
- Lifecycle Analysis (LCA) capability

Please explain your choices by defining the importance of each criterion to the EME ...

15. **What, in your opinion, are the principal barriers to adoption of excess materials exchange platforms in your organisation, or industry sector?**

Please explain …

16. **What, in your opinion, is the correlation between a circular material and its carbon footprint?**

Please explain …

17. **Are you familiar with the concept, and role, of carbon caps (limits)?**
18. **How would carbon caps (limits) if applied to your organisation, or industry sector, impact your organisation's transition to a CE?**

Please explain …

19. **In an ideal world, where would the ownership for a public-sector EME lie?**

- Public sector
- Private Sector
- A third sector (state agency/university or academic/research institution)

Please explain …

20. **Are there any other aspects of the concept of an EME that you would like to expand upon?**

Please explain …

APPENDIX L

Step 1: Prepare
- Understand what carbon pricing and emissions trading are and how they work
- Determine the objectives for your ETS
- Decide the ETS's role in the climate policy mix
- Understand the ETS's interaction with other policies
- Select criteria to assess ETS design options

Step 2: Engage stakeholders, communicate and build capacities
- Map stakeholders and respective positions, interests, and concerns
- Coordinate across departments for a transparent decision-making process and to avoid policy misalignment
- Design an engagement strategy for consultation of stakeholder groups specifying format, timeline, and objectives
- Design a communication strategy that resonates with local and immediate public concerns
- Identify and address ETS capacity-building needs

Step 3: Decide the scope
- Decide which sectors to cover
- Decide which gases to cover
- Choose the points of regulation
- Choose the entities to regulate and consider whether to set thresholds
- Choose the point of reporting obligation

Step 4: Set the cap
- Determine the ambition of the cap, type of cap, and approach to cap setting
- Create a robust foundation of data to determine the cap
- Choose time periods for cap setting
- Agree upon formal legal and administrative governance arrangements
- Agree on a long-term cap trajectory and strategy for providing a consistent price signal

Step 5: Distribute allowances
- Match allocation methods to policy objectives
- Define eligibility and methods for free allocation
- Define treatment of entrants, closures, and exits
- Set up auctions to play an increasing role over time while reducing free allocation

Step 6: Promote a well-functioning market
- Establish the rationale for, and risks associated with, market intervention
- Establish rules for banking and borrowing
- Establish rules for market participation
- Identify the role played by a robust secondary market
- Choose whether to intervene to address low prices, high prices, or both
- Choose the appropriate price or supply adjustment measure

Step 7: Ensure oversight and compliance
- Identify the regulated entities
- Manage emissions reporting by regulated entities
- Approve and manage the performance of verifiers
- Establish and oversee the ETS registry
- Design and implement the penalty and enforcement approach
- Regulate and oversee the market for ETS emissions allowances

Step 8: Consider the use of offsets
- Outline the potential role of offsets within an ETS
- Decide on the type of offsets allowed within the system (both geographical scope and governance of program)
- Weigh costs of establishing a domestic offset program versus making use of an existing program
- Decide on qualitative and quantitative limits on the use of offsets

Step 9: Consider linking
- Identify potential linkage partners
- Determine the type of link
- Identify the benefits and risks associated with the link
- Discuss compatibility of key program design features
- Form and govern the link

Step 10: Implement, evaluate, and improve
- Decide on the timing and process of ETS implementation
- Decide on the process and scope for reviews
- Identify why the design of the ETS may need to change over time
- Evaluate the ETS to support future improvement

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Source: Readiness and Partnership (2021)