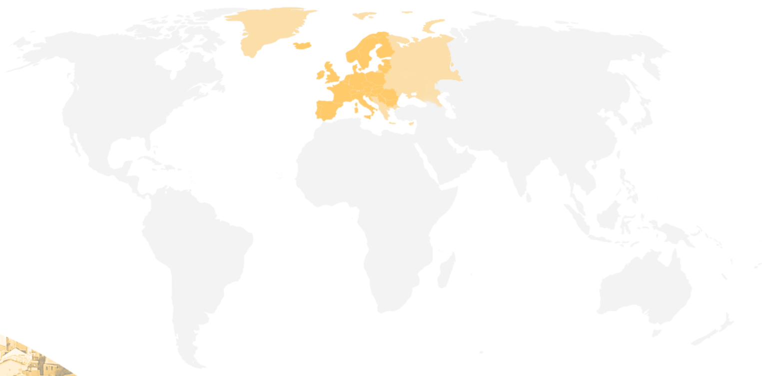

State of Play for Circular Built Environment in Europe

Countries considered:
the member states of the European Union, Iceland, Norway, Serbia and the United Kingdom

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One planet build with care

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One Planet Network

The One Planet network has been formed to implement the 10-Year Framework of Programmes on Sustainable Consumption and Production (SCP), which supports the global shift to SCP and the achievement of SDG 12. The One Planet Network acts as an enabler bringing actors from all regions to pool their expertise, resources, innovation and commitment towards a shift to more sustainable modes of production and consumption. The network comprises of six programmes: Sustainable Public Procurement, Sustainable Buildings and Construction, Sustainable Tourism, Sustainable Food Systems Programme, Consumer Information for SCP, Sustainable Lifestyles and Education.

Sustainable Buildings and Construction Programme

The Sustainable Buildings and Construction Programme (SBC) aims at improving the knowledge of sustainable construction and to support and mainstream sustainable building solutions. Through the programme, all major sustainable construction activities can be brought together under the same umbrella. The work involves sharing good practices, launching implementation projects, creating cooperation networks and committing actors around the world to sustainable construction. The goal of the programme is to promote resource efficiency, mitigation and adaptation efforts, and the shift to SCP patterns in the buildings and construction sector.

State of Play Reports

The Sustainable Buildings and Construction Programme has been preparing regional reports on the state of play for circular built environment in Africa, Asia, Europe, Gulf Cooperation Council countries, Latin America and the Caribbean, North America, and Oceania. In addition to regional outlooks, a global report has been produced to summarise and compare the state of play regarding circularity in different regions. A crucial role of the reports is not only to provide a benchmark but also recommendations on how to move forward towards a sustainable and circular built environment.

Table of contents

	List of figures	6
	List of tables	6
	List of acronyms and abbreviations	6
	Executive summary	7
1.	Introduction	8
2.	Significance of this work	8
3.	Impact of the built environment	9
	3.1 Impact on the environment	9
	3.2 Impact on the economy	10
4.	C&D waste stream	10
	4.1 Building-related waste per person	11
	4.2 Breakdown of waste into material categories	12
	4.3 Recovery rates	13
5.	Shifting from a linear to a circular economy	15
	5.1 Job creation	16
	5.2 Lifecycle phases	18
	5.3 Circular procurement models	19
6.	Policies	20
	6.1 Recovery targets regarding C&D waste	22
	6.2 Deconstruction and renovation permits and audits	22
	6.3 Landfill restrictions	22
	6.4 Hazardous waste	23
	6.5 Policies reducing the use of virgin materials or natural resources	23
	6.6 Enforcement	23
	6.7 Allow space for recycling or stockpiling	23
	6.8 Legislation and standards regarding recycled materials	24
	6.9 The public sector guiding and supporting the private sector	24
	6.10 Public procurement	24
	6.11 Increase research and foster innovation	25
	6.12 Carbon budgets	26

7. Incentives 26
7.1 Density bonuses 26
7.2 Influential taxation 26
7.3 Grants 27
7.4 Loans 27
7.5 Deconstruction aid 27
7.6 Performance-based procurement 27
7.7 Competitions 28
7.8 Who provides the incentives? 28
8. Design issues and policies/regulation 29
8.1 Lifecycle assessment and costs 30
8.2 Choice of material 30
8.3 Design for durability 32
8.4 Design adaptable buildings 32
8.5 Design for disassembly 33
8.6 Design for sharing 34
8.7 Information sharing 35
8.8 Labour upskilling 35
9. Analysis and evaluation 35
9.1 Conclusions and recommendations 37
References 43

List of figures

Figure 1	Leapfrogging into circular economy	9
Figure 2	Generation of C&D waste, EU, 2010–16	10
Figure 3	Generation of C&D waste per capita, EEA, 2016	11
Figure 4	Breakdown of total generated C&D waste, 2012	12
Figure 5	Recovery rate of non-hazardous mineral C&D waste, EEA, 2016	13
Figure 6	Treatment of mineral waste from construction and deconstruction, EEA, 2016	14
Figure 7	Linear versus circular construction	15
Figure 8	Circular economy job impacts across the EU's 28 sectors in 2030	17
Figure 9	Circularity checklist in different lifecycle phases	18
Figure 10	Circular procurement models	19
Figure 11	Desired material flow and supporting policies	21
Figure 12	Actors in the construction field and their impact on a building's durability and adaptability and the reduction of C&D waste	29
Figure 13	Share of operational emissions in a building's carbon footprint	31
Figure 14	CO_2e emissions and carbon storage capacity in building material alternatives	32
Figure 15	Design for disassembly	33
Figure 16	Goals and challenges related to key solutions	36

List of tables

Table 1	Building lifecycle impacts	38

List of acronyms and abbreviations

ARA	Housing Finance and Development Centre of Finland
BREEAM	Building Research Establishment Environmental Assessment Method
C&D	Construction and demolition
CPR	Construction Products Regulation
EEA	European Environment Agency
EFR	Environmental Fiscal Reform
EU	European Union
EC	European Commission
GDP	Gross domestic product
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
LEED	Leadership in Energy and Environmental Design
RAKLI	Finnish Association of Property Owners and Construction Clients
USGBC	United States Green Building Council
WFD	Waste Framework Directive

Executive summary

Europe has a population of approximately 748 million people, of whom 75% live in cities (UN 2019). The population growth in the region is expected to peak in 2021, whereafter it will slowly start to decrease. Whereas the overall population is expected to decrease by 15% by 2100, the urban population is expected to grow by 7–8%, while Europe's regional population will slowly start to get smaller. By comparison, the global population is expected to grow by almost 40% by 2100, accompanied by rapid urbanisation, especially in the Global South. Furthermore, the world is rapidly exceeding, and to some extent already has exceeded, the limitations set by nature.

Europe differs from the other regions not only because of its projected decrease in population and high development rate, but also because of the unity brought by the European Union (EU). The 27 European countries (out of 44) that are EU member states are committed to common legislation and to being forerunners to circularity in the built environment. Along the circularity spectrum, Europe is further along than other regions, mainly because of its head start of more than a decade. However, circular economy practice is still in its infancy, even in Europe. It has proven to be difficult to change the deep-rooted linear economy practices. Fortunately, the construction industry in Europe is already to some extent digitised, which makes it easier to introduce various digital tools to support sustainable development. In Europe, because of the projected decrease in population, the focus regarding circularity in the built environment should be on the existing building stock, while new construction practice is the focus in developing societies. Even though the need of new construction in Europe will decrease, it will not stop completely. All buildings, new and old, need to be (re)designed and (de)constructed with circularity in mind, in order to support closed loops of material also in the future.

In the EU, buildings are responsible for 40% of total EU final energy consumption while causing 35% of all greenhouse emissions (European Commission [EC] 2020a). Furthermore, the construction industry produces 25–30% of the generated waste, making it one of the major waste producers (EC 2019a). While a recovery target of 70% has been set for construction and demolition (C&D) waste in the EU, and most countries are reporting such rates, the recovery undertaken is mainly downcycling.

The EU and many European countries have legislation, guidelines and incentives that promote circularity. Good guidelines and practices (even though they might not be widely used) already exist when it comes to new construction. The main issue is the existing building stock, which has not been designed or built with circularity or adaptability (nor resilience from a climate change perspective) in mind, which is the main cause for the premature deconstruction of buildings. Innovation and new solutions are needed to prolong the lifespan of the existing building stock. Fortunately, the concept of circular economy has a strong presence in the media and is familiar to most people. Nevertheless, the transition is happening slowly, and new policies and incentives are in progress across the region, waiting to further boost circularity. The throwaway culture has to be systematically eliminated from construction, and buildings need to be seen as temporary material banks. When developing the required new strategies and practices, cooperation and information flow between all involved actors are crucial in order to achieve successful and sustainable transformation. Construction needs to be viewed holistically and changes need to be applied throughout society; to legislation, incentives, guidelines, common practices, procurement models and the mindsets of people. Ideally, the other regions of the world can learn from Europe's longstanding work towards more circular construction and thus avoid the common pitfalls and fast-track to a sustainable economy.

1. Introduction

The world is exceeding, and to some extent already has exceeded, the boundaries set by our environment. The built environment is responsible for almost 40% of global CO2 emissions and half of all extracted materials are used in construction (Global Alliance for Buildings and Construction 2019). The construction industry is one of the main industries causing global warming (ibid). Thus, there is a great need to change the way we construct and deconstruct our buildings. Decarbonising the construction industry and making the material flows cyclic are crucial if we intend to avoid environmental disaster. This change will require transformation of the prevalent economic model from linear to circular.

This report aims to determine where we stand regarding circularity in the built environment in the case of Europe. It begins with an explanation of why this transition to circular economy is important and how the building industry in this region affects both the economy and the environment. Furthermore, it aims to depict the current flow of construction materials and to pinpoint the problems in current practices. The current linear economic model is then compared with the sustainable circular economic model. This is followed by a discussion of a wide range of policies and incentives that are currently in use or should be used to promote a sustainable transformation. In addition, the report explains how the design culture needs to change in order to promote circular practice. Throughout the report, best (and in some cases worst) practices in the European Union or in individual European countries are considered to depict what the much-needed changes could look like in practice. The report also presents the actors involved in the construction process and their roles in this needed transition. The majority of solutions presented in this study originate from the reports of the European Commission (EC). After analysing the limitations of the status quo and presenting some possible solutions, final conclusions are drawn and recommendations for the future are proposed.

2. Significance of this work

According to the 2018 Special Report of the Intergovernmental Panel on Climate Change (IPCC) we need to stop global warming at 1.5–2 degrees Celsius if we intend to avoid irreversible environmental damage. Global emissions were approximately 52 GtCO2e in 2016 and they are projected to be 52–58 GtCO2e by 2030. However, for us to limit global warming to 1.5 degrees Celsius, the emissions must be half of the current projection (IPCC 2018). These emission reductions will require fundamental change in behaviours and technologies across the globe. At present, our buildings are responsible for almost 40% of global CO2 emissions (GlobalABC 2019), and half of all extracted materials are used in construction – facts that are increasing pressure on the construction industry to change.

The Paris Agreement has laid out a global framework for how to curb increases in global temperature. Additionally, it aims to support the committed countries and strengthen their ability to handle the effects of climate change. The agreement is the first of its kind – a universal legally binding global climate change contract. The EU and its member states are among the 194 states that have committed to the Paris Agreements goals. In 2018, the European Commission introduced a long-term strategy for how to make the EU the world’s first major economy to become carbon neutral by 2050 and meet the Paris Agreement’s goals.

Sustainable building and construction are achieved by reducing the environmental impact throughout a building’s lifecycle. Research shows that the EU’s building industry could reduce its greenhouse gas emissions by 90% by 2050 (EC 2011). Yet this requires significant systemic change and a shift from a linear to a circular economy.

The European region is highly developed and among the wealthiest in the world. However, because of the early development of the region, the existing economic models are deeply rooted and thus the required changes are happening slowly, and the transition to a circular economic model has to be carried out systematically. Nevertheless, Europe, in comparison to the other regions, is the most advanced regarding circularity because of its head start of more than a decade. Still, circular practices are in their infancy, even in Europe. Europe differs from the other regions also because of the unity brought by the EU. Most European countries are part of the EU and are committed to following common EU legislation. Additionally, the EU is committed to being a forerunner in circular economy. The role of the EU has been, and continues to be, crucial when it comes to the development of Europe, especially with regard to the construction industry. From a global perspective, much can be learned from both the mistakes and the successes in Europe. Ideally, the knowledge gained can be used to help the developing countries that are now shaping and building up their economies to leapfrog into a circular economy model.

Figure 1: Leapfrogging into circular economy

Source: Author
Graphics: Author

3. Impact of the built environment

This section explores the built environment and its associated economic and environmental impacts.

3.1 Impact on the environment

In the case of the EU, the buildings stand responsible for 40%, the largest share, of the total EU final energy consumption (EC 2020a). Furthermore, the construction industry is responsible for approximately 35% of the EU's greenhouse gas emissions (ibid.). Additionally, half of the extracted materials in the world are used for buildings and the construction industry is effectively turning these materials into waste. In the EU, the construction industry creates one of the biggest waste streams, since C&D waste accounts for approximately 25–30% of all waste generated (EC 2019a). Given this, the negative impact of the construction industry on the environment worldwide is significant.

3.2 Impact on the economy

The construction sector engages in several economic activities: extraction of raw materials, manufacturing and distribution of products, design, construction, management, maintenance, renovation, restoration and deconstruction (as distinct from demolition). It also carries out reuse, repair, remanufacturing and recycling of already used building components and materials. Thus, the construction sector is of great importance to the European economy. In 2017, the building construction sector accounted for 3.6% of the total number of enterprises and 2.3% of the total employment in the EU (Eurostat 2017). Approximately 18 million people work directly for the construction sector (EC 2020a), and the sector contributes to approximately 9% of the EU's Gross Domestic Product (GDP) (ibid.). Furthermore, much of the national wealth of many countries is generated from construction. For example, in Finland, 83% of the wealth is in the built environment, which includes buildings and infrastructure (ROTI 2019).

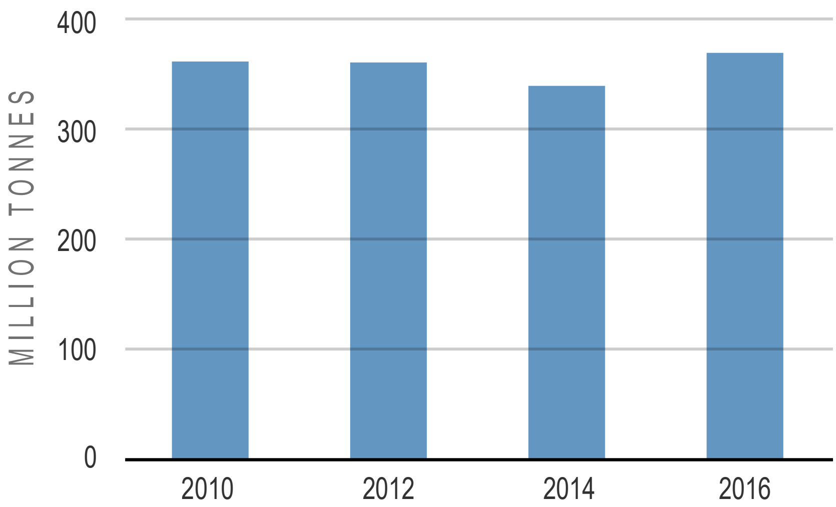

Figure 2: Generation of C&D waste, EU 2010-16

Source: Eurostat (2019a)
Graphics modified by author

4. C&D waste stream

C&D waste represents 25–30% of all waste generated in the EU (EC 2019a). The C&D waste stream is relatively stable and the generated amount in 2016 was approximately 374 million tonnes, making it the largest waste contributor by weight (Eurostat 2019a). The remainder of this section delves more deeply into the issue of waste, particularly with respect to the built environment.

4.1 Building-related waste per person

The EU states create approximately 0.7 tonnes of C&D waste per person per annum (Eurostat 2019a). However, the differences between countries are significant, as shown in Figure 3 below. Most of the C&D waste per person, almost 3 tonnes, is generated in Malta. At the other end of the spectrum are Romania, Ireland, Serbia and Greece, each of which produces less than 0.1 tonnes of C&D waste per person. However, the methods used to collect data vary across countries, affecting the reliability of the numbers and therefore the viability of cross-country comparisons (European Environment Agency [EEA] 2020a).

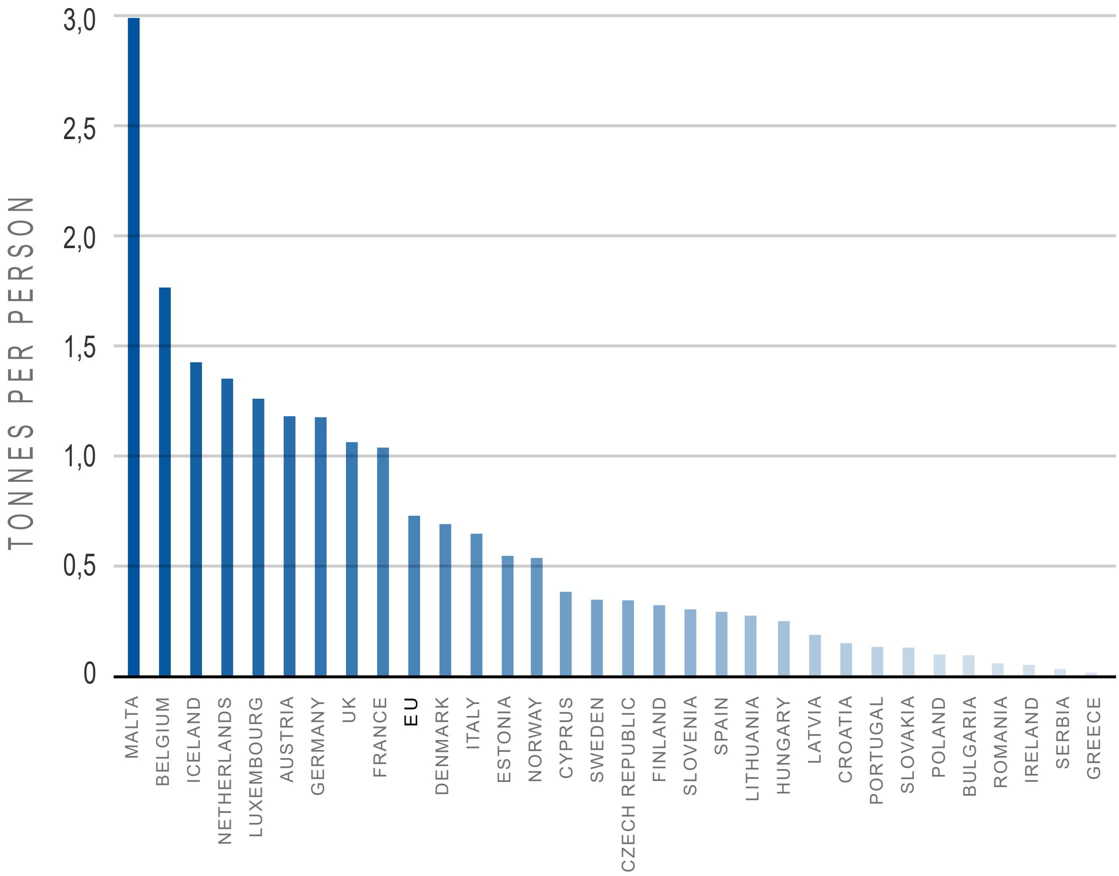

Figure 3: Generation of C&D waste per capita, EEA 2016

Source: Eurostat (2019a)
Graphics modified by author

4.2 Breakdown of waste into material categories

The EU data available provides a breakdown of the materials included in the C&D waste, as shown in Figure 4. It is clear that the majority of the generated C&D waste in the EU is composed of mineral waste.

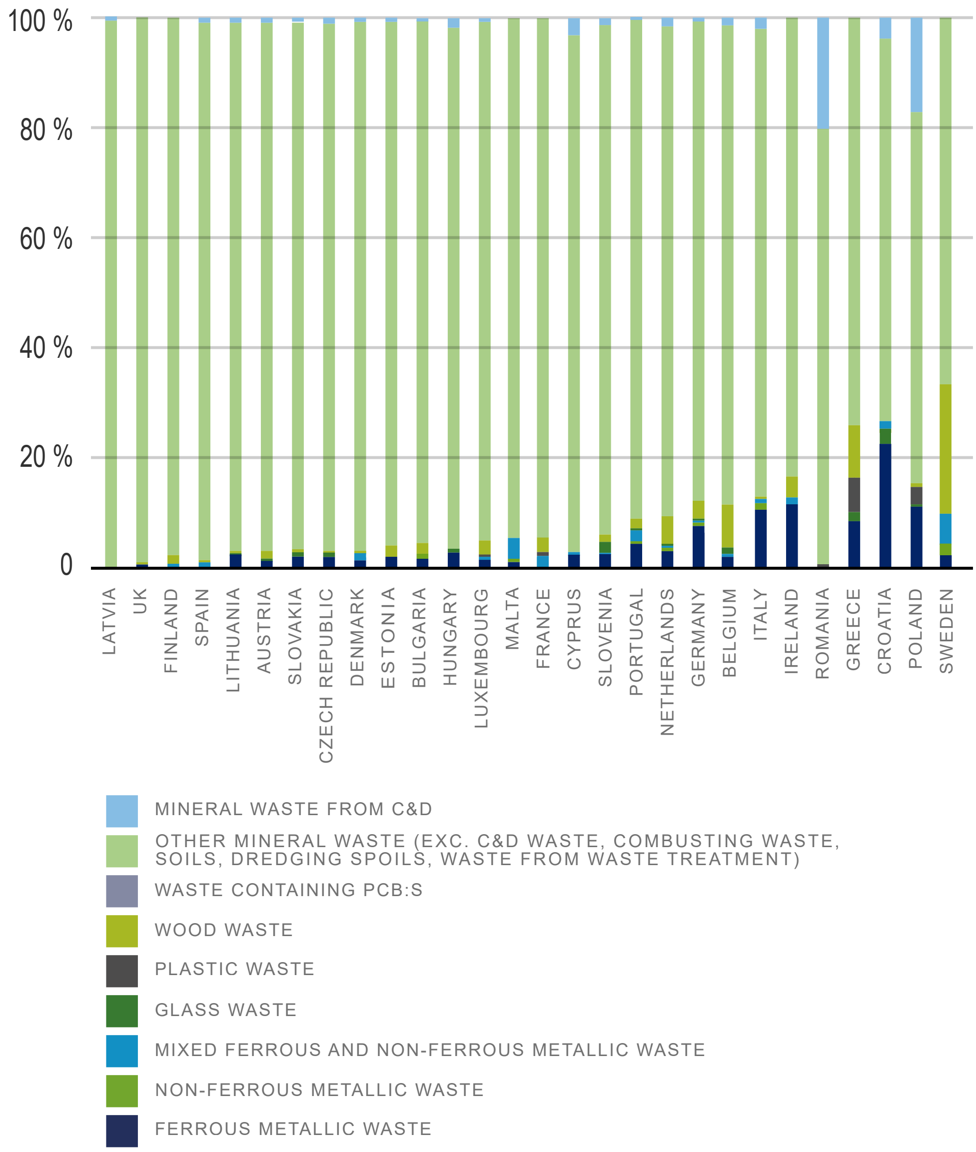

Figure 4: Breakdown of total generated C&D waste, 2012

Source: EC (2017a)
Graphics modified by author

4.3 Recovery rates

C&D waste is considered a priority area in the EU's Circular Economy Action Plan (EC 2020c). The revised EU Waste Framework Directive (WFD) sets waste prevention as the highest priority but also includes a recovery target of 70% for C&D waste. Driven by this, many European countries are reporting increasingly high recovery rates and most had exceeded the 70% target by 2016, as shown in Figure 5 below. This might give the impression that the construction sector is highly circular. However, the reported recovery rates include extensive amounts of low-grade recycling such as backfilling. The European Commission's Decision 2011/754/EU defines backfilling as 'a recovery operation where suitable waste is used for reclamation purposes in excavated areas or for engineering purposes in landscaping and where the waste is a substitute for non-waste materials'. Thus, this should not be considered recycling according to circular economy principles, since the inherent value of the material is drastically lowered and the material is downcycled. In this case, the waste is used instead of natural materials that can be easily extracted/produced without a significant negative environmental impact.

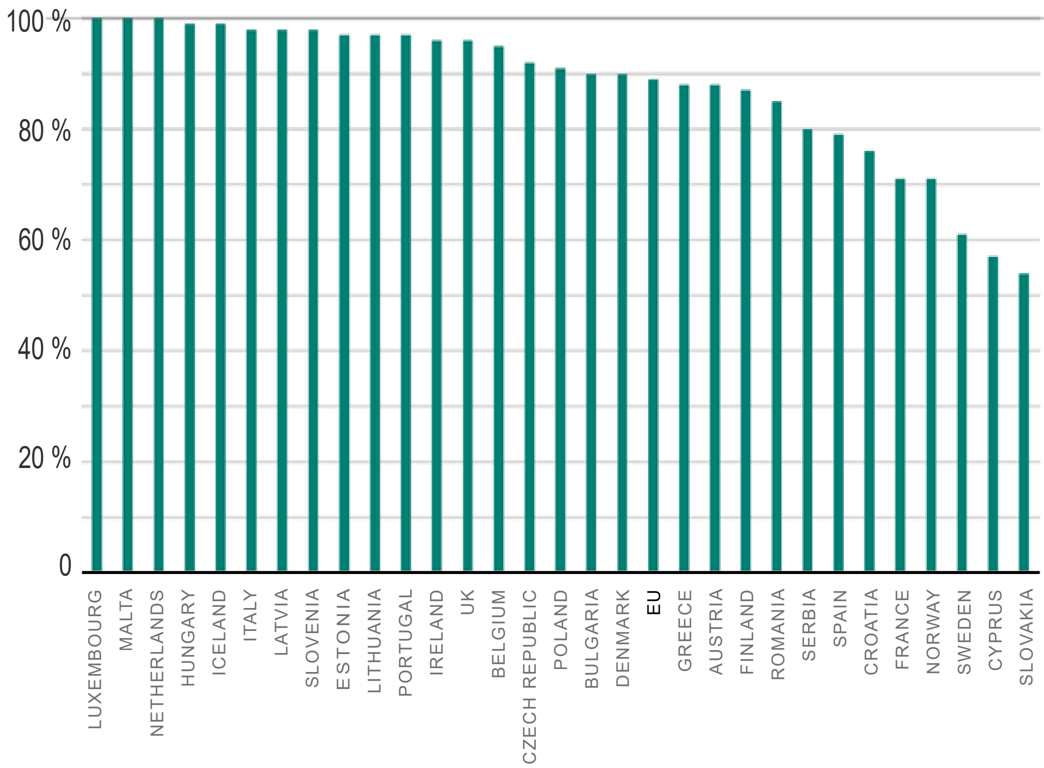

Figure 5: Recovery rate of non-hazardous mineral C&D waste, EEA 2016

Source: Eurostat (2019b)
Graphics modified by author

The Netherlands is one of the most progressive member states when it comes to C&D waste management, as seen in Figures 5 and 6. There, the recycling target of 70% was met prior to the year 2000, and now more than 98% of waste is recycled (Pacheco-Torgal et al. 2013). There are two main policies that lie behind the country's success in this area: the Netherlands has one of the highest taxes on waste disposal; and additional fees are imposed for mixed waste. These economic drivers encourage waste separation. This has led to efficient separation of C&D waste at the source, thereby improving the capabilities for reuse and recycling (Oosterhuis et al. 2009). Additionally, the Netherlands regulations impose minimum standards for waste recycling, such as a minimum of 10% recycled content in cement and concrete (Pacheco-Torgal et al. 2013).

Whereas the Netherlands is a pioneer state when it comes to recycling waste, one of the countries that is lagging most in terms of managing C&D waste is Serbia. In Serbia, 80% of the reported C&D waste is used as backfilling while most of the remaining 20% is landfilled, as seen in Figure 6 below. It is also important to note that only 60% of the total amount of waste in Serbia is disposed of in a controlled way into municipal sanitary landfills, which decreases the reliability of the reported data. The lack of accurate data is a result of the poor quality of monitoring and the lack of a unified information system on waste in this country. The situation concerning C&D waste in Serbia is rather serious since the country lacks detailed regulations and waste management strategies regarding this type of waste. Additionally, interest in collecting, sorting and recycling C&D waste is currently very low (Government of the Republic of Serbia 2010).

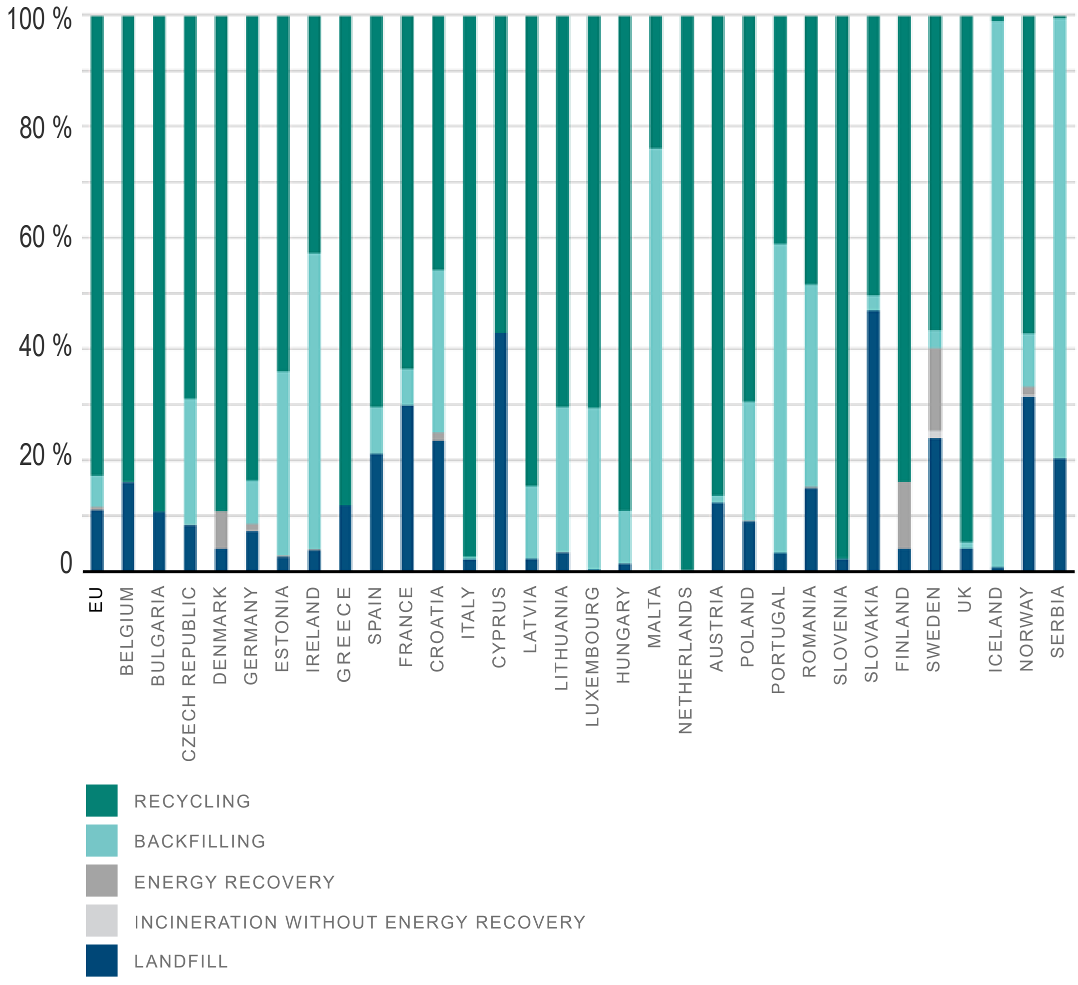

Figure 6: Treatment of mineral waste from construction and deconstruction, EEA 2016

Source: Eurostat (2019c)

Graphics modified by author

5. Shifting from a linear to a circular economy

At the moment we are in, the dominant economic model is linear. In other words, it is based on raw materials being extracted, turned into new materials and products, which are then used until they are disposed of. However, this model is based on the wrongful assumption that materials are always available and easy to get rid of, which is not the case in a time when we are exceeding, and to some extent already have exceeded, the limits set by our environment. The linear model is not sustainable in the long run and we need to shift our thinking and practices towards a more natural cyclic model, which focuses on eliminating waste.

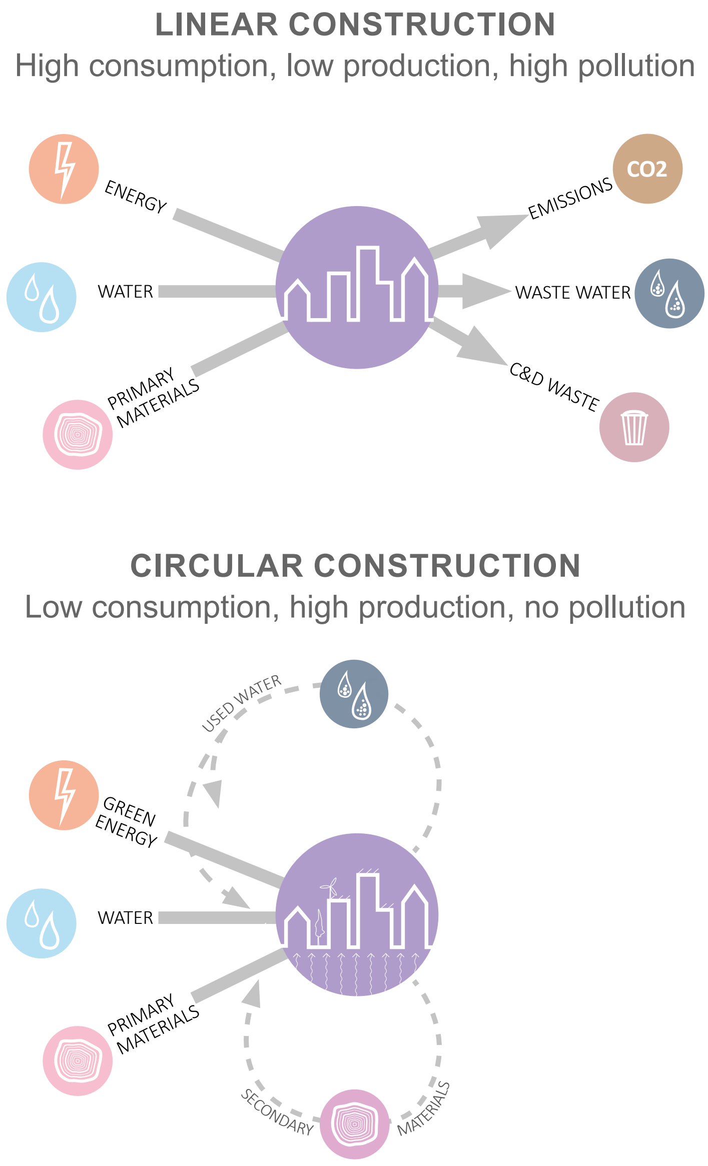

Figure 7: Linear versus circular construction

Source: Author
Graphics: Author

In a circular economy, materials are not taken out of the loop but are kept in the economy for as long, as efficiently and at the highest utility as possible. Circular economy approaches try to design out waste and to maximise the recycling of materials and products. Recycling can, however, be done in various ways. The aim is that the materials will be reused, meaning that they will keep their inherent value for as long as possible. In the best case, the value might even increase on the material's second round, which is referred to as upcycling. The least favourable recycling option is downcycling, in which the value of the material is noticeably lowered. All forms of recycling are, however, favourable against the option of energy recovery or landfill, where materials are taken out of the usage loop altogether.

In order to achieve the paradigm shift towards a closed-loop economy in the built environment, we need to take a holistic look at the status quo. When designing new buildings, circular economy needs to be kept in mind, since decisions at the start affect the entire lifecycle and thus also recyclability at the end of life. As already mentioned, Europe is struggling with an enormous stream of C&D waste. New buildings and refurbishments need to be designed and built in a way that ensures they are adaptable, reversible and circular. Fortunately, guidelines for sustainable new construction already exist and are continually being further developed. The next step is to make circular construction common practice. However, in the case of Europe, the building stock is relatively old. Additionally, at the present moment, the region lacks common legislation and guidelines that would push materials taken out of construction back into construction without a drastic loss of their initial value. Thus, the focus should be on how to apply circular economy practices to renovation, restoration and deconstruction.

5.1 Job creation

Circular economy practices such as recycling, repair and reuse could increase competitiveness across EU member states by reducing the annual spending on resources by approximately 600 billion euros (Green Budget EU 2016). Additionally, the transition towards a more sustainable economy is projected to increase the GDP in Europe by almost 0.5% by 2030 (EC 2018). The transition towards circular economy also has the potential to create new jobs while boosting innovation. There is a possibility to create up to 170,000 new jobs via waste management measures alone by 2035 in the EU member states (Green Budget EU 2016). Even though the circular economy has a positive effect on the labour market, some jobs will be lost, as the transition will entail occupational shifts and changes in skills requirements. According to a study commissioned by the EC, the total increase in jobs across EU member states could be approximately 700,000 (taking into account jobs that are lost) by 2030. This increase will be a result of growing labour demand from recycling plants, repair services and rebounds in consumer demand from savings generated through collaborative actions. The recycling and repair sectors are those that will benefit the most from the transition towards circular economy. However, the services sectors and the electricity sector are also projected to grow. Simultaneously, sectors that produce and process raw materials are expected to decline in size. Employment in the construction sector is expected to decrease as a result of new building techniques (EC 2018). Figure 8 depicts approximate numbers of jobs created and lost in the EU by 2030 as a result of the transition towards a circular economy.

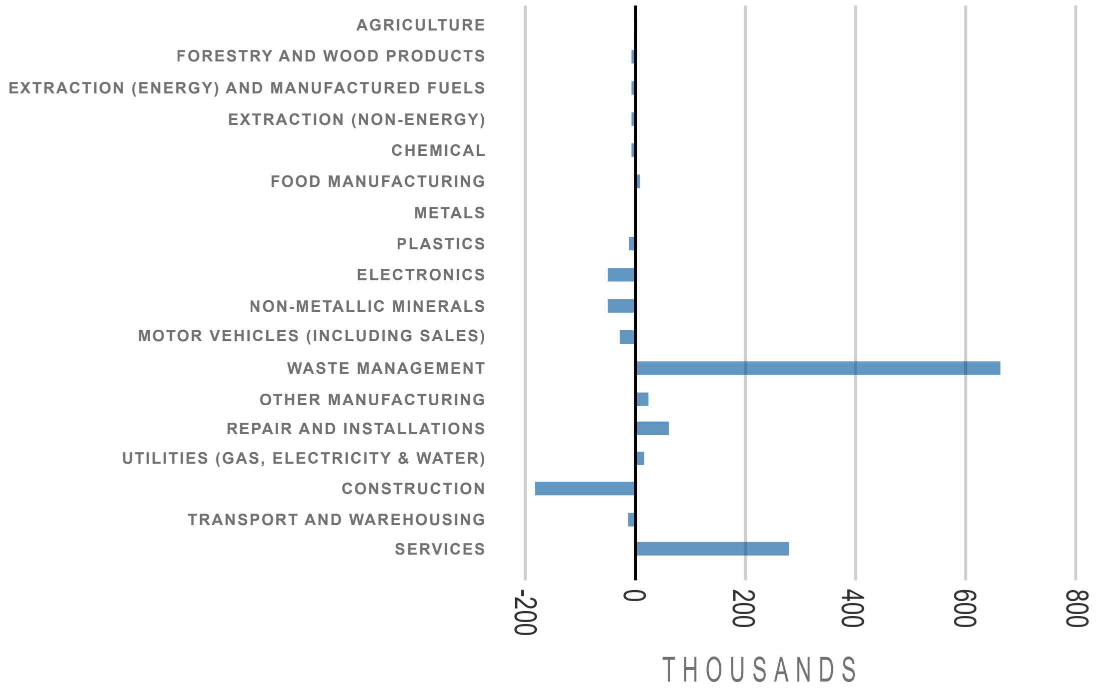

Figure 8: Circular economy job impacts across the EU's 28 sectors in 2030

Source: EC (2018)
Graphics modified by author

5.2 Lifecycle phases

It is necessary to focus on the entire lifecycle of construction products and buildings to ensure material use is truly cyclic. Typically, this lifecycle is split into the phases presented in Figure 9 below. The cycle can be started in any phase. For each phase, Figure 9 includes the measures that need to be taken to make construction circular.

MANUFACTURING OF BUILDING PRODUCTS

- ☑ Use of renewable materials
- ☑ Use of healthy materials
- ☑ Production processes with low environmental impact
- ☑ Materials have a high recycled content
- ☑ Durable materials
- ☑ Non-hazardous materials
- ☑ Products that can be reused, disassembled, and recycled
- ☑ Create material passports

DESIGN

- ☑ Design passive buildings
- ☑ Design resource-efficient buildings
- ☑ Design buildings with small carbon footprints
- ☑ Design using reclaimed materials
- ☑ Design healthy buildings
- ☑ Design long-lasting buildings
- ☑ Design for disassembly
- ☑ Design for reuse
- ☑ Design for sharing
- ☑ Design flexible buildings in function and ability to change volumes of the internal spaces
- ☑ Integrate nature-based infrastructure, e.g. green roofs
- ☑ Create Building Information Model (BIM) so construction process has clear documentation
- ☑ Create building passports

CONSTRUCTION

- ☑ Use performance-based contracts
- ☑ Avoid material surpluses so that materials aren't wasted
- ☑ Modular construction & prefabrication
- ☑ Use additive manufacturing processes
- ☑ Update building passports
- ☑ Use selective deconstruction when renovating and refurbishing

OPERATION & USE

- ☑ Keep the BIM model updated
- ☑ Keep building passport updated
- ☑ Use extended producer responsibilities
- ☑ Increase occupancy rate of buildings
- ☑ Extend the lifetime of the building by rehabilitation, reparation, etc.
- ☑ Support and ease maintenance and renewal of spaces rather than deconstruction/rebuilding
- ☑ Improve the user's understanding of the building's intended use, possibilities, and limitations.

DECONSTRUCTION END OF LIFE

- ☑ Commence qualitative pre-deconstruction audits
- ☑ Undertake waste management plans
- ☑ Agree to decontamination of the construction materials
- ☑ Enable monitoring deconstruction and renovation work
- ☑ Agree to selective deconstruction
- ☑ Take on preparation of materials for reuse, repurpose, recycle
- ☑ Support increased traceability (track and trace), high quality recovery and certifications for C&D waste
- ☑ Improve sorting for materials that cannot be collected separately in the deconstruction phase

RENOVATION

Same as in Construction Phase

Figure 9: Circularity checklist in different lifecycle phases

Information gathered from following sources: Thelen et al., 2018; Rizos et al., 2017; Pomponi and Moncaster 2016; BAMB, 2020; Enkvist & Klevnäs, 2018, 2018; Webster 2013; EC, 2019b; Ellen Macarthur Foundation and Arup, 2019; EEA 2020
Graphics: Author

5.3 Circular procurement models

Circular procurement models exist to help the purchasing party to carry out responsible procurement. There are three models for implementing circular procurement. The first is at the system level, which includes the contracts the purchaser can use to ensure construction takes place according to circular economy principles. One example of such a contract is a ‘take-back’ agreement, where a building or parts of it are sold back to the provider at the end of their lifecycle. A good practice example of this is presented in section 9.5. Another example of a system-level contract is buying product services rather than merely products. In the case of buildings, this would mean buying, for example, an office space with a deal that includes service and maintenance. The second model of procurement is at the supplier level, and describes how suppliers, in making their systems and processes circular, can ensure that the services and products they offer meet sustainable procurement criteria. The third model, at the product level, is strongly linked to the second level, and focuses on the products – that they are recycled, recyclable, have material passports, and so forth. Figure 10 below depicts the circular procurement models in greater detail.

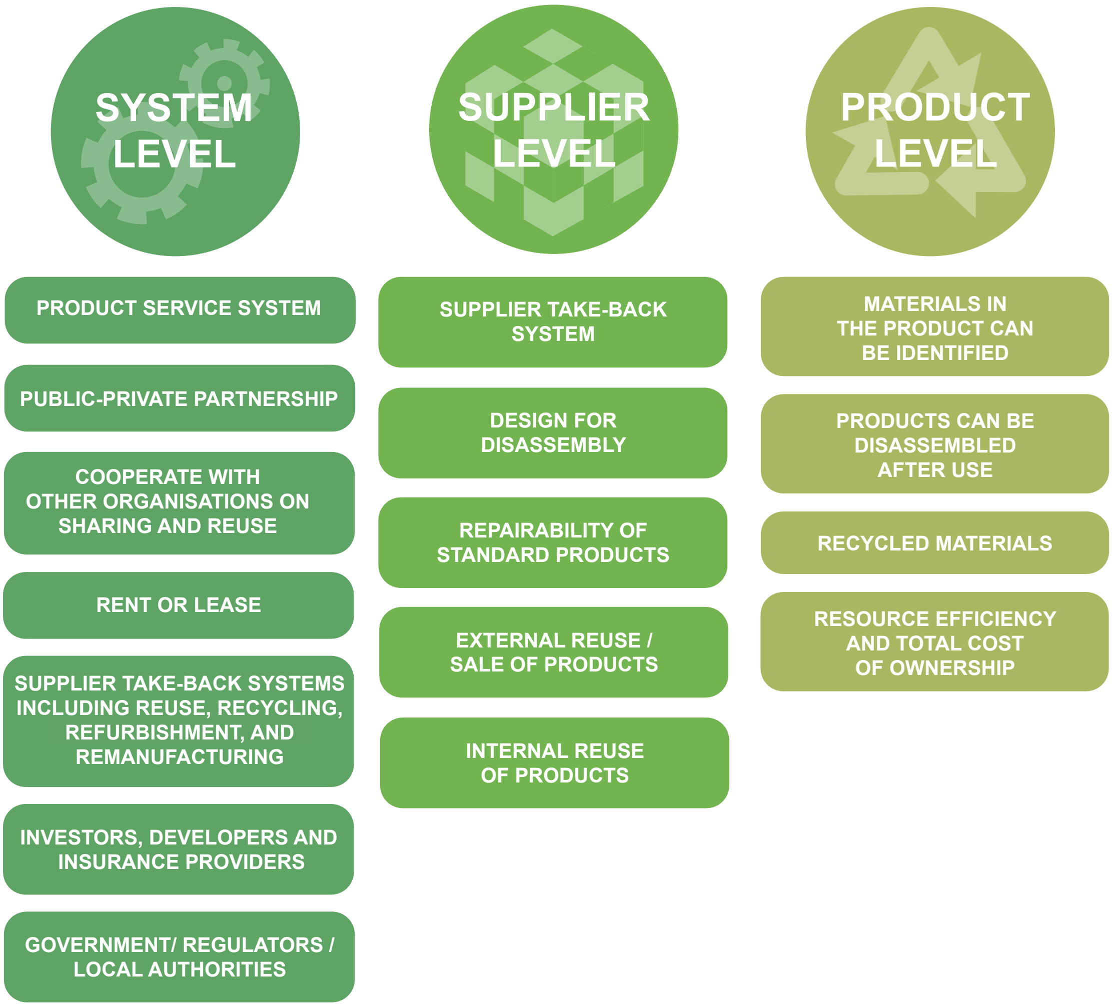

Figure 10: Circular procurement models

Source: SPP (2017)
Graphics: Author

6. Policies

Circular economy–driven policies focus on eliminating waste or decreasing the amount of waste generated. Additionally, they aim to increase the amount of recycling undertaken, keep the materials in the economy for as long as possible, maintain the materials' quality and value for as long as possible, and reduce the amount of hazardous substances in construction materials. Such policies also reduce the amount of deconstruction undertaken by supporting renovation and refurbishment. Additionally, they reduce the amount of waste by supporting the use of reclaimed materials and lower the extraction of new materials, since the previously extracted/produced materials stay in use for longer periods of time.

Figure 11 depicts the desired material flow and how different policies could promote this transition towards sustainable material use.

Successful regulation of C&D waste management requires that the ownership of the waste is clear, and that such management is carried out in accordance with national legislation and the contracts between building owners, deconstruction contractors, intermediate holders, recycling operators and end users of the secondary products (EC 2016a).

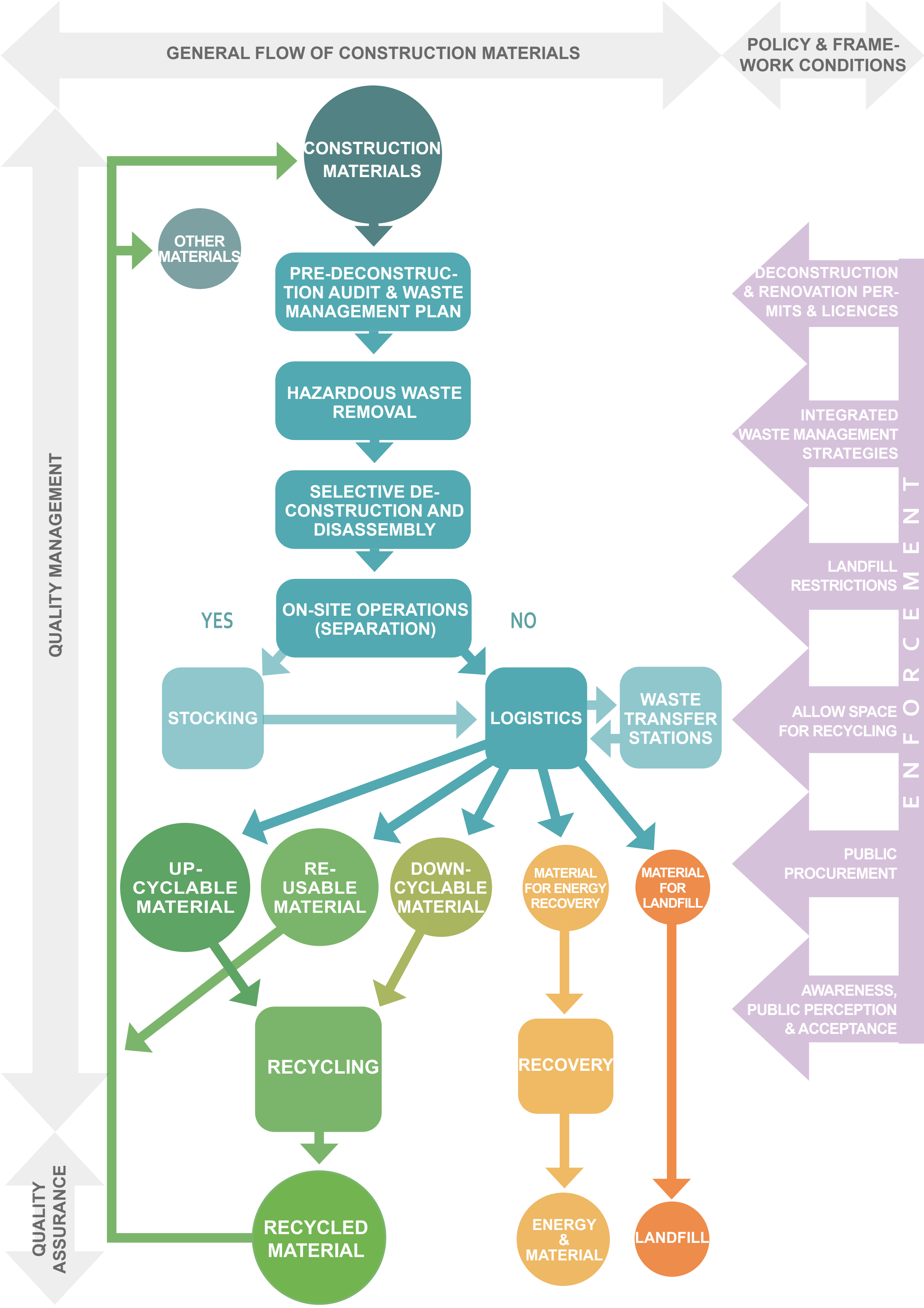

Figure 11: Desired material flow and supporting policies

Source: EC (2016a)
Graphics: Author

6.1 Recovery targets regarding C&D waste

As mentioned in section 5.3, C&D waste is considered a priority area in the EU's Circular Economy Action Plan (EC 2020c) and a recovery target of 70% has already been set and achieved in many member states. Additionally, countries that have not met the target yet have received a warning and a suggested plan for how to reach it. However, the recovery rates of EU member states cannot be seen as reliable circularity indicators, since extensive amounts of downcycling, such as backfilling, have been included in these figures. As a response to increased amounts of C&D waste being used for backfilling, the WFD of 2018 included the specification that C&D waste should be used as backfilling only to the extent necessary to achieve the functional and structural requirements. It is hoped that this will lower the rate of low-quality recovery of C&D waste and encourage countries to adopt better recycling practices.

6.2 Deconstruction and renovation permits and audits

Local authorities are in charge of issuing deconstruction and renovation permits or licences. Thus, they also have the opportunity to promote and enforce the recycling of C&D waste by requiring a pre-deconstruction audit and a deconstruction plan and undertaking a follow-up evaluation after deconstruction. Additionally, the requirement for a deconstruction report after a building has been torn down helps the government to monitor whether deconstruction has been carried out according to guidelines and policies (EC 2016a).

Pre-deconstruction audits and deconstruction plans are likely to gain popularity because of both changes in legislation and separate green deals and targets. One example is the Green Deal between the Finnish Association of Property Owners and Construction Clients (RAKLI) and the Ministry of the Environment. RAKLI is the most comprehensive and prominent association of professional property owners, real estate investors, corporate real estate managers and construction clients in Finland, and provides research information to help its clients develop and engage in responsible decision-making. Additionally, RAKLI's members are committed to being at the forefront of responsible construction. RAKLI and the Ministry of the Environment signed a Green Deal in 2020 that aims to boost the recycling of C&D waste by encouraging actors to undertake pre-deconstruction audits especially when entire buildings are being demolished or in the case of extensive renovations (RAKLI 2020).

6.3 Landfill restrictions

Landfill restrictions are essential for developing a successful market for recycled C&D materials. These restrictions can, for example, take the form of punitive measures such as bans and incentives and tax-based disincentives (EC 2016a). Such actions make the disposal of materials to landfill difficult and undesirable, thereby tipping the scale in favour of recycling.

6.4 Hazardous waste

The management of hazardous waste needs to be undertaken systematically across all processing stages and governments should take action that enforces existing legislation. Moreover, the treatment of hazardous waste needs to be regulated in the waste treatment stage through environmental regulation (EC 2016a).

In relation to waste identification, collection and sorting, legislation should require that producers of such waste develop a plan for how to handle hazardous material, through a pre-deconstruction review or waste management plan, for example. Additionally, this process should be carried out in a way that minimises contamination and the amount of unrecyclable waste produced. Such methods are in use, for example, in Austria, Luxembourg, Sweden and Finland. Some countries, like Belgium, have introduced a hazardous waste register. Nevertheless, policies regarding hazardous waste need to focus on banning the mixing of hazardous waste and include rules that help to track and control C&D waste streams. The former has been introduced in Finland and Hungary, while Sweden uses both strategies (EC 2016a).

6.5 Policies reducing the use of virgin materials or natural resources

Taxes on virgin materials and gravel have been trialled in various European countries and such taxes might be a viable option. However, the mentioned taxation practices have to be introduced with caution, since the outcomes are not always beneficial for the environment or economy. In some cases, these taxes only increase the price of construction and/or lead to a greater reliance on the importation of materials from countries where such taxes are not applied (EC 2016a).

6.6 Enforcement

Enforcement regarding C&D waste practices is primarily the responsibility of local and/or regional government, as is monitoring and ensuring that stakeholders are following policies and set guidelines. Appropriate sanctions are also essential for effective enforcement (EC 2016a).

6.7 Allow space for recycling or stockpiling

To promote the use of recycling, recycling facilities should be easily accessible. The recycling of C&D waste is most feasible in densely populated urban areas; however, such facilities are not necessarily provided with space or construction permits in proximity to cities. Public authorities and municipalities need to design frameworks for the recycling of C&D waste and allow for such facilities to be built in relative proximity to urban areas (EC 2016a).

Where permanent recycling facilities are not an option, temporary mobile recycling facilities can be used. Such plants could, for example, be used to crush concrete or bricks for later use on-site. This can reduce transportation costs and emissions while making recycled material more accessible. However, on-site recycling often generates both noise and dust. Thus, when local authorities are considering whether to permit such recycling, proximity to the city is often a problem (EC 2016a).

6.8 Legislation and standards regarding recycled materials

At the present time, the construction industry barely uses any secondary materials. A secondary material is a material that has ceased to be waste through appropriate preparation and processing (taking into account EN 15804) and can therefore be used as a substitute for primary materials. In the Netherlands, a country at the forefront when it comes to circular economy, secondary materials represent only 3–4% of all construction materials (EEA 2020a). Thus, we have a long way to go before construction becomes truly circular.

Inadequate legislation and a lack of standardisation complicates the recycling of C&D waste. Currently, when a material is taken out of a building during deconstruction it is classified as waste and its use for construction is regulated through different legislation than that covering construction materials, rendering it difficult to reuse in construction. The environmental and health implications of using C&D waste in construction fall under national and EU waste legislation. The technical aspects of C&D waste use in construction, on the other hand, is regulated by the Construction Products Regulation, CPR (EU, Regulation No 305/2011). In order to boost recycling, C&D waste can cease to be classed as waste and instead be given 'end of waste' status, so that the waste becomes a product. Thus, its use will no longer be regulated by waste legislation but will fall entirely under product legislation (Velzeboer & van Zomeren 2017). National end of waste criteria for C&D waste has the biggest impact on the use of mineral waste (Norden 2016). The concept of end of waste reduces the administrative work required to handle permits for the recycling of C&D waste, and was introduced with the aim of making the use of C&D waste more attractive by increasing trust in its quality. However, in 2016, only a few countries (Austria, Belgium, France, the Netherlands and the United Kingdom) had developed described criteria regarding C&D waste. Nevertheless, such criteria are being developed in several other European countries. Because of the limited data, it is too soon to draw any conclusions about whether the introduction of 'end of waste' has boosted the recycling of C&D waste (Velzeboer & van Zomeren 2017).

Stakeholders typically prefer virgin materials because of the quality assurance gained through warranties and standards. Thus, developing standards for secondary materials would increase trust in their structural properties and quality (EC 2016a).

6.9 The public sector guiding and supporting the private sector

Transitioning to circular economy is primarily in the hands of the private sector. This is because the private sector includes the majority of the companies that produce materials, and of the manufacturers, the construction firms, the product sellers, and the waste management and recycling firms. However, this does not mean that responsibility for transforming the dominant economic model into a sustainable one falls only on the private sector. The public sector is responsible for setting an example and for facilitating and encouraging the private sector (see section 7.10) (Enkvist & Klevnäs 2018).

6.10 Public procurement

Green public procurement guidelines have been developed by the European Commission and they include criteria to be applied to the construction of offices (EC 2016b) and roads (EC 2016c). These guidelines take into consideration the entire lifecycle and cover the use of secondary construction materials and how to design for disassembly (see section 9.5). Similar guidelines have been developed by local governments. For example, in Finland, the government advises that the carbon footprint of construction materials should be considered within public construction, and has introduced guidelines for how to achieve low-carbon construction throughout a building's lifecycle. Additionally, Finland is working on integrating Life Cycle Assessment (LCA) into the legislation (Land Use and Building Act) by 2025 (see section 7.12). As part of this initiative, low-carbon construction is included in the government's procurement criteria in relation to public construction (Ministry of Economic Affairs and Employment of Finland 2013, Finnish Government 2017). LCA is already incorporated into public construction procurement in some countries, such as Norway. Statsbygg, the key adviser to the Norwegian Government on the development of the built environment, alongside the constructor and the developer of state real estate, already requires LCA analysis in most of their projects. Additionally, they have strict recycling targets for materials such as steel, have banned the use of tropical wood and have committed to using only timber that is certified (Statsbygg 2020). These measures are all part of their sustainability strategy, which is aimed at reducing greenhouse gas emissions by 40% on conventional construction practices (Statsbygg 2019).

Circular economy can effectively be promoted through pilot projects. A few circular pilot construction projects – the Town Hall of Brummen, the Circle House and the Alliander Headquarters – are presented in section 9.5. A successful public procurement pilot program has also been carried out in the Netherlands. In 2013, the Dutch Government established the Circular Procurement Green Deal with the aim of boosting circular economy. This scheme connected 45 public and private parties and assigned each of them to execute two circular procurement initiatives, including construction projects. The purpose of these pilot projects was to increase the experience in this area, promote the sharing of knowledge gained and create a new set of good practices. Over a period of three years, 80 pilot projects were carried out and the insights gained were shared. In part because of the success of this program, the Dutch Government stressed the importance of circular procurement and the assessment of lifecycle costs in its 2016 Roadmap to a Circular Economy. Additionally, in its Roadmap the government included the goal of raising circular procurement to 10% by 2020 (EC 2017b).

Public procurement can also promote circular economy by increasing the recycling of C&D waste. The use of recycled C&D materials can be increased by prescribing in law that tendering documents include requirements for recycling. For example, in Bulgaria, the contracting entity involved in public construction procurement is legally obliged to include a requirement for the use of secondary materials in both contractor selection criteria and work contracts. Another good example is found in the Flanders region in Belgium, where waste management plans and pre-deconstruction inspections are included in the contracts for public construction procurement (EC 2016a).

6.11 Increase research and foster innovation

Policy-makers should enable and require more research regarding the efficiency of material use. At the present time, the volume of research on energy efficiency is a hundred times greater than that on material efficiency (Enkvist & Klevnäs 2018). Yet there is a need for greater understanding of the potential, the barriers and the economics related to circularity in construction. Needless to say, a steady knowledge base is crucial when setting policies aimed at implementing a circular economic model (ibid.).

6.12 Carbon budgets

One way in which to force the construction industry to adopt more sustainable practices is to regulate via construction permits. Some countries, such as Finland, are working on setting carbon budgets for certain building typologies and requiring LCA calculations that prove that a building's construction will be completed within the set budget before a construction permit is issued (YM 2019).

7. Incentives

The importance of incentives to support circularity practices in building and construction is outlined in this section. The incentives considered are density bonuses, influential taxation, grants, loans, deconstruction aid, performance-based procurement, competitions and the actors supporting such incentives.

7.1 Density bonuses

One way in which municipalities could make sustainable construction more desirable is by allowing more construction in exchange for better environmental performance, which could be proved, for example, by LCA. The provision of such incentives would not affect the municipality's revenue. However, it would make building according to circular economy principles more profitable for the developer as it would be more cost-effective. Additionally, the use of green assessments, such as Leadership in Energy and Environmental Design (LEED) certificates, have been proven to lead to higher market prices for certified buildings compared to regular uncertified buildings (United States Green Building Council [USGBC], 2019).

7.2 Influential taxation

Green taxes can help turn the economy circular. The Environmental Fiscal Reform (EFR) transforms taxation and consumption in line with environmental goals. This is achieved through green taxes, emissions trading, eliminating hazardous materials, green public procurement, border tax adjustments and deposit-refund schemes. The aim is, first, to re-balance pricing in a way that encourages circular economy business models and sustainable behaviour. Second, the goal is to increase the demand for sustainable technology and products. Third, the aim is to reduce more disadvantageous taxes, such as labour taxes. All these measures are intended to boost green economy and employment (Green Budget EU 2016).

In 2014, only 6.3% of all taxes and social contributions in the EU came from environmental taxes. Labour taxes, in comparison, accounted for more than half of the revenue in some member states. Additionally, only 3.6% of all green taxes came from resources and pollution, with the remainder coming from energy and transport (Green Budget EU 2016).

False price signals have to be corrected in order to change consumption behaviour. Stakeholders tend to favour cheaper materials, and virgin materials are typically cheaper than secondary materials, due to the latter's processing costs. Thus, recycled materials, and other sustainable materials, should be competitively priced via measures such as green taxes. Eventually, this will increase demand for recycled materials and make material use more cyclic. Some European countries, such as the Netherlands and Croatia, already have quite high taxes on virgin materials and pollution; while similar taxes remain low in other countries, including Italy, Portugal and Austria. These latter countries are slowing down the EU's transition towards circularity (Green Budget EU 2016).

Many circular economy practices, such as repair, research, development, deconstruction, and recycling, are labour-intensive. Thus, changes to taxation that make labour cheaper and unsustainable materials more expensive will boost sustainable economic growth (EC 2014).

Another way to encourage environmentally sustainable construction through taxation practices would be to relieve property owners of having to pay property tax for a certain period of time (SYKE 2019).

7.3 Grants

Circular economy practices can also be encouraged through recognition of best practices via grants. These grants can be awarded to property owners or developers to alleviate the costs associated with sustainable construction. These grants could be provided by the state, municipalities or public- or private-sector organisations.

7.4 Loans

Building according to circular economy practices can also be made easier by offering low-interest loans, or loans with long payback periods, to those aiming for sustainable construction, in exchange for LCA or other evidence of sustainable practices.

7.5 Deconstruction aid

In general, renovating a building is more sustainable than demolishing and building new. However, when there is no other option than deconstruction, circular economy principles should be incorporated when planning the deconstruction and what to do with the C&D waste. In these cases, financial aid can be a powerful incentive that encourages circular economy practice. A practical example of such an incentive can be found in Finland. The Housing Finance and Development Centre of Finland, ARA, offers financial aid to help cover up to 90% of deconstruction costs. However, those who receive this aid have to provide a deconstruction audit and their plan for how to recycle the C&D waste. Additionally, ARA promotes recycling by encouraging the use of an online platform (Materiaalitori.fi) through which C&D waste can be sold (ARA 2020).

7.6 Performance-based procurement

Most of the above-mentioned incentives focus on either the construction or the deconstruction phase of a building. However, the durability of a building can also be promoted for the period for which it is in use. This can be done, for example, through performance-based contracts that encourage optimal use and understanding of a building. Three good examples of such innovative procurement contracts from different European countries are presented (and more can be read about them at SCI Network 2012).

In 2008, the Italian municipality of Vinovo needed a new kindergarten and decided to use a specific form of Italian public–private partnership. Typically, this partnership is between a founder and a construction company. This model included that the financing and tendering for the design and construction be jointly carried out. In the case of Vinovo, a leasing contract was drafted, according to which the authority, for a set period of time, would pay leasing fees (capital and interest) for using the building. At the end of the lease period, the ownership of the building would then pass to the authority. Additionally, there was a design and build contract with a construction company, managed by the founder. The strong partnership enabled by this procurement helped to guarantee the quality of the construction.

In Alsace, France, there is strong political will to promote sustainable development. Therefore, the authorities wanted to explore new procurement possibilities when planning energy-efficient renovation for their schools, with the aim of reducing the annual energy costs. What they ended up doing was procuring through an energy performance contract. Such contracts are mostly financed through the energy savings achieved. Additionally, the experts involved were committed to being available for a three-year period to ensure that the buildings were used as intended. This included consulting in cases where user patterns changed during this period, thus optimising the performance of the adapted building.

In 2010, the Finnish city of Jyväskylä started the Jyväskylän Optimi project that aimed for increased innovation and promotion of lifecycle thinking in public procurement. In this case, the procurement was the construction of a school and day-care centre, with a focus on energy efficiency and sustainable development. The city tendered for a contractor to design, build and operate the building, seeking a contract focused on enhancing efficiency. Additionally, what made this procurement special is that, via the contract, it transferred the risk of exceeding the agreed targets on energy use from the customer to the service provider. At the same time, possible profits were shared 50/50 between the customer and the service provider. This sharing of costs, by contract, encourages both parties involved to ensure that the building is used optimally.

7.7 Competitions

Architecture competitions have become common practice in the construction business. High-profile public buildings in particular are often the result of a winning competition proposal. For this reason, competitions can be a great tool for finding innovative circular construction solutions. An example of such a competition was the Danish Circular Construction Challenge held in 2018, which aimed to address the global problems of waste overload, mass consumption and increasing resource use. The competition hosts called out for innovators to propose solutions for reducing waste throughout the lifecycle of a building. The makers of the three winning proposals were provided with help in finding the right team to bring the proposed solution into reality. Additionally, they got paid for an innovation process that lasted six months, financing of up to 135,000 euros for development, an extended network, public relations support, and partnerships. Among the winning proposals, one concept was to use fungi grown in waste as insulation in buildings. Another proposal involved reducing C&D waste by collecting and selling reused timber from construction sites in large-scale retail stores. The third concept used discarded building materials from roof renovations and turned them into sheds. Competitions such as the Circular Construction Challenge help promote circularity, while looking for new solutions and practices (read more about this competition at Challenges.dk). Additionally, such competitions have the potential to boost circular economy by helping existing companies evolve or by leading to the birth of new businesses that grow out of winning proposals.

7.8 Who provides the incentives?

Most of the incentives discussed above are provided by the government. This does not, however, discount the influence of the private sector on the market. According to Adams et al. (2017), the client has a crucial role to play in the shift towards circular economy, since they can set and commit to certain sustainability targets.

8. Design issues and policies/regulation

In order to achieve circularity in design and construction, the designers involved need to have knowledge about circular economy design principles and sustainable materials. Architects and designers should be familiar with strategies such as design for disassembly, design for adaptability and design for sharing. Additionally, they should be aware of, and understand, lifecycle assessment, how to increase the use of recycled content in construction, and how to make it possible to recycle what is used in construction (EC 2020b). The mentioned strategies aim to reduce C&D waste and increase the recycling of construction materials/products/elements, thus lowering the lifecycle costs of buildings. The key goals are durability, adaptability and waste reduction – which are also macro-objectives included in the Level(s) framework, which is further discussed in section 9.1 (EC 2017c).

Figure 12 below depicts the main actors in the construction field and the extent of their impact on the achievement of durable or adaptable buildings and reducing C&D waste.

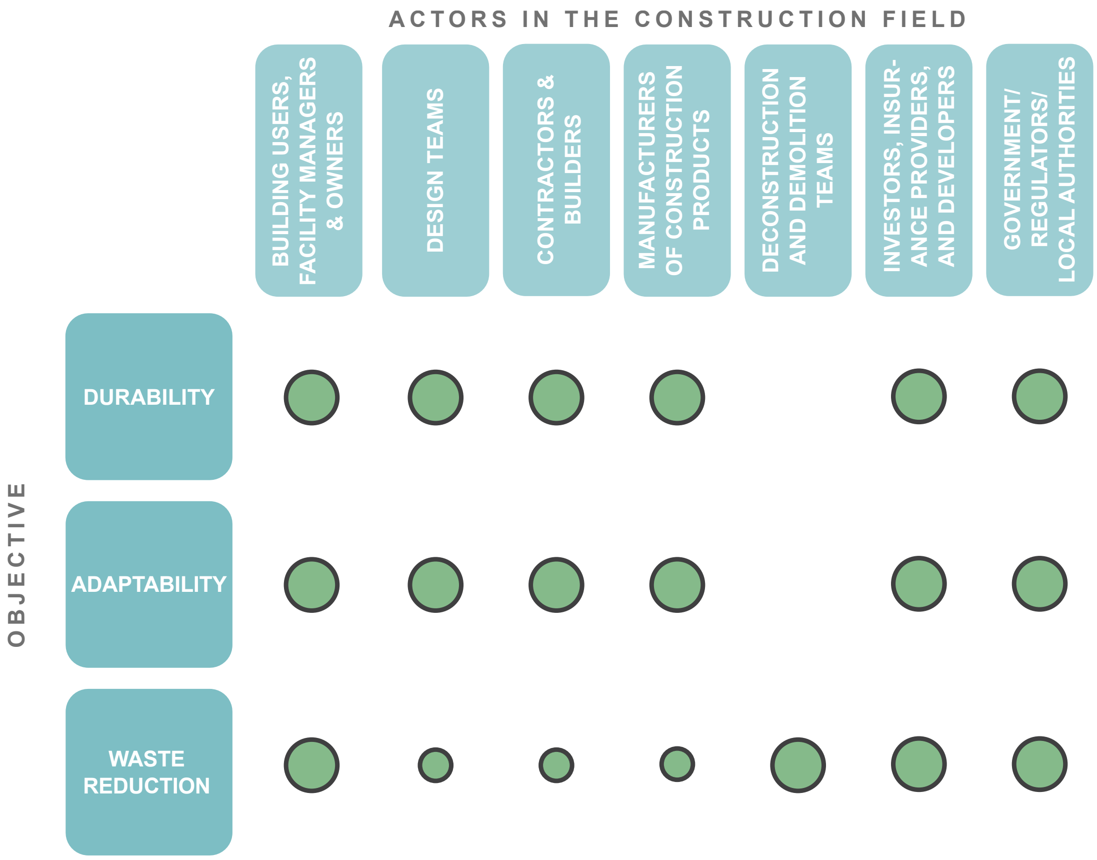

Figure 12: Actors in the construction field and their impact on a building's durability and adaptability and the reduction of C&D waste

NOTE: Size of the dot indicates whether the impact is big or small. No dot indicates no impact.

Source: EC (2020b)
Graphics modified by author

8.1 Lifecycle assessment and costs

The EC has developed Level(s), a lifecycle assessment tool that helps measure resource efficiency in construction. The methods used within the tool have been developed through extensive collaboration with EU member states and sustainable construction professionals. Furthermore, construction companies and organisations have played a crucial role in the development of Level(s) (YM 2020).

Level(s) covers six areas of sustainability (or macro-objectives): lifecycle carbon footprint; resource efficient and circular material lifecycles; efficient use of water resources; healthy spaces and indoor air quality; adaptation and resilience to climate change; and optimised lifecycle cost and value. Most of the objectives require the use of existing EN standards. However, some of these objectives, such as MO-2 on resource-efficient and circular material lifecycles, go further than the existing standards, since the standards and regulations regarding C&D waste are deficient. Furthermore, each goal can be measured according to three accuracy levels: simplified assessment, comparative assessment or detailed optimisation. These three different levels of accuracy and complexity have been developed in order to provide beginners with a simple assessment tool that has a low starting threshold, while the same tool at the advanced level is for experienced LCA professionals.

Through the use of Level(s), the EC seeks to establish a common basis for indicators regarding resource efficiency and environmental performance, and to create a common language and concept that improves the communication between member states. Furthermore, this framework can be applied to the development of commercial environmental certificates, such as the Building Research Establishment Environmental Assessment Method certificate (BREEAM), German Green Building Council’s certificate (DGNB), Leadership in Energy and Environmental Design (LEED) or Swan.

Sustainable design takes into consideration total lifecycle costs, which include environmental, societal and economic costs. In particular, financial statements that account for cumulative costs and earnings, and show financial gain, are often a good inducement for developers. However, in achieving environmentally sustainable buildings, LCA is a useful tool, which, together with legislation and incentives, guides designers and decision-makers alike (EC 2020b).

8.2 Choice of material

Choice of material plays a fundamental role in designing for a circular economy. Circular construction can be achieved by choosing bio-based, renewable (responsibly sourced) materials; healthy materials; secondary materials; materials with high recycled content; materials that can easily be recycled; and materials that are durable and easily maintained or replaced. Additionally, the selected materials should not be dependent on fossil fuels at any stage.

The chosen construction materials make up the ‘embodied carbon’ of a building, while ‘operational carbon’ refers to the greenhouse gas emissions released by using the building. For a long time operational carbon has been the main focus of efforts towards sustainability in Europe, and in the name of promoting energy-efficient buildings, strict regulations have been put into practice in various European countries. However, the energy sector is adapting to the requirements of climate change mitigation much faster than is the construction sector, which is lagging in this area. Typically, the focus on operational carbon has been justified on the basis that a building’s emissions during its lifespan are much greater than those produced by its construction. Yet the initiatives aimed at increasing energy efficiency in different member states, together with the green development of the energy industry, have reduced levels of operational carbon drastically. How much of the carbon footprint is caused by the operation of the building is hard to specify, as seen in Figure 13 below. Based on the presented research results, the average seems to be approximately 50%. However, if the energy sector continues on the path of green development, the focus in construction will need to shift to construction materials and methods, since the proportion of embodied carbon compared to operational carbon is becoming much larger than before. Thus, the way we construct our buildings has to change in order to reach the EU's goal of achieving climate neutrality by 2050.

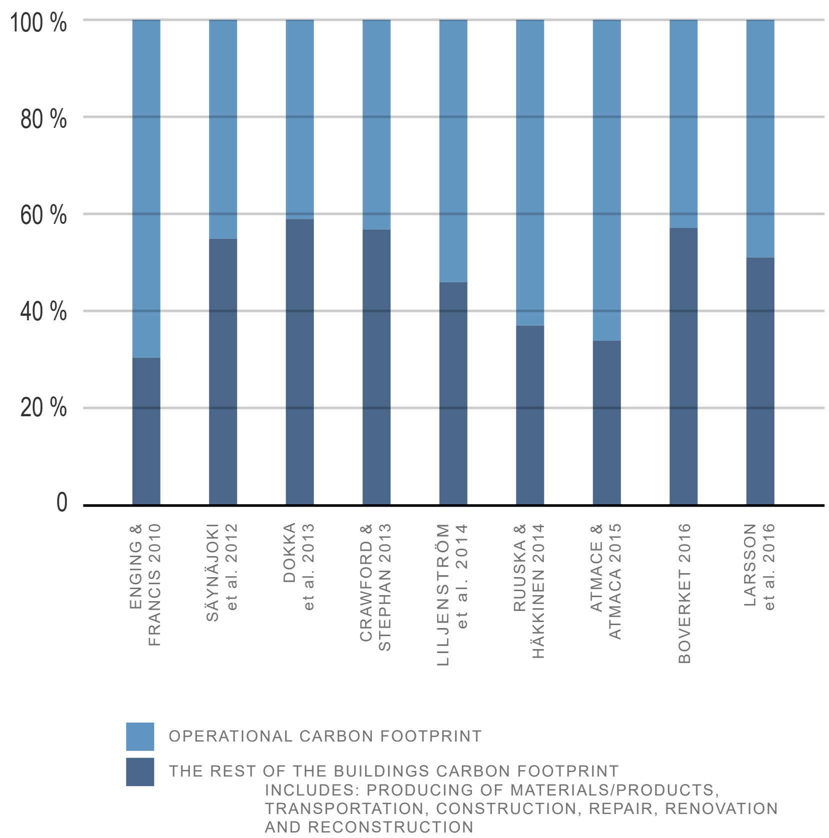

Figure 13: Share of operational emissions in a building's carbon footprint

Source: Finnish Government (2017)
Graphics modified by author

The aim in environmentally sustainable construction is to construct buildings with small carbon footprints (negative environmental impact) and high carbon handprints (positive environmental impact). Put simply, the overall environmental impact of a building can be said to be the footprint minus the handprint. Typically, a building's carbon footprint incudes the emissions caused by manufacture, transport and construction. The newer indicator, the carbon handprint, includes stored carbon, among other positive effects. Trees, and other plants, absorb carbon from the atmosphere when growing – approximately 1 tonne of carbon dioxide is stored in one cubic metre of wood. Thus, (massive) timber buildings have the potential to be excellent carbon storages. Typically, bio-based, renewable materials and materials with high recycled content have small carbon footprints and big carbon handprints. Research has shown, for example, that switching the load-bearing structure from the conventionally used concrete to massive timber can lower a building's emissions by 34–84% (Skullestad et al. 2016). Additionally, a massive timber building can store more than five times the carbon than a typical concrete one, as can be seen in Figure 14 (Takano et al. 2014). The carbon-storing capacity of timber makes it a carbon negative material – a material that stores more carbon than it releases.

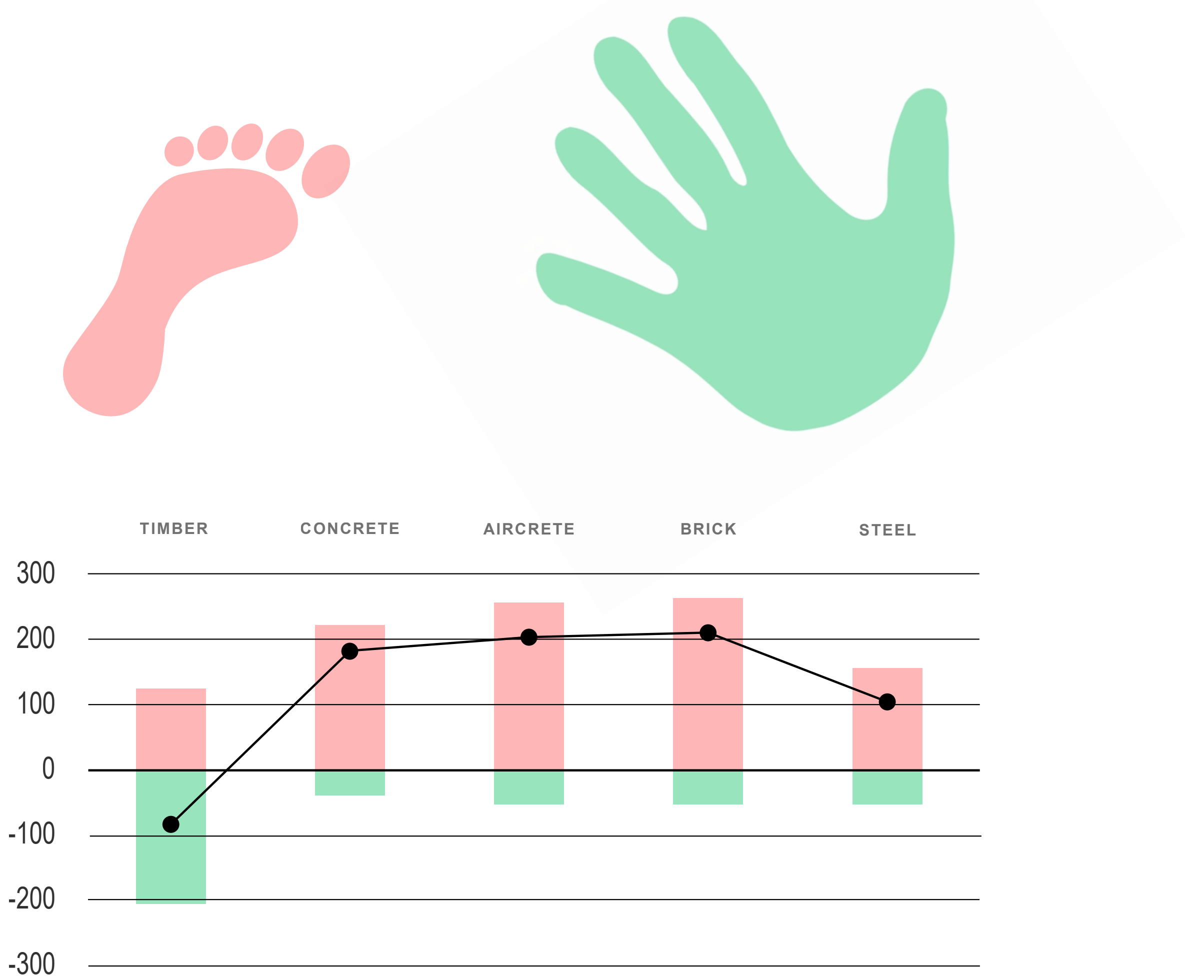

Figure 14: CO_2e emissions and carbon storage capacity in building material alternatives

Source: Takano et al. (2014)
Graphics: Author

8.3 Design for durability

A long-lasting building is often the result of good design, durable construction products and information sharing. First, buildings should be built to last for as long as possible. Ideally, this involves choosing and designing structural elements that last as long as the building does. Second, if the first option is not viable, the building should be demountable and recyclable – a topic further discussed in the next section (EC 2020b).

8.4 Design adaptable buildings

Design culture must change so that end-of-life and future-life are considered and incorporated in the original design of buildings. Premature building demolishment needs to be prevented by the anticipating the changes in the requirements for the buildings already in the design phase. Later adaptations and transformations of buildings and their use should be made possible to ensure a longer lifespan for buildings. The lifespan of a building can be prolonged by improving its ability to adapt and respond to shifts in market demand (EC 2020b). This means, for example, that a building that has been a hotel can be transformed into apartments if needed.

8.5 Design for disassembly

In order to prolong the lifespan of both our buildings and our construction materials, our perception and expectations of them has to change. In design for disassembly, a building is seen as a material bank; materials are temporarily stored in the building and can be released at the end of the building's lifespan to be reused in, ideally, another building. Design for disassembly is, at least in theory if not yet in practice, fast gaining popularity, and innovative pilot projects are showcasing how this design strategy could be incorporated into modern construction practice. However, dismantling and reassembling buildings is nothing new, even though such traditional practices have been decreasing in popularity. For example, traditional log structures are easily disassembled and reassembled, and represent an old and modest version of design for disassembly. Nevertheless, pilot projects are crucial for testing new practices that aim for circularity in the modern built environment, and much knowledge can be gained and shared through such projects. The Netherlands is a forerunner to such pilot projects and the Town Hall of Brummen is a good example of design for disassembly in a modern context. The Brummen town needed a town hall for at least 20 years and instead of traditional construction procurement, the city opted for a flexible and circular solution of 'leasing' a building under a 20-year service contract. The building was designed in a way that it could be disassembled. After disassembly, the building components (such as structural timber and metals) could be returned, by contract, to the suppliers, unlocking a minimum of 20% of their residual value. This project took into consideration the full costs of the building's 20-year occupancy and provided better price certainty than conventional approaches, while also closing the material loop (Kiser 2016; EC 2017b).

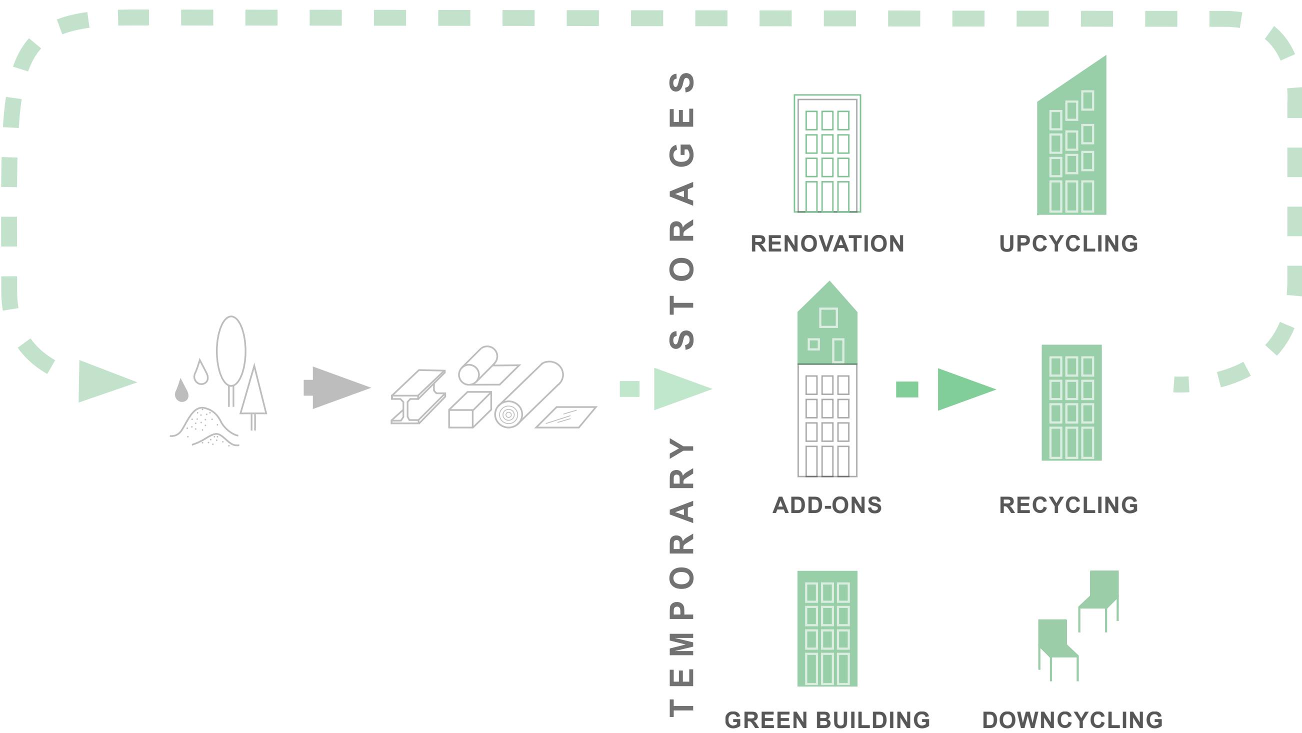

Figure 15: Design for disassembly

Source: Author
Graphics: Author

Another good practical example is the Circle House in Denmark. This project consists of 60 housing units, which are expected to be completed in 2020. Besides providing housing, the up-scalable demonstration project aims to provide the construction industry with new insights into circular economy construction practice. The project involves the design and construction of a variety of building systems that can be assembled, disassembled and reassembled without losing their economic or aesthetic value. The goal is that 90% of the materials used can be reused without significant loss in their value (GXN 2020).

In an ideal scenario, the starting point should not be how to construct something that can be disassembled and reassembled, but how to reshape and reconstruct using the same circular mentality. The latter approach is important, especially in Europe, where the fate of many buildings is premature deconstruction. A practical example of reconstruction is the renovation of the Alliander Headquarters in the Netherlands, which were completely transformed using circular practices. The existing buildings were retained and integrated, and 83% of existing constructions remained. Furthermore, existing facades were maintained, and an additional skin was added to the buildings to improve insulation. Circularity was also in the choice of renovation materials, since many of the materials were reused. For example, concrete from the demolished parts was reused in the new extensions. Additionally, the building was given a raw material passport to ensure the recyclability of the materials in the future. This document contains all the materials that were added during renovation, the new installations and the existing materials that were retained. Furthermore, it provides the information about who handled the materials and where the materials were temporarily stored, as well as suggestions for their future reuse. The Alliander Headquarters is the first renovation project in the Netherlands to gain the BREAAM-NL outstanding sustainability certificate.

8.6 Design for sharing

Enkvist and Klevnäs (2018) estimate that only 60% of European office spaces are in use, even during office hours. However, the way we work is in transition and thus new opportunities are emerging. With the trend of exchanging desktops for laptops comes flexibility regarding both time and space. The fact that so much office space is not used or is in little use highlights that there is much potential for space-sharing and modern co-working spaces. In co-working spaces there are no fixed working stations or fixed users. Thus, such design concepts provide opportunities for the space to be used more efficiently and for occupancy rates to be increased.

A concept similar to co-working is that of co-housing. The way co-housing is understood today derives largely from 1960s Denmark. The co-living concept has started gaining popularity within the past decade in particular because of high housing prices. In the case of Finland, more than 30% of inhabitants have excessive housing costs, which means that more than 40% of their salary is used to cover housing costs (Hypo 2016). In the co-housing concept, housing is seen as more than merely the sum of apartments. Thus, one apartment does not simply fulfil the needs of its inhabitant, but rather the entire housing complex fulfils the needs of all inhabitants. In practice, this means that private spaces are smaller than in conventional apartments but there are more common spaces and things, such as cars, that are shared. Co-housing has the potential to offer higher quality living for a better price, while also tackling other social problems such as rising loneliness and the high carbon footprints caused by construction and lifestyles.

8.7 Information sharing

In order for a building to be built as designed, used as intended, maintained as needed and deconstructed as planned, effective information flow is vital. It is crucial for the building owners and users to be informed and updated about the maintenance needs of the building. For example, BIM and building passports can facilitate the flow of information and help guide the users and maintenance teams regarding the best ways to use, maintain and repair the building. There should be documentation regarding what has been put into the building, how it has been done and when. Furthermore, this documentation has to be kept up to date. Such practices are of great importance in case something unexpected happens and the building must be adapted in response to a changed situation (EC 2020b).

8.8 Labour upskilling

When the aim is to radically change the way buildings are constructed, there is also a need for more knowledge in construction techniques. Construction workers must have the right knowhow, skills and tools. Specific funds should be allocated for the training of construction workers. Additionally, deconstruction techniques should be integrated into apprenticeship schemes. Both methods can work as inducement for gaining the needed knowhow (EC 2020b).

9. Analysis and evaluation

There is an acute need to apply circular economy principles to deasign and construction in order to reduce resource use in the future and thereby lower the environmental impact of buildings. Nevertheless, it is extremely difficult to incorporate such concepts into the construction business and achieve fast results. The construction industry is complex, and the actors involved are many and varied. Additionally, linear practices are deeply rooted in the construction industry's culture. Another issue is that all of the actors involved are facing dilemmas around whether to opt for building new or renovating old, structural resistance or easy disassembly, longevity or flexibility, or simple or complex products and structures, among other conflicting choices. Some of the key solutions proposed in this report, and the main goals and challenges linked to them, are presented in Figure 16.

HIGH-GRADE PRODUCTS WITH HIGH-RECYCLED CONTENT

Materials with high durability used in structural elements

GOAL

- Prolong construction's lifespan, thus contribute to waste prevention
- Creates demand for recycled materials in closed loops, increases quality of recycling

CHALLENGE

- Low price of virgin materials in comparison to secondary materials
- Doubts on recyclables, lack of standards

DESIGN FOR DISASSEMBLY

Designing buildings that can easily be dismantled into components that can be reused, reassembled, reconfigured, upcycled or recycled

GOAL

- Reuse is part of waste prevention, separation of components makes reuse and recycling easier

CHALLENGE

- Higher complexity of disassembly
- Potential conflict with other legis-lation, such as energy efficiency
- Lack of knowledge and information
- Very long time delay between implementation and results

SELECTIVE DECONSTRUCTION

Remove hazardous materials and increase source separation into high-value, pure material fractures

GOAL

- Increase quantity and quality of recycling

CHALLENGE

- More time consuming and potentially more costly demolition
- Lack of traceability
- Complexity of buildings and construction materials

MATERIAL AND BUILDING PASSPORTS

Sets of data describing defined characteristics of materials and components in buildings

GOAL

- Facilitates source separation of end-of-waste materials, increases recycling, quality, and closed loops

CHALLENGE

- Information and data management for long periods of time
- Costs of data gathering and storage

EXTENSION OF CONSTRUCTION SERVICE LIFE

Renovate, improve maintenance, upgrade, repair, and adapt constructions

GOAL

- Implementation of waste prevention
- Avoidance of new construction and related negative environmental impacts

CHALLENGE

- Energy inefficient buildings also extend their life span
- Risk from the presence of inferior materials in buildings and degradation of structural building elements
- High labour costs
- Changes in architectural preferences

Figure 16: Goals and challenges related to key solutions

Source: EEA (2020b)
Graphics: Author

9.1 Conclusions and recommendations

In the case of Europe, it seems entirely possible to turn design and construction circular in a way that benefits not only the environment but also the economy and society more broadly. In Table 1, the solutions proposed in this report are summarised and organised under the main areas of impact: capital cost, operational costs, environmental impacts, new businesses, and green jobs and skills. Additionally, the recommended actions are linked to the lifecycle phase most critical to them.

In Europe, in contrast to most other regions, the main focus regarding circular economy in construction needs to be on the existing building stock, on its renovation and on the ways to eliminate construction waste. Additionally, new construction has to be undertaken in a way that avoids the problems we are now battling with. In this report, a few good examples of circular construction have been presented. Now, the task is how to turn such best cases into standard practice. Designers need to learn how to design flexible resource-efficient solutions than can be disassembled. Researchers and inventors need to come up with high-quality secondary materials. Furthermore, designers must learn to design using secondary materials. These actors, together with builders and waste managers, need to come up with efficient ways to renovate and deconstruct existing buildings to prolong their lifespan. Additionally, the public sector needs to set an example by implementing sustainable public procurement. Furthermore, developers have to set and achieve environmental goals. In the case of Europe, the private sector is driving circularity in the construction industry, and it just needs guidance and a push in the right direction with the help of legislation and incentives, and a change in mindset.

The regulations and legislation regarding construction have to change and a holistic approach is needed. Reversibility, resource recovery and recycling should be prioritised, alongside requirements such as energy efficiency. Additionally, buildings have to be holistically assessed and monitored. In particular, the environmental performance of buildings during their one or multiple lifecycles needs to be assessed in order to ensure that legislation and regulations are not in conflict with one another or function against rather than for circularity.

Table 1: Building lifecycle impacts

Source: Author
Graphics: Author

CAPITAL COSTS

MANUFACTURE	Manufacturing from a capital cost perspective needs to support the cost benefits of the use of waste and by-products. Circular product development needs to be mainstreamed.
DESIGN	The design process needs to include considerations of a building's lifecycle to encourage better designs.
CONSTRUCTION	The economic benefits of circular building products from a construction perspective need to be fully explored.
OPERATION AND USE	Lifecycle cost savings provide increased value over the life of the building. This requires explicit recognition in the manufacturing process.
RENOVATION	Reusability and replaceability of building products and systems can support a growing renovations sector.
DECONSTRUCTION END OF LIFE	Opportunities for end of life need to be understood in terms of the value of recovered building products and upcycling should be investigated.

OPERATIONAL COSTS

MANUFACTURE	The running costs for manufacturing need to factor in the service life of buildings and their equipment.
DESIGN	Operational costs for design for multi-use are needed. Flexibility and adaptability also need to be thought through at the outset.
CONSTRUCTION	Construction for reduced waste needs to be explored. Attendant emissions will also be reduced through this process.
OPERATION AND USE	The renovation sector can engage with building products that use the principles of de-mountability and reusability of building products.
RENOVATION	De-mountability and reusability of building products, and design for disassembly and reassembly – these areas need further development.
DECONSTRUCTION END OF LIFE	The end of life of buildings needs to consider the value of recovered building products. Where possible, upcycling opportunities need to be explored.

ENVIRONMENTAL IMPACTS

MANUFACTURE	Assessment of environmental impacts needs to consider reduced emissions and reduced or no waste.
DESIGN	Design considerations should focus on LCAs and design for multi-use and flexibility, as well as design for disassembly where appropriate.
CONSTRUCTION	Construction materials and techniques should focus on reduced emissions and waste.
OPERATION AND USE	The environmental impact due to operations should focus on reduced emissions and waste.
RENOVATION	The renovations market should focus on materials and techniques that result in reduced emissions and waste.
DECONSTRUCTION END OF LIFE	The deconstruction phase should focus on reduced emissions and waste and consider the use of materials that can be used again in second life.

NEW BUSINESSES

MANUFACTURE	New business opportunities abound in a digital marketplace and for upcycling or developing new types of product from those that are already in the system, focusing on products with a second life.
DESIGN	Design should consider LCAs to enable support of multi-use and flexibility, design for disassembly and development of building passports for material use and reuse.
CONSTRUCTION	Construction should focus on circular construction practices and building passports should become the norm.
OPERATION AND USE	Operational considerations should focus on building passports and operating a building as a material bank for reuse in its second life.
RENOVATION	Renovations provide options for the assessment of the high-value recovery of building products, material passports and supporting reuse where possible.
DECONSTRUCTION END OF LIFE	The end of life should support the high-value recovery of building products and systems so that virgin materials need not be used.

GREEN JOBS AND SKILLS

MANUFACTURE

Manufacturing opportunities for green jobs and new skills need to be investigated to develop quality products from waste streams.

DESIGN

Design skills should support quality assurance of recycled products, and design for disassembly so that components can be reused many times over.

CONSTRUCTION

Construction skills should focus on building passports in circular construction and guidance for users to make the best use of the building as a resource and optimise this where possible.

OPERATION AND USE

Operation and use of buildings should focus on building new skills in supporting the idea of building and material passports and providing updates/options for circular maintenance in buildings.

Buildings and spaces should be purchased as services.

RENOVATION

The renovation sector can support high-value recovery and skills need to be developed so that the recovery materials may be identified.

DECONSTRUCTION END OF LIFE

Deconstruction of buildings also requires skills in identifying high-value recovery in circular deconstruction so that materials may be reused.

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