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# D3.4 Blueprint for resource-efficient secondary raw material based urban and peri-urban construction sector

## D3.4 November 2019 (M18)

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**This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 776751**

# Document Details

| | |
|---|---|
| Title: | Blueprint for resource-efficient secondary raw material based urban and peri-urban construction sector |
| Annexes: | 2 |

| | |
|---|---|
| Deliverable No. | D3.4 |
| Work Package: | WP3 |
| Task: | Task 3.4 |
| Deliverable Type: | Report |
| Lead Partner: | ZAG |
| Contributing Partner(s): | All |
| Due date of deliverable: | 31 May 2019 |
| Actual submission date: | 30 November 2019 |
| Date of revision: | 31 May 2020 |

| Dissemination level: | | |
|---|---|---|
| PU | Public | X |
| RE | Restricted to a group specified by the consortium (including Commission Services) | |
| CO | Confidential, only for members of the consortium (including Commission Services) | |



This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 776751

# EXECUTIVE SUMMARY

The construction sector is the largest sink of raw materials, consuming almost half of all extracted raw materials and one third of water in Europe. It also produces one third of European waste while directly employing 18 million Europeans and contributing to 9% of the EU's GDP. Construction activities are mainly localised in urban areas where the majority of Europeans are living. Therefore, a large potential for more sustainable society lies in increased resource efficiency in urban and peri-urban construction, decreasing not only costs but also improving the balance between economic, social and ecological factors, which is the main aim of Circular Economy.

The CINDERELA Blueprint for resource-efficient Secondary Raw Material (SRM)-based urban and peri-urban construction sector (in short **CINDERELA Blueprint** or **CinderBP**) discusses the major challenges and opportunities for urban and peri-urban construction to become more resource efficient. As a main result of this deliverable six guiding principles (**CinderGP**) are given, based on partners' experiences, desktop research and interaction with stakeholders. This deliverable is meant to serve as a first step towards on-going and improving activities which will result in a living document published and continuously improved on the CINDERELA website in alignment with developments in the studied area. Further, it will serve as a knowledge pool for the CINDERELA One Stop Shop (CinderOSS) service. The authors also wish for the CinderBP to serve as a basis for discussion with urban and peri-urban construction and waste industries and stakeholders, and as a guide to local, regional and national decision- and policy-makers. This will enhance the creation of stimulating ecosystems in order to implement more circular and resource-efficient urban and peri-urban construction.



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| **Keywords:** |
|---|
| Blueprint, Resource efficiency, Circular Economy, Urban and peri-urban construction, Secondary Raw Materials, Guiding principles. |



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# EXPLANATION OF ACRONYMS & ABBREVIATIONS

| Acronym | Full name |
|---|---|
| BaU | Business as Usual |
| BIM | Building Information Modelling |
| CE | Circular Economy |
| CDW | Construction and Demolition Waste |
| CEN | European Committee for Standardization |
| CinderBP | CINDERELA Blueprint |
| CinderCEBM | CINDERELA Circular Economy Business Model |
| CinderGP | CINDERELA Guiding Principles |
| CinderOSS | CINDERELA One-Stop-Shop |
| CP-DS | Construction Products – Dangerous Substances |
| CPR | Construction Product Regulation |
| CRM | Critical Raw Materials |
| EAD | European Assessment Document |
| EIT | European Institute of Innovation and Technology |
| EoL | End of Life |
| EoW | End of Waste |
| EOTA | European Organisation for Technical Assessment |
| ETA | European Technical Assessment |
| FTI | Fast Track to Innovation |
| GDP | Gross Domestic Product |
| GDSE | Geodesign Decision Support Environment |
| GIS | Geographic Information System |
| GPP | Green Public Procurement |
| hEN | Harmonised European Standard |
| IAEF | Innovative, Affordable, Economic and Feasible |
| IS | Industrial Symbiosis |
| KICs | Knowledge and Innovation Communities |
| KPI | Key Performing Indicators |
| LCA | Life Cycle Assessment |
| LCC | Life Cycle Costing |
| MFA | Material Flow Analysis |
| MS | Member States |
| NIMBY | Not in My BackYard |



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| Acronym | Full name |
|---|---|
| PESTLE Analysis | Political Economic Social Technological Legal and Environmental Analysis |
| PTE | Potential Toxic Elements |
| R&I | Research and Innovation |
| S-LCA | Social Life Cycle Assessment |
| SME | Small and Medium-sized Enterprises |
| SRM | Secondary Raw Materials |
| TRL | Technology Readiness Level |
| WP | Work Package |
| WFD | Waste Framework Directive |
| W2P | Waste To Product |

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# Document history

| Version | Date | Partner | Author | Changes |
|---|---|---|---|---|
| 1 | 12.03.2019 | ZAG | Ana Mladenovič, Primož Oprčkal, Alenka Mauko Pranjić, Kim Mezga | Creation of first document draft |
| 2 | 13.05.2019 | ZAG, TECNALIA | Ana Mladenovič, Alenka Mauko Pranjić Primož Oprčkal, Pierre Menger | Improvement of first version |
| 3 | 23.5.2019 | ZAG, all | Alenka Mauko Pranjić, Kim Mezga | Consultation with partners and creation of second version |
| 4 | 2.11.2019 | ZAG | Alenka Mauko Pranjić, Ana Mladenovič | Creation of third version |
| 5 | 30.11.2019 | ZAG | Alenka Mauko Pranjić, Kim Mezga, Urška Kropf | Final version |
| 6 | 31.5.2020 | ZAG, TECNALIA | Alenka Mauko Pranjić, Sebastjan Meža, Pierre Menger, Ana Mladenovič | Revised final version |


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# 1. INTRODUCTION

## 1.1. Overview of the CINDERELA project

The EU-28 total waste generation in 2016 was 2,538 million tonnes, 36.4% of which was from the construction sector[1]. The construction industry[2] is also one of the larger consumers of inorganic raw materials and water[3]. Construction activities are mainly localised in urban areas where by 2050 about 68% of the world's population is expected to live (83.7% in Europe)[4].

The CINDERELA project (www.CINDERELA.eu) aims to develop a new Circular Economy Business Model (CinderCEBM) for the use of Secondary Raw Materials (SRM) in urban areas supported with a developing One-Stop-Shop service called CinderOSS service. Through CinderOSS different industries (including the construction sector and municipal services) and stakeholders (including policy- and decision-makers) as well as the general public, will be connected. Different streams of waste produced in urban and peri-urban areas are studied in the project; e.g. construction and demolition waste (CDW), waste resulting from treatment of municipal solid waste and wastewater treatment, as well as different locally available industrial wastes. Most of these waste streams are currently transported over long distances, backfilled, landfilled or incinerated. Their suitability for use as building materials will be demonstrated through large scale demonstration activities in Slovenia, North Macedonia and Spain while the overarching business model and one-stop-shop service will be demonstrated in Slovenia, North Macedonia, Spain, Poland, Italy and the Netherlands. The project will contribute to a 20% reduction of environmental impacts along the value and supply chain, reducing the exploitation of primary materials and converting wastes to products. The sustainability of various business models will be proven with environmental, economic and social assessments through the whole life cycle with use of Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and Social Life Cycle Assessment (S-LCA) tools. The pre-feasibility analysis of the proposed CinderCEBM indicates an increase of recycling by 30% of CDW, 13% of industrial waste, 100% of heavy fraction and 25% of sewage sludge with a net profit of 18%.

## 1.2. Overview of WP3: Assessing waste to product opportunities

The construction sector exerts great pressure on resources. This inevitably leads to resource depletion and therefore to questioning of the conventional linear business model (extract – use – dump) in a very traditional construction industry. To deal with this problem, the Circular Economy (CE) paradigm proposes a systemic approach to optimise material and energy flows in an endless circuit, continually drawing value from waste or residual materials. CINDERELA work package 3 (WP3) reviews and applies some of the most advanced methods, such as the Geographic Information System (GIS) based material flow analysis (i.e. GDSE – Geodesign Decision Support Environment[5]) together with other methods for establishing circular business models, e.g. the PESTLE[6] analysis for evaluation of business ecosystems, assessment of existing value chains and technological valorisation of waste streams according to foreseen use in the construction industry.

[1] https://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics#Total_waste_generation
[2] By construction industry it is meant all industries connected to construction of buildings and civil engineering works
[3] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0571&from=EN
[4] https://ec.europa.eu/knowledge4policy/foresight/topic/continuing-urbanisation/worldwide-urban-population-growth_en
[5] http://h2020repair.eu/gdse-software-package/gdse-description/
[6] https://pestleanalysis.com/what-is-pestle-analysis/

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The main objectives of WP3 are:

- To develop a holistic protocol for waste assessment in urban and peri-urban areas for the purpose of predicting the most optimal waste-to-product (W2P) solutions based on waste properties, quantity, location, recyclability and other technological, socio-economic and environmental conditions of their occurrences and targeted construction market;
- To assess accessibility to public environmental data on produced waste, their quantities, current treatment, and fate (Task 3.1) in six selected urban and peri-urban areas;
- To execute the Geographic Information System (GIS)-based Material Flow Analyses (MFA) in six selected areas and regions, e.g. Maribor with neighbouring municipalities (Slovenia), Istria (Croatia), Basque country (Spain), Amsterdam Metropolitan Area (the Netherlands), Trentino (Italy) and Katowice with surrounding area (Poland) (Task 3.1);
- To valorise waste potential in three studied cases (Maribor, Umag and Madrid-Henares) for the production of SRM-based products (Task 3.2);
- To assess existing and potential value and supply chains and the main actors and stakeholders of the value and supply chains, including policy- and decision-makers, legislative bodies, and the general public (Task 3.3);
- To set up a framework for SRM-based urban and peri-urban construction (Task 3.4).

## 1.3. Overview of Task 3.4: Setting up a new framework for SRM-based urban and peri-urban construction

The main objective of this task is to develop the Blueprint for a resource-efficient, i.e. SRM-based, urban and peri-urban construction sector, including a study of the needs, conditions, potentials and obstacles of different local ecosystems across Europe. This includes assessment of technological and non-technological, legislative, administrative, socio-economic, and environmental issues, and is therefore developed in close interaction with relevant stakeholders. Experience shows that, beyond the technical, economic and environmental issues, the social element also plays an important role in developing industrial symbioses (i.e. cross-sectoral exchanges of resources in a local environment) as it strengthens (or hinders) the engagement of stakeholders which are required for the implementation. Therefore collaboration with all of the actors in local governance is very important in order to optimise resource use in the construction sector. Use of SRMs does not only generate benefits for industries but is also expected to have a positive impact to the entire region in which the opportunities are located. Within this context Task 3.4 builds up the socio-metabolic perspective, in order to embrace existing knowledge, creativity and capabilities to redesign, invent, and test strategies for a CE in urban construction living labs (see WP6).

## 1.4. Reading guide

This document provides a description of developed CINDERELA guiding principles (CinderGP) for establishing a resource-efficient urban and peri-urban construction sector. Each principle is first linked with a specific CINDERELA goal, followed by a description of the state of the art situation, enabling conditions and barriers. Finally, the Guiding Principles are completed with a short indication


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of what CINDERELA would contribute to improve their performance or facilitate their establishment in practice.

The document consists of the following sections:

- Section 1: Introduction of the purpose and structure of this document;
- Section 2: The CINDERELA Blueprint (CinderBP) methodology;
- Section 3: Explanation of the CINDERELA Guiding Principles (CinderGP);
- Section 4: Conclusions and future work;
- Section 5: Annexes.

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# 2. THE CINDERELA BLUEPRINT (CINDERBP) APPROACH

## 2.1. Current trends in resource-efficient urban and peri-urban construction

Despite the severe decline of the construction sector in the last decade (Figure 1) this sector is still one of the most important ones for European economies. Indeed, the construction sector contributes around 9% of European Gross Domestic Product (GDP) and creates 18 million direct jobs (7-8% of European employment[7]) mainly embedded in Small and Medium-size Enterprises (SME)[8]. It is also one of the largest consumers of raw materials and the largest producer of waste consuming around 50% of all extracted materials, 1/3 of water[9] and producing more than 1/3 of all waste generated in Europe (Figure 1)[10]. Given these premises, **it is to be expected that increased resource efficiency through the replacement of primary raw materials with recycled waste-based SRM could create – along with the application of other sustainability measures – a considerable change in the construction industry as well as in European society.**

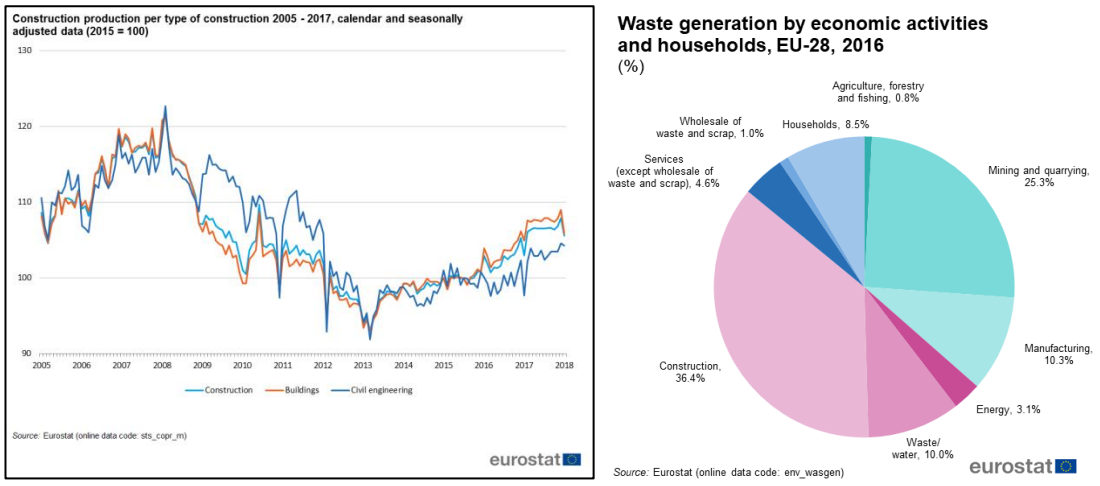


**Figure 1 - European construction production in the past decade and overall generation of waste in the EU in 2016 (Source: Eurostat) [11,12]**

In the past years several initiatives were launched covering the topic of resource efficiency at:

(i) Strategic level of the EU (e.g. Europe 2020 Strategy[13], The Roadmap to Resource Efficient Europe[14], 7th Environmental Action Programme[15], First[16] and Second[17] Circular Economy Action Plan, A European Green Deal[18]);

[7] https://ec.europa.eu/eurostat/statistics-explained/index.php/Europe_2020_indicators_-_employment#General_overview
[8] https://ec.europa.eu/growth/sectors/construction_sl
[9] Roadmap to a Resource Efficient Europe. COM (2011) 571final. 2011
[10] https://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics#Total_waste_generation
[11] https://ec.europa.eu/eurostat/statistics-explained/index.php/Construction_production_(volume)_index_overview#Construction_output_in_Europe
[12] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Waste_generation_by_economic_activities_and_households,_EU-28,_2016_(%25).png
[13] https://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf
[14] https://ec.europa.eu/environment/resource_efficiency/about/roadmap/index_en.htm
[15] https://ec.europa.eu/environment/action-programme/
[16] https://ec.europa.eu/environment/circular-economy/first_circular_economy_action_plan.html



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(ii) Sectoral level (e.g. SPIRE Roadmap[19], 2020 Vision for a Sustainable Aggregates Industry[20]); and,

(iii) Member States (MS) level (e.g. A Circular Economy in the Netherlands[21] and other countries).

All of these documents in part or in whole address resource efficiency in the construction industry.

## 2.2. Methodology adopted for developing the CinderBP

The CinderBP has been developed based on the knowledge and experiences of partners, interaction with stakeholders through organised workshops and interviews, communication and liaising with existing and past EU funded research and demonstration projects, such as REPAIR[22], HISER[23], BAMB[24], FISSAC[25], PaperChain[26], CIRCuIT[27], CICERONE[28], ECCA[29] and is also based on desktop research of existing policies, recommendations, national initiatives and other documents.

Interaction with stakeholders was done on several levels:

- Interviews and several workshops held across Europe, i.e. in San Fernando de Henares (Spain), Ljubljana (Slovenia), Umag (Croatia), Katowice (Poland), and Amsterdam (The Netherlands) in the spring of 2019 (Figure 2);
- Deep Dive sessions at the Initial CINDERELA conference (Figure 3) held in Amsterdam at the AMS Institute on 23rd May 2019; and
- 1st CINDERELA international seminar held at the ECOMONDO fair on 6th November 2019 and stakeholder interaction during the fair (Figure 4).

During the first series of workshops the participants discussed political, economic, social, technological, environmental and legal (PESTLE) factors, which support or hinder the implementation of new resource-efficient value chains in local urban and peri-urban construction works. The Deep Dive sessions during the Initial CINDERELA conference were focused on developing the CinderBP itself.

A seminar at the ECOMONDO 2019 served to present the best available practices along circular value chains presented by different actors along the knowledge triangle inside and outside the consortium, i.e. between:

- Industry (start-ups in the field of recycling, consulting companies and construction companies),
- Research institutes; and
- Academia.

[17] https://ec.europa.eu/environment/circular-economy/
[18] https://ec.europa.eu/info/node/123797
[19] https://www.spire2030.eu/what/walking-the-spire-roadmap/spire-Roadmap
[20] http://www.uepg.eu/uploads/ModuleXtender/Publications/30/15_03_10_UEPG_Vision_brochure.pdf
[21] https://www.government.nl/documents/policy-notes/2016/09/14/a-circular-economy-in-the-netherlands-by-2050
[22] http://h2020repair.eu/
[23] http://www.hiserproject.eu/
[24] https://www.bamb2020.eu/
[25] http://fissacproject.eu/en/
[26] https://www.paperchain.eu/
[27] https://cordis.europa.eu/project/rcn/223267/factsheet/en
[28] http://cicerone-h2020.eu/
[29] http://circularconstruction.eu/

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The presence of CINDERELA at two ECOMONDO stands (Figure 4) was an opportunity to present and exchange current interests and worries of different stakeholders for resource-efficient urban and peri-urban construction. During these exchanges, questions such as “Is it safe?”, “Is it economically viable?”, “How much decrease of $CO_2$ emission can you achieve?” were discussed and useful feedback gained for the consortium.

**Figure 2 - Workshops with stakeholders held in Umag, Croatia (upper left), San Fernando de Henares, Spain (upper right), and Ljubljana, Slovenia (lower left), during which enabling and preventing PESTLE factors were discussed in introducing new SRM-based construction products value chains (lower right).**



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**Figure 3 - Deep Dive sessions held between the CINDERELA consortium and stakeholders on the topic of the CinderBP (pictures above) and final plenary discussion in the CINDERELA Initial conference (pictures below).**

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**Figure 4 – The CINDERELA workshop (above) and presentation of CINDERELA at two stands during the ECOMONDO fair 2019 held in Rimini, Italy in November 2019.**

A summary of results of PESTLE analyses from workshops and results of Deep Dive sessions at the Initial CINDERELA conference are given in Annex 1.

The following six CinderGP have been established during the consultation process (Figure 5):

- Enabling legislation (**CinderGP#1**);
- Enabling an inclusive environment and raising responsible actors (**CinderGP#2**);
- Penetrating Circular Economy Business Models (**CinderGP#3**);
- Environmentally and socially acceptable new CEBM (**CinderGP#4**);
- Applicable technologies - rapid transition from laboratory to practice (**CinderGP#5**);
- Accessible data and efficient digital supporting tools (digital business ecosystem, MFA, BIM and others) (**CinderGP#6**).


**Figure 5 - Six CINDERELA Guiding Principles.**



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# 3. CINDERELA GUIDING PRINCIPLES

## 3.1. CinderGP#1 – ENABLING LEGISLATION

According to Article 6 (1) and (2) of the Waste Framework Directive (WFD) 2008/98/EC[30], 2018/851/EC[31], waste shall cease to be waste when it has undergone a recovery operation (including recycling) and complies with specific criteria such as:

- The substance or object is commonly used for specific purposes;
- There is an existing market or demand for the substance or object;
- The use is lawful (the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products); and
- The use will not lead to overall adverse environmental or human health impacts.

Currently, there is no European based set of criteria or guidance for different wastes to cease their waste status and to be used in the construction sector. This lack of standards and legal gap has an impact on the introduction of SRM-based construction products on the market and hinders greatly the transition towards a European resource-efficient construction sector. As established in the Regulatory Barriers document published by the EC in 2016 there is "a barrier referred to legislation that hinders the use of recycled materials in production processes. The rationale behind such legislation is frequently motivated by aspects of health and consumer protection and often undermines opportunities and benefits of circular approaches. In addition, in many cases, a lack of harmonised EU legislation mandating specific quality requirements has been identified as a major obstacle to high-quality recycling."[32]

However, some countries have issued national criteria (EoW) for selected materials to cease their waste status and enter product phase for different uses (e.g. recycling of CDW into recycled aggregates for road construction and earthworks). Beyond the establishment of common criteria there is also the possibility to assess EoW through a case-by-case approach. Table 1 gives a brief commentary to each EoW criterion as stated in WFD 2008/98/EC.

**Table 1 - Commentary to the specific criterion of End of Waste (EoW).**

| Specific criterion for EoW | Commentary to criteria |
|---|---|
| The substance or object is commonly used for specific purposes. | Recycled wastes can successfully replace primary materials in construction products as long as the essential properties of SMR-based construction products are compliant with requirements for intended use. |
| There is an existing market or demand for the substance or object. | Due to the large demand for materials in the construction sector, a market for SRM-based products exists and has great potential for growth. |
| The use is lawful (the substance or object fulfils the technical | Construction Product Regulation (CPR)[33] is not discriminative in use of primary and secondary raw materials for construction products as long |

[30] Directive 2008/98/EC on waste and repealing certain Directives.
[31] Directive (EU) 2018/851 amending Directive 2008/98/EC on waste.
[32] https://ec.europa.eu/growth/content/regulatory-barriers-circular-economy-lessons-ten-case-studies_en
[33] Regulation (EU) No. 305/2011 on laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC.

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| Specific criterion for EoW | Commentary to criteria |
|---|---|
| requirements for the specific purposes and meets the existing legislation and standards applicable to products). | as performance of the product is in accordance with the requirements for intended use. Further, use of SRM is encouraged, especially by introduction of the additional Basic Requirement #7 (Sustainable use of natural resources). |
| The use will not lead to overall adverse environmental or human health impacts. | This should be assessed for each individual waste. In general there is lack of EU guidance and national legislation in connection with Basic Requirement #3 (Hygiene, health and the environment) as well as criteria on inertness for recycled waste to be used in a construction product. See European CP-DS database for more information: Legislation on substances in construction products for more information.[34] |

### 3.1.1 The CINDERELA goal of enabling legislation

CINDERELA aims to contribute to the development of legislative and administrative procedures, which would enable the use of different materials at their End of Life (EoL) and putting on the market SRM-based construction products under strict conditions to avoid adverse environmental or human health impacts. For this purpose the CINDERELA project in WP5 develops guidelines for criteria - including limit values for pollutants where necessary - taking into account any possible adverse environmental effects of the waste material.

The CinderGP#1 goal:
**No regulatory barriers for putting on the market SRM-based construction products.**

### 3.1.2 Current status of W2P legislation

#### 3.1.2.1 ENABLERS

- **Existing EU legislation in the area of SRM to be used in the construction sector**
  The following documents on European and national levels render a general framework for using recycled waste as SRM for construction products:
  - Waste Framework Directive;
  - Construction Product Regulation;
  - Individual MS legislation;
  - Existing standards for production and construction with SRM-based construction materials, which can be either harmonised (i.e. harmonised standards (hEN) and Eurocodes of European Committee for Standardization (CEN)[35] and European Technical Assessments (ETA) coordinated by European Organisation for Technical Assessment EOTA[36]) or non-harmonised technical specifications (e.g. national technical specifications and standards). Exemplary list of harmonised technical specifications are given in Annex 2.

In recent years some national and regional documents have been published covering EoW criteria

[34] https://ec.europa.eu/growth/tools-databases/cp-ds_en
[35] https://www.cen.eu/Pages/default.aspx
[36] https://www.eota.eu/en-GB/content/home/2/185/


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mainly for recycling CDW into recycled aggregates (e.g. WRAP quality protocol Aggregate from inert waste[37] and Norden's End-of-Waste Criteria for Construction & Demolition Waste[38]), while other wastes have rarely been considered. In 2014, the EC Joint Research Centre published a Study on methodological aspects regarding limit values for pollutants in aggregates in context of the possible development of EoW criteria under the EU Waste Framework Directive[39]. This study gives an overview of limit values but is not implemented as a legislative act.

#### 3.1.2.2 BARRIERS

- **Complexity of interface between chemical, products and waste legislation**

There are numerous interfaces in product, waste and chemicals legislation concerning CE and use of SRM in the construction industry. This leads to conflicting objectives, e.g. with regard to the classification of waste in analogy to chemicals as well as at the border between waste and SRM that are further processed into products[40]. The EC is currently analysing policy options to address the interface between chemicals, products and waste legislation, including how to reduce the presence and improve the tracking of chemicals of concern in products.[41]

- **Lack of suitable tests for recycled materials and technical criteria for their use**

Construction Product Regulation (CPR) does not distinguish between primary and secondary resources, as long they comply with their intended uses. Nevertheless, most of the tests in technical standards for the individual construction products being prescribed for each essential characteristic (e.g. mechanical and physical properties, water absorption) and their limit values have been developed for primary materials. Lack of clear criteria, coherent legislation and appropriate technical standards covering explicitly SRM creates uncertainties in legislative procedures and marketing itself. This further hinders active participation of the industry from both sides of offer and demand which conclude that W2P process is too complicated, expensive, and not worth trying.

### 3.1.3 Actions proposed by CINDERELA for enabling legislation

Currently, some of the identified barriers are already tackled by different stakeholders as well in different action plans. In Table 2 an overview of proposed actions by the CINDERELA consortium on enabling legislation are given. This does not represent an exhaustive list but should be up-dated during implementation of the CINDERELA project.

**Table 2 - Actions proposed by the CINDERELA consortium on enabling legislation (L – long term perspective, S – short term perspective, C – within the CINDERELA project)**

| Proposed action | To whom it should be addressed | Time perspective |
|---|---|---|
| Identify real legislation stress and create space for pilots and experiments. | Governments, Research entities, Industry | S – L |
| Develop transparent procedures and measures for smooth transition of W2P. | Governments, Research entities, Industry, Academia | L |
| Create a successful tracking systems of material composition (e.g. material transports) through different | Governments, Research entities, | S – L, C* |

[37] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/296499/LIT_8709_c60600.pdf
[38] http://www.diva-portal.org/smash/get/diva2:1044870/FULLTEXT03
[39] https://susproc.jrc.ec.europa.eu/activities/waste/documents/Aggregates%20leaching%20Main.pdf
[40] Friege et al. 2019. How should we deal with the interfaces between chemicals, product and waste legislation. Environmental Sciences Europe 31. Springer.
[41] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0032&from=EN

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| Proposed action | To whom it should be addressed | Time perspective |
|---|---|---|
| life cycles. | Industry, Academia | |
| Work on Basic Requirement #7 in existing harmonised EN standards for construction products, which stands for Sustainable use of natural resources. | National standardization bodies, CEN bodies, EOTA | S, C** |
| Deliver proposal for EU-wide EoW criteria for waste recycled into SRM-based construction products (e.g. aggregates, building composites). | Governments and research entities | C*** |
| Solve legal and technical challenges under intersection of chemical (i.e. REACH), waste (i.e. WFD) and product (i.e. CPR) legislation. | Governments | S |

* WP4 - Setting up and optimising the CinderCEBM and the CinderOSS service

**Task 5.1 Development and testing of SRM-based products on the laboratory scale

***Task 5.2 - Preparing EoW criteria based on the intended use of recycled waste



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## 3.2. CinderGP#2 – ENABLING, INCLUSIVE ENVIRONMENT AND RESPONSIBLE ACTORS ALONG THE VALUE CHAIN

Enabling and inclusive national, regional and local ecosystems for transition of the construction sector into the CE, depends not only on the level of maturity and acceptance of the CE paradigm by governing bodies but also on the awareness of actors from the knowledge triangle (industry, research and academia) along the value chain, as well as the general public. Studies[42] show that the introduction of incentive instruments for increasing the demand of SRM, i.e. demand-side measures (e.g. increased taxes on primary resources) in different MS across Europe have different impacts. In ecosystems where awareness of environment and ecology is high (e.g. Sweden) the introduction of incentives like taxes had a positive effect on using SRM while in other MS no significant changes were observed. This and other examples show that the transition to CE is not a simple process but has a systemic and multidimensional impact that spans social, environmental, economic and technical domains. Further, observations seem to indicate that the introduction of subsidies and "command and control" regulations need to be introduced systematically. Integrated policies and other integrated measures are likely to be more effective in delivering environmental improvements than individual measures. In some cases, there seems to be a gap between top-down (from governance to operational) system-level changes driven by policy and operational directives and bottom-up (behavioural and business driving) approaches which impedes a smoother and more efficient transition towards circular practices.

### 3.2.1 The CINDERELA goal of enabling and inclusive environment and responsible actors

CinderGP#2 goal:
**National, regional and local ecosystems support the efficient use of resources in urban and peri-urban environments.**

The main goal of CINDERELA in the field of enabling and inclusive environment and responsible actors is to contribute to the development of systemic solutions for a smooth transition from linear to circular economy by developing bottom-up and top-down solutions and to raise awareness of good practices for a resource-efficient urban and peri-urban construction sector.

### 3.2.2 Current status of enabling, inclusive environment and responsible actors

#### 3.2.2.1 ENABLERS

- **Existing national, regional and local strategies/policies for CE, which include the construction industry**

In the past two decades sustainability has gained importance on the European political agenda and the topic is covered with a variety of policies and strategies. Different documents have focused on

[42] EEA Report No 2/2008. Effectiveness of environmental taxes and charges for managing sand, gravel and rock extraction in selected EU countries

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sustainable use of natural resources[43], climate change[44], inclusive and green economy[45], resource efficiency[46] and CE[47]. Especially, following the introduction of the EU Action Plan for the Circular Economy[48] in 2015, many European countries, regions and municipalities adopted their own strategies for transition to CE including resource efficiency in construction. Two examples of national and local strategies are given in Box 1[49] and Box 2[50].

BOX 1: **A Circular Economy in the Netherlands by 2050**
In 2016 the Dutch Ministry of Infrastructure and the Environment and The Ministry of Economic Affairs launched a Government-wide programme for a CE aiming at developing a CE in the Netherlands by 2050. One of the priorities of this document is the introduction of CE in the construction sector due to its high resource intensity and waste production. The document covers both the building sector and soil and civil engineering sector. The general vision of the strategy is that "*By 2050, the construction industry will be organised in such a way, with respect to the design, development, operation, management, and disassembly of buildings, as to ensure the sustainable construction, use, reuse, maintenance, and dismantling of these objects. Sustainable materials will be used in the construction process, and designs will be geared to the dynamic wishes of the users. The aim is for the built-up environment to be energy-neutral by 2050, in keeping with the European agreements. Buildings will utilise eco system services wherever possible (natural capital, such as the water storage capacity of the sub-soil).*" This vision is further developed in strategic goals, one of which is that both subsectors will use (mainly) renewable materials, and planned actions are elaborated.

BOX 2: **Strategy for the transition to CE in the Municipality of Maribor, Slovenia**
The Municipality of Maribor is currently the only municipality in Slovenia that redirects its activities, the operation of its companies and inhabitants into the model of circular management. This does not only include the concept of a CE in the field of municipal waste, but also implementation of the concept in construction and industry, energy, water management, land use and mobility in the city. One of the strategic project areas is "*Use of processed CDW and soil in urban construction*", the other being "*Sustainable management of land and regeneration of degraded areas*". The two strategic areas are well aligned with CINDERELA goals and implementation of four demonstrations in Maribor (WP6).

- **Existing demand side measures (increased taxes for virgin materials and landfill, Green Public Procurements, restrictions on landfilling) and other incentives for CE**

In the past years some MS have increased taxes of virgin materials (e.g. natural aggregate) in order to prevent depletion of natural resources and stimulate use of SRM. Green public procurement (GPP)[51], especially in the field of building and road design, construction and management, and the recently

[43] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52005DC0670&from=EN
[44] https://ec.europa.eu/info/business-economy-euro/economic-and-fiscal-policy-coordination/eu-economic-governance-monitoring-prevention-correction/european-semester/framework/europe-2020-strategy_en
[45] https://ec.europa.eu/europeaid/sectors/environment/environment-and-green-economy/green-economy_en
[46] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0571&from=EN
[47] https://eur-lex.europa.eu/resource.html?uri=cellar:8a8ef5e8-99a0-11e5-b3b7-01aa75ed71a1.0012.02/DOC_1&format=PDF
[48] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614
[49] https://www.government.nl/documents/policy-notes/2016/09/14/a-circular-economy-in-the-netherlands-by-2050
[50] https://ec.europa.eu/futurium/en/circular-economy/strategy-transition-circular-economy-municipality-maribor
[51] https://ec.europa.eu/environment/gpp/index_en.htm


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published GPP guidelines on public space maintenance, have further increased the potential for stimulating sustainable practices in urban and peri-urban construction. A total restriction on disposal of CDW in the Netherlands has been implemented since 2017.

- **Global market disruption leading to facilitation of use of SRM in local environments**

The waste market can be greatly impacted by changes occurring in other countries (e.g. restrictions on waste import). If such events may first represent some challenges for adapting, at medium to long term, these may also favour the transition towards more circular practices and creation of new value chains in the countries where wastes have been first generated. For example, in 2018, China restricted import of 24 recyclable materials, including plastic, due to its own internal growing waste generation and management[52]. Hence, until 2018, China was one of the main importers of European waste plastic over the last 25 years. With closure of the Chinese market most European collectors started to stockpile plastic waste in the hope that the market will soon reboot or were transporting it to incineration plants in Europe. This led to increased costs of waste management and incentivised waste owners to search for alternative solutions for their waste.

- **Existence of sectoral clusters and associations and CE promoters**

Sectorial clusters (e.g. national construction clusters), business associations, hubs and other associations (e.g. associations of municipalities) naturally lead to unification of value chains, not only in assuring higher quality of SRM-based products, but also jointly finding and promoting more circular solutions.

#### 3.2.2.2 BARRIERS

- **Lack of aligned value chains**

Conventional linear value chains are often associated with individual interests (short-term profit) of actors or group of actors in the value chain which are not looking for common solutions or value creation along the whole value chain. On the other hand, the CE essentially aims to unify all actors and stakeholders along the value chain simultaneously looking for common social, economic and environmental value creation.

- **Existing gap between different levels of operation**

Despite the fact that almost all governments in the EU are committed to CE, a large gap still exists between policy orientations and their actual implementation. This seems to be caused by a lack of operational (action) plans and clear Key Performing Indicators (KPI) which would unify the common goal of achieving CE. Further, there can be distrust between different levels of policy implementation resulting for example in slow adoption and lack of unified rules (e.g. lack of EoW criteria). Unfortunately, the implementation of CE at operational level, by using SRM is often hampered by distrust among the general public considering SRM as waste and construction with SRM as an illegal dumping enhanced by the desire of politicians to favour their voters.

- **Lack of long-life commitment of individual actors to products and construction projects**

Very often construction operations are executed by a set of different contractors and subcontractors. In this way responsibility for the quality of work is divided between numerous parties. Unfortunately, this can cause poor workmanship which in turn leads to construction defects and generates a poor reputation of SRM in the construction sector. Experience shows that when construction companies

[52] https://www.eea.europa.eu/themes/waste/resource-efficiency/the-plastic-waste-trade-in

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invest on their own construction projects they also take over the management of the building/infrastructure during its life span. In such cases, it is observed that the quality of work is much higher than if the construction would have been performed for an investor or another contractor. This situation indicates that in many cases there is still room for improvement of the quality of construction works. The quality of work can be enhanced even further by implementation of digital tools (e.g. Building Information Modelling, digital twins) and enhancement of digital business ecosystems (see Chapter 3.6) increasing transparency, traceability, accelerating and improving communication between different actors and decision-making.

### 3.2.3 Actions proposed by CINDERELA on enabling, inclusive environment and responsible actors

In Table 3 different actions for enabling and inclusive environment and responsible actors along the value chain are given. Some of these actions are already tackled inside the CINDERELA project and outside. This is not an exhaustive list of activities. This list will be updated during implementation of the CINDERELA project.

**Table 3 - Actions proposed by the CINDERELA consortium on enabling, inclusive environment and responsible actors (L – long term perspective, S – short term perspective, C – within the CINDERELA project)**

| Proposed action | To whom it should be addressed | Time perspective |
|---|---|---|
| Systemic introduction of subsidies and demand side measures for levering sustainable urban and peri-urban construction. | Government | L, C* |
| Closing the gap between governments and companies. | Government, Industry | S |
| Enhancing bottom-up approaches and dissemination of good practices. | Government, Research, Academia, Industry | S, C** |
| Engaging the whole value chain and enhancing social responsibility among actors. | Government, Research, Academia, Industry | L, S |
| High-level commitment and high ambitious, clustering and facilitating circular front runners. | Government | L, S |
| Enhancing sectoral associations, hubs, clusters towards resource-efficient construction and their joint action in promotion and awareness raising, dissemination of good practices, preparing guidelines and setting trends. | Industry | S, C*** |
| Innovative ecosystems, partnerships and collaboration of both stakeholders and competitors. | Government, Research, Academia, Industry | S |

*, **, *** WP4 - Setting up and optimising the CinderCEBM and the CinderOSS service

** WP8 - Communication, exploitation and dissemination


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## 3.3. CinderGP#3 – ENHANCING CIRCULAR ECONOMY BUSINESS MODELS

Circular business models in construction create financial benefit while preventing the depletion of natural resources, decreasing the amount of industrial and consumer wastes and producing other environmental and social benefits. The quantity of waste is decreased by transforming wastes into materials and products which serve as inputs for new products. These practices are contributing to a reduction of the environmental footprint of constructions.[53] It can be assumed that generally, the construction sector is rather conservative and generally reluctant to introduce new practices in terms of technologies and materials. This is also the reason why, generally, novel SRM-based construction products are only adopted by construction companies (and consequently by designers and investors) at a slow pace. As has been observed in several economic sectors at EU level, bringing innovative materials and technologies to the market is particularly difficult in the construction industry.

### 3.3.1 The CINDERELA goal of penetrating circular economy business models

The main goal of CINDERELA in the field of enhancing CEBM and fast transition from laboratory to the market is to contribute to recognition of SRM as excellent raw materials for construction products and drivers of successful business cases.

CinderGP#3 goal:

**Recognised value of SRM-based construction products as sustainable materials with increased economic value during their whole life.**

### 3.3.2 Current status of enhancing CEBM

#### 3.3.2.1 ENABLERS

- **Increased push from waste producers and holders**

Continuously increasing waste management costs creates a momentum of resource efficiency and recycling in the construction sector through a push from waste holders, who are looking for more sustainable and cheaper waste management.

- **High research and innovation level**

It can be assumed that the EU enjoys a reputation for research excellence and innovativeness and is a leader in the development of sustainable technologies and products. EU-based policies on sustainability and resource efficiency also lead to increased research and innovation funding in this area.

- **National CE priorities in developing Smart Specialisation Strategies**

CE priorities (e.g. resource efficiency, design, bio-economy, digitalisation, new business models, CE education etc.) are high on the agenda of developing Smart Specialisation Strategies and their horizontal and vertical domains across Europe. In Slovenia, for example, CE is one of the Smart Specialisation Strategy priorities called Networks for the Transition to Circular Economy[54].

[53] https://www.oecd.org/environment/waste/policy-highlights-business-models-for-the-circular-economy.pdf
[54] https://s3platform.jrc.ec.europa.eu/regions/SI

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#### 3.3.2.2 BARRIERS

- **Distrust by end-users (low interest on demand side)**

Primary raw materials have been used in construction for centuries, their properties are well known and unchanged over decades of exploitation and production. On the other hand lack of knowledge about the properties and functionality of SRM-based construction materials creates distrust among end-users, investors (public and private) and designers. Public investors additionally fear the prolongation of procurement procedures in case of disputes. Also, there is still less understanding of the concept of circularity and its benefits in construction. Sometimes circular products are more expensive than goods from primary sources. The combination of these factors limits consumer demand for circular products.

- **High competition from the primary raw material sector**

Primary raw materials such as non-metallic mineral raw materials represent the majority of raw materials in the construction sector. These materials are generally relatively cheap and abundant across Europe. Further, primary raw materials and SRM are often compared on the basis of cost-benefit analyses where externalities are not included and/or based on single phase economic benefits versus life cycle costing.

- **High costs of initial testing and quality control**

When waste is not separated at the source, i.e. during dismantling or deconstruction, SRM can be heterogeneous and additional procedures in production (separation, recycling, etc.) are needed. Another consequence of poor separation at the source is that these materials are then downcycled, meaning that their characteristics have less value than the original product. This is the case of CDW, which in the case of non-selective demolition can be used only for less demanding geotechnical works while if selected at the source their applicability could be broader and have sometimes even better properties in comparison with traditional materials. An example is recycled aggregate from concrete, where hydration reactions in recycled aggregate can lead to better loading capacity of the road base in comparison with conventional primary aggregates. The heterogeneity of SRM can lead to demand for more frequent testing and control of product quality which increases the initial costs and decreases the competitiveness of SRM-based construction products in comparison with primary materials.

- **Lack of market-based incentives for use of SRM-based materials**

Due to current taxation patterns, primary raw materials are often cheaper than secondary ones, weakening incentives to engage in business transformation.

### 3.3.3 Actions proposed by CINDERELA to enhance circular economy business models

In Table 4 different actions for enhancing CEBM in the urban and peri-urban construction market are given. Some of these actions are already tackled inside and outside the CINDERELA project. This is not an exhaustive list of activities but should be upgraded during implementation of the CINDERELA project.


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**Table 4 - Actions proposed by the CINDERELA consortium to enhance CEBM (L – long term perspective, S – short term perspective, C – within the CINDERELA project)**

| Proposed action | To whom it should be addressed | Time perspective |
|---|---|---|
| Introduction of demand side measures to enhance SRM-based construction market (increased taxes on virgin materials and landfilling, introduction of GPP rules, subsidence on using SRM-based construction materials, etc.). | Government | L |
| Education, awareness raising and capacity building among stakeholders and actors across the value chain. | Government, Research, Academia, Industry | S, C* |
| Expert trainings / how to apply, how to use, utilise these materials in specific applications. | Academia, Industry | S, C** |
| Promotion of sustainable business models (social and environmental impacts have monetary value). | Government, Research, Academia, Industry | S, C*** |
| Engaging the whole value chain in business development. | Industry | S |
| Focus on innovation, technological development and adaptation across the entire value chain. Emergence of enabling technologies. | Research, Academia, Industry | S, C**** |

*, **, ** WP8 - Communication, exploitation and dissemination

**, **** WP6 - Pilot demonstrations of SRM-based construction and testing of the CinderCEBM

*** WP7 - Monitoring and sustainability of the CinderCEBM

**** WP4 - Setting up and optimising the the CinderCEBM and the CinderOSS service and WP5 - Designing, development and testing of SRM based construction products for demonstration pilots

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## 3.4. CinderGP#4 – ENVIRONMENTAL AND SOCIAL ACCEPTANCE OF NEW CEBM

At its core, CE is a certain model of production and consumption taking into account environmental, social and economic benefits. Indicators are crucial for measuring advancement of CE in specific environments. Life cycle assessment tools, i.e. assessment of environmental (LCA), social (S-LCA) and economic (LCC) impacts during the whole life of product or service, have a long tradition and have increasingly been standardised in the past decades. Beside the conventional impact categories in S-LCA, so called social licencing[55] of innovative CEBM is also of great importance when introducing them into circular urban and peri-urban construction.

### 3.4.1 The CINDERELA goal of environmental and social acceptance of new CEBM

CinderGP#4 goal:

**Change of mind-set and decrease of total consumption level in the urban construction sector. Europe recognises the opportunity to be a forerunner in sustainable procurement in the construction sector. Quantifying environmental and social impacts**

The main goal of CINDERELA in the field of environmental and social acceptance of the new CEBM in urban and peri-urban construction is to highlight the need to change the mind-set of the construction industry and embrace more sustainable and resource-efficient practices. This change shall be supported by the development of fact-based evidence that proves the virtue of transitioning towards circular business models. We estimate this can be achieved through the creation of an appropriately set KPI based on Life Cycle Assessment as a practical tool for evaluating the circularity of novel CEBM in urban and peri-urban construction.

### 3.4.2 Current status of environmental and social acceptance of new CEBM

#### 3.4.2.1 ENABLERS

- **LCA is a recognised international standardised tool**

While environmental LCA has been recognised for some time as an internationally standardised tool (following the standard series ISO 14040 and ISO 14044) S-LCA and LCC methodologies are also rapidly developing.

- **Existence of environmental labels and declarations**

There are several environmental labels providing information about a product or service in terms of overall environmental benefits. ISO standard series 14020 considers three types of environmental labelling: (i) Type I environmental labelling; (ii) Type II self-declared environmental claims; and (iii) Type III environmental declarations.

- **LEVELs**

Level(s) is a voluntary reporting framework to improve the sustainability of buildings based on a

[55] https://socialicense.com/definition.html


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common EU approach to the assessment of environmental performance in the built environment. Each indicator in Level(s) is designed to link the individual building's impact with sustainability priorities at the European level, such as greenhouse gas emissions throughout the building's life cycle, resource-efficient and circular material life cycles, efficient use of water resources, healthy and comfortable spaces, adaptation and resilience to climate change, and life cycle cost and value. Each indicator within Level(s) can be used for different types of performance assessment, from a basic level through to a full Life Cycle Assessment (LCA).

#### 3.4.2.2 BARRIERS

- **Rapid development of different environmental labels and declarations**

While environmental labelling encourages the purchase of sustainable products the increasing proliferation of such labelling has led to concerns of "greenwashing" and exaggerated marketing claims which in the long-term creates distrust in products tagged as sustainable.

- **Prevailing short-term profits versus life costing**

Conventionally, the costs of construction products are evaluated based on cost-benefit analyses in which externalities are not included and/or based on single phase economic benefits versus life cycle costing.

### 3.4.3 Actions proposed by CINDERELA on environmental and social acceptance of new CEBM

In Table 5 different actions for sustainable CEBM in the urban and peri-urban construction sector are given. Some of these actions are already tackled inside and outside the CINDERELA project. This is not an exhaustive list of activities but should be upgraded during implementation of the CINDERELA project.

**Table 5 - Actions proposed by the CINDERELA consortium on environmental and social acceptance of new CEBM (L – long term perspective, S – short term perspective, C – within the CINDERELA project)**

| Proposed action | To whom it should be addressed | Time perspective |
|---|---|---|
| Implementing life cycle assessment tools in every day practice. | Government, Research, Academia, Industry | S, C* |
| Push by public sector on sustainable procurement in construction (e.g. available LCC tools taking into account externalities). | Government | S, C** |
| Creating collaborative models and systematic solutions (legislation, education, demand side measures, surveillance, increased transparency, and increased traceability). | Government, Research, Academia, Industry | S - L, C*** |

*, **WP7 - Monitoring and sustainability of CinderCEBM

*** WP4 - Setting up and optimising the CinderCEBM and the CinderOSS service

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## 3.5. CinderGP#5 – APPLICABLE TECHNOLOGIES - RAPID TRANSITION FROM LABORATORY TO PRACTICE

For a smooth transition from the linear to the circular economy both enabling and disruptive technologies are needed. The most rapidly adopted solutions for CE in the urban and peri-urban construction sector are those which can be introduced with knowledge and technologies that are similar to existing ones. In this sense, SRM in the construction industry should be based on properties that are similar to those of the primary source. As a result no major hindrance from a technological point should be expected for their adoption.

### 3.5.1 The CINDERELA goal of applicable technologies and rapid transition from laboratory to practice

The main goal of CINDERLA in this domain is to foster Innovative, Affordable, Economic and Feasible (IAEF) technologies and processes for sustainable recycling of waste into SRM-based construction products. Innovativeness should also be focused on decreasing the toxicity of substances in EoL products and extraction of Critical Raw Materials (CRM) before final application in construction. Circular urban and peri-urban construction should focus not only on recycling technologies but also on prevention of waste and its re-use. Off-site production, modular prefabrication and easy-to-separate materials seem to be the most sustainable solutions for prolonging the life span of buildings and infrastructures.

CinderGP#5 goal:
**Innovative, Affordable, Economic and Feasible (IAEF) technologies and processes for sustainable recycling of waste into SRM-based construction products.**

### 3.5.2 Current status of applicable technologies and rapid transition

#### 3.5.2.1 ENABLERS

- **Good practices of IAEF technologies**

Several good practices of IAEF technologies in the field of waste recycling for SRM-based construction products already exist: e.g. selective recycling of CDW into recycled aggregates, recycling of certain types of slag into manufactured aggregates, recycling of certain industrial wastes (ashes and other fine grain waste with binding properties) into alternative binders. The common enabler to these practices is that they are simple and can be used with the existing skills of construction workers and machinery while recognising the essential characteristics of novel SRM-based products.

- **Tools for assessment of Innovation Readiness**

The KTH Royal Institute of Technology has recently developed the KTH Innovation Readiness Level[56], a complete framework for guiding the development and assessing the level of innovative ideas for their introduction on the market. This model assesses the idea development on a scale from 1 to 9 into six key areas of innovation development: customer readiness level, team readiness level, business readiness level, intellectual property readiness level, funding readiness level and technology

[56] https://kthinnovationreadinesslevel.com/about/


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readiness level. All these indicators need to be balanced in order to enable a successful market entrance. The similar approach of assessing research-to-market of technologies and products has been adopted in CINDERELA WP4.

- **Funding of EU innovation for fast transition to the market**

The European Commission has adopted several innovation support programmes which promote close-to-the market innovation activities for fast transition to the market. One such programme is Fast Track to Innovation (FTI) in Horizon 2020[57], which is a fully-bottom-up support enabling co-creation and testing of breakthrough products, services or business processes that have the potential to revolutionise existing or create new markets. Another scheme for fast transition of innovative products and services to the market, starting new companies, and training entrepreneurs is in the frame of the European Institute for Innovation and Technology (EIT) and its dedicated Knowledge and Innovation Communities (KICs). Several KICs (e.g. EIT RawMaterials, EIT Climate, EIT Manufacturing) are covering innovation in CE and resource efficiency.

#### 3.5.2.2 BARRIERS

- **Focus on sophisticated, potentially disruptive technologies with low adoption rate**

Many researches are focused on highly innovative potentially disruptive technologies which on the other hand may find difficulties to enter the market due to different factors (e.g. high energy consumption, small target market, no clear financial viability, change of disruption focus, lack of historical proof of quality etc.). 3D printing is an example of cutting edge technology in numerous areas (e.g. medicine, aerospace, toolmaking industries) and has been present for some time in the construction sector but appears to have difficulty becoming a mainstream technology. It offers a significant potential to increase efficiency in the construction sector (e.g. faster construction, less waste, design freedom, greater safety) but on other hand is still expensive, has logistical problems, shortage of labour with specific skills for such construction, issues of quality control and durability.

- **Lower recyclability of SRM-based construction materials with time**

Decreasing functionality, deterioration of inherent properties, concentration of toxic components, and thus limited recyclability of SRM-based products in repeated life spans is one of the barriers for using recycled waste in urban and peri-urban construction.

### 3.5.3 Actions proposed by CINDERELA for applicable technologies and rapid transition from laboratory to market

In Table 6 different actions for the introduction of applicable technologies and rapid transition to the market are given. Some of these actions are already tackled inside and outside the CINDERELA project. The list in Table 6 is not exhaustive and should be upgraded during implementation of the CINDERELA project.

[57] https://ec.europa.eu/programmes/horizon2020/en/h2020-section/fast-track-innovation-pilot

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**Table 6 - Actions proposed by the CINDERELA consortium for applicable technologies and rapid transition from laboratory to market (L – long term perspective, S – short term perspective, C – within the CINDERELA project).**

| Proposed action | To whom it should be addressed | Time perspective |
|---|---|---|
| BREF or similar document on recycling for construction, increasing awareness about BAT technologies. | Government, Research, Industry | S, C* |
| Substitution and elimination of potential toxic elements (PTE) in EoL products and during recycling. | Research, Industry | L, S |
| New technologies, processes and products for prevention waste (e.g. prefabricated, easy to dismantle, modular construction elements). | Research, Industry | S, C** |

* WP4 - Setting up and optimising the CinderCEBM and the CinderOSS service
** Task 5.1 - Development and testing of SRM based products on the laboratory scale and WP6 - Pilot demonstrations of SRM based construction and testing of the CinderCEBM


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## 3.6. CinderGP#6 – ACCESSIBLE DATA AND DIGITAL SUPPORTING TOOLS

Building Information Modelling (BIM), Digital Twins (DT), Block chain, 3D printing, Augmented Reality, drones and robots are some of the cutting-edge technologies, which are increasingly being introduced to more conservative industries, including the construction sector. Among the above listed technologies, BIM is already largely displacing conventional data management techniques in the built environment as various stakeholders have recognised the benefits that correlate with all data in one (virtual) place - BIM approach. With the virtual inclusion of time plans (4D-BIM), cost analyses (5D-BIM), project lifecycle information (6D-BIM) a step in the right direction has already been taken from the perspective of economic optimisation of construction. By the same token in the context of circular economy, BIM is an important facilitator of digitalisation, where digital material passports can increase the transparency and traceability of SRM. Keeping in mind the positive impacts of ICT, it is reasonable to expect that ever more advanced technologies such as DT will continue to be utilised in the foreseeable future. DT may be defined as a virtual abstraction of physical assets and/or projects, which take data management to a higher level. By connecting real time monitoring data with physical objects, separate silos can be managed in an integrated way to increase operational effectiveness (e.g. time, cost, safety) as well as the sustainability of construction works. For digital imaging of construction works as well as for monitoring progress on building sites drones and satellite imaging is used. In the circular economy DT provides a virtual representation.

Despite the Aarhus convention from 2001 establishing the right of everyone to receive environmental information that is held by public authorities ("access to environmental information") the research in WP2 showed that full accesses to environmental information held by local, regional or national public authorities is in some cases difficult to access either due to format (large dataset), partial access or even non-disclosure of requested environmental data. Other sophisticated digital supporting tools can also increase the circularity of urban construction. Material Flow Analysis (MFA) is an analytical method to quantify the stock and flow of materials. In the CINDERELA project a GDSE developed in the REPAiR[58] project is used to determine W2P flows.

### 3.6.1 The CINDERELA goal of digital supporting tools

CinderGP#6 goal:
**Transparent, well planned and traceable resource-efficient urban and peri-urban construction projects which enable efficient management of materials from design through to the use and end/re-use stage.**

The main goal of the CINDERELA project in this domain is to facilitate transparent, well planned and traceable resource-efficient urban construction projects, resulting in efficient management of materials in construction works from early design, through use to the EoL/re-use stage. Early collaboration among all actors along the value chain in material efficiency is a necessary prerequisite for this. EoL treatment strategies have to be considered already in

[58] http://h2020repair.eu/gdse-software-package/gdse-description/

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early stages of the design processes. Digital tools facilitate these processes by enabling better communication between stakeholders along the value chain, streamlined collaboration, better tracking of processes and materials during the construction, use and EoL/reuse phases.

## 3.6.2 Current status of digital supporting tools

### 3.6.2.1 ENABLERS

- **Increased recognition of the importance and introduction of digital tools in waste management and construction**

The waste management and construction sectors are fast revolving due to pressure for change originating from different directions: increased demand for digitalisation by clients, new technology capabilities, new generation of craftsmen and professionals, supporting legislation, increased size of building and infrastructure projects[59]. Digitalisation is also one of the five areas for increasing European construction sector competitiveness[60]. It is increasingly recognised as a potential game changer for the sector[61].

- **Monitoring of environmental data, presence of key performing indicators**

Existing national waste monitoring and reporting systems are a good starting point for data mining with novel ICT tools; however, the level of sophistication varies greatly among MS.

### 3.6.2.2 BARRIERS

- Large datasets

Despite the rapid development of “big data” management a worldwide survey of 196 organisations by Gartner[62] showed that 91 percent of organisations have not yet reached a "transformational" level of maturity in data and analytics for business development, despite this area being a number one investment priority in recent years.

## 3.6.3 Actions proposed by CINDERELA for digital supporting tools

In Table 7 different actions for digital supporting tools are given. Some of these actions are already tackled inside and outside CINDERELA project. This is not exhaustive list of activities but should be upgraded during implementation of the CINDERELA project.

**Table 7 - Actions proposed by the CINDERELA consortium for digital supporting tools (L – long term perspective, S – short term perspective, C – within the CINDERELA project).**

| Proposed action | To whom it should be addressed | Time perspective |
|---|---|---|
| Awareness raising on digitalisation in the construction sector (BIM, MFA, digital business environment, disruptive technologies). | Government, Research, Academia, Industry | S, C* |
| Stimulating digital construction and quantifying circularity, e.g. integrating digital tools into legalisation, | Government | L |

[59] http://www.mmc.com/content/dam/mmc-web/Files/OliverWyman_Digitalization_in_the_construction_industry_web_final.pdf
[60] https://ec.europa.eu/growth/sectors/construction/competitiveness_en
[61] European Construction Sector Observatory - Trend Paper - Building Information Modelling in the EU construction sector – March 2019
[62] https://www.gartner.com/en/newsroom/press-releases/2018-02-05-gartner-survey-shows-organizations-are-slow-to-advance-in-data-and-analytics


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| Proposed action | To whom it should be addressed | Time perspective |
|---|---|---|
| policy, contracts or development programs. | | |
| Demonstrating good practices of using digital tools for resource-efficient urban and peri-urban construction. | Government, Research, Academia, Industry | S, C** |
| Continuous upgrading of CEBM in resource-efficient urban and peri-urban construction by applying disruptive technologies, such as 3D printing, cloud-based big data platforms, easy-to-access open mobile applications, augmented reality, drone and satellite imaging, and others. | Research, Academia, Industry | L, S, C*** |
| Increase the quality of public environmental data and their accessibility | Government, Research, Industry | S, C**** |

*,** WP4 - Setting up and optimising the CinderCEBM and the CinderOSS service
* WP8 - Communication, exploitation and dissemination
** Task 5.4 Detailed plan for technological pilot demonstrations
** WP6 - Pilot demonstrations of SRM based construction and testing of CinderCEBM
*** Task 4.3 CinderCEBM optimisation
**** Task 3.1 - Assessing the waste to resource opportunities in urban and peri-urban areas

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# 4. CONCLUSIONS AND FOLLOW-UP WORK

The current CINDERELA Blueprint for resource-efficient SRM-based urban and peri-urban construction sector is based on desktop research of the latest state of the art policies, strategies, documents, research projects, developments, interaction with stakeholders and the on-going activities of CINDERELA. The list of CinderGP is not exhaustive and may be subject of changes as the project generates new knowledge and gathers relevant new insights from stakeholders who are not yet considered in this document. Especially, we estimate that changes could emerge in the sector of digitalisation in waste management and construction planning and management. Both sectors are developing rapidly and may give rise to new issues to be integrated in this Blueprint. Such advances may also be considered for assessment and integration into CinderCEBM and CinderOSS.

Some of the CinderGP described above are already (partly) tackled by different stakeholder groups, especially under the EU Circular Economy Package. Given these circumstances, it can be expected that noticeable changes affecting CE in the construction sector may emerge: i.e. changes in legislation, good practices in enabling and inclusive local environments for circular urban and peri-urban construction practices may emerge, new business models may find better acceptance by end-users, investors, designers, politicians and the general public.

The current CinderPB document has set the goals and development path for increased performance of a resource-efficient urban and peri-urban construction sector. Different stakeholder groups will be continuously addressed during project implementation, especially in connection with different demonstrations of building with SRM based materials. At the end of the project an updated CinderBP will be published on the CINDERELA website and will become an integral part of CinderOSS service.

The CINDERELA consortium is highly committed to transition of the linear urban and peri-urban construction sector into a resource-efficient circular one. Understanding both the obstacles and opportunities of the implementation of CEBM in the urban and peri-urban construction sector is a crucial factor in the delivery of a local CE model enhanced by one of the main economic sectors in Europe, i.e. the construction sector. The transition can be made only by acknowledging the elements which hinder or facilitate its circularity.



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# 5. ANNEXES

## Annex 1 – RESULTS OF CONSULTATION WITH STAKEHOLDERS

**Table 8 - Summary of PESTLE analyses of new value chains prepared during workshops and interviews with stakeholders, identifying main barriers (B), enablers (E).**

| | |
|---|---|
| **Political** | A circular and sustainable economy is high on the agenda of almost all MS **(E)**, while there are different practices across Europe in its implementation **(E/B)**.<br>Similarly, in some countries demand side measures[63] for implementation of new CEBM, e.g. direct financial support for using SRM, tax deduction on SRM, prohibitions on landfilling, Green Public Procurement (GPP), and others, are already successfully implemented **(E)** while in others they are few **(B)**.<br>Regulation is established **(E)**, but administration procedures (e.g. for granting environmental permits) can be long and exclusive **(B)**.<br>Lack of dialog between decision-makers, legislators and actors **(B)**.<br>Lack of incentive to design for End of Life (EoL) and reuse **(B)**.<br>Significant influence of politics at the national and regional / local level (associated, for example, with the attitudes of citizens and local communities as potential voters / electorates) on use of SRM **(B/E)**. |
| Lower costs of SRM-based construction products **(E)**.<br>Push for recycling and new value chain creation from waste holders **(E)**.<br>Low price and high competitiveness of virgin raw materials in some countries **(B)**.<br>Scarcity of virgin raw materials in other countries **(E)**.<br>No encouragement for use of SRM-based construction products in some countries **(B)** while existing encouragement for use of SRM-based construction products in others **(E)**.<br>Locally orientated value chains in construction sector (high cost of transport) **(E/B)**.<br>Mismatch between supply and demand **(B)**.<br>Short-term profit thinking instead of life cycle thinking **(B)**.<br>Lack of interest among public producers for demanding SRM-based construction products **(B)**. | **Economic** |
| **Social** | Construction sector is in high demand of raw materials (locally available would be preferable) **(E)**.<br>Different level of social acceptance of SRM-based products in different countries ranging from very low social acceptance **(B)** to high social acceptance **(E)**.<br>Populistic media reporting on “bad news” in catastrophic way, spectacular environmentalism **(B)**.<br>Poor practices of using SRM-based construction products in the past leading to bad reputation of recycled waste and distrust among stakeholders **(B)**.<br>The commonly used word "waste" being strongly associated with SRM; SRM-based products regarded as landfilled while landfilling is usually connected with “Not-in-My-Back Yard” (NIMBY) effect **(B)**.<br>Existing knowledge for education and awareness raising **(E)** but poor acceptance of SRM-based products among value chain actors and end-users (“Not worth it!” “Complicated!” “Expensive!” “Unknown” “Recycled is the same as poor quality!”) **(B)**.<br>More effort needed by entrepreneurs to persuade investors and end-users that SRM-based construction products are of high quality and safe to use **(B)**.<br>Gap between policies and actual practice in some countries **(B)**. |

[63] https://ec.europa.eu/growth/industry/innovation/policy/demand-side-policies_en

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**… Continuation of Table 8.**

| | |
|---|---|
| Mostly easily applicable technologies with already existing machines and knowledge **(E)**.<br>Interest and investment in new technologies **(E)**.<br>Opportunity to connect SRM-based products with digital design tools (e.g. BIM) **(E)**.<br>Existence **(E)** or lack **(B)** of circular design guidance in MS.<br>Increased research activity (high innovation level) in the area of SRM-based products and circular economy **(E)** but slow transition of new technologies from laboratory to market in Europe in comparison with markets outside Europe **(B)**.<br>Distrust in new SRM-based products versus traditional materials, which have a tradition and their properties are well known **(B)**.<br>Increased demand for testing of SRM-based products in order to prove inertness. Also heterogeneity of some SRM-based construction products **(B)b**<br>Lack of waste separation practices (e.g. selective demolition) at the source and consequently poorer performance of SRM-based products **(B)**. | **Technological** |
| **Environmental** | Different level of environmental responsibility **(B/E)**.<br>Existence of life cycle tools and environmental certification (labelling) **(E)**.<br>Increased supply and demand for environmentally acceptable products **(E)**.<br>Still low priority on environmental aspects in construction projects **(B)**. |
| Lack and low level of control, supervision and inspections (fines) in waste management in some MS. Poor traceability and transparency of waste flows **(B)**.<br>Lack of clear and transparent legislation for SRM **(B)**.<br>Lack of End-of-Waste (EoW) criteria **(B)**.<br>Existing construction legislation, which does not differentiate between primary raw materials and secondary raw materials **(E)**.<br>Lack **(B)** or existence **(E)** of guidelines for use of SRM-based construction products.<br>Behaviour of unreliable entrepreneurs using potential legal gaps or using illegal practices which causes further restrictions for the entire industry and damage primarily to entities driving in a lawful and transparent manner **(B).** | **Legal** |



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Table 9 - Recommendations formed during the Deep Dive sessions at Initial CINDERELA Conference in Amsterdam, The Netherlands, on 23rd May 2019.

| | |
|---|---|
| **Session A**<br>**"Good building practices and demonstrations?"** | **Close the gap between governments and companies. Consider development/use of SRM-based construction materials in the frame of Quadruple helix[64]. Cluster management and/or building ecosystems along the value chain and with extended commitment of all stakeholders;**<br>**Identify real legislation stress and create space for pilots and experiments;**<br>**Provide more information/education within and between sectors;**<br>**Provide knowledge and technology transfer, e.g. about good waste sorting processes, to countries with information needs.** |
| **Session B**<br>**"Circular policy-making and procurements"** | As the public sector, **provide financial measures (based on Life Cycle Costing - LCC)** for companies so that they can calculate the true pricing of construction products and services;<br>As the public sector, set **ambition high, attract the right organisations and facilitate circular front runner companies**;<br>**Use green deals to initiate, find, evaluate and disseminate best GPP practices**. Make more use of green award criteria and develop protocols and methods for applying GPP. |
| **Session C**<br>**"Measurement leads to sustainability"** | **Measure complexity, deliver key messages;**<br>o Concentrate where it matters most;<br>o Data versus interface;<br>o Large-scope material passport (6D BIM), integrate the time and maintenance dimension.<br>**Develop better or more standardisation that allows LCA to be integrated in a nested modelling set-up** by:<br>o The complexity of thinking and acknowledging impacts through scales;<br>o Secrecy of information;<br>o Comparing alternatives.<br>**Europe can only keep its producing sector if it is in an advanced quality position.** |
| **Session D**<br>**"Identifying waste to resource opportunities through flow mapping and digital business ecosystem"** | **Introduce an international standard for waste management data, so that a waste information platform can provide universal data and value to worldwide companies and governments** (as some waste flows are traded at international markets). Current (European) standards on waste information can be improved by also demanding data on the waste processor, not only on the waste producer.<br>As a government, **stimulate the use of digital platforms** by for instance integrating them into legislation, policy, contracts or development programs.<br>**Reduce the position of recycling monopolies by focusing on niche markets at local and regional levels.** |

[64] https://edisciplinas.usp.br/pluginfile.php/3572572/mod_resource/content/1/8-carayannis2009.pdf

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## Annex 2 – LIST OF PUBLISHED HARMONISED EUROPEAN STANDARDS ON AGGREGATES

Table 10 - List of harmonised standards (hEN) for aggregates.

| Number of hEN | Title |
|---|---|
| EN 12620:2002+A1:2008 | Aggregates for concrete |
| EN 13043:2002/AC:2004 | Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas |
| EN 13055:2016 | Lightweight aggregates |
| EN 13139:2002/AC:2004 | Aggregates for mortar |
| EN 13242:2002+A1:2007 | Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction |
| EN 13450:2002/AC:2004 | Aggregates for railway ballast |
| EN 13383-1:2002/ AC:2004 | Armourstone – Part 1: Specification |

Table 11 - Some examples of EAD for complex products where SRM could be used[65].

| European Assessment Document (EAD) number | EAD Title |
|---|---|
| 010001-00-0301 | Precast concrete composite wall with point connectors |
| 010003-00-0301 | Precast balcony elements made of Ultra High Performance Fibre Reinforced Concrete (UHPFRC) |
| 010013-00-0301 | Lightweight panel made of mortar of cement and granulated EPS reinforced by a glass fibre mesh and an internal steel railing |
| 010028-00-0103 | Shallow and reusable foundation kit for lightweight structures |
| 040287-00-0404 | Kits for external thermal insulation composite system (ETICS) with panels as thermal insulation and discontinuous claddings as exterior skin |
| 090019-00-0404 | Kits for ventilated external wall claddings of lightweight boards on subframe with rendering applied in situ with or without thermal insulation |
| 090020-00-0404 | Kits for external wall claddings made of agglomerated stone |
| 090034-00-0404 | Kit composed by subframe and fixings for fastening cladding and external wall elements |
| 090062-00-0404 | Kits for external wall claddings mechanically fixed |

[65] https://www.eota.eu/en-GB/content/eads/56/


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