D 3.3: Report on the valorisation of existing end-of-life scenarios and alternative value chain

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Explanation of acronyms & abbreviations

Acronym	Full name
AEDHE	ASOCIACION DE EMPRESARIOS DEL HENARES
BEXEL	BEXEL CONSULTING DOO BEOGRAD
CEIM	Civil Engineering Institute Macedonia - CEIM
IETU	INSTYTUT EKOLOGII TERENOW UPRZEMYSLOWIONYCH
FGP	Fundación Gómez Pardo
KplusV	KplusV organisatieadvies B.V.
NIGRAD	NIGRAD d.d. komunalno podjetje
OP	Opencontent SCARL
POLOPN	POLO TECNOLOGICO DI PORDENONE SOCIETA CONSORTILE PER AZIONI
TECNALIA	FUNDACION TECNALIA RESEARCH & INNOVATION
TUDelft	TECHNISCHE UNIVERSITEIT DELFT
UB	UNIVERSITA COMMERCIALE LUIGI BOCCONI
ZAG	ZAVOD ZA GRADBENISTVO SLOVENIJE
D	Deliverable
EC	European Commission
FP	Framework Programme
H2020	Horizon 2020 The EU Framework Programme for Research and Innovation
ICT	Information and communications technology
M	Project month (e.g. M6 stands for month 6 of the project)
MIN	Minutes
NAT	National
NGO	Non Governmental Organisation
OTH	Other
PMT	Project Management Team
R&D	Research and Development
REG	Regional
S&T	Scientific and technological
SME	Small and medium enterprises
WP	Work package

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1. INTRODUCTION

The construction sector exerts great pressure on resources, whether renewable or not. This inevitably leads to their depletion and therefore casts doubt on the traditional linear business model. To deal with this problem the CINDERELA project leans upon a systemic research to optimize material and energy flows in an endless circuit, continually drawing value from waste or residual materials.

This research is based on a framework for structuring the analysed information obtained from both from the literature review as well as from direct communication with the stakeholders on various CIDNERELA events. Methodologically speaking we use the values chain assessment and the PESTEL analysis (Political, Economic, Social, Technological, Ecological, and Legal) analytical methods. The value chain assessment and PESTEL analysis result in a SWOT (Strengths, Weaknesses, Opportunities, and Threats), which displays the current status of the specific value chain and an overview of strategic decisions that can be made in order to shift towards a more sustainable and circular value chain.

Overall, the deliverable relates to the Work Package 3 (WP3), more specifically to the Task 3.3 (Value chain assessment and assessment of actors along the value chain). This Task's activities (e.g. identifying actors along the existing and new value chains) are connected with the involvement of stakeholders (WP8), as well as providing input for the establishment of a CinderCEBM framework (WP4), since inputs of actors are important for the initiation and optimization of CinderCEBM. This deliverable is also important for follow up activities in Task 3.4, since within Task 3.4 a blueprint will be developed for a resource-efficient secondary raw material based urban and peri-urban construction sector.

The main objective of Task 3.3 was to conduct a comprehensive analysis on the potential new value chains as well as existing (waste to landfill or waste to incineration) value chains for urban waste that connect together multiple sectors within urban and peri-urban areas.

The value chains for SRM-based construction products are evaluated on:

- The relevant actors along the value chains, with a focus on end-users and their needs;
- The benefits and constraints of conventional and alternative value chains;
- A simple evaluation of environmental and socio-economic potential impacts and;
- Non-technological and technological issues.

This document has ten sections and it provides descriptions on the different steps along the value chain and provides insight on the application of the process in specific case studies. The findings gathered in this report represent a starting point based primarily on the views, needs and experiences of stakeholders and does not represent the CINDERELA consortium views or in any case the EC views. The findings will be more systematically assessed and practically evaluated in the later stages of the implementation of the CINDERELA project.

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2. CINDERELA VALUE CHAIN ASSESSMENT METHODOLOGY

2.1.1 Value chain assessment

The overall goal of Task 3.3 is to identify the most optimal waste-to-product solution based on the assessed value chain. This is done through an analysis of the potential new value chains on the most occurring urban material flows in the six different case studies. For each case study a new value chain will be designed that is applicable in the construction sector.

A value chain is a physical representation of the various processes involved in producing goods or services, starting with raw materials and finishing with a delivered product at the end of the chain[1] It is based on the notion of added value at every link (read: stage of production) in the supply chain. The total value of a certain chain is the sum of all individual added values. Understanding the value chain of waste streams enables the generation of new valorisation schemes that allow for the reuse of these urban waste in the construction sector. Aligning the value chain of a conventional waste stream and of a conventional linear production chain might reduce the environmental footprint of both the industrial sector that produces the waste as well as for the construction sector that uses the secondary resources and facilitates the transition to a circular economy.

The value chain framework functions as an analytical lens, which allows for an overview as well as an in-depth understanding of a specific sector. Value chains describe how value is created along material flows, taking into account the interplay of the actors and their roles, stakeholders and their impact, the economic value of the material, activities that take place as well as broader socio economic and environmental factors. The value chain consists of a quantitative dimension, which is the material flow through space, as well as a qualitative dimension, which describes the actors that are connected to each step of the value chain and the value creating activities and interests they persuade. The waste-based value chain has four main steps, which are waste production, waste to resource processing, resource use (product production) and product use. All steps relate to a certain actor in the value chain, as seen in Figure 1.

Figure 1: CINDERELA value chain framework

In the CINDERELA value chain framework the following steps are included:

- **Actor A** is the waste producer, e.g. a demolition firm in the name of investor, a household producing household waste or an industrial firm which produces a waste stream.
- **Actor B** is the 'Waste to SRM' processor or in the case of disposing, the waste disposer. These are recycling companies that turn the waste into resources.
- **Actor C** is the actor who fabricates the SRM into a construction product.
- **Actor D** is the user of the SRM-based construction product, e.g. a construction company or individual.

A value chain consists of information on different levels:

- **Material flow:** the material flow consists of several properties, which include the material, geolocation, amount, quality, composition and availability.

[1] https://www.investopedia.com/ask/answers/043015/what-difference-between-value-chain-and-supply-chain.asp

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- **Stakeholder:** a value chain could include multiple active stakeholders per step. They could either be profit organizations or non-profit organizations such as a municipality. There could also be indirect stakeholders, such as architects, policy makers, environmental organizations etc.
- **Activity:** describes the activities which are performed on the material per step. How is the material produced/collected by the waste producer? How is it recycled, how is the product produced, and how is the product used/what is it used for?
- **Value creation:** describes how value is created throughout the chain. How do the activities add value to the material and how does it compete in the specific (end-)market of the material/product?
- **Interests/stakes:** the interest of the different stakeholders in the current c.q. new value chain.

2.1.2 PESTEL analysis

A PESTEL analysis is a framework that analyses the macro-environmental (external environment) factors that have an impact on a value chain or an individual organization. The results of the PESTEL analysis are used to identify threats and weaknesses that can be used in a SWOT analysis (paragraph 2.1.3).
PESTEL analysis is concerned with the socio-economic and environmental context in which a value chain exists. A PESTEL analysis will generate information about the context in which the different European cities operate and thus yield location specific challenges. The outcomes can aid the set-up of an approach that works for the six cities of the CINDERELA, but also for other European cities. The PESTEL analysis consists of six dimensions (Figure 2)[2]. These six dimensions are political, economic, social, technological, legal and environmental. Through the analysis of these dimensions, forces, drivers, trends or prevailing conditions that can impact the value chain, are considered.

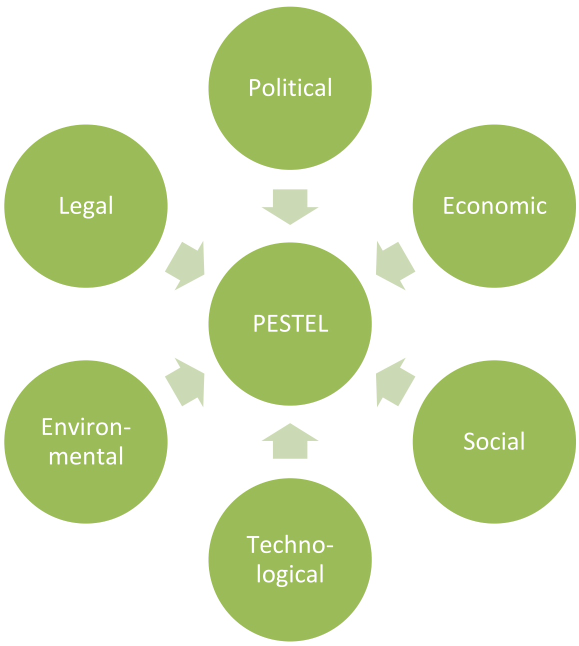

Figure 2: PESTEL Analysis Framework

[2] Source: https://www.professionalacademy.com/blogs-and-advice/marketing-theories---pestel-analysis

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2.1.3 SWOT analysis

SWOT analysis is a framework used to evaluate the position of a (value) chain of organizations and to develop strategic planning. SWOT stands for strengths, weaknesses, opportunities, and threats. SWOT analysis assesses internal and external factors, as well as current and future potential of the value chain as seen in Figure 3: SWOT analysis framework[3].

A SWOT analysis is designed to facilitate a realistic, fact-based and data-driven look at the strengths and weaknesses of a chain, its initiatives, an industry or an individual organization. It is a technique for assessing the performance, competition, risk, and potential of a chain of organizations, as well as an individual part of the chain such as the waste processor/recycler or the product producer.

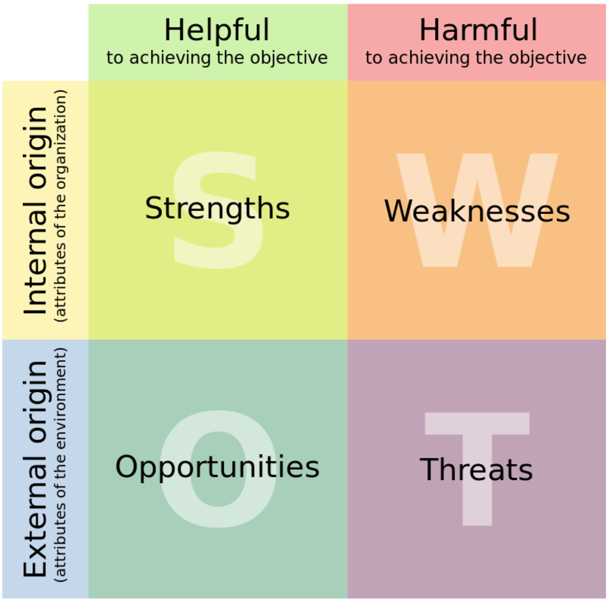

Figure 3: SWOT analysis framework

2.2. Methodological approach

2.2.1 Waste stream selection

As it is impossible to assess all the waste streams in a use case, a selection of potential waste streams has been made. The initial selection of the potential waste streams per use case is based on Task 3.1 methodology (see deliverable 3.1) and Task 3.2 selection of most prominent wastes for SRM in construction sector. Each case study has selected one European Waste code (EWC) from wastes representing 90% of waste streams quantities in the specific region. Paragraph 1 of the following chapters (3-8) will describe this initial selection. The first step in the selection process was to filter on the EWC-codes that represent the top 10-20 largest waste streams (90% by mass) in specific region. After this, additional criteria are being used to select the – to be assessed - waste stream, namely environmental impact, waste reduction, life cycle costs, performance benefit and reusability and recyclability.

Below in the Table 1 an overview is given of the selected waste streams per case study.

Table 1: Overview of assessed waste stream per use case

Region	Croatia	Netherlands	Italy	Poland	Slovenia	Spain
Selected waste stream	Mixed CDW waste	Concrete waste	Mixed CDW waste	Mining waste	Sewage sludge	Mixed CDW waste
EWC-code	17 (09 04)[4]	17 01 01	17 (09 04)[4]	01 01 02	19 08 05	17 (09 04)[4]

2.2.2 Current value chain assessment

Once a waste stream is selected, the potential of this waste stream is evaluated with value chain assessment and PESTEL analysis, generating a current value chain that is described in paragraph 2 of the following chapters. The basis for acquiring the necessary information is in-depth desk research and structured interviews.

[3] https://www.professionalacademy.com/blogs-and-advice/marketing-theories---swot-analysis

[4] In the Croatian, Italian and Spanish case studies all EWC codes starting with 17: CDW (construction and demolition waste) are assessed.

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In order to obtain all the information necessary for making a value chain, at least one interview for each stage (A,B,C,D) per value chain is required. These interviews aim at adding information to the value chain table that cannot be obtained through desk research. Interviews with experts as well as stakeholders can help to add information required in the steps of the value chain assessment. Even though the described guideline is divided in steps, this does not mean that one interview is required for each of these steps. Furthermore, the data acquired in Task 3.1 and discussed in D3.1 are consulted in assessing the current value chain. This data includes information concerning the amounts and the various actors involved.

In most cases separate workshops are organized in order to assess each step of this document. Organisers of the workshop also prepared a factsheet of the value chain which is used in the workshop to have a qualitative discussion.

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3. CROATIAN CASE STUDY

3.1. Introduction to the case study

3.1.1 Geographic region

The Croatian case was focused on material flow and value chains of CDW waste in the entire Region of Istria (Istarska županija). The Istria region was selected as a benchmark of the CINDERELA partnering country Croatia. The Istrian region covers most of Istria - the largest Adriatic peninsula. Istrian peninsula covers an area of 3476 km^2. This area is divided into three countries: Croatia, Slovenia and Italy. Total number of residents in Croatian Istria (Istrian County) is 208,055, which makes up 4.85% of the population of the Republic of Croatia. The Istrian County (Figure 4) is administratively divided into 41 territorial units (Figure 5) of local self-government - in 10 cities and 31 municipalities. Cities are Buje-Buie, Buzet, Labin, Novigrad-Cittanova, Pazin, Poreč, Pula, Rovinj-Rovigno, Umag-Umag and Vodnjan. The municipalities are: Bale, Barban, Brtonigla-Verteneglio, Cerovlje, Fažana, Funtana, Gračišće, Grožnjan-Grisignana, Kanfanar, Karojba, Kaštelir - Labinci, Kršan, Lanišće, Liznjan, Lupoglav, Marčana, Medulin, Motovun, Oprtalj-Portola, Pićan, Raša, Sveti Lovrec, Sveta Nedelja, Sveti Petar u šumi, Svetvincenat, Tar-Vabriga, Tinjan, Višnjan, Vižinada, Vrsar and Žminj.

Figure 4: Istria region on the map of Croatia

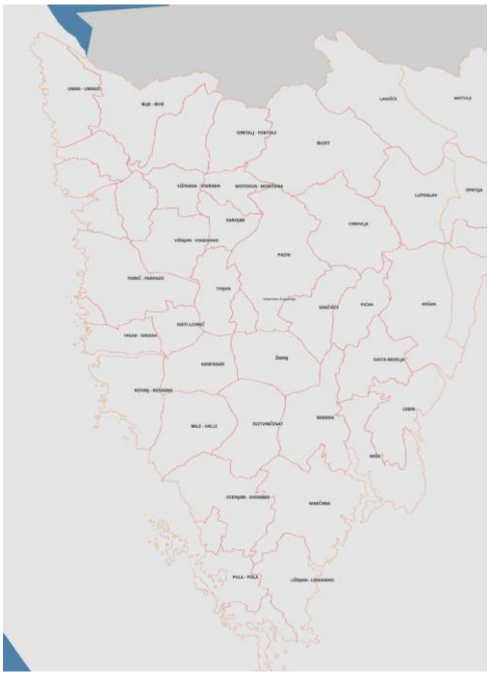

Figure 5: Istrian administrative units

3.1.2 Assessed waste stream

For the focus of the assessment, special emphasis was given to the waste stream of CDW – group 17.

The quantities reported by relevant actors to the Croatian Agency for Environment and Nature were significantly lower than expected assessments made by experts involved in the project, and significantly lower than average per capita CDW generation quantities. Total reported quantities of CDW generated (waste under EWC codes 17) in Istrian region were 19,814.875 tonnes in 2017, amounting to only 0.095 tonnes of CDW generated per capita - the European data for 2016 shows that there was 1.67 tons of CDW generated in EU per capita.

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Table 2 depicts distribution of CDW in Istrian administrative units.

Table 2: Officially reported quantities of CDW in Istrian region in 2017

City / Administrative Unit	Sum (tonnes)[5]
Buzet	369,419
Cerovlje	71,75
Červar Porat	218,4
Funtana (Fontane)	13,581
Galižana (Gallesano)	55,6
Kanfanar	122,475
Koromačno	343,73
Kršan	42,048
Labin	118,659
Lupoglav	3,74
Marčana	6,98
Medulin	31,22
Motovun (Montana)	16,593
Novigrad (Cittanova)	657,22
Pazin	1860,548
Pićan	64,08
Plomin	447,968
Podpićan	4039,565
Poreč (Parenzo)	787,565
Pula (Pola)	5607,824
Rabac	447,353
Raša	150,76
Roč	9,511
Rovinj (Rovigno)	3968,59
Savudrija (Salvore)	3,02
Tar (Torre)	28,561
Umag (Umago)	66,488
Vodnjan (Dignano)	208,26
Vrsar (Orsera)	28,717
Žminj	15,23
Total	**19814,875**

3.2. Current value chain

3.2.1 Material flow

In Croatia, the legislative aspect of CDW is similar to other European countries, thus determining the officially represented value chain of said waste from producer through transporter and processor of waste responsible for handling..

3.2.2 Stakeholders and their interests

In general, actors of the value chain are divided in two groups (Figure 6): CDW producers

[5] all quantities of EWC codes 17 waste reported

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(demolishing companies) and CDW processors (recycling company), whereas the second group was represented in the respective workshop only by one actor. Present demolishing company is acting as a waste processor with the aim of offering an additional service to large investors and construction companies, but not with the aim of secondary raw materials production. Further subgroups division is given in Table 3.

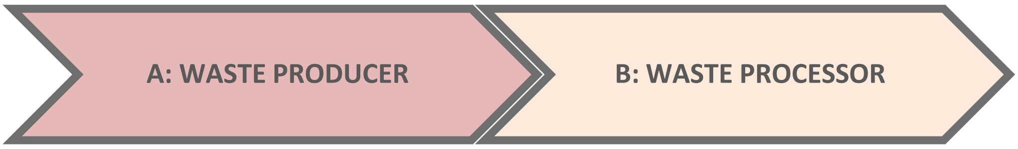

Figure 6: Existing CDW value chain actors in Istria

Table 3: Group of actors and their subgroups with respective definitions

Group of actors	Actors inside the group	Description[6]
Waste Producers	**Waste Producer**	Anyone whose activities produce waste (original waste producer) or anyone who carries out pre-processing, mixing or other operations resulting in a change in the nature or composition of this waste.
	Waste Holder	The waste producer or the natural or legal person who is in possession of the waste
Waste Processors	**Waste Processor**	Legal entity or natural person whose activity is waste processing.
	Waste Collector	Anyone whose activity is gathering of waste, including the preliminary sorting and preliminary storage of waste for the purposes of transport to a waste treatment facility
	Waste Transporter	Legal entity or natural person whose activity is transport of waste from Waste Holder according to Decree on Waste.
	Waste Broker	Any undertaking arranging the recovery or disposal of waste on behalf of others, including such brokers who do not take physical possession of the waste
	Waste Dealer	Any undertaking, which acts in the role of principal to purchase and subsequently sell waste, including such dealers who do not take physical possession of the waste.

Different stakeholders as illustrated in Table 4 influence individual actors directly or indirectly.

[6] Waste Directive

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Table 4: Stakeholders with direct and indirect influence on actors

ACTOR	STAKEHOLDERS	EXAMPLE	INFLUENCE
WASTE PRODUCERS	**INVESTORS AND CONSTRUCTION DESIGNERS**	Public (e.g. municipalities and other public entities)	Calculating the cost of waste within investment costs and demanding lawful handling from their contractors
	NATIONAL DECISION-MAKERS	E.g. Croatian Agency for Environment and Nature	Supervisory role of rules of conduct.
	MUNICIPALITIES	e.g. Municipality of Umag	Indirect influence on waste management through public procurement, behaviour in their own investments.
WASTE PROCESSORS	**NATIONAL DECISION-MAKERS**	E.g. Croatian Agency for Environment and Nature	Supervisory role of rules of conduct.

3.2.3 Activity and value creation

CDW producer (demolishing company in the name of investor) and CDW holder is responsible for lawful CDW disposal or reprocessing by an entity that fulfils all necessary legal conditions (consents, permits etc.) to act as a CDW processor. Sometimes waste producers are also waste processors, as was the case of one actor present at the conference in the subject area. Waste collectors, transporters, brokers and dealers are usually not performing any additional activities on CDW; nevertheless their profit is usually the highest in the whole value chain. Recovery operators (recycling companies) are producing new materials out of CDW through different operations of recycling, but in the subject area said activities were not noticed by the partnership with exception of one case.

As is clearly visible from the data and descriptions above, there is a significant unexploited potential for CDW in the subject area. Currently, investors that should be paying the cost of CDW handling, are shifting these costs to their contractors (demolishing companies, construction companies – subcontractors), which do not calculate said costs in their services to stay as competitive as possible on a crowded market. New potential value chains were determined by the partnership, with particular emphasis on restoration of current illegally landfilled waste and establishing collecting / processing service (Figure 7).

Figure 7: New value chain connected with restoration of illegally landfilled waste

In order to develop new value chains, certain demand-side measures (Figure 8) will have to be taken, on one hand to discourage responsible parties of waste creation to handle them within the bounds of Croatian and European legal framework and according to environmental standards, and on the

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other hand to encourage the establishment of appropriate waste processor and supporting the use of end products. The biggest interest in implementation of said measures has currently been determined to lie in the municipalities of Istria and the Istrian Region.

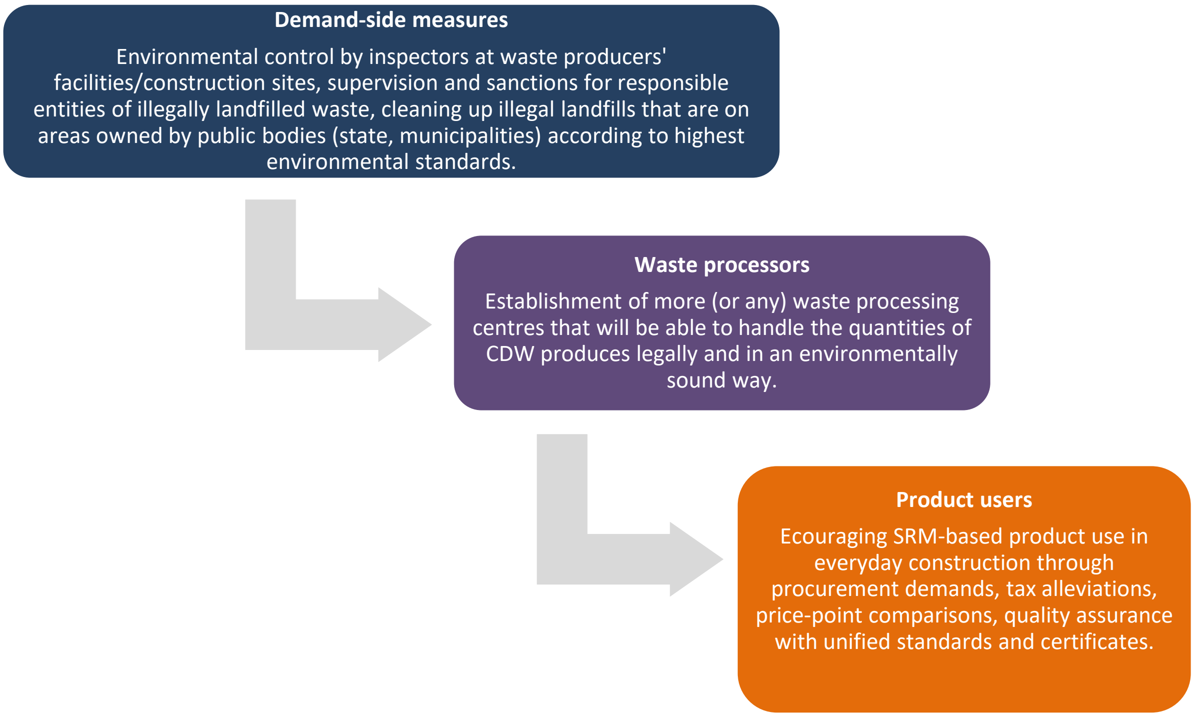

Figure 8: New value chains, certain demand-side measures

Due to extreme annual growth of tourism expected to increase even more in the following years, said official actors have a vital interest to have the tourist environment clean and illegal landfills restored, but they have limited influential power on top-down implementation of corrective measures. The Republic of Croatia has adopted a comprehensive set of policies and legislation on national level for tackling the issues of illegal landfilling.

3.3. Potential new value chain

Considering the complex current situation as previously defined, the potential new value chain determined by the partnership is the activity of 6.MAJ and by extension of the Municipality of Umag to map illegally landfilled waste that are located on municipal (and potentially state) land, to remove them and process them into new, valuable SRM based construction products that will be then used for their own municipal investments. The jurisdictional scope of municipalities in Croatia does not allow any other type of governmental actions (e.g. sanctions, fines).

3.3.1 Technological developments

The technological development of processing CDW in combination with other potentially useful waste should go in the direction of quality recycled waste based product (SRM-based construction products) development. These products, which will be demonstrated in CINDERELA pilot demo in WP6 (Task 6.4), should be developed and tested in way to directly correspond to specific climate conditions of the subject area (coastal region, use in sea water) to ensure their wider uptake.

3.3.2 Determination of potential impact points

Positive impact points in current value chains, which favour creation of new value chain, are:

- Growing interest of municipalities in subject area to established a transparent, lawful and environmentally sound system for CDW management.
- Pressure by private companies and citizens to tackle these issues in order to encourage tourism and economic growth.
- Negative impact points in current value chains, which hinder creation of new value chain, are:
- Total lack of supervision for which national bodies are responsible.
- The prices of virgin materials are still very low, especially compared to other EU markets.
- Lack of environmental consciousness by relevant actors.

3.3.3 Identification of end market

In the frame of the CINDERELA project, we are focused mainly on construction sector, which would use SRM-based construction products. In order to make said materials interesting for specific subject area's market, the partnership has determined that specialised product would present the best possibility for uptake. Particularly, products that would correspond to the needs of maritime environment with its special conditions such as wave protection products – tetrapod (Figure 9). Potential of available waste in the region will be assessed and production of pre-cast product will be delivered within Tasks 6.4 by CINDERELA partner 6.MAJ.

Figure 9: Tetrapods, specialized SRM-based construction products for protection against waves

3.3.4 Socio-economic and environmental context

Table 5 present barriers and incentives in the existing value chain, which can hinder/foster its transformation into new value chain.

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Table 5: PESTEL analysis of Croatian case

Political	• Regulation is established and would be sufficient, but is not implemented – lack of supervision. (barrier) • Lack of dialog between decision-makers, legislators and actors. (barrier) • Demand-side measures are needed but currently not present for use of SRM-based construction products made from recycled. (barrier)
Economic	• Currently, there is no final market for SRM-based construction product in the subject area. (barrier) • Low price of virgin raw materials. (barrier) • Little encouragement for use of SRM-based construction products. (barrier)
Social	• Increasing social acceptance of SRM-based products. (opportunity) • Fact-based responsible media coverage of SRM-based products use is needed. (opportunity) • Education and awareness raising (opportunity).
Technological	• Dissemination of BAT is very important as well as lifelong learning and education. (opportunity) • Investment in new technologies is important. (opportunity)
Environmental	• A gap between policies and actual practice is observed. (barrier) • Low awareness among general public in industry about environmental responsibility. (barrier)
Legal	• Legislation should be implemented via a top-down approach (supervision, inspections, and fines). (opportunity)

3.3.5 Overview of potential new value chain

Potential new value chain, the aim of which would be to use CDW for production of end products (e.g. tetrapods for wave protection), would consists of at least four actors, whereas the first three actors could be conjoined into one entity, or at least the second and third actor could be the same entity:

- Waste producers or waste holder, which can be the investors into interventions where waste is generated, contractors or subcontractors of such work.
- Waste collector and/or waste processor, which would provide the waste to the next actor qualified to reprocess the waste in the value chain.
- Product producer equipped with suitable equipment and knowledge to reprocess the waste into new end products (demonstrated in Task 6.4).
- Product users (e.g. authorities in charge of wave protection – municipalities, port authorities, private port owners/concession holders).

3.4. SWOT analysis

The SWOT analysis presented below (Table 6) is an assessment to support the creation and optimization of a semi-existing value chain and transformation into a new, more sustainable one in Istrian region regarding the use of CDW and reprocessing into useful new end products.

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Table 6: SWOT analysis of Croatian case

Strengths	Weaknesses
• Strong interest by some actors to tackle the issue of CDW recovery in a sustainable and environmentally sound way. • Existing awareness of some stakeholders that new, better practices are definitely needed. • Adequate national legislative acquis and policies.	• Lack of supervision over waste producers and their practices of CDW handling, which is in national jurisdiction. • Disrigard by some stakeholders to environment driven by economic gain. • General awareness about CDW is still very low among decision-makers and general public.
Opportunities	**Threats**
• Lower costs of management in the case of recycling into SRM-based construction products. • Significant improvement of local environment by eliminating illegal landfilling. • Economic growth by establishing virtually a new sector or sub-sector of waste recovery. • Increased attractiveness of developing tourism activities in the region.	• Inexpensive virgin materials. • Fragmentation of responsibilities between investors, construction companies, transporters, collectors and other stakeholders. • Insufficient numbers of public supervisory employees. • Poor dialogue between national, regional and municipal actors, and with stakeholders within the of value chain.

3.5. Conclusion

3.5.1 General findings

The most bothering and obvious conclusion the partnership drew from studying CDW in Istrian region is occurrences of illegal dumps. The municipalities that are interested in economic development boosted by tourism and subsequent activities in the last decade are aware of said problems, but lack the jurisdiction and resources to resolve the issues. Led by economic gain, investors relay the cost of CDW to their contractors, which then shift the burden to their subcontractors. After the stakeholder workshop held in Umag, several representatives of CINDERELA's partners have informally spoken to the stakeholders present and found out that everyone in the region is aware of the problem, everyone desires a strategic, holistic and structured solution, but are unable to influence such developments.

3.5.2 Recommendations

Enhanced dialogue among different stakeholders, local and national government, as well as raising awareness activities among value chain actors and general public should be implemented in order to prevent illegal dumping practices of CDW. With such proactive role of all involved parties the CINDERELA's objectives and aims could truly be reached within Istria region.

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4. DUTCH CASE STUDY

4.1. Introduction to the case study

4.1.1 Geographic region

The Amsterdam Metropolitan Area (Metropoolregio Amsterdam, in short MRA)[7] is located in the Netherlands, spans the boundaries of two provinces (North-Holland and Flevoland) and encompasses the capital of Amsterdam as well as 32 municipalities (Figure 10). For this deliverable, statistics from 2016 are used which show that, in the MRA, there are 33 Municipalities with 339 neighbourhoods containing 2,410,330 inhabitants, covering an area of 2580 km2. The region is responsible for a range of policies including economic development, transport, aspects of spatial planning related to urbanisation, landscape management, and sustainability . Besides the former port areas, Amsterdam Schiphol airport is a crucial part of the MRA. It is located 9 km southwest of Amsterdam in the municipality of Haarlemmermeer and is the third busiest airport in Europe by passenger numbers[8] .

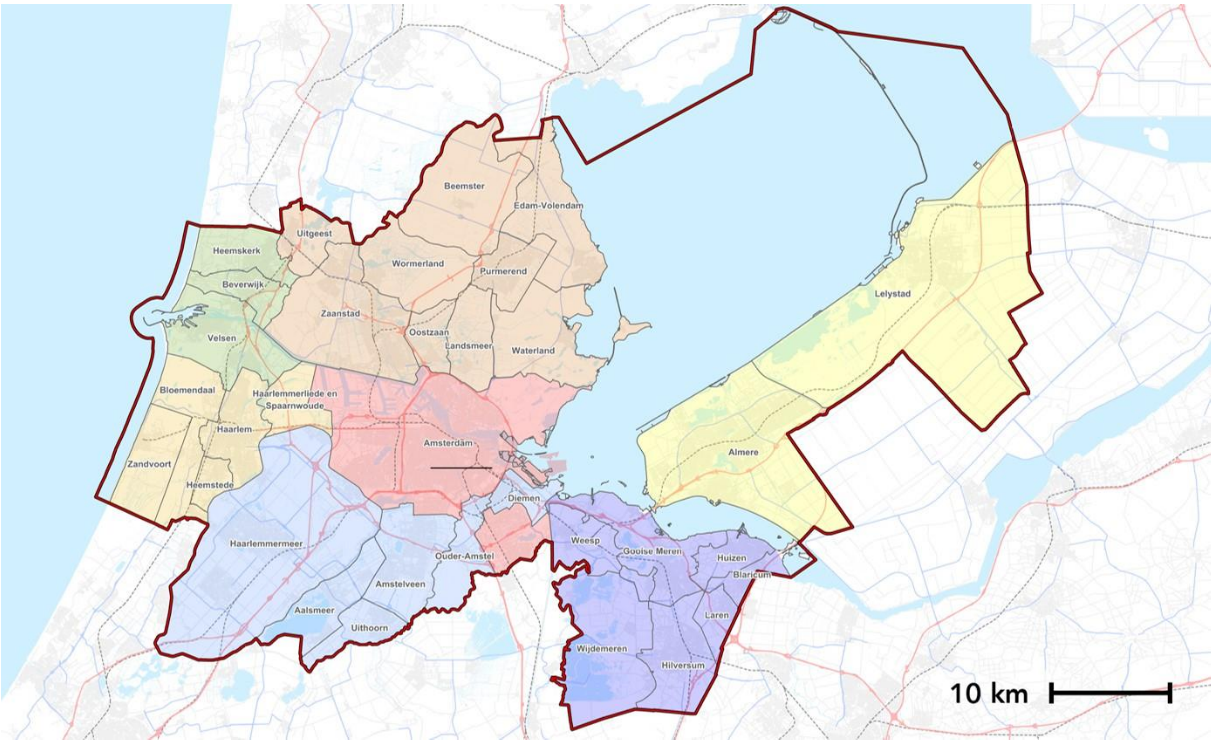

Figure 10: MRA region

The Amsterdam case is part of the Dutch national ambitions to transition towards a Circular Economy (CE), which are formulated in the policy report 'Nederland Circulair in 2050' that states the necessity to strive for a transition towards a circular economy for three reasons: (1) substantial growth in resource use, (2) dependency of the Netherlands on other countries for resource supply and (3) the relation to climate change in the form of CO_2 emissions. Next to facing these problems, the national

[7] Metropoolregio Amsterdam, 2017.

[8] www.aci.aero. Geldermans et al., 2018. Geldermans, B., Bellstedt, C., Formato, E., Varju, V., Grunhut, Z., Cerreta, M., Amenta, L., Inglese, P., Leer, J. van der, Wandl, A., (2017) Introduction to methodology for integrated spatial, material flow and social analyses, Resource Management in Peri-urban Areas (REPAiR), Horizon2020, European Commission

government sees many benefits in transitioning to a circular economy, such as economic opportunities[9].

The municipality of Amsterdam has high ambitions for this subject and wants to be one of the leading transition cities. Amsterdam's CE ambitions already began in 2009 with the initiation of circular Buiksloterham[10]: an urban regeneration project testing and implementing CE principles. Within this new housing development, circular concepts were used to develop a zero-waste neighbourhood. Afterwards, Amsterdam adopted CE within their 'sustainability agenda' and promoted the concept of CE as one of the biggest opportunities to facilitate sustainable growth in the future[11] . After including the transition within their sustainability agenda, a roadmap towards CE, 'Amsterdam Circulair' was presented in 2015.

4.1.2 Assessed waste stream

To select a waste stream for value chain assessment, we first adopt a simplified choice matrix that was recently used by a research for the MRA about circular building materials and value chains. This choice matrix considers the three variables of mass, environmental impact and value.

The following persons were interviewed to select a waste stream for value chain assessment:

- Grondbank Amstelveen;
- Kras Recycling;
- Renewi & Zero Waste Foundation;
- Cirwinn;
- AEB Amsterdam;
- Metabolic;
- VolkerWessels, Bouwhub Utrecht and Primum;
- MRA (Metropool Regio Amsterdam);
- New Horizon.

From these interviews, concrete waste appeared as the right waste stream for the MRA value chain assessment. This also becomes apparent when considering the choice matrix variables:

- Regarding mass, concrete is by far the largest waste stream in the MRA, but also worldwide. Furthermore, concrete is also the most used material in the construction sector.
- When omitting land-use as environmental impact, concrete has by far the highest environmental impact, especially in terms of CO_2 equivalent. In fact, concrete, and then specifically the production of cement, which is an essential part of concrete production, is the largest non-combustion related emitter of CO_2[12].
- The current value chain of concrete has not been analysed yet and therefore the value of concrete cannot be assessed with regard to waste selection. Task 3.3 is set out to analyse the value chain of the chosen material, which is an opportunity to further understand the barriers

9 Rijksoverheid, 2016.
10 Metabolic, 2014.
11 Gemeente Amsterdam, 2015
12 Olivier, Peters, & Janssens-Maenhout, 2012

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and opportunities for creating a SRM of concrete (the value chain framework for this analysis has already been made).
- The scarcity of natural resources for concrete in the Netherlands is growing which makes it urgent to look towards other recycled resources.

The factors described above indicate that concrete waste is the right waste stream to assess for the MRA use case. As concrete is both an in- and output material, a new value chain for concrete could allow for recycling as well as waste reduction. This is an advantage as opposed to other waste streams which are not an output of the CDW sector.

For these reasons, the urgency from a circularity perspective to address the concrete chain is quite large. Political interest in the concrete chain is high, which is reflected in the numerous policies and agreements on various levels of government in the Netherlands. Not only the public sector is acting upon this urgency, but also the private sector is increasingly taking action. Many circular innovations for the reuse or recycling of concrete are emerging, which provides a major potential for bundling or scaling up to create real impact.

Concrete waste in MRA

Concrete waste is the largest waste stream in the MRA, 35% of CDW is made up of concrete waste (17 01 01) and 32% is mixed CDW, which also contains concrete waste[13]. Since landfilling was forbidden in the Netherlands in 1997, close to all CDW is recycled as aggregate for the foundation for infrastructure, such as roads[14]. At the same time, concrete is also the most used material, with a total demand of almost two megatonnes per year in the MRA[13]. However, a large share of the primary materials that are required for the production of concrete are imported to the Netherlands and additionally these primary materials are becoming increasingly scarce[14].

Due to the increased use of concrete as a building material in the past, the availability of concrete waste is increasing, whereas the demand from the infrastructural sector for recycled aggregate as subbase for roads is diminishing. Instead of recycling concrete waste as subbase for infrastructure, it can also be used as aggregate in new concrete, replacing some of those increasingly – in the Netherlands - scarce primary materials. Currently only 2% of concrete waste is applied in this way[15]. There is thus a large potential for increasing this share. However, the demand for new concrete is much higher than the supply of concrete waste[13]. Thus, even when maximally recycling concrete waste as an aggregate in new concrete, it cannot cover the entire demand for aggregate. The use of primary materials will remain necessary, or other alternatives have to be found.

4.1.3 Strategical approach

An in-depth understanding of the concrete sector is required in order to identify the main impact points for increasing the share of recycled concrete waste in new concrete. This chapter therefore first analyses the current concrete sector and then determines the key enablers and barriers for increasing the circularity of concrete. We therefore ask the question: 'What are enablers and barriers for increasing the circularity of the concrete value chain in the MRA?'. To answer this question and formulate an old and new value chain, multiple persons were interviewed, desk research was performed, and an interactive workshop was held. A complete list of interviewees is found in Annex

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13 TNO & EIB, 2018

14 Bakker, M., & Hu, M. (2015). Closed-loop economy: case of concrete in the Netherlands. Delft University of Technology, Delft, Netherlands.

15 Netwerk Betonketen, 2014

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2. Findings from a workshop about enablers and barriers of circularity in the concrete chain are included in the analysis. The following paragraphs aim at providing a comprehensive overview of the current concrete sector in the MRA and highlighting key barriers and enablers of a transition to a circular approach to concrete waste.

4.2. Current value chain

4.2.1 Material flow

Following the value chain methodology, this paragraph identifies four steps of the value chain of concrete waste: (A) concrete waste production, (B) processing of concrete waste, (C) concrete production and the use of concrete based recycled aggregate and finally (D) concrete use. The figure below (Figure 11) visualises how these steps of the value chain are connected. Concrete waste is produced through the demolition, deconstruction or refurbishment of the built environment. This concrete waste is then processed in either concrete based recycled aggregate or mixed recycled aggregate. Concrete based recycled aggregate can replace aggregate of primary materials (virgin stone) in the production of concrete. The concrete is eventually used in the built environment.

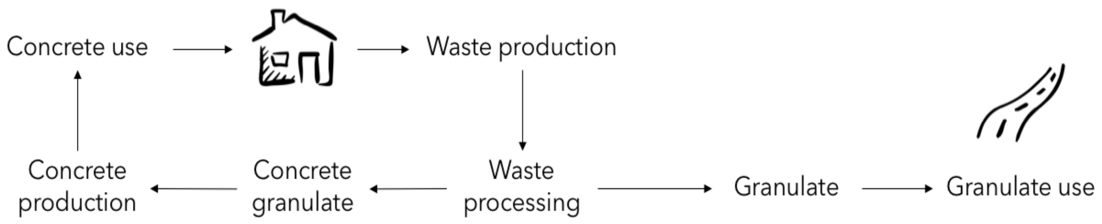

Figure 11: Visualisation of the current concrete value chain

4.2.2 Stakeholders and their interests

There are various stakeholders active in the concrete value chain in the Amsterdam metropole region. In the Netherlands various stakeholders joined forces in an alliance called 'Betonketen Amsterdam'. The stakeholders which are active in this network platform are (Table 7):

Table 7: Overview of stakeholders in Amsterdam concrete value chain[16]

Role in value chain	Name of the organisation	Description
Local government	Municipality of Amsterdam	The municipality of Amsterdam has its own 'Material desk' which is responsible for the public procurement of the entire public environment. Their aim is to create a more circular and more sustainable public environment by stimulating the use of SRM-based products.
Recycling	Oskam	Oskam Group is one of frontrunner companies in recycling techniques of CDW waste streams. They strive for sustainability throughout their entire organisation.
	Rewinn	Rewinn is specialised in recycling and upgrading in all sorts of CDW waste streams and especially concrete waste streams. They are a supplier of secondary resources.

[16] http://www.bouwcirculair.nl/p/betonketen-amsterdam

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Role in value chain	Name of the organisation	Description
	A. Jansen BV	A Jansen recycles over 1.2 million tonnes of waste streams a year. 95% is being recycled in their own products or into certified SRMs. Their goal is to become 99.9% circular within 5 years.
	Rutte Groep	Rutte Groep is the first larger recycling companies to adopt the 'Smart Crushing' technique (see sub paragraph 4.3.1). This technique enables to recycle the different resources in concrete: cement, fine and coarse aggregate.
Recycling and product producing	PARO BV	PARO is an organisation active in waste collecting, waste processing, and production of secondary resources. PARO adopted various steps of the value chain within one organization which enables them to make strategic steps towards SRM-based building materials.
	CRH bedrijven	Struyk Verwo Infra (part of CRH Bedrijven) is market leader in public pavements. They specialized in sustainable pavement building products and various sustainable concrete products.
Product user	Van Gelder	Van Gelder is one of the larger contractors which adopts sustainable and circular building materials on a large scale.

4.2.3 Activity and value creation

Step A – Concrete Waste Production

Step A of the concrete chain is the production of concrete waste through demolition or increasingly through deconstruction for the increased recovery of materials. This process is generally done by demolition companies. After demolition, they either sell the materials as products, or they pay for the waste to be processed. Demolition companies are private companies that are hired for demolition projects on a relatively regional scale.

Demolition projects might create CDW, which is an unseparated and thus mixed streams of all kinds of materials (see interview findings, Annex 2). If separation does take place then the materials are usually separated into mineral fraction and other streams, such as plastic or wood. The demolition process can be divided in two stages, which result in different types of composition of CDW. In the first stage the upper construction is removed, which yields mixed CDW. In the second stage the foundation is removed, which is made of concrete and therefore yields purer concrete based CDW.

There are a number of technological, practical and economic constraints to higher rates of separation of demolitions (also see interview findings, Annex 2). Firstly, in the past buildings were not constructed for deconstruction and technologies are not yet available to separate these materials during demolition. Secondly, demolition projects often take place in a confined space, which complicates extensive separation. Thirdly, time constraints of demolition projects limit the possibility to separate more. And lastly, small demolition projects can yield low amount of to be recycled waste, which makes separation unprofitable.

Nonetheless, source separation (selective demolishing) is becoming increasingly common, which means higher rates of separation. An increasing number of demolition companies separate at the source in order to create a purer waste stream. Today, about 20% of demolition projects are deconstructed for the recycling of the freed materials. Especially municipalities increasingly require this approach in their tenders. Higher costs can in part be compensated through selling of the freed

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materials. The remaining costs of deconstruction for reuse mean a price increase of about 15-20%.

Step B – Concrete Waste Processing

Step B of the concrete chain concerns the processing of concrete waste. This is usually done by recycling companies, unless demolition companies break CDW on site and use or sell the resulting product directly (then they become actor C at the same time). Recycling companies are paid for receiving waste. They separate and process the waste and subsequently sell the resulting product to other parties. Most recycling companies are private companies. They are organised on a larger scale than demolition companies, however, CDW in particular is organised regionally, due to its weight.

CDW from demolition projects is sometimes broken to mixed recycled aggregate on site and sold directly to infrastructure companies. The mixed recycled aggregate produced this way automatically contains at least 50% concrete and often more, because of the relatively low rate of separation. Producing concrete based recycled aggregate for the production of concrete on site is usually not profitable, because smaller fractions (fines, 0-4 mm) will still have to be transported elsewhere, which increases the costs of transportation as opposed to producing recycled aggregate that can be used for foundations (see interview findings). The production of recycled aggregate for foundations makes for a profitable business case with a steady demand. The higher the share of concrete in the recycled aggregate, the better it can be sold (see interview findings).

Waste producers pay a variable amount of money for delivering waste at recycling companies. As a rule of thumb, the more separated the delivered waste is, the lower the costs of the delivery. Thus, delivering CDW, which is a very mixed stream is more expensive than delivering pure concrete waste (approximately 90 euro as opposed to 4 euro). At the recycling company, it is determined through visual inspection whether a CDW delivery contains pure concrete. Concrete waste deliveries are kept apart and are processed to concrete based recycled aggregate. Most delivered concrete waste is part of mixed streams and thus processed into mixed recycled aggregate. However, some recycling companies apply advanced separation technologies, which enables them to retrieve a larger and purer stream of concrete waste, than only through visual inspection, such as for example Paro in Amsterdam or Twee "R" in Twente.

In order to produce mixed recycled aggregate, the mixed CDW requires to be broken with a heavy breaker and sieved into fractions. Additional processing steps are required for concrete based recycled aggregate, because of additional quality requirements on concrete based recycled aggregate as opposed to mixed recycled aggregate. These steps include the filtering of larger and the very small fractions by sifting, as only certain fractions (usually 4/16, 4/22 or 4/32) are used in new concrete. Large fractions can be broken again, whereas smaller fractions (0/4) cannot be applied and are therefore used in mixed recycled aggregate for low-grade applications. However, innovative technologies increasingly enable the use of the 0/4 fraction[17]. Concrete recycled aggregate has to consist for at least 90% of broken concrete[18]. Mixed recycled aggregate contains at least circa 50% concrete due to the (lack of) quality of the non-concrete materials in the mixed recycled aggregate. The remaining share consists mainly of waste from masonry and bricks[18].

The non-concrete share of mixed recycled aggregate has only a small number of use cases and low structural properties[18]. By mixing it with concrete (or by simply not removing the concrete fraction), the properties of the resulting mixed recycled aggregate become similar to those of concrete based

[17] Wassink, J. (2017). The last step in concrete recycling. Retrieved on 24 March 2019 from https://www.delta.tudelft.nl/article/last-step-concrete-recycling

[18] BRBS Recycling (n.d.). Informatieblad Toepassingsmogelijkheden Recyclinggranulaten. Retrieved on 20 March 2019 from https://www.cementbouw.nl/cms/wp-content/uploads/2018/12/Infoblad-toepassingsmogelijkheden-recyclinggranulaat_V2.pdf

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recycled aggregate[19]. However, mixed recycled aggregate is usually not reused in new concrete due to its high contamination with other non-concrete materials. One of the reasons for the production of mixed recycled aggregate is the prevention of a surplus of lower quality recycled aggregate of masonry and bricks. The produced recycled aggregate is certified by VROM (Dutch Ministry for Housing, Spatial planning and Environment) as a product and therefore have no attached EWC-code[19]. Both types of recycled aggregates are sold, either to concrete producers or to companies that do infrastructural works. The price of the recycled aggregate can fluctuate per day and is determined by factors such as transport, processing, availability of the recycled aggregate, which depends on the number and type of demolition projects in the region, but also availability of the primary materials[14].

There is a high demand for mixed recycled aggregate, and the more concrete the mixed recycled aggregate contains, the higher its market value. The production of concrete based recycled aggregate as compared to mixed recycled aggregate does not generate additional value for many recycling companies. However, companies that have access to recycling infrastructure for concrete waste or produce concrete themselves can make more profit with concrete based recycled aggregate than with mixed recycled aggregate.

Step C – Concrete production and use of mixed recycled aggregate

Step C of the concrete chain is the production of concrete with concrete based recycled aggregate or the use of mixed recycled aggregate as subbase for infrastructure. Concrete producers replace some of the primary aggregate materials with concrete based recycled aggregate for either the production of fresh concrete or concrete prefabricated elements. There thus are two types of concrete producing industries: the prefab concrete industry (approximately 40%) and the fresh concrete industry (approximately 60%)[20].

Conventional concrete contains three main ingredients; cement (one quarter of the concrete), aggregate (three quarters of the concrete), and water, which activates binder (Betonhuis, n.d. a)[21]. The aggregate has to consist of inert material. It is common to use a surplus of cement in order to let the concrete harden faster.

Concrete producers buy certified concrete based recycled aggregate from recycling companies. Depending on the application of the concrete, additional requirements for the concrete based recycled aggregate are necessary, because the quality of the concrete based recycled aggregate that replaces the virgin aggregate can influence the final quality of the concrete[22]. The more concrete based recycled aggregate is applied in new concrete, the cleaner the material has to be. One concern is the pollution of the recycled aggregate, especially pollution with materials that can float in wet concrete are problematic, such as wood and plastic. Currently, the recycling norm is at a maximum of 30% concrete based recycled aggregate as a replacement of virgin aggregate, even though higher percentages of replacement are technically possible. Shares that are higher than these 30% are applied outside the norm but are tested on general quality requirements. This is done in agreement with the customer, which also takes responsibility for the unconventional product.

Step D – Use of concrete

Contractors or implementors use concrete with a certain content of concrete based recycled aggregate for construction. The utility sector has the largest demand for concrete (41%), followed by

[19] Bodemrichtlijn (n.d.). Puin en granulaten. Retrieved on 20 March 2019 from https://www.bodemrichtlijn.nl/Bibliotheek/bouwstoffen-en-afvalstoffen/puin-en-granulaten

[20] Betonhuis (n.d. b). Marktinformatie Beton. Retrieved on 20 March 2019 from http://www.cementenbeton.nl/marktinformatie/betonmarkt

[21] Betonhuis (n.d. a). Beton als bouwmateriaal. Retrieved on 20 March 2019 from http://www.cementenbeton.nl/materiaal

[22] Requirements of concrete recycled aggregate are declared according to the European harmonised standard EN 12620: Aggregates for concrete

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the residential sector (34%)[23]. The remainder of the demand is infrastructure and sewage.

The price of concrete - one of the decisive factors for the composition of the concrete - lies between 85 and 140 euro per m^3, depending on its final application. The building owner can receive a (Dutch, Vamil) subsidy of maximum 50 euro per m^3 if the applied concrete contains 30% concrete based recycled aggregate according to the certificate 'Sustainable concrete' of the Concrete Sustainability Council[24]. Such subsidies should be considered temporary until the processing technologies will mature and thus make SRM-based concrete more affordable. Another factor is certification. Using concrete based recycled aggregate as replacement for virgin aggregate is one of the factors that enables the building owner to receive sustainability certificates that increate the market value of buildings, such as the BREAM certificate. These two factors, subsidy and certificates, currently act as financial motivation for applying concrete based recycled aggregate.

4.3. Potential new value chain

4.3.1 Technological developments

There are various techniques which are currently being developed in the field of recycled concrete. Below a list is given:

- **Concrete to Cement and Aggregates technology (C2CA):** aims at a cost-effective system approach for recycling high-volume concrete waste streams into prime-grade aggregates and cement. C2CA technology includes selective demolition to produce crushed concrete with a low level of contaminants. The material is then mechanically upgraded into an recycled aggregate product with sensor-based on-line quality assurance and fines that can be processed (off-site) into calcium-rich material for new clinker production. Classification technologies used are Advanced Dry Recovery (ADR) and Heating Air Classification System (HAS)[25] which can both separate and add value to the coarse fraction (60% of End-of-Life (EoL) concrete) and the remainder fine fraction (40% of EoL concrete).
- **Smart crusher (SC):** SC is an alternative technology, patented by Koos Schenk as compared to C2CA that recovers fine and coarse fractions of aggregate and cement fraction from concrete waste. SC uses a combination of a wind sifter and the smart breaker to separate the hydrated cement fraction from the non-hydrated cement. The inventor claims when the recycled aggregate and virgin aggregate are used together in a new concrete product, about 25% less cement is needed because of the increased quality[26] .
- **Heating-Air classification System (HAS):** HAS technology enables the final step, allowing the separation of 0-4 mm fine fraction of concrete waste, in an economic feasible and sustainable way. The HAS simultaneously heats, grinds and separates the concrete in fluidized-bed-like conditions[27] . This weakens the bond between silica and cement paste, allowing the production of clean sand and cement clinker-type products. The project will upscale the lab scale facility to an economically viable 3000 kg/hour system, using its output

[23] TNO & EIB, 2018.

[24] Rijksdienst voor ondernemend Nederland (2019). Duurzaam (beton)product met ten minste 30% gerecycled content. Retrieved on 20 March 2019 from https://www.rvo.nl/subsidies-regelingen/milieulijst-en-energielijst/miavamil/duurzaam-betonproduct-met-ten-minste-30-gerecycled-content

[25] Di Maio, Lotfi, Bakker, & Hu, 2017

[26] Bakker & Hu, 2015

[27] Lofti, 2016

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to construct 100% recycled concrete buildings at The Green Village (a demonstration location at the TUDelft).

- **Advanced Dry Recovery (ADR):** ADR is a low-cost classification technology that removes the fines and light contaminants of crushed concrete with an adjustable cut-point of between 1 and 4 mm for mineral particles. ADR uses kinetic energy to break the bonds that are formed by moisture and fine particles and can classify materials almost independent of their moisture content[28] . After breaking up the material into a jet, the fine particles are separated from the coarse particles. The output is coarse aggregate product and a fine fraction, which includes the hardened cement, fine fractions of aggregate (to be treated in the HAS) and light contaminants such as wood, plastics and foams.

There are also some more conceptual innovations which are being developed which reduce the footprint of concrete and/or reduce the amount of waste generated:

- **Design for deconstruction:** Optimizing construction of future buildings to ease concrete recycling and speed up the smart demolition process. Prefabricated slabs in buildings could possibly be used entirely instead of having to be taken apart for recycling. This would lead to a move towards reuse[29] .
- **Decreased amount of cement used in concrete production**: There are several methods with which the amount of cement needed for the production of concrete can be reduced. The first one is to improve the aggregate packaging. This can lead to the reduction of 10% the necessary cement [30]. The less cement is used the longer it takes for concrete to reach a required strength. Therefore, another way of reducing the amount of cement is to allow for more time for the concrete. This primarily applies to prefab concrete33.
- **Decrease amount of reinforcement needed: The** amount of steel that is used for reinforcement could be reduced by replacing it with steel fibres. This might lead to the same properties as conventional reinforced concrete, which is currently being researched. However, in the current demolition methods this steel cannot be completely recycled, this would be the case if smart demolishing is applied[31] . In conventional recycling only 86% of the fibres can be recovered [32].
- **Electric pulse:** With electric pulse technology fines (0-4 mm) can be separated from coarse fractions of aggregate to size 150 mm, producing clean and high quality aggregates. The method is tested by Japanese researchers in Kumamoto University [33]. The dielectric breakdown of gas occurs in concrete by the pulsed electric discharge at first. Ionized gas forms plasma and an explosive change in gas volume tears the concrete structure. A shock wave is also generated at the same time, which generates tensile stress at the boundary that separates mortar from aggregate. This method is environmentally beneficial as compared to dry or wet methods, in terms of CO2 footprint. However electric pulses will need to be controlled according to properties of demolition material.
- **Geopolymer concrete:** Ordinary Portland Cement (OPC) based concrete involves virgin resources and an energy-intensive production process. Geopolymer concrete uses industrial by-products, significantly reducing the CO2 footprint while offering improved mechanical

[28] Lofti, 2016
[29] Bakker & Hu, 2015
[30] van Lieshout et al., 2013
[31] van Lieshout et al., 2013
[32] BEwerken, 2013
[33] Inoue et al., 2008

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properties. Still, its durability is unknown. The TUDelft Geopolymer team has developed concrete mixtures and is performing experimental and numerical investigation of the various degradation mechanisms. The ultimate goal is to bring the geopolymer concrete to a level where it can be tested in real life applications. Then, industry will be able to use optimized mixtures in structural applications, with provided recommendations for in-situ testing.

4.3.2 Determination of potential impact points in value chain

The analysis of the value chain of concrete as presented above lays the basis for identifying overarching enablers and barriers for increasing the circularity of the concrete chain. They were identified through the careful analysis of literature, documents, websites and the interviews and subsequently confirmed during a workshop about circular concrete. In this section these overarching barriers and enablers are presented and discussed. In more general terms the relation between barriers and enablers can be described as a substitutive one, thus a barrier that is addressed and thus removed becomes an enabler. The identified barriers can be categorized into three categories:

- Public sector
    - Rules and regulations;
    - Public procurement;
    - Norms and certificates.
- Concrete chain
    - Alignment concrete chain;
    - Guidelines and deals;
    - Path dependency.
- Overarching factors
    - Technological innovations;
    - Geographical scale;
    - Time and effort.

RULES AND REGULATIONS

Governmental regulations offer security and safety, however, while doing so they might restrict flexibility. In the concrete sector there is an increasing amount of innovative technologies, which cannot be applied due to strict regulations. Innovative actors in the concrete sector have to adapt their new technologies, processes and approaches to these older regulations. Additionally, laws and regulations differ on a regional and local level, which complicates the process of innovation. The interviewed actors therefore see a large role for governments to impact the circularity of the concrete chain, by adapting and aligning new regulations for concrete. However, a certain caution is required in order not to trade off too much of the much-needed security and safety. Additionally, recycling practices that increase circularity can be stimulated through subsidy, such as the Vamil subsidy for building owners, which applies when the concrete used in the building has the 'Sustainable concrete' certificate.

PUBLIC PROCUREMENT

The largest share of new concrete is used in utility and infrastructure[34]. This illustrates that much of the construction that takes place with concrete is commissioned by a governmental body. Public procurement thus plays a major role in the concrete sector and largely influences which types of

[34] TNO & EIB, 2018

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concrete are used and how demolition takes place. The government can contribute to optimising the recycling of CDW by prescribing the use of concrete based recycled aggregate in new construction projects and selecting demolition companies based on whether they practice source separation. By having a clear vision and ambition public procurement could lead to an increasingly cooperative concrete chain with actors and processes that are well aligned.

NORMS AND CERTIFICATES

Quality standards for concrete based recycled aggregate that is to replace virgin aggregate are determined in the 'BRBS / VOBN Productinformatieblad Betongranulaat 4/32'. These standards conform with the CUR-recommendations 112 (CROW, Dutch knowledge platform) and NEN-EN 5905 (which is the Dutch interpretation of NEN-EN 12620 Aggregate for concrete). According to NEN-EN 5905 concrete based recycled aggregate has to consist for more than 90% of broken concrete. The concrete based recycled aggregate requires a (KOMO) product certificate which contains the environmental, hygienic and technical specifications, and has to be tested according to BRL 2506 (concrete guideline). CUR advice 112 currently allows for 30% concrete based recycled aggregate as replacement for primary aggregate, but also specifies that higher percentages are possible, with adapted calculations (Betonhuis, n.d. c). Technically a much higher percentage than the current 30% norm is possible, but this outside the norm concrete is only applied in specific situations of mutual consent between concrete producers and their clients. Norms and certificates, as e.g. certificates for the quality of recycled aggregate, are made by the sector itself, which is not always equally open to change. Therefore, these norms and certificates are only limitedly progressive and do not lead to meaningful change. Further, they often do not match the requirements of the subsequent users (as is the case with concrete based recycled aggregate).

ALIGNMENT OF CONCRETE CHAIN

All actors in the concrete chain have differing activities and interests (workshop findings). Additionally, while some are quite conservative and work in the traditional way, others are innovative and work more progressively (see interview findings). Therefore, they do not have a shared vision or ambitions. Alignment of the concrete chain is essential for making meaningful change towards a more circular concrete chain. In order to do so, all actors need to become aware of the requirements and responsibility at the end of the chain and thus need to establish a shared vision and ambition (workshop findings). Specific points of action are required to realise such an alignment, as is it essential to increasing the circularity of the concrete sector. Until now such an approach is lacking, even though many actors point to the gap in the concrete chain as a particular barrier for achieving more circularity. Green deals on concrete and matching actions are required, including the sharing of knowledge and experience and aligning the visions and ambitions of the different actors.

GUIDELINES AND DEALS

Within the concrete sector there are already a few guidelines and deals for its increased circularity, e.g. the 'Green Deal Beton' and the latter 'Betonakkoord'. However, Dutch stakeholders do not consider these specific enough as they do not suggest a concrete course of action. This is even more applicable for the 'Green Deal Beton' than for the 'Betonakkoord'[35]. Additionally, critics as well as some actors from the concrete sector find them not sufficiently ambitious[36]. They argue that the concrete sector is less ambitious than the Paris climate accord, also because it is not directly linked with this agreement. Others argue that the deal is too ambitious, leaving the goals specified in it unattainable. However, supporters point out that ambitious goals are necessary for change[37].

PATH DEPENDENCY

35 Verlouw, 2018
36 NRC, 2018
37 Cobouw, 2017

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Many concrete producers are linked to the only cement company in the Netherlands, called ENCI, whose mother company is Heidelberg Cement. These concrete producers are dependent on the cement industry for their primary materials. Therefore, the cement industry influences the recipes of concrete. Since the cement industry needs a market for their cement products, it does desire a change of the concrete industry, such as using less cement and recycling concrete waste into cement. However, concrete producers that are not linked to ENCI are more open for change (see interview findings). This way the concrete sector is split in two groups: the ones that work in the traditional/conventional way (and are linked to the cement industry) and those that are willing to change (and are independent of the cement industry). Due to the dependence on the cement industry, the former group of concrete producers is less able or eager to change towards an increased circularity of the concrete sector.

TECHNOLOGICAL INNOVATION

Eventually primary materials become so scarce that concrete waste has to be reused in new concrete (see interview findings). The availability of concrete waste does not cover the demand for new concrete. Therefore, the use of innovations that enable a replacement of primary aggregate through concrete based recycled aggregate significantly higher than 30% is questionable. A target rate for the use of concrete based recycled aggregate in all concrete structures may prove more useful than single projects that replace primary materials completely by secondary materials.

GEOGRAPHICAL SCALE

Transport and processing of concrete waste to concrete based recycled aggregate can result in the environmental impact (CO_2 footprint) of concrete based recycled aggregate being larger than that of primary materials (see interview findings). Moreover, transportation of these heavy materials is expensive (see interview findings). Therefore, the transport distances between the different activities of the concrete chain needs to be as short as possible. Match-making between demand and supply on a local scale is essential to environmental and economic gain. This can be achieved by providing several functions in one location and through intensive cooperation between value chain actors (workshop findings). This process identifying opportunities for local and direct reuse of concrete and the following matchmaking can be facilitated by big data, as demonstrated by the Material Flow Analysis (MFA) in CINDERELA deliverable D3.1 (workshop findings).

TIME AND EFFORT

In order to develop new technologies, processes and collaborations actors of the value chain need to invest time, effort and money. However, in general, money is short when time is available, and money is available when time is short (workshop findings). Due to this trade-off, actors of the concrete chain are unable to invest as much time and effort as they would like in order to increase the circularity of the concrete chain.

4.3.3 Identification of end market

In the Netherlands there is a growing awareness of dealing with circular and more sustainable concrete. There are various techniques which are focussed on recycling the concrete waste in new concrete. Due to lack of knowledge on technical performance of the SRM-based concrete products, these products are often used in low-performance ways such as paving or as 'lego' blocks (Figure 12).

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Figure 12: Examples of use of SRM-based concrete products

4.3.4 Socio-economic and environmental context

Below in the table (Table 8) the PESTEL analysis is given in the Dutch case. Different barriers and enablers are given in the socio-economic and environmental context.

Table 8: PESTEL analysis Netherlands case

Political	• Political agenda on circular and sustainable economy (enabler) • Financial support programs to use SRMs (enabler) • Shift from taxes on materials towards taxes on labour (enabler) • Tax deduction on SRMs (enabler) • Certifications and norms to ensure materials get back in the loop (enabler) • Implement additional conditions for demolishing permit (enabler) • Prohibit of landfilling of CDW (enabler) • Public procurement (enabler/barrier) • Ownership of material flows within the construction sector (barrier) • Lack of incentive to design for EoL (barrier)
Economic	• Scarcity of natural resources in the Netherland (enabler) • Locally oriented value chains, one knows another (enabler) • Balance between material costs vs labour costs (barrier) • Mismatch between supply and demand (barrier)
Social	• Long-term strategic relationships between the supplying parties (enabler) • End-user centred (service-models) (enabler) • Integrated local residual flows (enabler) • Hubs for SRMs in the region (enabler) • Short-term thinking (barrier) • Gap between public and private organisations (barrier) • (Lack of) knowledge on sustainability and circularity (barrier) • Market is dominated by few larger organisations (barrier) • Fragmented supply chain (barrier)
Technological	• Digital design tools (enabler) • Circular design guidance (enabler) • GDSE tooling (enabler) • New technological recycling techniques (enabler) • BIM (enabler) • (lack of) alignment of scientific research of materials with the recycling industry (barrier) • Complexity of buildings (barrier) • (low) quality of recycled aggregate (barrier)
Environmental	• Holistic life cycle certifications and awards (enabler) • Awareness on sustainable building products and materials (enabler) • Transition towards a life-cycle approach (enabler) • Asset's lifespan vs sustainability (barrier)

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	• low priority of environmental aspects in building projects (barrier)
Legal	• More detailed EWC codes (enabler) • Assurance scheme for recycled concrete aggregate (enabler) • Life cycle contracts (enabler) • Regulations/commissioning to new technologies (barrier) • Strict Dutch building law (barrier)

4.3.5 Overview of potential new value chain

In the new value chain all of the concrete waste which is produced will be recycled and brought back into the concrete value chain as seen in Figure 12. From that point it can be reused in newly produced concrete and from there it can last another 10-50 years, or even longer.

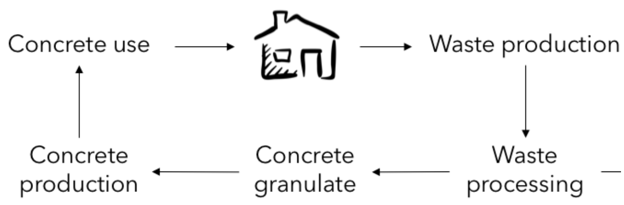

Figure 13: Potential new concrete value chain

4.4. SWOT analysis

Below the SWOT analysis is given for the Dutch concrete value chain (Table 9).

Table 9: SWOT analysis Dutch concrete value chain

Strengths	**Weaknesses**
• Frontrunners unified in 'circulaire betonketen' • Many recycling companies active in recycling concrete • Landfilling is prohibited • Much technical knowledge on product.	• Demand of total need exceeds supply of SRMs • Market is segmented • Market is locally oriented. In every region the value chain is different • Lack of proper certification for SRM-based products
Opportunities	**Threats**
• Growing (pubic) interest in green public procurement (GPP) • Various technological innovations that are being introduced to the market • Strong scientifically research on new concrete techniques with three technical universities and various technological institutes. • Agenda of the national government to become 100% circular in 2050 and to be halfway by 2030 • Stricter regulation for enforcing more recycling on a higher level	• Economic competitiveness of virgin materials is strong • Business case of a mixed recycled aggregate is better than a more pure recycled concrete aggregate • The different public organisations responsible for public procurement apply different conditions for circular concrete • Demand of SRMs for subbase as foundations is large compared to demand of SRMs in concrete products

4.5. Conclusion

4.5.1 General findings

The recycling of concrete waste has large potential for improvement, and the overview and enablers and barriers presented in this chapter can contribute to the fulfilment of this potential. However, in order to truly mitigate the adverse effects of the concrete industry, additional approaches to this waste-based recycling approach are required. Two main additional interventions that are necessary for a new value chain emerged from this research, some of which are more radical than increasing

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the rate of high value recycling.

First, the highest share of CO_2 comes from the production of cement[38]. Finding alternatives or at least mitigating the CO_2 production of cement is paramount for increasing the sustainability of concrete. Second, rethinking the demand for construction and finding a way to build less with primary raw materials would certainly reduce the adverse impacts of CO_2 demanding products such as Portland cement based materials.

4.5.2 Recommendations

In the Amsterdam Metropole region various networking platforms have organised themselves to enable to speed up projects which apply SRM-based building products. Stimulating this movement by facilitating this enhances the possibilities for recycling organisations to apply different innovative techniques.

Influencing the market can be considered as another enabler for stimulating the circular concrete value chain. This can be done in various ways:

- By the use of green public procurement
- Subsidizing different techniques and/or projects which apply SRMs in their circular concrete products
- Adjusting the tax system to lower taxes on SRMs and increasing them on virgin materials (this being as intermediate intervention until a more mature, self-reliant, SRM-based market for the circular construction is developed).

Various actors in the value chain have created strategic alliances to ensure supply and market for their SRM-based concrete building products. Other organisations have adopted these various steps of the value chain within their own organization by stretching out from step A (waste collection) to step C (product producing) and in some occasions even step D (product use).

[38] Bijleveld, M., Bergsma, G., & van Lieshout, M. (2013). Milieu-impact van betongebruik in de Nederlandse bouw. Delft: CE Delft Report.

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5. ITALIAN CASE STUDY

5.1. Introduction to the case study

The Italian case is based on the data collected in two different regions in the north of Italy: Trento and Friuli Venezia Giulia Region (FVG). It has been developed jointly by the project partners: Opencontent and Polo Tecnologico di Pordenone (POLO PN). Trento and Pordenone are small medium cities. Specifically, Trento does not have a high presence of industries in construction and demolition sector. Therefore, we decided to join the effort with Pordenone that has a more flourishing industrial environment.

5.1.1 Geographic region

Trento is an autonomous province of north-eastern Italy. It is one of the two provinces that belong to Trentino-Alto Adige/Südtirol region. Its capital is the town of Trento. The province has an area of 6208 km² and a total population of 538,604[39].

Friuli Venezia Giulia is an autonomous region of the north-eastern Italy that includes the provinces of Pordenone, Udine, Gorizia and Trieste (capital). The region has an area of 7924 km² and a population of 1,216,853 (2018).

5.1.2 Assessed waste stream

In our analysis we focused on the waste from construction and demolition (CD) sector, given the fact that for both the provinces this represents the kind of waste with the highest amount (Annex 3).

Specifically, for Trento CD sector represent a group of very significant waste in quantitative terms, corresponding to a little less than 50% of non-hazardous waste produced at the provincial level (Figure 14). Two thirds of the total CDW consist of essentially mixed main fractions of CDW (17 01 07 - mixtures of concrete, bricks, tiles and ceramics) and mixture of CDW (17 09 04 - mixed CDW), followed by the wastes coming from the excavations (17 05 04 - soil and stone), and the bituminous mixtures (17 03 02) coming from the road demolition, while homogeneous waste such as metals (17 04), plastics (17 02 03), wood (17 02 01) and glass (17 02 02) are produced and managed in small quantities.

Also, for FVG region, CD sector represents a group of very significant waste in quantitative terms, corresponding to a little less than 40% of non-hazardous waste produced at the regional level (Figure 15).

[39] Eurostat 2018: "https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/base-profile/trento"https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/base-profile/trento

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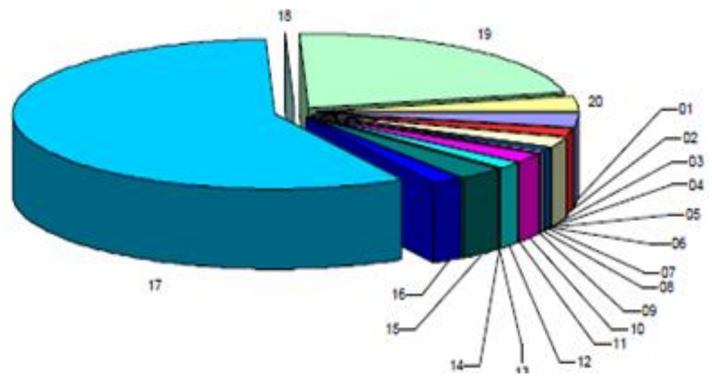
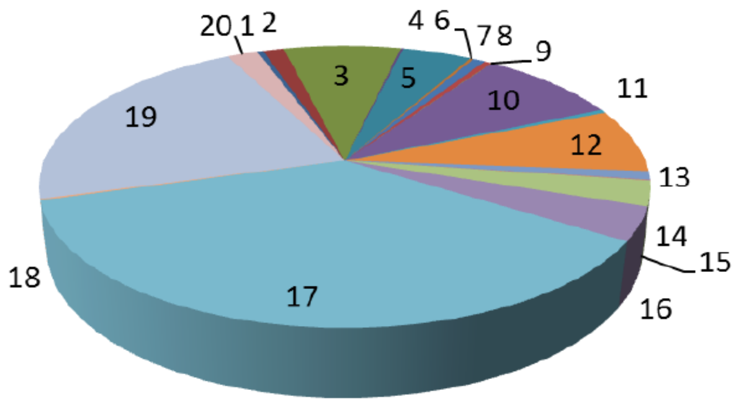


01 extraction; 02 agriculture; 03 wood and paper; 04 leathers and textiles; 05 ref. Petroleum; 06 inorg. chems; 07 organic chems; 08 from paints and enamels; 09 photo; 10 thermal; 11metal coating; 12 plastic coating; 13 oils; 14 solvents; 15 packages; 16 other waste; 17 C & D; 18 health; 19 treatment of waste; 20 urban

Figure 14: Data on waste collection in Trentino (2015)



01 extraction; 02 agriculture; 03 wood and paper; 04 leathers and textiles; 05 ref. Petroleum; 06 inorg. chems; 07 organic chems; 08 from paints and enamels; 09 photo; 10 thermal; 11metal coating; 12 plastic coating; 13 oils; 14 solvents; 15 packages; 16 other waste; **17 C & D;** 18 health; 19 treatment of waste; 20 urban

Figure 15: Data on waste collection in Friuli Venezia Giulia (2016)

5.1.3 Strategical approach

The content in this section is a combination of the information gathered by means of unstructured interviews with actors and stakeholders belonging to the two selected Italian areas. Differently from the other partners we decided to administer interviews instead of organizing focus groups. The reason behind this choice is mostly due to the fact that Opencontent and POLO PN did not have a nurtured network of stakeholders in this sector and therefore a different approach for engagement of new stakeholders was needed. In total we administered 9 interviews to actors and stakeholders (Table 10).

Table 10: Overview of interviewed actors and stakeholders

Actors	Stakeholders
• Ecoopera (Waste collector and treater)	• Provincial agency for environment protection

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Actors	Stakeholders
• Moretto srl – Multiservizi (waste collector, waste treater, product producer) • Zanini Oliviero srl (waste collector, waste treater, product producer) • Logica srl (waste collector, waste treater, product producer) • Lorenzon F.lli Srl (waste collector, waste treater, product producer)	(Trentino) • Service for environmental authorizations and assessment (Trentino) • Head of Trentino mining consortium • Environmental regional agency of Friuli Venezia Giulia • Municipality of Pordenone • National Association of Building Constructors (Friuli Venezia Giulia)

5.2. Current value chain

5.2.1 Material flow

CDW includes all the waste that derives from the construction, maintenance, renovation and demolition of buildings and transport infrastructures. Most of the waste derives from the demolition activity, secondly from maintenance and construction activities. The high costs of the demolition activity and the crisis in the building sector are leading to an increase in the maintenance and restructuring activity compared to the demolition activity[40]. The composition of waste from CD is very variable, due to the different origin of the waste, different local types of buildings and construction techniques, and the local availability of raw materials and building materials. The demolition activity is that which generates the most homogeneous waste, with a prevalence of concrete and brick compared to the metallic and light fraction (wood, paper, plastic, etc.).

In the Province of Trento, the management of the overall recycled CDW materials is close to one million cubic meters. The dominant share, around 80%, is made up of mixed CDW used in construction and road construction works for fillings, embankments and foundations. Modest, less than 10%, is used to produce other products (for example aggregates for concretes and for asphalt).

These products must meet the requirements provided by current regulations (i.e. Construction Product Regulation – CPR[41]) with regards to the technical and environmental suitability, based on the type of product and future utilization. For the production and usage of recycled aggregates the Autonomous Province of Trento has approved specific technical and environmental standards described and collected in the Provincial Resolution by the Provincial Council n. 1333 24/06/2011 'Technical and environmental regulations for the production of recycled materials and their usage in the construction and maintenance of building works, roads and environmental recoveries'[42].

5.2.2 Stakeholders and their interests

Currently, main stakeholders contributing to the value chain of CDW are policy makers and companies involved in the building sector. Specifically, stakeholders are subjects that may affect or be affected by the CD sector, whereas actors are subjects that derive a direct interest and are actively involved in the CD value chain such as companies dealing with production, collection and treatment of CDW. Based on this description we can outline the following:

Stakeholders:

- The Provincial Agency for Environmental Protection plays a crucial role in the definition of

[40] https://ec.europa.eu/docsroom/documents/33521/attachments/2/translations/en/renditions/native
[41] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011R0305&from=EN
[42] https://cet-servizi.it/wp-content/uploads/2018/09/Allegato-B-Norme-tecniche-e-ambientali-per-la-produzione-dei-materiali-riciclati.pdf

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policies since manages data about the authorizations issued and the waste (delivery).

- The Trentino Mining Consortium represents the interests of companies involved in the extraction and treatment of materials for the construction sector.
- Environmental agency of FVG has expressed the will to report the impact points identified in the study in the round table dedicated to the definition of the regional strategy for sustainable development.
- The Municipality of Pordenone has expressed the interest to stimulate the FVG Region to set up operational protocols on how to apply the existing legislation on GPP and minimum environmental criteria (CAM) regarding construction.

Actors:

- Landfill managers: they represent the traditional option to waste management and they have been constantly reduced in numbers.
- Excavating companies: they are responsible for production of virgin material.
- Large, medium-sized and small construction companies that produce waste in the construction and renovation of buildings.
- Public utilities companies that generate demolition waste by carrying out infrastructure maintenance activities.
- Transporting companies: they are involved by waste producers for waste management but deal exclusively with transport to landfills or recycling plants not owned by them.
- Companies performing demolition activities, which also manage the stages of the supply chain related to the transport of waste to their recycling plants, waste recycling and production of new products.
- Notifying Bodies (Certifiers): they release the certification to the production plant guaranteeing the quality of the recycled products.
- Final users of the products: currently they are mostly construction companies and public bodies such as municipalities.

From our interviews the economic aspect emerged as the main driver for the activities of actors involved in CD sector.

5.2.3 Activity and value creation

The three main phases in the development of recycled CDW materials are:

1. Demolition:
    a. Traditional demolition: requires minimum planning of the intervention, minimum organization of the site and does not require the use of high professionalism. It allows reducing the time and costs of the construction site but produces too heterogeneous waste that compromises the possibility of recycling waste with satisfactory levels of quality and costs.
    b. Selective demolition: this is a disassembly process that takes place in reverse mode with respect to construction operations. It allows to immediately separate the homogeneous fractions of waste, increasing the possibility of recycling the waste generated by the yard. Selective demolition requires more time and costs than traditional demolition as it is necessary to plan the intervention, organize the site and resort to different skills.

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2. Treatment: the main phases that characterize a process of treatment and recovery of CDW can be divided into:
    a. Crushing, aimed at obtaining a reduction in the size of the waste to make it suitable for final use.
    b. Separation, aimed at eliminating unwanted materials in the final product. In general, the recycling plant basically divides the incoming material into three flows
        i. The mineral material that can be used again (bricks, concrete);
        ii. The light fraction (paper, plastic, wood, impurities, etc.);
        iii. The metallic fraction.
    c. Screening, aimed at separating the grains according to their size to obtain homogeneous grain size fractions. The different fractions will give rise to products with different uses. The process of treatment may take place in-situ (mobile recycling and production plant at the demolishing site) or off-site (stationary recycling and production plant).
3. Product production: the treatment and recycling process allows the creation of SRM for construction products that:
    a. May be placed on the market as products as they are – recycled aggregates.
    b. Or be used to make mixes with virgin materials or other secondary raw materials (even those not related to CDW, for example the foundry sand with EWC 10 09 08) - mixed aggregates.

Aggregates as construction products may further be used for production of concrete, for unbound and hydraulically bound materials for use in civil engineering work and road construction, for bituminous mixtures, roads and traffic areas etc. Before being placed on the market, the products must pass two other phases required by CPR[43]:

- Tests for assessing product performance: The use of recycled aggregates is also subject to verification of conformity regarding their intended use. The analytical laboratory test is aimed at verifying also the impact on the environment of the produced recycled aggregate and therefore its environmental compatibility. It must be verified that the impurities present (e.g. wood, glass, plastic) and the release of potentially polluting substances are below the limits set by the national legislation according to specific uses of the product.
- CE marking: The Construction Products Regulation (CPR 305/2011 EEC) and the related decrees predict that natural, recycled and manufactured aggregates, to be allowed to enter the market, must be subject to the procedures of CE marking. The Producer must plan and implement material checks during the manufacturing process and on the finished product or with other words, the producer must establish procedures for so called 'Assessment and Verification of Constancy of Performance - AVCP', which can also include third party verifier or so-called notified body.

The main End Market for recycled aggregates are 1) recycled aggregates for the realization of foundations and foundation layers of transport infrastructures, civil and industrial yards and 2) recycled aggregates used for making concretes.

The activities with the greatest added value in the supply chain are those that guarantee the quality of the recycled aggregate, which consists in the product's ability to have the same performance as the product obtained with virgin materials and to be competitive on the market. The quality of the

[43] http://ec.europa.eu/DocsRoom/documents?tags=ce-guide

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recycled aggregate is lowered if the mix of materials used is too heterogeneous. In particular, if there are materials other than mineral fractions such as iron, plastic, wood, plaster present. Therefore, an activity with a high added value is the separation of the stone material from the light fraction and from the metallic fraction. This activity is carried out:

- During the demolition phase: it has to be noted that the more the waste is divided into homogeneous fractions, at the time of production, the more it is possible to increase the quantity and quality of the materials to be sent to the respective recycling processes. The waste produced during traditional demolition consists of a variety of materials among which there are also unwanted fractions (e.g. paper, plastic and wood, plaster, etc.), which impoverish the quality of the recycled aggregate. On the one hand, CDW produced by selective demolition saves on disposal or treatment costs (they increase considerably with the heterogeneity and presence of pollutants), and on the other hand selective demolishing guarantees that the recycled material has an adequate level of quality to replace virgin materials.
- During the treatment phase in the recovery plant: the possibility of separating the stone material from the metal and light fractions depends on the technology of the treatment plant and on the homogeneity of the incoming material.

Another activity with a high added value is the creation of products where the recycled aggregate obtained from CDW is mixed with other materials, virgin or other SRM different from those obtained from CDW. Private product users currently choose recycled aggregates for the lowest price for the same performance, compared to quarried aggregates. The risk is that in order to keep prices low, companies that produce products based on SRM:

- Do not carry out the selective demolition (more expensive than the traditional one), obtaining an excessively heterogeneous mix of waste.
- Produce products obtained with a mix of recycled aggregates and other cheaper SRMs not originating from CDW for example furnace slag and foundry moulds.

5.3. Potential new value chain

5.3.1 Technological developments

The selective demolition can contribute to gain a higher quality of the recycled aggregates because it allows to immediately separate the homogeneous fractions of waste, increasing the possibility of recycling the waste generated by the construction site. The presence of mixed waste means that the de-construction processes of the works, in general, do not follow the rules of selective demolition. The waste production phase is particularly critical for recycled materials, in fact it is difficult to obtain recycled products with high performance characteristics from the processing of non-homogeneous materials in the constituent matrices (stone material, concrete, brick, plaster and bituminous mixtures). Selective demolition requires more time and costs than traditional demolition as it is necessary to plan the intervention in more details, organize the site and resort to different skills. For this reason it has not been applied in a large scale.

In the Province of Trento the treatment of CDW is mainly carried out at fixed plants. On average, these plants handle 67% of the CDW coming from the areas where the same plant is located, with considerable reduction of transfers. Overall, only 8% of waste is treated in mobile plants directly at construction sites. Increasing this way of treatment and recovery would allow for a further reduction in transport and air pollution.

In FVG region, in order to use a mobile plant it is necessary to request an authorization from the FVG Region and the regional environmental agency similarly as for stationary recycling plants. Transport costs are reduced, but administrative practice requires costs and times that are convenient to support only for large construction sites.

5.3.2 Determination of potential impact points in value chain

Enablers in the current value chain are:

- Competitive price of recycled aggregates, on average 50% less than the virgin aggregates.
- The same procedure for CE marking of recycled aggregates as for virgin aggregates contributed to draw attention on the performance characteristics.
- Barriers in the current value chain are:
- Belief by private professionals (designers and construction managers) that performance characteristics of the SRM are poorer than those of virgin materials.
- Scarce attention given by the recycling companies to the potential added value that can derive from recycled aggregate.
- Low intervention from the public authorities which do not push much forward the usage of recycled aggregate.
- Distrust of public and private contracting stations due to the lack of clear rules.

5.3.3 Identification of end market

Here follow some market opportunities for recycled materials:

- The supply of recycled aggregates for public utility companies that carry out the maintenance of gas, water and electricity infrastructures as bedding material for pipes and cables.
- The supply of recycled aggregates to make landfill cappings.
- Public constructions once the law related to the GPP will be applied.
- Development of decorative products (Figure 16) to be used for containment or paving of private and public spaces.

Figure 16: Usage of recycled materials for decorative products

5.3.4 Socio-economic and environmental context

Below in the table (Table 11) the PESTEL analysis is given in the Italian case. Different barriers and enablers are given in the socio-economic and environmental context.

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Table 11: PESTEL analysis Italian case

Political	Despite the competitive price of recycled aggregates, on average 50% less than the natural aggregates, the use of recycled materials continues to assist a moment of serious difficulty due to the distrust of public and private contracting stations to the lack of clear rules. (barrier) The Autonomous Province of Trento intended to encourage the recovery of CDW, making available the same guidelines and technical standards for the production of recycled aggregates to be allocated to the construction of building and road works in replacement of natural aggregates. It approved specific technical standards applicable to recycled aggregates, which made it possible to give the necessary certainties and therefore greater market opportunities for producers. (enabler) Furthermore, the province promoted GPP for the materials for building, road and recovery works, which have been included among the commodities for which the Province commits to buy 'green'. (enabler) Nevertheless, there is a fundamental related issue, i.e. a low level of control on the application of the regulation. (barrier)
Economic	Waste management is a private activity therefore companies act from a mere economic perspective. This means that waste managers have paid much more attention to satisfying construction companies by offering an easy place to confer their waste, than investing in the recycling process, by for example forcing construction companies to bring in already selected material. The result is low prices against low quality of the product and a very little amount of investment in added-value activities. (barrier)
Social	One of the major difficulties that nowadays invalidate use of recycled materials in the construction sector in studied areas is the belief by private professionals (designers and construction managers) that performance characteristics of the secondary raw materials are poorer than those of virgin materials. This belief is, in part, based on a scarce attention given by the recycling companies in this sector to the potential added value that can derive from recycled aggregates. (barrier) Furthermore, there is not a strong intervention from the public authorities which do not push forward to the usage of recycled aggregates. (barrier) Finally, there are also bad examples of usage of SRM-based aggregates in public works that have caused structural failure (e.g. use of slag aggregate with high expansion coefficient). (barrier)
Technological	The industrial production processes are today supported by technologies that allow to get a wide range of recycled products, based on the characteristics that the outgoing materials must possess in order to be regularly employed. (enabler) The production lines are typically based on the sequence of crushing and selection machines installed with reference to the types of materials produced. Treatment plants are categorized based on their mobility degree, which can be fixed or mobile, stable or itinerant. (neutral)
Environmental	The waste production phase is particularly critical for recycled aggregates, in fact it is difficult to obtain recycled aggregates with high levels of technical performative characteristics from the processing of non-homogeneous materials in the constituent matrices (stone material, concrete, brick, plaster and bituminous conglomerate). This is

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	due to the de-construction processes that in general, do not follow the rules of the selective demolition. (barrier)
Legal	Production processes are regulated by a particularly articulated legislation that includes the characterization of waste constituents, treatment procedures and the qualification of recycled products. As regards the types of recycled products, the classification according to their destination in mainly three categories: products for works of construction and road construction, constituent materials for the production of other products and products for environmental recovery works. Indeed, the products must comply with the standards that define the technical requirements, for suitability for use (CE marking) and environmental requirements. With the introduction of the CE marking for building materials and publication of harmonized standards on aggregates, the traditional distinction of the aggregates according to their nature (virgin aggregates versus recycled and manufactured aggregates) has been overcome, posing the focus on the actual performance characteristics of the material. (enabler) The legislation, however, fails to guarantee the quality of the final product because it does not set stringent standards regarding the composition of the products, but it requires compliance with environmental limits and technical performance standards only at the time of the release test. (barrier)

5.3.5 Overview of potential new value chain

Currently, there are many small plants either specialized in treatment or recovery of waste spread on the territory. This leads to a scattering of resources, increased concurrency and subsequent little quality in the final products. The new value chain should push towards the creation of agglomeration of plants, which can deal with both treatment and recovery of waste. Such 'multi-functional' plants will contribute to a more rationalized service and guarantee a more accurate management of the waste. Furthermore, being a unique waste management point, they will decrease the amount of transfers of materials from one place to another, reducing air pollution. In addition to this, the usage of smaller and mobile plants should be endorsed in order to optimize the process of selective demolition directly at the construction site. This will ensure a good quality of the waste already from the source, required in order to obtain quality recycled aggregates. Therefore, value chain should be focused on promoting investments in added-value activities related firstly with selective demolition. Secondly, new collaboration should be encouraged between constructors and demolition companies. Finally, public actors need to acquire technical competences to be able to assess public procurements and apply the regulations correctly.

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5.4. SWOT analysis

Below the SWOT analysis is given for the Italian value chain (Table 12).

Table 12: SWOT analysis Italian case

Strengths	Weaknesses
• Good quality of the recycled material. • High quantity of materials. • Treatment plants respecting ecological standards. • GPP recommendations for using recycled materials. • In general, lower prices of recycled aggregate in comparison with virgin aggregate.	• No effective incentives for using recycled aggregates. • High level of bureaucracy. • Certification of recycled aggregate strictly applied only to GPP. • Less in-situ recycling.
Opportunities	**Threats**
• Circular economy regulation. • Digitalization of procedures.	• Building and construction sector is steady.

5.5. Conclusion

5.5.1 General findings

There is a general trend in the regulations for CD sector that aims at giving priority to the recovery and requalification of inert materials while reducing landfill disposal activities. For both Trento and Pordenone mixed CDW represents a high percentage of the total CDW managed in the treatment plants, showing that much still needs to be done in order to promote ecological awareness among main actors of the value chain. The main driver is still economic driven and little impact has also the certifications which are required only for the GPP. Furthermore, for GPP the mandatory amount of recycled material is relatively small, having to represent up to 30% of the total cost of the work.

The market in this sector is not as articulate as we expected. In terms of actors, for example, it was difficult to find specific actors to link to the 4 categories we outlined in this Task. We have in fact noticed that companies are not specialized in one single category but usually who deals with construction is also the user of products, and who deals with treatment is also the producer of the products. Therefore, based on our experience we can redefine the categories grouping them in 2: constructors (including actors A & D) and treaters (including actors B & C).

Finally, the increased knowledge of recycled products and their technical and environmental characteristics contributes to give priority to waste recycling, focusing on the quality of recycled products both from a technical and environmental point of view, thus reducing the amount of material to be allocated to the disposal. More incentives should be promoted by institutional level for certifying and assessing product's compliance with technical and environmental requirements and consequently encouraging their acceptance both for the construction of public and private works.

5.5.2 Recommendations

Based on our research we recommend the following:

- Promoting selective demolition and selection of the generated waste: quantitative reduction of the mixed waste destined to landfills and the increase in the production of high-performance recycled materials are possible if the demolition processes are analysed, designed and implemented with the criteria of the selection of the generated waste. Therefore, the design of a building or infrastructure must also include demolition activities. Furthermore, selective demolition could be incentivized by streamlining bureaucratic procedures.

- Gathering metric calculation of the recycled products used in the building: the efficiency level of waste management in the construction industry is measured by determining the recycling rate that allows assessment of compliance with EU and national requirements. In addition to the overall analysis of the aggregated data it is necessary to foresee the measure for each intervention be it a new construction and/or maintenance one. The executive project should therefore also include a metric calculation of the waste and recycled products used in the work.
- Need for a greater knowledge about the recycled aggregates and their technical characteristics: the origin of recycled aggregates from 'waste' leads the final consumer to think of a poor-quality product, although it is technically proven that, from a performance standpoint, there is no difference between virgin-based and recycled products. Although the CE marking itself constitutes a first important element to remove the recycled aggregates from the idea of 'waste', it is possible to affirm that this objective has not yet been reached.
- Need for the necessary data about the quantity and quality: the essential condition for correctly setting up a waste management policy is to know the actual quantities involved. The extreme difficulty in the census of data relating to the entire supply chain that follows the path of waste, from their production to reuse, does not allow to know the dimensions of the problems and implement, in real time, the necessary improvement actions. Therefore, it is necessary to implement a continuous monitoring of the sector that allows having the necessary data to evaluate its development.
- Need for a training of the civil servants and policy makers about new regulations and treatment procedures. This will ensure a better definition and application of new regulations about CDW management.

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6. POLISH CASE STUDY

6.1. Introduction to the case study

6.1.1 Geographic region

Katowice is the capital of the Silesian-Zagłębie Metropolis. The metropolis consists of 41 municipalities, mainly urban, with a population of over 2.5 million inhabitants. As a project area, we have selected a group of 11 municipalities located around Katowice, in Upper Silesia, with an area of 1650 km^2, in which nearly 1.73 million people live. In this selected project area is generated annually 3.1 million tonnes of waste.

The project area is shown in Figure 17 below (11 municipalities marked with a dark red colour) surrounded by yellow line.

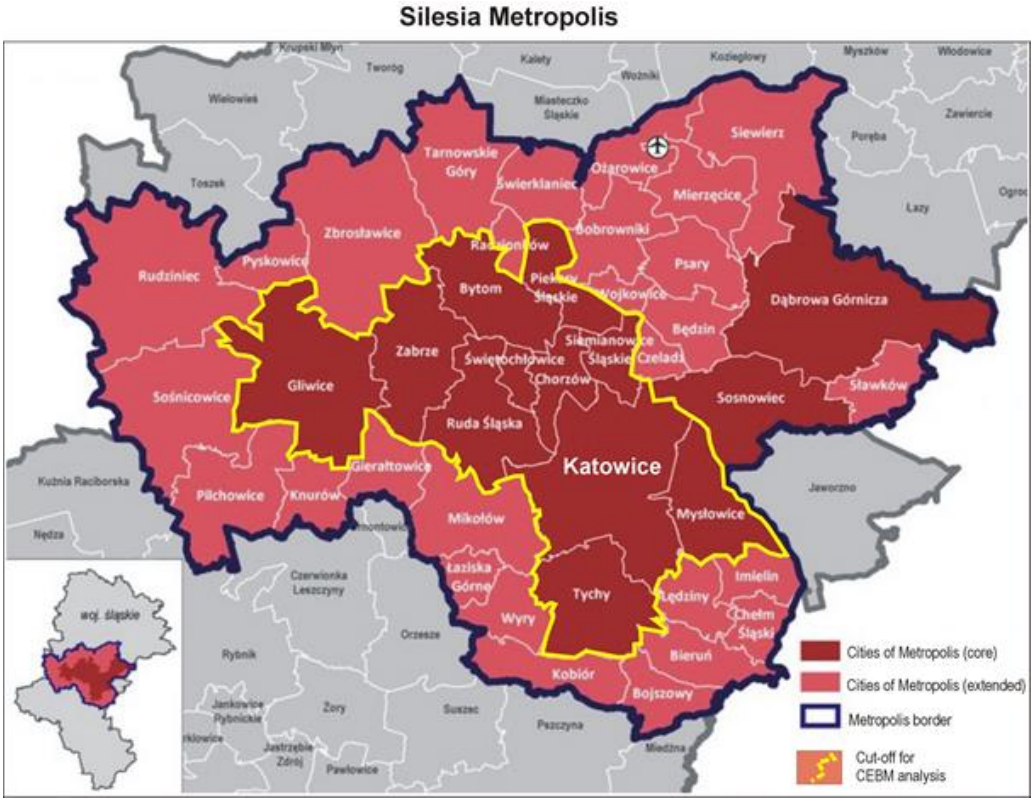

Figure 17: Katowice case study area

6.1.2 Assessed waste stream

Amounts of waste according to their types generated in the project area, from the EWC code list adopted in the project were analysed. Table 13 presents stream of most significant wastes in range of annual amount of mass generated (14 of waste codes).

Table 13: Waste quantities in the Katowice case study

EWC code	EWC name	Weight [tonnes]
01 01 02	Wastes from mineral non-metalliferous excavation	1,006,522
19 12 12	Other wastes (including mixtures of materials) from mechanical treatment of wastes other than those mentioned in 19 12 11	436,952

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EWC code	EWC name	Weight [tonnes]
10 02 01	Wastes from the processing of slag	254,197
17 05 04	Soil and stones other than those mentioned in 17 05 03	188,297
10 01 24	Sands from fluidised beds	179,362
12 01 01	Ferrous metal filings and turnings	176,822
19 08 05	Sludges from treatment of urban waste water	137,400
10 01 01	Bottom ash, slag and boiler dust (excluding boiler dust mentioned in 10 01 04)	110,197
19 05 03	Off-specification compost	94,379
19 12 05	Glass	90,136
17 01 01	Concrete	56,773
19 12 09	Minerals (for example sand, stones)	50,425
17 01 07	Mixtures of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06	48,219
17 01 02	Bricks	48,134
	Total (of 14 codes)	***2,877,818***
	Total amount of considered waste	**3,182.817**

The 14 waste streams from this list represent 90% of the mass of waste produced (Table 14).

Table 14: Assessment of recovery potential of waste streams for applications in construction in Katowice region

EWC code	EWC name / Assessment	Percent	Material part of the waste
01 01 02	Wastes from mineral non-metalliferous excavation	31.62	Mining wastes are a mixture of rock waste from layers that accompany coal seams and from layers of these seams. The coal waste consists of clays, clay shales, siltstones, coal shales, sandstones, sporadically conglomerates, and crumbs of coal. They are mainly used for leveling brownfields and open pitches, less frequently used in the construction of foundation layers, shaft cores and slopes. Old mining dumps were often self-igniting and material from a blown up so called 'red stone' is willingly used in road and water construction.
19 12 12	Other wastes (including mixtures of materials) from mechanical treatment of wastes other than those mentioned in 19 12 11	13.73	Material with a very diverse composition. By considerable means, it can be used to create artificial soil suitable for the reclamation of landfills and brownfield sites, or to extract fragments of minerals and refuse waste, but their separation from organic contaminants, plastics and paper is difficult.
10 02 01	Wastes from the processing of slag	7.99	Slag from metallurgical processes is an alloy containing ore impurities, fluxes and some amount of metal oxides, residues from coal combustion, coke, is a mass containing mainly enamel sintered with mineral

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EWC code	EWC name / Assessment	Percent	Material part of the waste
			components. It is used for the construction of leveling and stabilizing layers, mortar and concrete components, less often as a thermal or sound insulation layer.
17 05 04	Soil and stones other than those mentioned in 17 05 03	5.92	Earth or stones coming from construction works, most often used at the investment site or near surroundings when arranging areas around the investment.
10 01 24	Sands from fluidised beds	5.64	A fine-grained mixture of silicon sands with the participation of fuel combustion products, eagerly used in the production of building materials.
12 01 01	Ferrous metal filings and turnings	5.56	Scrap, usually steel with low usefulness for construction purposes.
19 08 05	Sludge from treatment of urban waste water	4.32	Mostly it may be used as an addition to artificial grounds, but on the condition that they meet the standards of cleanliness and they are thoroughly mixed with inert material.
10 01 01	Bottom ash, slag and boiler dust (excluding boiler dust mentioned in 10 01 04)	3.46	Very finely divided mineral materials, mainly enamel and sintered fuel residues, very often used in the building materials industry - in the production of cement, masonry and plaster mortars and self-leveling masses.
19 05 03	Off-specification compost	2.97	In the case of the possibility of separating mineral parts - sands and stones it can be used for reclamation mixtures, however, due to the costs of such operations and the availability of other materials rather unsuitable in construction.
19 12 05	Glass	2.83	Glass granules can be an addition to aggregates and concretes, but they are usually recycled.
17 01 01	Concrete	1.78	Crushed concrete is a highly sought as replacement for virgin aggregates in road construction. In small architecture, it can also be reused in the production of concrete.
19 12 09	Minerals (for example sand, stones)	1.58	In the case of unpolluted organic fraction and other municipal waste, such sands and stones can be used for reclamation mixtures, but are usually heavily contaminated.
17 01 07	Mixtures of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06	1.51	Similarly to crushed concrete, this material may be a substitute for aggregates in construction, however, it requires segregation and cleaning of undesirable components. It can usually be used for leveling.
17 01 02	Bricks	1.51	Brick aggregate can be a substitute for mineral aggregates in concrete mixes.

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In the case of the majority of waste found in the case area Katowice, designated as a source of materials for construction from recovery, it was stated that it could be used. In the case of negatively evaluated waste, the main reason for such an assessment is the content of the organic fraction (biomass) and mixing with undesirable components that are difficult to separate.

Mining wastes account for over 30% of the mass stream of waste generated annually in the Katowice area of the project. They create the largest surface environmental threats, and their resources are huge - hundreds of millions of tonnes. Therefore, possibilities of recovery of this waste stream was analysed for the purpose of this case study, and key actors from this scope of interests were invited to the workshop meeting.

6.1.3 Strategical approach

The strategic approach consists of desktop work based on IETU experiences and engagement with relevant stakeholders through workshop.

The introductory part of the workshop presents a summary of the important characteristics of extractive waste, which are divided into several material groups that have different uses:

- Mining wastes: rock material mined during mining preparatory works, making new coal deposits available. These wastes are mostly large rock fragments, partly left at the bottom and located in excavations, with a grain composition in the range of 0-500 mm.
- Tailings waste: Barrens lying mainly in the floor and ceiling of coal seams, also overgrowth, which during exploitation of coal seams get into the spoil and together with it are extracted to the surface, and then separated in the processing plant. They are divided into: coarse (200-20 mm), fine (20-1 mm), flotation and other muds (less than 1 mm).

In the total weight of these wastes, the share of mining waste is less than 20%, and processing (tailing waste) is over 80%. Their considerable resources are found in active heaps, dumping grounds, settlers, abandoned or reclaimed facilities.

Some collected mining waste is in a blown form - the so-called ‘red stone’, which resources are estimated at approx. 25-30 million tonnes, but which is less than 5% of deposited coal mining waste.

The basic directions of use of recycled waste rock and mining waste are:

- Reclamation of degraded areas.
- Roads.
- Production of aggregates.
- Production of full-value energy products.
- Liquidation works in hard coal mines and backfilling of excavations.

The analysis of these developmental trends began with a discussion of a group of specialists present at the workshop on the selection of currently existing material chains and promising concepts of new material chains, which should be subjected to a detailed assessment of the value chain.

The Table 15 describes the participants of the workshop and discussion.

Table 15: List of participants in the workshop

Stakeholder name	Main activity	Activity description
Polska Grupa Górnicza S.A. *Polish Mining Group*	Hard coal exploitation maintenance Mineral waste	Polska Grupa Górnicza (PGG) is a key partner in building the energy security of Poland. In response to the expectations of cheap and high

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Stakeholder name	Main activity	Activity description
	processor Product (aggregates) manufacturer	quality energy, the Company strives for raising the effectiveness and optimizing the production costs, maintaining high standards of environment protection, as well as health and safety issues. PGG has the greatest hard coal resources and extraction potential in the European Union.
Polska Grupa Górnicza S.A. Biuro innowacji i implementacji nowych technologii *Polish Mining Group* *Bureau of innovation and implementation of new technologies*	Hard coal exploitation maintenance Mineral waste processor Product (aggregates) manufacturer	PGG unit responsible for development and implementation of new, innovative technologies for coal and gangue treatment
HALDEX S.A.	Hard coal recovery from mining waste. Mineral waste processor Product (aggregates) manufacturer	The main activity of Haldex S.A. is the recovery of valuable raw materials from material coming from current mining activity, as well as mining waste dump sites re-exploitation. They operating waste-free processing installations, where certified products for reuse are manufactured. The company exists since 1959.
Zakład Przerobu Odpadów Wydobywczych CTL Haldex S.A *Waste Extraction Processing Plant CTL Haldex S.A.*	Hard coal recovery from mining waste. Mineral waste processor Product (aggregates) manufacturer	Activity of CTL Haldex S.A. focuses on the acquisition and technological processing of industrial waste in order to recover or valuable raw materials enrichment. Company deal with technological recovery of hard coal from coal-mining waste produced from the direct production of hard coal mines, processing plants and raw materials found in dumps. The company exists since 2013.
AGC Bytom Sp. z o.o.	Mineral waste processor Product (aggregates) manufacturer Building company	The AGC company conducts activities in the field of construction works, land reclamation and production of aggregates from mineral waste. One of the flagship investments is the design, construction and maintenance of the Armada Golf Club, made with the SRM-based aggregates from hard coal processing.
SEGO Sp. z o.o.	MSW treatment plant operator SRM-based soil substitute processor	SEGO Sp. z o.o operating the municipal solid waste treatment plant. Within waste collection system separate receiving of ashes from households is introduced. Based on ashes, sewage sludge and compost, soil

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Stakeholder name	Main activity	Activity description
		substitute for reclamation purposes is manufactured. It has product status, and is commonly used for brownfields reclamation and revitalization
IMiBiGS Instytut Mechanizacji Budownictwa i Górnictwa Skalnego (Warszawa) Oddział Zamiejscowy w Katowicach *IMiBiGS Katowice Institute of Mechanized Construction and Rock Mining (Warsaw)* *Branch Office in Katowice*	Scientific Institute R&D Certification body	It is a state research and development body operating in the field of mechanized construction, industrial automation and the construction industry, mechanical engineering and safety, construction equipment and rock mining machinery, waste management and recycling, information science, technical and economic information. Main office located in Warsaw. Katowice division include: Center for Low Energy Building Technologies and Environmental Management, Waste Utilization and Environmental Management, Workshop of Thermo and Hydroinsulating Materials, Construction Materials Laboratory 'IZOLACJA', Certification Bureau and Technical Assessment Section
Urząd Marszałkowski Województwa Śląskiego, Katowice *The Marshal Office of the Silesian Voivodeship,* *Katowice*	Local government Regulator body Managing the waste database	The Marshal Office of the Silesian Voivodeship coordinates waste management issues in regional scale. Operator of waste management database. Responsible body for preparation and implementation of waste management plan for Silesia Voivodship (recent plan were developed under cooperation with IETU and IMiBiGS)

As a result of the discussion a list of currently used mining waste recovery methods was created. It covers the product and recovery outside installations.

The products are:

- Coal, mud granules;
- Aggregates:
  - Crushed stone for the ceramic and cement industry,
  - Crushed stone for engineering works,
  - Crushed stone for filling;
- Lightweight aggregate;
- Other mixtures based on muds, tailings and crushed stone - artificial soils, reclamation media, additives for ceramic products.

Recovery outside installations consists in:

- Use in road engineering,

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- Technical reclamation of degraded areas and in hydrotechnical construction,
- Use for the disposal of shafts and voids after exploitation of seams,
- The use of post-flotation wastes in caulking,
- Flotation waste management in dense backfills.

In the next stage of the discussion, a list of the most widely used and innovative applications of mining waste possible to be used in the construction industry was selected. This included:

- Light aggregate for concretes,
- Artificial soils and reclamation grounds,
- Broken stone for the ceramic and cement industry.

For value chain analyses the following materials were selected:

- Aggregate for engineering works (road engineering, water engineering, replacement of land for development) - as a representative of current value chain,
- Slimming additive for ceramic masses - as a new recovery direction with a different valuation approach - as a representative of potential new value chain.

In further work, we used the general diagram of value chain analyses as depicted in the Figure 18.

Aggregates (crushed stone) for construction industry value chain

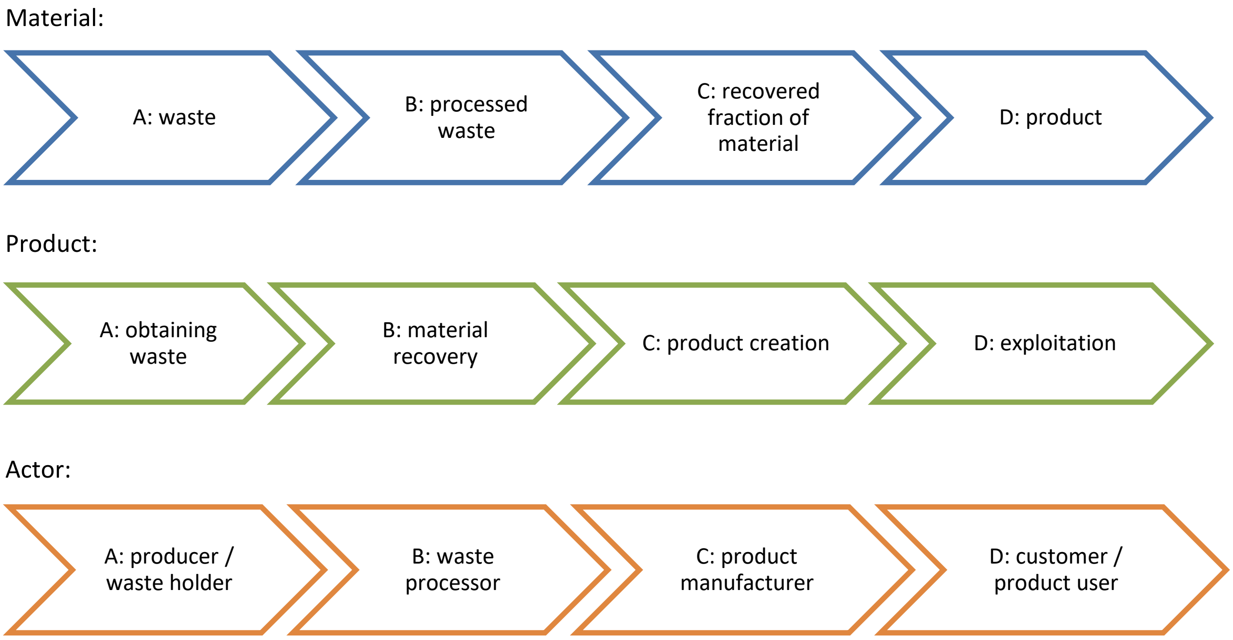

Figure 18: Diagram for Katowice value chain analysis

6.2. Current value chain

6.2.1 Material flow

Aggregates for the construction industry

Topic of the discussion was concerning the aggregates and materials for the foundation, use in road engineering and for the preparation of sites for building construction (e.g. warehouses, depots,

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covered markets etc.). Figure 19 displays scheme of current value chain of aggregates production for construction industry. Table 16 presents the PESTEL analysis.

Aggregates (crushed stone) for construction industry value chain

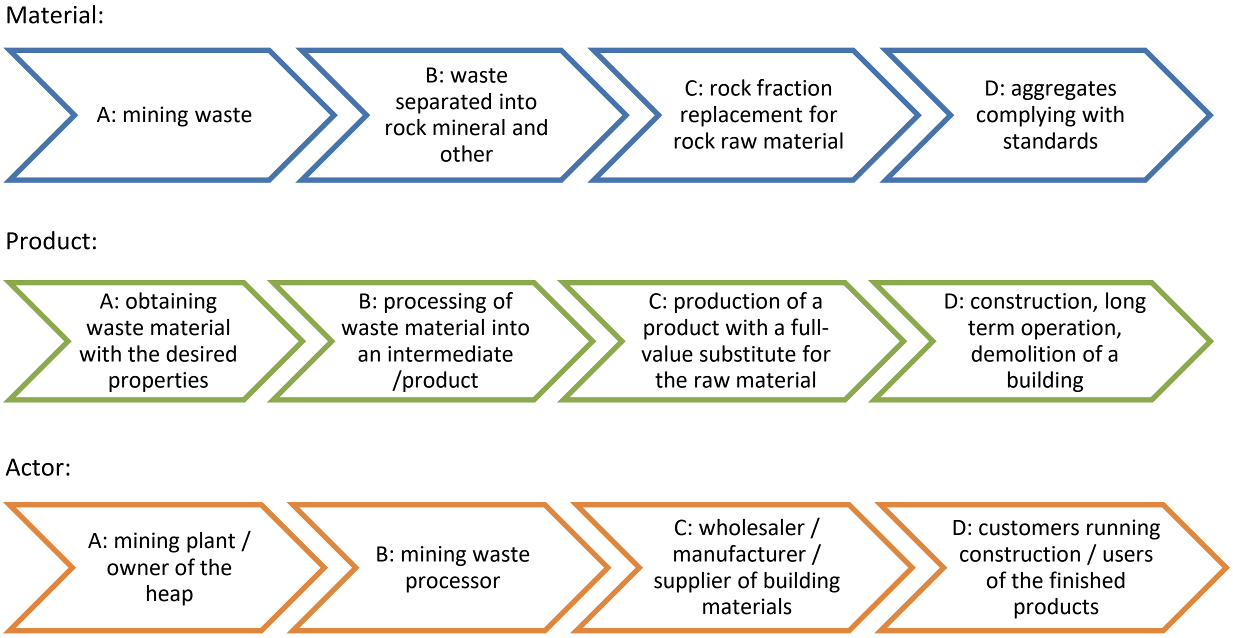

Figure 19: Aggregates for construction industry value chain.

Table 16: PESTEL analysis Katowice current value chain

Political	• Lack of investor confidence in the scope of unexpected changes in the law, and the scope of these changes. (barrier) • 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). (barrier or enabler) • In the planning documents in the field of waste management, there are provisions regarding the increase of waste recycling, re-use, etc. (enabler) • In practice, they are not implemented (local authorities should be aware when issuing decisions, or implementation of public procurement). (barrier) • Tax policy - lack of clear concessions that would support the economic use of products based on waste. (barrier) • Implementation of public procurement procedures in the use of locally available raw materials and materials from recycling, or allowing for the avoidance of mineral waste - in the case of large investments in the field of road construction, carried out for the benefit of the State Treasury and other state-owned entities. (enabler)
Economic	• The use of derivative aggregates from gangue treatment, reduces the investment costs of road construction. (enabler) • The use of these aggregates in land preparing for further cubature construction investment (service halls/ depots, warehouses, logistic centres) is a potential large market. (enabler) • The lack of issued standards for the use of aggregates in building construction reduces the attractiveness of revitalized areas for potential investors, or causes them to give up investments. This is mainly a problem for the entry of foreign investors. (barrier)

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	• On the one hand - the origin of the material causes a lack of confidence in its use, on the other there is a deficit of building materials whose requirements the aggregate meets (if it is well prepared and on the basis of a rock material with suitable properties). (barrier) • Problems with current aggregate sales (logistic or quality issues; transport costs) are an obstruction for launching of new processing plants. (barrier) • The costs of selective enrichment of mineral aggregates in the hard coal processing to obtain raw material of very good quality (e.g. pure sandstone) are high and exceed the market value of such raw material or raw material based aggregates. (barrier) • Advanced enrichment and separation of waste rock would be profitable only if the product made on the basis of separated mineral waste can be sold at a good price. (barrier or enabler)
Social	• Implementation of the investment involving the use of waste rocks from hard coal mining, or made on their base derivative aggregate is often a discomfort for the entrepreneur and the additional workload due to the need to persuade a number of stakeholders about the fact that the materials used are good quality and safe (the authorities, investors, society). The commonly used word 'waste' is strongly associated with this material. (barrier) • Despite the certified technical approvals for aggregates made of coal accompanying rocks, there is limited investor confidence for this material. (barrier) • Needs for popularization, promotion of activities and implementation of case studies of products use, in order to build trust and convince potential of investors that secondary raw materials meet quality requirements and their use is safe (health and safety, environment). (potential)
Technological	• There are two potential sources of raw material for SRM-based construction products - from current production of coal, and material from mine dumps. (potential) • Two types of potential SRM - 'black' slate (from current production and from heaps) and 'red' slate from old 'blown' mine heaps. (potential) • The 'black' slate is a mixture of slates and sandstones. Application in atmospheric conditions (access of water, precipitation, temperature changes) results in shale disintegration (slake, crumble) which can makes its widespread use difficult. (barrier) • The 'red' slate has excellent strength properties and is resistant to weather conditions. It is a much sought after raw material for the production of secondary aggregates. (enabler) • In most cases, processing plants do not produce waste, but the product as an aggregate. Most of the aggregates made of grain class of 0/3, 3/6, 6/20. The first two are widely used in road construction. (enabler) • Standards for the use of aggregates in road and hydrotechnical construction are issued and implemented. (enabler) • Currently, old mud settlers with coal sludge are often recovered and directed to energy recovery (granulation, pelletization) in the power industry. (enabler) • Such excavations pits are usually reclaimed using gangue or secondary aggregates. If it is intended for investment purposes, then the waste is used as a deep foundation, i.e. below the freezing zone. The top layer is usually made of red slates (if locally available). (enabler) • Lack of standards for the use of aggregates in building construction (liquidation of mud settlers, exchange of ground – e.g. during the restoration of functions to degraded areas). (barrier) • In place of the waste removed, secondary aggregate made on the basis of rock waste from hard coal enrichment characterized by an appropriate load capacity is built-in. (enabler) • Aggregate produced by a specialized processing plant (the operation of such a plant

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	is a secondary coal recovery - such as HALDEX) is coal free. These aggregates are of good quality. (enabler) • The problem for construction applications may be the material that directly generates the coal mine processing plant (waste / product), which may contain minimal amounts of coal, and these quantities are too small to make it profitable to subject the entire stream of this material to recovery by specialized processing plant. (barrier) • In the case of aggregates with the even 'minimal' carbon content, appropriate compaction technologies are used (with muds, inert sludges, ashes from energy, etc.). (enabler) It is only a good practice, there are no approvals in this area. (barrier) • The method of reusing poor quality aggregates in road construction may be appropriate stacking and compacting technology. Similar to currently used on mine dump sites (e.g. with ash sealing, maybe it would be possible to use waste mud for this purpose) (opportunity) • The problem is the separation of rock raw material into quality classes (slate, sandstone and sand). (barrier) Such a separation would allow for the production of aggregates with more stable quality standards (obtaining sandstone, elimination of the weakest slates being quickly crumbled). (opportunity). This is technically possible in a heavy liquid technique, but it is not profitable. Dry enrichment methods are also tested, but they are profitable only for coal and not for mineral fractions. (barrier) • Currently in the Upper Silesia region, the classification of rock raw materials for the production of aggregates is based on the location of the mine where the waste originates from (some mines can be categorized as exploiting deposits that are lithological formed in rocks associated with better or worse quality: sandstone / slates). This is the basis for information on the potential quality and suitability of the aggregate. (potential / barrier) • On the basis of rock raw materials (slate) of lower quality, substitutes for construction aggregates are produced as mixtures with other waste, e.g. ash from energetic plants (mineral-rock mixtures or composites). (enabler) • On the basis of rock raw materials (slate) of lower quality, covers of road embankments can be made. In open atmospheric conditions, with the access of air, water and seasonal temperature changes - this material is quickly disintegrated, which provides suitable minerals and accelerates for the soil-forming process. The potential resulting from disintegrating (slake, crumble) of slate rocks is a clay formed as a result of weathering, containing large amounts of clay minerals, including bentonite, depending on the type of native rocks. (enabler) • Derivative aggregates performed from coal muds – artificial, expanded clay. Granulation and sintering. The product was of excellent quality (very stable lightweight aggregate), but the production was very burdensome for the environment. Used by HALDEX to the 90's. Currently, the process is abandoned. Potentially – currently could be the subject of research on new technologies as associated processes in plants where high parametric waste heat and anti-emission infrastructure are available. (potential)
Environmental	• Lack of standards for the use of gangue based aggregates in building construction. (barrier) • Research in this area is required, first of all in the field of potential CO_2 emissions, confirming the lack of negative impact on the environment and health. (potential) • If a certain amount of carbon is found in the rock material, there is a potential risk of fire or secondary $CO2$ emissions. (barrier) • Aspects of leaching of impurities from aggregates (mainly chlorides and sulphates). (barrier)
Legal	• Lack of standards for the use of gangue based aggregates in building construction. (barrier)

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	• The use of aggregates in reclamation and revitalization have been carried out for years in the Silesia region due to local needs and the rock material availability, however many of these activities are carried out in a disorderly manner from the formal side. Lack of clear and transparent legal regulations in this area. (barrier) • Behaviour of unreliable entrepreneurs using potential legal gaps or using illegal practices - it causes further restrictions for the entire industry. As a result it causes damage primarily to entities driving in a lawful and transparent manner. (barrier) • Simplifications would require a procedure for moving unpolluted earth masses (e.g. those managed by one entity carrying out investments in neighbouring locations, where the entire documentation is already required for the transport of land as in the case of typical waste) (barrier) • Shortening the official path for the use of rock raw materials and low quality aggregates is needed. (barrier) • Implementation of GPP in the area of use of locally available raw materials required in road construction, and preferences for derived aggregates produced on the basis of mining waste. (potential) • Legal tools are needed to improve the profitability of secondary aggregate production (establishing tax breaks, surcharges, allowances etc.). (potential)

6.2.2 Stakeholders and their interests

Plenty of stakeholders appear in the entire value chain. The influence of national and local administration is important at every stage. This is related first of all to the applicable law and issued administrative decisions. Important elements are the banking institutions, due to the financing of investments. Some investments in the field of waste management, especially concerning implementation of CE rules, may be co-financed by the National Fund for Environmental Protection. Commercial banks could be also considered here.

An important stakeholder is the municipality, which receives taxes on entrepreneurs for industrial activities. The commune wants to keep the ‘status quo’ for economic and social reasons, such as ensuring stable income and providing jobs for residents. The key to creating a market for the SRM-produced (secondary) aggregate is to obtain approval from other stakeholders. From the technical side, these are certifying institutions (notified bodies) and institutions nominated for issuing technical approvals, which in the next step allow for an administrative procedure to End-of-Waste (EoW) status. A successful result is obtaining product status for the SRM-based aggregate, confirmed by the administrative decision (with trade name/ trademark). In the last part of the value chain where a commercial application of SRM-based aggregate takes place, there is a large group of stakeholders related to different reasons of using this material in the environment.

Main actors and stakeholders in this value chain are given in table below (Table 17).

Table 17: Overview of main actors and stakeholders in the Katowice value chain

Step	Main actor	Main stakeholders
Coal exploitation and enrichment	Coal mine	State government, Local government, Financial institutions, NGO’s, Local community, Society, Media
Gangue treatment	Waste processor	Coal mine, State government, Local government, Financial institutions
SRM-based aggregates technical approvals	Waste processor	Certification and standardization bodies, R&D, State government, Local government
EoW administrative	Waste processor	State government, Local government

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procedure		
SRM-based product distribution	Waste processor SRM product retailer	State government, Local government, Financial institutions
SRM-based product use	Building companies Land reclamation companies	State government, Local government, Financial institutions, Competitors, Land reclamation companies, developers, NGO's, Local community, Society, Media

At every stage of the existing value chain appears interested stakeholders. The area of interest and reason are different and depending on the type of entity. For entrepreneurs, interests have a mainly business foundation, but the quality conditions of the product (both construction and ecological) must be met. Environmental or social aspects are a key for some stakeholders. In practice, they should be met in the first place so that the widespread use and application of SRM-based aggregates will receive social approval.

6.2.3 Activity and value creation

There are two main types of rock raw materials from the exploitation of hard coal mining due to its origin depending on the work carried out:

- The rock from the facilitate works.
- The rock (gangue) from coal mining and enrichment process.

Main activities in this value chain are given in the table below (Table 18).

Table 18: Overview of activities along the Katowice value chain

Step	Who/ Actor	Activity	Output
Facilitate works	Coal mine	The works include facilitate a coal deposit, drilling shafts and underground tunnels	Rocks
Coal exploitation and enrichment	Coal mine	During the exploitation mix of coal with waste rock is obtained. The separation of these two raw materials takes place during enrichment process. Wet technique is used more often; hence coal mud appears as an additional waste. For simple earthworks gangue from this step could be used directly	Hard coal, Gangue Coal mud
Gangue treatment	Waste processor	Rocks conditioning. Main possible processes are crushing, grinding and grain classification	Crushed stone in different grain fractions
Technical approvals	Waste processor	Research and administrative proceedings for certified technical approvals for aggregates made of coal accompanying rocks	SRM-based crushed aggregates (market product)
Product use	Building companies	Use of certified crushed aggregates in road building	Road investment
Product use	Land	Use of aggregates in preparation of land	Recovered land for

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	reclamation companies, developers	for further investment. Very often is provide as brownfields redevelopment and/or reclamation	further investment

At each stage of the value chain, a specific added material value is created and it gradually increases until the end product is obtained. Further cost inputs increase the value of the final product. This applies to each stage the value chain, from the coal exploitation and enrichment, rock separation, preparation of the aggregate as well as the final product. The competition on the aggregate market is high. Main reason is easy availability and comparable prices of natural aggregates. Upgrade of the competitiveness of SRM-based aggregates is possible by creating pro-ecological attitudes among investors, which in order to function must be supported by legal regulations and / or requirements of public procurement rules, or direct financial incentives in the form both of financial or tax concessions.

6.3. Potential new value chain

6.3.1 Technological developments

Slimming additives for ceramics

The next stage of the workshop was devoted to technological developments in the recovery of mining waste, in particular new method for use of muds as a raw material in building ceramics - fillers and slimming additives for ceramic masses (Figure 20). Such technology has been developed and implemented on a technical scale.

Aggregates (crushed stone) for construction industry value chain

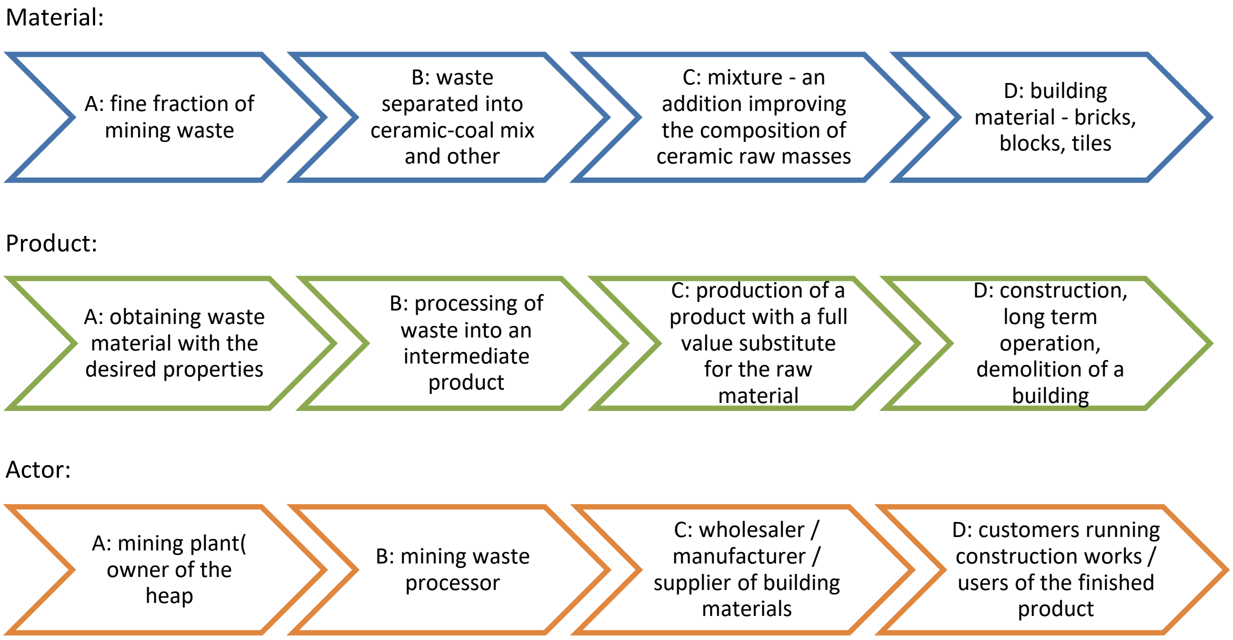

Figure 20: Slimming additives for building ceramics production value chain

6.3.2 Determination of potential impact points in value chain

In addition to technological costs, the distance of material transport to the place of processing and the product produced to the recipient is also important. It is therefore profitable to shorten transport

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routes and search for good quality material.

6.3.3 Identification of end market

In case of the value chain being analysed, we are dealing with a component improving the properties of ceramic masses, i.e. the material from which very sought after products are manufactured - ceramic building materials. Ceramic building materials are the basic material in each building and they can be easily adapted to the customer's needs by melding elements appropriate for current needs, finding soonest buyers. Slimming additives allow obtaining good quality products even from inferior types of clays and loams and improve the thermal balance of the ceramic production processes, thus improving the competitive position of the building materials manufacturer on the market.

6.3.4 Socio-economic and environmental context

Below in the Table 19 the PESTEL analysis is given for the slimming additives. Different barriers and enablers are given in the socio-economic and environmental context.

Table 19: PESTEL analysis for the slimming additives

Political	• The main issue highlighted by actors and stakeholders in range of political aspects is lack of tax allowances that would support and make favourable the economic use of products based on waste. (barrier) • The feedstock is postprocessing mud from hard coal enrichment. The whole sector is strongly dependent on political moods at the national as well as EU level. The energy policy - it is often 'social blackmail'. (barrier)
Economic	• Technology complements the value chain of hard coal mud waste management. It is not a competition for energy applications of mud, but closure of the material circulation loop. So far high-calorific value mud (above 10 MJ/kg) is a sought after raw material for the production of coal recycled aggregate, used as secondary fossil fuel in the power industry. Low calorific value mud was not effectively used, despite the high potential (mineral composition). This technology allows for its cost-effective use. This approach is profitable for entrepreneurs processing coal-fired silts and producing granules for use in building ceramics, but the quality of the final product must be excellent. (enabler) • Any transport of input material is a significant cost in the general economic calculation, even if concerning silt with the desired quality parameters furthermore incorrect transport may cause a waste of raw material. If the mud is mixed with stones (gangue), the separation of silt is unprofitable. (barrier) • Under consideration of other solutions, if the silt and stone are mixed, from a technical and economic point of view, such material can be used for earthworks or road construction. The cost of transport determines the profitability. An option to improve the economic calculation could be the coal mine (coal postprocessing mud producer) participation in the costs of silt reception/transport. Acquiring from other entities on a commercial rules is unprofitable. (enabler) • The chlorine content is a critical parameter. An appropriate quality material could be obtained from waste seasoned on mine dump sites, where during the years the chlorides content is lowered. However crushing and grinding of this material is groundless due to high costs, as well as environmental issues (energy consumption, carbon footprint). In this range, a cost-effective chlorine removal technology from currently available mud is inquired. It can open a large market. (potential)
Social	• Considered technology consists producing the component as a high-quality building material/ ceramic component from a seemingly useless material. A prestigious and innovative activity. (enabler)
Technological	• Considered technology is particularly demanding for the input material. Coal postprocessing mud being a raw material, must be properly prepared and collected

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	in a selective manner. Use of mud from an old settlers of coal postprocessing sludge is unfeasible (because they are contaminated with stone). In terms of this technology, muds of filter presses from direct production are primarily considered, and favoured. The material needed is pure sludge (in granulometry meaning) with a defined, low chlorine content, and preferred caloric value 6-8 MJ/kg. (barrier / opportunity) • Due to the common way of transport (rail / truck transport where the bottom of the container is lined with rock to enable unloading) mixing of mud with rock material is usual obstacle. The raw material delivered in this way is useless because the cost of its preparation becomes too high, and use of such mixed input may result in the technological line damage. Only methods of (clean, separated) transport are approved. (barrier) • The chlorine content is a critical parameter. There are difficulties to keep it on acceptable level. This is the main technological problem. The second critical parameter is the lime content, which can't be too high. (barrier) Thus mixing the mud sludge with using of powerplant ashes (which is efficient) to reach the lower chlorine level as possible, but only in a narrow range, is an option. (enabler) • Research on new technologies for removing chlorine from coal sludge is needed. They must give simple and cheap solutions. (potential) • Coal post-processing muds contain a suitable mixture of aluminosilicates and clay minerals. Ceramic materials manufactured with the addition of such silts have better thermal parameters than produced without these additives. (enabler)
Environmental	• The main issue is that input material must keep standards for the content of hazardous substances, including of chlorine and fluorine volatile compounds. Technology makes feasible reuse of coal postprocessing muds with calorific value of 6-7 MJ/ kg which are not valuable as an energy resource (too low calorific value). For coal enrichment plant muds with low calorific value are typical waste. Commonly this material was used for land reclamation or was dumped. (opportunity)
Legal	• Legal tools are needed to improve the profitability for valuable use of coal postprocessing mud (establishing tax breaks, surcharges, allowances etc.). This is closely connected with political issues. (barrier and potential)

6.3.5 Overview of potential new value chain

Considering the technical and mineralogical properties of the coal postprocessing muds, the potential new value chain can consists production of geopolymers, i.e. amorphous synthetic aluminosilicate polymers. The chemical composition of such a product is similar to zeolite, however, it has an amorphous structure. This can have widespread application:

- On the production of construction materials (bricks, panels, sandwich panels, ceramic tiles).
- In industry in areas where heat resistance and fire resistance of the final product are required.
- As construction material used, among others in power plants, combined heat and power plants.
- Heat shields and fire barriers in construction.
- Material for protective coatings different types of steel.
- In foundry as a component of melding sands and material for foundry melds in aluminium foundries.
- Emergency repairs, among others airport runways.
- Supporting material for the stabilization of toxic waste, including radioactive substances.
- Traditional aggregates and light aggregates (sintered) production.

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- Other building/ construction materials.

In proposed, future value chain beside the actors and stakeholders involved now, the participation or stronger engagement should be taken by:

- Science, research and academia;
- Certification and standardization bodies;
- Industries (as a potential end users);
- Building and construction companies (as a potential end users);
- Developers (as a potential end users);
- State and local government;
- Financial institutions;
- NGO’s;
- Media.

6.4. SWOT analysis

SWOT analysis for both analysed value chains are depicted in Table 20 and Table 21.

Table 20: SWOT analysis Poland case: aggregates for the construction industry

Strengths	Weaknesses
• Widespread availability of rock material. • Processing plants are available and operated. • SRM-based product is price-effective for local applications. • Common demand for a product. • Technical approvals are issued for specific applications and products. • Low quality aggregates can be incorporated through appropriate compaction and stacking technologies. • Low quality aggregates can be used in a way that allows to exploit its mineralogical potential.	• Input material (gangue) differs qualitatively depending on the place of its exploitation. Some types of low quality slates are quickly crumbled. • Lack of cost-effective technologies for separation and enrichment of waste rock (separation of sandstone and slate). • Despite the low price of SRM aggregates, transport costs limit its use. • Lack of GPP procedures for use of SRM-based aggregates for large investments (e.g. road construction). • Competitively low prices of with high quality aggregates, exploited in stone quarries.
Opportunities	**Threats**
• Producing SRM-based aggregates. • Existing standards for the use of these aggregates in road and hydrotechnical construction. • The activity is inscribed into Circular Economy strategy. The activity allows for lowering the exploitation of virgin resources (e.g. aggregate produced in stone quarries). • Despite the technologies already developed, the whole issue is a large work field for scientific institutions. • Previous experience allows producing high quality SRM-based aggregates, including processed aggregates, e.g. sintered crumbs (light aggregates, expanded clay/ gravelite).	• Lack of investors' confidence due to unexpected changes of legal regulations. • Lack of GPP procedures for large investments (road construction) that would make favourable preferences for the use of recycled aggregates • No incentives or tax reduction that would lower costs, and allow for production of better quality aggregates. • The term ‘waste’ in the public opinion is strongly associated with this material, even though it is a product • Stone quarries exploitation is destructive to the environment and landscape. Regulations and economic mechanisms for preferred reuse of mineral waste that are gathered during the

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• Possibility of cooperation in the field of sintered aggregates production with other industrial branches (e.g. cement industry).	exploitation of hard coal use need to be implemented.

Table 21: SWOT analysis Poland case: slimming additives for ceramics

Strengths	Weaknesses
• Basic material is easy available. Processing plants already exist. • There is possibility to manage filter presses for muds from direct production. • There is demand for this high quality product. • Technology of coal mud processing and ceramic mass component preparation is fully implemented. • Low-calorific value mud was not effectively used as far, despite the high potential (mineral composition). This technology allows for their economic use.	• Basic material (post coal mud) cannot be contaminated by stones, thus the batch material must be collected selectively and accordingly transported. • Use of mud from an old settlers of coal postprocessing sludge could be unfeasible (stone contamination). • Transport costs plays important role in whole process. • The chlorine content in coal sludge is a critical parameter. There are difficulties to keep it on acceptable level. • Lack of a low-cost method for chlorine remove from sludge limits its use.
Opportunities	Threats
• Technology complements the value chain of hard coal mud waste management. • It is not a competition for energy applications of mud, but closure of material circulation loop. Activity is inscribed into Circular Economy strategy. • A low-cost chlorine removal technology from coal mud is inquired. Large work field for science and academia. • A prestigious and innovative activity - turning seemingly useless material into a high-quality ceramic component. • Even if the silt and stone are mixed, such material can be used for earthworks or road construction (possible of creation of new, easy applicable value chain).	• Incorrect transport may cause a waste of raw material. If the mud is mixed with stones (gangue), the separation of silt is unprofitable. • No incentives or tax reduction that would lower costs of coal mud processing, and allow for production of better quality components.

6.5. Conclusion

6.5.1 General findings

The conclusions presented in the SWOT analysis lead to several basic statements defining the diagnosis of the existing situation:

- Mining wastes are a material resource that can be used in construction as building materials or as a component for their production.
- These wastes are available in quantities that can satisfy a large part of the building materials market in the region.
- In some cases the cost of management such waste can be higher due to the need for more tests and labour-intensive preparation for use.

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- There is a social reluctance to use them associated with a bad opinion about waste and the conviction about lower quality of products from waste.
- Appropriate certification procedures should be developed for these materials and information on their properties should be disseminated to all actors of the investment process in construction and users of construction facilities.
- Closing material circuits in construction requires the use of direct and indirect subsidizing mechanisms balancing the advantage of primary raw materials.

6.5.2 Recommendations

Mining wastes constitute a huge material resource, which in large part can be used in construction both as building materials and as a component for their production. Such application requires recognition of the properties of waste, as only a part of them is suitable for use in the construction, occurring in a mixture with waste that is not suitable for this kind of recovery.

For their widespread use of such SRM-based products, it is necessary to build trust among stakeholders in recycled material and change the common belief that products from waste are always of lower quality and their presence in the product lowers its value. Unfortunately, good quality guarantees are associated with the need for promotional and advertising activities that are wider than in the case of virgin resources. The value of recovered materials is also influenced by preparatory and processing processes, more costly than in the case of obtaining virgin mineral materials and with a higher risk of incurring repeated fees for waste management. The other cost components are similar to those for virgin mineral materials, where the critical are costs of transport, storage and operations related to the sale and supply of customers.

The improvement of existing situation requires regulatory measures in the political and legal sphere based on the awakening of civic awareness in the area of actions needed for the citizens' living environment. Unfortunately, the current policy usually aims at administrative and fiscal activities, which causes raising non-material costs and transferring them from the regulator and budget funds to final recipients who bear them as a component of the retail price. It is therefore hardly surprising that such activities are not accepted by the public, and the market mechanism causes them to be neutralized by reducing trade turnover on regulated markets, as well as importing and developing the shadow economy. It is necessary to regulate by redistributing existing public funds, for example, at the expense of ceasing to stimulate consumerism or rationalization of state and local government structures and stopping the expansion of the administrative apparatus.

Such activities together with the pro-ecological design of building structures enabling the re-use of structural elements, maintenance and modernization of exploited objects and closing material flows through the recovery of demolition materials are the axis of material management balance and an opportunity for creating new value chains in sustainable construction.

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7. SLOVENIAN CASE STUDY

7.1. Introduction to the case study

7.1.1 Geographic region

The Slovenian case was focused on material flow and value chains of sewages sludge. The sewage sludge is one of the most voluminous wastes streams in urban areas - as demonstrated in D3.1 - occurring during municipal waste water treatment.

For the purpose of the study we selected the whole region of Slovenia. The reason for this was the fact that Slovenia is relatively small area in relation to other European regions and the whole area is facing similar issues in sewage sludge treatment and management. Also, the legislative and administrative procedures are the same for whole Slovenia and are not regionally dependent.

The area of Slovenia is 20,273 km^2 with the population of 2,076,595 habitants (2018[44]). Slovenia is divided in two cohesion regions - NUTS2: Eastern Slovenia and Western Slovenia and 12 statistical regions - NUTS3[45] (Figure 21). The capital of Slovenia is Ljubljana, located in the Osrednjeslovenska region, with 289,518 habitants in 2018[46]. The second largest city in Slovenia is Maribor, located in the Podravska region, with 105,089 habitants in 2018[47].

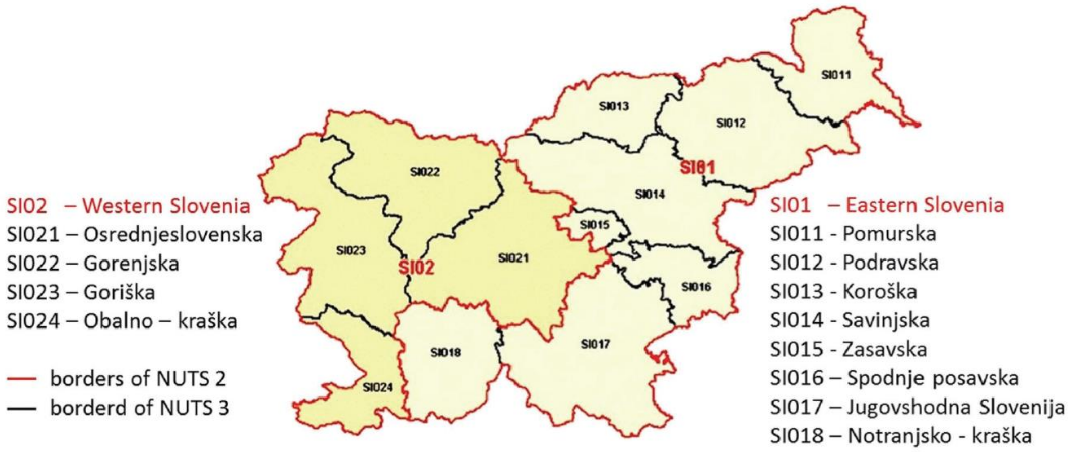

Figure 21: Cohesion (NUTS2) and statistical (NUTS3) regions of Slovenia

In general, Slovenia has orientated very early towards circular economy, at least on political level. This is well supported by the fact that Slovenian government joined Ellen MacArthur Foundation 'Circular Economy 100' programme already in 2016[48], that one of the nine priority domains in Slovenian 'Smart Specialisation Programme' is dedicated to the CE[49], that in 2017 and 2018 Slovenia prepared a special document 'Roadmap towards Circular Economy in Slovenia'[50] and that the CE is

44 https://www.stat.si/StatWeb/news/Index/7363

45 https://www.revolvy.com/page/NUTS-statistical-regions-of-Slovenia

46 https://www.ljubljana.si/sl/o-ljubljani/ljubljana-v-stevilkah/

47 https://www.stat.si/statweb

48 https://www.ellenmacarthurfoundation.org/our-work/activities/ce100/members

49 http://www.svrk.gov.si/en/areas_of_work/slovenian_smart_specialisation_strategy_s4/

50 http://www.vlada.si/fileadmin/dokumenti/si/projekti/2016/zeleno/ROADMAP_TOWARDS_THE_CIRCULAR_ECONOMY_IN_SLOVENIA.pdf

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implemented in every domain of national decision making. Separately from this, many companies recognized economic added value in CE business models and industrial symbiosis (even if they are not called so). For the construction sector this is important especially in domain of recycling, including recycling of waste into SRM-based construction products. On the other hand, there are still gaps between policy orientations and practical examples in Slovenia, the latter many time being hinder by poor social acceptance (SRM-based product are not recognized as products but have reputation of being 'waste'), and opposition from local communities, complex administrative procedures and lack of legislative acts such as EoW criteria.

7.1.2 Assessed waste stream

The selected waste sewage sludge with European waste code 19 08 05 was selected due to the following reasons:

- Sewage sludge is one of the most frequent urban waste streams in Slovenia (see Table 22);
- Past experiences show that sewage sludge is suitable for recycling into construction products (see for example Pavšič et al. 2014[51]), especially for low strength geotechnical composites; and
- There is a high interest among waste producers (public utility companies) in Slovenia for new management routes, since prices for current handing over wastes are relatively high (from 70 to 150 euro per tonne depending on the type of recovery or disposal).

Table 22: Overview of 90% of waste mass (selected EWC codes for CINDERELA) in Ljubljana (data for 2017) and Maribor with surroundings municipalities (data for 2016)

Ljubljana		Maribor with 24 surrounding municipalities (study case in D3.1)	
EWC	**Mass (tonnes)**	**EWC**	**Mass (tonnes)**
17 05 04	353,777.338	17 05 04	59,744.129
19 08 05	121,721.650	19 08 05	31,348.351
17 05 06	53,034.447	17 05 06	26,017.506
12 01 02	20,443.413	12 01 02	25,023.559
17 03 02	19,157.408	10 03 16	12,053.233
17 01 07	13,462.386	17 01 01	11,477.937
10 01 01	12,570818	17 09 04	9,945.750
		17 01 07	8,649.478
		17 03 02	5,676.427
		12 01 01	4,235.695

The total amount of treated waste water in Slovenia in 2017 was 150.114 million m3 and the total capacity of wastewater treatment plants was 2,676,580 PE[52] . The total amount of sewage sludge in 2017 in Slovenia was 203,059.174 tonnes. The largest quantity of the sewage sludge was produced in Osrednjeslovenska statistical region (129,165.93 tonnes or 64%), among this almost 94% or

[51] Pavšič, P., Mladenovič, A.,Mauko, A., Kramar, S.,Dolenec, M., Vončina, E., Pavšič Vrtač, K. and Bukovec, P. 2014. Sewage sludge/biomass ash based products for sustainable construction. Journal of Cleaner Production 67, 117-124. Elsevier.
[52] http://okolje.arso.gov.si/onesnazevanje_voda/vsebine/podatki-1

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121,353.32 tonnes was produced by JP Vodovod-Kanalizacija d.o.o. (JP VO-KA), which performs utility service for the city of Ljubljana and some neighbouring municipalities. This is also the largest company in Slovenia in terms of the wastewater drainage and treatment system.

The second largest statistical area in the terms of the produced sewage sludge is Podravska region with 22,130.26 tonnes (11%) of sewage sludge with more than half of it (12,974.26 tonnes) produced in the City of Maribor. Distribution of the sewage sludge production across Slovenia is given in Table 23.

Table 23: The number of polluters and amount of sewage sludge per statistical areas as reported to Slovenian Environmental Agency in 2017 (source: ARSO)[53]

Statistical region	Number of waste producers	Amount (tonnes)	Percentage (%)
Gorenjska	12	7,630.361	4
Goriška	7	5,522.73	3
Jugovzhodna Slovenija	11	3,401.200	2
Koroška	7	1,076.700	1
Obalno – kraška	5	7,218.250	4
Osrednjeslovenska	13	129,165.930	64
Podravska	9	22,130.260	11
Pomurska	20	5,779.935	3
Posavska	7	1,073.950	1
Primorsko-notranjska	4	1,857.170	1
Savinjska	19	16,064.360	8
Zasavska	4	2,138.320	1
Total	**118**	**203,059.170**	**100**

Data reported to Slovenian Environmental Agency (ARSO) show that 62.7% or 127,232.16 tonnes of produced sewage sludge in 2017 were treated by waste producers themselves. 36.5% (74,167.42 tonnes) was handed over to the waste collector in Slovenia and 0.8% (1,659.6 tonnes) was directly shipped in another EU country.

Based on statistical reporting of sewage sludge collectors to ARSO in 2017 the total amount of collected sewage sludge was 64,169.20 tonnes, from which 4% (2,370.83 tonnes) was handed over to other collector in Slovenia, 46% (29,689.28 tonnes) was handed over to the waste treater in Slovenia and half of the collected waste (32,388.17 tonnes) was handed over in another EU country, where sewage sludge was treated according to recovery operation designated as R3 (‘Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes)’). Management of collected sewage sludge in Slovenia in 2017 is illustrated in Figure 22.

[53] http://www.arso.gov.si/varstvo%20okolja/odpadki/poro%c4%8dila%20in%20publikacije/

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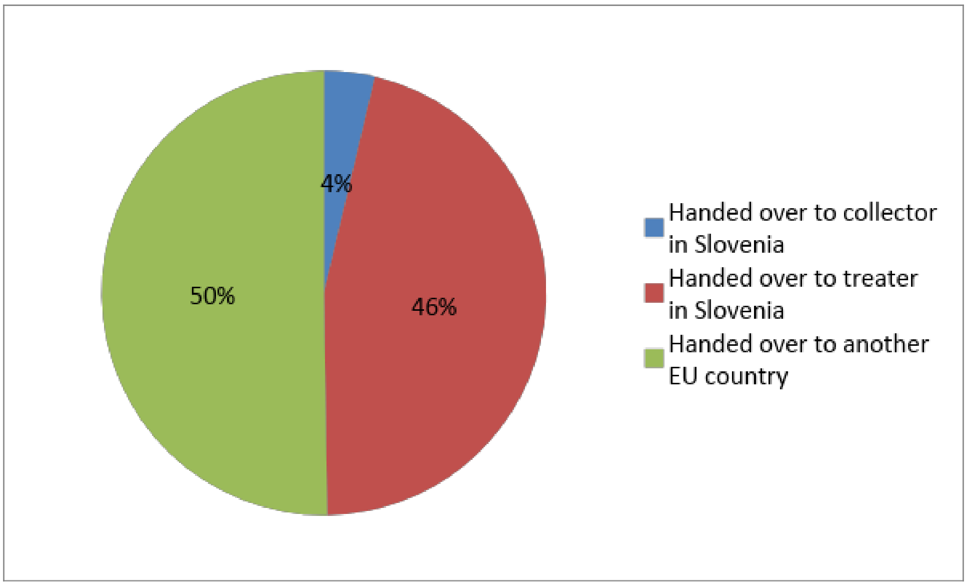

Figure 22: Handing over of collected sewage sludge in Slovenia as reported to ARSO in 2017

Based on the input of the stakeholders, shipment of the sewage sludge (either treated or non-treated) to another EU country other EU country (e.g. Hungary) is currently prevailing waste route in Slovenia.

7.1.3 Strategical approach

The strategical approach towards assessment of the current and new value chains of sewage sludge treatment was gathering information based on:

- Experiences and know-how of Slovenian CINDERELA partners NIGRAD and ZAG;
- Information gathered at the workshop in Bilbao (Spain) during the consortium meeting on 15.1.2019 (Figure 23);
- Information gathered at the workshop organized by ZAG and NIGRAD on 7.3.2019 held at the ZAG premises (Figure 24).

26 participants from different stakeholders (Figure 23) gathered at the workshop at ZAG on 7.3.2019. The agenda of the workshop is given in Annex 4. After short introduction by Ana Mladenovič (ZAG), CINDERELA project and the main objectives and actions were presented by Kim Mezga (ZAG). This was followed by presentation of Maribor demonstration cases by Tomislav Ploj (NIGRAD). Participants had opportunity to hear about the latest technologies of sewage sludge recycling into construction products (presented by Ana Mladenovič, ZAG) and overview of current situation and legislation in Slovenia, connected with sewage sludge treatment (presented by Mirko Šprinzer, NIGRAD). Following this, participants discussed current and potential value chains of sewage sludge. The whole workshop was three hours in duration. The results of the workshop are given in following chapters.

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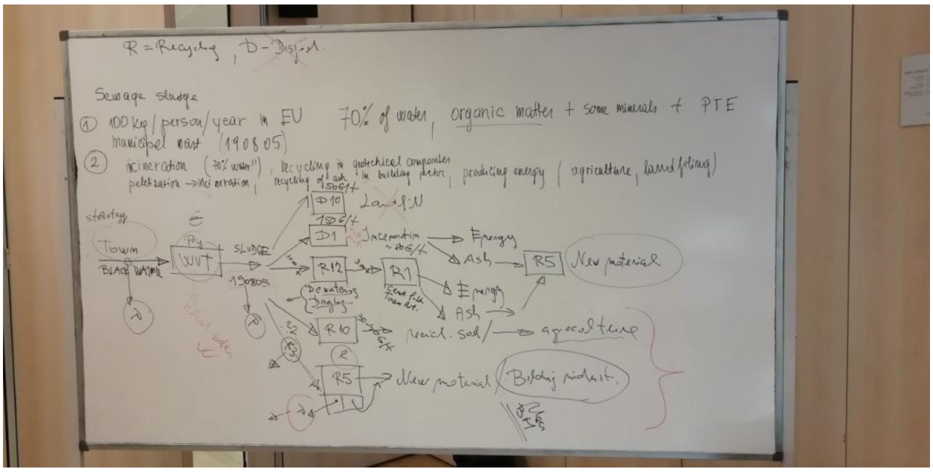

Figure 23: Schematic presentation of possible material flows of sewage sludge resulting from discussion of partners at the workshop in Bilbao on 15.1.2019

Figure 24: Workshop 'Use of secondary raw materials in construction sector – recycled sewage sludge', organized by ZAG and NIGRAD and held on 7.3.2019 at the ZAG's premises

Table 24: Stakeholders gathered at the workshop, organized by ZAG and NIGRAD, in Ljubljana

Stakeholder	Type of stakeholder	Number of participants
SALONIT ANHOVO	Cement producer (used to be user of sewage sludge based fuel) (Actor D)	1
KOSTAK	Public utility company, Waste treatment center, Construction, Producer of gravel and others. (Actor B, C and D)	3
BOJAN JELEN S.P.	Designer (Stakeholder)	1
KOMUNALNO PODJETJE VELENJE	Public utility company (Actor A)	1
KOMUNALA SLOVENSKA BISTRICA	Public utility company (Actor A)	1
JP VODOVOD-KANALIZACIJA	Public utility company (Actor A)	1
MARJETICA KOPER	Public utility company (Actor A)	3
KOMUNALA NOVO MESTO	Public utility company (Actor A)	2
EOS PROJEKT	Consulting (Stakeholder)	1
KSD D.O.O. AJDOVIŠČINA	Public utility company (Actor A)	1
NIGRAD	Public company for municipal road management, public lighting and traffic lights, sewage system (Actor B, C and D)	3

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PKG	Consulting (Stakeholder)	1
Prodnik	Public utility company (Actor A)	1
IJS	Research (Stakeholder)	1
ZAG	Research / Notified Body (Stakeholder)	5
Total		**26**

7.2. Current value chain

7.2.1 Material flow

Sewage sludge is non-hazardous waste in usually semi-solid form (Figure 25). Its consistence and composition depend on water content and type of wastewater treatment. The water content is usually from 70% to 85% of the total weight. The remaining dry matter of the waste is almost all organic matter with addition of some mineral component. Potential Toxic Elements (PTE) such as Cd, Cr, Pb, Ni, Hg and others are frequently present.

Figure 25: Sewage sludge mechanically dehydrated and hygienized with lime and prepared for laboratory testing

Figure 26 illustrates how quantities of produced sewage sludge in Slovenia were increased through the year which is due to:

- Construction of new infrastructure for wastewater treatment and
- More population attached to the public sewage system.

Following this, in 2017, 203,059.17 tonnes of sewage sludge was produced, which is 15% more than in 2014 when 172,951.05 tonnes was produced.

Figure 25 also depicts types of treatment of sewage sludge. From 2010 on landfilling was decreased, while incineration was increased.

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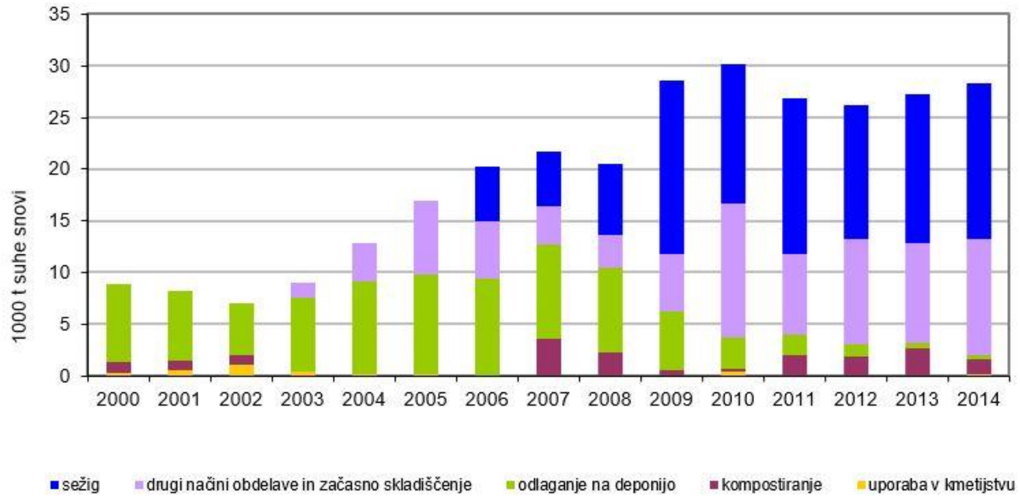

Figure 26: Amount of dry matter in sewage sludge from 2000 to 2014 and different types of sewage sludge treatment (blue colour – incineration, violet colour – other types of treatment and temporary storage, green colour – landfilling, red colour – composting and yellow colour – use in agriculture) (Source: ARSO)[54]

Based on data gathered, the most frequent ways of sewage sludge treatment in Slovenia, are presented in Figure 27.

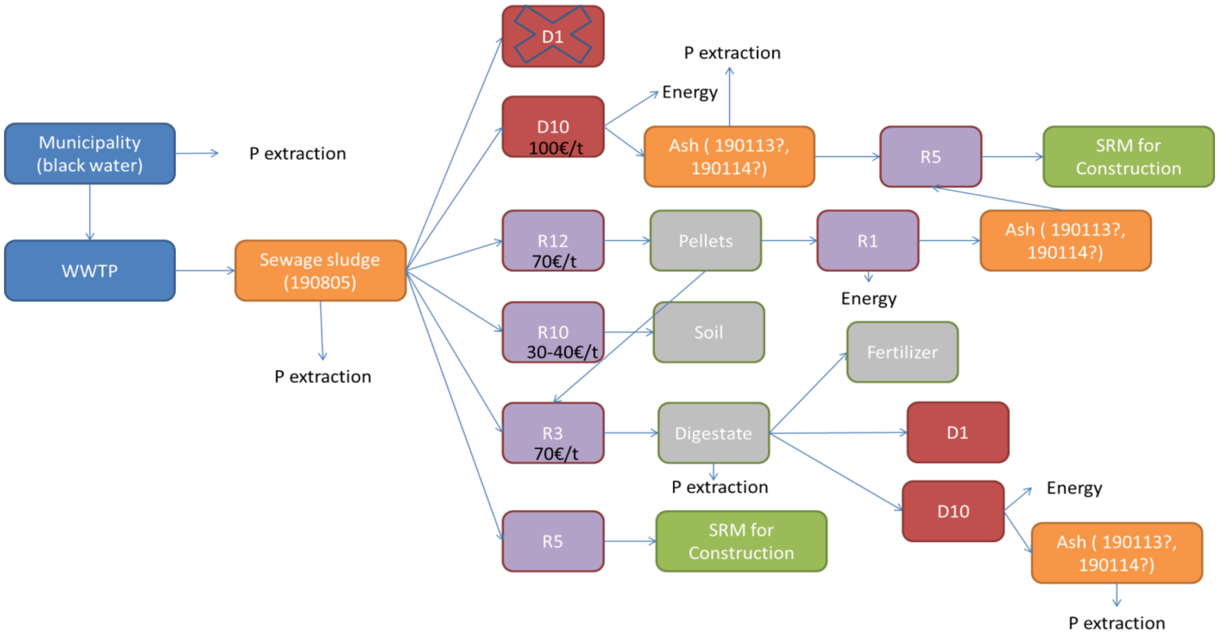

Figure 27: Possible treatment routes (material flows) of sewage sludge in Slovenia

The sewage sludge is processed through following disposal (D) / recovery (R) operations[55]:

- D1 - Deposit into or on to land (e.g. landfill, etc.);
- D10 - Incineration on land;

[54] http://kazalci.arso.gov.si/sl/content/blato-iz-komunalnih-cistilnih-naprav-2
[55] shttps://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0098&from=EN

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- R1 - Use principally as a fuel or other means to generate energy;
- R3 - Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes);
- R5 - Recycling/reclamation of other inorganic materials;
- R10 - Land treatment resulting in benefit to agriculture or ecological improvement;
- R12 - Exchange of waste for submission to any of the operations numbered R 1 to R 11.

Based on possible treatment routes the following six Material flows (MFs) were identified.

- Disposal trough D1;
- Disposal trough D10 and potential recovery of incineration ash through R5;
- Recovery through R12 into pellets and later through R1 into solid fuel;
- Recovery through R12 into pellets and later through R3 into digestate;
- Recovery through R10 into substrate for land treatment benefiting in agricultural and ecological improvement;
- Recovery through R3 into digestate and potential use as waste-based fertilizer or disposal through D1 or D10;
- Recovery through R5 – new value chain.

Disposal of sewage sludge trough landfilling and similar: According to the waste management hierarchy[56], landfilling is the least preferable option and should be limited to the necessary minimum. Disposal of sewage sludge through D1 operation ('Deposit into or on to land (e.g. landfill, etc.)') was prevailing treatment in Slovenia until 2008 (Figure 26). Landfilling of sewage sludge is today not possible anymore, due to high content of Total Organic Content (TOC) in sewage sludge.

Disposal of sewage sludge trough incineration and potential recovery of incineration ash through recycling: This material flow foresees 'Incineration on land' (D10). Between 2009 and 2014 this was one of the main ways of sewage sludge treatment (Figure 26). Incineration through D10 or recovery through R1 ('Use principally as a fuel or other means to generate energy') is occasionally still high on political agenda in Slovenia and is also predicted as prevailing treatment until 2030 in 'Operational plan for waste management'[57]. On the other hand, in 2017 only 2,694.56 tonnes of sewage sludge was incinerated, which shows that in practice only small quantities are processed through D10 or R1. In this material flow ash from incineration could be further used as secondary raw material in construction sector by recycling through R5 ('Recycling/reclamation of other inorganic materials'). Extraction of P from incineration ash is also possible but not yet implemented in Slovenia.

Recovery of sewage sludge through pelletisation into solid fuel: In this case the sewage sludge is dehydrated and pelletized through R12 ('Exchange of waste for submission to any of the operations numbered R 1 to R 11') into pellets of dry sewage sludge, which can be used as solid fuel (R1). Only one company in Slovenia (JP VO-KA) has treatment plant for sewage sludge pelletization in Slovenia. In the past these pellets of recycled sewage sludge with calorific value of ca. 13 MJ/kg were used by cement production kiln in Slovenia (Salonit Anhovo) but this practice stopped due too low calorific value and presence of PTE, which are formed during the co-incineration.

Recovery of sewage sludge through pelletisation into digestate: Pellets of sewage sludge treated

[56] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0098&from=EN
[57] http://www.pisrs.si/Pis.web/pregledPredpisa?id=ODLO1739

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through recovery procedure R12 can be later recovered in biogas plants into digestate according to R3 procedure ('Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes)'). From here different possibilities of digestate management are given, e.g. using in agriculture, disposal or incineration. JP VO-KA is currently handing over their pelletized sewage sludge to biogas plant in Hungary. The costs of handing over pelletized sludge waste are in this way lower due to smaller weight. The waste producer has no information what the final usage of digestate formed through this process is.

Recovery of sewage sludge into substrate for land treatment benefiting in agricultural and ecological improvement: In theory one of the possible treatment ways (also one of preferred options according to the 'Slovenian Operational plan for waste management') would be recovery of SRM from sewage sludge through recovery procedure R10 ('Land treatment resulting in benefit to agriculture or ecological improvement'). Currently very little or no substrate for land treatment is recovered through this process due to low limiting values for heavy metal and other parameters[58] for the final product.

Recovery of sewage sludge into digestate and potential use of digestate as waste-based fertilizer or disposal of digestate due to high content of heavy metal and other parameters: This is currently one of the most often material flows in Slovenia. Hygienized and stabilized sewage sludge is transported and handed over to biogas plants in Hungary. There are several options of further handling of digestate: (a) using digestate as fertilizer in agriculture land (if PTE value is not too high); (b) disposal of digestate through procedure D1 (if TOC value is not too high); or (c) incineration trough D10.

Recovery of sewage sludge into secondary raw materials for construction (potential new value chain): There is already a small amount of sewage sludge which is recycled through R5 procedure into secondary raw material for construction product (geotechnical composites). Currently there are two holders of Slovenian Technical Approval for construction product based on sewage sludge in Slovenia[59].

Participants at the workshop emphasized that in current material flows in Slovenia no extraction of phosphorus (P) occurs. Extraction of P has large potential since it is one of 27 critical raw materials for the Europe[60]. Due to high content of P in sewage sludge it would be beneficial to consider the use of P for fertiliser production. Also, participants are of opinion that in the future only one incineration plant for sewage sludge (mono-incineration) would be appropriate, which would additionally enable extraction of P from bottom ash.

7.2.2 Stakeholders and their interests

Based on the MFs originating from sewage sludge identified in Slovenia we further divided the direct stakeholders (Actors) as presented in Table 25. It is often the case that some actors have double or even triple role in the value chain. For example, sewage sludge producers can also be sewage sludge processors or even producers of products. Many times, sewage sludge processor is also product producer. In the latter case, the same process is carried out according to the environmental legislation (waste processing) and also according to the product (product producing). For example, waste processor is recycling sewage sludge according to the recovery procedure R5, where sewage sludge is mixed with additive with puzzolanic or other binding activities. This process is at the same time production of geotechnical composite, i.e. construction product. Further, since production is carried out in-situ, the processor is also final user of the product.

[58] Decree on the management of sewage sludge from the urban waste water treatment plants (Off. Gaz. RS no 62/08)
[59] http://www.zag.si/si/tehnicna-soglasja
[60] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52017DC0490&from=EN

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Table 25: Group of actors in Slovenian sewage sludge value chains

Group of actors	Actors inside the group	Description[61, 62]
Sewage sludge producer / holder	Waste Producer	Anyone whose activities produce sewage sludge or anyone who carries out pre-processing, mixing or other operations resulting in a change in the nature or composition of sewage sludge. These are usually public utility companies.
	Waste Holder	The sewage sludge producer or the natural or legal person who is in possession of the sewage sludge.
Sewage sludge processors, collectors, transporters, brokers, and dealers	Waste Processor[63]	Legal entity or natural person whose activity is processing sewage sludge according to disposal and recovery operation in Waste Directive.
	Waste Collector	Anyone whose activity is gathering of sewage sludge, including the preliminary storage of sewage sludge for the purposes of transport to a sewage sludge treatment facility. This is rare in Slovenia.
	Waste Transporter	Legal entity or natural person whose activity is transport of sewage sludge from sewage sludge holder according to Waste Directive.
	Waste Broker	Any undertaking arranging the recovery or disposal of sewage sludge on behalf of others, including such brokers who do not take physical possession of the sewage sludge.
	Waste Dealer	Any undertaking which acts in the role of principal to purchase and subsequently sell of sewage sludge, including such dealers who do not take physical possession of the sewage sludge.
Producer of the sewage sludge-based product	Product Producer	Anyone who is producing products based on recycled sewage sludge for different purposes.
User of the sewage sludge-based product	Product User	Anyone who is using product based on recycled sewage sludge.

Figure 28 presents the sewage sludge value chains based on identified MFs in Slovenia with the most frequent actors.

[61] Waste Directive

[62] Decree on waste (Off. Gaz. RS no. 37/15 and 69/15)

[63] For the purpose of this deliverable we included in this group Waste Disposal Operators and Waste Recover Operators.

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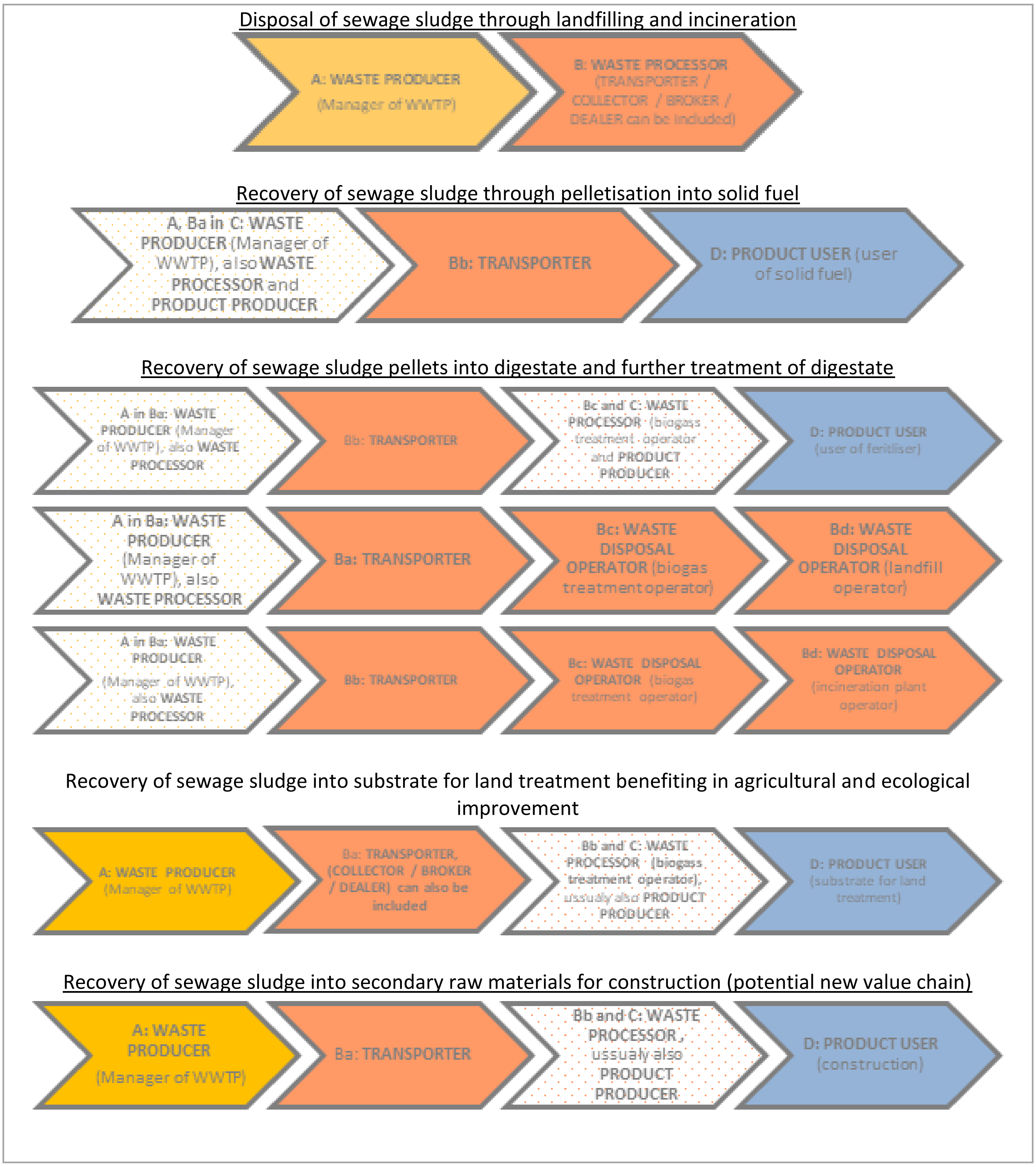

Figure 28: Actors of different sewage sludge value chains in Slovenia based on identified MFs

The following section describes individual steps of value chain, actors and their interests.

STEP A - Sewage Sludge Producer / Holder

Producers of sewage sludge in Slovenia are usually public utility companies, responsible for wastewater treatment. They are obliged to carry out pre-processing of sewage sludge in the form of stabilization and hygienization. If the sewage sludge producer doesn't possess infrastructure for its pre-treatment, the company is obliged to hand over sewage sludge to the one, which can suitably treat the waste.

Some sewage sludge producers in Slovenia (i.e. JP VO-KA) possess more complex treatment plants, which enable easy handling due to decrease volume of sewage sludge waste. In this case they are

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also waste processor (R12 procedure) or even producers of solid fuel.

Sewage sludge producers have the largest interest for changing current situation due to high costs of handing over sewage sludge to different waste processors or others (up to 200 EUR per tonne). Their interest creates certain push for new value chain as well as for changing accompanying legislation and administration. High costs for handing over sewage sludge has also negative connotation among citizens who have to pay wastewater charges. Increased interest for creation of new value chains was well seen during the workshop organized at ZAG where 1/3 of participants present were from this group. At the end of workshop an initiative was created for altering existing and creating new policies, which could improve recycling of sewage sludge before other ways of waste treatment.

This group of actors is influenced by different other stakeholders:

- Municipalities, who are granting concessions for wastewater treatment and sometimes directly pay for sewage sludge handling;
- The Slovenian Environmental Agency (ARSO) to whom they report annually about sewage sludge production;
- Citizens, who must pay wastewater charges, create public opinion and have engage in decision-making;
- NGOs, environmental organizations, general public and media, which create public opinion. Their influence can be either positive or negative. Especially, local communities can have substantial impact on public utility company's operations by granting social licence, especially in adopting new technologies for treatment.

STEP B – Sewage sludge processor (collector, transporter, broker, dealer)

There are several actors from group B involved in current sewage sludge value chains in Slovenia. Beside different waste processors, who are either preparing for and/or disposing / incinerating sewage sludge or recovering it through different recovery operations, high impact on the value chain has a subgroup of sewage sludge transporters, collectors, dealers and brokers. This subgroup is not involved in any process of material transformation but based on the workshop findings they create the biggest profit in the existing sewage sludge value chain and therefore have the largest interest for maintaining current situation. Many of these actors are involved in cross-border transportation and management of sewage sludge, where it is handed over further down the pipeline to second or third processor. Such long value chains are usually not sustainable due to high environmental impacts of transport and there are also problems with traceability of materials and transparency of value chain (e.g. unknown final destination of sewage sludge).

This group of actors is influenced by different other stakeholders:

- municipalities, who is giving approvals for use of land for certain operations;
- ARSO to whom they report annually about sewage sludge collection, processing and transport;
- Research, which is developing new processing techniques,
- NGOs, environmental organizations, general public and media, which create public opinion.

STEP C – Product Producers

Based on Figure 28, different materials can be produced from recycled sewage sludge, e.g. ash, solid fuel, substrates for land treatment, waste-based fertilisers and construction products (geotechnical composites). Some of them have status of product (e.g. construction products) while others are wastes with special status for their use (e.g. substrates for land treatment). For CINDERELA project the most interesting products are sewage sludge-based geotechnical composites, which can be put

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on the market through Slovenian Technical Approval. Slovenian Technical Approval is a technical specification granted by Body of Technical Approvals, such as ZAG, which is nominated by Ministry of the Economy. Slovenian Technical Approvals are used for the construction products which are not included in any harmonized technical specification according to the Construction Products Act[64].

The major interest of producers of sewage sludge-based products is to offer competitive product on final market. Such producers are often also sewage sludge processor.

This group of actors is influenced by different other stakeholders:

- Decision makers, policy makers, legislators, who are developing policies, legislation and administrative procedures for production and putting products on the market (certification, quality control etc.);
- Municipalities, who are giving approvals for use of land for certain operations;
- Experts, who are developing guidelines for quality of sewage sludge- based products;
- Market developers, trend-setters, developing SRM-based products markets;
- Investors, demanding SRM-based products;
- NGOs, environmental organizations, general public and media, which create public opinion and grants social licenses for SRM-based products.

STEP D – Product Users

Based on 27 there are several final users of sewage-sludge based products. For CINDERELA project construction companies which are constructing with sewage sludge-based geotechnical composites are the most interesting. Currently, there are only a few companies in Slovenia, which use sewage sludge-based geotechnical composites in construction, mainly for revitalization of degraded areas or landfill covering. While some good practices of use of SRM-based construction products in Slovenia already became everyday practice (e.g. use of Electric Arc Furnace (EAF) slag – based manufactured aggregate for wearing courses in road construction or use of reclaimed asphalt) and different documents (e.g. national recommendation in GPP for use of reclaimed asphalt, a document 'Recycled and other Alternative materials', prepared by National Road Authority), construction companies, as well as other connected actors and stakeholders (e.g. designers, architects, large national infrastructural companies, e.g. railways, motorways etc), are in general still less interested in such products. The construction sector in Slovenia is very conventional, using traditional materials, which properties are well known and abundant (e.g. virgin aggregates). There is also general reluctance of using SRM-based products and there are different arguments for this, e.g. higher costs of conformity assessment, heterogeneity of materials, poorer performance etc. A high priority was recognized for education and promotion of usage of SRM-based materials in construction which is also part of CINDERELA project.

The major interest of users of sewage sludge-based geotechnical composites are: (a) lower prices than virgin materials and (b) local availability of materials (low costs of transport). Users of sewage sludge-based geotechnical composites are usually also producers of sewage sludge-based geotechnical composites, which are built in in-situ by mixing sewage sludge with appropriate waste-based binder (e.g. different ashes) at optimal moisture for compaction and sometimes with other components (e.g. recycled aggregate).

This group of actors is influenced by different other stakeholders:

- Decision makers, policy makers, legislators, who are developing policies, legislation and

[64] http://pisrs.si/Pis.web/pregledPredpisa?id=ZAKO6535

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administrative procedures for using SRM-based construction products, including demand side measures such as GPP, taxes for natural materials, etc.;

- Investors and architects, which creates pull for use of SRM-based construction products;
- Experts, who are developing guidelines and the latest state-of-the-art for constructing with SRM-based construction products;
- NGOs, environmental organizations, general public and media, which create public opinion and grants social acceptance of SRM-based products.

7.2.3 Activity and value creation

Sewage sludge producers are responsible for wastewater treatment, in which sewage sludge is produced. All sewage sludge producers are obliged to stabilize and hygienize the sewage sludge. Most of sewage sludge in Slovenia is only mechanically dehydrated and hygienized with lime.

More complex treatment of sewage sludge has only JP VO-KA. The result of this treatment is pelletized sewage sludge with more than 90wt% of dry matter in the form of 2-4 mm large pellets. Such form of treated sewage sludge is easier to transport and has higher calorific value. The plant at JP VO-KA (Figure 29) was structured with the purpose of production of solid fuel for co-incineration (R1). In the past the material was used in the cement production plant Salonit Anhovo however discussion at the workshop at ZAG showed this is not the case anymore due to too low calorific value in comparison with needs of cement producer and presence of PTE, which are not able to properly capture during incineration. For the JP VO-KA processing of sewage sludge means decrease of costs for handing over waste though they needed to invest into processing infrastructure. Here some costs are decreased but investments costs for treatment plant are quite high.

Based on consultation with stakeholders at the workshop, currently in Slovenia the largest profit is created in the group B, especially among sewage sludge collectors, transporters, brokers and dealers. This sub-group of actors does not perform any additional activities with material and have minimal costs. It was assessed that large operation of sewage sludge handling and management are outside Slovenia, mostly in Hungary. There is some ambiguity regarding the final destination in this material flow; sewage sludge producers getting coordinates of the treatment but they lack information on final usage of processed waste. Participants at the workshop thought that processed digestive is used as fertilizer on agricultural land.

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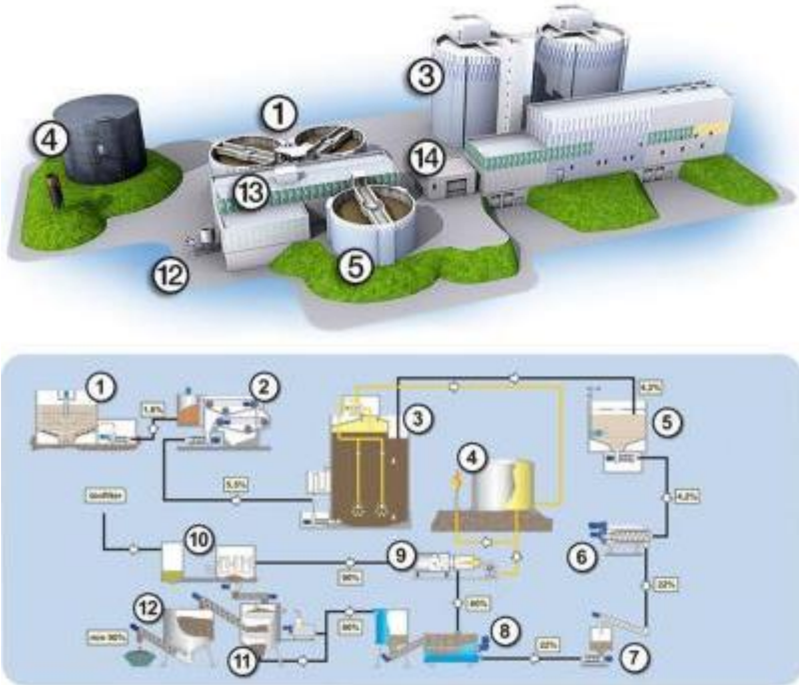

JP VO-KA

- 1 – primary densificator,
- 2 - pressure densificator,
- 3 – rotter,
- 4 – gas holder,
- 5 – secondary densificator,
- 6 – centrifuge,
- 7 – wet silos,
- 8 – sludge mixer,
- 9 – drying drum,
- 10 – filter,
- 11 – sieve,
- 12 – silo of final product,
- 13 – facility for machined treatment,
- 14 – facility for reception of sewage sludge)

Figure 29: Sewage treatment plant at public utility company in Ljubljana[65]

Sewage sludge disposal operators are either landfilling (D1) or incinerating (D10) sewage sludge usually without any additional pre-treatment. Sewage sludge recovery operators are producing new materials from sludge either through different operations of recycling into organic substances with simultaneous biogas production (R3), into inorganic substances by mixing with puzzolanic or other binding additives (R5) or other processing.

Product user is using product according its intended use and producer's declaration.

7.3. Potential new value chain

7.3.1 Technological developments

The latest technological developments for sewage sludge treatment are described in the latest BAT (Best Available Techniques) documents such as:

- BAT Reference Document for Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector[66];
- BAT Reference Document for Waste Treatment[67];
- BAT Reference Document for Waste Incineration (final draft)[68].

Above stated documents are focusing either on sewage sludge treatment at the site of the production of waste such as thickening, stabilisation, dewatering and drying or on techniques of recovery through fuel generation, and recycling of organic substances. Recovery of inorganic

[65] Source: VO-KA
[66] http://eippcb.jrc.ec.europa.eu/reference/BREF/CWW_Bref_2016_published.pdf
[67] http://eippcb.jrc.ec.europa.eu/reference/BREF/WT/JRC113018_WT_Bref.pdf
[68] http://eippcb.jrc.ec.europa.eu/reference/BREF/WI/WI_BREF_FD_Black_Watermark.pdf

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materials, such as for example recycling into SRM for construction sector, is less emphasized in these documents; still it is mentioned as one of the BAT technologies.

Overview of the different techniques for treatment of sewage sludge to its final recovery is depicted in 'Technical guide on the treatment and recycling techniques for sludge from municipal waste water treatment' published by German Environment Agency[69] (Figure 30). Recycling into geotechnical composites is not given in this picture, obviously due to lack of common practice.

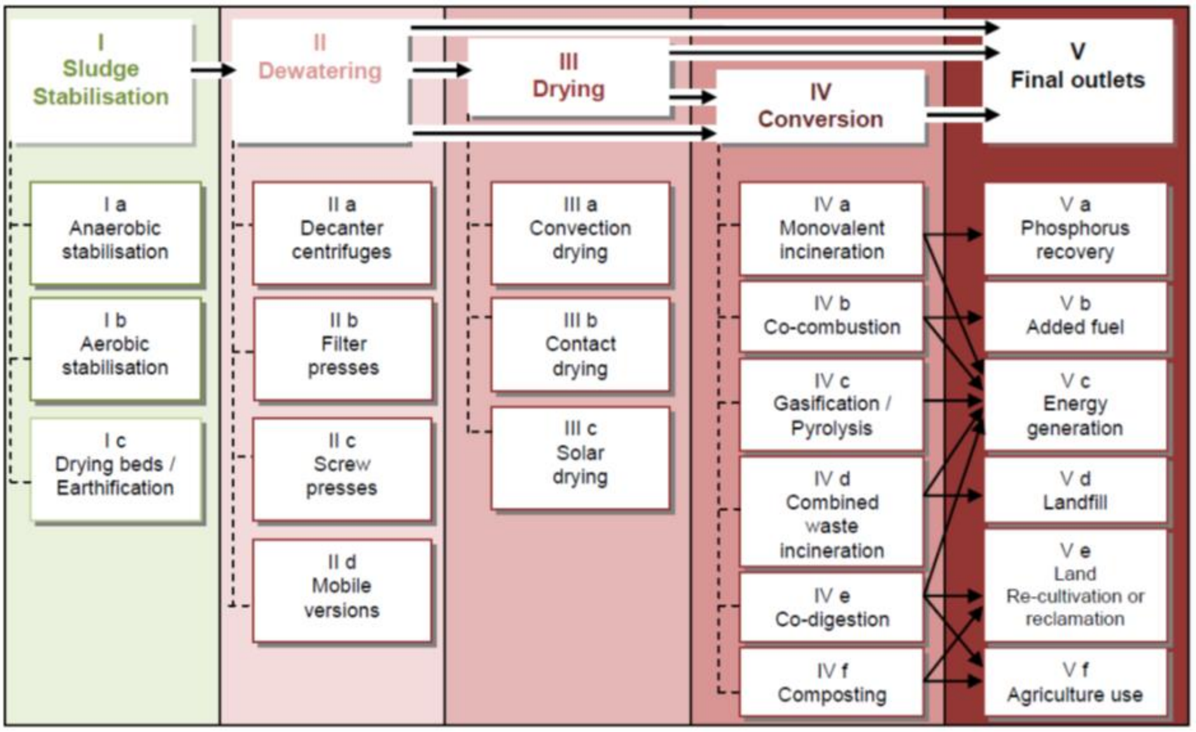

Figure 30: Overview of different treatment techniques of sewage sludge into final outlets (Source: UBA)[57]

In the frame of CINDERELA project we are looking for new sustainable usage of recycled sewage sludge as SRM-based construction product, which is currently less applied in the studied area but is also relatively new practice around Europe. The approach is well aligned with waste management hierarchy[70] which favours recycling before recovery and disposal.

Overview of potential usages of sewage sludge in construction sector is given by Swierczek et al. 2018 [71]. Recycled sewage sludge is the most often used in construction sector in the form of low-strength composites, which can be used in geotechnical applications (backfills, bedding material, landfill covers etc.) or in road construction (subgrade layers or shoulders). Pavšič with co-workers (2014)[72] is describing an example of such recycled sewage sludge-based composites and their properties. In the process of recycling, the sewage sludge is mixed with additive (which can be also waste-based) with puzzolanic or hydraulic properties (e.g. ashes with high content with reactive calcium). The mixture is compacted at the optimal moisture, which enable obtaining maximal density of the composite. During the curing of composites strengths are increasing and due to high pH and

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[69] https://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/technical_guide_on_the_treatment_and_recycling_techniques_for_sludge_from_municipal_waste_water_treatment_0.pdf

[70] http://ec.europa.eu/environment/waste/framework/

[71] Swierczek, L., Cieslik, M.B. & Konieczka, P. 2018. The potential of raw sewage sludge in construction industry. A review. Journal of Cleaner Production 200, 342-356

[72] Pavšič, P., Mladenovič, A., Mauko, A., Kramar, S., Dolenec, M., Vončina, E., Pavšič Vrtač, K. & Bukovec, P. 2014. Sewage sludge/biomass
ash based products for sustainable construction. Journal of Cleaner production, vol, 67, 117-124.

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temperature biological activity is also inhibited. Analysis of chemical compositions of water leachates also show that such composites are inert due formation of new minerals which inlocks PTE and as such do not pose threat to environment. In order to increase sustainability of composites they can also be mixed with recycled or manufactured aggregates (Figure 31).

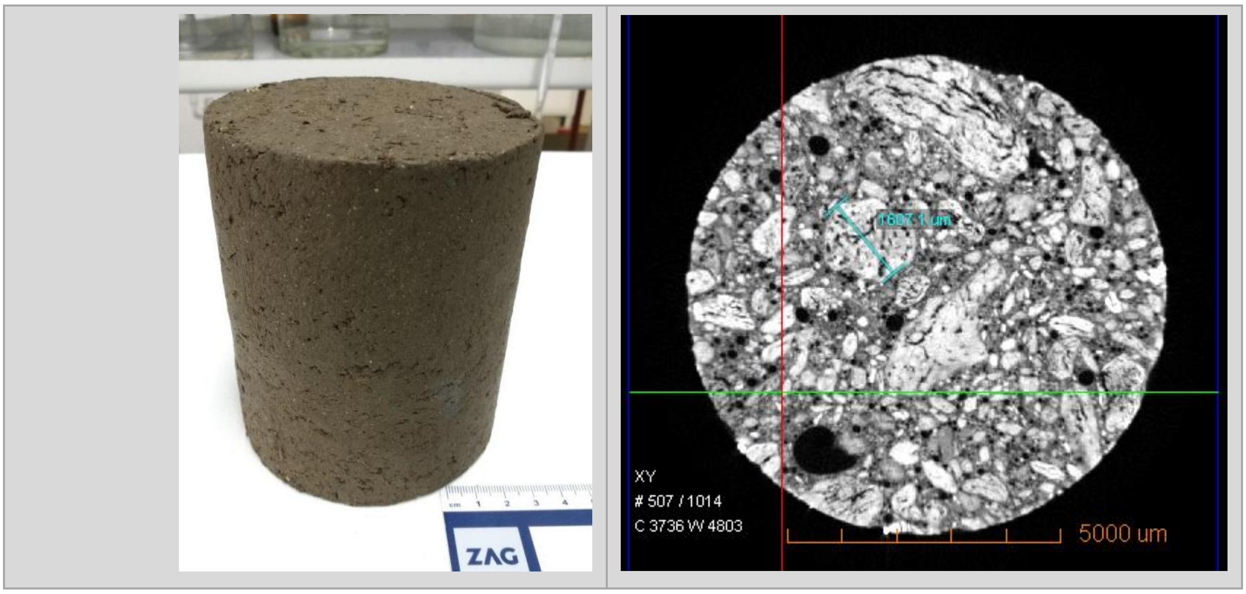

Figure 31: Sewage sludge based composites (left) and tomographic cross section of 28 days old composite with addition of sewage sludge

The final product (geotechnical composite) is put on the market with Slovenian Technical Approval[73] through which it fulfils requirements of construction product legislation. In order to fulfil requirements for safety in use for the usages outside landfill AVCP system 1+ is applied, if used outside the landfills. In this system the notified body issues certificate of constancy of performance of the construction product through a) initial inspection of the manufacturing plant and factory production control; and b) continuous surveillance, assessment and evaluation of factory production control while producer is maintaining factory production control and carries out testing of samples in the frame of factory production control.

According to Swierzcek et al. other application than geotechnical composites are also possible for recycled sewage sludge such as usage in cement composites as fine aggregate or filler, usage in alkali activated composites, sintering in light aggregates or ceramics. Nevertheless, these usages are usually more energy demanding or/and smaller volumes of sewage sludge can be used. None of the latter has been implemented in Slovenia yet.

7.3.2 Determination of potential impact points

Positive impact points in current value chains, which favour creation of new value chain with sewage sludge-based geotechnical composite, are following:

- Push from sewage sludge producers, which currently pay for waste collection up to 200 euro per tonne of sewage sludge;
- Closing of existing markets for processed sewage sludge due to higher environmental demands (e.g. prohibited use for land treatment for agricultural purposes), unsuitability of materials (e.g. too low calorific value and presence of PTE for use in cement kiln), unpredictable volatile markets, non-transparency and non-traceability of material flows etc.

[73] http://www.zag.si/si/tehnicna-soglasja

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Negative impact points in current value chains, which hinder creation of new value chain with sewage sludge-based geotechnical composites, are following:

- Strong brokers, dealers and collectors lobby, which have currently the highest financial added value in the value chain;
- Sometimes exclusive legislation and complex administrative procedures;
- Lack of national guidelines on sewage sludge processing and use of sewage sludge-based materials based on BAT and the latest state-of-the art;
- Poor reputation of using SRM from recycled waste and poor social acceptance of general public and local communities;
- Lack of GPP guidelines for use of sewage sludge-based materials.

7.3.3 Identification of end market

In the frame of CINDERELA project we are focused on construction sector, which could use recycled sewage sludge-based construction products such as sewage sludge-based geotechnical composites. The biggest potential for use of such products on the current EU construction market is in high demand for sustainable construction materials with low environmental impacts. This is supported with increasing interest for construction products with environmental declarations (e.g. EPD – Environmental Product Declaration) which proves environmental (social and economic) benefits of products during their whole life span.

The existing enablers of sustainable Slovenian construction market are established paths of putting sustainable products on the market (e.g. also through Slovenian Technical Approvals), high awareness among policy makers and to certain level, established demand side measures such as GPP (but only for road construction, maintenance and rehabilitation); while the barriers are related to reserved attitude towards sustainable products among final users and investors and poor acceptance of recycled product not only among general public but also among some decision-makers. The biggest advantage for using SRM-based construction products (new value chain pulls) would be lower price of SRM based construction products with the suitable properties according to intended usages similar or better to conventional products.

7.3.4 Socio-economic and environmental context

Table 26 presents results of PESTEL analysis, carried out at the ZAG workshop with the barriers and enablers in the current value chain, which can hinder / foster its transformation into new value chain.

Table 26: PESTEL analysis Slovenian case

Political	• Regulation is established but sometimes exclusive and not aligned with the practice. (obstacle) • No dialog between decision-makers, legislators and actors along the sewage sludge value chain. (obstacle) • Cross-border agreements are not functional in the practice (the final destiny of the sewage sludge shipped to other EU countries is not known to sewage sludge producer). (obstacle) • No demand side measures (e.g. GPP, subsidies) for use of sewage sludge-based construction products. (obstacle)
Economic	• Established markets are important. Currently, there is no final market for solid fuel. (obstacle) • Construction sector is in high demand of raw materials (locally available would be preferable). (enabler) • Low-price and abundance of primary raw materials, e.g. virgin aggregate. (obstacle) • Well functional SRM-based construction market in Slovenia still needs to be

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	established. (obstacle/opportunity) • Little encouragement for use of SRM-based construction products among investors and other stakeholders. (obstacle) • Construction sector was mostly hit in the last crises. New crises could do the same. This could also be opportunity for new technologies. (incentive)
Social	• Very important is social acceptance of SRM-based products. Generally, there is mistrust against such products despite of established policies on circular economy in Slovenia. (obstacle) • Media can have important influence on implementation of circular economy. (obstacle or barrier) Fact-based responsible reporting is needed. • Populism. Local governments establishing negative pressure presenting recycling company or SRM-based product producers as polluters. (obstacle) • Lower sustainable awareness among general public and industry. (obstacle) Education and awareness rising of sustainable practice is therefore very important. Knowledge on use of sewage sludge-based construction products and practice already exist. (enabler)
Technological	• Dissemination of BAT is very important as well as lifelong learning and education. Knowledge exists. (enabler) • There is interest for new technologies. (enabler)
Environmental	• Negative social pressure (social acceptance of new recycling technologies) is very strong. (obstacle) • There is a gap between policies and actual practice. (obstacle) • A gap between awareness among general public and industry about environmental responsibility and sustainable acting. (obstacle)
Legal	• Legislation is not harmonised among individual member states. (obstacle)

7.3.5 Overview of potential new value chain

The potential new value chain (Figure 31) consists of at least four actors:

- Sewage sludge producer, which is usually manager of wastewater treatment plant;
- Sewage sludge transporter,
- Sewage sludge-based geotechnical producer, which is usually also constructor (product user);
- Product User, i.e. construction company, which places composite according to the order of investor and Slovenian Technical Approval.

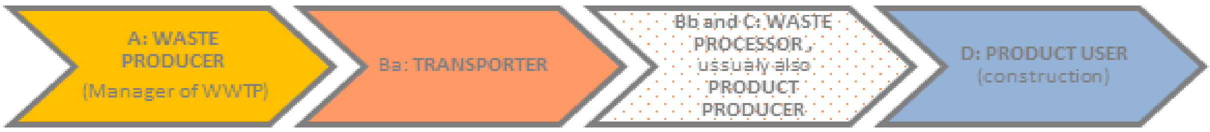

Figure 32: New value chain of recycling sewage sludge into geotechnical composite.

Due to the specifics of material several roles of actors can be merged (e.g. waste producer can be also waste processor / product producer and final user, or waste processor can be also transporter, product producer and final user (construction company which places the product).

The geotechnical composite is produced in-situ (Figure 33) with mixing of sewage sludge with suitable binder and compacting at optimal humidity. SRM-based construction product is put on the market through Slovenian Technical Approval under AVCP system 1+ (if product is used outside the landfill) or less strict system (AVCP 4) if product is used on the landfill as cover.

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Figure 33: Example of in-situ mixing of binder with waste for production of geotechnical composite

7.4. SWOT analysis

Table 27 represents conclusions of the sewage sludge value chain study in Slovenia in the form of the SWOT analysis.

Table 27: SWOT analysis Slovenian case

Strengths	Weaknesses
• Existing practice of sewage sludge dewatering at the sewage sludge producer site which decreases costs of transport and enhances handling of the waste. • Strong pull from the sewage sludge producers for change (establishing clearer procedures, legislation, new value chains with decrease costs of handing over the sewage sludge). • Publicly available and well implemented national databases on waste.	• Sewage sludge is transported in other MS country. Scarce information about the final destiny of the waste. • No unified management plan / strategy on the national level. • Difference between Plan for waste prevention and actual situation (plan is favouriting incineration, which is practically not existing) • High costs of collection and transport, long value chains and many actors, without actual improvement of material
Opportunities	**Threats**
• Lower costs of management in the case of recycling into SRM-based construction products. • Already existing practice of production of sewage sludge-based geotechnical composite. • Existing knowledge and experiences with material. • Relative simplicity and ease of recycling into geotechnical composites. • Approved better environmental impact (LCA). Lower environmental impacts (use of several wastes, shorter transport distances…). • Sewage sludge in geotechnical composites is stabilized and inertized.	• Poor transparency and traceability of cross border material flows (threat of illegal usage or treatment of sewage sludge) • Poor dialogue between legislator and actors of value chain (especially Waste Producers).

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7.5. Conclusion

7.5.1 General findings

Sewage sludge-based geotechnical composites have large potential in construction especially in the form of low-strength composites, which can be used in geotechnical applications (backfills, bedding material, landfill covers etc.) or in road construction (subgrade layers or shoulders). Their potential is due to sewage sludge local availability and abundance, low cost, easy handling with conventional equipment, better environmental performance due to short routes and use of other waste-based materials, existing knowledge and experiences with the product, and comparable properties with virgin materials for the same usage. Never the less there are some critical issues in implementing sewage sludge-based geotechnical composites value chain on the broader level. These are:

- Low interest for SRM-based materials among investors (even public ones), architects/designers and construction companies;
- Strong lobby of certain actors in existing value chain;
- Public opposition in using SRM-based material in local environment (NIMBY effect – Not in my backyard).

On the other hand, the major pulls for creating new value chain is on the side of the sewage sludge producers, who are not satisfied with the current situation and are willing to act for change. This is well supported with national policies for CE and existing knowledge and practices on CE business models based on recycling.

7.5.2 Recommendations

CINDERELA project has already important role in creation of environment for better management of sewage sludge in Slovenia, including implementation of new sewage-sludge based value chain for construction products. Sewage sludge-based composites will be demonstrated also in WP6 of the project. During the CINDERELA workshop in Ljubljana, organized by ZAG and NIGRAD, an initiative was raised by participants for creation of Action Plan for sewage sludge treatment. Currently, a letter is prepared to the Ministry of the Environment and Spatial Planning, together with Chamber of Public Utilities (branch association of Chamber of Commerce and Industry of Slovenia), large sewage sludge producers, ZAG and other entities (see Annex 5). It is expected that this will result in better communication between legislative bodies, national decision makers and stakeholders of sewage sludge value chains and implementation of more sustainable, transparent and traceable sewage sludge-based value chains.

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8. SPANISH CASE STUDY

8.1. Introduction to the case study

8.1.1 Geographic region

The Region of Madrid in this case of study (Figure 34), and most specifically the Henares Corridor is a residential, industrial and business axis developed in the fertile plain of the Henares River around the Northeast highway and the Madrid-Barcelona railroad between the Spanish cities of Madrid and Guadalajara.

It includes highly industrialized cities such as Coslada, San Fernando de Henares, Torrejón de Ardoz, Alcalá de Henares, Azuqueca de Henares and Guadalajara, which constitutes an urban agglomeration of more than 600,000 inhabitants, and an urban industrial continuum with industrial and business parks that they are developed around the main axes of communication.

The productive actions of this region has been centralized during decades in a full industrial and construction sector which activities have been producing great amount of industrial and CDW which has not been recycled as we have the possibility nowadays.

Figure 34: Madrid area

In comparison, CDW data in the Basque country in the north of Spain, which was the study case in CINDERELA D3.1 (Figure 35), was also studied. The Basque Country is one of the most important industrial concentrations in Spain. The industrial production is diverse. All of the activities from metals, such as the production of steel and machine-tools, are very important. However, other sectors such as the chemical and petrochemical industry and refineries are also noteworthy, accounting for a very significant part of the region's Gross Domestic Product (GDP). The strongest industrial sectors of the Basque economy are machinery, aeronautics and energy.

Of the total value of waste generated in the Basque Country (excluding CDW), 3.45 million tonnes, or 71.54%, are generated in the industrial sector. Out of 3.45 million tonnes 1,471,125 tonnes or about 43% were landfilled. Another intensive sector in the generation of waste is the construction sector,

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with 1.26 million tonnes generated in 2016, of which 12.32% were landfilled.

Figure 35: Basque country area

8.1.2 Assessed waste stream

For this case, following the nomenclature of the EWC the selected waste fraction has been the one with the code 17 09 04 (Mixed construction and demolition wastes other than those mentioned in 17 09 01, 17 09 02 and 17 09 03). Group 17 09 04 considers non-hazardous waste.

The selection of this waste stream is due to the great economic impact that has been in the construction sector and the production of construction materials, as well as the extraction of their raw materials for the sector in Madrid – Henares area for decades. Due to the desertion of a great amount of locations in the Spain devoted to construction activities caused by economic recession in construction sector in 2008, we can find frequently tailings of different kind of CDW as concrete debris, asphalt, excavated stone or even scrapyards from demolitions or not finished and abandoned construction structures.

These waste streams are frequent waste fraction also in other regions of Spain like in Basque country. During the first phase in CINDERELA WP3 ‘Data collection’ (D3.1), the list of the top 13 waste streams in Basque Country, presenting the 80% of the total volume of the waste streams defined in the EWC CINDERELA List (Table 28), were selected. Six waste streams out of 13 belong to Group 17 (CDW).

Table 28: 80% waste streams in Basque Country and annual production (in tonnes) for 2016

EWC	Description	Total (t)	Álava	Bizkaia	Gipuzkoa
12 01 01	ferrous metal filings and turnings	621,313	75,543	188,875	356,895
10 02 02	unprocessed slag	517,099	69,664	272,207	175,228

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EWC	Description	Total (t)	Álava	Bizkaia	Gipuzkoa
17 01 01	concrete	317,560	60,011	143,653	113,896
17 01 03	tiles and ceramics	237,108	44,808	107,259	85,041
19 12 12	other wastes (including mixtures of materials) from mechanical treatment of wastes other than those mentioned in 19 12 11	217,639	135,092	41,748	40,799
17 02 02	glass (150107, 160120, 191205)	206,318	30,194	100,702	75,422
20 01 38	wood (170201; 200138; 30301; 150103; 191207;150103;150103)	149,148	19,532	59,074	70,541
17 03 02	bituminous mixtures	113,948	21,534	51,546	40,869
03 03 09	lime mud waste	89,701	0	67,293	22,408
10 09 08	casting cores and moulds which have undergone pouring other than those mentioned in 10 09 07	80,846	13,628	29,789	37,429
10 02 10	mill scales	74,320	12,870	18,556	42,893
17 09 04	mixed construction and demolition wastes	63,248	11,952	28,611	22,685
17 01 02	bricks	58,347	11,026	26,394	20,927

This waste stream has been selected concerning its potential for reuse and recycling in the construction sector. Considering that large quantities which are generated in area are not taken in advantage, it has been stated that this waste stream can be useful in relation to the aims of the CINDERELA project (especially in demonstration projects built in WP6).

8.1.3 Strategical approach

The strategy to develop a new value chain is to fix the problem that when a facility or a building is demolished, no advantage in the form of recycling into valuable products is taken from produced CDW.

In Madrid region, all CDW Processing Plants are designed to obtain recycled aggregates from the mineral fraction of the CDW. In fact, the CEDEX (public entity for Public Works Experimentation and related studies) has published a catalog of recycled waste that can be used in construction, where recycled CDW are included.

In Spain, for example, the technical specifications that refer to the use of recycled aggregates in the construction of infrastructure or buildings are included in the UNE-EN standard (12620 – Aggregates for concrete, 13043 - Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas 13242 - Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction, and 13285 - Unbound mixtures - Specifications), the technical specifications and general specifications for works and roads (PG3) and the conservation one (PG4) . The CEDEX website offers different examples of application in public roads construction .

Although there are normative for CDW recycling and applications, according to the Madrid region public information, during 2015, 40%wt of the CDW collected in the Processing Plants were discarded in a controlled landfill .

The problem with the recycled aggregates is that, as the workshop attendants clarified, it is more

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expensive than virgin aggregate due to the treatment and indirect cost applied to them, so the market that belongs to private construction companies that buy material for their own constructions and in some case contests for public construction, consider only to buy the material with the lower price and so, buying the primary material one.

The idea of creating a new value chain is to develop a model in order to give value to this waste and make it possible to create new products and applications that can fit in the market and be a quality competitor to virgin materials.

The strategical approach towards assessment of the current and new value chains of 17 09 04 was gathering information based on a dedicated workshop (Figure 36) which has been organized on 6.3.2019 at the CTC premises (third link party of AEDHE). The main aim of the workshop was to assess the current and new value chain for the mixed CDW, to establish a discussion session among the workshop participants (Table 29) and to discuss the preliminary assessment of mixed CDW value chain done by the Spanish partners in the CINDERELA project (AEDHE, FGP and TECNALIA).

Figure 36: Discussion of the two groups during the workshop 'Use of secondary raw materials in construction sector', organized by AEDHE and CTC on 6.3.2019

Table 29: Participants of the Madrid workshop

Stakeholder name	Main activity	Activity description
ANEFHOP	Precast concrete manufacturing	National Association of precast concrete manufacturers
FUNDACION SOSTENIBIILDAD	Non-profit foundation	Private entity which works for an environmentally more sustainable and socially fairer model of economic development.
GRÚAS CORREA	Crane services supplier	Rental of cranes and construction machinery, transport services and roadside assistance
ETRECSA	Waste transport	Rental of waste containers
BOETCHERR IBERICA	Rubber materials manufacturing	Manufacture of pulley coating, ebonite and polyurethane rollers, rollers for Graphic Arts and for the Paper Industry and friction wheels.
SURGE AMBIENTAL	Waste treatment	Waste management activities and supporting services regarding with waste management plans
COMUNIDAD DE MADRID	Madrid regional Government	-

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MANCOMUNIDAD DEL ESTE	Waste treatment	Public entity for the management, treatment and disposal of urban solid waste from the Henares corridor
CUATRO PALOMAS	Ceramic products manufacturing	Manufacture of bricks, tils and other ceramic products
FERROVIAL SERVICIOS	Waste treatment	Design, maintenance, operation and integral management of public and private transportation infrastructures, environment, industrial, natural resources (oil, gas and mining) and utilities (water and electricity), and in the provision of facility management services (maintenance of infrastructures)

The outcomes of the workshop served to shed light over new business processes and are shown during the next chapters. Additional information about the workshop is presented in the Annex 6.

8.2. Current value chain

8.2.1 Material flow

The selected waste stream of mixed CDW is a mixture of materials generated when a building is demolished so its composition depends on the type of building from which has been generated. The waste streams usually include mineral fractions, plastics, metals and other kind of different materials.

In order to identify the type of companies that generate these waste streams, we used a 'mapping table' that links different economic activities with the waste generated by each of the activity. If we filter economic activities for EWC 17 09 04, the following NACE codes shown in the Table 30 are obtained.

Table 30: Economic activities that generated the CDW with EWC 17 09 04

NACE	Description
F-4110	Development of building projects
F-4120	Construction of residential and non-residential buildings
F-4211	Construction of roads and motorways
F-4212	Construction of railways and underground railways
F-4213	Construction of bridges and tunnels
F-4221	Construction of utility projects for fluids
F-4222	Construction of utility projects for electricity and telecommunications
F-4291	Construction of water projects
F-4299	Construction of other civil engineering projects n.e.c.
F-4311	Demolition
F-4312	Site preparation
F-4313	Test drilling and boring
F-4321	Electrical installation
F-4322	Plumbing, heat and air-conditioning installation
F-4329	Other construction installation

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NACE	Description
F-4331	Plastering
F-4332	Joinery installation
F-4333	Floor and wall covering
F-4334	Painting and glazing
F-4339	Other building completion and finishing
F-4391	Roofing activities
F-4399	Other specialised construction activities n.e.c.

Since official waste data for Madrid-Henares Corridor was not possible to obtain, we analysed number of companies and generated waste for the Basque Country and their regions, where around 13,000 companies which due to their activities (NACE codes identified in the Table 30), generate the 63,248 tonnes of the waste stream 17 09 04 (Table 31) in the three provinces of the Basque country.

Table 31: EWC 17 09 04 Waste generation (in tonnes) in the Basque Country during 2016

	Total (t)	Álava	Bizkaia	Gipuzkoa
Waste generated	**63,248**	11,952	28,611	22,685

There are 26 waste processors which are authorized to treat this waste stream in the Basque country (Table 32).

Table 32: Waste processor authorized for processing of 17 09 04 waste by the Basque Government

Company name
OBRAS PUBLICAS ONAINDIA, S.A.
UTE RCD GARDELEGUI 2005
BIRZIKLAPENAK BENTABERRI RECICLAJES, S.L.
CONTAINERS SUSPERREGI, S.L.
URKIONDO EKOLUR, S.L.
BIZKAIKO TXINTXOR BERZIKLATEGIA, S.A. (BTB)
ERLIA CONTENEDORES, S
GABIKA EXCAVACIONES, S.L.
JUAN RAMON ANASAGASTI, S.L
MUNGIA UGARTE, S.L
PALETS DEL VALLE, S.L.
HIERROS NAPARRA, S.A.
CONTENOR, S.L.
CARLOS SANTAMARIA, S.L.
CONTENEDORES ESCOR VITORIA, S.L.
ZORROZA GESTIÓN S.L.
ARREGI ETXABE JUAN JOSE, S.A.
BAÑU-ETXE, S.L.
CONTENEDORES SARASOLA, S.L.
EKOTRADE RCDS, S.L.
CONTENEDORES TXORIERRI, S.L.
CONTENEDORES VASCOS, S.A.

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Company name
GALDAMES KONTENEDOREAK, S.L.
MUGARRI RECUPERACION DE MADERAS, S.L.
PROSINOR, S.L.
TXARAKA KONTENEDOREAK, S.L.

In Madrid case, the Construction and Demolition Wastes Management Plan of the Madrid region for 2017-2024[74] describes the current flow of the CDW (Figure 37). According to the Madrid regional legislation, big construction activities are bound to classify and separate the CDW on-site before delivery at the waste management facilities, which requires the implementation of a separation system during the building activities. In case of small construction activities, this is not mandatory, and all CDW are delivered together, without previous classification. The CDW not classified on-site are delivered to Transfer Plants where classification is performed. Then, the classified CDW (including 17 09 04) is transferred to the Processing Plants which are authorized facilities for valorisation. In these Processing Plants crushing and sieving operations are performed to remove dangerous materials and light fractions from the CDW. Processing Plants capacity varies between 10 kilotonnes per year to 2.6 million tonnes per year, but around 70% of them have more than 50 kilotonnes per year of treatment capacity. All facilities are equipped to obtain recycled aggregate, and only a few for recycling other specific materials like gypsum or bituminous mixtures. The fraction of the treated CDW which cannot be set out in market as a new product due to the limitations of the treatment facility or due to the waste composition (if any) is discarded in a controlled landfill. Landfilled fraction of processed CDW represents 40%wt of the CDW collected in 2015. The CDW classified on-site are directly delivered at Processing Plants.

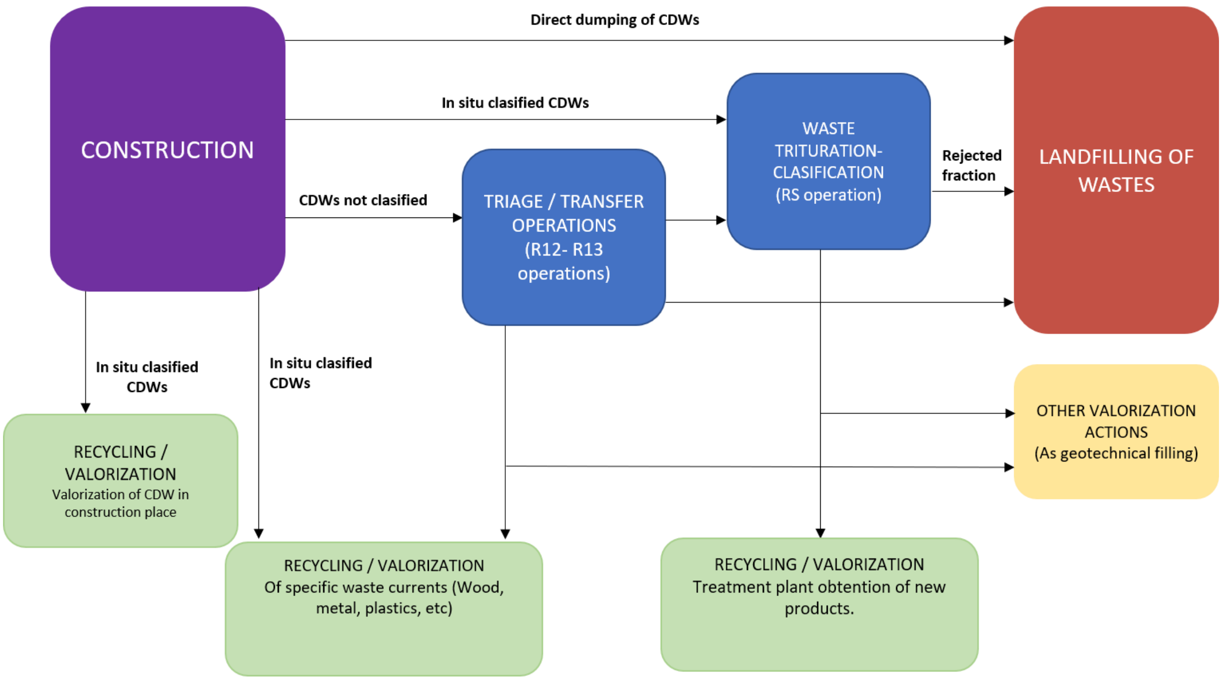

Figure 37: CDW flow in the Madrid region management system (Source: Ministry of Environment, Local Administration and Territorial Planning of the Community of Madrid)

[74] Document in phase of Public Information, part of the Environmental Strategic Study and first version of the Strategy of Sustainable Management of the Waste of the Madrid Region: http://www.madrid.org/es/transparencia/normativa/informacion-publica-del-estudio-ambiental-estrategico-y-version-inicial-estrategia-gestion

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There is scarce public information about the generation of the waste 17 09 04 in Madrid region by individual waste producer. The following figure (Figure 38) shows the CDW amount delivered in the Processing Plants in the Madrid region in the 2004-2015 periods.

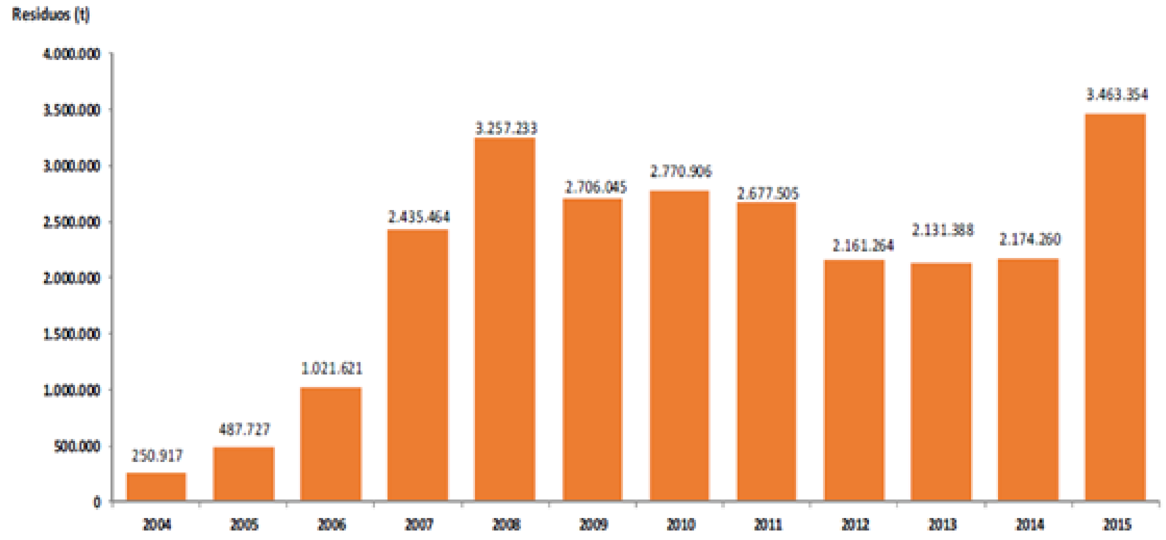

Figure 38: CDW delivered (in tonnes) in the Processing Plants in the Madrid region in the 2004-2015 period (Source: Ministry of Environment, Local Administration and Territorial Planning of the Community of Madrid)

The total amount of CDW delivered in the processing plants in the Madrid region is 3,463,354 tonnes for 2015, which is 3,239,279 tonnes not including 17 05 04 (soil and stones not contaminated). Considering the Madrid region population in 2015 (6,436,996 habitants), this means 538 kg per capita of CDW delivered at the Madrid region processing plants.

Regarding its spatial distribution within the region, it should be noted that most of the CDW recycling facilities are concentrated south of the municipality of Madrid, the Henares Corridor and municipalities of the metropolitan south (Figure 39). In the map, the dots indicate CDW's private treatment plants (blue dots) and publicly owned CDW's treatment plants (red dots).

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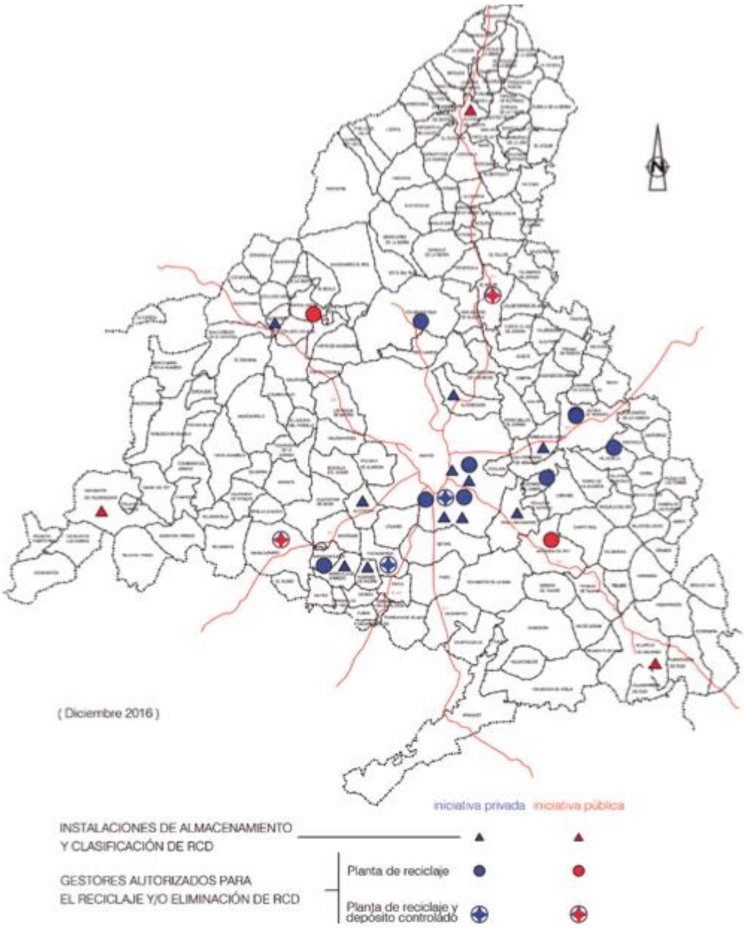

Figure 39: Authorized facilities for CDW management in Madrid region, 2016. Source: Ministry of Environment, Local Administration and Territorial Planning of the Community of Madrid

In any case, it should be noted that the typology of the CDW collected in the processing plants corresponds mainly to the EWC 17 01 01 (concrete), 17 01 07 (mixtures of concrete, bricks, tiles and ceramic materials) and 17 09 04 (mixed CDW). The CDW of the EWC 17 01 07 represent around 50wt% of the total amount collected in the processing plants. It is also observed that in recent years (period 2012-2015) the percentage of concrete input (EWC 17 01 01) has fallen by almost 10%, while that of mixed CDW (EWC 17 09 04) has increased by more than 10%. This increase in the generation or collection of 17 09 04 is related to the variation in the typology of construction works in recent years (decrease in civil works and increase in refurbishing) and is also related to the crisis in the construction sector and the fall of prices in many facilities, which has reduced the separate collection and does not allow the proper treatment of the CDW.

In addition, there are around 3,700 companies in the Madrid Region public data base that generate CDW. 26 of those companies are authorized to manage it (Table 33).

Table 33: CDW's processor authorized by the Madrid Government

Company name		
ETRECSA	CONTENEDORES NIDO S.L.	RECICLAJE Y CLASIFICACION DE RESIDUOS S.L.U.
ASFALTOS Y CONSTRUCCIONES ELSAN, S.A	CONTRA S.A.	RECICLAJES EN OBRA S.L.
GEDESMA, S.A	DERSA RECICLAJE Y GESTION S.L.	RECICLAJES GADARAI S.L.
SURGE AMBIENTAL S.L	GESTION DE RESIDUOS PAZ S.L.	SAINT GOBAIN DISTRIBUCION

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Company name		
		CONSTRUCCION S.L.
TRYOB OBRAS Y SERVICIOS, S.L.	HERMANOS SAN JUAN S.L.	SAINT GOBAIN PLACO IBERICA S.A.
TRANSPORTES Y CLASIFICACION DE RCD, S.L	JUAN CASTRO E HIJOS S.L.	SELECCION Y RECICLADO S.L.
TECNOLOGIA Y RECICLADO, S.L	MACOTRAN S.L.	SUMINISTROS RUFINO NAVARRO S.L.
SALMEDINA TRATAMIENTOS DE RESIDUOS INERTES, S.L.	MATERIALES Y AZULEJOS PETRI S.L.	
CESPA GESTION DE RESIDUOS S.A.	NORTOBRAMA S.L.	

Considering the previous summarized information, and although the exact amount of generated waste is unknown, the availability of the CDW in Madrid Henares area is obvious.

In Madrid region, 33 facilities are authorized to perform management activities with 17 09 04 CDW, from which, 7 are of public ownership (Table 34).

Table 34: Facilities authorized by the Madrid Government to perform management activities with waste 17 09 04 in the region on February 2019[75]

Company name	Authorized processes with 17 09 04 waste
CCR LAS MULAS, S.L.	Treatment
CESPA GESTION DE RESIDUOS, S.A.	Treatment
CONTENEDORES NIDO, S.L.	Classification and storage
CONTRA, S.A.	Classification and storage
DERSA RECICLAJE Y GESTION, S.L.	Classification and storage
GEDESMA, S.A. (7 facilities)	Classification, Treatment and storage
GESTION DE RESIDUOS PAZ, S.L.	Classification and storage
HERMANOS SANJUAN, S.A.	Classification and storage
JUAN CASTRO E HIJOS SC	Temporary storage
MACOTRAN, S.L.	Classification and storage
MATERIALES DE CONSTRUCCION RIFER, S.L.	Storage
MATERIALES Y AZULEJOS PETRI, S.L.	Classification and storage
NORTOBRAMA, SL	Treatment
RECICLAJE Y CLASIFICACION DE RESIDUOS SLU	Classification and storage
RECICLAJES EN OBRA, S.L.	Classification and storage
RECICLAJES GADARAI, S.L	Treatment
S. GOBAIN DISTRIBUCION CONSTR., S.L. (4 facilities)	Storage
SALMEDINA TRATAMIENTOS DE RESIDUOS INERTES SL	Treatment
SELECCION Y RECICLADO, S.L.	Treatment
SUMINISTROS RUFINO NAVARRO, S.L.	Storage

[75] Public Information from Madrid Regional Government: http://www.comunidad.madrid/servicios/urbanismo-medio-ambiente/listados-gestores-transportistas-residuos

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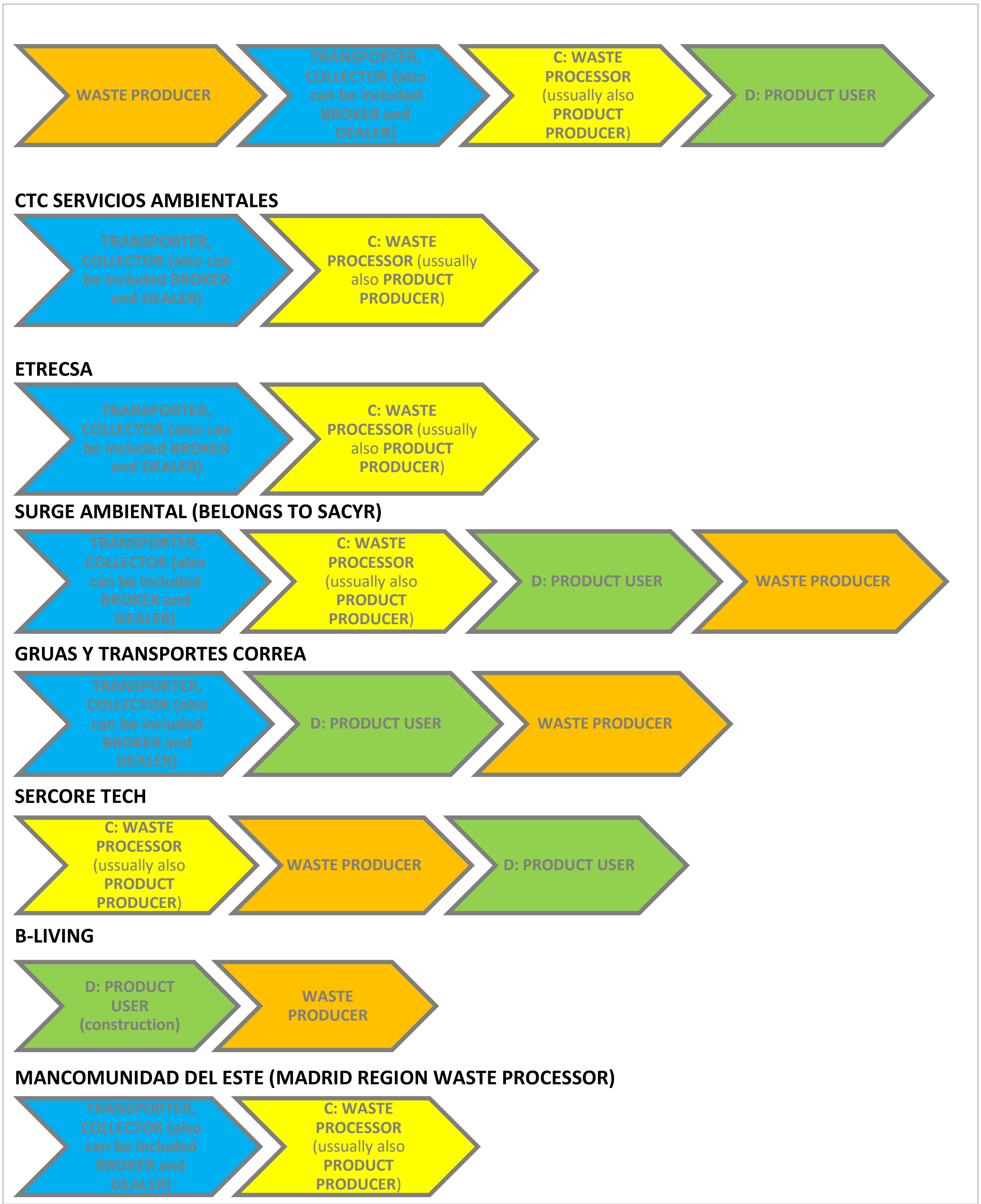
Company name	Authorized processes with 17 09 04 waste
SURGE AMBIENTAL S.L.	Treatment
TECNOLOGIA Y RECICLADO, S.L.	Transference classification and treatment
TRANSPORTES Y CLASIFICACION DE RCD, S.L.	Classification and storage
TRYOB OBRAS Y SERVICIOS, S.L.	Classification and storage

In Figure 40 roles of the companies participating the workshop are described. The order of activities is set for main activity on the left to the secondary ones towards right.



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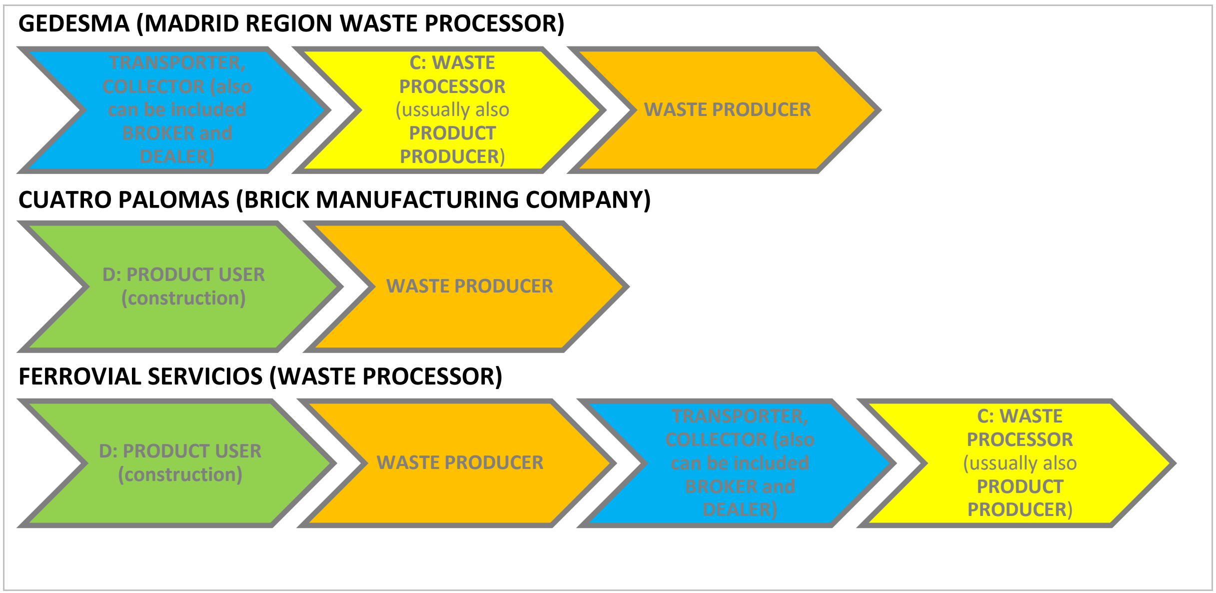

Figure 40: Roles of the participant at the CINDERELA workshop in Madrid in the CDW value chain

8.2.2 Stakeholders and their interests

There are multiple stakeholders in existing value chains (Table 35) such as companies involved in CD, companies for waste management and those dedicated to waste collection and transportation.

The companies involved in the construction sector are the ones that could take advantage of SRM for their activities if these SRM-based products fit the technical specifications needed and are cheaper to use than primary materials concerning price or/and benefit to use it.

We can also find some indirect stakeholders in assessed value chain such as policy makers who can impact creation new value chain by making regulations and implementing a fee/taxes system to those who do not use recycled materials. This would improve the valorisation and use of SRM-based construction products and punishing the fact of not doing a reuse or waste treatment process. The impact is also in the side of environmental organizations whose efforts to reduce waste and pollution will be recognized. Their interest is also revitalization of degraded areas, for which recycled aggregate could be used.

There is a great interest shown by the waste processors of CDW in creating a new value chain. At the moment, this type of materials has no outlet in the market. The opinion of stakeholders in the workshop was that it is difficult for recycled aggregates to be certified and affixed with CE. Also attestation is more expensive due to the treatment of mixed CDW and these indirect costs are included in the price of product for the final user. This makes recycled aggregates less competitive than the primary ones in the Spanish market. Based on this there is a great interest among stakeholders in getting new construction materials using regulated and certified SRMs and their use supported by the governments through different demand side measures since its use would contribute to elimination of large amounts of waste that are accumulated on degraded areas and represent a problem for the environment.

Table 35: Stakeholders with direct and indirect influence on actors

ACTOR	Indirect stakeholder	Influence
ACTOR A: CDW PRODUCER	MUNICIPALITY	Granting licenses for CDW waste processing
	CONSTRUCTION, DEMOLITION COMPANIES as well as CITIZENS	Paying industrial, CDW charge when producing and getting rid of it
	ENVIRONMENTAL	Public opinion about how waste treatment should be

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ACTOR	Indirect stakeholder	Influence
	ORGANIZATIONS, GENERAL PUBLIC, MEDIA	improved with new government policies and support
ACTOR B: WASTE PROCESSOR	SPANISH REGIONAL GOVERNMENT	Granting waste processing licences and verifying processes with annual reports
	MUNICIPALITY and PRIVATE COMPANIES	Owners of degraded areas, where recycled aggregates can be used in largest quantities. Impacting quality of the CDW classification by posing regulations.
	GENERAL PUBLIC, CITIZENS, MEDIA	Public opinion about how waste treatment should be improved with new government policies and support
ACTOR C: PRODUCT PRODUCER	SPANISH GOVERNMENT (MINISTRY OF INDUSTRY) / EUROPEAN BUREAU	Certification of production and quality to use in constructions in private and public market
	MUNICIPALITY	Owners of degraded areas, where recycled aggregates can be used in largest quantities.
	EXPERTS, WASTE PROCESSORS (VALORIZATION)	Developing guidelines for quality compliance of SRM-based products
	GOVERNMENT	Contribution to sustainability and good exploitation of resources
	LOCAL COMMUNITY	Public opinion. Granting social Licence.
ACTOR D: PRODUCT USER	DECISION-MAKER, LEGISLATOR	Construction legislation and use of SRM-based construction products.
	INVESTOR / BUYER /ARCHITECTS	Demand for sustainable and low-cost products.
	EXPERTS, BUSSINIES ASSOCIATIONS, CONSTRUCTION AND INDUSTRIAL COMPANIES	Guidelines for the using of new recycled based construction products.
	POLICY MAKERS	Policies for transition into CE and sustainable use of products.

8.2.3 Activity and value creation

The current value chain includes the CDW generators and the CDW processors while the aim of this framework is to find a potential new value chain which includes the recycled CDW-based product producers and the recycled CDW-based product user.

It is necessary to understand the different activities which take part in the actual current chain. A description of the recycling processes in some of the waste processors is given in the next paragraphs:

- Volbas: Volbas S.A., in Erandio Basque Country, is one of the authorized waste processors for the fraction 17 09 04. This kind of waste which includes mixed mineral fraction, plastics, wood, paper etc., is treated by different processes. Among these, it is worth mentioning the materials manual separation (wood), the separation by fan (plastics and papers) and the densiometric bath (gypsum). After that the mixed CDW is crushed and then used as recycled aggregate.

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- Bizkaiko Txintxor Berziklategia (BTB): BTB also collects CDW and generates recycled aggregate. However, the process in their plant is more complex due to the mixing of different waste streams to fabricate the recycled products. The process scheme can be seen in Figure 41.

The main adding value in the whole value chain takes place in the recycling process, since the value of recycled aggregate can be increased by modification of separation processes. The waste fraction is introduced into the recycling system. First there is visual control, following by a manual/mechanical preselection, then by a storage of separate materials and a classification of the different fractions of recycled aggregate according to the size of grains. Grain size distribution is important for the quality of the output product that can be sold on the market. The value is added when the impurities are removed creating recycled aggregates.

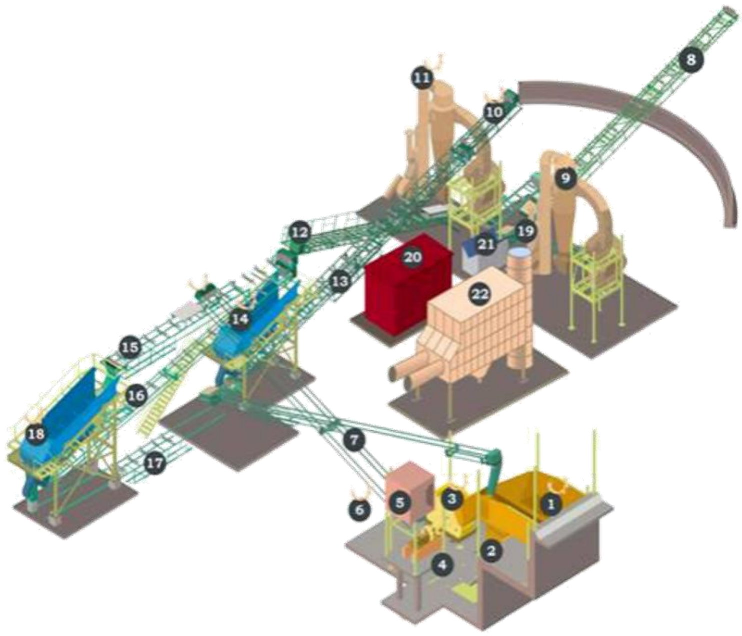

Figure 41: The recycling process of construction and demolition waste scheme in BTB plant in Vizcaya, Basque Country

8.3. Potential new value chain

8.3.1 Technological developments

The new value chain of SRM-based construction products will establish a new framework in which new technologies can be developed by the main actors, which can be focused on the mixing or joint use of different types of CDW as recycled aggregates to offer new possibilities to CDW and to create a valuable, and if it is possible, a cheaper construction products.

8.3.2 Determination of potential impact points in value chain

The increased volume of residues with controlled landfilling in Madrid region from 2013 to 2018 is related to the increase in the percentage of collection of mixed CDW (17 09 04) and the decrease of concrete based CDW (17 01 07) to CDW recycling plants. This means that CDW is currently not recycled in a way to obtain value or benefit from it, and that most part of it is still discarded due to presence of the impurities and non-mineral components. The possibility of creating new value chain of SRM-based construction products would significantly impact the volumes of landfilled CDW in controlled landfills, which would be reduced due to the new value chain.

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The creation of a new value chain will not only give a new life to abandoned (illegally dumped) CDW but it will create opportunity for degraded areas to be revitalized and become a new valuable asset.

Within this new value chain, a new sustainable model will be created in terms of new product producer that use new techniques to develop new materials and new users or new clients for the final product. The model will provide environmental benefits as it will help to decrease extraction and depletion of virgin materials.

Enablers for the creation of new value chain:

- Technology innovations providing new applications for the recycled CDW;
- Favourable legislation that increase the mandatory percentages of recycled materials used in construction;
- Financial incentives to use SRM-based construction products.

Barriers for the creation of new value chain:

- Fragmented supply chain (in the less densely populated areas of the north, east and west of the Madrid region where there are no treatment facilities for this type of waste);
- Short-term thinking, also in the sense of creating short-term profit;
- Cost and difficulties associated to the 17 09 04 recycling due to the impurities and non-mineral fractions;
- The composition of the CDW differs qualitatively depending on the original materials used for the demolished facilities.

8.3.3 Identification of end market

The market where these SRM-based products can be sold directly depends on the processed CDW. In an overall approximation, the industries which will need them and actually use, are those who process them to create construction materials used finally to create bricks, concrete or similar. Recycled aggregate based on mixed CDW could be used for foundations mixed with concrete or other materials to reinforce the construction settlement. The product that can be developed with this kind of processed waste will be defined by the technology available.

8.3.4 Socio-economic and environmental context

A PESTEL analysis (Table 36) was carried out for a better understanding of the current value chain that was presented during the workshop that took place in Madrid.

Following the PESTEL analysis, the social and economic implication of creating a new value for the CDW will take advantage of a great amount of not used resources that will create new products to be introduced in the market. This will help the economy of the region and give a new life to the degraded areas where those waste are illegally dumped.

In terms of environmental impact, it will reduce the extraction and depletion of primary materials. Due to locally availability of SRM-based construction products it can also decrease environmental impacts due to short transport routes. This will create a sustainability model that will help to preserve the ecosystems and environment having a profitable model.

Table 36 presents results of PESTEL analysis with the enablers in the current value chain, which can hinder / foster its transformation into new value chain.

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Table 36: PESTEL analysis Spanish case

Political	• Europe 2020: Strategy for smart, sustainable and inclusive growth. • Roadmap towards an efficient Europe in the use of resources. • VII Environmental Framework Program 2020 • Towards a Circular Economy: a zero waste program for Europe • Close the circle: an EU Action Plan for the Circular Economy. Proposals for modification of several Directives. • Communication from the European Commission: Strategy for plastics • Prevention and waste management plan of the CAPV 2020 (enablers)
Economic	• Positive GDP variation in Spain from 2014 to 2018. (enabler)
Social	• 2011 Basque country region Eco barometer. Greater awareness of citizenship in relation to the environment. This could be extended to whole Spain. (enabler) • Generation of 'green' jobs. (enabler)
Technological	• Research lines in production and construction technologies. (enabler) • GDP destined to – Research, Development and Innovation (RDI) in the Basque country, has increased since 2016 (in 2017 there was an increase of 5.4%).(enabler) • New technologies for the construction sector: 3D printing, self-repairing structures, etc. (enabler) • IHOBE – Guideline for the use of recycled material in construction. (enabler) • DELOITTE- Construction and Demolition Waste management in Spain (enabler)
Environmental	• The construction sector is the world's leading consumer of natural resources and raw materials. (enabler) • In Europe, the production of buildings represents an energy consumption of 40-45% in society. (opportunity)
Legal	• ORDER of January 12, 2015, of the Minister of Environment and Territorial Policy, which establishes the requirements for the use of recycled aggregates from the recovery of CDW. (enabler) • DECREE 112/2012, of June 26, which regulates the production and management of CDW. (enabler) • BOE TO 2011-13046: Before 2020, the amount of CDW destined to the preparation for the reuse, recycling and other valuation of materials. (enabler)

8.3.5 Overview of potential new value chain

The result of creating a new value chain focused on the valorisation of CDW will promote the creation of new technologies and business models to the Waste processors that will be used to achieve and increase the market creating new clients that could be those construction companies that use it for their current activity or new ones that use this SRM to develop new sustainable secondary products from them. This valorisation of CDWs could consider a new economic and environmental impact to the region and the market contributing to the sustainability of the existent natural resources.

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8.4. SWOT analysis

In the workshop that took place in Madrid, participants from different fields and steps of the value chain were present. They contributed with information and experience to carry out the SWOT analysis (Table 37).

Strengths	Weaknesses
• Growing of technical knowledge. • Tested qualities of SRMs. • Price will depend on how much SRMs are used (the more used, the cheaper they will be). • CE enriches market. • No problem on growing costs on producers or extractors of materials. • SRM production cost is not affected by the potential grow of the costs of traditional construction products manufacturing or the raw materials extraction costs. • Use of SRM is the same than in case of conventional products for similar applications. • High residues availability coming from old constructions and facilities. • For new construction works, in-situ separation is currently mandatory in Madrid region.	• Legal and policy makers regulations produce a resistance on the market to use them. • The composition of the CDW differs qualitatively depending on the original materials used for the demolished facilities. • More difficult and expensive recovery of mixed CDW (17 09 04) with non-mineral fractions. • Potential decrease of residue availability, if in-situ separation and policies have the expected result. 17 09 04 is mixed residue, mainly coming from minor works like housing reform and rehabilitation where in-situ classification is not currently mandatory in Madrid region.
Opportunities	**Threats**
• Opportunity to contribute and create a CE model. • Preservation of natural resources. • Lower costs of management in the case of recycling into SRM-based construction products. • Already existing practice of production of geotechnical composite produced from CDW residues and other applications. Existing knowledge and experiences with material. • There is a large market and demand for construction products. • Illegal CDW dams can be removed and recycled. • Improved public perception of the recycling companies. • According to the Waste framework directive (2008/98/CE, art 11.2.b) by 2020 preparation for re-use, recycling and other recovery of materials, including landfill operations that use waste as substitutes for other materials, from non-hazardous RCD waste shall be increased to a minimum of 70%, which provides an opportunity to exploit this application for the 17 09 04 residue.	• No final users for mixed recycled aggregate in practice. • No confidence from final users about mixed recycled aggregates, their characteristics, properties, and benefits. • Transport costs of the material can increase the production cost. • Legal and policy problems to use mixed recycled aggregate on the market as some applications and products are currently not considered. • No current regulations to improve or promote the use of the recycled aggregate. • Lack of investors' confidence due to unexpected changes of legal regulations. • Lack of procedures for large investments (road construction) that would make favourable preferences for the mixed recycled aggregate.

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8.5. Conclusion

8.5.1 General findings

The recycling of CDW has large potential of applications, and the overview and enablers and barriers presented in this chapter can contribute to the fulfilment of this potential. However, in order to truly mitigate the adverse effects of waste industry, additional approaches to current CDW recycling are required. Four main additional interventions emerged from the CAME (Correct, Adapt, Maintain, Exploit) model:

- Need of changes in policies;
- Encourage and increase of incentives for the use of SRM-based products;
- Landfill controls and increment in cost of them;
- More R&D investments into waste conversion to products.

Figure 42 shows the objectives of these actions in the framework of the CDW valorisation scenario.

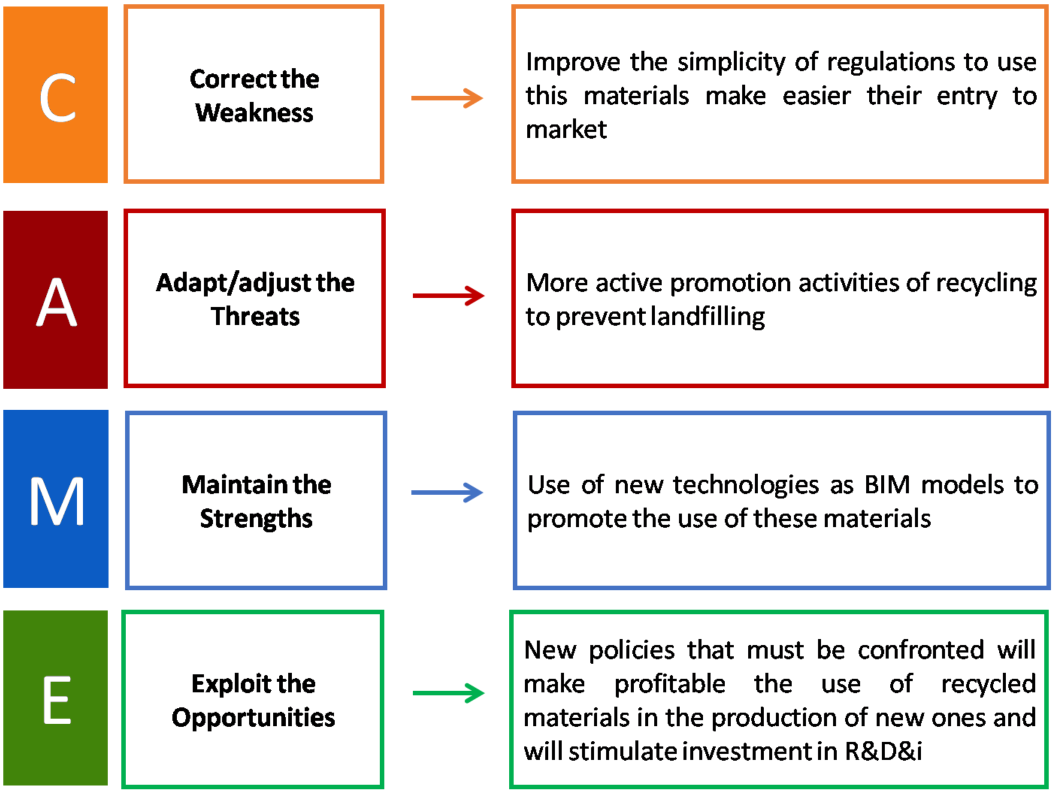

Figure 42: CAME analysis

8.5.2 Recommendations

Based on the discussed research, the following recommendations have been presented:

- Promotion and award-winning from the Government recycling models.
- Funding for the development of new technologies and use of recycled construction materials.
- Prioritize in bidding specifications (both public and private) the use of construction materials produced from waste valorisation versus ones use primary raw materials.

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- Promotion of reduced tax burdens for materials produced from SRMs.
- Increase controls by Public Administration on the destination of SRMs and developing of legislation for the effective recovery of them.
- Simplification of waste recovery regulations.
- Need for a greater knowledge of recycled products and their technical characteristics to encourage consumers to use them.

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9. Conclusions

9.1. Generalisation of results

Each use case conducted a value chain analysis on an existing value chain for waste management and explored possible future value chains where the different waste streams are recycled and used as SRM-based building product. Based on these six assessments (one assessment per use case) the following conclusions can be derived:

- In several use cases recycled aggregates are already used as SRM-based building products, however the level of recycling and production maturity depends greatly from country to country. The Netherlands for example is giving focus to advanced recycling techniques and also on pure waste streams, while in other countries like Croatia practice of putting recycled CDW on the market is still relatively poor and even the most low cost recycling and production routes (use of mixed recycled aggregates) are not recognized as beneficial. Further, some of studied countries are facing with problems of illegal dumping of CDW (Croatia, Spain) and problems of accurate reporting (Croatia) and publicly available data (Spain).
- Stakeholders in all countries demonstrated increased interest for putting SRM-based construction products on the market, but differences among individual stakeholders' group is significant. For some waste flows (e.g. sewage sludge in Slovenia) the biggest push for change towards new value chains was observed among waste producers who are facing increased costs of handing over wastes. In other cases, pull was observed among policy makers on local level (creating policies for management of individual waste streams and circular economy) or among producers (applying new processing techniques, like in the Netherlands for upcycling of concrete waste).
- There is a need for more transparency and traceability of waste flows. This is a high issue in many countries (e.g. lack of access to public data in Madrid-Henares region, cross-border traceability of sewage sludge flow in Slovenia and other EU countries, lack of accurate data in Croatia, etc.).
- The value chains assessment conducted in this WP3.3 has been conducted within strong cooperation with the industry. This makes the assessment practically applicable. At the same time it provides insights for the participants of the workshop which for example in the Slovenian case lead a mutual approach letter towards the Ministry of the Environment and Spatial Planning for addressing lack of operational plan for sewage sludge management. Since these value chains are highly complex and have many influencing factors it is almost necessary to apply a 'hands-on' approach in close relationship with representatives of the industry to discover potential impact points in the chain.
- The presented uses case show different maturity of waste recycling, e.g. downcycling of CDW into mixed recycled aggregate versus upcycling of CDW into pure concrete based recycled aggregates. These two approaches are not necessary to be classified as one being better than other, since downcycling is usually done with less effort, simplified processing methods and more waste, which otherwise would be landfilled is consumed; in comparison with more complex processing methods of upcycling where the final product can be used for more demanding end-uses but in lower quantity. In WP7 environmental, economic and social comparison of these two approaches through LCA will be done.
- There is strong need for unification (and certification) of quality of SRMs. Product producers are strongly focussed on quality and reliability of their resources. They need to be sure that the SRMs are in quality equal to natural resources according to their intended uses.

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- There is a lack of knowledge among actors in step D on how they can demand for SRM-based building products. Due to the fact that the value chains are segmented, actors active in step A of the value chain are not connected to step D of the value chain.
- Demand side measures: Some of the use cases reported about GPP or other policies emphasizing and recommending use of certain amount of SRM-based products (e.g. Italy, the Netherlands, Slovenia, Spain). These impact points for creation of new value chains can be distinguished into several demand side measures: the point of obligatory certification, subsidies or demands for using certain percentage of SRM-based construction products. Increased taxes for virgin materials and landfilling would probably also create certain pressure for creation of new value chains.
- Two additional barriers are identified: discrepancy between legislation and actual practice, which was emphasized in several cases (e.g. Croatia, Slovenia, Spain) and lack of interest among final users, investors, architects (e.g. Croatia, Slovenia, Spain). Many countries report on opinion among group D of actors (product users), who think that SRM-based product are of poorer quality than those of virgin raw materials, that confirming compliance with attended use (testing for CE marking) is more expensive than for natural materials etc. Use cases where such opinions are present report also about abundance of low price virgin materials. Based on this, alignment along the value chain is necessary (e.g. initiative made by Slovenian sewage sludge producers).

9.2. Vision for transition to SRM-based value chains

Based on the value chain assessments various barriers and enablers are identified which can be addressed in order to transition towards SRM-based building products. For each of the PESTEL analysis categories recommendations are given in this chapter.

POLITICAL

In the different use cases a variety of political agenda's concerning the reduction of waste streams and the stimulation of SRM-based products can be recognized. Setting the agenda with a goal in the future (10-20 years) gives private organisations the certainty that the industry will head into a specific direction. What we see nowadays is that private organisations are willing to invest and to execute R&D projects as long as they know which way the industry is heading. Setting such a direction on a political (European, national, regional or local) might stimulate the adoption of SRM-based products.

ECONOMIC

There are various economic drivers which will increase the potential of SRM-based products. The global market of natural resources is one of the main economic drivers. Some natural resources will become scarce in the coming decades, e.g. phosphorous. To be able to adapt to such a situation local as well as private organisations which rely strongly on these resources start to experiment which these SRM business models. Other economic drivers on a more national or local scale influence the use of SRM-based products as well. E.g. subsidiary measures or tax shifts where natural resource has a higher tax rate.

SOCIAL

We see a shift in different organisations structure and the way value chains organise themselves. There is a stronger belief in cooperating to shift towards the CE. This means different organisations have to reason from a common ambition/goal and work with shared incentives in working towards this goal. The ‘gap’ between contractors and clients will be closed and sharing knowledge will become more common.

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TECHNOLOGICAL

The knowledge institutes spread over Europe are currently working hard on developing new technologies to enable waste streams to be recycled and used as SRM-based products. The technological developments for separating mixed waste streams in homogeneous waste streams are rapidly evolving. This can be applied for various waste streams, e.g. mixed CDW waste streams, mixed plastic waste streams, residual household waste streams, etc. The technological developments for recycling techniques are rapidly evolving as well. To create new high quality secondary resources which can replace 1-on-1 (or even exceed) the required natural resources is an ultimate goal.

ENVIRONMENTAL

From an environmental aspect there is a large momentum with the global attention for waste streams. The public pressure increases for the industry to operate in a more sustainable way so we can reduce the amount of waste generated each day. The strong focus on the reduction of greenhouse gasses from the Paris 2015 agreement is adopted as well on a global as well as European scale. Exploring business models where we shift from using SRM instead of natural resources might reduce the greenhouse gas emission as well. An LCA as a foundation for these business models for SRM-based products is essential to connect this goal to the goals of the Paris 2015 agreement. On a more local scale environmental aspects play a crucial role, pollution and contamination of water and soil and the physically growing ‘pile’ of waste is something that will effect local communities which will lead to public pressure to address these issues as well.

LEGAL

From a legislative perspective there is a variety of measures local, regional, national and/or the European government can take in order to create more sustainable SRM-based products. In the Netherlands for example is has been illegal to landfill various CDW waste streams over 20 years. In order to use such a measure this law needs to be maintained by public agents to prevent illegal landfilling as like it is the situation in Croatia for instance. Another example for a local government is to change their demolishing permits which have a higher focus on the recycle potential of all the resources which are harvested in the demolishing project.

9.3. Next steps in CINDERELA

In practical terms the outcomes of Task 3.3 are important also for the following Tasks and WPs within CINDERELA:

- Task 3.4: Developing Blueprint for resource efficient SRM-based urban and peri-urban construction sector;
- WP4: Information for development of CinderCEBM and CinderOSS;
- WP5: Information on new value chains for developing and testing the most suitable SRM-based construction products for large scale demonstrations (Task 5.1); information for needed EoW (end-of-waste) criteria (Task 5.2) as well as information on materials for designs of large scale demonstrations;
- WP6: Information on involvement of stakeholders into pilot demonstrations and their optimisation;
- WP7: Issues to be solved with LCA-based methods.

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10. ANNEXES

10.1. Annex 1: Croatia

10.1.1 Invitation to the CINDERELA workshop, held on 21.3.2019 at Municipality of Umag, Umag

CINDERELA

Novi kružni ekonomski poslovni modeli za održiviju gradsku izgradnju

web: www.cinderela.eu
mail: info@cinderela.eu

Poziv

Pozivamo vas na radionicu

»Uporaba sekundarnih sirovina u graditeljstvu - Građevinski otpad – problem i istodobno izazov«

u četvrtak, 21. ožujka 2019, s početkom u 10:00

Grad Umag, Ulica G. Garibaldija 6, Umag, Vijećnica

U gradovima se stvara otpad kao što je građevinski otpad, otpad nastao preradom komunalnog otpada i otpadnih voda, te razni industrijski otpad, koji nakon prerade može biti izvrsna sirovina za građevinske proizvode. U sklopu projekta CINDERELA Horizon 2020 organiziramo radionicu na temu građevinskog otpada. Cilj radionice je utvrditi tehničke i zakonske mogućnosti recikliranja te vrste otpada u sekundarnu sirovinu u svrhu ponovne upotrjebe u graditeljstvu.

Program:

Trajanje	Program
10:00 – 10:05	Uvodni pozdrav organizatora - 6.maj Umag
10:05 – 10:20	Građevinski otpad – Problem istovremeno izazov – Mirko Šprinzer (PKG)
10:20 – 10:30	Prezentacija projekta CINDERELA – Kim Mezga (ZAG)
10:30 – 10:40	Prezentacija demo prikaza projekta u Umagu – (6.maj)
10:40 – 10:50	Tehničke mogućnosti upotrebe recikliranih materijala – Ana Mladenovič (ZAG)
10:50 – 11:00	Uvod u radionicu – Kim Mezga (ZAG)
11:00 – 11:30	Rad u grupama
11:30 – 11:50	Kratka prezentacija rezultata grupnog rada i diskusija
11:50 – 12.00	Zaključci radionice
12.00 – 13:00	Druženje i umrežavanje

Pozivamo Vas, da potvrdite svoje sudjelovanje na adresu sanjin.lukic@6maj.hr do srijede, 20. ožujka 2019.

Ulaz na radionicu je besplatan!

Ljubazno pozvani!

Organizator radionice: 6. maj Umag, partner projekta CINDERELA

Projekt Cinderela financira Europska Unija u programu Horizon 2020 (Program istraživanja i inovacija) ugovorom br. 776751

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10.1.2 Figures from the workshop

10.2. Annex 2: The Netherlands

10.2.1 Transcript of interviews

René Oudt | Director, Oudt Zwanenburg

René Oudt owns a demolition company and is therefore is a representative of step A of the value chain. During this interview the demolition process was discussed and the barriers to increasing the sorting rate at the source. The demand for recycling aggregates as a subbase for infrastructure was covered as well as the demand for circular recycling practices and the effect of these demands on demolition practices. Rules and regulation about the demolition process and recycling rates and guidelines and deals of the concrete sector were also a topic of this interview.

Rens Groeneveld | Manager Mineral Streams, Sortiva

Sortiva is a recycling company that recycles concrete waste into concrete recycled aggregate among others, and therefore this interviewee is a representative of step B of the value chain. The interview covered the processing steps of concrete waste, and the considerations of increasing recycling rates for concrete recycled aggregate that can be reused in the concrete production. Use cases of recycled

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aggregates and the profitability of their production were considered. The relationship to partners and their perceived stakes were discussed, as well as norms and certificates concerning concrete recycled aggregate.

Marga & Alexander Pouw | Board, Theo Pouw

Theo Pouw is a recycling company, that also produces concrete mortar. Therefore, Theo Pouw is representing two steps of the value chain, namely step B and C. During this interview the drawbacks and benefits of using concrete recycled aggregate as replacement for primary aggregate materials were discussed. Barriers and opportunities of recycling concrete in new concrete were covered, as well as the demand for concrete containing recycled aggregate. The interview also covered the benefits of combining two steps of the value chain and the geographical scale of the concrete value chain.

Richard Giesen | Manager R&D Concrete Mortar, Bruil

This actor is a representative of the concrete producing industry, and therefore directly linked to step C of the value chain. In this interview the various aspects of concrete recycling and the future of concrete were discussed. The first part of the interview was about the drawbacks and benefits of using concrete recycled aggregate as replacement for primary aggregate materials. Barriers and opportunities of recycling concrete in new concrete were covered, as well as the demand for concrete containing recycled aggregate. Additionally, existing regulations, norms and certificates of concrete recycled aggregate and their implications on the quality of the concrete were discussed. The second part was concerned with the future of concrete in terms of technological possibilities, but also in terms of environmental impact.

Leonie Pijnenburg | Procurement 100% Circular Concrete, Heijmans

Leonie Pijnenburg was interviewed as a representative of step D of the value chain, since Heijmans is one of the major contracting authorities in the construction sector in the Netherlands. During this interview the role of Heijmans in the concrete sector in relation to the circular economy was discussed. Heijmans strategy in working with more sustainable concrete was covered. The relevance of sustainability deals about circular concrete was talked about. Other topics included the influence of different actors, including the government, on the concrete chain and the environmental impact of circular solutions.

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10.2.2 Invitation letter

Van afval naar grondstof:
Op weg naar een circulaire betonketen in de MRA.

12 maart 2019

CINDERELA

Welke stakeholders spelen (potentieel) een rol in een nieuwe circulaire betonketen in de metropoolregio Amsterdam? Welke nieuwe methodieken en werkwijzen zijn er de afgelopen jaren ontwikkeld binnen de betonketen? En hoe komt het dat deze methodieken en werkwijzen nog niet op grote schaal ingezet worden? *Tijdens de workshop 'Op weg naar een circulaire betonketen in de MRA' gaan wij graag samen met u aan de slag om het antwoord te vinden op de vragen! Er vinden al verschillende circulaire pilots plaats, maar het is nu van belang om dit op te schalen naar een volwassen model. Door verschillende spelers binnen de keten bij elkaar te brengen en de kansen en belemmeringen te identificeren, geloven wij dat wij gezamenlijk tot nieuwe waardeketens kunnen komen waarbinnen circulaire oplossingen voor secundaire grondstoffen tot stand komen.*

Programma:

14.00 u **Ontvangst & Koffie**
14.15 u **Inspiratie**: Cinderela project & huidige waardeketens
14.45 u **Aan de slag:** samen opzoek naar potentie & uitdagingen
16.30 u **Pitch & reflectie**
17.00 u **Wrap-up & borrel**

Nieuwsgierig?
Meer weten over het Cinderela project? Neem een kijkje op de website.

Aanmelden voor de workshop of meer informatie? Neem contact op met Lisette Sant: l.sant@kplusv.nl of 06-13773809

Locatie: AMS Institute, Kattenburgerstraat 5, 1018 JA Amsterdam

In de EU bedroeg de totale afvalproductie in 2014 2598 megaton afval, waarvan 33.5% afkomstig is uit de bouw, met name in stedelijke gebieden. Met 13 partners uit 7 landen werken TU Delft en KplusV binnen het Cinderela project samen om nieuwe circulaire business modellen te ontwikkelen voor het gebruik van secundaire grondstoffen in stedelijke gebieden, waarbij verschillende industrieën, de bouwsector en gemeentelijke diensten worden verbonden. Eén van de onderdelen van het Cinderela project richt zich op de betonketen; één van de waardeketens met het grootste potentieel voor circulariteit en met de grootste impact op het milieu binnen de Metropoolregio Amsterdam. Zo kunnen we de MRA volhoudbaar verduurzamen en dragen we bij aan de verdere verduurzaming van de bouwsector in de hele EU.

This project has received funding from the **European Union's Horizon 2020 research and innovation Programme under grant agreement N° 776751**

AMS AMSTERDAM INSTITUTE FOR ADVANCED METROPOLITAN SOLUTIONS — TUDelft — K PLUS V

10.3. Annex 3: Italy

10.3.1 Wastes presenting 80% of waste quantities in Trento region

No.	EWC name	EWC
1	Mixed construction and demolition wastes other than those mentioned in 17 09 01, 17 09 02 and 17 09 03	170904
2	Gypsum-based construction materials	170802
3	Concrete	170101
4	Mix. Concrete, bricks, tiles and ceramics	170107
5	Soil and stones	170504
6	Waste from mechanical treatment of wastes	191212
7	Track ballast	170508
8	Wastes from cement-based composite materials	101311
9	Street-cleaning residues	200303

10.3.2 Wastes presenting 80% of waste quantities in FVG region

No.	EWC name	EWC
1	Mixed construction and demolition wastes other than those mentioned	170904

No.	EWC name	EWC
	in 17 09 01, 17 09 02 and 17 09 03	
2	Soil and stones other than those mentioned in 17 05 03	170504
3	Other wastes (including mixtures of materials) from mechanical treatment of wastes other than those mentioned in 19 12 11	191212
4	Plastic and rubber	191204
5	Bituminous mixtures other than those mentioned in 17 03 01	170302
6	Concrete	170101
7	Sludges from treatment of urban waste water	190805
8	Mill scales	100210
9	Mixtures of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06	170107
10	Other linings and refractories from metallurgical processes other than those mentioned in 16 11 03	161104
11	Ferrous metal filings and turnings	120101

10.4. Annex 4: Poland

10.4.1 Selected CINDERELA waste list in Katowice and surrounding municipalities

EWC code	EWC name	Weight [tonnes]
01 01 02	Wastes from mineral non-metalliferous excavation	1,006,522.3
19 12 12	Other wastes (including mixtures of materials) from mechanical treatment of wastes other than those mentioned in 19 12 11	436,952.2
10 02 01	Wastes from the processing of slag	254,197.4
17 05 04	Soil and stones other than those mentioned in 17 05 03	188,299.6
10 01 24	Sands from fluidised beds	179,361.9
12 01 01	Ferrous metal filings and turnings	176,821.7
19 08 05	Sludges from treatment of urban waste water	137,400.1
10 01 01	Bottom ash, slag and boiler dust (excluding boiler dust mentioned in 10 01 04)	110,197.2
19 05 03	Off-specification compost	94,378.7
19 12 05	Glass	90,136.0
17 01 01	Concrete	56,773.0
19 12 09	Minerals (for example sand, stones)	50,424.5
17 01 07	Mixtures of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06	48,219.3
17 01 02	Bricks	48,133.9

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EWC code	EWC name	Weight [tonnes]
16 11 04	Other linings and refractories from metallurgical processes other than those mentioned in 16 11 03	44,586.3
10 01 02	Coal fly ash	33,802.8
15 01 02	Plastic packaging	27,696.1
12 01 02	Ferrous metal dust and particles	20,946.1
10 09 08	Casting cores and moulds which have undergone pouring other than those mentioned in 10 09 07	20,281.5
19 12 04	Plastic and rubber	19,978.8
15 01 07	Glass packaging	15,845.7
10 12 99	Wastes not otherwise specified	15,050.8
17 09 04	Mixed construction and demolition wastes other than those mentioned in 17 09 01, 17 09 02 and 17 09 03	13,166.6
10 02 10	Mill scales	11,362.6
10 02 99	Wastes not otherwise specified	8,792.3
10 02 02	Unprocessed slag	8,316.3
20 03 06	Waste from sewage cleaning	8,256.6
10 02 08	Solid wastes from gas treatment other than those mentioned in 10 02 07	6,604.4
17 03 02	Bituminous mixtures other than those mentioned in 17 03 01	6,363.9
12 01 03	Non-ferrous metal filings and turnings	5,536.2
19 08 02	Waste from desanding	5,259.1
15 01 05	Composite packaging	4,105.5
19 08 01	Screenings	3,402.5
10 12 08	Waste ceramics, bricks, tiles and construction products (after thermal processing)	3,095.5
17 02 01	Wood	2,524.3
20 03 03	Street-cleaning residues	1,910.7
10 01 03	Fly ash from peat and untreated wood	1,891.4
17 05 06	Dredging spoil other than those mentioned in 17 05 05	1,761.4
12 01 04	Non-ferrous metal dust and particles	1,703.2
10 11 99	Wastes not otherwise specified	1,317.6
20 02 02	Soil and stones	1,226.7
19 08 14	Sludges from other treatment of industrial waste water other than those mentioned in 19 08 13	1,074.1
17 06 04	Insulation materials other than those mentioned in 17 06 01 and 17 06 03	1,063.1
10 10 03	Furnace slag	975.3
10 09 12	Other particulates other than those mentioned in 10 09 11	932.2
01 04 08	Waste gravel and crushed rocks other than those mentioned in 01 04 07	803.4

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EWC code	EWC name	Weight [tonnes]
10 02 15	Other sludges and filter cakes	784.7
101112	Waste glass other than those mentioned in 10 11 11	580.3
10 01 05	Calcium-based reaction wastes from flue-gas desulphurization in solid form	536,8
07 06 99	Wastes not otherwise specified	456.8
10 09 03	Furnace slag	421.2
12 01 05	Plastics shavings and turnings	373.6
10 12 10	Solid wastes from gas treatment other than those mentioned in 10 12 09	357.3
15 01 09	Textile packaging	322.9
03 03 11	Sludges from on-site effluent treatment other than mentioned in 03 03 10	299.0
10 11 05	Particulates and dust	291.4
17 02 03	Plastic	154.3
20 01 39	Plastics	95.0
02 03 04	Materials unsuitable for consumption or processing	83.5
10 01 99	Wastes not otherwise specified	83.4
17 02 02	Glass	80.1
12 01 17	Waste blasting material other than those mentioned in 12 01 16	76.8
10 01 21	Sludges from on-site effluent treatment other than mentioned in 10 01 20	65.0
17 01 03	Tiles and ceramics	55.0
10 02 12	Wastes from cooling-water treatment other than those mentioned in 10 02 11	42.1
10 09 10	Flue-gas dust other than those mentioned in 10 09 09	33.5
10 01 23	Aqueous sludges from boiler cleansing other than those mentioned in 10 01 22	27.7
01 04 09	Waste sand and clays	25.4
10 05 04	Other particulates and dust	24.5
16 10 04	Aqueous concentrates other than those mentioned in 16 10 03	18.9
10 01 25	Wastes from fuel storage and preparation of coal-fired power plants	18.8
10 11 14	Glass-polishing and -grinding sludge other than those mentioned in 10 11 13	14.0
10 01 19	Wastes from gas cleaning other than 10 01 05, 10 01 07 and 10 01 18	11.6
20 01 10	Clothes	9.9
20 01 02	Glass	9.1
17 08 02	Gypsum-based construction materials other than those mentioned in 17 08 01	7.1
20 01 11	Textiles	5.6
20 02 03	Other non-biodegradable wastes	0.5
01 04 13	Wastes from stone cutting and sawing other than those mentioned in 01 04 07	0.2
02 01 03	Plant-tissue waste	0.1
19 12 08	Textiles	0.1

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10.5. Annex 5: Slovenia

10.5.1.1 Invitation to the workshop, held on 7.3.2019 at ZAG, Ljubljana with agenda

Novi krožni gospodarski poslovni modeli za bolj trajnostno urbano gradbeništvo

web: www.cinderela.eu
mail: info@cinderela.eu

Vabilo

Vabimo vas na delavnico

»Uporaba sekundarnih surovin v gradbeništvu – reciklirano blato iz komunalnih čistilnih naprav«

v četrtek, 7. marca 2019, s pričetkom ob 10. uri

ZAG, Dimičeva 12, Ljubljana, 5. nadstropje

V mestih nastajajo odpadki, kot so npr. gradbeni odpadki, odpadki nastali pri predelavi komunalnih odpadkov in odpadne vode ter različni industrijski odpadki, ki so lahko po predelavi odlična surovina za gradbene proizvode. V okviru Obzorje 2020 projekta CINDERELA organiziramo delavnico na temo blata iz komunalnih čistilnih naprav. Cilj delavnice je identificirati tehnične in zakonodajne možnosti za recikliranje tega odpadka v sekundarno surovino.

Program:

Trajanje	Program
10.00 – 10.05	Uvodni pozdrav – Ana Mladenovič (ZAG)
10.05 – 10.10	Predstavitev projekta CINDERELA – Kim Mezga (ZAG)
10.10 – 10.20	Predstavitev Mariborskih demo prikazov – Tomislav Ploj (NIGRAD)
10.20 – 10.45	Zakonodajne in tehnične možnosti ravnanja z blatom – Mirko Šprinzer (PKG), Ana Mladenovič (ZAG)
10.45 – 10.55	Uvod v delavnico – Kim Mezga (ZAG)
10:55 – 11:30	Delo v skupinah
11.30 – 12.00	Kratka predstavitev rezultatov skupinskega dela in diskusija
12.00 – 12.15	Zaključki delavnice
12.15 – 13.00	Druženje udeležencev ob pogostitvi

Vljudno vas vabimo, da svojo udeležbo potrdite na naslov kim.mezga@zag.si, do ponedeljka, 4. marca 2019.

Vstop na delavnico je prost!

Vljudno vabljeni!

Projekt Cinderela financira Evropska Unija v programu Obzorje 2020
(Program raziskav in inovacij) s pogodbo št. 776751

10.5.2 Invitation on ZAG's web-page to the workshop held on 7.3.2019 at ZAG, Ljubljana

10.5.3 A draft letter with initiative to prepare a National Plan for sewage sludge treatment

Ministry of the Environment and Spatial Planning

Dunajska 48, SI-1000 Ljubljana

Environment Directorate

Mrs. Tanja Bolte, Director General

Subject: Initiative for a new National Plan for sewage sludge treatment

Dear Mrs. Tanja Bolte, Director General

Slovenian National Building and Civil Engineering Institute, the coordinator of H2020 project CINDERELA - New Circular Economy Business Model for More Sustainable Urban Construction - together with project partner NIGRAD organized on 7.03.2019 a workshop entitled 'Use of secondary raw materials in construction sector – recycled sewage sludge'. The workshop was participated by 26 stakeholders and actors of sewage sludge value chain in order to discuss existing and potential new value chains of sewage sludge. The highest interest for workshop was observed among sewage sludge producers (public utility companies responsible for wastewater treatment) which presented 1/3 of participants. Some of the conclusions of the workshops were following:

- There is discrepancy between national vision for sewage sludge treatment written in the Operational plan for waste management and actual practice. The discrepancy is due to the fact that currently very little of sewage sludge is processed in ways foreseen in the Operational plan (e.g. R3 recycling of sewage sludge into digestate and compost for use in agriculture; reclamation of sewage sludge according to R1 for use as a fuel; or a long term storage of

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sewage sludge for aim of recuperation of Phosphorous, which is on the European list of Critical Raw Materials).

- Current sewage sludge value chain is not transparent since large percentage of sewage sludge (50% in 2017) is handed over to collector in another EU countries (most probably in Hungary) and the final destiny of produced sewage sludge in Slovenia is not known.
- There is no mention in the Operational plan about recycling of sewage sludge into new materials such as construction composites despite the fact that so called 'industrial recycling' is one of the BAT technologies for sewage sludge treatment (see Best Available Techniques (BAT) Reference Document for Waste Treatment, 2018).

Based on this and due to the fact that there is high interest among stakeholders of sewage sludge value chain, especially among waste producers, to change current situation of sewage sludge treatment in Slovenia, we would like to propose a joined meeting among representatives of Directorate of the Environment, Slovenian partners of CINDERELA project (ZAG and NIGRAD), Chamber of Public Utilities and other relevant stakeholder in order to discuss possibilities to establish a document, which would enable achievement of main objectives of the Program and would include the latest state-of-the-art of the technology in a way to maximize resource, energy and economic efficiency and which will fulfil national strategy of transition into circular economy. Such document is already partly foreseen in the current Programme in Chapter 6.7 under Actions 31 and will also be align with other actions (e.g. Action no. 17, no. 18).

By this letter we would kindly ask the Directorate for a meeting in which we would jointly discuss further steps in creating the most sustainable management in sewage sludge in Slovenia.

With kind regards!

Signed by:

Representatives of Slovenian National Building and Civil Engineering Institute, NIGRAD and other stakeholders

10.6. Annex 6: Spain

10.6.1 Introduction

The workshop was to bring together stakeholders of the value chain to identify potential impact points for creating SRM-based construction products and designing a new value chain. In the case of the Spanish workshop, a dedicated event was organized on 6.3.2019 at the CTC premises that aimed to assess the current and new value chain for the mixed construction and demolition wastes (17 09 04). The workshop aims were to present the preliminary assessment done by the Spanish partners in the project (AEDHE, FGP and TECNALIA) and obtain their feedback and establish a discussion session among the workshop attendance. The workshop was organized by AEDHE in collaboration with CTC Servicios.

The outcomes of the workshop were used to prepare this deliverable. The discussion arose during the presentation, together with the after the workshop assessment done by the Spanish partners of the project helped to better fulfil the key sections.

10.6.2 Organization and communication

In order to organize the workshop the following actions were carried out:

- Selection of the attendance stakeholders to which the workshop has to address

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- Preparation and send of the save-the-day announcement considering the objective attendance stakeholders
- Preparation of a tentative agenda, considering the final aim of the workshop.
- Reminder announcement to attain the attention of further potential interested stakeholders
- Final announcement with the final agenda
- Communication by different channels

The above-mentioned actions carried out had a profound effect on the integration workshop result. The organizer carefully selected the kind of stakeholders so as all the actors involved in the value chain were equally represented.

10.6.3 Agenda

The workshop organizers decided to organize a half-day event. The workshop consisted of four main parts:

- An introduction presentation of the project by the organizer of the workshop, with a brief summary of the project: partners, main goals, tools, demonstrations)
- The Construction and demolition waste stream, types and value chain including a PESTEL analysis was presented to contextualize the current situation.
- Explanation of expected objectives of the Workshop and a brief introduction to methodologies used: SWOT & CAME
- Guided discussion taking as starting point the PESTEL and evolving towards proposals for the valorisation of wastes as SRMs in two groups to provoke the discussion between the participants and inspire the audience with new ideas.

Following is the table of the agenda:

	AGENDA
10:15	**Workshop registration**
10:30	**Welcome and opening** AEDHE and CTC
10:45	**Introduction in CINDERELA project** Ignacio Vilela – AEDHE
11:00	**Construction and demolition wastes: types and value chain** Ignacio Vilela – AEDHE
11:10	**Explanation of expected objectives for the Workshop and introduction to methodologies used: SWOT & CAME** Alejandro Bernabé - AEDHE
11:30	**Coffee break**
12:00	**Guided discussion towards proposals for the valorisation of wastes as SRMs** Alejandro Bernabé and Ignacio Vilela – AEDHE
13:00	**Wrap-up and conclusions**
13:30	**workshop closure**

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10.6.4 Workshop save-the-date announcement

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