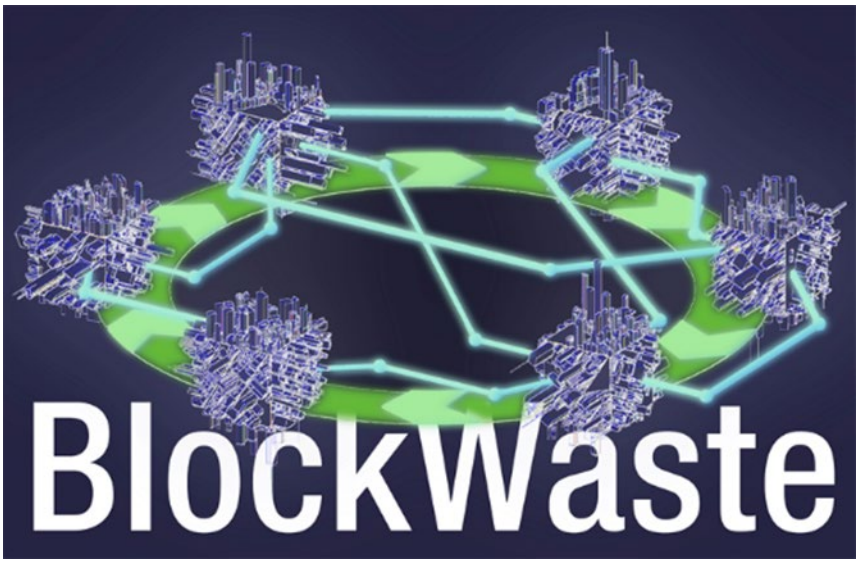
O2.A1.2 Comparative study of MSW curricula in Higher Education Systems of Estonia, Germany, Greece, the Netherlands and Spain



ΙΔΡΥΜΑ ΚΡΑΤΙΚΩΝ ΥΠΟΤΡΟΦΙΩΝ IKY

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Abbreviation	**Definition**
CE	Circular Economy
ECTS	European Credit Transfer System
EU-27	European Union of 27 countries
HEI	Higher Education Institution
IT	Information technology
IoT	Internet of Things
MSW	Municipal solid waste
SME	Small and Medium Enterprises

Executive summary

The results of the Activity O2 “European Common Curricular on MSW Applying Blockchain Technologies for Circular Economy Strategies” and in particular Task O2/A1.2 “Comparative study of the curricula of municipal waste management (MSW) in the participating countries” are presented in the following document.

The aim of this comparative study is to identify the teaching guides that educational entities currently offer on training and education in the field of Urban Waste Management in the participating countries. Moreover, the comparative study aims at highlighting best practices and identify gaps and weaknesses. In particular, focus is placed on how these educational plans approach waste management from the point of view of the Circular Economy and on their progress in the technological environment (IoT and Blockchain technology) that will lead to the Smart Cities. With a view to facilitating comparisons, a scoring system was developed consisting of three criteria, teaching, research and publications.

The main findings show that although there are a lot of courses/modules regarding MSW management and CE, in the majority of the cases there are no exclusive MSW/CE degrees. As a general rule, MSW/CE courses are found in engineering schools curricula, such as civil and environmental engineering. In many cases, both at undergraduate and post-graduate level, the courses include in their respective learning objectives the principles of recycling, sustainable development and circular economy to some extent. However, more often than not the examined courses do not have a circular economy mind-set in their core. Furthermore, there is almost an absence of Industry 4.0 elements like Big Data, smart technologies, IoT and blockchain. Therefore, a redesigned or advanced curriculum for higher education in circular economy focusing on the application of Blockchain Technology in Municipal Waste Management, should have a certain degree of interdisciplinarity. For example, an IT student might be a specialist in blockchain but should also learn about the environmental aspects of waste management, legal aspects, business, change management, etc. Similarly, a student in an environmental faculty might be an expert in environmental aspects but should learn some basics about process design, business, IoT, blockchain, waste legislation etc. as well. In addition, the syllabus should have a focus on circular economy and sustainability goals. A shift of paradigm is needed to move the emphasis from waste treatment and disposal towards reducing waste, recovering/reusing materials and recycling.

The report is structured as follows: First, it presents the current situation regarding waste production and waste management in the EU. The second part consists of the national reports of the five participating countries (Greece, Estonia, Germany, The Netherlands and Spain) in terms of municipal waste management in their respective universities curricula. The third part deals with the screening and scoring system of these university curricula. The document concludes with the analysis of the best cases and the main findings. The latter will feed the Activity O1/A3. “Handbooks of Circular Economy strategies applied to Municipal Waste Management using Blockchain technologies”.

1 Introduction

1.1 Brief project description

The BlockWASTE project aims to address the interoperability between waste management and blockchain technology and promote its proper treatment through educational training, so that the data collected will be shared within a safe environment, where there is no room for uncertainty and mistrust between all parties involved. For this purpose, the objectives of BlockWASTE project are, as follows:

- To conduct a research on solid waste generated in cities and how it is being managed, so that it can be used to create an information base of good practices, in order to reintroduce waste into the value chain, promoting the idea of Intelligent Circular Cities.
- To identify the benefits of the Blockchain Technology within the municipal waste management (MSW) process.
- To create a study plan that allows the training of teachers and professionals of the organizations and companies of the sector, in the field of Waste Management, Circular Economy and Blockchain Technology.
- To develop an interactive tool based on Blockchain Technology, which will make it possible to put into practice how the data obtained from urban waste would be managed, thus visualizing the way in which the data is implemented in the blockchain and being able to evaluate different forms of management

BlockWASTE aspires to develop new educational contents aiming at training students and providing them with the necessary basic skills that will allow them to be trained as future workers in the sector, adding digital competences required by companies on the ground of an ongoing digital transformation. In this direction, the project is addressed to:

- Enterprises and SMEs, IT professionals, urbanisms and waste management professionals.
- Universities (professors, students and researchers).
- Public bodies

The project includes four Intellectual Outputs, as follows:

- O1. Learning materials for interdisciplinary Blockchain-MSW
- O2. European common curricular on MSW applying Blockchain technologies for Circular Economy strategies
- O3. E-Learning tool based-on Blockchain-MSW focused on Circular Economy
- O4. BlockWASTE Open Educational Resource (OER)

1.2 Objectives and methodological approach

This document presents the results of the Activity O2 “European Common Curricular on MSW Applying Blockchain Technologies for Circular Economy Strategies” and in particular Task O2/A1.2 “Comparative study of the curricula of municipal waste management (MSW) in the participating countries”. The comparative study report aims to compile the different teaching guides that educational entities offer on training and education in the field of Urban Waste Management in the participating countries. Furthermore, after analysing the respective national reports, the comparative study aims at highlighting best practices and identify gaps

and weaknesses. Special emphasis is placed on how these educational plans approach waste management from the point of view of the Circular Economy and on their progress in the technological environment (IoT and Blockchain technology) that will lead to the Smart Cities. Regarding the methodological approach, BlockWASTE retrieved and analysed data from the official websites of universities in the participating countries. The curricula, modules and contents of the respective courses were analysed and national reports for each participating country were carried out. At a second stage, this integrated report consolidates these findings. In order to obtain a certain degree of comparability and provide ranking, a scoring system was developed consisting of three criteria, teaching, research and publications. The report concludes with the main findings of the comparative study, which will feed the Activity O1/A3. "Handbooks of Circular Economy strategies applied to Municipal Waste Management using Blockchain technologies".

1.3 Waste

In the past years, waste generation has been an inevitable and in most cases undesirable by-product that has been linked mainly to the economic activity and development of a society. However, modern technology and careful management have assisted in breaking this cyclical link. Processing and management practices aimed at reviewing this situation are the key elements of the EU's environmental policy. Efforts are towards managing waste in an environmentally sound manner and making use of the secondary materials they contain. The Waste Framework Directive 2008/98/EC which is the EU's legal framework for treating and managing waste defines "waste" as any substance or object which the holder discards or intends or is required to discard. The main scope of Directive 2008/98/EC is to lay down measures to protect the environment and human health by preventing or reducing the adverse impacts of the generation and management of waste and by reducing overall impacts of resource use and improving the efficiency of such use. Directive 2008/98/EC introduces an order of preference for waste management called the "Waste Hierarchy" which should be applied as a priority order in waste prevention and management legislation and policy and includes prevention, preparing for re-use, recycling, other recovery, and disposal (Figure 1).

Figure 1:*Waste Hierarchy. Source: European Commission – Environment.*

The implementation of the above Waste Hierarchy scheme should promote solutions that have as an outcome the best overall environmental practice in regard with the generation and management of waste. Priority must first be given, following this management hierarchy, to prevention activities that will also form part of the product-waste management cycle.

1.3.1 Waste generation

In 2018, the total waste generated in the EU-27 by all economic activities and households amounted to 2,317 million tonnes. In the EU-27, construction contributed 36.0 % of the total in 2018 and was followed by mining and quarrying (26.2 %), manufacturing (10.6 %), waste and water services (9.9 %) and households (8.2 %); the remaining 9.1 % was waste generated from other economic activities, mainly services (4.2 %) and energy (3.5%) (Figure 2).

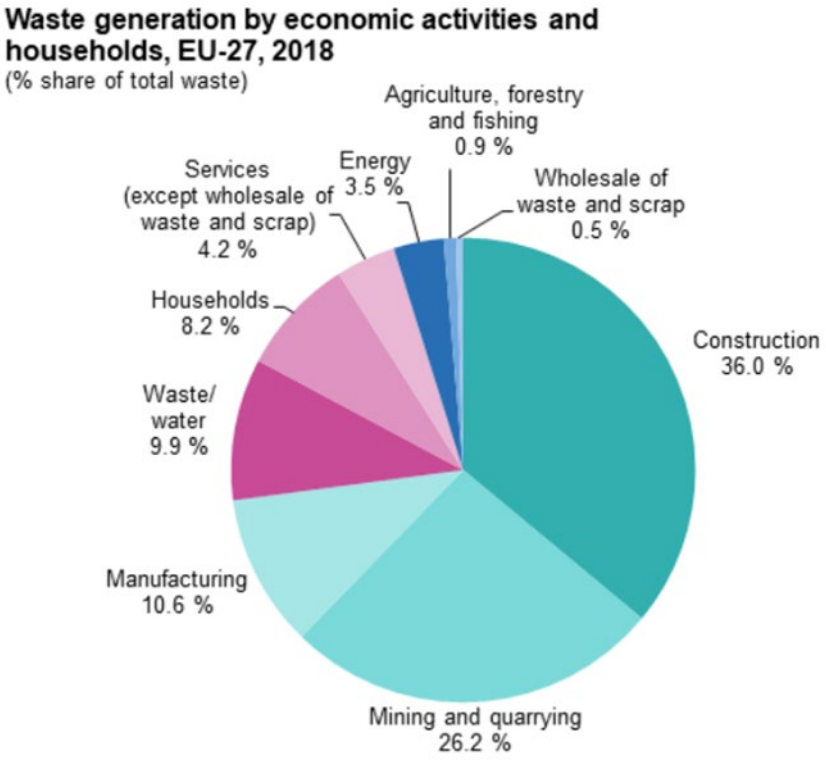


Figure 2:*Waste generation by economic activities and households, EU-27, 2018 (% share of total waste). Source: Eurostat.*

1.3.2 Municipal waste

The definition of 'municipal waste' used in different countries varies, reflecting diverse waste management practices. According to Eurostat “municipal waste” is mainly produced by households, though similar wastes from sources such as commerce, offices and public institutions are included. The amount of municipal waste generated consists of waste collected by or on behalf of municipal authorities and disposed of through the waste management system. Municipal waste makes up less than 10% of total waste generated in

the EU however it appears as one of the most polluting waste type. It should be noted, however, that variations in the definition of municipal waste used across EU-27 and how it is collected (e.g. household waste collected together with waste from commerce, trade and administration) means that such comparisons are made with caution. The variations reflect differences in consumption patterns and economic wealth, but also depend on how municipal waste is collected and managed. Figure 3 shows municipal waste generation by country expressed in kilograms per capita.

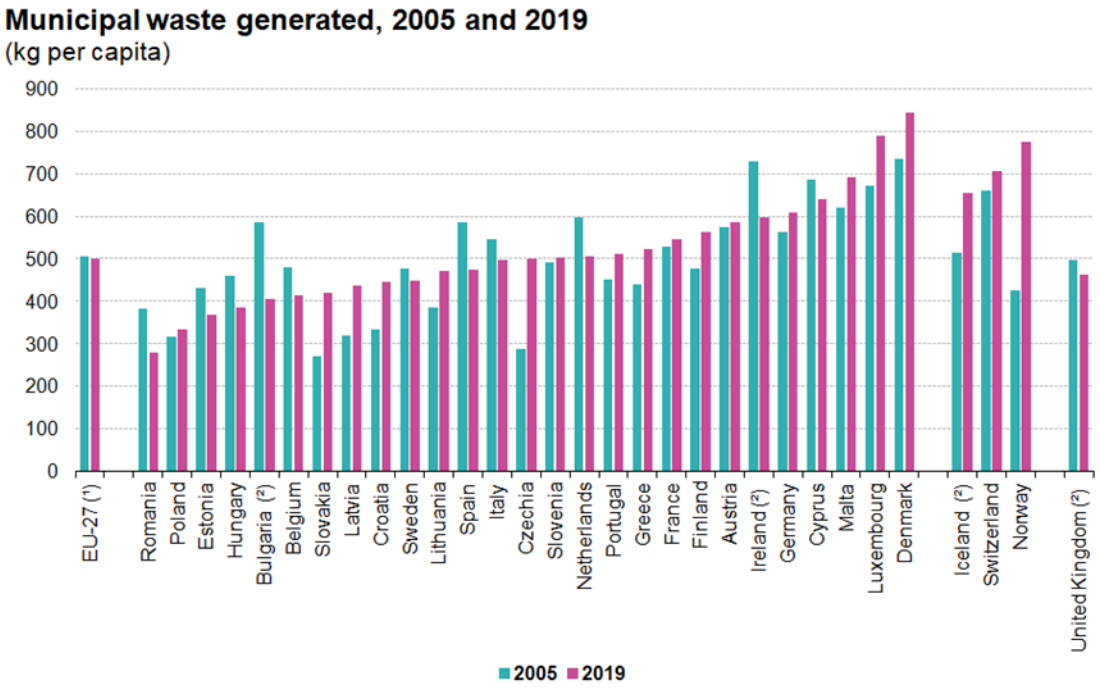


Figure 3:*Municipal Waste generation EU-27, 2005-2019. Source: Eurostat.*

Around 225 million tonnes of municipal waste was generated in the EU in 2019. The figure corresponds to 502 kg per person. Denmark generated the most municipal waste per person among the EU Member States in 2019 (844 kg), followed by Luxembourg (791 kg), Malta (694 kg), Cyprus (642 kg) and Germany (609 kg). Romania generated the least municipal waste per person (280 kg) followed by Poland (336 kg), Estonia (369 kg) and Hungary (387 kg). In general, EU Member States with higher Gross Domestic Product (GDP) produce significantly more waste per capita than those with lower GDP.

1.3.3 Waste Management and Treatment practice

In Europe, municipal waste management can be performed through different models, depending on if the responsibility of the waste management is public, private or shared. Most common model is the one where public service is responsible for the municipal waste management. Specifically, municipalities are obligated to create and maintain an effective system for managing their waste, including collection, transport, treatment and disposal, which can be carried out either by themselves or through contracts with the private sector. However, municipal waste management in Europe vary significantly between Members States

(European Environment Agency, 2019) concerning elements that have to do with waste production, collection models and treatment techniques but also implementation of waste related European Directives, making it difficult to have a clear comparison with valuable conclusions. Figure 4 shows the amount of waste generated at EU level and the amount of waste by treatment category landfill, incineration, material recycling, composting and other.

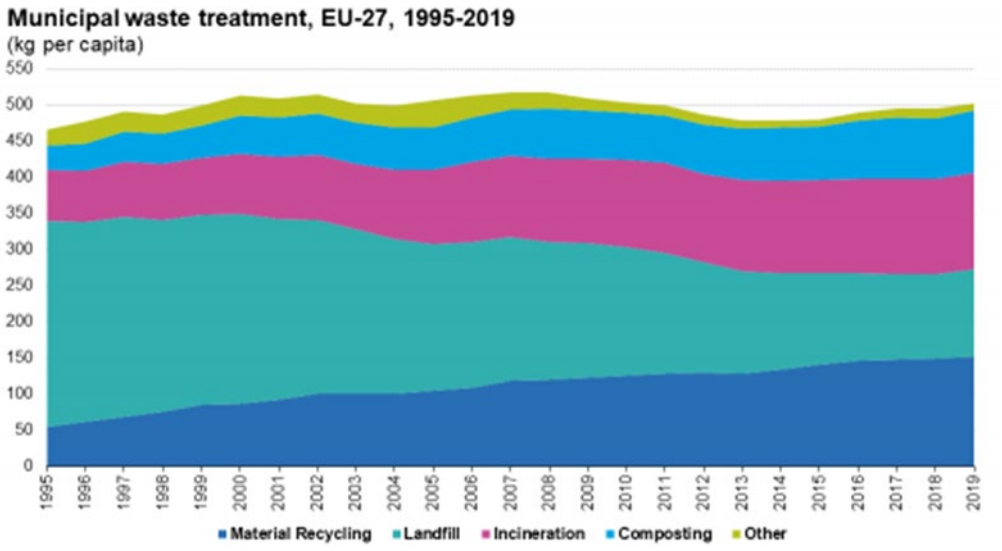


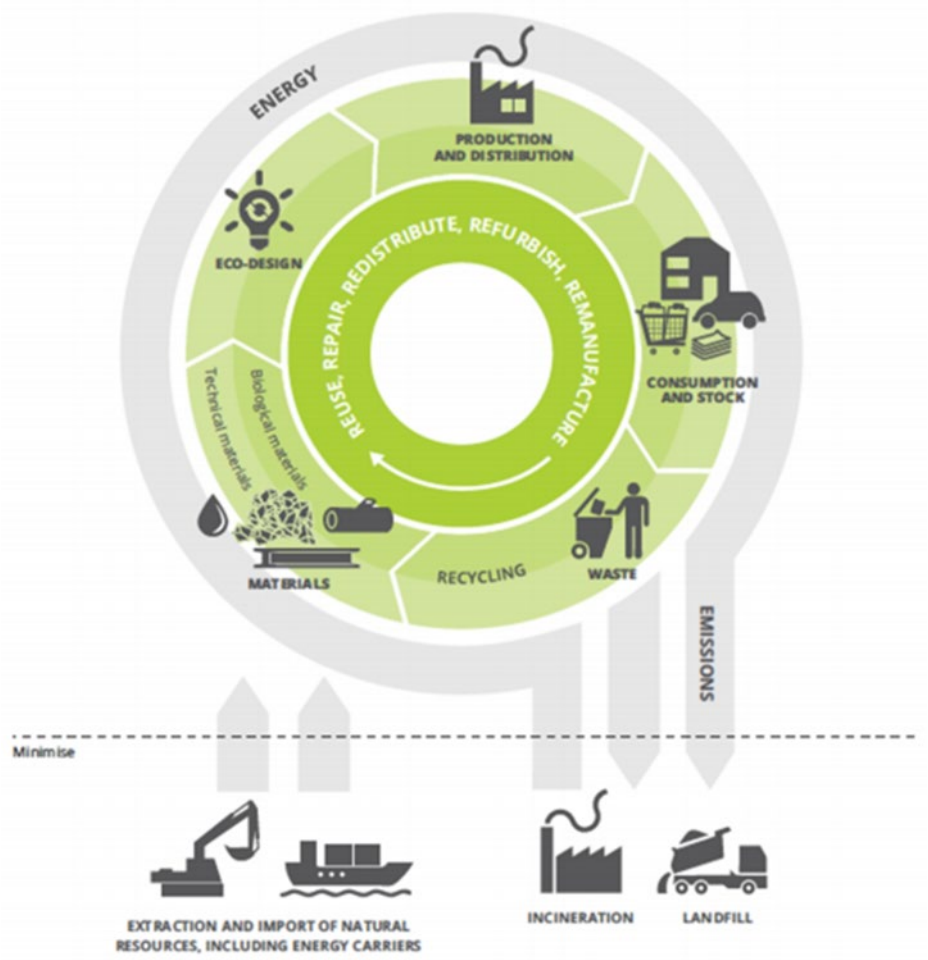
Figure 4:*Municipal Waste generation EU-27, 2005-2019. Source: Eurostat.*

Concerning the treatment of generated municipal waste, the total amount of municipal waste landfilled in the EU fell by 67 million tonnes, from 286 kg per capita in 1995 to 54 million tonnes (120 kg per capita) in 2019, corresponding to an average annual decline of 3.3 %. The landfilling rate dropped from 61 % in 1995 to 23 % in 2019, partly attributed to the implementation of European legislation. The amount of waste recycled (material recycling and composting) rose from 87 kg per capita in 1995 to 239 kg per capita in 2019 at an average annual rate of 4.3 %. The share of municipal waste recycled overall rose from 19 % to 48 %. The European Commission adopted an ambitious Circular Economy Package, which includes revised legislative proposals on waste with a higher common target for the recycling of municipal and packaging waste and lower limits for landfill of municipal waste. According to the Amending Directive (EU) 2018/851, by 2025, at least 55% of municipal waste by weight will have to be recycled. This target will rise to 60% by 2030 and 65% by 2035. Waste incineration has also grown steadily in the reference period, though not as much as recycling and composting. Since 1995, the amount of municipal waste incinerated in the EU has risen from 70 kg per capita to 134 kg per capita in 2019.

1.3.4 Municipal Waste management in the Circular Economy

Municipal waste management is currently an important area of Circular Economy implementation in European countries. The EC recommended that the member countries develop planning documents for the implementation of the CE in various areas of activity, with particular emphasis on municipal waste because this issue occurs in all countries (Smol

et al., 2020). Central to the circular economy concept is the notion that the value of materials and products is kept as high as possible for as long as possible, turning if possible waste into a resource. This helps to minimise the need for the input of new material and energy, thereby reducing environmental pressure linked to the life-cycle of products, from resource extraction, through production and use to end-of-life. Increasing recycling is part of the transition to a circular economy. In a circular economy, the distinction between raw materials, products and waste becomes increasingly unclear. Figure 6 presents a simplified figure of such a circular economy.



Source: EEA, 2015

Figure 5:*Municipal Waste generation EU-27, 2005-2019. Source: EEA.*

1.3.5 IT solutions used in Municipal Waste Management

The diffusion of technology in every aspect of society is largely a result of continuing advances in hardware and software progress and falling costs. Digital transformation is characterised by the European Commission (EC) as “a fusion of advanced technologies and the integration of physical and digital systems, the predominance of innovative business models and new processes, and the creation of smart products and services” (Going Digital (GD) Horizontal Project, 2017; European Commission, 2020). In the case of Waste management digital

technology is expected to put in a different prospective the way we manage waste. Some examples of digital technologies that are currently used but also expected to have a major impact in future include robotics, the Internet of Things, cloud computing, artificial intelligence, data analytics and distributed ledger technology (European Environment Agency, 2020a, b). In the context of waste management, robots are largely used in pneumatic sorting producing defined waste streams of high purity but also used in identifying and sorting recyclables and critical materials through image recognition/IR scanning/AI vision systems. Also, advanced algorithms that belong in the domain of machine learning are used for classification and pattern recognition improving the efficiency of sorting. For the waste and recycling industry, the opportunities of IoT exist above all in sensor-supported containers, in the simple, electronic processing of documentation, and in the networking of vehicles to improve logistics, whereas data analytics and cloud based software solutions make it easy to process and analyze data in order to identify patterns and trends, extract valuable information, optimise workflows by standardising and optimising internal procedures, real-time order management, route planning and optimisation. Finally, distributed ledger technology (Blockchain Technology) will provide solutions for improvements in waste management and transition to a Circular Economy, since tracking material flows and waste could be easily stored and monitored preserving them in a distributed ledger and knowing product's history and lifecycle.

1.4 Higher Education and Municipal Solid Waste/Circular Economy

Our societies have always been producing waste and will continue to do so in the future. The differences in the composition of waste streams or the variations in the quantities a human society produces reflect changes in technology, production methods, economic status, culture, etc. In general, the need to deal with the waste we produce in an efficient way is constant and is also subject to changes and adaptations. The world is gradually moving towards the concept of Circular Economy where the consumption of raw materials and energy is reduced by re-using waste and inserting them in the production cycle, by producing energy from waste and by increasing the rate of recycling. This transition requires a reform in higher education curricula that deal with these subjects. Furthermore, the universities themselves, as organisations, need to be sustainable. They should have a well-defined sustainability strategy with measurable sustainability indicators publicly available for credibility and accountability reasons.

Traditionally universities have three main functions: teaching, research and knowledge and technology transfer. The latter refers to the targeted use and transfer of academic knowledge to help resolve diverse societal challenges and constitutes the foundation of this study. Universities act as a driver of change for society, to stimulate the knowledge transfer into the regional economy, public administration and civil society organisations. This university function or mission is illustrated by Piirainen et al (2016) in Table 1.

Table 1: University and the third-mission activities

Category	Outputs	Examples of activities & services
Research, development and innovation (*RDI, Technology transfer*)	-Contracts with industry -Contracts with public bodies	-Student training -Licensing

	-Intellectual property -Spin-offs -Dissemination	-Consultancy and advisory -Commissioned research -Collaborative research
Continuing education (*Outreach*)	-Human resources -Access to knowledge and resources	-Industrial PhD programmes -MBA Programs -Open access teaching materials -Access to scientific infrastructure, libraries, laboratories
Social engagement and dialogue (*Engagement*)	-Participation in policy making -Involvement in social and cultural life -Public understanding of science	-Campus visits, open days -Science camps and fairs -Museums -Student and staff involvement in cultural life

Therefore, through this study and the analysis of the current university curricula on MSW management and CE we aim to describe and propose an integrate curriculum that not only addresses the contemporary needs but also incorporates all the latest technological advances and innovative tools from the field of IT and blockchain.

2 Municipal waste management curricula

2.1 Estonia

The Estonian system of higher education relies on four pillars (Ministry of Education and Research, 2021):

1. Public Universities (6): Estonian Academy of Arts, Estonian Academy of Music and Theatre, Estonian University of Life Sciences, Tallinn University, Tallinn University of Technology, University of Tartu
2. Private universities (1): Estonian Business School
3. Private professional higher education institutions (5): The Institute of Theology of the Estonian Evangelical Lutheran Church, Estonian Methodist Theological Seminary, Euroacademy, Estonian Entrepreneurship University for Applied Sciences, Tartu Theological Seminary
4. State professional higher education institutions (8): Estonian Aviation Academy, Estonian National Defence College, Lääne-Viru College, Estonian Academy of Security Sciences, TTK University of Applied Sciences, Tallinn Health Care College, Pallas University of Applied Sciences, Tartu Health Care College

These institutions offer wide range of study programmes: from social and theological to technical and IT. Also, entrepreneurship, security, medicine and health, aviation, veterinary and natural sciences, applied technical topics are covered in the wide range of studies offered by these higher education institutions.

In the following analysis we have focused on 4 biggest public universities in Estonia: Tallinn University of Technology (TalTech), Tallinn University (TLÜ), University of Tartu (TÜ) and Estonian University of Life Sciences (EMÜ). The selection of these universities was made based on their technical and natural sciences background, so it was assumed that they might offer the largest number of study programmes, which are related to MSW management or Circular Economy topics. Also, these are the biggest universities in Estonia by the total number of students. According to Estonian Statistics Office in 2019 the total number of students in these four universities comprise 74% of the total number of students involved into Bachelor's, Master's, Integrated Bachelor's and Master's, Doctoral or Professional higher educational studies (33 464 vs 45 178 students in total) (Estonian Statistics, 2021).

The Waste Management or Circular Economy topics were covered in larger or smaller extend in all 4 screened universities curricula:

- At Tallinn University of Technology, the topics of MSW or Circular Economy were mainly found in the subjects of the School of Engineering and to some extend - in the School of Science. No subjects in this regard were found only at Estonian Maritime Academy.
- In general, sustainability topics (including waste management) were very well presented in the curricula of Tallinn University. The most subjects related to greater or smaller extend to MSW or Circular Economy were found in the School of Natural Sciences and Health and less subjects were found in the curricula of the School of Digital Technologies.
- The courses related to solid waste management at University of Tartu were mainly running in the curricula connected with environmental technology (on bachelor and

master level) in the Faculty of Science and Technology. At smaller extend circular economy were integrated to some subjects from biology and biodiversity conservation and economy of business administration curricula. One free online course "Auditing waste management" is available for all interested students free of charge.

- In Estonian University of Life Sciences compulsory courses related to solid waste management and circular economy were mainly found in the curricula's focused on Environmental protection in both bachelor and master level. At the master level curricula "Environmental Governance and Adaptation to Climate Change" there are separate block dedicated to waste management and circular economy. Several subjects in bachelor and master level, which cover MSW and circular economy to smaller extend are mainly focused on Environmental management and protection as well as sustainable bioeconomy.

2.2 Germany

Germany's higher and third-level education institutions

The German system of third-level education relies on three (or four, depending on perspective) pillars:

1. **Public full-size universities** with a balanced spread between teaching, research and transfer
2. **Public universities of applied sciences** (appearing under a variety of designations) with often a highly specific teaching mission and an applied research profile that emphasizes transfer into the business community and society at large
3. **Private universities** (often of applied sciences) mostly offering specific teaching and sometimes research profiles, mostly in mass disciplines like business, IT, social sciences and communication. There are no known offers for waste nor circular economy degrees in this sector.
4. An additional pillar in third-level education is **vocational education** as an alternative to university-level studies. Vocational education offers a large variety of long-term training courses leading to highly specialized and certified occupational profiles enabling graduates to perform technical, social and administrative functions professionally. Certified vocational training programs combine job-based training with theoretical college instruction and come with an employment contract under private law. Certified occupations are e.g.
    - Supply, Recycling and Material Stream Technician (*Fachkraft für Kreislauf- und Abfallwirtschaft*) (FachKrW 2021)
    - Circular Economy Master Craftsman (*Meister in Kreislauf- und Abfallwirtschaft*) (MeiKrW 2021) A specific feature of vocational education (2-3 years' on-the-job training in vocational college, employment contract under private law) is the combination with an academic degree (Fig. 7). As of now, this option is highly sought-after by student of classic Business and Engineering disciplines but has not yet been extended to Waste Management. This dual-stream program is likely though to find immense popularity once more universities offer more specific Circular Economy or Waste Management or Sustainable Business degrees.

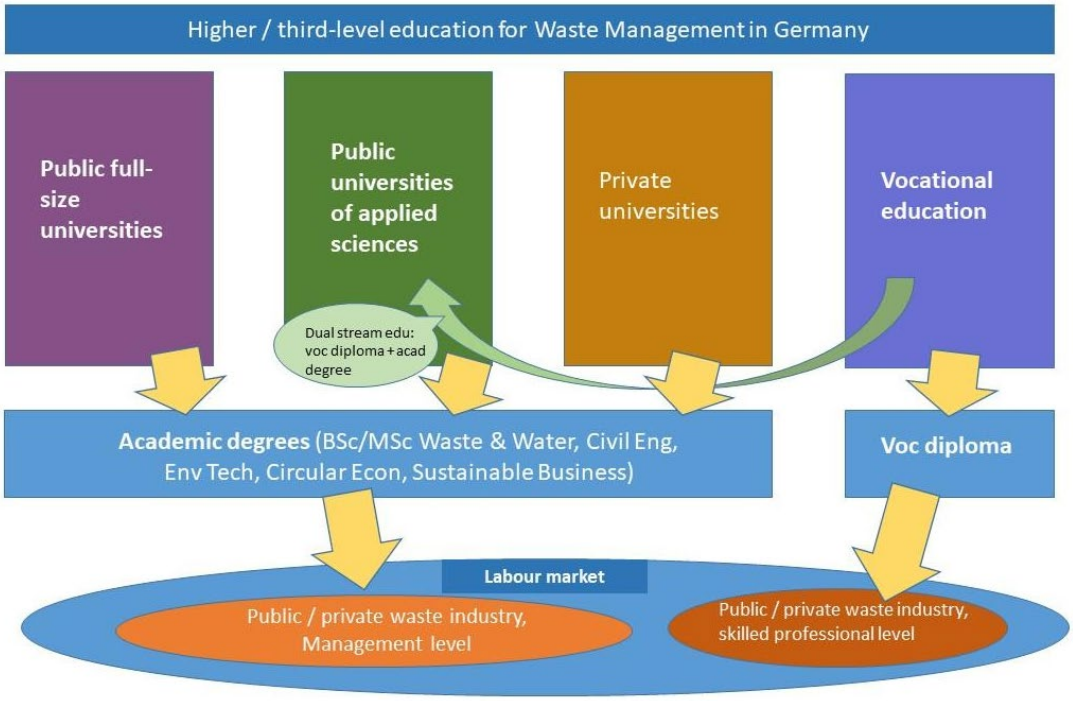


Figure 6: *This diagram shows the classic options plus specific educational variations leading into the Waste Management labour market (source: R. Lenz and B. Kleinheyer).*

For the purposes of this study, this pillar will be considered as one of four educational options as vocational curricula show the most elaborated and detailed repertoire of waste-related learning items, skills and occupational profiles even if their taxonomic target is below academic level.

Waste management and circular economy in university curricula

Study and training profiles related to waste management and circular economy can be found in pillars 1, 2 and 4 mostly as part of wider degrees and often appear under the name of *Circular Economy Studies*, *Sustainability Studies* or *Waste Economy*. As in other countries, the shift in concept from waste management to circular economy has thus trickled through to university curriculum design in Germany, at least in terms of wording.

Waste management and / or Circular Economy studies can be found as part of these types of degrees (with no difference discernable between municipal and private-sector waste management):

Degree profiles			
Waste Management / Circular Economy in classic **Engineering** studies (mainly	**Waste Management / Circular Economy studies** as part of **Environmental Technologies** and **Environmental**	**Waste Management / Circular Economy** studies as part of **Business** and **Economics**	**Municipal Waste Management** as a module on **Engineering** courses

Civil Engineering)	**Informatics** degrees	studies	

(source: Rainer Lenz and Bernd Kleinheyer)

- **Classic Engineering studies**
  In order to understand the penetration level of Waste Management / Cirular Economy studies, both wider, more general engineering programmes and specific Waste Management degrees have been considered and their content in specific Waste Management / Circular Economy modules analyzed.

Waste Management studies as part of Civil Engineering degrees

Waste Management and Technologies are, in most cases, offered as one of several topics, modules or electives on engineering degree programmes at 12 faculties (undergraduate and graduate levels). Most of these degrees would have a Civil Engineering profile and offer conventional foundation modules such as Physics of Construction, Structural Analysis, Fracture Mechanics and Integrity, Finite Elements etc and specialization like Public Works, Water, Utility and Supply Systems and also Waste, often in conjunction with Water. Circular Economy will usually appear as a secondary sideline if at all. Not surprisingly, Digitalization is usually not found as a cross-cutting topic, let alone Blockchain or specific information technologies.

Waste Management studies as full-size degrees

The number of full-length degrees on Waste Management and / or Circular Economy Studies is very limited. Few universities seem to have taken the risk of offering highly specialized degrees focusing on waste in a circular economy. One possible reason could be that at the operative and shopfloor level, highly specialized vocational profiles (cf pillar 4 above) have been in the labour market for at least 20 years whereas positions requiring specific management skills seem to have been filled with holders of Environmental Technologies or Civil Engineering degrees, i.e. broader qualifications mostly comprising basic overview of waste management technologies. It is unclear whether the waste industry has little demand for deeper and more specific 'waste' skills or whether those skills are so hard to find that more general engineering skills are thought of as the closest equivalent.

The few universities offering **stand-alone degrees** focusing on Waste Management are

- Berlin University of Technology,
- Clausthal University of Technology
- Dresden University of Technology
- Stuttgart University,

and, as the only university of applied sciences at the top of the ranking

- Magdeburg-Stendal University of Applied Sciences

Most of them will have specific modules on the Circular Economy on their curricula.

- **Waste Management studies** as part of **Environmental Technologies** and **Environmental Informatics** degrees Typical Environmental Technologies degrees comprise a wide selection of sector-specific technologies: energy, manufacturing, mobility, emissions, water purification, building materials, and also waste management / circular economy. They also offer cross-cutting module topics like sustainability accounting and management, communication and others and seem to be addressed to engineering-leaning applicants that seek a versatile and somewhat 'holistic' degree without committing themselves to a sector-specific profile. Waste is, however, a secondary topic typically appearing, if at all, in one or

two modules. Given the cross-disciplinary nature of these degrees, they seem to offer potential for integrating digital technologies into their curricula all the more as they also focus on management and process-steering skills. As for Environmental Informatics degrees, their typical profile is more in management support, statistics, measuring techniques and data science without coming anywhere close to digitalization of entire processes in the waste chain. Given the IT-based management support function these degrees target they could, in the future, absorb digital process technologies (e.g. Big Data Analysis and AI) in their curricula, thus enabling managers of circular economy systems to draw value from digitalization.

- **Waste Management** studies as part of **Business and Economics** studies German universities offer, under various designations, a small but growing number of degrees in the line of sustainability management. They target students wishing to reconcile business and management with environmental and social awareness and responsibility. Considering the broad spectrum of sectors awaiting the 'sustainability turning', waste and circular economy are and will be only one of a range of sectors addressed. These degrees typically focus on non-technical management and business analysis from a sustainability perspective. Considering the rapidly growing impact of data-based decision-making and digitalized management techniques, they will sooner or later incorporate e.g. Big Data analysis and distributed computing like Blockchain, provided their planners are ready to devote much more module capacity to IT skills. This will enable graduates to take up responsibilities in the changing waste industry without acquiring profiles specifically related to the sector.
- **Municipal Waste Management** as a module topic in its own right among those degrees supplying engineering skills related to waste cycles the specifics of public-sector waste services are rarely addressed as such. The only degree making a passing mention of public-sector environments is Technische Hochschule OWL's Environmental Engineering BSc. For the purpose of the present project, the question of public or private governance will therefore be disregarded when determining the penetration of Waste Management studies and curricula in university studies in Germany. No distinction will thus be made between Waste Management and Municipal Waste Management and respective study programs. It would, however, be misleading to conclude from this that legal status and (public/private) governance are irrelevant issues not worth appearing as subjects on waste-related degrees. It should be remembered from what was stated above that most curricula analyzed here are of an engineering type and only provide, if at all, basic legal and business skills. It can therefore be assumed that more attention will go to governance aspects and respective curricula once the waste sector has made, in the way it is viewed by both users and operators, the full shift from linear disposal orientation to a circular economy driver.

All relevant degrees considered, it can be stated that:

- … waste and circular economy are predominantly found as subjects of 'sectoral' (mostly civil) engineering degrees
- … popular Environmental Technologies degrees with their broad character provide, as of now, only few skills specific to the waste sector but, in return, often build a 'circular mindset' encouraging sustainability and resource efficiency thinking.

- … in their vast majority, they treat waste and the circular economy as one of several environmental sectors or disciplines governed by specific principles and presented in their basic characteristics
- … waste and / or the circular economy have become the defining topic for specific degrees in four to five cases only, which suggests the demand for graduates with specific 'waste' or circular economy skills is still limited.

2.3 Greece

Higher Education in Greece

Higher education is the last stage of the formal education system in Greece. According to the Greek Constitution (article 16), higher education is public and it is provided only by institutions, Higher Education Institutions (HEIs; Ανώτατα Εκπαιδευτικά Ιδρύματα) which are legal entities of public law.

The total number of HEIs is 25, with 141 schools and 431 departments / divisions.

Waste management and circular economy in university curricula

After screening the entire higher education sector in Greece for municipal solid waste and circular economy courses, modules or entire degrees, the following conclusions can be drawn:

- A total of 25 undergraduate and 7 post-graduate courses were found.
- 2 post-graduate degree programs and 1 short program (e-learning) were also found:
  - University of Thessaly: MSc "Sustainable Management of Environmental Change and Circular Economy"
  - Hellenic Open University: MSc "Waste Management" and short program "Introduction to Waste Management"
- As a general rule, the courses are part of Engineering Schools curricula. Usually Civil, Chemical and Environmental Engineering Departments.
- The focus of the courses' syllabus is on waste in general and on treatment technologies. Some courses focus specifically on MSW. For the majority, MSW is part of the course teaching material.
- Another popular subject included in the teaching material is recycling, re-use and material recovery. The principles of circular economy are mentioned in very few cases.
- No course offers teaching regarding IT/smart technologies/blockchain in MSW.

2.4 The Netherlands

In the Netherlands, there are no full programmes on waste management or MSW management. There are, however, a number of programmes that focus on the circular economy and are aimed at cities. We have reviewed the offerings of Dutch universities and universities of applied sciences and selected those programmes that devote part of their teaching or research to waste management. Often, this is a limited part of the total programme. Dutch universities offering urban waste management as a part of the curriculum in minor of major parts are:

Wageningen University & Research (WUR),

-Urban Environmental Management, Full master programme.

The MSc programme Urban Environmental Management is an international and interactive programme providing a balanced curriculum of theory, tools and application. It aims to train students to guide the future along the path of sustainable urbanisation. Waste management is part of the programme.

-Living Lab - Metropolitan Analysis, Design and Engineering.

In the Living Lab students of the master's Metropolitan Analysis, Design and Engineering work on real-life cases within the city of Amsterdam. Waste management is part of the many issues being examined.

Erasmus University Rotterdam - Erasmus School of Social and Behavioural Sciences

Urban Management and Development, Full master programme.

The Infrastructure and Green Cities specialisation track within the M.Sc. in Urban Management and Development addresses the planning, management and finance of urban infrastructure using a smart and green infrastructure lens. The track focuses on topics such as public transportation, drinking water, sanitation and waste management, (renewable) energy and digital infrastructure, including technologies related to 'smart city' solutions.

University of Amsterdam, Track Environmental Management, part of Master Earth Sciences

Environmental Management is a programme which integrates knowledge from natural science disciplines such as (physical) geography, landscape ecology, environmental chemistry, sustainability and transition management. Waste management is one of the themes covered in this track. Research is also being conducted into urban waste management in Amsterdam

University of Twente, Environmental & Energy Management

The core of this one-year, English-taught programme consists of three interconnected domains of sustainability: Environment, Energy and Water.

The programme teaches the interrelated management & governance of these three crucial domains, with respect to climate change mitigation and adaptation, resilience, energy transition, circular & social entrepreneurship, and achieving (related) sustainable development goals (SDGs). Waste management is one of the themes covered in this programme.

Professional training courses

Enquiries made to a number of field contacts in the MSW sector reveal that many students who come to do an internship or thesis have a civil engineering background and have developed an interest in the field of MSW themselves. The sector trains these people itself or organises refresher courses and training to professionalise the sector and train new employees. Examples are:

- Waste- and resource management training, Studiecentrum voor Bedrijf en Overheid, 5-day programme, https://www.sbo.nl/milieu-ro/opleiding-afvalmanagement/

- Training Management in the Circular Economy, Studiecentrum voor Bedrijf en Overheid, 5-day programme, https://www.sbo.nl/milieu-ro/opleiding-regie-circulaire-economie/
- Basic course in Waste Management Law, Berghauser Pont Academy, 1-day course, https://www.berghauserpontacademy.nl/aanbod/cl171/basiscursus-afvalstoffenrecht/

2.5 Spain

The Spanish university system is made up of a total of 82 universities with the following characteristics: 50 public universities (47 on-campus, 1 off-campus and 2 special universities - UIMP and UNIA-) and 32 private universities (28 on-campus and 4 off-campus).

The total number of students enrolled in the Spanish University System (SUE) in the 2019-2020 academic year is 1,633,358. Undergraduate and Bachelor's degree students represent 80.2% of the students enrolled, Master's degree students 14.3% and Doctorate students 5.5%. 80.5 % of students are enrolled in public universities. Students in non-face-to-face universities represent 16.2% of the total.

University studies are official higher education courses of a voluntary nature that train students for the exercise of professional activities.

The unit of measurement used in the framework of the EHEA to structure the curricula of university studies is ECTS credits (European Credit Transfer System). Each credit includes between 25 and 30 hours of student activity, including classroom learning hours, study hours, tutorials, assignments, etc. In general terms, 60 ECTS credits are equivalent to one academic year.

University degrees include three types of subjects:

- Basic subjects: these are compulsory and are linked to the different branches of knowledge into which the degree courses are organised. A minimum of 60 credits of core subjects must be taken in each degree, which will be recognised if a student moves between related degrees.
- Mandatory subjects: subjects with content specific to the degree that must be taken by all students.
- Optional subjects: these are subjects that students must choose from among those proposed by the degree programme on the basis of their academic or professional interests. They can be grouped into pathways.

Moreover, the syllabus of a university degree necessarily culminates with the preparation of the final degree project (TFG), and may also include external internships and other training activities such as, for example, seminars.

The courses, degrees, masters, and doctorates that, a priori, have a greater relationship with waste management and the circular economy are:

Specialization in Waste Management and Treatment (UNIVERSIDAD DEL PAÍS VASCO / EUSKAL HERRIKO UNIBERTSITATEA)

https://www.ehu.eus/es/web/master/master-ingenieria-ambiental/programa

The progressive incorporation into legislation of European directives on environmental matters, the growing social sensitivity, the civil and criminal liability of companies for damage caused to the environment, the problems of air pollution and the progressive increase in waste, especially toxic and hazardous waste, among others, has forced companies and public administrations to develop and incorporate effective environmental management tools, requiring the implementation of effective environmental policies to achieve a continuous improvement of the environment.

Aware of this reality, our institution, from a policy of anticipation, has been offering specialized training that effectively enables to intervene safely and effectively in the management of the environment.

Circular Economy Expert (Universidad de Cádiz)

https://formacion.fueca.es/?curso=oeu201122_i-experto-en-economia-circular

Acquisition of sufficient theoretical and practical knowledge to successfully face the transition from a linear economy to a circular one.

Raise awareness and train students in the life cycle approach and tools such as eco-design, environmental, water and carbon footprint, life cycle analysis and waste management.

To raise awareness and train professional experts in circular economy to face future business challenges in order to meet the objectives set by the United Nations 2030 Agenda for Sustainable Development and the new package of directives on circular economy published by the European Union.

Master's Degree in Organic Waste Management, Treatment and Valorization

(Universidad Miguel Hernández de Elche)

http://masterresiduos.edu.umh.es/

The master's degree offers you the opportunity to specialize in the treatment, management and recovery of organic waste and to embark on a research career through a doctoral program.

Municipal Waste Management Course (IUSC)

https://www.iusc.es/ambientales/item/gestion-de-residuos-municipales-pres

The progressive incorporation of European environmental directives into the Spanish domestic legal system, the responsibilities associated with incorrect management of activities and the growing social awareness, has forced companies and public institutions to develop effective waste management systems and plans. Today, there are many waste management facilities in operation or under construction, facilities that must be managed by professionals trained in the specialty.

Aware of this reality, our institution offers with this course a specialized training specifically designed to achieve an effective training in the safe and efficient management of waste.

Master's Degree in Urban Waste Management (ESNECA)

https://www.mastermania.com/master-en-gestion-de-residuos-urbanos-online-296764_q08.html

The master's degree in urban waste management is intended for businessmen, entrepreneurs or workers in the field of waste. It provides knowledge of the collection and transport of urban or municipal waste, the treatment of urban or municipal waste and the management of inert waste.

Master's Degree in management, treatment and use of wastes. (Universidad de Valencia)

https://postgrado.adeituv.es/es/cursos/area_de_seguridad__salud_y_medio_ambiente-6/tratamiento-aprovechamiento-residuos/datos_generales.htm

The progressive incorporation into legislation of European directives on waste and the civil and criminal liability of companies for damage caused to the environment, pollution, increased waste has forced both companies and public administrations to develop and incorporate environmental management tools to eliminate and minimize the problem. That is why the Master in Management, Treatment and Use of Waste offers a window of opportunities in this regard.

The elimination, reduction and recycling of waste, the maximization of available resources, as well as the maximum use of those elements whose generation could not be avoided, are urgent themes to be addressed. Aware of this, the Universitat de València has specialized training for effective training to intervene safely and efficiently in the management of the environment.

Course on Circular Economy and Innovation. (Escuela de Empresa)

https://escueladeempresa.com/cursos-universitarios-6-meses/economia-y-financiera/curso-en-economia-circular-e-innovacion/

To provide participants with knowledge and tools in the field of circular economy and innovation that can be used to enhance the value of territories, organizations and companies.

Master's Degree in Circular Economy and Sustainable Development (Universidad Internacional de Valencia)

https://www.universidadviu.com/es/master-economia-circular-desarrollo-sostenible

Provides students with the theoretical and practical knowledge to obtain a global and transversal vision of all the most important areas and sectors of application of the Circular Economy and Sustainable Development. Graduates will be able to design strategies that will allow both private and public companies to reorient their current production model to the circular model we need, while promoting entrepreneurship and innovation as ways to generate wealth and employment.

Master's Degree in Circular Economy (Universidad de Burgos)

https://www.ubu.es/master-universitario-en-economia-circular-semipresencial

The transition from linear to circular economy implies combining different technical and strategic measures, acquiring knowledge on life cycle analysis, eco-design, efficient energy management, efficiency and profitability in resource use and waste management, incorporation of environmental costs in prices, substitution of consumption for use, improvement of production systems, lean manufacturing, management of products and companies in circular economy, new business models, ... among others.

Master's Degree in Circular Economy (Universidad de Navarra)

http://www.unavarra.es/sites/masteres/economia-y-empresa/economia-circular/presentacion.html

Acquire a multidisciplinary training, from scientific-technical to economic-legal aspects, essential for the implementation of the principles of circular economy in companies and public and private institutions. Get ready to participate in the design of a future aimed at sustainable development.

Master's Degree in Green and Circular Economy (INESEM Business School)

https://www.inesem.es/Master-Economia-Verde-Circular

Among the UN goals for 2030 are climate action and responsible production and consumption, which can only be achieved through new economic and production models that lead to improved social and environmental development. In view of this, a new labor market with a future and aware of the need for change is emerging: the Master in Green and Circular Economy is an opportunity and an instrument to achieve these goals.

Master's Degree in Circular Economy, specializing in Minerals and Construction Products. (Universidad Politécnica de Madrid)

https://www.upm.es/Estudiantes/Estudios_Titulaciones/Estudios_Master/Programas?id=13.7&fmt=detail

The University Master's Degree in Circular Economy is a new Intercenter postgraduate program with a common training block and two differentiated itineraries: Consumption and Management of Natural Capital, and Minerals and Construction Products, coordinated respectively by the School of Forestry, Forest and Natural Environment Engineering (ETSIMFMN) and the School of Agricultural, Food and Biosystems Engineering (ETSIAAB), both of the Polytechnic University of Madrid (UPM).

University expert in circular economy and engineering (Universidad Católica de Murcia)

https://www.ucam.edu/estudios/postgrados/economia-e-ingenieria-circular

The Circular Economy and Engineering (CEE) emerges as an alternative to traditional production, sustainable over time, which emphasizes the management of material, energy and water resources, and the reduction of negative externalities, such as CO2 emissions and waste. The responsibility of companies, institutions and citizens implies acting to change the current model towards a more sustainable one, such as the Circular Economy and Circular Engineering.

This program organized by the International Chair of Social Responsibility of the UCAM tries to address all these dilemmas and questions through a blended and online training of 500 hours.

Course on Circular Economy. New Economic Model of Production and Consumption. (Instituto superior del medio ambiente)

https://www.ismedioambiente.com/programas-formativos/economia-circular/

In the Circular Economy course we will see how, through the circular economy: companies can create value by reusing and recycling products; and designers can come up with smart solutions, with which to contribute to the principles of the circular economy can be applied.

Circular Economy and Zero Waste Workshop (AEC)

https://www.aec.es/formacion/catalogo-cursos/taller-de-economia-circular-y-residuo-cero-en-directo/

To analyze the fundamental role of waste management in the business model of sustainable growth in its change towards a circular economy.

To present opportunities that are opening up in relation to waste management: to valorize and monetize by-products and waste; and to save management costs.

To study the existing ways for the implementation of a Zero Waste Management System. Success stories and examples.

3 Screening Higher Education Systems for municipal waste management curricula

Since one of the objectives of the project is to produce a European common curriculum containing:

- The essential basic points of the functioning of the blockchain technology, analysed and studied in the subtask O2/A1.1.
- The essential basic points of the solid urban waste management analysed and studied in the subtask O2/A1.2.
- Innovative training material linking both topics, which will allow the development of basic skills, competences and theoretical knowledge for the implementation of blockchain in the management of solid urban waste.

It is more efficient and productive to apply a scoring method in order to provide a ranking among the results. Each national report applied each own scoring system and respective criteria. The results were presented using a 3-color code, namely "green" for the leading cases, "yellow" for the average performers and "red" for those cases that fall short of the criteria applied.

3.1 Estonia

In order to obtain some comparability, the following «traffic lights» ranking approach was applied to compare performance of 4 different universities regarding WM/CircEcon coverage:

Teaching	R&D	Events
At least 5 major subjects related to WM/CircEcon	Min 2 running projects on WM OR Min 10 publications on WM	Min 3 over the last 2 years
At least 3 major subjects related to WM/CircEcon	Min 1 running project on WM OR Min 5 publications on WM	Min 1 over the last 2 years
No subjects related to WM/CircEcon	No running project on WM OR less than 3 publications on WM	None

Results

Rank	University	Teaching	R&D	Events
2	Tallinn University of Technology	At least 5 major subjects + 8 minor subjects	At least 3 projects + at least 9	At least 2 events related to

			publications in 2020	smart cities (during 2019-2020)
4	Tallinn University	At least 3 major subjects + 8 minor subjects	At least 2 projects + at least 1 publication in 2020	0 (during 2019-2020)
3	University of Tartu	At least 6 major subjects + 6 minor subjects	At least 4 projects related to green economy, wastewater treatment in 2020 + 0 publications	0 (during 2019-2020)
1	Estonian University of Life Sciences	At least 6 major subjects + 6 minor subjects	At least 3 projects related to circular economy in 2020 + several publications in the field of solid waste management and circular economy	At least 4 events organized during 2020-2021 related to green economy, sustainability, food waste

3.2 Germany

In order to be of value to the project's curriculum design effort, the analysis of curricula in use in Germany needs to go beyond an overview of the spectrum of teaching offers. This is why a ranking of institutions and degree programs supported by a simple scoring mode was found to produce the most relevant view of those degrees that could act as models of good practice. The scoreboard comprised three criteria:

- The existence of one or several specific Waste Management or Circular Economy degrees (across all academic cycles); alternatively the number of modules (or summer schools) on the same topics offered on more broadly based degrees
- The number of university events organized around those topics
- The number of research projects and publications focusing on waste management and / or the circular economy

The underlying logic is that teaching as the principal focus of this study cannot be considered without looking at the anchor the institution's / faculty's research profile has in the subject. This research focus in its public articulation at events (one major aspect of transfer) is the third variable that was to be considered to determine the viability of the curriculum.
Not surprisingly, it turned out that the larger universities of technology with their powerful research and transfer structures complementing their relatively sustained teaching offers came out on top.

Ranking

In order to obtain some comparability, the following ranking was applied to those study offers that come closest to full implementation of Waste Management and Circular Economy degrees, electives or modules.
The criteria chosen are relative to the state of topic penetration found in the field.

Teaching	R&D	Events
min 2 specific modules, summer schools etc on WM/CircEcon	Min 2 projects on WM OR Min 10 publications on WM	Min 3 over the last 5 years
Min 1 specific module, summer school etc on WM	Min 1 project on WM OR Min 5 publications on WM	Min 1 over the last 5 years
No module, no summer school on WM	No project on WM OR Less than 3 publications on WM	None

Scoreboard: penetration of Waste Management and Circular Economy studies in German higher edcuation
Note: *Water* and *Biomass/Biogas* were disregarded as subjects

Rank	University	Teaching	R&D	Events
1	**U-Stuttgart**	1 degree, 5+ modules	10+ publications (2019)	4+ (2019)
2	**Dresden UT**	1 degree, 3+ modules	4+ publications (2019)	2+ (2019)
3	**Berlin UT**	2+ modules, 1 summer school	6 publications (2019)	5+ (2019)
4	**Aachen UT**	2 modules	6 projects (2019), 23 publications (2019)	1 (2019)
5	**Magdeburg-Stendal UAS**	2 modules	1 project (2019)	0

In the cases of Aachen, Dresden and Stuttgart, a strong dominance of water-related research (not considered here) at faculty and institute level can be observed. Solid waste management comes as a secondary research area.

3.3 Greece

Since the aim of the project is to design a model curriculum in the field of MSW/circular economy a summary of the university curricula offered in Greece with their relevant description would not be sufficient. It would be more efficient and helpful to apply a second level of process by using a scoring method in order to provide a ranking among the results. The scoring was based on three criteria:

- The existence of one or several specific Waste Management or Circular Economy degrees (across all academic cycles); alternatively the number of modules or courses or summer schools on the same topics offered on more broadly based degrees.
- The number of university scientific publications in peer-reviewed journals on those topics.
- The number of research projects (mainly EU funded projects under the FP7 ad Horizon 2020 programs) focusing on waste management and / or the circular economy.

Ranking

The following ranking was applied to those study offers that come closest to full implementation of Waste Management and Circular Economy degrees, modules or courses.

Teaching	Research	Publications
Min 2 specific courses, modules, etc. on WM/CircEcon	Min 3 projects on WM/CircEcon	Min 10 over the last 5 years
Min 1 specific course, module, etc. on WM	Min 1 project on WM/CircEcon	Min 5 over the last 5 years
No course, module etc. on WM/CircEcon	No project on WM/CircEcon	Less than 5 over the last 5 years

Rank	University	Teaching	Research projects	Publications
1	National Technical University of Athens	4 courses (3 undergraduate – 1 post-graduate)	>5	>10

2	Aristotle University of Thessaloniki	5 courses (4 undergraduate – 1 post-graduate)	>5	>10
3	University of Patras	3 courses (undergraduate)	>3	>10
4	Technical University of Crete	2 courses (1 undergraduate – 1 post-graduate)	>1	>10
5	Democritus University of Thrace	7 courses (4 undergraduate – 3 post-graduate)	>1	>10
6	University of Thessaly	2 courses (1 undergraduate – 1 post-graduate)	1	>5
7	University of Western Macedonia	3 courses (undergraduate)	>1	1
8	Harokopio University of Athens	3 courses (2 undergraduate – 1 post-graduate)	0	3
9	International Hellenic University	2 courses (undergraduate)	0	3
10	Hellenic Open University	2 degree programs (1 MSc degree and 1 short program)	0	3
11	University of the Aegean	1 course (undergraduate)	0	3
12	University of Western Attica	1 course (undergraduate)	0	0

3.4 The Netherlands

In order to obtain some comparability, the following «traffic lights» ranking approach was applied to compare performance of 4 different universities regarding WM/CircEcon coverage:

Teaching	R&D	Events
At least 5 major subjects related to WM/CircEcon	Min 2 running projects on WM OR Min 10 publications on WM	Min 3 over the last 2 years

At least 3 major subjects related to WM/CircEcon	Min 1 running project on WM OR Min 5 publications on WM	Min 1 over the last 2 years
No subjects related to WM/CircEcon	No running project on WM OR less than 3 publications on WM	None

Results

Rank	University	Teaching	R&D	Events
1	Wageningen University & Research (WUR)	At least 5 major subjects	At least 2 projects + >10 publications in 2020	At least 3 events related to urban environmental management (during 2019-2020)
2	Erasmus University Rotterdam	At least 8 major subjects	At least 2 projects + >10 publications in 2020	1 (during 2019-2020)
3	University of Amsterdam	At least 3 major subjects	At least 1 project on urban waste in Amsterdam + 10 publications in 2020	1 (during 2019-2020)
4	University of Twente	At least 1 minor subject	0 project + 1 publications (thesis) in 2020	0 (during 2019-2020)

3.5 Spain

In order for the study sample to be representative, the 10 public universities with the most students enrolled in Spain and the 3 private universities that meet the same requirement were selected for this study. The sample selected represents a total of 767,740 students, which corresponds to 47% of the total number of students enrolled in all universities in Spain.

To facilitate comparison between the different countries participating in the study, the following “traffic light” scoring system has been used to classify the relationship that the universities studied have with Waste Management and the Circular Economy.

Teaching	R&D	Publications

Min 2 specific modules, summer schools, etc. on WM/Circular Economy	Min 3 projects on WM/Circular Economy	Min 10 publications on WM/Circular Economy over the last 5 years
Min 1 specific module, summer school, etc. on WM/Circular Economy	Min 1 project on WM/Circular Economy	Min 5 publications on WM/Circular Economy over the last 5 years
No module, no summer school on WM/ Circular Economy	No project on WM/Circular Economy	Less than 3 publications on WM/Circular Economy over the last 5 years

University	Teaching	R&D	Publications
Universidad Nacional de Educación a Distancia	4	1	2
Universidad de Sevilla	6	4	>10
Universidad Complutense de Madrid	0	0	>10
Universidad de Granada	4	3	8
Universidad de Valencia	4	3	>10
Universidad de Barcelona	3	5	>10
Universidad del País Vasco	3	4	>10
Universidad Rey Juan Carlos	2	3	>10
Universidad Politécnica de Madrid	3	3	>10
Universidad de Málaga	2	2	>10
Universitat Oberta de Catalunya	0	0	>10
Universidad Internacional de La Rioja	0	0	4
Universidad Ramón Llul	0	0	1

4 Best practices

Best practices in Estonia

The screening process of 4 largest universities in Estonia regarding courses, modules or entire degrees in Municipal Solid Waste and/or Circular Economy has identified that:

1. at least in 20 courses the topic of MSW or Circular Economy was covered to major extend
2. at least in 28 courses the topic of MSW or Circular Economy was covered to some (minor) extend

In general, the waste and/or circular economy topics were in larger or smaller extent very well presented in the curricula of all 4 screened universities. Based on the analysis of running projects and publications content the Tallinn University of Technology (TalTech) has the strongest research regarding solid waste management. The Estonian University of Life Sciences, in turn, has the strongest research regarding circular economy topics. Also, this university has quite a comprehensive list of events organized in recent years related to the green economy, sustainability, food waste, etc.

Tallinn University and Estonian University of Life Sciences have the strongest research and curricula regarding general sustainability topics. These two universities also have a title of «green university». In turn, Tallinn University of Technology has recently joined the Green Tiger initiative - a collaboration platform, which is designed to boost environmental awareness and create a basis for a green economy (https://rohetiiger.ee/en/). It is believed that TalTech will test different practices for sustainable and climate-neutral economy, which would potentially increase the cross-disciplinary design and general handling of Circular Economy topics.

Best practice items in Germany

The intention of the review of specific degrees was to identify curricula that address the following advanced requirements:

- cross-disciplinary design (civil/mechanical/chemical) engineering, management, economics, geo-sciences, social sciences, IT)
- Circular Economy and climate-aware approach and ‘mindset’ incl legal issues
- data-driven analytics and management skills
- innovation-leaning and innovative, student-centered learning design (‘methodology’)

To identify an existing curriculum showing a close match and defining the national state of the art in higher education for waste management / circular economy skills, a micro-level review of the degrees selected for the ranking in chapter 3.2 was carried out. The best combination was found in RWTH Aachen’s MSc Environmental Engineering (Aachen_MSc_EnvEng)

	Matches of requirements	**Gaps, mismatches**
Cross-disciplinarity	Mostly; very multi-disciplinary (in an	Solid waste secondary

	additive sense?), strong focus on Water	
Circular Economy (CE) incl legal issues	partly	Integration of CE as a cross-cutting principle?
Data-driven approaches	low	Sideline topic
Innovation in learning items and learning design	low	Strong emphasis on lecturer output; broad choice of specializations, project spaces allowing for individual profiling and student initiative

Best practices in Greece

The screening process of the entire higher education sector in Greece regarding courses, modules or entire degrees in Municipal Solid Waste and/or Circular Economy returned the following results:

- A total of 25 undergraduate and 7 post-graduate courses were found.
- 2 post-graduate degree programs and 1 short program (e-learning) were also found:
  - University of Thessaly: MSc "Sustainable Management of Environmental Change and Circular Economy"
  - Hellenic Open University: MSc "Waste Management" and short program "Introduction to Waste Management"

After applying a scoring methodology, the Universities were ranked on the grounds of their performance with regards to the criteria used, namely: number of courses, modules or degrees offered, their participation in research programs funded by the E.U. and the number of scientific publications in peer-reviewed journals.

According to the final ranking, 5 institutions: The National Technical University of Athens (NTUA), the Aristotle University of Thessaloniki (AUTH), the University of Patras (UPatras), the Technical University of Crete (TUC) and the Democritus University of Thrace (DUTH) appear to be the most active in the fields of municipal solid waste and circular economy. These five universities offer courses in these fields both at undergraduate and post-graduate level. In addition they are very active in terms of research and publications as they have participated in a significant number of EU funded research programs during the last 10 years and they have published a great volume of papers in peer-reviewed journals over the last five years. NTUA and AUTH in particular can be considered as best practice examples as besides their scores are among the oldest universities, they have significant infrastructure and are ranked highest according to the Webometrics Ranking of World Universities (2020).

Best practices in the Netherlands

WUR is a leading international university (Fig. 8). WUR's ranking in the QS World University Rankings in 2020 for Environmental Sciences is 8 worldwide. Wageningen University & Research is the cooperative framework of Wageningen University and the Wageningen Research Foundation, which comprises nine independent research institutes. They work together in five Sciences Groups. One department of the university is organisationally integrated within each Sciences Group together with one or more research institutes. This combination of forces allows education and research to partner in focused, high-quality projects.

In 2019/2020, there were 12,337 students, excluding PhD students, with a total of 102 different nationalities. The diversity of backgrounds, the reinforcing nature of the different research themes and the close cooperation with industry and governments, national and international, make the education and research programme unique. Urban Waste Management is a topic of Environmental Sciences and 20 chair groups at WUR.

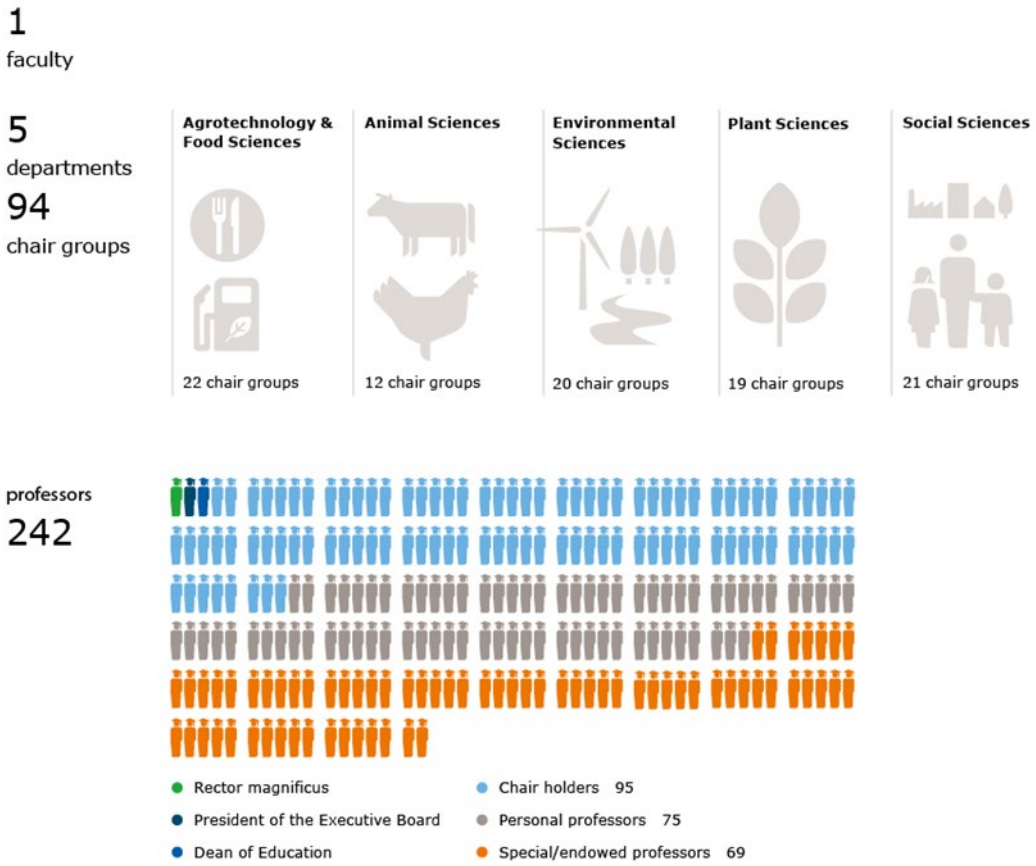


Figure 7:*The Wageningen University of Research in numbers (source: https://www.wur.nl).*

Best practices in Spain

After carrying out this study, we can observe that Public Universities have a higher activity related to waste management and circular economy than Private Universities in Spain.

Out of the 10 Public Universities, 9 of them offer studies related to Waste Management and/or Circular Economy, 7 of them have a high research activity and 2 of them have medium activity. Finally, all the Universities have publications related to Waste Management or Circular

Economy, which shows that although they are not present as subjects, courses or masters, they are present in the form of final degree projects, publications, etc.

On the other hand, private universities do not present training on waste management or circular economy or research activity. The only activity they present is in the form of publications, in many cases consisting of Bachelor's or Master's degree final projects of their students. In most cases, the academic curriculum offered is associated with undergraduate studies in Environmental Sciences, Environmental Engineering or Civil Engineering.

Among the universities included in this report, the University of Seville is the one with the largest academic offer in terms of waste management and circular economy, which could be an example of good practice, as could the University of Valencia, which has a Master's degree in Circular Economy with two specialisations: minerals and construction products or sustainable consumption and management of natural capital, and the University of Barcelona with research projects such as RES URBIS, which produces bioplastics from urban organic waste.

As for the activity of the University itself, the University of Barcelona stands out together with the University of Malaga, the Polytechnic University of Madrid, the University of the Basque Country and the National University of Distance Education, as they clearly reflect the detailed reports of the entity's activity on their respective websites.

5 Conclusions

The first step before we can draw the main conclusions of this report is to describe the current situation, in other words the status quo regarding MSW and CE university curricula in the five countries as stated in the provided reports. We try to identify similarities and common elements among the offered university curricula as well as weaknesses in the existing courses. Moreover, we look for links with the industry and the degree of collaboration with waste management stakeholders. The main findings are as follows:

- Although there are a lot of courses/modules regarding MSW management and CE, in the majority of the cases there are no exclusive MSW/CE degrees. With the exception of Spain where we find a few post-graduate degrees offering specialization in CE.
- As a general rule, MSW/CE courses are found in engineering schools curricula, such as civil and environmental engineering. These courses/modules can be core courses or elective courses, the latter part of a specialization.
- The content of these courses displays a variety of subjects: waste characterization, types of waste, environmental pollution, waste treatment methods, waste disposal, sanitary landfill design, incineration etc. In many cases waste water and water pollution is an important part of the syllabus.
- Many courses, both at undergraduate and post-graduate level include in their respective learning objectives the principles of recycling, sustainable development and circular economy to some extent.
- More often than not the examined courses do not have a circular economy mind-set in their core.
- Similarly, there is almost an absence of Industry 4.0 elements like Big Data, smart technologies, IoT and blockchain.

At this point, we should underline that waste management and circular economy are, in general, cross-cutting topics and their teaching content should be designed in an interdisciplinary manner. Beside the engineering and environmental aspects, there are also elements from business studies, economic studies, legislation etc. Therefore, with a view to developing or re-designing an advanced curriculum for higher education in circular economy focusing on the application of Blockchain Technology in Municipal Waste Management, we can highlight some general features/requirements/principals of such an ideal curriculum:

- The curriculum should have a certain degree of interdisciplinarity: for example an IT student might be a specialist in blockchain but should also learn about the environmental aspects of waste management, legal aspects, business, change management, etc. Similarly, a student in an environmental faculty might be an expert in environmental aspects but should learn some basics about process design, business, IoT, blockchain, waste legislation etc. as well.

- The syllabus should have a focus on circular economy and sustainability goals. A shift of paradigm is needed to move the emphasis from waste treatment and disposal towards reducing waste, recovering/reusing materials and recycling. Furthermore, new technologies like big data, IoT and blockchain should be introduced.

In the process of designing an advanced Waste Management / Circular Economy curriculum, the following re-design and re-structuring efforts should be considered:

- Combining relevant engineering skills (civil, environmental, process).

- Linking engineering skills to Circular Economy awareness, skills and mindset.
- Addressing data-driven approaches (analytics, production, management) as a cross-cutting discipline.
- Defining open innovation and design thinking as development drivers in the learning process.
- Installing interactive learning design with open curricula and room for student research, innovation and entrepreneurship.
- Linking the curriculum to the waste management stakeholders (municipalities, waste management industry, etc.).
- Innovative Didactic, constructivist approach. This particular learning approach encourages students to construct their role and learning path within projects largely on their own responsibility.

Finally, we should not forget that universities, as providers of such a curriculum, should be sustainable as an organization. To this end, they should have a clearly defined sustainability strategy, explicit goals and should publish annual reports of their performance in this area.

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