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Waste Management and the Circular Economy in Cyprus—The Case of the SWAN Project

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Abstract: The increase in waste volume and greenhouse gas emissions and decrease in raw-material reserves are some of the serious problems that our planet is facing. The measures needed to address these issues cannot be implemented under the prevailing linear economy model; hence, the circular economy model has been introduced. The successful implementation of circularity, whose basic principles include waste reduction, reuse, and recycling, requires a change in the behaviour of all the parties involved and is expected to lead to industrial–urban symbiosis schemes. The present paper looks at the current state and future prospects of the circular economy in Cyprus, based on the evidence drawn from an EU-funded project entitled "a digital Solid Waste reuse plAtform for BalkaN" (Project Acronym: SWAN). The project's main objective was the design and development of a digital solid waste reuse platform involving four countries: Greece, Albania, Bulgaria, and Cyprus. Using the data collected, in the context of this project, from a sample of Cypriot industries, we looked into the familiarisation of the respondents with the basic concepts of circularity and their willingness to participate in symbiotic value chains. Moreover, we examined the composition of the waste streams produced by those industries and proposed potential waste reuse business models and subsequent symbiotic clusters.

Keywords: waste management; circular economy; industrial symbiosis; solid waste; SWAN project; Cyprus

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1. Introduction

The United Nations glossary defines waste as "materials that are not prime products for which the generator has no further use in terms of their own purposes of production, transformation or consumption, and of which they want to dispose" [1]. In other words, waste is any unwanted or unusable material or any substance that is discarded after primary use or is worthless, defective, and of no use. They can be solid, liquid, or gas, and each type requires different methods of treatment and management. Our focus in this paper will be on industrial, commercial, and municipal solid waste (MSW).

Waste management involves the activities and actions from waste generation to the final disposal, including the collection, transportation, treatment, and disposal, together with the monitoring activities and regulation aspects. It follows a generally accepted hierarchy from the most preferred to the least preferred option: reduction, reuse, recycling, recovery, incineration, controlled landfill, and landfill [2,3]. The first four methods are

usually referred to as waste diversion methods while the last three are referred to as waste disposal ones.

The waste management approach adopted in a specific case depends largely on the prevailing economic model. The linear economy model, which has been dominant for many decades throughout the world, cannot support the waste diversion methods, especially reduction and reuse. This has led to several serious problems, such as the decrease in raw-material reserves, the increase in waste volume, and increase in greenhouse gas emissions. The efforts to reduce the environmental impact of the linear economy model have had very limited success since the reusing/recycling techniques of the existing products have reached their limits. Hence, there is great pressure for the transition to an alternative model, the circular economy model, where the products will be used for a much longer time with a parallel minimisation of virgin-raw-material use and, at the same time, they will be disassembled and reused with the minimal possible effort and processing.

The circular economy is one of the twelve priority thematic areas set by the New Urban Agenda of the European Union (EU) in 2016 [4], which constitutes the common vision of the EU countries for a better and sustainable future, in the context of the United Nations Agenda 2030 for sustainable development [5]. The successful implementation of the circular economy depends on all the parties involved (central government, local authorities, producers, and consumers) and their cooperation, requiring a change in their behaviour, which will lead to what we call industrial–urban symbiosis.

Circular economy principles may be applied to several sectors of economic life, but their effective implementation requires the presence of new and suitable business models. The business model is a conceptual tool providing an abstraction of how a firm operates. It reflects the firm's realised strategy, highlighting the combination of production factors needed to implement such a strategy and the functions of all the involved actors [6]. Furthermore, it serves as a means for designing business activities as well as for a comprehensive cross-company description and analysis. Many formal definitions of business models have been provided by the literature. According to one of those, business models are simplified representations of the value proposition, value creation, and delivery as well as value capture elements and the interactions between these elements within an organisational unit [7].

Urgent issues such as growing inequality and the deterioration of our natural livelihood make the transformation to a more sustainable economic system increasingly desirable. One of the key challenges to tackle the pressure of a sustainable future is designing business models that are able to ensure that firms capture economic value for themselves through delivering social and environmental benefits. In this regard, sustainable business models are models that "create competitive advantage through superior customer value and contribute to a sustainable development of the company and society" [8]. In particular, the value proposition of a sustainable business model must include positive effects for society and the environment, in addition to the economic value for the firm. Firms can create such a proposed value by implementing technological, organizational, and management innovations.

The literature describes different subsets of sustainable business models, the most important of which are the circular models. These models do not only incorporate proactive multi-stakeholder management, create monetary/non-monetary value for a broad range of stakeholders, and hold a long-term perspective but also dematerialise and close resource loops.

Circular economy models may be classified in various ways on the basis of different criteria. The selection of the best model depends on its application area. The SWAN model, built in the context of the EU-funded Interreg Project SWAN, focuses on solid waste management.

Following this brief introduction, the paper is structured as follows. Section 2 describes the current state of solid waste and its treatment in Cyprus. Reference will be made to the sources of waste, its volume, and the management methods used. The dependence of these

methods on the prevailing linear economy model as well as the extent to which circular business models have been or may be implemented will be examined. It also gives a brief overview of the SWAN project and describes the role of the Cyprus University of Technology in the project. Section 3 briefly describes the methodology used for identifying technically feasible symbiotic schemes. Section 4 focuses on the analysis of the data collected in the context of this project from Cypriot industries and municipalities. The first part investigates the views of the stakeholders involved in waste management issues and their familiarisation with new concepts, such as the circular economy and urban–industrial symbiosis. The second part examines the profile of the Cypriot industries participating in the project, the quantitative and qualitative characteristics of the waste produced by the various waste sources and required by potential receivers, and the possible matching between waste supply and demand, which may lead to the formation of industrial symbiosis clusters. Finally, Section 5 summarises the findings, comments on them, and makes suggestions for further research.

2. Waste Management and the Circular Economy in Cyprus: Current Status

2.1. Waste Management in Cyprus

The Cypriot policy on waste management is based mainly on waste hierarchy (reduction, reuse, recycling, recovery, and disposal) and the correct environmental handling. The aim is to protect the environment and human health. This is achieved through the reduction/elimination of the harmful effects of the generation and management of waste, the promotion of reuse, recycling, and recovery and, generally, environmentally sound management, in order to reduce disposal in landfills and to reduce the overall impact of the use of resources by improving the efficiency and effectiveness of their use.

In the above context and following the Directives of the European Commission (EC) on waste, the Department of Environment has developed the 2012 Management Plan for Household and Similar Type of Waste, which, after public consultation (2012) and new political decisions, was changed into the 2015–2021 Municipal Waste Management Plan. At the same time, a summary description of the Municipal Waste Management Plan entitled "Municipal Waste Management Strategy" was prepared for the period 2015–2021 [9]. The strategy and plan for municipal waste have been developed following wide consultation with all the stakeholders as well as the European Commission. It is noted that management plans for the remaining waste streams will follow, for the Republic of Cyprus to fully comply with the EC directives.

The main axes of the strategy, upon which this plan is based, are: (i) compliance with the obligations arising from the European directives on waste management that fall under the municipal waste stream; (ii) full utilization of existing private and state waste management infrastructure; (iii) maintaining the waste management hierarchy, with emphasis on prevention and separate sorting of waste; and (iv) the adoption of best practices with the lowest cost.

Within the above context, qualitative and quantitative objectives have been set. The main qualitative objectives evolve around the axes of the circular economy, resource efficiency, the reduction of carbon dioxide emissions, a green growth economy, and capacity building. The main quantitative objectives may be summarised as follows:

- 50% separate collection on total MSW and 15% separate collection of the organic waste in MSW by 2021;
- 50% recycling of paper, plastic, metal, and glass by 2021;
- Reduce landfilling to a maximum of 20% of MSW by 2021 and 10% by 2035;
- Increase recycling and reuse of municipal waste to 55% by 2025, 60% by 2030 and to 65% by 2035.

The total amount of waste generated in Cyprus in 2018 amounted to 3,132,000 tonnes or 3576 kg per capita compared to 7050 for the EU [9]. Excluding major mineral waste, this figure came down to 815,000 tonnes or 930 kg per capita, compared to EU's 1818 kg per capita [10,11].

Looking into its generation per type of economic activity, 45.8% was generated by construction and demolition activities (compared to the EU's 35.9%), 16.8% by households (EU: 8.2%), 16.3% by manufacturing (EU: 10.6%), 14.5% by other economic activities (EU: 15.4%), 6.6% by mining and quarrying (EU: 26.6%), and 0.1% by energy generation (EU: 3.4%) [10].

Moreover, regarding its treatment, 55.4% of the total amount treated was landfilled (compared to the EU's 44.7%), 20.4% was recovered and backfilled (EU: 10.7%), 17% was recovered and recycled (EU: 37.9%), and 7.2% was used for energy recovery purposes (EU: 6.0%) [12].

Turning to the municipal waste (MW) in particular, the total amount generated in Cyprus in 2019 stood at 566,000 tonnes, compared to 562,000 tonnes in 2018, recording a small increase of 0.73%. This corresponds to 643 kg per capita in 2019, which is the fourth-highest figure in the European Union after Denmark (844 kg), Luxemburg (791 kg), and Malta (694 kg). The average amount of municipal waste generated per inhabitant in the European Union in 2019 was 502 kg [13].

From the total amount of 469,000 tonnes treated in Cyprus in 2019, 80.8% was disposed in landfills, 16.3% was recycled, 1.7% was composted, and 1.1% was used for energy recovery purposes [14]. Waste treatment data for the remaining 97,000 tonnes, or 17% of the total amount, are missing. The respective figures for the EU were 24% disposed in landfills, 48% recycled and composted, and 27% used for energy-recovery purposes. The data missing at a European level are less than 2% of the total amount [15].

Following a steady decrease in 2009–2014, the landfilling rate increased again in the last few years. The Commission published an "early warning report", setting out priority actions for Cyprus to comply with the goals set. Cyprus should make a considerable investment in recycling and separate collection in the coming years to reach the goals.

The difficulties Cyprus still faces in implementing the relevant EU waste policy and in meeting the targets set, despite the efforts made, are mainly due to the lack of: (i) infrastructure and systems for separation and collecting recyclables at the source and for diverting biodegradable waste from landfills, (ii) coordination between different administrative levels and lack of capacity at local level, (iii) incentives towards waste management, and (iv) extended producer responsibility schemes for various waste streams.

Preventing and reducing waste generation, combined with the necessary increase in reuse and recycling, could improve the resource efficiency of the Cypriot economy, increase business opportunities, and create jobs in the recycling sector [16].

The situation, however, seems to have been changing lately. The Ministry of Agriculture, Rural Development and the Environment is currently revising the national municipal waste management strategy and the waste prevention program. The focus is on waste minimization and management to reduce waste generation, increase sorting at source as well as waste reuse and recycling, and significantly reduce the amount of waste that reaches the landfill.

A first decisive step towards the attainment of these objectives was the definite closure of the illegal landfills in Vati and Kotsiatis, after an operation of about 30 years, in February 2019. This was, according to the Ministry of Agriculture, "part of the government's broader environmental policy to reduce the uncontrolled disposal of waste in landfills and its proper utilisation and an obligation of the Republic of Cyprus in the implementation of the European directives for management of waste". Equally critical steps were the operation of the integrated waste-management facilities (IWMF) in Pentakomo, serving Nicosia; and Koshie, serving Limassol; as well as the plans for the transformation of the landfill of Paphos into an IWMF [2,17,18].

The IWMF in Koshie has been operating since 2010, in parallel with the landfills in Vati and Kotsiatis. The unit applies mechanical and biological treatment to mixed primary municipal waste. Following the closure of the uncontrolled landfill (XADA) of Kotsiatis, the municipal waste from Nicosia (140,000 tonnes) is transferred (since October 2018) to the IWMF in Koshie. The total capacity of the unit currently amounts to 250,000 tonnes, out of

which 75%, or 190,000 tonnes, concerns the mixed waste stream. The unit is expected to be upgraded to be able to treat all the waste from the provinces of Larnaca, Famagusta, and Nicosia. Furthermore, the construction of one or more waste-transfer stations is planned in order to ensure the most effective and efficient transport of waste from remote areas to the IWMF in Koshie [2].

The IWMF in Pentakomo and the waste-transfer station in Kantou have been operating since November 2017 for all mixed municipal waste from the Limassol district. The capacity of the unit amounts to 140,000 tonnes and produces large quantities of secondary fuels RDF (refuse-derived fuel) and SRF (solid-recovered fuel) intended for energy production. The transfer of SRF from the facility to a local cement plant has been tested successfully. Furthermore, it is expected that a proper treatment of the RDF will soon be achieved. Finally, certain modifications have been scheduled in order to improve the quality and marketability of the fuel produced [2].

Recently, the European Commission called on Cyprus to correctly apply the Landfill Directive. This requires member states to ensure that only waste that has been subject to treatment is sent to the landfilling, following the Green Deal's zero pollution goals. The Commission revealed shortcomings in three districts, particularly in Paphos, where waste is not pre-treated at all before going to the landfill [19]. In the following period, the creation of a new upgraded "unit" in the Sanitary Landfill of Paphosis has been planned. This will increase its capacity to meet the current demand and give time for carrying out a viability study for the construction of an IWMF in Paphos. The goal of this project is to improve the processing of waste streams before landfill. The completion and full operation of these projects is expected to enable Cyprus to improve its waste management performance and meet all the targets set.

The citizens bear the costs for municipal waste management in the form of fees paid to the local authorities. For packaging waste (and other streams, such as waste electrical and electronic equipment (WEEE), batteries, accumulators, and tires), extended producer responsibility schemes apply, and the costs are borne from the producers/distributors of the products. In this case, the producers and distributors of the goods are responsible only for taking back the waste within their territories. The producers are responsible for paying a fee to the collective management system according to the quantity of products placed on the market [20]. Cyprus still faces difficulties in implementing the relevant EU policies and meeting its targets. This is mainly due to: (i) the lack of infrastructure and systems for collecting recyclables and diverting biodegradable waste from landfills, and (ii) a lack of coordination between different administrative levels and lack of capacity at a local level. Some measures to address these weaknesses have been introduced, including the ongoing capacity building and technical assistance programme for public administration, local authorities, stakeholders, and the public. In addition, the planned introduction of legislative measures assigning responsibility to local authorities to establish separate collection schemes is also expected to improve the situation [21].

2.2. Circular Economy in Cyprus

The concept of the circular economy meets the ambition for sustainable development, in the context of increasing pressure from the production and consumption of resources and the environment of the planet and is the economic development model that will bring solutions to the economic, ecological, and social crisis that humanity is experiencing today.

The Circular Economy Action Plan, which was adopted by the European Commission in 2017, emphasises the need to move towards a life-cycle-driven 'circular' economy, reusing resources as much as possible and bringing residual waste close to zero. This can be facilitated by developing and providing access to innovative financial instruments and funding for eco-innovation. The transition to a more circular economy offers great opportunities for Europe and, consequently, Cyprus and its citizens.

Cyprus' performance so far falls short of the EU average in terms of resource productivity (i.e., how efficiently the economy uses material resources to generate wealth)

with EUR 1.14/kg (EU average: EUR 2.04/kg) in 2017 [22]. Moreover, there is currently no overarching policy framework for the circular economy in Cyprus. Policy and funding measures and other means of promoting a circular economy still largely depend on co-financing through the European Structural and Investment Funds (ESIF).

Cyprus is also lagging behind the other EU countries in various other dimensions of the circular economy. With just EUR 100,000 investment, it provides the lowest amount an EU member state invests in the circular economy. In contrast, Germany has investments of 30 million euros, the Netherlands invests 5.2 million, Poland 4.7 million, Romania 1.1 million, Greece 0.6 million, and Bulgaria 0.5 million [23].

The low amount of Cyprus' investments in the circular economy is also reflected in the only four patents that the country's research potential has to present from 2000 onwards. It is important to look at the performance of EU member states. First on the list is Germany, with 1260 patents. Belgium, Finland, Austria, and the Netherlands have 105, 111, 122, and 169 patents, respectively, while more than 20 patents have been granted in Portugal, Luxembourg, Romania, Hungary, Ireland, Sweden, Denmark, and the Czech Republic [24].

The circular (secondary) use of material in Cyprus was 2.3% in 2016, well below the EU-28 average of 11.7%. On the other hand, Cyprus performed above the EU-28 average on the number of people employed in the circular economy (1.99% of total employment in 2016 vs. the EU-28 average of 1.73%) [24].

The number of EU Ecolabel products and EMAS-licensed organisations (EMAS is the European Commission's eco-management and audit scheme—a programme to encourage organisations to behave in a more environmentally sustainable way) in a country can give a rough measurement of this transition. These two indicators show to what extent the circular economy transition is engaging the private sector and other national stakeholders. These two indicators also show the commitment of public authorities to policies that support the circular economy. As of September 2018, Cyprus had only 87 products and 7 licences registered in the EU Ecolabel scheme (EU total 71,707 products and 2167 licences). In addition, as of May 2018, 84 Cypriot organisations were registered in EMAS [24]. Finally, Cyprus ranked 18th on the 2018 European Innovation Scoreboard. However, despite a significant improvement, with a total score of only 45 (EU average 100) in the Eco-Innovation Scoreboard 2017, the country was second to last in the EU.

The rapid realisation of the opportunities—and the facing of the challenges—of the circular economy depends on its strong societal support. The involvement of non-governmental organisations (NGOs), business and consumer organizations, academia, research institutes, and other stakeholders is essential at all levels of government. Action is also needed to communicate the ideas and benefits of the circular economy to citizens in their daily lives—in the workplace, in schools, and in local communities. Social media and digital media can also make a positive contribution.

For Cyprus, the circular economy is both a challenge and a solution since its island character can create difficulties but also gives advantages which, with the help of the financial tools offered by the EU and with an abundance of scientists and the natural resources of the island, can turn the whole country into an innovative "product".

However, the transition from linear to circular economy business models is not easy. There are many obstacles at both company and value chain levels, as well as in adopting new policies at an EU and national level. Difficulties in financing new business models, tax systems, resistance to change, and the perceived lack of demand from consumers are examples of obstacles that hinder or do not contribute to the circular transformation [2]. In addition, trade barriers, such as taxation and regulation of the use of secondary raw materials, remain, as well as the lack of international standards and the lack of both harmonization and integrated recycling plans throughout the EU.

From a political point of view, the EU action plan for the circular economy as well as the strategy on plastics and the availability of funding are important factors at the EU level in supporting companies wishing to achieve their circular objectives.

The Cyprus Employers and Industrialists Federation (OEB) have been playing a leading role in the effort to remove obstacles and facilitate the transition of Cypriot companies to a circular model. The understanding of both the obstacles and the opportunities in applying the business models of the circular economy is crucial for the development of circularity. Only by identifying the elements that hinder or facilitate the transition can business guidelines and policy proposals be designed to support the transformation effectively and successfully. Towards this end, OEB had suggested a number of measures to the relevant ministries, such as: financial and tax incentives for circular business models, and the promotion of "circular products" and adoption of international quality standards for "circular products", which are expected to remove the obstacles that hinder the transition to the circular economy [24]. Recently, OEB came back with a comprehensive plan for the circular economy, suggesting, among others: the creation of a Forum for the Circular Economy, building of an online resource-exchange platform, adoption of national standard CY BS 8001: 2017 and/or development of a standard for the circular economy, creation of targeted guidelines, holding of skills development seminars for the circular economy, setting-up a circular economy platform for the promotion of good practices and development of business sponsorship scheme verified for circular economy principles [25].

2.3. The SWAN Project

The project "a digital Solid Waste reuse plAtform for BalkaN" with the acronym "SWAN" has developed sustainable innovative practices addressing the burning issue of waste management in the context of circular economy, industrial symbiosis, and the closing of the resource loops. Its main innovations and contributions include the design and development of a digital platform which maps solid waste resources and potential receivers of waste streams, the building of an algorithm which matches supply with demand and proposes national and transnational waste reuse pathways and the establishment of a collaborative network of relevant stakeholders in the Balkan region and Cyprus, which would promote circular value chains. The project ran for 24 months and was co-funded by the European Union Cooperation Programme "Interreg V—Balkan-Mediterranean 2014–2020"and national funds of the four participating countries: Greece, Albania, Bulgaria, and Cyprus.

The project's consortium consisted of seven partners from the four countries under the leadership of the Association of Municipalities in the Attica Region-Solid Waste Management (EDSNA). The remaining partners included the Ministry of Environment and Energy and the University of the Aegean—Department of Business Administration from Greece, the Ministry of Tourism and Environment and the NGO ILIRIA from Albania, the Bulgarian Industrial Association, and the Cyprus University of Technology—Department of Chemical Engineering.

The project consisted of the following six work packages:

- WP1—project management and coordination, which set the basic management principles of the project.
- WP2—project communication and dissemination, which developed a communication plan, aiming at the promotion of the project and the dissemination of its activities and results.
- WP3—development of a digital solid-waste reuse platform, which built a digital platform, acting as the basis for the establishment of solid-waste reuse value chains.
- WP4—sink and source mapping, which developed the SWAN map of solid-waste sources and potential receivers in the Balkan region and Cyprus.
- WP5—sink and source mapping, which developed the algorithm that processes the SWAN solid-waste map and provided different alternatives for the solid-waste reuse chains and related business models.
- WP6—integration and synthesis, which ensured the management of knowledge and the synthesis of the results and led to the establishment of an industrial ecosystem.

The Cyprus University of Technology had a significant contribution to the successful completion of the project. More specifically, it participated in WP3 by carrying out tests, reports, development modifications, and updates of the Cyprus SWAN platform as well as the customisation of the SWAN platform for the case of Cyprus; WP4, with the collection of data from 108 industrial units and their subsequent entry in the Cypriot database; WP5, with the preparation and submission of a proposed list of profitable solid-waste reuse business models for Cyprus; and WP6, with the preparation and submission of a study policy recommendation for solid-waste management in Cyprus.

3. Methodology

The methodology followed in order to identify and assessed symbiotic schemes has been described in detail in [26]. The SWAN platform algorithm performs the technical matching in two different steps based on the data collected through the questionnaires (including the type and location of industry as well as the type of waste streams and the amount of waste produced, where available).

The first step of the matching algorithm combines the type (expressed using the Statistical Classification of Economic Activities in the European Community—NACE Code) Statistical Classification of Economic Activities in the European Community (NACE Code) of the regional industrial sites with the data collected for the SWAN best practices database. The database includes various alternative existing symbiotic schemes, sorted based on the type of solid-waste-supplying industry and the type code of the receiver. The algorithm can propose similar schemes for the region and can also give an indication about how common such a pairing is, based on the number of occurrences in the best practices database.

The second step of the matching algorithm is based on the data on waste streams collected via the questionnaires. The interviewees were asked to provide a list of the waste streams produced (with the corresponding codes) as well as a list of the solid input streams (with the corresponding codes), used as resources, which could potentially be replaced by a waste stream (and the industrial plant would consider that as an option). Based on the codes of both the available waste streams and the input streams, a 1-to-1 matching is developed and incorporated in the platform database, which leads to the identification of the potential (region-specific) symbiotic schemes.

4. Analysis of the Cypriot Data

The present section presents and comments on the main findings drawn from the processing of the data collected from 108 Cypriot industrial units using the questionnaire developed in the context of the SWAN project. The questionnaire was built around the following four main themes:

- General characteristics of the industrial units, such as the name, type (NACE code) and location;
- Major solid-waste streams, including their type (as described by the European waste classification type or the EWC-Stat type), the available quantity and seasonal variations, and the current management method together with the relevant cost;
- Solid input streams that can be considered for waste reuse, including their type, the required quantity and seasonal variations, and the current supply method together with the current supply cost; and
- Supplementary questions, describing the knowledge around the concepts of industrial symbiosis and willingness to participate in symbiotic schemes and the SWAN industrial ecosystem.

The total sample for Cyprus consisted, as already stated, of 108 industrial units (Figure 1). The data collection procedure included a face-to-face meeting in the industry, phone conversation or e-mail communication. It was carried out in early 2021 and the quantitative data recorded refer to 2020. The following three subsections summarize the findings of the questionnaires and draw some initial conclusions for the proposed business models.

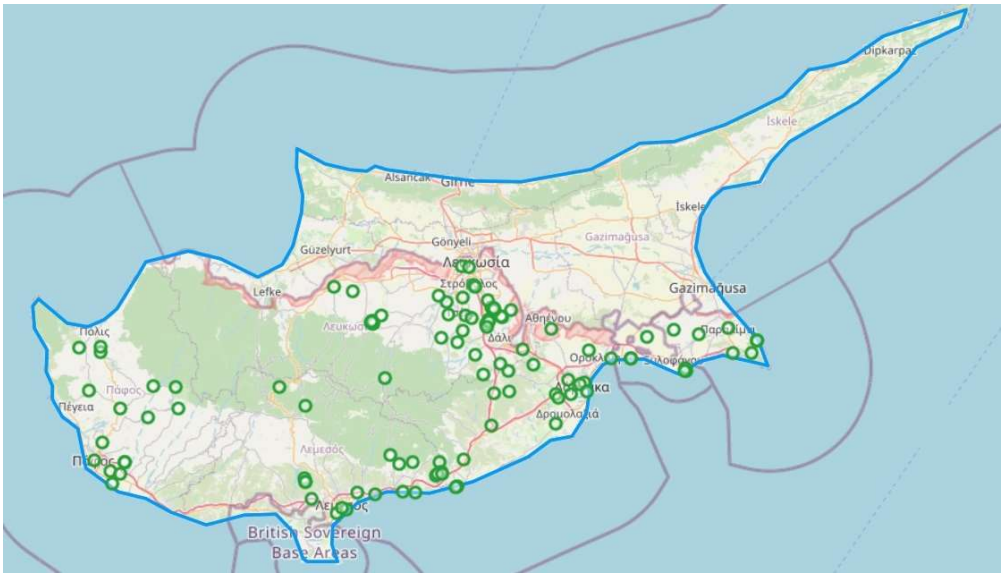

Figure 1. Mapping of the SWAN industrial ecosystem in Cyprus.

4.1. Participants Profile

Food production companies (NACE Code C10) constitute the main type of industries that participated in the analysis (17%). The other prevailing industrial types involve quarries and mining sites (B8.1.1—15%), wastewater treatment (E38.2—8%), and brick manufacturing (C23.3.2—7%). An overview of the country's industrial profile per type is presented in Figure 2. The codes on the horizontal axis correspond to the NACE code of the industrial sites (Statistical Classification of Economic Activities in the European Community).

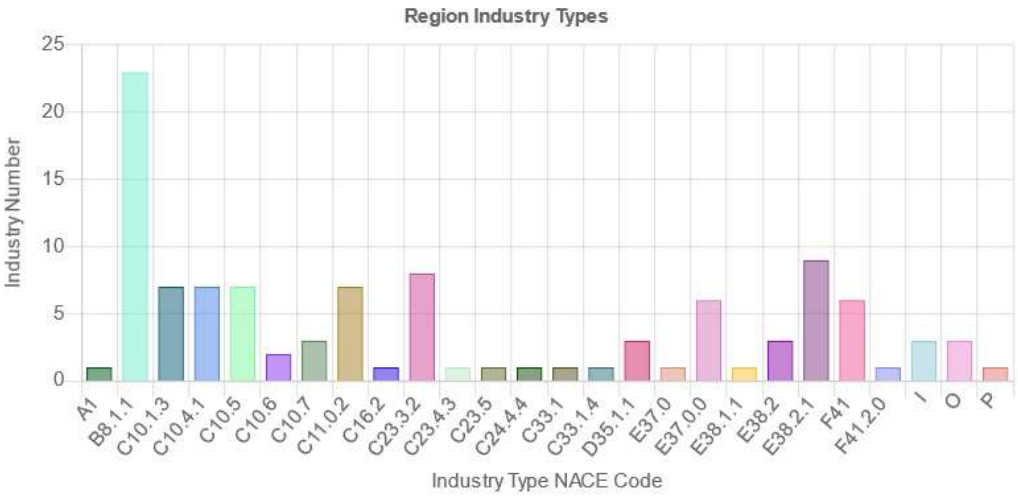

Figure 2. Industrial profile per type for the SWAN industrial ecosystem in Cyprus.

In terms of size (Figure 3), 62% of the industrial plants that answered the questionnaire in Cyprus are small and medium enterprises (SMEs). These industries are usually at a disadvantage, compared to bigger industries, to participate in novel business models and implement circularity principles, and this should be borne in mind when analysing the field research results.

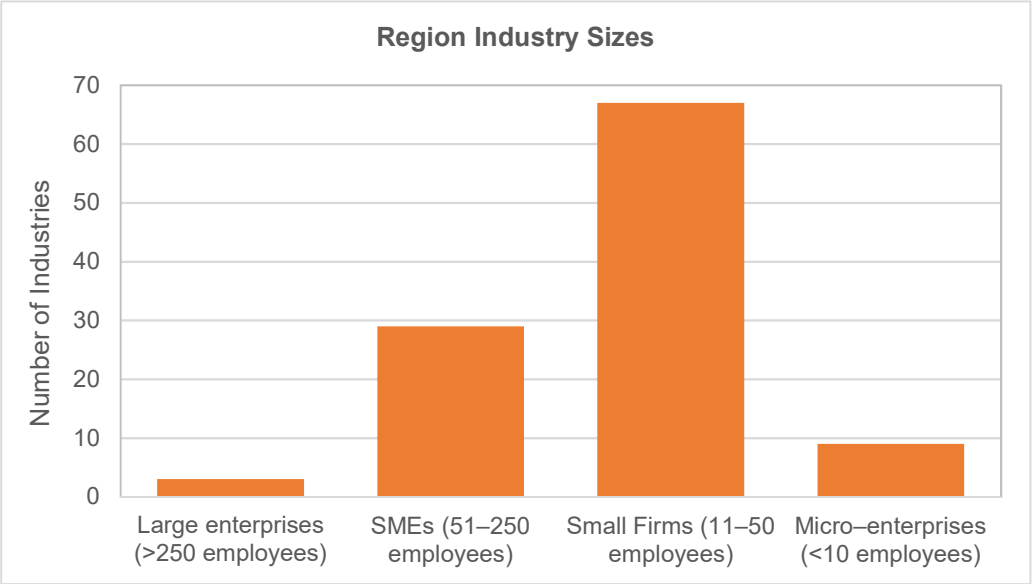

Figure 3. Industrial profile per size of the SWAN industrial ecosystem in Cyprus.

Finally, Figure 4 shows the composition of the waste streams, as identified in the completed questionnaires for Cyprus. Waste streams are defined as streams that the holder discards, intends to discard, or is required to discard, based on the Directive 2008/98/EC. In this case, it can be extracted from the questionnaire that 65 of the Cypriot units in the sample have recorded plastic waste streams (EWC Code: 7.4), 61 of these units have recorded paper and cardboard waste streams (EWC Code: 7.2), and 32 have recorded sludge (both agricultural and industrial).

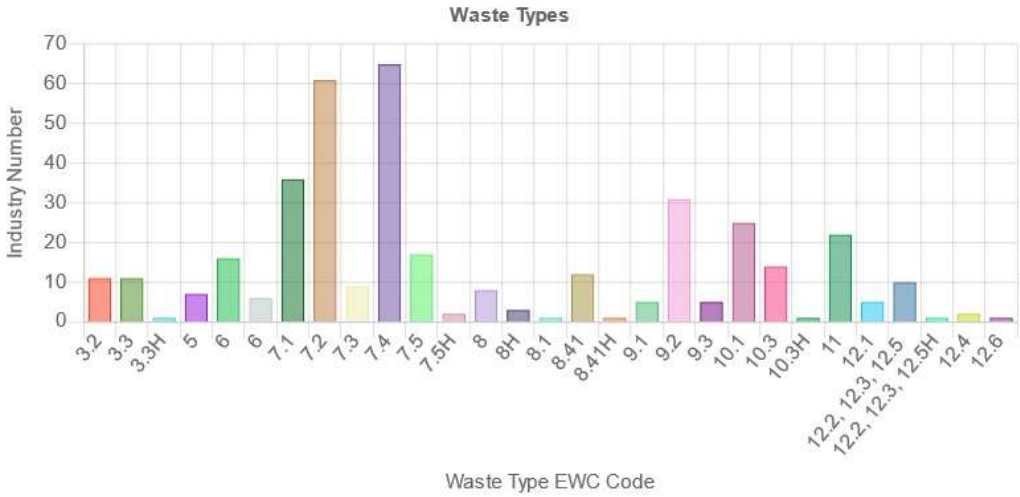

Figure 4. Available waste profile of the SWAN industrial ecosystem in Cyprus.

4.2. Industrial Views on Industrial Symbiosis

The responses of the final section of the questionnaire were processed in order to assess the familiarisation of the respondents with the basic concepts of circularity and the willingness of the industrial plants to participate in potential novel business models, based on solid waste reuse. The following four questions are the most appropriate and representative, in order to analyse the opinions of various directly involved actors, and the answers are presented in Figure 5.

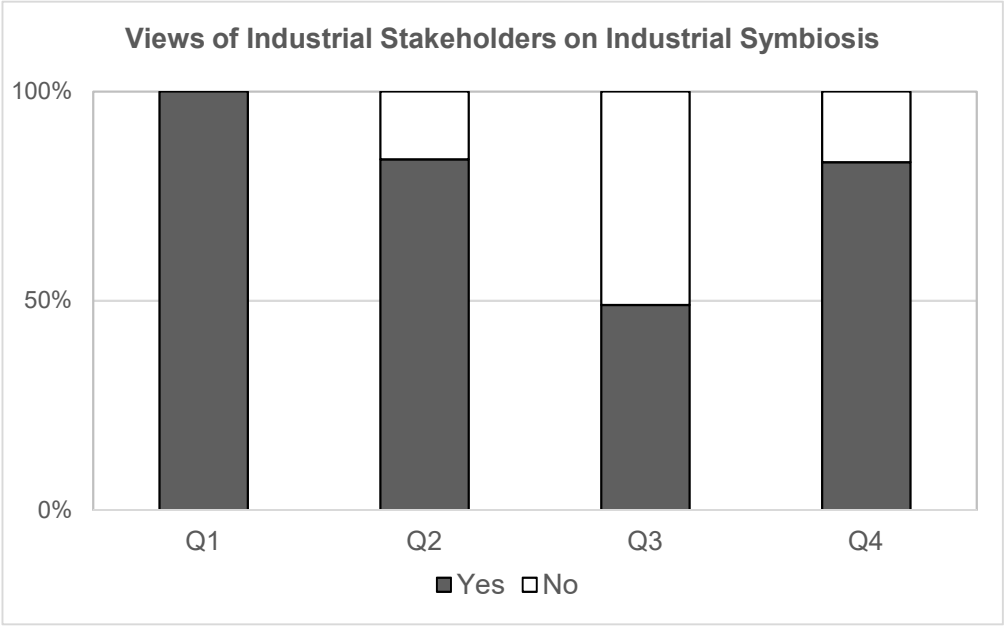

Figure 5. Views on circular economy and industrial symbiosis of the SWAN industrial ecosystem in Cyprus.

- Q1. Are you familiar with the concept of the circular economy, and if yes, what do you consider to be its main benefits?
- Q2. Are you familiar with the concept of industrial symbiosis?
- Q3. Are there any existing symbiotic links in the company?
- Q4. Would the unit be interested in participating in symbiotic value chains?

All the respondents answered positively to Q1, which indicates their very high degree of awareness on the subject and, hence, the very good prospects for the spread of the circular economy and its applications. Regarding the benefits of the circular economy, the reduction in waste seems to be the dominant one, a finding that reveals a rather conservative approach to its much greater potential. Hence, further effort is needed to highlight and promote its wide range of applications.

An interesting finding comes from Q2, where a large number of the respondents (~84%) answered positively. Given that industrial symbiosis is a specialised concept, their high familiarisation with the topic confirms the findings of the first question. Contrary to the familiarisation, just under half of the respondents (~49%) answered that industrial symbiosis links are available in their organisations (Q3). However, despite the low percentage, the answers to these questions confirm the industrial symbiosis potential and the good prospects for the wider implementation of the circular economy.

This is further enhanced by the answers in Q4, where the majority of the respondents (~82%) declared an interest in participating in symbiotic value chains. This finding reflects their high awareness of the circular economy and related issues and the good prospects for the spread of circular economy applications. Nevertheless, further qualitative analysis is needed in order to reveal the main reasons behind the negative answers (~18%). The rather high ratio of negative answers may be related to the limited implementation of industrial symbiosis applications in Cyprus so far. However, further research on this issue is required.

4.3. Proposed Business Models

Approximately 30% of the industrial units produce sludge (characterised either as common sludge or industrial sludge). Based on the data provided by the industrial plants, there are five different plants that could consume sludge. However, the four of them are actually wastewater treatment plants, which will only treat the sludge. The main potential consumer of the sludge is a cement plant. It should be noted that the amount of sludge

produced from each plant is too small, which makes transportation economically non-viable. In this case, a collective scheme of transportation for sharing expenses could be examined. Similarly, the second most prominent waste stream is plastic and rubber waste. The cement plant again has indicated that it could potentially consume such waste streams. For a more detailed analysis, the potential symbiotic schemes are also analysed based on the type of source industry and are presented in the following sections.

4.4. Based on the Type of Source Industry

4.4.1. Wineries

The total waste streams from all seven wineries included in the database (in tonnes/year) are presented in Table 1. From these streams, the most significant ones (in terms of quantity) are waste from grape compression and sludge. Regarding the waste from grapes compression, grape pomace is an excellent material for the extraction of functional components (e.g., grape seed oil, flavonols, flavanols, phenolic acids) and as a source for natural antioxidants (which can be further used by pharmacological, cosmetic, and food industries [27]. According to Bustos et al. [28], the residue of grape processing in wine and juice can be used as a bio-adsorbent for the desalination of water. Appropriate receivers were not identified. Further research might be required to examine if the existing wastewater treatment plants would be interested in such a technology. As an organic waste, winery residues could also be used to produce methanol, ethanol via fermentation [29], or in a gasification process, to produce hydrogen and syngas. In addition, the treatment through anaerobic digestion can generate biogas that can be used for energy (electricity and heat). However, the quantities in our case are too small to justify such an approach. In addition, wineries in the same area can gather their waste, so the valorization of waste with a higher volume could potentially be economically viable.

Table 1. Wineries' waste streams (in tonnes per year) [1].

Waste Type	Quantity
Crimps (waste from grape compression)	27.8
Filters	0.4
Glass packaging	2.8
Marbles (waste from grape compression)	102.6
Paper and cardboard packaging	2.4
Plastic packaging	2.8
Wine sludge (heavy)	11.8
Wine sludge (light)	29.4

[1] Data presented in the table have been extracted from the SWAN project website (http://swanplatform.eu/—Last accessed on 20 October 2021).

Regarding the sludge, according to the SWAN best practices database, non-hazardous industrial effluent sludges can be used in C17.1 manufacture of pulp, paper, and paperboard; C23.3.2 manufacture of bricks, tiles, and construction products, in baked clay; and C23.5 manufacture of cement, lime, and plaster. In this case study, there are eight industrial plants with NACE Code C23.3.2 and one plant with NACE Code C23.5. A potential collaboration with the eight local brick manufacturing facilities could thus be explored. Moreover, industrial organic sludge could be also used, with other organic residues and sewage sludge, to produce fertilizer and biogas for vehicles (a symbiotic scheme installed in Händelö Island Industrial Park).

4.4.2. Meat and Poultry Industry

The total waste streams (in tonnes/year) from the seven meat and poultry industries in the Cyprus database are presented in Table 2. From these streams, the most significant one (in terms of quantity) is animal manure. The development of an incineration plant, which will incinerate manure to generate energy, has been proposed as a solution to poultry manure surplus in the Netherlands [30].

Table 2. Meat and poultry industry waste streams (in tonnes per year) [1].

Waste Type	Quantity
Animal manure	5340
Clinical waste	5
Dead chickens	5
Municipal waste (from personnel)	14
Paper and cardboard packaging	12
Plastic packaging	12
Expired products	12

[1] Data presented in the table have been extracted from the SWAN project website (http://swanplatform.eu/—Last accessed on 20 October 2021).

Manure can be used as a feedstock for biogas plants, and the waste heat for the plant can be supplied to local greenhouses [31]. It can also be used as a fertiliser, by being discharged to arable lands [32]. Such receivers have not been identified in the local ecosystem, since these were out of the scope of the project, and further analysis is required.

4.4.3. Dairy Industry

Another waste that can be valorised is cheese whey, which is officially classified as a liquid by-product but has been reported by the interviewed industries as a significant waste stream. The largest dairy industry in Cyprus generates around 81 m^3 of cheese whey per day [32]. Traditionally, in Cyprus, whey was fed to animals. Due to excess whey being produced in Cyprus, the anaerobic co-digestion of cheese whey on a large scale, combined with other types of waste such as sewage sludge or pig manure, could be another option. Many laboratory studies proposed using cheese whey as a feedstock for the production of high-value-added products [33] such as the production of bioethanol or functional food. However, further research is required to examine if any of these novel options are economically viable in Cyprus.

4.4.4. Grain Mill Industry

The total waste streams (in tonnes/year) from the two manufacturers of grain mill products in the Cyprus database are illustrated in Table 3. From these streams, the most significant ones (in terms of quantity) are flour dust and paper/cardboard packaging. Regarding flour dust, there has been no research published on its reuse due to the respiratory health issues related to that waste stream.

Table 3. Grain mill industry waste streams (in tonnes per year) [1].

Waste Type	Quantity
Paper and cardboard packaging	73
Flour dust	30
Flour products (expired)	28
Plastic packaging (HDPE)	2
Scrap metal	18

[1] Data presented in the table have been extracted from the SWAN project website (http://swanplatform.eu/—Last accessed on 20 October 2021).

Regarding the paper and cardboard packaging, based on the SWAN platform best practices database, such waste streams can be used by C16 manufacture of wood and products of wood and cork; C16.2 manufacture of products of wood, cork, straw, and plaiting materials; and C17.1 manufacture of pulp, paper, and paperboard. There is only one such industrial plant in the local industrial ecosystem. The distance between the two grain mill industries and the receiver are 5 km and 75 km, respectively, so a potential symbiotic scheme could be assessed for the two neighbouring industries. The main findings of this section are summarised in Table 4.

Table 4. Potential circular business models.

Waste Producers	Main Waste Produced	Potential Waste Receivers Type Based on the SWAN Best Practices Database	Potential Waste Receivers in the Case of Cyprus	Next Steps	Critical Points
Wineries (7 units)	Crimps	Pharmacological, cosmetics, and food industries	N/A [1]	Further research is required	Quantities produced/required Producer-supplier distance and way of transport Collective waste gathering and transportation
		Waste treatment plants	Four waste treatment plants	Examine the possibility of matching	
	Sludge	Manufacture of pulp paper and paperboard (C17.1)	N/A	Further research is required	
		Manufacture of brick, tiles and construction products (C23.3.2)	Eight industrial plants (C23.3.2)	Examine the possibility of matching	
		Manufacture of cement, lime and plaster (C23.5)	One manufacturing facility (C23.5)	Examine the possibility of matching	
		Fertilisers and biogas producers	N/A	Further search is required	
Meat and Poultry Industries (8 units)	Animal Manure	Biogas plants Use as fertiliser to arable lands	N/A	Further research is required	
Grain Mills (2 units)	Paper and Cardboard Packaging	Manufacture of wood, wood products, and cork (C16)	One industrial unit	Examine the possibility of matching	
		Manufacture of wood, wood products, cork, straw, and painting materials (C16.2)	N/A	Further research is required	
		Manufacture of pulp, paper, and paperboard (C17.1)	N/A	Further research is required	
	Floor Dust	No research published on its reuse due to the respiratory health issues related to it			

[1] N/A: No appropriate receivers identified in the local ecosystem.

5. Discussion

The scope of this paper was to look into waste management and circular economy practices in Cyprus through the findings of the SWAN project. Following a brief introduction, Section 2 presented a general overview of the current status of waste management and the circular economy in Cyprus, and Section 3 described the SWAN project and analysed and processed the data collected in Cyprus in the context of the SWAN project. Finally, the present section summarises the basic findings of the paper and makes suggestions for further research.

Municipal waste generation in Cyprus in 2019 was significantly higher than the EU average (642 kg/y/inhabitant compared to around 502 kg/y/inhabitant on average). Until recently, most of the municipal waste in Cyprus ended up in landfills (80% compared to an average of 24% for the EU). Recycling accounted for 18%, including 1.7% of composting, significantly lower than the EU average (48%).

The situation, however, seems to have been changing lately. The Ministry of Agriculture, Rural Development and the Environment recently revised the national municipal waste management strategy and the waste prevention program, and some of the main goals set are to reduce landfilling to a maximum of 10% by 2035 and increase the recycling and reuse of municipal waste to 55% by 2025, 60% by 2030, and to 65% by 2035. A first decisive step towards the attainment of those goals was the definite closure of illegal landfills in Vati and Kotsiatis, after an operation of about 30 years, in February 2019. Equally critical steps were the operation of the integrated waste-management facilities (IWMF) in Pentakomo, serving Nicosia; and Koshie, serving Limassol; as well as the plans for the transformation of the landfill of Paphos into an IWMF. Cyprus is also lagging behind the other EU countries in the field of the circular economy. It provides the lowest amount an EU member state invests in the circular economy, and this is reflected in the only four patents that the country's researchers have to present from 2000 onwards.

The transition from linear to circular economy business models is not easy. There are many obstacles, at both company and value chain levels, as well as in the adoption of new policies at the EU and national levels including difficulties in financing new business models, resistance to change, and trade barriers such as taxation and legal frameworks. The Cyprus Employers and Industrialists Federation has been playing a leading role in promoting the circular economy and has recently submitted a set of proposals for the promotion of the circular economy to the competent ministry, including financial and tax incentives for circular business models, promotion of "circular products", adoption of international quality standards for "circular products, building of an online resources exchange platform, and development of business sponsorship scheme verified for circular economy principles.

Finally, the analysis of the data that have been collected in the context of the SWAN project for 108 industries in Cyprus concerned the following two points: (a) awareness of the industrial community about the circular economy and related issues, the extent of its use, and their willingness to participate in the SWAN or a similar project; and (b) the profile of the country's industrial stock (i.e., type of activity, size of the units), the waste streams, and the proposed waste reuse models have given some very interesting results. Regarding the first point, we may say that:

- The awareness of the responders about the circular economy (CE) is very high but becomes lower as we move into more specialized topics such as industrial symbiosis (IS). However, less than half of the respondents (49%) answered that industrial symbiosis links are available in their organisations.
- The interest of the respondents in participating in the SWAN or a similar project is very high.

Regarding the second point, it is clear that:

- Most of the industries that responded were small firms (~62.5%), followed by SMEs (~27%). Moreover, most of the industries were quarries (~21.5%), followed by waste treatment and disposal facilities (~8.5%).
- The main waste output streams were plastic, followed by paper/cardboard and glass, while the main input streams were solid mineral materials, followed by composites and organic material.
- Based on both the collected data and the best practices available, the potential waste reuse business models are (i) sludge exchange between wineries as well as other industrial units and cement, bricks, and tile factories and (ii) paper and cardboard packaging between grain mills and wood, wood products, and cork manufactures.

However, the establishment of the respective industrial symbiosis schemes requires the prior examination of certain key points such as the waste quantities produced/required, the transport facilities, and the possibility of collective waste gathering and transportation.

In conclusion, we could say the transition to a more circular economy offers great opportunities for Europe and, consequently, for Cyprus and its citizens. The country, as it has been made clear in this paper, has taken considerable initiatives, especially in the last years, in the direction of the circular economy; however, a lot remains to be done. However, all the stakeholders involved seem to be aware of the concept and its potential benefits but are also ready to apply it on a large scale. Hence, the competent authorities now have a good chance to set the foundations for a circular economy through the embodiment in the country's legislation of the recent relevant European directives and the subsequent reconsideration of the national approach to waste management.

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