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Using an online platform for the improvement of industrial symbiosis and circular economy (in Western Macedonia, Greece)

Dounavis A.S.[1,2,3,4,*], Kafasis P.[5] and Ntavos N.[1,5]
[1]University of Western Macedonia (UOWM), GR-50100 Kozani, Greece
[2]Western Macedonia University of Applied Sciences, GR-50100 Kozani, Greece
[3]Technological Research Centre of Western Macedonia (TRC-WM), GR-50100 Kozani, Greece
[4]School of Science and Technology, Hellenic Open University (HOU), GR-26335 Patras, Greece
[5]Company Waste Management of Western Macedonia S.A. (DIADYMA S.A.), GR-50100 Kozani, Greece
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*to whom all correspondence should be addressed: e-mail: ath.sot.dounavis@hotmail.com
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Abstract

The part of industrial ecology known as industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water and by-products (Dounavis *et al.,* 2015; Dounavis *et al.,* 2016; Ravindran and Jaiswal, 2016; Kourmentza *et al.,* 2018; Keskisaari and Kärki, 2018; Ayadi *et al.,* 2018). The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity. Industrial symbiosis includes initiatives in which two or more industrial entities develop both beneficial relationships and the circular economy (Chowdhury *et al.,* 2018). Since, the symbiosis encourages the sustainable development and promotes the economy growth (de Jesus *et al.,* 2018).

This paper presents an online industrial symbiosis and circular economy platform created by a LIFE project (still ongoing) which aims to demonstrate the usefulness of a digital on-line platform at European level for the cataloguing, use and exploitation of industrial waste produced in a local area in order to improve the overall performance of industrial processes and circular economy in a local level. All this will happen both through the increased use of waste within the area itself and by the less dependence on the disposal of waste to be disposed of, taking into account the reduction of used raw materials and the reduction of waste itself. The platform will be created through the European LIFE M3P Project (Material Match Making Platform for the promotion of the use of industrial waste in local networks) which is still on-going and ends at the end of September 2019.

Keywords: Western Macedonia, industrial waste, circular economy, industrial symbiosis, on-line platform.

Abbreviations: DIADYMA S.A. – Company Waste Management of Western Macedonia S.A.; EU – European Union; MBT – Mechanical Biological Treatment; MSW – Municipal Solid Waste; NWMP – National Waste Management Plan; RWMP – Regional Waste Management Plan; SMEs – Small and Medium-sized Enterprises; SPD – Special Development Program; WEEE – Waste Electrical and Electronic Equipment.

1. Introduction

Circular economy is defined as extending product lifetime, at the same time saving non-renewable natural resources, with more reuse, recycling and energy and materials recovery. It is essentially the switch from the linear model of "take, make, consume, dispose" to a new model which emphasizes "reduce, reuse, repair, recycle, recover" (Lepawsky *et al.,* 2017; Overgaard Zacho *et al.,* 2018). It is certain that this topic is based in another development model (Barla *et al.,* 2017; Tseng *et al.,* 2018).

The development of prosperity in European society, which has been recorded over the last decades, has implied a steady increase in waste generation and difficulties in disposal, as all human activities, especially those of an economic nature, involve waste and scrap (Jovane *et al.,* 2017).

The environmental objective of this work is to make effective use of material resources, particularly in terms of more efficient recovery of industrial waste and its use as a raw material through industrial symbiosis and the circular economy (Álvarez *et al.,* 2017; Cui *et al.,* 2017).

In general, industrial symbiosis has not become a common practice in Greece yet. The state of development of industrial symbiosis in Greece is quite low. In the last few years a growing interest has risen towards industrial symbiosis and circular economy mainly through funded projects from the European Union, but still national projects are rare and, in general, industrial symbiosis as a concept is not well known among stakeholders, policy makers and regional authorities (they do not include it in their development strategies) (Herczeg *et al.,* 2018). In this framework, also the Region of Western Macedonia has not included the concept of industrial symbiosis and circular economy in its SDP.

Turning waste into a resource is one key to a circular economy. The objectives and targets set in European

legislation (based on the "waste hierarchy") are key drivers to improve waste management, stimulate innovation in recycling, limit the use of landfilling, and create incentives to change consumer behavior (Van Ewijk *et al.,* 2018). If we re-manufacture, reuse and recycle, and if one industry's waste becomes another's raw material, we can move to a more circular economy where waste is eliminated and resources are used in an efficient and sustainable way (Nasiri *et al.,* 2018).

Improved waste management also helps to reduce health and environmental problems, reduce greenhouse gas emissions (directly by cutting emissions from landfills and indirectly by recycling materials which would otherwise be extracted and processed), and avoid negative impacts at local level such as landscape deterioration due to landfilling, local water and air pollution, as well as littering (Martin *et al.,* 2017). In general, it should significantly decrease the consumption of primary resources and, in particular of non-renewable resources, therefore enhancing the environmental impact of the products produced from waste and the companies which produce these products (Miah *et al.,* 2018).

The new legislative proposals in the European Union set clear targets for waste reduction and set up an ambitious, credible and long-term course of waste management and recycling. In order to ensure implementation effectiveness, the reduction targets are accompanied by firm measures so that practical obstacles and different situations can be overcome in each Member State of the European Union (Eurostat, 2018).

In order to implement the NWMP's guidelines, RWMP is being drafted in each Region which specify the integrated management of all waste generated in their geographical unit according to the objectives and forecasts of the NWMP (Kayakutlu *et al.,* 2017). On this basis and the existing legislation, the RWMP is developed and implemented by the Regional Solid Waste Management Authority. The RWMP defines the areas which constitute the waste management modules, the management methods to be applied in each management unit, and specify specific objectives, measures, conditions and constraints to achieve the strategies and objectives of L.4422/2012 and the NWMP (Han *et al.,* 2017; Sacirovic *et al.,* 2018).

For certain waste categories (hazardous waste, infectious hospital waste, etc.), the Ministry draws up special NWMP, which regulate the management of these streams at a national level and take into account the provisions of the NWMP.

The Management Plan of Western Macedonia in the meanwhile determined the organizational structure of the system, according to which the collection/transportation of MSW (mixed, recyclable, bulky and bio-waste) belongs in local government and in particular the twelve municipalities of the region of Western Macedonia. In this region, DIADYMA S.A. is the responsible body for the management of recyclables and bio-waste, transferring and processing/exploitation of mixed and bulky municipal waste and the land filling of waste, in accordance with the provisions of current legislation (Diadyma S.A., www.diadyma.gr).

Moreover, DIADYMA S.A., which deals with the software development, environmental studies and risk assessments, will display a significant role in order to develop a digital on-line platform for the waste management. The on-line platform, which will be created by the European project LIFE M3P 2014-2020, is fully functional and based on a upgradeable database of the industrial waste of a local area, will allow to improve the environmental impact of the area, enhancing the use of material resources (Herczeg *et al.,* 2018; Liu *et al.,* 2018), notably: a) sustaining the survey and the cataloguing of each industrial scrap or waste produced in the local area by the companies and b) acting as "material match making system" to support experts and technicians of the companies to find a better use of materials inside the local area.

The LIFE M3P program, co-funded by the European Commission under the LIFE 2014-2020 program, will study and implement this electronic platform to promote the exchange of industrial waste initially between businesses operating in the European Regions of its partners and which are: a) Lombardy (Italy), b) Flanders (Belgium), c) Western Macedonia (Greece) and d) Asturias (Spain).

2. Key aims and scopes related to the sustainable development

The objectives of the RWMP must follow the general objectives of the NWMP in Greece. Below the key aims and scopes related to the Industrial Symbiosis and Circular Economy are presented:

- Priority in the sorting of materials at the source aiming to subsequently move to decentralized management structures, in the valorization of MSW.
- Complete the necessary network with the addition of the new network of Green Points – Recycling Centers for waste management infrastructure by 2020.
- Minimize the total amount of recoverable waste with final destination landfill.
- Routine redesign of existing management infrastructure design with the aim of radically upgrading recycling and recovery by separate collection by 2020.
- Further use of secondary materials (compost type A) ensuring strict quality standards.
- Development and implementation of local decentralized management plans by all Municipalities.

The quantitative targets to be attained at the regional level include:

- Reduction of biodegradable waste to 35% of the year 1997 by 2020.
- Bio-waste recovery with separate collection at the source, 40% by weight by 2020, of which 3% through domestic composting or mechanical composting on the spot.
- Preparation for reuse of recyclable materials at least for paper, plastic, glass and metal, 75% by weight. By 2020 and 65% with the separation at source programs for the same materials.
- Recycling of packaging materials at 80.2% by weight and partial targets of 92% by weight for paper, 70% by weight for glass, 70% by weight for metals, 70% by weight for plastics and 80% by weight for wood. In 2020 60% by weight for paper, 60% by weight for glass, 50% by weight for metals, 22.5% by weight for plastics and 15% by weight for wood.
- Recovery of Waste Electrical and Electronic Equipment *(*WEEE*)*, 85% by weight by 2019.
- Separate collection and recovery of 75% by weight of edible oils.
- Total recovery of MSW at a percentage > 70% by weight by 2020.
- Safe disposal of non-recoverable MSW at <30% by weight by 2020.

3. Applications fields

Taking into account the Local Waste Management Plans of the 12 Municipalities of the region of Western Macedonia, the development of the RWMP, as the NWMP also requires, is specified in the following thematic units: a) Municipal solid waste, b) Sludge (urban type), c) Waste from sanitary units, d) Industrial waste, e) Agricultural and animal husbandry waste, f) Mining, construction and demolition waste, g) Electrical and electronic waste, h) End-of-life vehicles, i) Oil wastes, j) Waste of batteries, k) Waste of accumulators from vehicles and industries, l) Used vehicle tires.

In particular, the targets for the industrial waste management are:

- Ensuring the traceability of industrial waste production and management.
- Ensuring the rational management of industrial waste generated on the basis of the waste hierarchy and the best available techniques.
- Development of an electronic waste platform to promote synergy between industrial sectors for the recovery of industrial waste.
- Organize and operate an adequate industrial waste disposal infrastructure network.

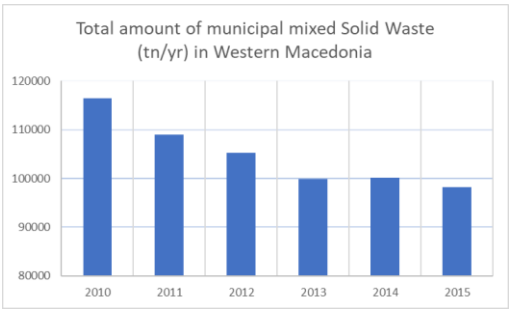

Figure 1. Total amount of municipal Solid Waste (tn/yr) in Western Macedonia

3.1. Critical issues coming from the application

Based to the monthly measurements by the waste management authority (DIADYMA S.A.), for the period 2010-2015, it can be seen from the below Figures 1–4 that:

- there is a continuous reduction from 2010 to 2015 (with an exception of a rise in 2014) of 15.60% of the produced Municipal Solid Mixed waste,
- there is a continuous and significant reduction from 2010 to 2015 (with an exception of a big rise in 2013) of 71.14% of the produced Mixed Waste by private companies,
- there is a continuous rise from 2010 to 2015 (with an exception of a reduction in 2012) of 22.68% of the total recyclable waste by collection at source programs to the municipalities,
- there is a reduction in the first three years and a rise in the next three ones with a total rise of 17.58% from 2010 to 2015 of the total Industrial and Commercial Packaging Waste by collection at source programs

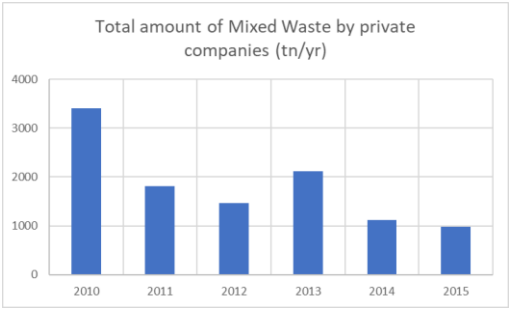

Figure 2. Total amount of Mixed Waste by private companies (tn/yr)

As far as the first two categories of waste are concerned, this reduction is especially due to the financial crisis which led to the reduction of the purchasing power of the consumers and as a result to the reduction of the waste production (Gálvez-Martos *et al.,* 2018).

The other two categories show a rise which confirms the commitment of the private sector to the waste recycling

through collection at source programs which are developed from the municipalities and DIADYMA S.A.

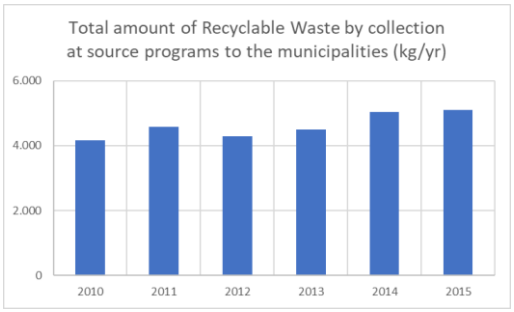

Figure 3. Total amount of Recyclable Waste by collection at source programs to the municipalities (kg/yr)

Figure 4. Total amount of Industrial and Commercial Packaging Waste by collection at source programs (kg/yr)

From all the above, it may be resumed that the targets which are specified not only on national, but also on regional level as well, are very high and they need a lot of effort in order to be achieved. As far as the recovery of recyclable materials is concerned, in addition to the contribution of the MBT plant, all the separation at source programs must be strengthened in order to achieve the targets by 2020 (Colón *et al.,* 2015).

4. Implementing the circular economy

The methodological approach consists of:

- Inquiry of similar experiences, developed in other areas, and definition of the current technical, social and legislative framework for waste (Mickovski *et al.,* 2017).
- Development of a web-based platform (Material Match Making Platform, M3P), including data collection and characterization of waste streams. This action aims to involve effectively the highest number of businesses, as well as relevant stakeholders of the four local areas, where the project will be implemented, and achieve a detailed survey about produced waste. Moreover, this covers the development of the platform, as tool to support materials and waste investigation, matching of materials for re-use, and new applications development (Koutra *et al.,* 2018).
- Development of pilot cases of industrial symbiosis by using the platform M3P and implementing in-depth studies about significant waste streams. Waste streams will be experimented with few quantities of materials. Pilot cases will experiment at lab scale possible treatments and processes, useful to transform waste in second raw materials for other industries and applications. It is not foreseen to realize any pilot plant nor industrial plant in situ. Then the main results will be several feasibility plans to implement recovering processes.
- Development of eco-design concepts based on the selected waste, aiming at finding innovative creative material applications for alternative uses and also fostering the creation of new businesses (Simboli *et al.,* 2015).

Moreover, further actions to monitor the environmental and socio-economic impact of the project will be carried out in parallel with dissemination and diffusion of the concepts of industrial symbiosis and the circular economy as well as the results of the project itself.

5. Technical specification regarding M3P platform

The M3P platform is based on Open 2.0 environment developed by Lombardy Region according to European Commission FESR Program (Open 2.0 Platform, http://www.open2.0.regione.lombardia.it). Talking about standards, Open 2.0 architecture claims to use World Wide Web Consortium (W3C) standards widely and implement open data. It is “open data” compliant with European Regulation which underlines the use and re-use of open solutions and data from public sectors. The platform has a human interface research system and tag research system which can help in an easy way SMEs to use it as database for their technological investigations. It could be implemented through dedicated plug-in with Artificial Intelligence solutions through interaction with semantic engines and big data access.

Open 2.0 is based on the Yii2 framework for the object-oriented programming (OOP) development of large-scale PHP applications, according to the Model-View-Controller design pattern. Therefore, it inherits numerous state-of-the-art technological features, including: a) Database Access Objects, Query Builder, Active Record, DB Migration, b) Integrated form creation and validation, c) Authentication and authorization (RBAC), d) Application cache management, e) Web services (SOAP, RESTfull), f) I18N and L10N for localization management, g) Security: prevents SQL injection, cross-site scripting (XSS), cross-site request forgery (CSRF), and cookie tampering and h) XHTML compliance.

The information system is based on the LAMP stack (Linux Apache MySQL and PHP) on the Yii2 framework which makes the application structure compliant with the "MVC" model and ensures interoperability with heterogeneous systems (Business and External). The application infrastructure highlights the following tools:

- Web server: Apache2, designed to manage HTTP/HTTPS requests.
- App server: Used to host the application platform. In the balanced system view, it can be divided into several slave servers to balance the load (using a balancer).
- Database server: MySQL is the database manager where the application data resides. In heavy load environments it is possible to install the database on a specific and dedicated machine.
- Web Services (WS): This layer allows interoperability between applications in a distributed context.
- Amos 4: Software component that aims to guarantee the standards of development and application modularity.
- Yii2: Open Source development framework with MVC model.

In compliance with safety standards, the system is able to guarantee the security of its data. Protection is obtained through measures aimed at ensuring: a) user access through authentication only, b) service availability through access lists, c) data integrity and d) data encryption. Moreover, there is an extended and detailed waste checklist with specific characteristics for different sectors. Actual specific waste sheets are for polymers, textile, chemical products, wood and construction disposal waste.

6. Discussion and expected results

The actions will focus on the following two priorities: a) Protecting the environment, promoting sustainable transport and public infrastructure and b) Strengthening the local economy.

The quantified results from all project actions will be:

1. 1 web-based platform (M3P) developed and implemented in real operating conditions in the four industrial districts by at least 10 SMEs.
2. 1 waste database
3. 1 report
4. At least 230 SMEs involved/interviewed
5. At least 500 waste identified
6. 100/120 material/scraps/waste investigated
7. At least 24 waste deeply characterized
8. At least 3 sectors involved
9. At least 10 pilot cases
10. At least 40 companies implementing the proposed solution
11. At least 4 business cases implemented
12. At least 40 young designers involved during the product concept development phase
13. 72 new product concepts
14. At least 16 prototypes
15. At least 4 start-up studies
16. Reduction of waste production at the cluster level and at the SME level
17. Improvement of investments by companies in socio-economic aspect such as training activities
18. Improvement of socio-economic indicators selected to assess the project impact
19. At least 2 other industrial areas/clusters, different than the partners' ones, involved in transfer of a web-based platform M3P.

Despite the project focus is on materials, we expect to also obtain energy and water savings dependent on the re-use of the material waste stream, like: a) reduction of energy consumption at the cluster level, b) reduction of use of non-renewable sources at the cluster level, c) reduction of water consumption at the cluster level and d) reduction of the emissions of CO_2 at the cluster level (DIADYMA S.A., www.diadyma.gr).

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