A Database of Existing Solid Industrial Waste Reuse Schemes as the Basis for an Industry Matching Algorithm

Solomou K.[1], Arampatzis G.[2], Dedousis P.[3] , Angelis-Dimakis A.[1,*]

[1]Department of Chemical Sciences, School of Applied Sciences, University of Huddersfield, UK
[2]School of Production Engineering and Management, Technical University of Crete, Greece
[3]School of Chemical Engineering, National Technical University of Athens, Athens, Greece

*corresponding author: e-mail: a.angelisdimakis@hud.ac.uk

Abstract
For the purposes of the SWAN Project, an integrated suite of on-line resources and tools has been developed aiming to assess novel industrial business models based on solid industrial waste reuse. One of the major components of this platform is an inventory of commercially implemented best practices. This inventory will both inform all registered users about the current opportunities for waste reuse and also serve as the basis for the SWAN matching algorithm.

For all the practices or technologies included in the database, the following characteristics have been collected: (i) The type of the industrial plant supplying the waste stream; (ii) The type of the industrial plant receiving the waste stream; and (iii) The type of the waste stream exchanged between source and sink;

The Statistical Classification of Economic Activities in the European Community has been used for the categorization of the industrial plant types whereas for the waste streams both the European Waste Catalogue and the European Waste Classification for Statistics have been applied. The database has been populated with more than 100 entries and has led to the identification of the most common symbiotic opportunities based on solid waste reuse.
Keywords: Solid Waste, Industrial Symbiosis, SWAN Project, Best Practices

1. Introduction

Industrial Symbiosis describes two industries living harmoniously together. It is one of the main tools considered by national and European environmental policy makers towards resource efficiency without deteriorating economic development. The key to develop a Symbiotic Scheme between two or more industries is to identify the industrial plants, which can satisfy a set of criteria, either geographical, technical or economic.

The most important aspect of this process is the technical matching, especially since there is an endless numbers of potential waste streams created (characterized by varying composition and quantities) and an equally vast range of resources used in industrial systems. There are three major developed methodologies for industrial symbiosis matching, which do not necessarily apply only to solid waste streams but are more generic and can be applied to different types of waste streams.

1.1. Semantic matching algorithm

Cecelja et al. (2015) have introduced a semantic matching methodology using ontology engineering for the development of an industrial symbiosis network. The matching algorithm is based on the characteristics of the involved industrial plants and the defined metrics in the ontology domain.

The characteristics/attributes of the industrial plant include the type of resource(s) available/required, the quantity of resource(s), the pattern of supply (batch or continuous), their availability and the location of the sites (described by the longitude and latitude).

The proposed matches can be implemented through three alternative types of matching: (i) Direct matching; (ii) Chain matching; and (iii) Resource decomposition matching.

1.2 Knowledge base matching

Alvarez and Ruiz-Puente (2016) developed a similar ontological framework in order to identify potential synergies among industries. For that purpose, two different types of information are used: (i) dynamic information from participating companies, which include the name, location, coordinates, industrial area and number of workers; and (ii) an Industrial Symbiosis related knowledge base, consisting of implicit knowledge from existing partnerships, experience from industrial experts and case studies from the scientific literature.

Two different types of symbiotic schemes have been assessed, under this framework: (i) substitution of a raw material of an industrial plant using the waste of another plant; and (ii) synergies of mutuality (sharing service/infrastructure or joint waste management schemes).

1.3 Spatial taxonomy based matching

The simplest method to identify symbiotic schemes is by considering spatial and organisational factors. Such an approach is applicable in a specified area/region and can applied through an extensive field survey (using interviews/questionnaires) in order to identify potential input/output matchings (Liu at al., 2015). In this case, three different levels of industrial symbiosis are defined (Chertow, 2004): (i) individual firm level; (ii) inter-firm level; and (iii) regional level.

2. SWAN Technical Matching

The goal of SWAN project is to facilitate the development of solid waste reuse value chains in the Balkan Med region, through the collaboration of an industrial solid waste source and a potential solid waste user. This can be achieved by adopting a three-step process: (a) map and characterize the potential sources and sinks of solid waste in the partners' countries; (b) match them based on technical and financial criteria; and (c) identify, assess and finally propose potentially feasible business models for opportunity exploitation, both at national at transnational level.

The technical matching that will implemented for the purposes of the SWAN project will combine characteristics from the three above-mentioned methodological approaches.

As a first step, a knowledge base has been developed and populated based on commercially applied symbiotic solutions. For each IS practice/technology, the following characteristics have been collected: (i) the type of the industrial plant supplying the waste stream and of the plant receiving the waste stream (using the Statistical Classification of Economic Activities in the European Community); (ii) the type of the waste stream exchanged between source and sink (using the EWC-Stat Categories); (iii) an indication about the technology readiness level of this option; and (iv) a scientific reference.

Based on the information collected, a list of the technically plausible pairings is developed, which also includes the information on how common such a pairing is (based on the number of occurrences). From the data collected so far (Table 1), it can be seen that the most common source of the implemented industrial symbiosis scheme are the power plants (NACE Code D35.1), which participated in 18 of them, usually supplying fly ash (as the major waste stream). On the other hand, the most common receiver are the Cement Plants (NACE Code C23.5), being supplied with different aggregate material (e.g. fly ash with EWC Stat-Code 12.2) from a variety of industrial plants (with the power plants being, again, the most common option).

Table 1. Most common existing IS schemes

Source Name and Type		Receiver Name and Type		Instances
Power Plants	D35.1	Cement plants	C23.5	18
Chemical industries	C20.1	Cement plants	C23.5	9
Olefins	C13.1	Plastics	C22.2	4
Refineries	C19.0	Chemical industries	C20.1	4
Pharma Industries	C21.0	Biogas plants	D35.2	3
Lime/Plaster Industry	C23.5	Cement plants	C23.5	3
Iron&steel	C24.1	Chemical industries	C20.1	3
Iron&steel	C24.1	Cement industries	C23.5	3

3. Conclusions and Further Research

The collected data can inform all registered users about the current opportunities for waste reuse. This type of analysis also serve as the basis for the identification of the potential (literature based) symbiotic schemes in any given region and is the first step of the matching algorithm (Literature Based Technical Matching).

The next steps would be to assess the temporal matching of the proposed symbiotic schemes and calculate the distance between the source and the potential receiver, the transportation and storage (if needed) cost. For the all technically feasible combinations, a feasibility assessment will be performed to formulate a list with the economically viable combinations and an agreed selling price for the waste stream for each one of them.

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