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247 - Low cost method of industrial symbiotic network on large amounts of residual materials

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Abstract

Industrial symbiotic networks for the exchange of residual materials within a regional economic community have been set up. High-perceived costs of organizations that coordinate industrial symbiotic networks could be a barrier for funding by e.g. governments. Therefore, a low cost method of an industrial symbiotic network was tested and compared to three programs that coordinate an industrial symbiotic network (NPSI, SILVER and FISCH). The low cost network was tested by inviting companies to meetings, find matches between companies to exchange a residual material, and interview the attendees. This method was compared to the three programs by interviewing the managers and/or project leaders. The low cost method was compared to the three programs. In the two years the method was tested the personnel input was a 0,07 to 0,11 full-time-employee equivalent (fte), compared to other programs which took at least 2 fte. The low cost method had reached 55 companies. Attending companies found barriers in exchanging residual materials in strict governmental regulation on waste and involvement of waste firms. This corresponds with the findings in the three programs and literature. The method tested in this research shows the absolute minimum to start a group of companies exchanging residual materials three aspects are required: a trusted coordinating body, recruitment of attendees, and basic knowledge on materials in order to match these. Governments can support such a coordinating body by flexible regulation in waste management and by services that map material flows in industrial areas.

Keywords: Industrial Symbiosis, Network Coordination, Waste Exchange Platform

Introduction

The exchange of materials in a regional economic community can be stimulated or facilitated between normally unrelated companies. An example of a facilitation brokerage program of industrial symbiosis opportunities is the National Industrial

Symbiosis Program (NISP). This program runs in the United Kingdom and other countries, like France, Belgium, and The Netherlands. The methodology is expected to be relevant to countries in which industrial activity is similar in maturity and diversification, as is shown by the empirical work of Jensen et al. (Jensen et al, 2011). The activities of NISP-employees were grouped in three categories: conversation, connection, and co-creation. The action of conversation contained raising awareness amongst potential partners and recruitment of companies for exchange of materials. For the recruitment by the organization, the credibility as a coordinating organization had to be developed. Connection was the action to introduce relevant firms around specific exchanges. Co-creation meant that high-value industrial symbiosis exchanges were replicated and 'resource infrastructure' projects were supported with e.g. help on environmental permitting or offering technical assistance. The projects helped developing future exchanges or expanded regional capacity around key resource materials (Paquin and Howard-Grenville, 2012).

Lombardi and Laybourn (2012) stated that the "mental distance" of the companies exchanging materials, the costs of the transaction (e.g. monitoring materials, time of management) and the cost of transport are important factors in exchanging materials. The spatial scale of materials exchange is limited by the economic value and therefore is mentioned as cost of the specific materials. In the case of the NISP this was found to be on its specific materials in the United Kingdom 20,4 miles (32,6 kilometres) average (Jensen, 2011). The specific materials were recyclable waste materials such as glass, metals, textiles and plastic, but also organic and inorganic chemicals and fuels. Lombardi and Laybourn (2012) however noted that although geographical proximity is associated with industrial symbiosis, it is neither necessary nor sufficient for materials exchange.

To understand numerous instances of industrial symbiosis different taxonomy has been proposed in literature. Chertow (2004) proposed a taxonomy of materials exchange that considers spatial and organizational elements. The taxonomy includes 5 types; though waste exchanges (type 1), within a facility, firm or organisation (type 2), amongst firms co-located in a defined eco-industrial park (type 3), among local firms that are not co-located, such as Kalundborg (type 4) and among firms organised virtually across a broader region (type 5). In the dynamics of industrial symbiosis seven types were defined (Boons et al., 2017), characterised by initial actors, their motivation, overall storyline and typical outcome. These 7 types were self-organisation, organisational boundary change, facilitation brokerage, facilitation-collective learning, pilot facilitation and dissemination, government planning and eco-cluster development. In anchoring two types of anchoring activities have been defined (Sun et al., 2017), physical and institutional anchoring. Stimulating social actions and knowledge support are examples of institution anchoring. Facilitating industrial symbiosis networks of residual materials in a broader region such as for example the NISP program (Paquin and Howard-Grenville, 2012) is a 'type 5' according to Chertow (2004), 'facilitation brokerage' according to Boons et al (2017) and an example of 'institutional anchorage' (Sun et al, 2017).

There are different factors that stimulate industrial ecosystems. Motivation and trust are important factors for the establishment and functioning of industrial ecosystems (Schiller et al., 2014). Increasing diversity, redundancy and multi-functionality of the industrial symbiosis system is recommended in type 4 material exchange (Chopra and Khanna, 2014). More geospatial industrial diversity provides more opportunities for local industrial symbiosis according to Jensen (2016). Paquin et al. (2014) however stated that diversity amongst collaborating firms reduced the chance on an industrial symbiosis exchange. Mirata and Emtairah (2005) find that inter-organizational collaboration and learning is important for the innovation process in the industrial symbiosis networks. Governmental policy plays a large role in stimulating industrial symbiosis. Pajunen et al. (2013) find that an innovative approach to environmental permitting should receive more focus in decision-making. Costa et al. (2010) found in Denmark, the UK, Portugal and Switzerland that to develop industrial symbiosis flexible regulation in waste management and strong economic and regulatory instruments that penalizes lower waste management options are advised. Voluntary coordinating programs could provide information for companies to identify economic viable alternatives for their disposed materials. Mirata (2004) found that the extent of peer pressure, nature of companies operations and industrial history in regions, and the positioning of a coordinating body in the region have major influences of the progress of industrial symbioses programs. Universities and other agents could collect information for stimulating policy of industrial symbioses development (Costa et al., 2010). To encourage development and facilitation of industrial symbiosis, policies should include teams that map material flows in industrial areas and offering technical and financial assistance to increase the number of interactions (Chertow, 2007). Chen and Ma (2015) used a material flow accounting tool to extract potential exchange patterns from the data of the Taiwanese Environmental Protection Agency.

There are different barriers for setting up industrial symbiosis networks. In pilot projects undertaken in the Italian Emiglia Romana region barriers for forming an industrial symbiosis network were found to be an inadequate regulatory framework, lack of collaboration between different companies, not sharing sensitive data, inadequate communication between stakeholders and inadequate or misunderstood economical gain (Iacondini et al, 2015). Bacudio et al. (2016) found as barriers the lacking of: awareness of industrial symbiosis, willingness to collaborate, institutional support for integration, coordination and communication, top management support and funding or to promote industrial symbioses. Paquin et al. (2015) noted that waste firm involvement in industrial symbiosis could decrease the likelihood of creating eco-efficiencies, due to the likeliness to focus on an appropriate value in the exchanges for their own firm.

Funding for expanding and maintaining the industrial symbiosis network is crucial. The funding of NISP was 8.25 million GBP between 2005 and 2007, and fell back to 5.825 million GBP in 2008 and 2009 due to austerity measures (Jensen 2011). Although industrial symbiosis network facilitation is valuable for a region, it is dependent on funding. A perception of high costs for a methodology for exchanging residual materials could be a barrier for a funding body, such as governments and companies. Therefore

the research question posed here is if a low cost variant of an industrial symbiosis network facilitation such as NISP is creating could be applied, and how it would compare in costs and results to other existing industrial symbiosis network facilitation like the NISP.

Methods

The methodology applied is to set up sessions to develop an industrial symbiosis network facilitation method that functions but at low costs. The costs could be personnel costs or other costs e.g. communication, costs for rooms and reporting. The developed low cost industrial symbiosis network facilitation is compared to others. To develop a low cost industrial symbiosis network facilitation physical meetings were set up. Because sharing sensitive data is identified as a barrier (Iacondini et al., 2015), these meetings were physical, and not online. In the action of connection (Paquin and Howard-Grenville, 2012) a meeting for an attendee should not take up more time than half a day (4 hours) including traveling, in order not to challenge the support from management (Bacudio et al., 2016). Taking a maximum of 1 hour traveling time into account, the meetings did not take more than 2 hours. To keep the travel time as low as possible the meetings were organised in an industrial area, or as much as possible in the centre of the companies that sent attendees. The meeting places could be governmental buildings (such as municipal buildings), as well as the office of an attendee. In the meeting the attendees were asked to introduce themselves, to orally present their materials offered and requested, to answer questions and to discuss possible usage. The information about the materials requested or offered consisted of the description, amount (tons per year) and in most cases some minor information about the composition and the process the material originates from. Per attendee this takes about 10 minutes time. In order to have a meeting in 2 hours, and taking into account the time for an introduction and closing of the meeting on the organiser, a maximum of 10 persons could attend the meetings. The meetings were organised and chaired by the researcher to the Delft University of Technology. This researcher sent the attendees a report of the meeting containing data about the offered and requested materials. The meetings were free of charge for the attendees.

One of the barriers is misunderstood economical gain (Iacondini et al., 2015). Therefore the minimal amount of materials was chosen to be 100 tons per year (t/y). This fairly high minimal amount was expected to attract larger companies for the meetings. Another reason to choose the minimal amount of 100 t/y is to prevent time being spent during the meeting on contacts that are likely not to lead to a fruitful exchange due to a lack of economical profit, although the researcher is aware that some potential matches could be missed. The number of 100 t/y was chosen on the basis of experience of the researcher and because the number is easy to communicate.

After the meeting the requested and offered materials were matched to the materials of former meetings. To confidential treat the information of the materials given by the attendees of the meetings in case of a potential match, the offering party was sent an e-mail by the organiser of the meetings that a company was requesting these materials, because the offered materials contained more commercially sensitive information than requested materials. Sharing sensitive data is another barrier (Iacondini et al., 2015). The e-mail contained only a short message of the materials requested, and the name and e-mail address of the employee of the requesting company. In the matching of the offered and requested materials companies were placed in contact with each other only when 10 times more or less materials were requested or offered, Companies seemed not to be interested when an offered amount is 10 times less as the required amount, due to administrative handling and costs for quality control. This approach was chosen to keep the research method workable and practical. Attending companies orally expressed their appreciation of this approach.

Companies were invited for the meetings via relevant Linked-In groups, via electronic mailings of the personal contacts of the researcher, via newsletters of branch organisations of the Dutch Chemical Industry Association and the Federation of Dutch Food Industry. Companies were also invited via direct calls. These companies were found for the meeting via lists of industrial area's in e.g. Zaanstad and Amsterdam. All companies were called on these lists, with the exception of companies that only had a transportation function, such as container terminals. In doubt, companies were called to invite for the meetings. All the calls were made by the researcher of Delft University of Technology. There was no historic connection of the researcher to those companies. After the calls the researcher send the employees of the companies an e-mail explaining the meetings. Companies were called maximum three times. When a relevant employee was not reachable, their e-mail addresses or that of the reception of the company were given, to invite them via e-mail. With the employees, the most convenient date was set. The employees of the companies that were invited, got an explain e-mail with route description to the meeting. In this e-mail all e-mail addresses of the invited employees of the different companies were placed in the cc., so that before the meeting everybody knew who was coming. The region of which the companies were selected from are the Netherlands. Because the involvement of waste firms could decrease the likelihood of creating eco-efficiencies due to the likeliness to focus on an appropriate value in the exchanges for their own firm (Paquin et al., 2015) these firms were not invited. Because this is likely to be valid for consultants and traders, these were not invited as well.

The low cost industrial symbiosis network facilitation is compared to other industrial symbiosis network facilitation. For the comparison industrial symbiosis network facilitation were selected in the same region as the Netherlands. The results are the amount of attending companies, potential matches and exchanges, within a period of time. A potential match is a contact by e-mail of two attendees that points out a possibility for a match, based on the product specifications. An exchange is material physically being exchanged. The costs could be build up by monetary costs and

personnel input. For a numerical comparison the facilitation were compared on costs and results, by relating the amount of attendees to the meetings, potential matches and exchanges to the amount of fte's involved and the amount of time an activity (program) ran. For the comparison also barriers were studied. The information on costs, results and barriers were obtained by interview by telephone.

In the NISP, the practitioners often visited facility sites to collect information about residual materials as part of the further development of a potential match (Paquin and Howard-Grenville, 2012). However, this paper does not deal with alternatives for top management or other possible institutional changes at that level, therefore only the time pressure for higher management is taken in to account. The attendees were interviewed about finding a match or not, on the social contacts, the societal point of view and how materials exchange could be more or less facilitated:

- By asking about the social contacts, possible barriers as lack of motivation and trust (Schiller et al., 2014), possible inadequate communication, willingness to collaborate (Iacondini et al., 2015)
- By asking about the societal point of view, barriers and stimuli from society were addressed, such as permits (Pajunen et al., 2013) and regulations (Costa et al., 2010).
- By asking about facilitation, possible barriers due to inadequate communication, misunderstood economical gain (Iacondini et al. 2015), the role of top management support and funding, and functioning communication and coordination (Bacudio et al., 2016).

Results and Discussion

A low cost method for industrial symbiosis network facilitation was tested in the Netherlands in order to find opportunities for substantial material exchange between companies. The method was tested within the framework of the project 'Reduction of commercial waste', that was commissioned by the Dutch province of North-Holland. To test the method, the first three meetings in the Netherlands were organized for companies in their own industrial area. This kept travel time short in order to address management support. The meetings in the industrial area of Zaandam and Amsterdam were hosted by the local municipals and one civil servant per meeting attended the workshop as observer. The participants did not have any discomfort in having civil servants of the municipal attending. In Rotterdam the meeting was held at the office of an invited company. For these three meetings the companies were invited by direct telephone calls. To find the companies in an industrial area information of the industrial area was gained via internet. This information was the overview of companies in the area, as well as the activities of a company and their contact data. All companies in the area were invited via telephone. Finding and inviting the companies took about 16 hours (2 working days). Having the meeting, including travel time cost about 4 hours. Reporting took 2 hours, and connecting attendees via e-mail on an possible match

afterwards via e-mail took in the second and third time about 1 to 2 hours. In total the amount of time was about 22 hours, close to 3 working days.

After these large Dutch industrial areas were tried, in the fourth and fifth meeting companies over the whole of the Netherlands were invited. The invitations were made via random invitations in the whole of the Netherlands via electronic mailings, relevant discussion groups on Linked-In and via newsletters of the branch organizations Dutch Chemical Industry Association and the Federation of Dutch Food Industry. Sending the invitation via these channels took about 4 hours. Answering telephone calls and e-mails took about 12 hours. Reporting took 2 hours, and connecting attendees via e-mail on an potential match afterwards via e-mail took in the fourth and fifth time about 2 hours. Although there were more matches, the amount of time was not increased significantly, due to matching via material groups in an excel file and sending very short mails. In total the amount of time was about 22 hours, close to 3 working days. In all five meetings the most convenient date was set with the respondents. After these five meetings 5 companies, more sent information on requested and offered materials via e-mail. Potential matches were found with the information of these companies in about 1 hour per company. This is relatively more than the 2 hours required for 8 to 13 companies in the five meetings (table 1) due to an extra phone call and matching one company at a time, which is less efficient. These mails were a reaction of a discussion the researcher had in two meetings, explaining briefly the method. One meeting was related to industrial symbiosis network facilitation. The other meeting was related to activities in the chemical industry. For these companies sharing neither sensitive data nor a lack of trust was a barrier.

In all cases the matching was done by asking the attendee how to describe the offered or requested material in one word. These words were used to find potential matches quickly in an excel sheet. Any further description of the material helped to see if finding a potential match was useless on forehand. When a potential match was found, the offerer received a mail of the researcher with the e-mail address of the requesting party. In total over two years, this costs about 15 days. On a working year with 235 days, that is about 0,03 fte. Of 29 found potential matches two matches are being investigated by the contacted companies. No further costs were made. The five meetings were given between November 2014 and April 2016. The materials mentioned in the e-mails were sent in the months of September and October 2016. Table 1 gives an overview or the meetings, the cumulative growth of the potential matches and the ratio of potential matches to attendees. Exchange opportunities were found. Although it takes time it takes time for the companies to investigate these opportunities, they had sufficient time to explore opportunities.

Table 1: Attendees at meetings and via e-mail

Area	Date	Attendees	Attendees (accumulated)	Offered materials	Requested materials	Potential matches (accumulated)	Ratio potential matches

							to attendees
Zaandam	November 5th 2014	8	8	26	15	1	0,13
Amsterdam	March 20th 2015	10	18	23	6	1	0,05
Botlek (Rotterdam)	November 24th 2015	9	27	33	9	9	0,33
National (Gouda)	January 18th 2016	10	37	42	10	12	0,32
National (Nieuwegein)	March 30th 2016	13	50	54	12	19	0,38
Via e-mail	September - October 2016	5	55	12	11	29	0,58
Total		55		190	63		

Table 1 shows a significant increase in the identified potential matches after the third meeting (in Rotterdam) and after the e-mails. This increase is coincidental. There is no reason this significant increase is to be expected. All the companies in the industrial areas were invited by telephone, had all the same phone scripts as well as the same e-mails. A significant increase or decrease could have been expected between the third and fourth meeting, because in the fourth (and fifth) meeting the companies were invited not only by direct phone calls but via Linked-In groups, newsletters of branch organisations and electronic mailings. However, no significant increase in potential matches was found. Another significant increase of potential matches is at the companies who sent e-mails with information about requested and offered materials. The five companies that sent e-mails heard about the method via meetings. They actively made contact with the researcher and sent information. There were no companies that contacted the researcher, and that did not sent information. The ratio of potential matches to companies seems to increase after more meetings or e-mails with information. The increase however is not gradual.

Table 2: Types of materials offered and requested

Type of materials	Offered	Requested	Examples
Acid	9	11	Chloric acid, sulphuric acid
Leigh	3	10	Potassium and sodium hydroxide
Organic material	28	5	Fats, free fatty acids, bio and fossil based oils
An-organic material	41	16	Calcium oxide, magnesium oxide, phosphates
Sand/sludge/ash	23	6	incinerator ash, metal containing sludge
Biomass	31	4	Food production residues, cellulose fibre
Waste/residual water	4	2	Waste waters containing (an)organic substances
Diverse	51	9	Bleaching earth, textiles, plastic
Total	190	63	

The low cost industrial symbiosis network facilitation was compared to other methods in area's in or surrounding the Netherlands with comparable industrial activity in maturity and diversification. These programs were set up programs were set up in France (Programme National de Synergies Inter-Enterprises; PNSI), Belgium (FISCH; Flanders Innovation Hub for Sustainable Chemistry program "valorisation of residual streams") and in the Dutch province of Limburg (SILVER; Dutch acronym, meaning "Symbiosis in Limburg Accelerating and Realising"). These programs are studied by

interviews to obtain an insight on their characteristics such as costs, personnel, approach and findings, in order to compare them on the costs (personnel) versus potential matches within the perspective of that approach.

In order to compare the low cost industrial symbiosis network facilitation with FISCH and SILVER, the amount of attendees, potential matches and exchanges have to be regarded per year and per personnel input. A complete comparison on cost cannot be made due to lack of data on personnel costs. Therefore the costs related to SILVER are minimal cost due to the extra costs for the program of 70.000 euro. Table 3 gives an comparison of the programs in relation to the years they ran and the personnel input, so amount of attendees, potential matches and exchanges, per year per fte.

Table 3: Comparison FISCH and SILVER

Program		low cost industrial symbiosis network facilitation	FISCH	SILVER
Attending companies	(per year per fte)	917	45	33
potential matches	(per year per fte)	483	150	120
exchanges	(per year per fte)	33,3	1,8 – 2,1	6

Contrary to the low cost approach with a minimum of 100 t/y materials, FISCH and SILVER did not have a minimum amount and did included exchange of energy in their efforts. However per year and per fte the low cost approach had significantly more attending companies. In table 1 a crude above linear increase of the amount of matches to the amount of attendees was observed at the low coast approach. SILVER and FISCH had about four to six more attendees, not as many potential matches per year per fte. Also the exchanges were higher at the low cost approach although 2 potential matches by this method is low in order to substantiate this. In costs and personnel, the NISP-approach should be regarded as a single project. This method with 0,03 fte should be relatively easy integrated in the task of an employee.

The most mentioned reasons that potential matches were not brought to a final match in this research were costs (9 attendees out of a total of 53), product specifications not matching (8/53), and time constraints to follow through the opportunity (3/53). The costs of residual materials contain basically the price of the residual material without further processing and depend also on the transportation costs. This cost has to compete with the cost of primary materials. Transportation costs are connected with the geospatial distance (Jensen et al., 2011) of an industrial symbiosis, but also depend on the cost difference of primarily materials and the offered residual material.

For this method most attendees (25/53) find the contacts to be easy and pleasant. Some did not have time for contacts (4/53), and a small amount had some issues with lack of trust (2/53). Governmental regulations are found to be a barrier, by the attending companies, such as the perceived long time procedures took. Pajunen et al. (2013) found that in decision making there should be more focus on an innovative approach to environmental permitting. Costa et al. (2010) found in different countries flexible

regulation in waste management being advised. This was also noted in the NISP-programs. Waste regulations (FISCH, PNSI), REACH (FISCH) and tender regulations (SILVER) were found to be possible barriers.

Paquin et al. (2015) state that although waste firms play an important role in the development of industrial symbiosis, especially on reverse logistics and greener supply chains, their involvement does not always support the firms' business strategy. This was confirmed by NPSI, SILVER and FISCH. Waste firms were not invited or even asked to leave industrial symbiosis meetings. In this research, waste management firms were not invited, and some attendees (2/53) mentioned that waste groups were not desired, when asked in an open question about facilitation.

This method shows a low cost method of a type 5 material exchange (Chertow, 2004) in a regional economic community. It suggests that for a minimal configuration to start a group of companies exchanging residual materials, by means of meetings, three aspects are required. The first one is a coordinating body (Mirata, 2004) that is trusted (Schiller et al., 2014). The credibility of this organization has to be developed (Jensen et al., 2011). The second is recruitment of attendees. The third one is basic knowledge on materials in order to match these. For this in most cases the attendees themselves give possibilities, however a basic knowledge of chemistry is advisable. The Dutch ministry of Economic Affairs and the Netherlands Enterprise Agency can be seen in the low cost approach as support for such a coordinating body in two ways. The first one is creating flexible regulation in waste management (Costa et al., 2010). The second one is by having teams or services that map material flows in industrial areas (Chertow, 2007), which could support recruitment for this method. An example is the data of the Taiwanese Environmental Protection Agency used by Chen and Ma (2015) to find potential exchange patterns.

Conclusions

In this research, a method for the exchange of materials within a region was tested. Compared to similar programs as the NISP-program this method is very low in cost, about 10 times as low, on the condition that only materials are regarded with a flow larger than 100 tons per year. In the two years the method was tested the personnel input was a 0,07 to 0,11 full-time-employee equivalent (fte), considering the rate of other NISP-programs contacting companies, which should make this method easy implementable in the tasks of an employee, in comparison to other methods which takes at least 2 fte. In this method, about 2/3rd of the time spent is for recruitment of attending companies. The method had only reached 55 companies so far, and 2 potential matches were investigated by companies.

Exchange opportunities were found, however other opportunities were not followed up on. Different product specifications, high transport costs and time constraints seems to be the major reasons that opportunities were not followed further.

The barriers and stimuli for exchange of materials found in testing this method was similar to those found in literature and found in other methods. Data of companies were handled confidential, and during the exchange meetings companies felt confident in sharing data. Strict governmental regulation on waste and exchange of materials were found by attending companies to be a barrier. Involvement of waste firms is not desired by the attending companies, corresponding with the findings in other materials exchange programs and literature.

The method tested in this research shows that a minimal configuration to start a group of companies exchanging residual materials three aspects are required: 1) a coordinating body, 2) recruitment of attendees, and 3) basic knowledge on materials in order to match these. Governments can support such a coordinating body by creating flexible regulation in waste management and environmental regulation, and by having teams or services that map material flows in industrial areas that could support recruitment of attendees.

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