Industrial Symbiosis in Iskenderun Bay: A journey from Pilot Applications to a National Program in Turkey

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Abstract

In Turkey, the industrial symbiosis (IS) approach was realized within the scope of the project "Industrial Symbiosis Project in Iskenderun Bay – Implementation Phase" between January 2011 and February 2014. Technology Development Foundation of Turkey (TTGV) carried out the project with the consultancy of Middle East Technical University (Turkey) and International Synergies Limited Company (United Kingdom). Throughout the project a pilot scale IS network comprising 264 institutions was established and more than 500 IS opportunities were identified between institutions. 10 IS opportunities were selected and studied in detail.

An "Industrial Symbiosis Implementation Network" was established in Iskenderun Bay by integrating 10 IS opportunities. Analyses indicated that full-scale implementations of 10 identified IS opportunities (from different sectors) would enable landfill diversion of 327,250 tons solid waste annually. Mentioned IS opportunities have also important potential in terms of energy production/saving (33,580 MWh) and associated CO_2 reduction (36,700 tons/year). In addition to abovementioned environmental gains, implementations would bring economic returns as well. Companies would save 6,370,500 $/year in total. Calculations show that 6,965,000 $ of investment cost is required in order to realize the mentioned IS opportunities. In other words, applications would have a payback period of 1.1 year when combined.

As a major outcome of project activities 19 regional development agencies integrated industrial symbiosis into their 2014-2023 period regional plans and similar IS projects were recently initiated by some of them in cooperation with TTGV. Moreover, the concept was also integrated into the "National Efficiency Policy" prepared by the Ministry of Science, Industry and Technology.

Keywords: Waste recycling, Industrial symbiosis, Industrial ecology, Iskenderun Bay, Turkey

1. Introduction

Industrial symbiosis represents that two or more industrial operations, which are preferably close to each other physically and work independently, form long-term partnerships and work in solidarity to increase resource efficiency, environmental performance and competitiveness. From this aspect, by-products or wastes generated by an enterprise can be used as raw material or resource for other enterprise, for example in organized industrial zones, industrial parks, etc. As a result, economic advantages can be provided besides prevention of industrial environmental problems. Companies and activities in which the indicated type of synergy relations presented constitute the industrial symbiosis network.

Industrial Symbiosis (IS) can provide an important enhancement at resource utilization efficiency and effectiveness of companies. In this context, "resource" term contains a broad meaning and represents all of raw material, energy carriers, water, production substructure, carriage, logistic substructure, human resources and waste management and disposal substructure components. More effective and efficient utilization of these resources will ensure minimization of environmental damage and economical acquisitions which will enhance competitive capacity.

More specifically benefits of IS are given below:

- Enhancing raw material quality and minimize costs
- Energy costs minimization
- Waste processing and disposal costs minimization

- Development of new products
- Transportation and logistics costs minimization
- To achieve a richer idea and human resource pool
- To produce less waste
- To ease compliance with environmental law and regulations

In Turkey, the industrial symbiosis (IS) approach was realized within the scope of the project "Industrial Symbiosis Project in Iskenderun Bay – Implementation Phase" between January 2011 and February 2014. The project was carried out by Technology Development Foundation of Turkey (TTGV) with the consultancy of Middle East Technical University (Turkey) and International Synergies Limited Company (United Kingdom). The general objective of the project was to introduce of IS into the area of Iskenderun Bay (Adana, Mersin, Iskenderun and Osmaniye), as a mechanism to increase the collaboration and solidarity between companies for the purpose of achieving both environmental and economic improvement in the region, as well as creating a background for a national IS program.

Specific objectives of the project are listed below:

- To establish a technical and administrative infrastructure for realizing IS applications
- Development of IS opportunities and pilot applications in Iskenderun Bay
- Creation of a database and communication network in Iskenderun Bay for IS applications
- Dissemination of IS applications and strengthening the communications among stakeholders
- Preparation of a National IS Programme implementation model and plan

2. Methodology

The project is expected to create and involve processes and outcomes which provide sufficient data and justification for interest both at governmental and private sector levels, as a motivation to initiate a Government-supported IS Programme at national level.

Within the framework of the project core activities were implemented under the framework of below mentioned axes;

- Preparatory and background studies
- IS network and database
- Communications and dissemination
- IS opportunities and pilot applications
- Regional sustainability and national policies

Table 1 summarized the activities conducted within the scope of these axes.

Table 1 Summary of activities conducted within the framework of project

Axes	Activities
Preparatory and background studies	• Regional and sectoral analyses • Literature review and compilation of case studies • Training of project team • Establishment of advisory committee
IS network and database	• Establishment of a pilot scale network consisting of private sector, public institutions, universities, experts, umbrella organizations, etc. • Two-component IS Database (pilot scale) which are still being improved.
Communications and dissemination	• Project launch event • Site visits and discussions with local stakeholders • Introductory meetings in the region • Advisory committee meetings • Continuously updated project web-site • Close communication with media

	• Becoming a founding member of the European Industrial Symbiosis Association (EUR-ISA)
IS opportunities and pilot applications	• Synergy workshops for the identification of IS opportunities • R&D Brokerage Event for the identification of IS opportunities • Selection of IS opportunities that will be worked in detail • Feasibility studies for the selected IS opportunities
Regional sustainability and national policies	• Workshop for Regional Development Agencies • Integration of industrial symbiosis concept to 2014-2023 period regional plans • Discussion with related governmental institutions

The identification of symbiotic relations (IS opportunities), implementation of feasibility studies and realization of pilot applications are the backbone of the project. For this purpose a regional network of companies was established as a result of company visits and interactive workshops, in which potential synergies (symbiosis options) were developed. A systematic procedure (See Figure 1) was followed in order to carry out feasibility studies and facilitate full-scale application of selected IS opportunities. So, 10 IS opportunities were selected and studied in detail. As a result of the above mentioned procedure, IS opportunities that were studied in detail were determined as below;

- Production of bio-remediation product from cotton seed waste
- Production of animal feed from orange juice wastes
- Utilization of arc furnace slag in road construction
- Biogas production from agricultural and animal wastes generated in çukurova region
- Recovery of lead from waste accumulators
- Electricity production from waste oils
- Recovery of end of life tires and producing granules for road construction
- Utilization of different types of wastes as a fuel in lime production
- Utilization of soda process waste as a minor additive in cement manufacturing
- Production of fertilizer from induction and arc furnace slag

The major purpose of the feasibility studies was to determine environmental/economic benefits of possible full-scale applications. As a result of these studies below listed phases were achieved in all of these applications:

- 4 IS opportunities were decided to be realized by the companies. So, construction/implementation activities are continuing for these applications.
- 2 IS opportunities were realized in pilot scale and proven highly efficient/economic. Companies are working towards building partnerships for forthcoming full-scale implementations and relevant investments.
- 1 IS opportunity was realized in pilot-scale. Companies are implementing more detailed economic feasibility studies and searching for the most feasible technological solutions.
- Feasibility studies were carried out for 3 IS opportunities. More detailed studies, market analyses need to be carried out and/or legislative procedures need to be satisfied in order to make these opportunities possess commercial/environmental value.

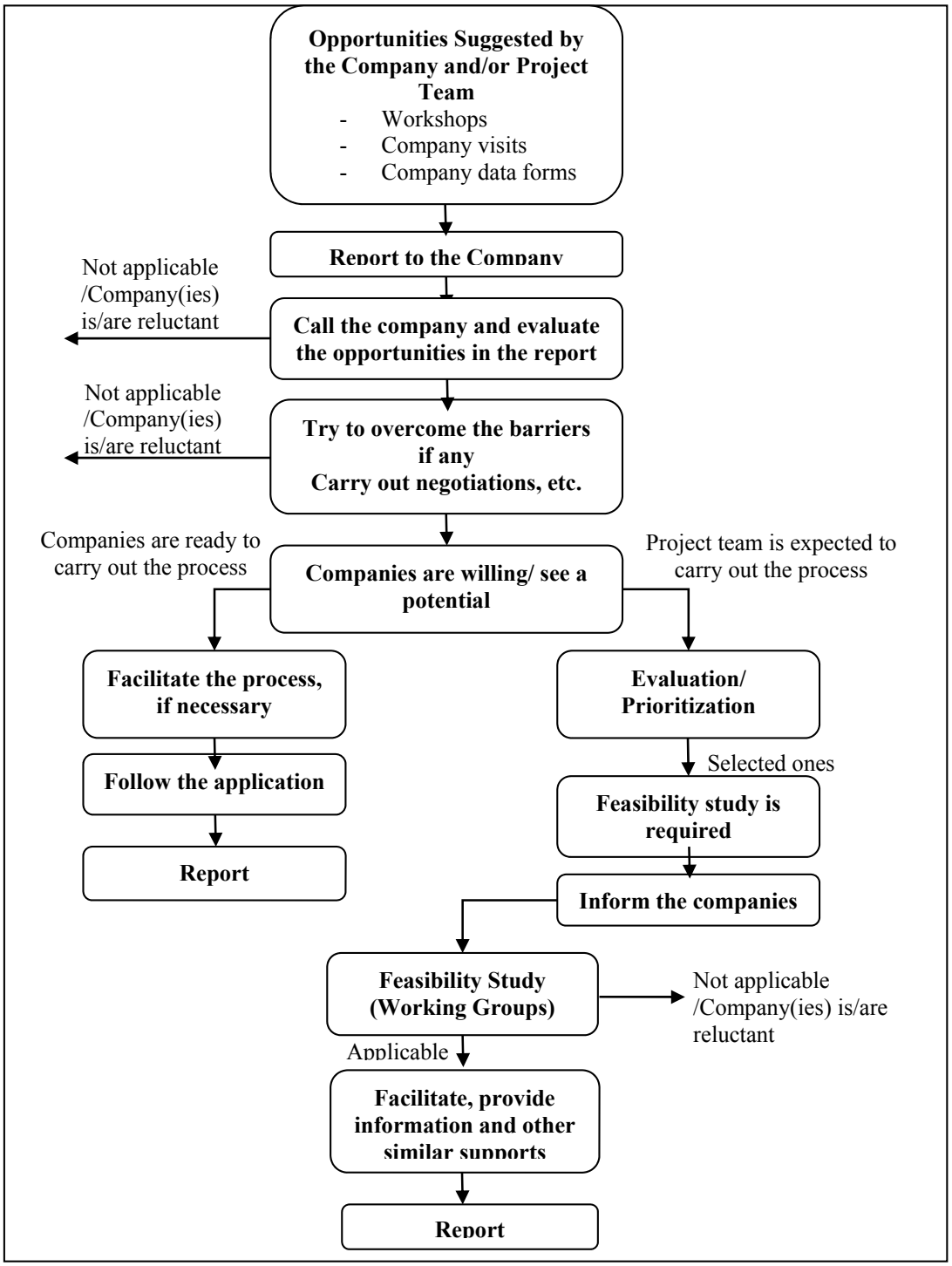

Figure 1 The general synergy management approach of the project

3. Results and Discussions

An "Industrial Symbiosis Implementation Network" was established in Iskenderun Bay by integrating 10 IS opportunities. Analyses indicated that full-scale implementations of 10 identified IS opportunities would enable various environmental and economic benefits. In this section detailed information about the selected IS application and expected gains incurred will be summarized.

3.1 Production of Bio-remediation Product from Cotton Seed Waste

Utilization of bio-product produced from cottonseed waste (lint: generated in the cottonseed production process) for the remediation of soils polluted by petroleum is the content of this opportunity. For the evaluation of bioremediation and adsorption potential of produced product on-site tests and laboratory analyses were conducted. According to results of these analyses, product's performance is found to be successful in terms of bioremediation. Furthermore, it was revealed that product has a good adsorption capacity and can prevent petroleum to leach groundwater. Studies for the commercialization of the product are the next step for the bio-product producer company. Potential gains for this implementation are given in Table 2.

Table 2 Potential gains for production of bio-remediation product from cotton seed waste opportunity

Type of Gain	Amount
Landfill diversion (ton/y)	1,000
Water conservation (m^3/y)	6,500
Labour force saving (man.day/y)	180
New employment (person)	3
New product type	1
Participated corporations (unit)	7

3.2 Production of Animal Feed From Orange Juice Wastes

Usage orange juice waste originated from juice Producer Company in animal feed production by a lime producer was also one of the selected pilot applications. Waste heat of the lime producer is used for drying of the orange juice waste. For the evaluation of this opportunity preliminary analysis, laboratory analysis and pilot production were conducted. Results of these analyses show that the product has high-energy content; therefore, commercialization potential of the product is also high. Furthermore, the pilot production trials revealed that the product quality is comparable to commercial animal feeds in market. Studies for the commercialization of the product are the next step for realization of this opportunity. Potential gains for this implementation are given in Table 3.

Table 3 Potential gains for production of animal feed from orange juice wastes opportunity

Type of Gain	Amount
Landfill Diversion (ton/y)	12,000
Energy Conservation (kwh/y)	954,292
CO_2 Emission minimization (tCO_2/y)	3,490
New product type	1
Participated corporations (unit)	4

3.3 Utilization of Arc Furnace Slag in Road Construction

Usage of arc furnace slag of an iron and steel company in for road construction is the content of this opportunity. For the evaluation of this opportunity, preliminary and laboratory analysis were conducted. Obtained results showed that arc furnace slag is suitable to use for various types of materials(sub-base material, granule base

material, plant mix base material etc.) in road construction. Potential gains for this implementation are given in Table 4.

Table 4 Potential gains for utilization of arc furnace slag in road construction opportunity

Type of Gain	Amount
Landfill Diversion (ton/y)	250,000
Natural Resource Substitution (ton/y)	262,700
Area Saving (m^2)	45,000
Energy Conservation (kwh/y)	145,601
Labour force saving (man.day/y)	3,285
New product type	2
Participated corporations (unit)	4

3.4 Biogas Production from Agricultural and Animal Wastes Generated in Çukurova Region

Corn wastes, cattle and poultry manures originated from different companies were investigated to be used in biogas and fertilizer production. For this purpose characterization, analysis of wastes, biochemical methane potential (BMP) tests and technology analysis for the plant were conducted. Different combinations of wastes (with different amounts) were analysed in terms of their BMP values. Results of these analyses revealed the most suitable waste combinations for biogas production. Contact with possible investors for the construction and management of a biogas plant in the region is in progress. Potential gains for this implementation are given in Table 5.

Table 5 Potential gains for biogas production from agricultural and animal wastes opportunity

Type of Gain	Amount
Landfill Diversion (ton/y)	41,000
Natural Resource Substitution (ton/y)	753
Energy Production (kwh/y)	8,760,000
CO_2 Emission minimization (tCO_2/y)	8,308
New product type	2
New employment (person)	3
Participated corporations (unit)	4

3.5 Recovery of Lead from Waste Accumulators
3.6 Electricity Production from Waste Oils
3.7 Recovery of End of Life Tires and Producing Granules For Road Construction

An integrated waste recovery facility was started to be implemented in the Adana region. Waste accumulators will be collected and recycled by waste recycling facility to recover lead and plastics. Construction of the facility is currently in progress. Potential gains for this implementation are given in Table 6.

Table 6 Potential gains for the integrated waste recovery facility

Type of Gain	Amount
Landfill Diversion (ton/y)	21,000
Natural Resource Substitution (ton/y)	12,800
Energy Production (kwh/y)	9,184,000

New product type	4
New employment (person)	5
Participated corporations (unit)	4

Same facility will also produce electricity from waste oil collected from various producers. Construction of the facility is currently in progress. Potential gains for this implementation are given in Table 6.

Waste recycling facility will also produce plastic granules from end-of-life tires received from the national authority responsible for the collection of waste tires (LASDER). Granules will be used for different purposes including road construction projects. s. Potential gains for this implementation are given in Table 6.

3.8 Utilization of Different Types of Wastes as A Fuel in Lime Production

A lime producer will utilize various wastes from different sectors to generate heat to be used in lime kilns instead of petroleum coke. Limekiln construction is currently completed and the facility will be activated Potential gains for this implementation are given in Table 7.

Table 7 Potential gains utilization for using different types of wastes as a fuel in lime production

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Type of Gain	Amount
Landfill Diversion (ton/y)	2.250
Energy Conservation (kwh/y)	14.569.552
CO_2 Emission minimization (tCO_2/y)	24.432
Participated corporations (unit)	7

3.9 Utilization of Soda Process Waste as a Minor Additive in Cement Manufacturing

Soda process waste of is planned to be used in cement production instead of clinker in cement factory. For the evaluation of this opportunity preliminary analysis, pilot production, laboratory analysis, research on available drying technologies were conducted. According to results of pilot production, usage of soda process waste as %5 minor additive instead of clinker has no negative impacts on product quality and operation conditions. Regarding the drying of waste communications are in progress; some further details are being studied on technical issues.

3.10 Production of Fertilizer from Induction and Arc Furnace Slag

Induction and arc furnace slag from iron and steel companies are planned to be used in fertilizer production. For this purpose waste characterization analysis, soil characterization analysis, pilot fertilizer production and pilot trials to evaluate fertilizer's performance were conducted. Performance evaluation is still in progress.

4. Conclusions

Currently two of the IS opportunities among the 10 identified ones are still in R&D and feasibility phase. Remaining 8 IS opportunities were proved to be suitable for implementation and they were started to be realized. Total possible gains by the realization of these 8 IS opportunities are listed in Table 8.

Table 8 Expected results from IS applications

Environment - Efficiency	**Value**
Landfill diversion (tons/year)	327,250
Water saving (m^3/year)	6,500
Natural resource substituted (tons/year)	276,250
Workforce saving (man-day/ year)	3,500

Energy produced/saved (kWh/year)	33,580,000
CO_2 reduction (tons/year)	36,700
Land recovery (m^2)	45,000
Social - Cooperation	
New employment (person)	21
Number of new initiatives	6
Number of organizations participated	27
Number of universities contributed	5
Economic - Competition	
Types of new products	10
Amount of new products (tons/year)	283,000
Investment costs ($)	6.965.000
Annual net earnings ($)	6.370.500
Pay-back period (years)	1.1

IS implementation network in İskenderun Bay and the related waste exchanges are shown in Figure 2

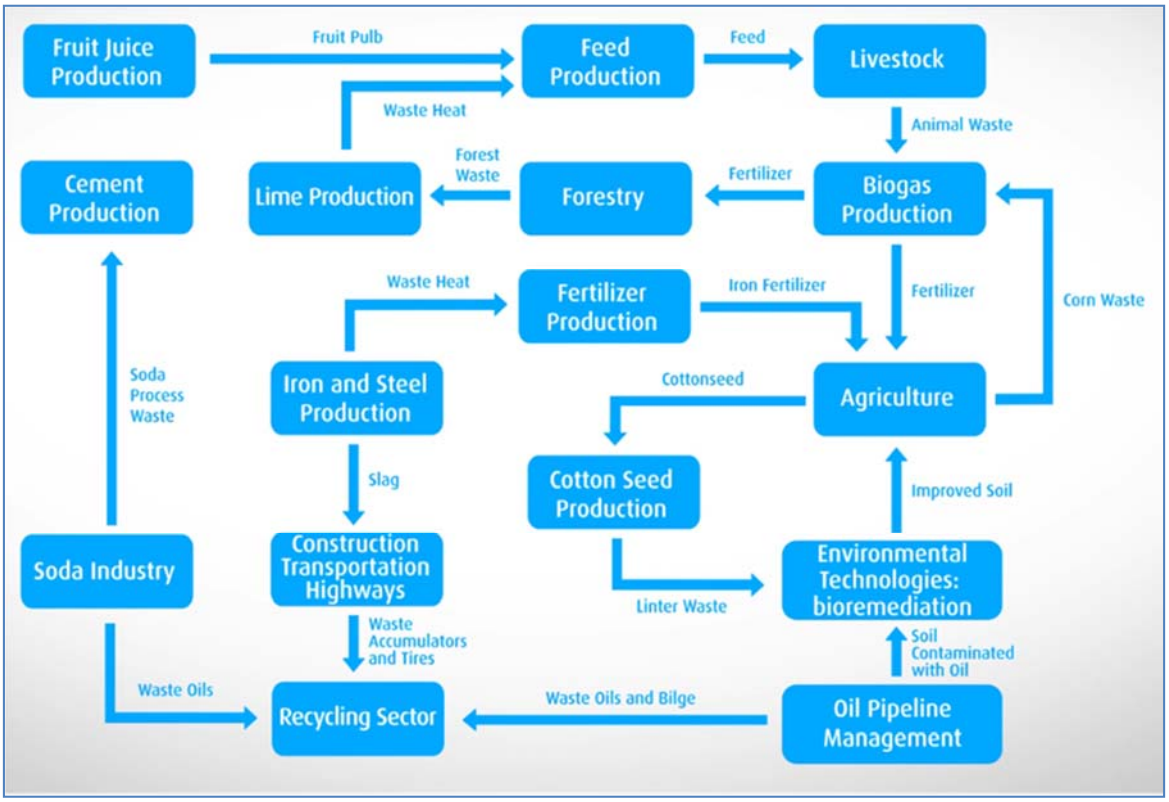

Figure 2 Industrial symbiosis implementation network in Iskenderun Bay

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