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Industrial symbiosis for a sustainable city: technical, economical and organizational issues

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Abstract

In this paper, we propose the adoption of industrial symbiosis approach within cities as a tool to improve their environmental sustainability. In particular, organic waste can be used to produce electric energy required by cities. In this way, a resource closed loop is generated, able to reduce the amount of waste disposed of in landfill and the energy purchased from outside the city. We develop a conceptual model that identifies symbiotic flows and processes that generate and receive them. We model these processes using the input-output approach. An efficiency measure of the symbiotic approach within urban areas has been proposed. Finally, we employ three case examples in order to show how the model works. As a result, we provide some useful managerial suggestions for policy makers about the implementation of industrial symbiosis within cities.

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Keywords: City sustainability; Industrial Symbiosis; Input-Output Approach

1. Introduction

Whereas in 1900 only 10% of the global population were urban dwellers, that percentage now exceeds 50% and will rise even more, accounting for two-third of the world population by 2050 [1]. Individual cities are growing to

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unprecedented sizes, both in developed and in developing countries. These rapid changes are generating negative impacts on city sustainability, in particular from environmental point of view. In fact, cities actually consume a large amount of materials and energy, and produce a high quantity of waste [2,3]. However, the polluting role of cities is further critical if we consider the expected future trends. Recent estimations preview that cities will use 80% of global energy by 2040 [4] and will double waste production by 2025 [5].

Actually, a huge amount of the electric energy (about 60% of total generation) is produced exploiting fossil fuels [6]. Hence, the electricity consumption is one of the main reasons of greenhouse gas (GHG) emissions [7], which are widely recognized as the principal responsible of climate change [8].

The use of landfills to dispose urban waste is largely adopted both in low-income and in high-income countries, like United States and many European countries [5,9,10]. Even the two most populated countries in the world, China and India, make extensive use of landfills, where over the 80% of their municipal solid waste (MSW) is disposed [11,12]. Landfills are responsible for methane gas emissions, leachate production, chemical and microbiological contaminants in air, water, and soil [13].

Global efforts are in force to solve both energy and waste problems. About energy problem, the main actions have been oriented to efficiency improvements in energy production and replacement of fossil fuels by various sources of renewable energy [14]. To address waste problem, technologies, operations, and business models oriented to waste reduce, reuse, and recycle have been developed [15].

In this paper, we propose the adoption of industrial symbiosis (IS) as a tool that cities may use to reduce energy and waste problems, then improving their sustainability. Accordingly, in the next section we present the IS approach. In section 3, we present our conceptual model that describes symbiotic flows and processes that generate and receive them. In section 4, we develop a measure to analyze the efficiency of IS in solving energy and waste problems. Finally, three case examples are provided to simulate how the model works.

2. Industrial Symbiosis

«Industrial Symbiosis is a subfield of industrial ecology that engages separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy and services» [16]. In particular, waste resulting from a generic production process can be used as primary inputs (materials or energy) for other production processes.

The IS approach allows to achieve environmental, economic, and social advantages [17]. The environmental benefit is a result of the potential reduction of wastes, emissions, primary inputs and energy [16]. The economic convenience comes from the savings due to minor costs for waste disposal and for primary inputs purchase [18]. Finally, the IS approach may foster new firms and new jobs [17].

The usefulness of IS approach has been also recognised by European Commission, which has explicitly recommended IS approach to boost resource use and production efficiency. Specifically, the Roadmap to a Resource Efficient Europe [19] sustains that the IS approach could reduce the amount of material directly used in the EU economy and increase firms competitiveness, saving 1.4 billion of euros per year and generating 1.6 billion of euros in sales.

Applications of IS are available in both developing and developed countries, confirming the effectiveness of IS in pursuing eco-sustainable development. The eco-industrial park in Kalundborg, Denmark, represents the most famous example of IS in the world with a complex network of symbiotic exchanges among firms. The main environmental benefits consist in 50.000 tons of fossil fuels saved per year, in 200.000 tons per year of waste not disposed of in the landfill, and in 150.000 tons per year of avoided GHG emissions [20].

Although the IS approach is typical of industrial contexts, some studies have investigated its extension to urban areas, in order to exploit MSW produced as primary inputs for industrial operations [21].

We propose the IS approach within cities to mitigate both waste-to-landfill and high electricity problems exploiting MSW to produce electric energy required by city. This approach allows to guarantee a resource closed loop where wastes generated by city are transformed in products consumed by the same city, consistent with the idea of circular economy [22]. Three main environmental benefits can be obtained: i) less amount of waste disposed of in landfill; ii) less amount of energy produced using traditional processes, and iii) less GHG emissions in atmosphere, due to lower energy production using conventional processes. In addition, economic advantages are produced in terms of cost reduction about waste disposal and energy procurement from outside the city.

In the next section, the model of IS within a city is presented in detail.

3. An urban model of industrial symbiosis

In this section we define our model of IS by identifying symbiotic flows within cities, in terms of waste and energy, and processes involved in their generation and use.

At first, we identify the kinds of waste could be exploited in the energy production. The World Bank [5] indicates the average composition of MSW: 46% by organic waste, 17% by paper, 10% by plastic, 9% by glass, 4% by metal, 18% by others. Despite of the capacity of all these wastes to produce electric energy, we limit the analysis to organic waste for two main reasons. The first is that organic waste is the principal component of MSW, accounting for almost the 50% of all MSW produced. The second reason is that all MSW except organic waste can be managed in a more sustainable way than energy recovery, according with European Waste Framework Directive (2008/98/EC). In fact, the Directive recommends waste prevention as the most sustainable approach, followed by reusing, recycling, energy recovery, and disposal, ordered by decreasing sustainability degree.

Following the IS approach, organic waste is collected and addressed to waste-to-energy facilities. Thereby, the IS chain involves three phases: waste production, waste collection, and waste-to-energy production.

We model all these phases by adopting the input-output approach, through which each process is conceptualized as a "black box" that produces outputs absorbing primary inputs and generating waste. A linear relationship is assumed to exist among outputs, inputs, and waste.

Waste production is due to four urban processes, i.e. household consumption, food retail, food service (restaurants and canteens as sub-processes), and green areas maintenance (grass and shrubs as sub-processes) [23,24]. The first three processes produce food waste whereas the last generates yard waste. Each process only has one output: people served (household consumption and food retail), number of meals served (food service), and square meters of green area (green areas maintenance). A technical production coefficient points out how many units of waste are generated by one unit of process output during a certain period of time. Hence, greater the dimension of urban processes (i.e. the amount of process output) and greater the amount of waste produced, *ceteris paribus*.

Collection phase is modelled as one process that picks up waste within urban area (input) and makes them available (output) to waste-to-energy facilities. Because collection activities may be operated by road vehicles, this phase generates environmental impact due to fuel consumption and GHG emissions. The environmental impact is assumed proportional to the amount of waste collected.

Waste-to-energy production phase may be generically composed by *n* processes, each of them stands for a different facility to energy production from waste. We consider three main technological solutions: anaerobic digestion, pyrolysis, and gasification [25,26]. The generic waste-to-energy plant absorbs waste and produces electric energy as output. We assume the amount of energy produced is proportional to the amount of waste absorbed. In particular, the anaerobic digestion plant also produces compost that can be destined to urban green areas maintenance. In this way, a further symbiotic flow is generated in addition to electric energy flow. Waste-to-energy processes take into account the environmental impact due to waste transportation from city to facilities. As for collection process, the amount of fuel required and GHG emitted in atmosphere is proportional to waste absorbed (input) by generic process. Figure 1 shows symbiotic flows and processes involved.

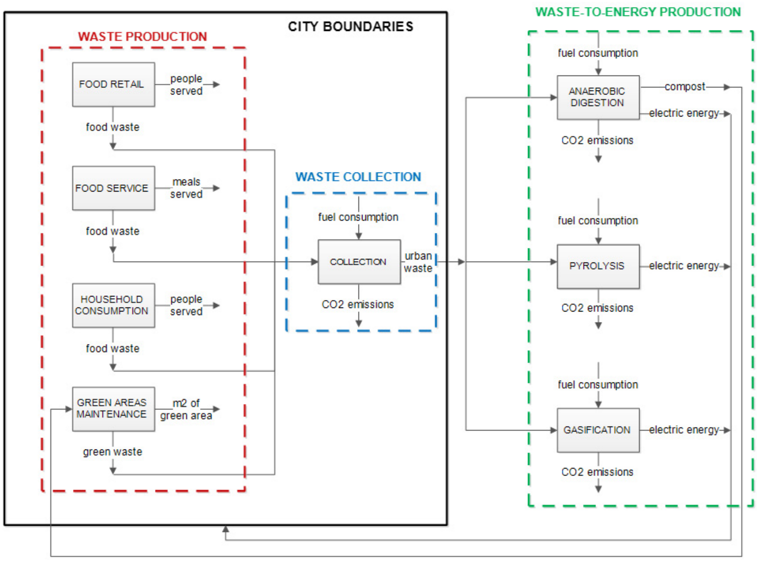

Fig. 1. Graphical representation of conceptual model proposed

Considering the model as a whole, the amount of electric energy that a city could produce from MSW depends on the amount of waste, which is affected by process outputs and technical waste production coefficients. However, some studies suggest that waste production rates may be affected by various urban features, like household dimension and composition, average age, frequency of food purchasing, average income, collection management offered by municipality, waste disposal costs, economic incentives to recycling, food prices [27,28,29,30]. Therefore, the efficiency of the application of IS approach may be different depending on specific city considered.

4. How efficient is industrial symbiosis within cities?

In this section we discuss about efficiency of IS approach within cities. In the best possible scenario about IS approach, no amount of organic waste is disposed of in landfill and at the same time the city is self-sufficient from electric energy point of view, i.e. all electric energy required is produced exploiting urban waste. This scenario is consistent with the "perfect symbiosis", defined by Albino et al. [31] as the condition where no wastes are disposed of and no primary inputs are purchased from outside the system considered. Hence, the achievement of the perfect symbiosis can be a complete solution for energy and waste problems of cities.

A symbiotic system is much more technically efficient the lower its distance from the perfect symbiosis [32]. This distance can be calculate on the Cartesian plane, where the x-axis denotes the percentage of organic waste exploited in the energy production on the total amount of organic waste produced, whereas the y-axis indicates the percentage of electric energy produced from waste on urban electric energy demand. Each axis range between zero (0%) and one (100%) (Figure 2).

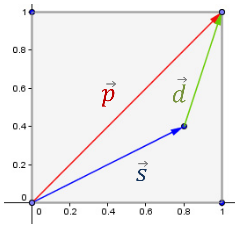

Fig. 2. Vectors in the Cartesian plane to calculate efficiency of IS approach

The vector $\vec{p}\,(1,1)$ denotes the perfect symbiosis condition (100% of organic waste produced is exploited by waste-to-energy process and 100% of urban electric energy demand satisfied by energy produced from waste), whereas the vector $\vec{s}(s_x, s_y)$ the actual scenario of city.

In particular, s_x is the ratio between the amount of organic waste exploited to produce energy and the amount of organic waste produced by urban processes. This ratio can be calculated using following equation:

$$s_x = \frac{\alpha^T(W' \cdot \beta)}{{w_U}^T \cdot x}$$

being W' the 4x3 matrix where the generic element W'_{ij} denotes how many units of waste produced by urban process *i* are sent to *j*-th waste-to-energy process, α is the 4x1 unitary vector, and β the 3x1 unitary vector. *x* is the 4x1 vector of urban process output and w_U the 4x1 vector of technical production coefficients where the element ${w_U}_i$ denotes how many units of urban waste are produced by one unit of *i*-th process output. If all organic wastes produced are exploited to produce energy, the following identity results:

$$\alpha^T(W' \cdot \beta) = {w_U}^T \cdot x$$

s_y is the ratio between the amount of electric energy produced exploiting organic waste and the urban demand of electric energy. It results:

$$s_y = \frac{\alpha^T \cdot (W' \cdot t)}{e}$$

being *t* the 3x1 vector where the generic element t_i denotes how many units of electric energy are produced by *i*-th waste-to-energy process exploiting one unit of waste and *e* denotes the urban energy demand, independent from waste production.

In the Cartesian plane, the vector $\vec{d} = \vec{p} - \vec{s}$ denotes how far the actual condition is from perfect symbiosis. The technical efficiency η can be calculated using the following equation:

$$\eta = 1 - \frac{|\vec{d}|}{|\vec{p}|}$$

Symbiotic efficiency ranges between zero and one. In particular, the system has efficiency equal to zero when no symbiosis occurs ($\vec{d} \equiv \vec{p}$) and efficiency equal to one in the case of perfect symbiosis ($\vec{d} \equiv \vec{0}$). For instance, considering a city that exploits 80% of organic waste to produce energy ($s_x = 0.80$) that satisfies 20% of urban electric energy demand ($s_y = 0.20$), its symbiotic efficiency is equal to

$$\eta = 1 - \frac{\sqrt{(1-0.80)^2 + (1-0.20)^2}}{\sqrt{1^2 + 1^2}} = 0.4169$$

The technical efficiency measure evaluates how IS approach is useful in mitigating waste and energy problems. In fact, the lower the organic waste disposed of in landfill and the higher the energy not purchased from outside the city, *ceteris paribus*, efficiency is much higher.

Accordingly with previous equations, the efficiency of IS approach depends on three factors: i) how much organic waste rather than the total amount produced are exploited to produce energy; ii) the amount of electric energy produced by urban waste; and iii) the amount of electric energy required by city.

5. Case examples

In this section, we provide three case examples in order to verify how the model works. Multiple-case offers more generalizable and robust evidence than single-case studies, allowing for further theory extension. Let us assume A, B, and C as three cities, different each other for numerical values of observed process output during one year (Table 1).

Table 1. Process output for three cities considered

		A	B	C
People served (households and food retail)		20.000	30.000	300.000
Number of meals served	Restaurants	100.000	4.000.000	3.000.000
	Canteens	800.000	1.200.000	21.500.000
Square meters of green areas maintained	Shrubs	400.000	300.000	1.200.000
	Grass	1.600.000	1.200.000	4.800.000

A is a small city characterized by large availability of green areas (100 m^2 per capita). B is a small town characterized by significant flow of tourists which results in a greater use of restaurants (greater number of meals served). Finally, C may be a town marked by a greater use of canteens and low availability of green areas per capita (20 m^2).

For the sake of simplicity, we consider the same waste production rates for all cities considered: therefore, $w_U(A) \equiv w_U(B) \equiv w_U(C)$. For calculations, we use numerical values shown in Table 2.

Table 2. Waste production technical coefficients

Urban process		w_{U_i}	**References**
Households consumption		46 Kg/(citizen*year)	[23]
Food retail		8 Kg/(citizen*year)	[23]
Food service	Restaurants	0,095 Kg/(meal*year)	[33,34]
	Canteens	0,12 Kg/(meal*year)	[33,34]
Green areas maintenance	Shrubs	6 Kg/(m^2*year)	[35]
	Grass	3 Kg/(m^2*year)	[35]

Let us assume that all cities produce energy using the same technology, for instance anaerobic digestion.

From data of Table 3, we observe that household consumption and green areas maintenance are the most important waste production processes for symbiotic flows generated and for electric energy that can be produced. Green area availability per capita discriminates which of the two processes is more important in terms of contribution to energy production. In fact, green area availability per capita makes green maintenance the most important process. In city A, the contribution of food service can be considered negligible in front of its low contribution in energy production.

shows the amount of waste produced by each urban process for each city ($w_{U_i} \cdot x_i$) and the amount of electric energy that can be produced from their exploitation ($W'_{ij} \cdot t_j$). All symbiotic flows refer to a period of one year.

We have assumed 0.4 Nm^3 and 0.1 Nm^3 of bio-methane produced per unit of food waste and yard waste, respectively, relying on technical data of existing plants, 8.500 Kcal/m^3 as heating value of bio methane, and 0.35 as efficiency of cogeneration plant, under the hypothesis to burn all methane produced.

Table 3. Waste generated and energy produced cities A, B, C

		A		B		C	
Urban processes		Waste produced [Kg]	Energy produced [% of total]	Waste produced [Kg]	Energy produced [% of total]	Waste produced [Kg]	Energy produced [% of total]
Households consumption		920.000	30,82	1.380.000	39,50	13.800.000	56,42
Food retail		160.000	5,36	240.000	6,86	2.400.000	9,81
Food service	Restaurants	9.500	3,53	380.000	15,00	285.000	11,71
	Canteens	96.000		144.000		2.580.000	
Green areas maintenance	Shrubs	2.400.000	60,29	1.800.000	38,64	7.200.000	22,07
	Grass	4.800.000		3.600.000		14.400.000	

From data of Table 3, we observe that household consumption and green areas maintenance are the most important waste production processes for symbiotic flows generated and for electric energy that can be produced. Green area availability per capita discriminates which of the two processes is more important in terms of contribution to energy production. In fact, green area availability per capita makes green maintenance the most important process. In city A, the contribution of food service can be considered negligible in front of its low contribution in energy production.

Table 4 shows the environmental benefits (in terms of s_x and s_y) and the symbiotic efficiency, under the hypotheses that all organic wastes generated are used for energy production. In the same table, we provided the economic benefits assuming the same unitary costs for all cities: 104 €/t of organic waste disposal of in landfill and 0.16 €/Kwh of energy purchase, based on actual data. In addition, we assume the electric energy demand equal to 2.200 Kwh per capita for all cities.

Table 4. Environmental and economic benefits from IS approach

	A	B	C
% of organic waste exploited	100	100	100
% of electric energy saved	12,52	9,77	6,84
Symbiotic efficiency	38,14	36,17	34,13
Avoided waste disposal cost [€]	872.092,00	784.576,00	4.229.160,00
Avoided energy purchase cost [€]	661.094,79	773.694,59	5.417.412,17

Because all cities exploit all organic waste generated to produce energy, the symbiotic efficiency depends on the amount of electric energy produced compared to urban demand. Although the absolute value of the benefits obtained, IS approach is more effective for the city A rather than other ones (0.3814 compared to 0.3617 and 0.3413) because it is able to replace a higher proportion of external demand for electricity (0.1252 compared to 0.0977 and 0.0684), *ceteris paribus*.

6. Conclusions

This paper proposes the application of industrial symbiosis to enhance environmental sustainability of cities. Some previous studies proposed this approach mainly regarding the use of municipal solid waste as primary inputs for recycling and remanufacturing operations. We only focus the exploitation of urban organic waste to produce electric energy required by a city. In this way, cities can reduce the amount of waste disposed of in landfill and decrease the amount of electric energy purchased from outside.

A conceptual model has been developed involving the following processes: waste production, waste collection, and waste-to-energy generation. In particular, organic waste production has been modelled as the contribution of four urban processes: household consumption, food retail, food service, and green areas maintenance. In addition, a measure to evaluate the technical efficiency of IS approach within cities has been developed. Finally, we have discussed three case examples with the aim to simulate how the model works.

From these cases, important managerial implications arise. Based on their contribution to electric energy production, the most important urban processes producing waste appear to be household consumption and green areas maintenance. Therefore, in implementing IS approach, we need to mainly consider these two processes.

We also note that symbiotic efficiency keeps quite low values. This means that applying IS approach, cities are still far from perfect symbiosis, the condition that allows to fully deal with waste and energy problems. This occurs because IS approach reveals to be effectiveness in mitigating waste disposal problem whereas it ensures poor performance in solving electric energy problem. Therefore, in order to further enhance environmental sustainability of cities the IS approach should be integrated with other tools, for instance allowing to increase energy savings.

In this paper, the conceptual model has been applied to case examples. A next step could regard its application to some real cities in order to build and analyze real case studies. Finally, the model could be extended to involve other possible symbiotic flows, for instance water or thermal energy flows.

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References

[1] United Nations, World Population Prospects: The 2012 Revision, New York: United Nations, 2013

[2] D. Satterthwaite, Cities’ contribution to global warming: notes on the allocation of greenhouse gas emissions, Environment & Urbanization 20 (2008) 539-459

[3] N.B. Grimm, S.H. Faeth, N.E. Golubiewski, C.L. Redman, J. Wu, X. Bai, J.M. Briggs, Global change and the ecology of cities, Science 319 (2008) 756-760

[4] Shell International BV, New Lenses on Future Cities, [online] 2014, available from: http://s05.static-shell.com/content/dam/shell-

new/local/country/sgp/downloads/pdf/new-lenses-on-future-cities.pdf
[5] The World Bank, What a waste? A Global Review of Solid Waste Management, Washington: The World Bank, 2012
[6] International Energy Agency, Key World Energy Statistics 2014, Paris: International Energy Agency, 2014
[7] U. Soytas, R. Sari, B.T. Ewing, Energy consumption, income, and carbon emissions in the United States, Ecological Economics 62 (2007) 482-489
[8] IPCC, Summary for policymakers, in: Climate Change 2014: Impacts,Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, 2014, pp. 1-32.
[9] U.S. Environmental Protection Agency, Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2011, [online] 2014, available from: http://www.epa.gov/osw/nonhaz/municipal/pubs/msw2009-fs.pdf
[10] EUROSTAT, Municipal waste statistics, [online] 2014, available from: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Municipal_waste_statistics
[11] M. Sharholy, K. Ahmad, G. Mahmood, R.C. Trivedi, Municipal solid waste management in Indian cities – A review, Waste Management 28 (2008) 459-467
[12] X. Chen, Y. Geng, T. Fujita, An overview of municipal solid waste management in China, Waste management 30 (2010) 716-724
[13] P. Kjeldsen, M.A. Barlaz, A.P. Rooker, A. Baun, A. Ledin, T.H. Christensen, Present and long-term composition of MSW landfill leachate: a review, Critical reviews in environmental science and technology 32 (2002) 297-336
[14] H. Lund, Renewable energy strategies for sustainable development, Energy 32 (2007) 312-919
[15] A.V. Shekdar, Sustainable solid waste management: an integrated approach for Asian countries, Waste Management 29 (2009) 1438-1448
[16] M.R. Chertow, Industrial symbiosis: literature and taxonomy, Annual review of energy and the environment 25 (2000) 313-337
[17] M. Mirata, Experiences from early stages of a national industrial symbiosis programme in the UK: determinants and coordination challenges, J. Cleaner Production 12 (2004) 967-983
[18] Z. Yuan, L. Shi, Improving enterprise competitive advantage with industrial symbiosis: case study of a smeltery in China, J. Cleaner Production 17 (2009) 1295-1302
[19] European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the regions. Roadmap to a Resource Efficiency Europe, Bruxelles: European Commission, 2011
[20] N.B. Jacobsen, Industrial symbiosis in Kalundborg, Denmark: a quantitative assessment of economic and environmental aspects, J. Industrial Ecology 10 (2006) 239-255
[21] R. Van Berkel, T. Fujita, S. Hashimoto, Y. Geng, Industrial and urban symbiosis in Japan: Analysis of the Eco-Town program 1997–2006. J. Environmental Management 90 (2009) 1544-1556
[22] World Economic Forum, Toward the Circular Economy: Accelerating the scale-up across global supply chains, Geneva: World Economic Forum
[23] BIO Intelligence Service, Preparatory study on food waste across EU 27, Paris: Bio Intelligence Service, 2011
[24] J. Parfitt, M. Barthel, S. Macnaughton, Food waste within food supply chains: quantification and potential for change to 2050, Philosophical Transactions of the Royal Society B: Biological Sciences 365 (2010) 3065-3081
[25] I.I. Ahmed, A.K. Gupta, Pyrolysis and gasification of food waste: syngas characteristics and char gasification kinetics, Applied Energy 87 (2010) 101-108
[26] J. Mata-Alvarez, S. Mace, P. Llabres, Anaerobic digestion of organic solid wastes. An overview of research achievements and perspectives, Bioresource technology 75 (2000) 3-16
[27] M. Canali, K. Östergren, P. Amani, L. Aramyan, S. Sijtsema, O. Korhonen, K. Silvennoinen, G. Moates, K. Waldron, C. O'Connor, Drivers of current food waste generation, threats of future increase and opportunities for reduction, Bologna: European Commission, 2014
[28] WRAP, The food we waste, Banbury: WRAP, 2008
[29] H.C. Noehammer, P.H. Byer, Effect of design variables on participation in residential curbside recycling programs, Waste Management and Research 15 (1998) 407-427
[30] Barilla Centre for Food and Nutrition, Food waste: causes, impacts and proposals, [online] 2012, available from: http://www.barillacfn.com/wp-content/uploads/2012/11/WEB_ENG.pdf
[31] V. Albino, V.A. Romano, D.M. Yazan, How Far is an Input-Output Production System from Perfect Industrial Symbiosis? 20th International Input-Output Conference, Bratislava, 25th-29th June 2012
[32] V. Albino, L. Fraccascia, A.C. Garavelli, Technical Efficiency Measure of Industrial Symbiosis Networks using Enterprise Input-Output Approach, 22nd International Input-Output Conference, Lisbon, 15th-18th July 2014
[33] J. Marthinsen, P. Sundt, O. Kaysen, K. Kirkevaag, Prevention of food waste in restaurants, hotels, canteens and catering. Copenhagen, Nordic Council of Ministers, 2012
[34] K. Silvennoinen, J.M. Katajajuuri, H. Hartikainen, L. Jalkanen, H.K Koivupuro, A. Reinikainen, Food waste volume and composition in the Finnish supply chain: Special focus on food service sector, Fourth international symposium on energy from biomass and waste, Venice November 2012
[35] W. Giacetti, R. Venturi, P. Lepore, Le raccolte differenziate dei rifiuti organici: sistemi di raccolta della frazione umida a confronto, *ETRA Spa* (2008)