A web-GIS tool for industrial symbiosis – Preliminary results and perspectives

Guillaume Massard, Suren Erkman
Université de Lausanne, Faculty of Geosciences and Environment, Industrial Ecology Group, IPTEH
Bâtiment Amphipôle, CH-1015 Lausanne, Switzerland
guillaume.massard@unil.ch
suren.erkman@unil.ch

Abstract
Cycling the use of material in product manufacturing is the conceptual framework of industrial ecology. Within this context, industrial symbiosis creates physical exchanges of materials, energy, water, and/or by-products among economic activities that are collocated or spread through a state or region. Detecting and assessing potential industrial symbiosis and promoting eco-industrial development on a multifunctional territory call for decision support methodologies and tools. Information on material flows needs to be stored in a way that allows data treatment to detect potential exchanges of residues and service mutualization and to assess their feasibility. A database was created to store data on economic activities, manufacturing processes and related material and energy flows. A clearly defined terminology allows application of algorithms for treatment and retrieval of information. In addition, a geographic information system interface (web-GIS) was developed as technical and decision support tool for engineers and territorial planners. It allows, among other things, the detection and the visualization of potential exchanges, the assessment of technical and geographical feasibility, the detection of new potential partners within the manufacturing activities and the identification of optimal location for new facilities based on material flows consideration. Interactions with other spatial layers extend the detection to other economic activities such as agriculture, housing or services. The methodology and the tool developed aim at providing useful information for a more efficient and local use of resources. They may be a valuable instrument in the hands of public and private institutions seeking information on manufactures and their organization. This paper aims at establishing how a web-GIS tool for industrial symbiosis may support decision making in industrial and territorial planning. This paper focuses on the experience initiated by the state and republic of Geneva (Switzerland). Since 2004, the state’s Agenda 21 supports a project aiming at detecting and implementing industrial symbiosis on its territory.

1. Introduction: Industrial Ecology, industrial symbiosis and GIS

1.1 Industrial symbiosis and territorial planning

Industrial ecology explores the idea that the industrial system can be seen as a certain kind of ecosystem. As natural ecosystems, the industrial system can be described as a particular distribution of materials, energy and information flows (Erkman, 1997). The analogy with the concept of food chains in natural ecosystems is clear, leading to the idea of closing the loops within the traditionally linear industrial system and to divert products and materials that would otherwise be designated for landfill. The reuse or sharing of by-products, energy and water resources among firms in a defined area is known as industrial symbiosis in the industrial ecology literature. Industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchanges of materials, energy, water and/or by-products (Chertow, 2000). Industrial symbiosis and its numerous synonyms are currently broadly recognized to include the reuse of previously disposed by-products from one facility by another, as well as supply, utility and even facility sharing among collocated firms (Cohen-Rosenthal, 2003; Lowe, 2001; van Beers et al., 2007; van Berkel et al., 2005). Many regions in the world are currently developing industrial symbiosis as it is recognized as a strategy towards developing more sustainable industrial estates and regions (Jacobsen, 2006; Mirata and Emtairah, 2005).
The multifunctional use of land in urban areas implies a wide range of planning rules, property issues, land prices, and physical obstacles (utility networks and infrastructures, buildings, etc.). The proximity of housing, industrial and agricultural activities in densely populated areas like Switzerland requires stricter constraints on resources availability, health and environmental risk management. Industrial symbiosis implementation deals with physical, geographic, and planning constraints that reflect the territory’s stage of development.

At present, there is a need for methodologies and tools that will facilitate the creation of links between relevant economic agents to promote a more efficient use of resources at the urban and state levels. Currently, very little is done to optimize the material flows within urban and peri-urban areas in industrialized countries like Switzerland. Industrial ecology may provide methodologies able to fulfill this gap. Industrial symbiosis and its related knowledge on material and energy flows may contribute to better understand and plan economic and industrial activities.

1.2 Industrial symbiosis and geographical information systems

Geographical information systems (GIS) appear as an essential support to territorial planning in urban areas. In the last decades, GIS has become necessary to understand the complexity of land use and economic activities by providing an alternative key to data, a method of access based on geographical location. Key issues are data capture, collection and measurement, creation of algorithms, processes and analytical tools, spatial statistics and display. In other terms, GIS allow through the combination of computer-based database management system with visualization and geographic analysis, the collection, storage and analysis (through computation of constraints) of spatial data (Goodchild, 1992; Huxhold, 1991). In relation with urban and territorial planning, GIS increase territorial understanding at different scales by overlapping spatial layers and data. In particular, GIS allow spatial problem solving such as: calculation of Euclidean distance between objects, definition of preferential path and spatial buffer and choosing a location that meet some requirements (Burrough and McDonnell, 1998; Özyurt and Realf, 2002).

However, a weakness of GIS systems is that they are expensive and often only designed for one single user or a small group of user. Another problem comes from the compatibility with other software packages. As an answer, GIS have recently become integrated in numerous internet-applications. Web-based GIS benefit from modest development cost as well as distributed access and centralized control for updates. In other terms, the users can get spatial information of all kinds and interact with these systems from all over the world (Dragicevic, 2004; Ingensand et al., 2008). In addition, database development and management is rather inconvenient when achieved directly within the most widely used GIS programs. Web-GIS technology appears therefore as an innovative solution to easily manage and share information.

Combining GIS with a material and energy flow management database may help to geographically anchor networks and processes. Early research program approached industrial symbiosis at different spatial scales using database management tools and sometimes GIS (Brown et al., 1997; Chertow, 2000; IE, 1998). More recently several industrial symbiosis projects around the world claims to use material and energy flow database as decision support (Mirata, 2004; van Beers et al., 2005). However, few projects use GIS to add value to material and energy flow data and to support decision in territorial planning. Linking the knowledge on material and energy flows offered by industrial ecology and industrial symbiosis methodologies with GIS may provide a new vision of territorial organization. Based on the experience of the state of Geneva in Switzerland, this paper aims at providing arguments and ideas to fulfill this gap.

The purpose of this research is to develop an interactive spatial information-system (web-GIS) in order to make the information editable and analyzable by experts and stakeholders involved in territorial and industrial planning.
2. Case study: The Geneva Industrial Symbiosis Project, Switzerland

2.1 Industrial ecology in Geneva

The Republic and Canton of Geneva (hereafter the «state of Geneva») is one of Switzerland’s 26 cantons. Its surface area is 278.5 square kilometres, including the lake and rivers, and its population is 447,000 as of 2007. It is considered a city-state, where economic activities, housing, and agriculture are in close proximity and interconnected. The state can be considered as a moderately industrialized area as the manufacturing activities means only 15% of global resources consumption compared to 35% for the service sector and 45% for households (Erkman, 2004). Geneva does not host any heavy industries but high added value manufacturing activities like watch, chemical and pharmaceutical industries. Activities like machines and equipment manufacturing, building materials and equipments, wood manufacturing, printing and agro-food industry depict the common industrial areas (figure 1).

The state Agenda 21 is the result of a broad consultation process, including all local actors. Due to local awareness, the notion of industrial ecology was introduced in the law establishing the Agenda 21. Its article 12 stipulates that “the State facilitates possible synergies between economic activities in order to minimize their environmental impacts”. An advisory board for industrial ecology was established in 2002, involving six government agencies in a collaborative approach: the agencies for sustainable development, economic development, public buildings, energy and waste management, as well as the “Foundation for industrial land” – which manages most of the industrial areas within the state. Project coordination and research are run in collaboration with the Industrial Ecology Group from the University of Lausanne, Switzerland, and the consulting company SOFIES in Geneva.

In order to set priorities for industrial ecology implementation, a regional assessment of resources (MFA) was carried out between 2002 and 2004 for seven key indicative resources: water, energy, metals, wood, plastics, food and building material. The analysis pointed up the consumption of resources by economic sectors. It clearly brought out that households and the tertiary sector are the primary consumers of resources. However, the results highlighted the potential for industrial symbiosis (Erkman, 2004).

2.2 The Geneva Industrial Symbiosis Project

The Geneva industrial symbiosis project was launched in 2004. The scope of the project is to provide efficient solutions to companies to reduce resource consumption while increasing competitiveness. By setting up very restrictive environmental laws and applying the polluter payer principle, the Swiss legislation and policies tend to charge the companies for the real costs of supply and waste management. Therefore, the companies themselves are often searching for alternative outlets for their residues in order to reduce their costs.

The methodology adopted for industrial symbiosis detection and assessment was first developed in France (Adoue, 2004). Improved and adapted to the Swiss context, the methodology currently uses both empirical and deductive approaches. To broaden the opportunity spectrum, data collection includes face-to-face meetings, thematic workshops and literature review. Therefore, the industrial symbiosis project turned to an expert-driven network (coordinator) that connects economic actors on the issue of resource efficiency and residues exchanges. The role of the coordinator ranges from informing economic actors on industrial symbiosis, promoting experience sharing on flow management, identifying, assessing and implementing potential industrial symbiosis (taking into account numerous social, geographic, physical, environmental, and economic constraints) and to advise policymakers (Massard and Erkman, 2007).

While the project initially focused on manufacturing actors, other economic actors were added to investigate the potential for industrial symbiosis among manufacturing, housing, and proximity agriculture throughout the state. As of January 2009, the project involved 32 companies from 12 industrial sectors (figure 1). 17 industrial symbiosis opportunities are identified within the manufacturing activities and between manufacturing, services, housing, and agriculture.
As in the Kalundborg example, residual heat and energy can be reused either for manufacturing processes or for agricultural or residential purposes (Jacobsen, 2006). For example, residual heat from liquid cooling or air-cooling fittings may be exchanged through collection-distribution networks in industrial estates. If no projects are implemented so far, facilitating residual heat reuse integers the state new energy policy in 2009. Water reuse like cooling water from manufacturing processes may be transferred, after heat extraction, to neighboring agricultural areas for irrigation purpose. In both cases, multifunctional land use broadens the perspectives for industrial symbiosis. Several material flows also present opportunities for reuse. First, re-connecting manufacturing with agriculture and housing offers great opportunities to reuse CO₂ for yield increase in greenhouses. Then, if some direct reuse of acids and solvents from the pharmaceutical, chemical, and printing industries are already implemented; more opportunities exist for wastewater treatment.

Finally, building and inert materials deserve particular attention. To avoid a shortage in the region and avoid landfills, several shared processing-crushing-calibration platforms are already in service or are being planned to produce concrete made of recycled gravel. However, several new industrial symbiosis trans-sectoral opportunities have been identified to increase inert materials reuse: incorporation of sand from the wastewater treatment and foundry in concrete production; reusing sawdust and shavings from the wood products industry in ceramic products or as fuel in local wood burning plants; and, reusing wood ashes in ceramic products.

The results obtained so far are not outstanding in terms of quantities exchanged. In fact, many feasibility studies disclosed two important points:

- First, existing waste management and recycling networks provide efficient solutions and, thus, may be better investigated.
- Second, all economic activities in Switzerland can be considered small or mid-size industries with low resource consumption, thus blunting high economic gains from potential symbioses.
3. Web-GIS tool development

3.1 Goals, technical choices and data availability

The coordination work done by the authors in Geneva revealed the need for a tool that allows the visualization of economic activities and supports the detection of industrial symbiosis. Depending on data availability, the tool should also be usable as decision support for feasibility analysis and economic activities planning. Feasibility analysis should include preferential transportation means, path and facility location and environmental risks assessment.

The tool was built using three distinct technologies:

- First a sector-based database on material and energy flows was developed using MySQL language.
- Secondly, spatial data were collected and stored on a Mapserver (mostly in a vector-oriented format).
- Finally, PHP computing language was used to create the user’s interface. PHP allows the communication between the user and the database tables as well as with the Mapserver. Upon request, the server mines the database, built a map by merging the database request’s result with the selected spatial layers and sends it to the user’s interface.

The web-GIS system dedicated to material flow optimization and industrial symbiosis needed numerous types of spatial and non-spatial data. The Territorial Information System Office (SITG) from the state of Geneva possesses numerous spatial layers that are already used for risk assessment and territorial planning at the state level. The still undergoing huge work to create these data in the last decade leads to unexploited potential in analysis. Pertinent data for this project were identified as raster data (aerial orthorectified photography, state map and high scale map) and vector data layers (like land-use, land registry, parcel allocation, protected perimeters, building and facilities, industrial, households and agricultural zoning, surface and ground water networks, transportation networks, supply and draining networks and economic activities). In addition, the Solidarity and Employment State Department (DES) centralizes non spatial information on economic activities, including name, address, contact, activity, activity code (NOGA), commercial code (ID_Reg), number of employees and geographical positioning.

Data from SITG and DES are however not sufficient to detect industrial symbiosis and advise planners on material flow optimization. The Geneva industrial symbiosis project collected input/output data on material, water and energy flows from 32 companies among the biggest resource consumers in the secondary sector as well as data from literature. The database also includes information on industrial processes, on physical and chemical parameters, on current waste handling and becoming and on waste treatment technologies (figure 2).
3.2 Results: potential for resource efficiency and territorial planning

By compiling all the above-mentioned data, the pilot tool developed reveals itself as being efficient to store data and as decision support tool. First, the database appears to be of great help to store all data on material flow and economic activities. The information is stored in a way that allows data treatment in order to detect industrial symbiosis potentials and facilitates feasibility assessment. The database can be searched in order to highlight matching were output flows from one or more companies match with the input flows from another economic activity. The results are shown either on a table or on a map processed through the Mapserver. The GIS interface facilitates, among other, the visualization of detected opportunities and the assessment of technical and geographical feasibility. The material flow database can also be searched by industrial sectors allowing economic activities to be visualized using spatial buffers as sources and sinks of material and energy flows. The proximity between industry, housing and agricultural activities can therefore be studied in order to detect new potential reuse of residues.

The first studies revealed that the web-GIS tool was also very convenient to visualize economic activities and there proximity to transportation networks. As the database can be search be name or industrial sector (NOGA codes, compatible with the European NACE) studying the proximity between industrial sectors and activities that have great potential to set up exchanges of residues and to mutualise services or part of their production appeared to be facilitated. Studies using systematic or deductive data may be of great help for planners. In addition, the tool can be use to study the proximity between some activities and recycling activities as they are considered as an industrial sector.
Thus, finding the more efficient recyclers in the neighbourhood of a particular activity may help optimizing resource management. Finally, crossing the land use, the economic development zoning and the transportation networks layers with the economic activities and material flow data appears to be of good support to suggest options for the location of new industrial facilities. The facility location can therefore be chosen from a material flows viewpoint.

4. Conclusion and outlook

The database on material flows and the web-GIS tool developed indicate that material flow and industrial symbiosis have a great potential as new layer for territorial planning and economic development. First results and discussion with the state of Geneva indicate that, in the future, material flow may be considered in industrial estate and territorial planning.

The GIS create added value for industrial symbiosis detection and to perform feasibility assessment and industrial risk assessment. The tool can be used to set up priorities and to detect quick wins for an efficient and local use of resources. It also reveals ability to be use as decision support to choose the location of new facilities and therefore to influence economic development. Finally, the tool has a high potential in terms of visualization and communication to stakeholders.

These perspectives create great interest from the state and regional stakeholders in Switzerland. It is likely that knowledge on material flow will influence public policies on territorial planning in a near future. The undergoing fieldwork at the state level involves an exhaustive study of industrial symbiosis and resource optimization potential. At the same time more research is done to feed the database with more literature references and data in order to improve industrial symbiosis detection, recycling network optimization and facility location.

References


