# By-product synergy networks, driving innovation through waste reduction and carbon mitigation

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## ABSTRACT

By-product synergy (BPS) is the practice of matching under-valued by-product streams with potential users. BPS can offer true business opportunities beyond cost-reduction if wastes are viewed not as wastes, but as raw materials for other industries. The US Business Council for Sustainable Development has developed a process to help regions cultivate these waste-to-product networks. These synergies reduce waste, promote the efficient use of natural resources, and create a legally protected forum in which companies can explore reuse opportunities. Along with reducing waste and avoiding pollution, BPS can reduce climate-changing greenhouse gas emissions.

***Keywords***: by-product synergy, waste to energy, waste to profit network

## 1 INTRODUCTION

***By-product synergy*** (BPS) is the matching of under-valued waste or by-product streams from one facility with potential users at another facility to create new revenues or savings with potential social and environmental benefits. The process may involve the physical exchange of materials, energy, water and/or by-products and represents a crucial business opportunity to innovate across industrial processes and organizations by exercising best practices in waste reduction and environmental mitigation. By turning waste output from one company into a product stream for another company not only are there reductions in waste, greenhouse gas emissions, and the need for virgin-stream materials, but there are also great opportunities for innovating new products and processes. The process brings clusters of facilities together to create closed-loop systems in which one facility's wastes become another's raw materials.

The US Business Council for Sustainable Development (US BCSD) has cultivated and facilitated by-product synergy networks throughout the United States and abroad in locations including Chicago, along the Gulf Coast, in Kansas City, and the Pacific Northwest.

Several terms are used in discussing concepts similar to by-product synergy. A **waste exchange** refers to a static process, whereas by-product synergy is an active process that may involve process changes that allow synergies that would otherwise not be feasible. Unlike **eco-industrial parks**, BPS networks do not depend upon co-locating industries, but rather taking advantage of existing ones in heavily industrialized areas.

This paper will describe the origins of BPS, briefly outline the process that a region would undertake to develop a network, describe some of the barriers and benefits of BPS, and provide an example of such a network in Chicago. This paper will illustrate the ways in which BPS has provided an opportunity for addressing waste reduction and carbon mitigation through process innovation and cross-sector interaction.

## 2 BPS ORIGINS

Industrial symbiosis and BPS have been cited as tangible and applied examples of Industrial Ecology, a term defined in 1989 by Frosch and Gallopoulos [1]. Industrial symbiosis as described by Chertow et al. engages traditionally separate entities in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products [2]. Following the United Nation Conference on Environment and Development in Rio de Janeiro, the Business Council for Sustainable Development of Latin America was founded in 1992. A member organization was established in 1993, the Business Council for Sustainable Development for the Gulf of Mexico (BCSD-GM), an organization of business leaders with the belief that business success is increasingly measured by contribution to economic, social and environmental sustainability. This organization evolved to become the US BCSD in 2002.

In 1995, the EPA, working with industry to promote incentives for green twinning (as it was called by EPA) established grants to promote joint commercial development of one economic sector with a related environmental sector. Later that year BCSD-GM received an EPA grant to identify case studies and opportunities in green twinning, which the BCSD-GM called by-product synergy. This venture stemmed from the efforts of Gordon Forward, then president of two neighboring companies in Texas, Chaparral Steel and Texas Industries [3]

### 2.1 Chaparral Steel and CemStar

One of the first companies to formulate the BPS concept was Chaparral Steel Company (now Gerdau Ameristeel), based in Midlothian, Texas. Its parent company, Texas Industries (TXI), produced construction materials from sand, aggregates, cement and concrete. In the early 1990s, led by company president, Gordon Forward, managers of the two jointly-owned businesses began exploring synergies through a series of conversations. Several potential synergies emerged from these conversations, illustrated in Figure 1, to remove redundancies between the two companies [4].

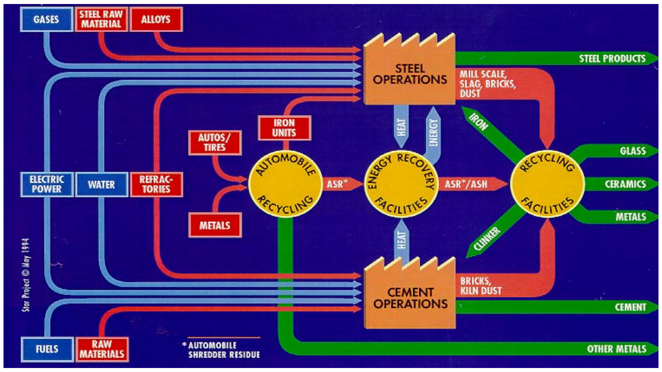


**Figure 1: Proposed Flow Diagram at Chaparral steel**

The primary synergy to emerge was based on the premise that steel slag could be converted to a raw material in Portland cement, thereby patenting the CemStar process. Steel slag contains dicalcium silicate, formed by the high temperatures of steelmaking, which constitutes a building block of Portland cement. By using lime that has already been calcined, cement manufacturers were able to skip a energy and $CO_2$ intensive step in their process [5]. Previously, slag was cooled, crushed, and sold to the road construction industry. By using the steel slag instead of purchased lime, TXI significantly reduced the energy requirements and related emissions of the cement making process. CemStar has resulted in 10-15% overall energy savings, 10% $CO_2$ reductions, 25-45% $NO_x$ reductions, and 5-15 % production increase. In addition, the value of slag increased 20 times over its previous use as road construction fill [5].

Chaparral discovered further potential synergies using a density separation process originally developed to sort carrots in Belgium. With the auto shredder working through one million automobiles per year (one every nine seconds) Chaparral was producing approximately 120,000 tons of shredder residue. Auto shredder residue (ASR), also called fluff, consists of about 25% of the automobile by mass [6] and includes materials not removed by standard steps in the shredding process, such as plastics, oxides, fluids and foams. The food industry-imported technology enabled high throughput and inexpensive separation of these materials, including 15% additional metals over what was obtained in the shredder. In addition, this separation generated a stream of concentrated non-chlorinated plastics, a potential fuel source that would otherwise be landfilled. This potential ASR-derived fuel source has a calorific value of 14,000 btu/lb, the equivalent of a light bituminous coal. A version of this synergy is being pursued by Gerdau Ameristeel and Lafarge Cement as part of the Kansas City BPS project [7]. The regulatory hurdle preventing final implementation involves the 50 ppm of polychlorinated biphenyl (PCB) present in the fluff, however the incineration process used in the kilns may prove to be as effective as current methods for destroying PCBs [4], [8].

## 3 BPS METHODOLOGY

The US BCSD BPS methodology involves establishing a forum where companies, regulators and municipalities explore reuse opportunities through collected information and facilitated interactions. Participants sign an agreement that spells out deliverables, confidentiality issues and intellectual property rights. Rather than simply declaring potential exchanges, the BPS process fosters relationships among companies and municipalities. The process is about information gathering and facilitation, but also about trust and bridge building.

Teaming with a local coordinating body, often a local non-profit such as the Chicago Manufacturing Center in Chicago or Bridging the Gap in Kansas City, is an important component. Making use of an independent facilitator eases the difficulties in bringing together companies of all shapes and sizes across traditional sector and industry boundaries [9]. Several additional components need to be in place for a potential synergy network, including project champions, a researched and justifiable location, and several interested stakeholders. Adequate funding is also necessary to staff the network, search for synergies, and perform ongoing evaluation and measurement. Implementation requires broad based support from local, state and federal government agencies as well as network participants. The government's role in developing synergy networks has been to provide technical expertise and funded grants, coordinate learning and resource sharing across regions, and ensure the appropriate regulations are in place. However, there are limits to what the government can enforce; by-product synergy networks need to evolve synergistically, with the support of agencies, but without mandates [10].

## 4 BARRIERS AND CHALLENGES

The BPS process provides many opportunities for businesses and municipalities, but in order for networks to be implemented successfully, participants must overcome substantial challenges and barriers. These challenges, described in detail below, include regulatory, technical, economic and organizational (or communication) barriers.

Potential by-product synergies may be at odds with local and national environmental ***regulatory*** requirements. However, viewing regulators as partners rather than obstacles enables the network to account for the correct regulations along the way and not simply when a process is ready to be changed. Regulators have been willing to consider permitting reuse options when projects produce environmentally beneficial results [3]. In some cases, regulation provides incentive for by-product synergy development through mechanisms such as landfill bans and disposal fees.

The ***technical*** feasibility of exchanges could provide another barrier to execution. From the outset, tracking and characterizing materials flows requires a level of technical expertise within a company. In some cases research and development may be necessary before a particular synergy can be pursued. As new processes are added to a company's repertoire, the proper training must be performed to enhance employee capabilities.

***Economic*** barriers can also stand in the way of successful synergies. Companies will do what is in their economic interest and if possible, through incremental improvements or through broader scale process redesign, they will eliminate waste in a cost-effective manner. Companies are less likely to pursue synergies if the potential savings are not clearly demonstrated.

A further economic consideration is the size, scope, and consistency of feedstock supplies if by-products are to be used as feed to another commercial process. This is of economic concern because of costs and risks associated with qualifying a new feed stream to existing process, or in developing new conversion technology to deal with a new feedstock. Companies may be actively working to improve yields to existing processes and would therefore reduce byproducts, which might lead to a decrease in the volume of a byproduct stream. Therefore a crucial objective in researching potentially useful byproducts is to identify streams that will exist in the future, are of sufficient volume to support process development, and can be effectively blended with existing process without impacting process or product reliability.

Synergies require sufficient ***communication*** among interested parties. Companies must freely exchange waste and by-product characteristics, resource requirements, conversion technologies, economic information, and other factors that affect project feasibility. Communication and trust are important when materials are being exchanged or infrastructure is being shared because of potential liabilities. Participating industries may use different terms to describe their processes, which can create confusion and inhibit collaboration. Strong social networks can facilitate the discovery and implementation of synergies [11].

The keys to BPS are collaboration, motivation, innovation and participation. All levels of an organization should be involved in identifying, evaluating and implementing the project to ensure that all potential barriers to success are identified and overcome. Successful networks include a diverse range of industries and organizations that allow for broadening of markets to find opportunities.

## 5 BENEFITS AND OPPORTUNITIES

BPS enables economic, environmental and social benefits. Manufacturing innovations may improve efficiency and productivity, boosting revenue. BPS can eliminate or reduce disposal and treatment costs, and cut the costs of energy, transportation and materials while improving internal processes. Under ideal conditions, the waste produces new revenue through connection to new markets.

The network and region as a whole benefit from these reductions in pollution, emission and waste streams. Overall reduced resource use can result in savings of energy, water, petroleum or other natural resources. Another benefit is the reduced carbon emissions resulting from the reuse of existing materials rather than use of new materials with carbon intensive extraction or production impacts. Companies may also discover opportunities to obtain materials locally rather than importing them.

Participating in BPS creates opportunities for regional and national leadership in sustainability. The relationships established by these networks lead to improved community perception and connections, enhance networking and partnership and opportunities to showcase sustainable practices and processes. Opportunities to address regulation issues arise to reduce barriers in materials exchange processes. Industrial areas may be made more attractive to incoming companies interested in clustering around synergistic opportunities. Another important social impact would be the creation of new jobs and businesses.

The strength of a BPS network stems from the development of accurate measuring protocols and diagnostic metrics. The need for quantifiable results in showing environmental benefits has increased in recent years due to concerns about $CO_2$ emissions and climate change [12]. Benefits are quantified by measuring the changes in consumption of natural resources and in emissions to air and water through increased cycling of materials and energy. Economic benefits are quantified by determining the extent to which companies cycling by-products can capture revenue streams or avoid disposal costs; those businesses receiving by-products benefit by avoiding transport fees or obtaining inputs at a discount. The final section of this paper presents an example of a BPS network in Chicago.

## 6 EXAMPLE: CHICAGO NETWORK

In the fall of 2005, the Department of Environment for the City of Chicago was looking for a proven, but exciting process for developing eco-industrial activities in the Chicago region. Coincidentally, the Chicago Manufacturing Center (CMC) had begun collaborating with the US BCSD to create a BPS process toward business resiliency. Through this partnership, with assistance from EPA Region V, the City of Chicago could leverage both groups' expertise to develop the type of network that the city had hoped to develop. The Chicago Waste to Profit network (CWTPN) was launched in October of 2006 by the mayor, Richard M. Daley. As many as 80 companies have become a part of this network and have discussed more than 100 synergies. Fifty of the projects have been implemented in


Clean Technology 2008, www.ct-si.org, ISBN 978-1-4200-8502-0

this partnership mentored by the city of Chicago, US BCSD and the CMC [13].

Through City of Chicago leadership, additional investments were provided through the State of Illinois' Dept of Commerce and Economic Opportunity Recycling Expansion and Modernization Program, and the National Institute of Standards and Technology's Manufacturing Extension Partnership. Company participants paid fees to be part of the network. Using the hybrid approach of *innovation networks* between fee-paying companies as well as smaller *community networks* the CWTPN has enabled involvement by smaller companies and entrepreneurial firms. The innovation network, based on the US BCSD BPS model, forms the core of the CWTPN, and is coordinated by a team providing communication, technical expertise, and facilitation. This network is designed for 10- to 25 organizations that have signed an agreement spelling out deliverables, confidentiality, intellectual property issues [14]. The great variety of companies involved in this network has allowed for a diversity of potential materials streams increasing the probability of synergistic exchanges including food waste, plastics, solvents, chemicals, paper, construction materials, soils, and metal.

An important structural element in the Chicago network typical of BPS projects is a series of working or affinity groups divided along types of potential synergies. These subcommittees of the larger network focus on individual opportunities within one type of by-product stream. For example, the organics group involves 12 companies and two city departments collaborating on 11 synergies with a current estimated total waste diversion from landfill of 4,400 tons. This group focuses on long term projects involving alternative fuels, composting, anaerobic digestion, and changing regulations to reflect changing resources. Another affinity group, the chemicals group focusing on transformation of hazardous waste into revenue streams involves 10 companies, five city departments collaborating on 14 synergies, with a current estimated total waste diversion from landfill of 1117.5 tons. Two other groups include the metals group and building and construction group. In the future, these affinity groups will expand to include water and energy sections [14].

The CWTPN has framed itself as a metrics-driven network from the beginning and focused on Chicago area manufacturing sectors in a ratio proportionately aligned with its prominence in the area. As of this publication, the CWTPN has completed its pilot year, and it has diverted approximately 22,118 tons of landfill bound waste, saved 4.5 million dollars in costs and new revenue creation, and reduced almost 50,000 tons of $CO_2$ emissions [15]. This network will continue to expand; taking on more companies in both the innovation and community networks and continue to implement product synergies while developing the capacity within firms to increase their sustainability.

## 7 CONCLUSIONS

As our world becomes more carbon-constrained, it will become increasingly important to find ways to reduce wastes by reusing by-product streams. The business opportunity provided by BPS presents the potential for important economic development through increased product revenues and jobs. In addition, product innovation can result from this inter-company conversation. As BPS networks develop, industry goals may shift from reducing waste generation towards producing zero waste and finally to producing 100 percent product, all while lowering emissions and reducing energy use. The gold at the end of the rainbow is product redesign stemming from by-product synergy and sustained networks that engage and benefit their communities.

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