Sustainable Development through By-Product Synergy

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ABSTRACT

Phase I of the Gulf Coast By-Product Synergy (BPS) project, sponsored by The Dow Chemical Company (Dow) and the U.S. Department of Energy and facilitated by the U.S. Business Council for Sustainable Development, is now complete. The concept behind By-Product Synergy is also referred to as Industrial Ecosystem, Industrial Symbiosis, or "Industrial Ecology" (IE) system. The philosophy of the IE approach is to enhance the leading edge emergence of an industrial manufacturing system that relies on cooperation among the entities involved, in that they use each other's by-product materials and energy as resources. In this way the system's virgin material extraction from the earth and energy input is minimized, so is the waste and emission output.

This paper discusses key lessons learned from the Phase I effort and the planned activities for Phase II. In Phase I we looked for internal synergy opportunities within the six major Dow Gulf Coast sites in Texas and Louisiana, to gain experience on how to make the BPS process work. The search for synergy opportunities among many companies and many industries is called Phase II.

Since the beginning of the project, we have held the belief that most of the untapped synergy opportunities would be outside Dow. For the IE concept to have a better chance to work, a broad diversity that involves other industries' participation, a transparent communication platform for participants and strong partnerships are critical.

Introduction

Principles of By-Product Synergy

By-product synergy (BPS) has been defined by the United States Business Council for Sustainable Development (US BCSD) and the U.S. Environmental Protection Agency (EPA) as follows: "The synergy among diverse industries, agriculture, and communities resulting in profitable conversion of by-products and wastes to resources promoting sustainability" (Mangan 1997). BPS contributes to strategic sustainable development through "dematerialization" or "substitution."

The US BCSD members have identified six fundamental principles for achieving success in by-product synergy: collaboration (among generators and consumers), motivation (by all the project stakeholders at all organizational levels), communication (among project stakeholders), innovation (of new conversion technologies or creation of new strategies), participation (throughout the collaborating organizations) and evaluation (throughout its life-cycle, before, during and after BPS implementation) (Mangan 1997).

Review on The Dow Chemical Company's Efforts in Promoting Sustainable Development

The chemical industry started waste minimization efforts that were driven by yield improvement as is shown in Figure 1 of sustainable development practices concerning waste management. As time moves on and the cost of managing waste becomes more expensive, dedicated efforts were spent on waste minimization such as "at-source reduction" within the production unit and "recover, reuse and recycle" within the company.

As the chemical industry manufacturing processes became more complex, many new products were developed from by-products that were generated in older manufacturing processes. This resulted in site integration evolution in large chemical manufacturing sites where many manufacturing units were owned by the same company. In an integrated chemical manufacturing site, maximum utilization of material, energy and other key utilities (water, air, nitrogen, etc.) are carefully planned among the various manufacturing units at the site. This can be the start of an IE effort within the same company.

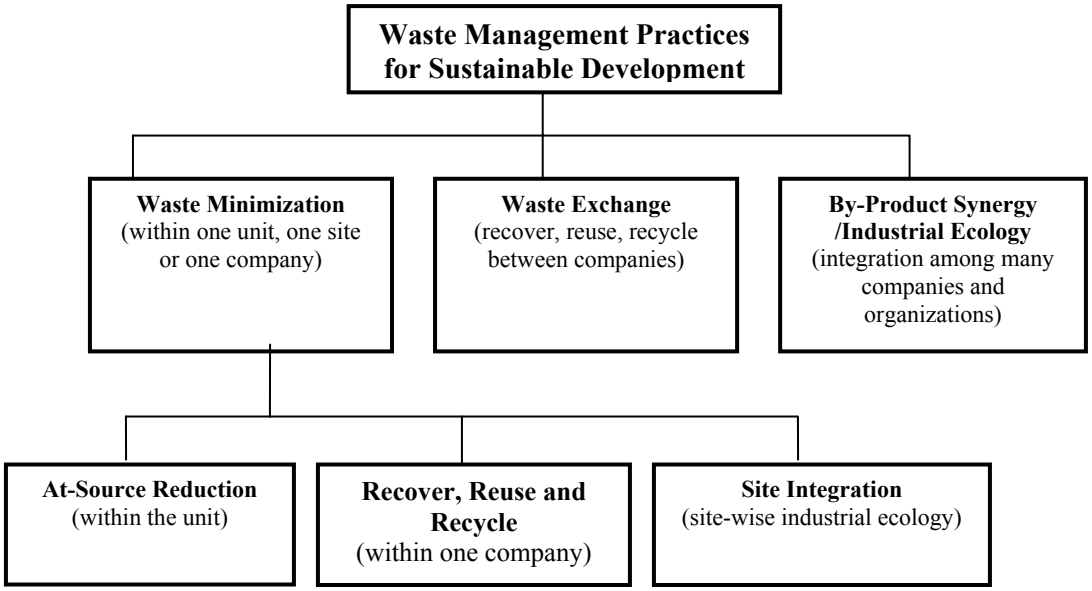
While the above-stated efforts were mostly carried out within the same company, other efforts also started to evolve in exchanging by-products with outside companies. There were some limited efforts for companies that were located close to each other to integrate their resources utilization when there were obvious synergistic benefits. However, there was a lack of "well organized" and dedicated efforts to move toward IE among different companies.

Industries will need to move to the next level of operation with dedicated efforts for better cooperation and partnership as Earth's resources become scarcer and more expensive. Dow started to work with US BCSD in late 2002 to start a By-Product Synergy project intended for an organized effort to promote Industrial Ecology. The U.S. Department of Energy (DOE) co-sponsored this project with a matching grant that funded half of the project contractor's (US BCSD) cost for the Phase I effort. DOE has recognized the potential for energy efficiencies and greenhouse gas emission reductions resulting from by-product synergies and co-funded the project as part of its Industries of the Future program, aimed at identifying energy-efficient production and manufacturing techniques that can be leveraged across US industries. For Dow, this is a switch of its focus to more by-product synergy to promote a culture change. This change is instrumental for the next generation of industrial manufacturing systems to evolve - following the principles of IE "through co-operation and partnership between the actors involved, in that they use each other's waste material and energy as resources and in this way minimize the system's virgin material and energy input, as well as the system's waste and emission output" (Korhonen 2001).

It is Dow leadership's perspective that "*we don't view sustainable development as a choice. It is an imperative, a 'must do', an absolute responsibility for any company doing business in today's global economy.*" One of the goals in our by-product synergy effort is to foster a culture change by constantly challenging ourselves:

- What if we were pursuing business opportunity and not just cost reduction?
- What if we began to speak in terms of 100% raw materials utilization instead of zero by-products generation?
- What if our so-called "by-products" weren't by-products at all, but were raw materials for other industries?

Figure 1. Evolution Process of Waste Management



Gulf-Coast By-Product Synergy Project

The By-Product Synergy (BPS) process developed by the US BCSD offers companies an opportunity to reduce pollution and save money by working with other companies and communities to reuse and recycle by-products. The process brings clusters of companies together to create closed-loop systems in which one company's "by-products" can become useful raw materials for another. These synergies, which result from brainstorming among process-knowledgeable experts and company engineers, help to reduce by-product quantity and promote efficient use of natural resources. As one participant put it, "BPS establishes a culture of possibilities."

Dow started to work with US BCSD on a Gulf Coast BPS project in order to gain experience and to develop work processes on how to make BPS work effectively. The project was planned to be carried out in two phases: Phase I was planned to look for internal Dow synergy opportunities, and Phase II was planned to be expanded to external companies. The following are the driving forces for Dow's BPS program:

- Supports Dow's public goals for waste reduction;
- Provides awareness and incentives for BPS;
- Enables a culture change across the corporation;
- Provides a forum for communication between businesses within Dow and between Dow and outside industries to address and overcome technical barriers;
- Provides support to address regulatory barriers and liabilities;
- Deliver environmental benefits, new business opportunities and cost savings; and
- Achieve the balance of social, economic and environmental goals.

BPS Project Phase I

Within the six Dow Gulf Coast sites in Texas and Louisiana, 40 manufacturing plants were invited to participate in the Phase I study. The 40 plants represented various businesses that were supported by 14 business Technology Centers and were identified as major non-chlorinated by-product generators (over 1 million pounds/year of all by-products at each plant). This provided an opportunity for identifying potential by-product synergies by crossing the boundaries between businesses, plants and operation sites. The focus of this part of the DOE-sponsored project was on non-chlorinated by-products and to gain experience with the BPS work process. The reasons to choose non-chlorinated by-products are that (1) Dow has a Global Chlorinated Organics function for the integration of all Dow's chlorinated organics, be they raw materials, products or by-products; and (2) non-chlorinated by-products will have less environmental regulatory barriers and less potential adverse impacts than chlorinated organics.

The Phase I effort was launched in May 2003 and was intended to have all by-product data collected and potential synergy areas identified. As expected, very limited internal synergy opportunities were found and opportunities to be explored are mainly exterior. The results will be discussed in more detail under "Results and Discussion".

Project Phase II

The organizing effort involving Dow and all other companies for the BPS project Phase II was kicked off in May 2004 and is on-going. The objective of this organizing effort is to have the actual Phase II project organization functional with all contracts signed by the second quarter 2005. Legal and operational obstacles have slowed engagement of interested companies, but the project remains on track, while not developing as rapidly as had been hoped.

Results and Discussion

Project Phase I Results

The by-product synergy project carried out during Phase I involved the following activities:

- Design data collection templates to capture raw materials, by-products and potential synergy ideas;
- Work with each plant representative to complete data collection on time;
- Analyze data and compile a Potential Synergies report;
- Facilitate a brainstorming session with all plant representatives to evaluate potential synergies and establish sub-envelope teams to define and prioritize synergies;
- Sub-envelope teams describe synergies using the Synergy Project Charter Document tool;
- Evaluate Synergy Project Charters and submit to business Technology Center Directors for consideration of implementation;
- Technology Centers assign Project Manager for prioritized synergy projects; and
- Conduct more detailed study, implement synergy projects and measure performance.

The BPS process began by cataloging each participating plant's material flows in a uniform database that is later analyzed for synergies by the project team and through facilitated working sessions with the participants. The project team composed of representatives from all 14 Technology Centers and the plants they support. All 40 participating plants were requested to complete two survey forms about their production processes, raw material needs, and waste streams. All data were compiled in a central database. By-product synergy ideas were generated during the course of data collection and analysis, as well as at subsequent Phase I idea development meetings. The synergy ideas were then voted against pre-defined criteria: economic, technical, regulatory, environmental/social and legal. The results were eight Identified Potential Synergy Project Categories. Correspondingly, eight sub-envelope teams were formed. Through subsequent evaluation efforts by the eight sub-envelope teams, 14 highly-ranked projects that identified high potential opportunity by-product streams were submitted to their business Technology Centers for further study and consideration of implementation. After discussing with the businesses, we realized that a more coordinated effort to search for by-product application ideas is needed. We are now refocusing on the idea generation mechanism before we get back to businesses again for implementation. Table 1 lists the eight identified potential synergy project categories.

As a result of Phase I project effort, the DOE published a brochure about the project which was distributed in a DOE sponsored national conference and also in several other meetings/conferences that Dow and/or US BCSD were invited to give presentations. Dow and/or US BCSD also gave many presentations to various groups and have held discussions with various government agencies to introduce and promote the concept of the BPS project. All those efforts have started a culture change toward more cooperation and partnership among various stakeholders in the nation.

Key Learnings

Obtaining support from the 14 business Technology Centers was the key for the success of the Phase I BPS effort. The BPS process involves establishing a forum where process knowledgeable experts from different businesses within Dow can explore by-product reuse opportunities during the Phase I effort. Unlike waste exchange, BPS recognizes that the acceptance of one business' or company's waste as a feedstock for another takes more than simply announcing its availability. Rather, it is an information collection and evaluation process between individual businesses/companies.

Out of the Phase I effort, we realized that more and active participation of scientists from Research and Development is crucial. Scientists can contribute to the success of any BPS efforts in many ways. These include but are not limited to new application ideas by the scientists themselves, evaluation of technical feasibility of ideas by others, identification of potential environmental, health and safety issues and validation/invalidation through lab and pilot studies.

Table 1. List of Identified Potential Synergy Project Categories

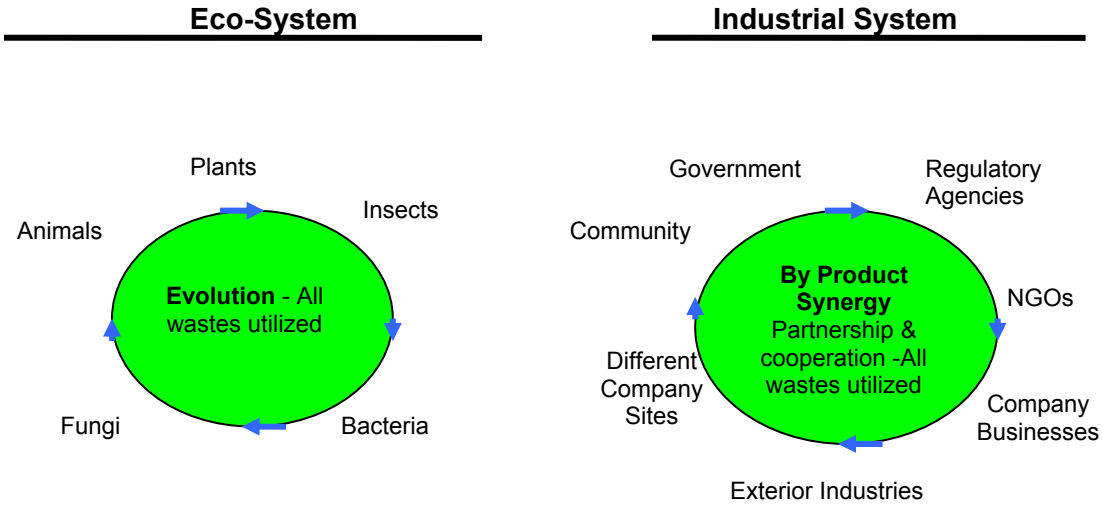
BPS Project No.	BPS Project Name	Description of the BPS Project	Total Potential Energy Saving and CO_2 Emission Avoidance[1]
1	Hydrocarbon recovery and spent solvent recovery	15 large quantity hydrocarbon and solvent waste streams were identified as either (1) having potential for further separation and use of the constituents, or (2) the material may have some application as is or after further treatment.	Energy saving: 900,000 million BTU/year CO_2 emission avoidance: 108 million lbs/year.
2	By-product alkalinity	Re-use of low strength waste sodium hydroxide (~5%) inside or outside Dow	
3	Sulfuric acid	Re-use of medium strength waste sulfuric acid (~50%) inside or outside Dow	
4	Spent Methocel polymer	The material is identified to have potential new applications other than landfill or incineration	
5	Ortho-toluenediamine	Potential new application of this material as is or after some further treatment	
6	Hydrogen gas	More efficient use and integration of hydrogen gas between generators and users	
7	Magnesium silicate cake	Deferred to Phase II. Many production plants generate magnesium silicate containing cake that may be used outside Dow.	
8	Spent solids	Deferred to Phase II. Many production plants produce various types of organic or inorganic spent solids that may find use in other industries.	

We also realized that numerous BPS opportunities lie outside Dow. This is not a surprise because large companies like Dow normally have a high degree of integration within one site and/or among different sites. Through their continued historical efforts in waste minimization, a large portion of BPS opportunities will be found in other industrial entities. One of the key elements for successful BPS is to maintain a diversity of participating industrial entities. Figure 2 illustrates how we envision BPS success. In a natural sustainable eco-system, the whole system is able to maintain stability due to cooperation and mutual support among a diversified set of members – animals, plants, insects, fungi and bacteria. These effective complex systems are the result of significant evolutionary processes. To fully realize the values of BPS, human beings need to learn from eco-systems. A culture change must occur in the society to promote cooperation and partnership among different stakeholders – the community, Non-Government Organizations, government, regulatory agencies and different types of industries/companies. On

[1] Lump sum numbers are estimated here. Energy saving number was calculated based on average energy consumption for per pound of product at the six participating sites times the pounds of wastes if all converted to useful products. CO_2 emission avoidance was calculated by using an emission factor of 120 lbs of CO_2/million BTU for the potential energy saving calculated.

technical level, we need to involve more diversified members to form a workable industrial eco-system or "virtual industry ecology park." We need to explore the potential usage of the by-product either in total or the majority of it based on its unique physical and/or chemical characteristics that some other members in the industrial eco-system can use. In addition, greater understanding and openness to cross-industry collaboration will be needed among the various industrial participants to allow the by-product synergy concept to "evolve" to its peak effectiveness.

Figure 2. Analogy (or Metaphor) between Eco-System and Industrial System



Path Forward for Project Phase II

The planned activities for Phase II are listed below:

- Spread the BPS efforts to Louisiana, Mississippi and Alabama;
- Recruit five or more companies to participate;
- Establish formal state government support for the economic development, environmental and social benefits;
- BPS Team to provide sponsorship and oversight to keep momentum moving forward;
- Address regulatory barriers/issues; and
- Organize R&D resources to provide application ideas and address technical barriers/issues.

Enhance advocacy and provide incentives for BPS. Continued efforts on BPS advocacy should be in place in order for a culture change to promote more cooperation and partnership among various businesses and sites within the company, and between different companies.

A major barrier to by-product reuse is the lack of incentive for companies to develop sophisticated reuse programs. This is particularly true at locations where disposing of by-product streams can be done at extremely low costs, and therefore it is hard to justify the expense for reuse. To overcome this barrier, the BPS process operates at two levels simultaneously: (1)

seeking investments that would turn by-products into profitable streams; and (2) working with regulators to create incentives. The value proposition calls on customers to realize that many cross-industry reuse opportunities exist but have not been explored because organizations are focused on their core competencies. Typically, organizations do not take the time to look across the fence for other possibilities where by-product synergy could provide by product re-use opportunities and incentives at a reasonable cost.

Future successful BPS examples should be recognized for their potential/actual environmental benefits, new business opportunities and cost savings when the right synergy partners are connected and the right synergy ideas are implemented.

Provide support to address regulatory barriers and liabilities. Regulatory barriers to by-product reuse include the definition and classification of materials, the need for a separate regulatory framework for by-product, and liability issues. Definition and classification of materials by regulatory organizations subject materials to state and federal laws. The vague and varying definitions and classifications of by-product material make it difficult to convince businesses to reuse by-products generated by another organization. Once something is defined as a waste, it is subject to a unique set of regulations governing its transportation and disposal. Regulations often do not allow for reuse, thus it is a cumbersome process for an industry to gain permission to adopt approaches other than those outlined within given regulations. It is not always clear who is liable for the reuse of the by-product - the generator or the end user. This means both parties in a by-product synergy transaction must take a calculated risk based on incomplete information. Regulatory barriers need to be overcome through strategic partnerships formed with regulating organizations.

As the result of the Phase I dialog with regulatory agencies both at the Federal and State levels to introduce the concept, support was obtained with promise to help overcome the regulatory barriers when good synergy ideas are identified. The US EPA continued its support of BPS co-funding the Kansas City By-Product Synergy project and invited the US BCSD to present the synergy process at the National Resource Conservation and Recovery Act meeting in August 2003. EPA is interested in BPS as a means of demonstrating the value of a policy shift in materials management and has encouraged US BCSD to work on a voluntary agreement on BPS.

The U. S. Environmental Protection Agency (EPA) published its proposed changes to the definition of "solid waste" on October 28, 2003. EPA proposes that <u>any material generated and reclaimed in a continuous process within the same industry</u> (as defined in the proposal) is not "discarded" for purposes of Subtitle C, <u>provided that the recycling process is "legitimate</u>." As is evident from the underscoring added here for emphasis, the proposed exclusion has a number of qualifying conditions. Under this approach, when generation and reclamation occur on a continuous basis within a single industry (as those terms are defined in the proposal), secondary materials will not be regulated as solid waste. While the proposal is intended to encourage recycling and resource conservation and may do so to a limited extent, significant constraints will remain if the proposal is adopted. Specifically, EPA has not recognized the potential for reuse of secondary materials within and across industries other than those in which the material is generated. This opportunity for "by-product synergy" between different industries is significant and should be encouraged. A broader exclusion described in the proposed regulations will offer an exciting opportunity to move along the path toward EPA's RCRA Vision for 2020 (US EPA 2003).

We believe that BPS is a tool to effect the changes necessary to make the Vision a reality. BPS should be seen as one approach leading to viable cross-industry reuse that will benefit the environment, society and the economy (Mangan & Morriss 2003).

Support for regulation change also comes from US EPA officials like Mr. Thomas P. Dunne, Acting Assistant Administrator for the EPA´s Office of Solid Waste and Emergency Response. At the 2004 Byproducts Beneficial Use Summit in Kansas City, Mr. Dunne commented that "the Agency must collaborate with industry, environmental groups and third-party scientific institutions, such as universities and testing agencies, to encourage the reuse of industrial byproducts. It doesn't make long-term economic sense to use materials once and throw them away…" (Waste News 2004).

The Texas Commission on Environmental Quality (TCEQ) is ready to permit by-product synergies within an industry or across industries if they are shown to serve as effective ingredients or substitutes in industrial processes. TCEQ staff suggested that the Texas Governor's Office would support the Gulf Coast By-Product Synergy Project as an economic development initiative for the state, helping to retain current companies and encouraging new companies to locate in Texas.

Similar efforts are moving ahead in Louisiana and Mississippi supported by the state and local governments

Provide a forum for communication between businesses within Dow, and between Dow and outside industries to identify value-added synergy projects. To succeed in by-product synergy, good communication among all project stakeholders —businesses, communities, and government agencies—is essential. In addition, greater understanding and openness to cross-industry collaboration will be needed among the various industrial participants to allow the By-Product Synergy concept to "evolve" to its peak effectiveness. To identify, evaluate, and implement by-product synergy projects, information on the following topics must be exchanged by potential partners:

- Waste and by-product characteristics;
- Resource requirements;
- Conversion technologies; and
- Technical, economic, geographic, regulatory, legal, business, social, time, informational, and other factors that affect project feasibility.

Even if they are not direct partners in the project, affected communities and government agencies should be recognized as vital stakeholders and therefore included in communications. This will help the effort proceed more quickly and overcome barriers to success.

The Phase I organization formed within the company provided communication mechanism within the company. The Phase II organization being formed will provide communication mechanism among various stakeholders. It will also provide a mechanism to overcome legal communication barriers – e.g. anti-trust, protection of intelligence property.

Provide a mechanism to search for synergy and to address technical barriers. As discussed earlier, in a sustainable eco-system, the whole system is able to maintain stability due to cooperation and mutual support among a diversified set of members. These effective complex systems are the result of significant evolutionary processes. There is a need for similar

"evolutionary" process to help the planned "virtual industry ecology park" function among the different members in the "Industrial Ecosystem". Each by-product has its special functional characteristics (reaction/dissolution kinetics, lubricity, surfactancy, biological activity, permeability…), and therefore should have some corresponding applications (cleaning, deicing, paints, paper manufacturing, electronic cleaning, moisture control …). The "Evolution" process we need is to organize research scientists in the company to study the by-product streams for their special physical and/or chemical characteristics. The scientists can then discuss among themselves what applications the by-product streams may have. Further development work may be needed to make the application a reality. Effort is on-going at Dow to form such a function.

The work process planned for Phase II will include a mechanism and the associated legal structure that would allow dialog among scientists within the company and among the companies to encourage out-of-box thinking and to search for breakthrough ideas.

Once the Gulf Coast By-Product Synergy Project Phase II organization is completed, scientists from different participating companies may need to work together and go through the "Evolution" process to help establish the "virtual industry ecology park" and make the associated "Industrial Ecosystem" a reality.

Concluding Remarks

The Dow Chemical Company is actively engaged in the Gulf-Coast By-Product Synergy project. This paper reviews the key accomplishments to date, key lessons learned, and a path forward. There may be numerous barriers encountered during BPS process, and each synergy may have its own unique set of barriers to overcome. Realizing the barriers and trying to eliminate them by maintaining high degree of participants' diversity, efficient and transparent communication and strong partnership among all the stakeholders will result in the success of by-product synergy. Successful BPS projects, proactive and non-regulatory driven, will greatly drive business value while reducing the environmental impacts (thus creating win/win versus just a cost to the business for waste management). Though the evolution to the ultimate "industrial ecosystem" may take a long time, it is part of humanity's journey toward sustainable development.

Acknowledgement

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References

The Dow Chemical Company. 2004. By-product synergy supports sustainable development. DOE Plant-wide assessment project final report (UT-Battelle Subcontract No. 4000022272).

Korhonen, J. 2001. "Four ecosystem principles for an industrial ecosystem." *Journal of Cleaner Production* 9(2001): 253-259.

Mangan, A. 1997. By-product synergy: a strategy for sustainable development. The Business Council for Sustainable Development – Gulf of Mexico

Mangan, A. and Morriss, J. 2003. US Business Council for Sustainable Development, Comments on EPA's proposed revision to the definition of "solid waste" - a case for a broader exclusion.

US EPA. 2003. "Beyond RCRA: Prospects for Waste and Materials Management in the Year 2020; Final White Paper" Available on line: http://www.epa.gov/osw/vision.htm

Waste News. 2004. *"EPA should focus on material reuse, recycling, Thomas Dunne says,"* Available online: http://www.wastenews.com.