INNOVATE
MOTIVATE
COMMUNICATE
COLLABORATE
PARTICIPATE
EVALUATE
SYN

The Business Council for Sustainable Development–Gulf of Mexico (BCSD-GM)

The Business Council for Sustainable Development–Gulf of Mexico (BCSD-GM) is a non-profit assembly of business leaders from the United States and Mexico dedicated to creating cross-border, public-private partnerships for promoting and implementing sustainable development. Established in 1993, BCSD-GM was founded on the belief that business success will increasingly be measured by its contribution to economic, social, and environmental sustainability. The Council's goal is to pursue projects and policy options that offer concrete, measurable ways to achieve sustainable development.

The BCSD-GM is divided into U.S. and Mexico chapters. These groups share common goals and are designed to serve both sides of the border between the two countries. An executive director serves both chapters and each has a chairman, vice chairman, and treasurer. Members pay dues, offer in-kind services and expertise, and attend bi-annual meetings. Member companies are represented by senior executives of their respective companies.

The BCSD-GM's current projects address topics such as environmental cost accounting, border infrastructure, regional modeling, sustainable forestry, and by-product synergy.

The BCSD-GM is also a member of the Business Council for Sustainable Development for Latin America (BCSD-LA) and the chairmen of both the U.S. and Mexico chapters serve as BCSD-LA members. The BCSD-LA was created following the 1992 Rio Conference. Latin American business leaders actively participate in the organization through several task forces. They are currently focusing on eco-efficiency principles in small business, sustainable infrastructure, education and training, environmental policy development, joint implementation, conservation of the Amazon, and policy creation for sustainable development.

Both the BCSD-GM and the BCSD-LA are members of the World BCSD (WBCSD). The WBCSD, a 125-member body focused on global sustainable development policy issues, is based in Geneva, Switzerland.

By-product Synergy: A Strategy for Sustainable Development

A Primer

Presented by:

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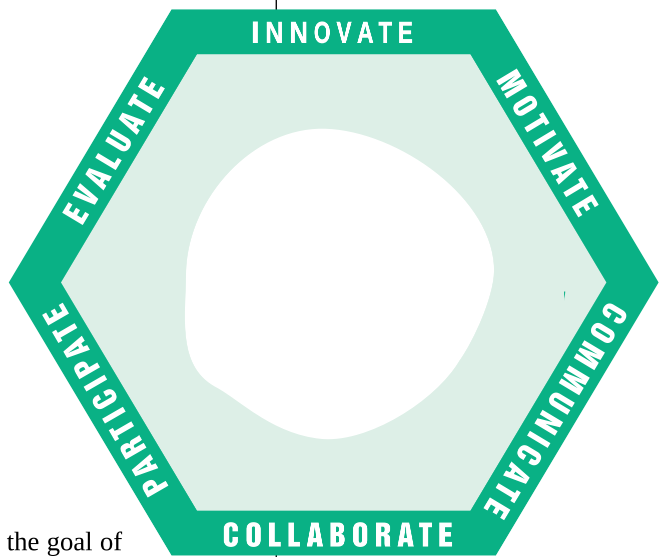
April 1997

Preface



In March 1995, the U.S. Environmental Protection Agency (EPA) announced that it would work with industry to develop incentives for "Green Twinning." According to Dr. Alan D. Hecht, EPA Principal Deputy Assistant Administrator for International Activities, "The concept of Green Twinning is to promote joint commercial development of one economic sector with a related environmental sector. In practice this means the waste product of one industry can be used by a second industry."[1]

The Project

Later that year, the Business Council for Sustainable Development–Gulf of Mexico (BCSD-GM) received an EPA grant to identify case studies and opportunities in green twinning, or, as the BCSD-GM refers to it, "By-product Synergy." The BCSD-GM also was asked to identify regulatory and other barriers to more creative ways of recycling, recovering, and reusing materials.

The EPA-supported project stemmed from an effort launched in 1994 by the BCSD-GM under the direction of Dr. Gordon Forward, President and CEO of Chaparral Steel Company and current Chairman of the BCSD-GM. That effort was aimed at identifying the by-product, waste, and resource streams of BCSD-GM member companies in both the United States and Mexico with the goal of finding opportunities for by-product synergy.

The work described in this primer supports the Clinton Administration's efforts to enhance the relationship between commercial development and sustainable development. Aiding U.S. competitiveness through by-product synergy is expressed in the national goals set forth by the President's Council on Sustainable Development in its recent report, *Sustainable America: A New Consensus for Prosperity, Opportunity, and a Healthy Environment for the Future*[2]. By-product synergy also addresses the recommendations made to Vice President Al Gore as a result of the White House Briefing and Conference on Environmental Technologies, where the National Environmental Technology Strategy was discussed by 200 representatives from industry, the federal government, and other key sectors.[3]

EPA and other U.S. government agencies have agreed on a policy of commercial diplomacy and export promotion for American companies through organizations like the BCSD-GM. In awarding this grant, Dr. Hecht's vision was for the BCSD-GM to help EPA make the concept of by-product synergy a reality, with the goal of helping U.S. industry export this kind of eco-efficient technology.

The purposes of the primer are education, communication, illustration and, most importantly, *inspiration* about how business, society, and the environment can all benefit from by-product synergy as a strategy for sustainable development.

This Primer

During the course of the project, the BCSD-GM realized that, to maximize the value of its work, its product should be a primer for business, community, and government leaders in positions to promote and practice by-product synergy. The purposes of the primer are education, communication, illustration and, most importantly, *inspiration* about how business, society, and the environment can all benefit from by-product synergy as a strategy for sustainable development.

This primer provides concrete examples of how companies have increased their profitability, and reduced pollution and natural resource use through innovative cross-industry collaboration. The potential for gaining even more benefits from by-product synergy is also described. This information is aimed especially at developing economies that have a chance to begin projects from the grass roots level. At publication, companies in Asia, North America, South America, and Europe had told the BCSD-GM of their interest in the results of this project.

Acknowledgments

EPA and the BCSD-GM co-funded the development of this primer. Andy Mangan, Executive Director of the BCSD-GM, directed the project under the guidance of Alan Hecht. Greg Behrens and Nancy Phillips of Radian International LLC wrote the primer. Gordon Forward and Libor Rostik of Chaparral Steel Company provided leadership throughout the project. Valuable input was also received from the following people:

- David Allen, The University of Texas at Austin Department of Chemical Engineering
- David Batt, Florida Phosphate Council
- David Cobb, Bechtel Corporation
- Gwen Eklund, Electric Power Research Institute
- Scott Freeburn, Florida Power & Light
- Tina Huyck, Radian International LLC
- Ron Jones, Texas Institute for Applied Environmental Research
- Terry Killian, Conoco, Inc.
- Jamison Koehler, EPA, Office of International Activities
- G. Michael Lloyd, Jr., Florida Institute of Phosphate Research
- Milton Owen, Radian International LLC
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- Nancy Roen, Florida Power & Light Company

Judy Mataya and Nancy Gates of Radian International LLC edited, designed, and prepared the primer for publication.

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Background and Overview of By-product Synergy

Sustainable Development

Sustainable development is defined as a way "... to meet the needs of the present without compromising the ability of future generations to meet their own needs."[1] Put another way, "Sustainable development represents the quest for an economy that exists in equilibrium with the earth's resources and its natural ecosystems. Sustainable development brings environmental quality and economic growth into harmony, not conflict. It is a concept that recognizes that economic activities and environmental considerations need to be integrated for humanity's long-term well-being."[2]

In its recent report, *Sustainable America: A New Consensus for Prosperity, Opportunity, and a Healthy Environment for the Future*[3], the President's Council on Sustainable Development (PCSD) observed that "... in looking to the future, society needs to adopt a wider range of strategic environmental protection approaches that embrace the essential components of sustainable development: economic prosperity, environmental health, and social equity and well-being."

By-product Synergy

One strategic environmental protection approach that provides economic, environmental, and social benefits is by-product synergy. Referred to also as "green twinning," "industrial symbiosis," "zero waste/zero emissions/100% product operations," and "cradle-to-cradle eco-efficient manufacturing," by-product synergy has been defined by the Business Council for Sustainable Development–Gulf of Mexico (BCSD-GM) 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."

By-product synergy supports the U.S. goals for sustainable development as set forth by the President's Council, especially to "create a widely held ethic of stewardship that strongly encourages individuals, institutions, and corporations to take full responsibility for the economic, environmental, and social consequences of their actions."[4]

By-product synergy also supports the goals developed by the Eco-efficiency Task Force appointed by the PCSD to foster *eco-efficiency* as the standard practice for businesses, individuals, and governments in the United States.

By-product Synergy

The synergy among diverse industries, agriculture, and communities resulting in profitable conversion of by-products and wastes to resources promoting sustainability.

[1] *Our Common Future,* The World Commission on Environment and Development (The Brundtland Commission), Oxford Press, 1987.

[2] *The Greening of Industrial Ecosystems*, National Academy of Engineering, Allenby, Braden R. And Richards, Deanna J., editors, National Academy Press, 1994.

[3] *Sustainable America: A New Consensus for Prosperity, Opportunity, and a Healthy Environment for the Future*, The President's Council on Sustainable Development, ISBN 0-16-048529-0, February 1996.

[4] Ibid.

"Progress toward sustainable development makes good business sense because it can create competitive advantages and new opportunities. But it requires far-reaching shifts in corporate attitudes and new ways of doing business. To move from vision to reality demands strong leadership from the top, sustained commitment throughout the organization, and an ability to translate challenge into opportunities."

World Business Council for Sustainable Development

Eco-efficiency, a term coined by the World Business Council for Sustainable Development (WBCSD), is described by the Task Force as "the production, delivery, and use of competitively priced goods and services, coupled with the achievement of environmental and social goals."[5] Specific Task Force goals for an eco-efficient economy supported by by-product synergy are:

- Economic growth
  Economic growth in the expanding global marketplace should be maximized, as measured by indicators that account for social and environmental issues.
- Sustainable resource utilization
  The U.S. economy should efficiently produce and use globally competitive goods and services while reducing the use of resources to sustainable levels, thereby greatly reducing adverse effects on natural systems.
- Environmental quality
  Pollution prevention, waste reduction, and product stewardship should be standard practices to ensure a safe and clean environment. All people and ecosystems should be protected, and economic and social well-being enhanced.

By-product synergy also supports the goal of the National Environmental Technology Strategy: "to strengthen the policies and partnerships between the public and private sectors needed to encourage innovation and investment in environmentally sound technologies, products, and practices, both here and abroad."[6]

A Primer on By-product Synergy

The WBCSD points out that "Progress toward sustainable development makes good business sense because it can create competitive advantages and new opportunities. But it requires far-reaching shifts in corporate attitudes and new ways of doing business. To move from vision to reality demands strong leadership from the top, sustained commitment throughout the organization, and an ability to translate challenge into opportunities."[7]

To help you, your organization, and your community use by-product synergy to move toward sustainable development and share in its economic, environmental, and social benefits, the BCSD-GM offers this primer. Its purposes are education, communication, illustration, and most importantly, *inspiration* about the value of by-product synergy as a strategy for sustainable development.

In the following sections, the primer addresses the *practice, principles, process, problems,* and finally, the *power* and *promise* of by-product synergy. Here's an overview of what you will find.

The Practice of By-product Synergy

Three case studies of BCSD-GM member companies illustrate by-product synergy in action:

- In seeking "zero waste/100% product" steel production, **Chaparral Steel Company** has significantly increased profits while concentrating on environmental issues. For example, Chaparral is using a process in which one of its by-products, slag, is used as a resource in the manufacture of cement, thereby reducing energy consumption, conserving natural resources, and lowering greenhouse gas emissions. Chaparral has recently acquired the technology to separate another by-product stream, residue from its automobile shredding operation, into essentially pure components that can be reused, for instance as a clean fuel.
- **The Bechtel Corporation**, together with the Brownsville (Texas) Economic Development Council and the City of Brownsville, is developing a computer-

[5] *Eco-Efficiency Task Force Report*, The President's Council on Sustainable Development, U.S. G.P.O. 1996-404-680:20023, 1996.

[6] Summary, *White House Briefing and Conference on Environmental Technologies: National Environmental Strategy*, April 30, 1996.

[7] *Changing Course: A Global Business Perspective on Development and the Environment*, Schmidheiny, Stephan, with the [World] Business Council for Sustainable Development, 1992.

ized database and software tools to promote "industrial symbiosis" among numerous diverse regional industries in the U.S. and Mexico. By orienting companies to look at wastes as commodities to be sold or recycled, the eco-industrial park promises to boost companies' financial performance while reducing the demand for virgin feedstock materials, minimizing the cost of treatment and disposal of wastes, and alleviating the adverse environmental impact of industrial development.

- As part of its commitment to environmental stewardship, **Florida Power & Light Company** (FPL) operates a Central Reclamation and Salvage Department that has collaborated with regional businesses in converting various by-products and wastes from its operations and maintenance activities to resources for other applications. This operation is now a profit center for FPL.

The Principles of By-product Synergy

Through the kinds of practical experience described in these case studies, BCSD-GM members have identified six fundamental principles that are needed to successfully practice by-product synergy: *collaboration, motivation, communication, innovation, participation,* and *evaluation.* Applying each of these principles does not guarantee success in overcoming the many barriers you may encounter, but neglecting these principles can lead to failure. This section of the primer discusses the importance of each principle in achieving by-product synergy success.

The Problems of By-product Synergy

Although by-product synergy can be profitable, as well as environmentally and socially beneficial, it sometimes is not easy. The BCSD-GM has identified numerous barriers to by-product synergy that you may encounter, including technical, economic, geographic, regulatory, legal, business, social, time, informational, and others. This section of the primer offers general guidance on how to overcome these barriers. It also includes a case study that describes the ongoing efforts of **The Fertilizer Institute** (TFI) and the **Florida Phosphate Council** (FPC) in attempting to overcome regulatory barriers to by-product synergy projects involving phosphogypsum, a radioactive by-product of the wet-process phosphoric acid fertilizer industry.

The Process of By-product Synergy

In this primer, you'll learn about the principles and the problems associated with by-product synergy and see some concrete examples of how it can be used to increase profits and reduce pollution. But how do you do it yourself? To help you get started, a general process of by-product synergy is outlined in this section. You will find general guidance for developing and implementing by-product synergy projects, including identifying candidate streams, characterizing the streams, and identifying potential collaboration partners.

Conclusion: The Power and The Promise of By-product Synergy

The power and promise of by-product synergy lie in its ability to raise profits while reducing pollution and promoting sustainable development. This section of the primer summarizes the evidence of this trend.

Observations and Lessons Learned on Chaparral's STAR Project

Libor Rostik is Vice President, Technology and Development at Chaparral Steel Company in Midlothian, Texas. Some of his observations and "lessons learned" as a result of working toward by-product synergy follow.

"We at Chaparral believe that, in the future, it will not be enough to be a producer of quality products. Manufacturers will have to accept the responsibility for the environmental worthiness of the entire process including the generation of the co-products and wastes. We believe in this and we set for ourselves a new challenge: zero waste/100% product steel making."

Managerial Challenges: "The first requirement for success is that the people who will make it work adopt the Project Vision as their own. That includes everybody from the operators to the Board. The managerial challenge was to secure full commitment and support for a totally new concept."

Technological Challenges: "New industrial culture, new challenges call for new technologies. We have to accept the environmental issues as an integral part of our process."

Economic Challenges: "We are in business to be profitable. We have to find the harmony between environmental and business responsibilities."

Chaparral Steel Company: By-product Synergy through Zero Waste/100% Product Steelmaking

Chaparral Steel Company, located in Midlothian, Texas, owns and operates a technologically advanced steel mill that produces bar and structural steel products by recycling scrap steel. Chaparral's facilities and operating philosophy reflect the latest worldwide advancements in electric arc steel making. Chaparral Steel is a publicly traded company, 84% owned by Texas Industries, Inc. (TXI), a large cement producer.

Chaparral is committed to incorporating new technologies intended to provide the best quality products at internationally competitive prices. In addition, the company considers itself to be a world-class recycling facility. Chaparral produces steel using the most stringent environmental controls and seeks to be at the leading edge of environmental technology.

Chaparral Steel's initial production of 228,000 tons in 1976 grew to 1.6 million tons in 1995. In 1992, a large beam mill was completed, further expanding the company's capacity and product range. Chaparral now has two electric arc furnaces with continuous casters, a bar mill, structural mill, and a large beam mill that enables the company to produce a broader array of steel products than traditional mini mills.

Chaparral's steel products include beams, reinforcing bars, special bar quality rounds, channels, and merchant quality rounds. These products are sold primarily to the construction industry and to the railroad, defense, automotive, mobile home, and energy industries. Chaparral's principal customers are steel service centers, steel fabricators, cold finishers, forgers, and original equipment manufacturers in North America, Europe, and Asia.

Chaparral's primary source of scrap steel is old automobiles. To recycle this material, an automobile shredder facility, the largest and most productive in the world, is located next to the mill.

The shredder operation provides Chaparral with a competitive advantage in the acquisition of raw material. In 1996, the shredder transformed over 700,000 tons of old cars and other light scrap into raw material. This volume represents about 40% of Chaparral's total scrap needs (the remainder is purchased). Chaparral intends to increase the volume of material processed through the shredder in order to expand on the competitive advantage it provides.

Scrap is melted by two computer-assisted ultra high powered electric arc furnaces (EAFs). The EAFs are complemented by two high-efficiency ladle furnaces that ensure the high productivity and quality of the steel.

Wastes and by-products from Chaparral's steel making process include three significant ferruginous streams: EAF slag, mill scale, and baghouse dust. In addition, auto shredder residue, non-ferrous particulate, and spent refractories are produced in the process.

For years, mill scale has been recognized as a by-product that can be sold as a source of iron oxide to portland cement producers. In the early 1990s, its experience with mill scale inspired Chaparral to ask: "Are there opportunities for other wastes, or by- or co-products to be used as replacement for raw materials in the cement industry? Or in any other industry?"

The STAR Project

When Chaparral recognized that these wastes and by-products were candidates for by-product synergy and other pollution prevention measures, its "Systems and Technology for Advanced Recycling" (STAR) project was born. Initiated jointly with TXI to organize environmental efforts effectively, the STAR project is dedicated to reducing process wastes, conserving natural resources, and preventing pollution through the environmentally and economically sound recycling of waste materials generated by steel and cement manufacturing.

The mission of the STAR project is to develop synergies between the steel and cement manufacturing processes and the automobile shredding facility, all located in Midlothian, to achieve project goals.

According to Libor Rostik, Vice-President of Technology and Development, "The Chaparral vision is to push the limits of steel-making practice to the point where everything that the steel mill produces, will, in synergy with the adjacent enterprises, be a useful product. The ultimate goal of the project is to achieve zero waste [or 100% product] from the complex through better understanding of the process requirements and application of innovative technology and sound economics."[8]

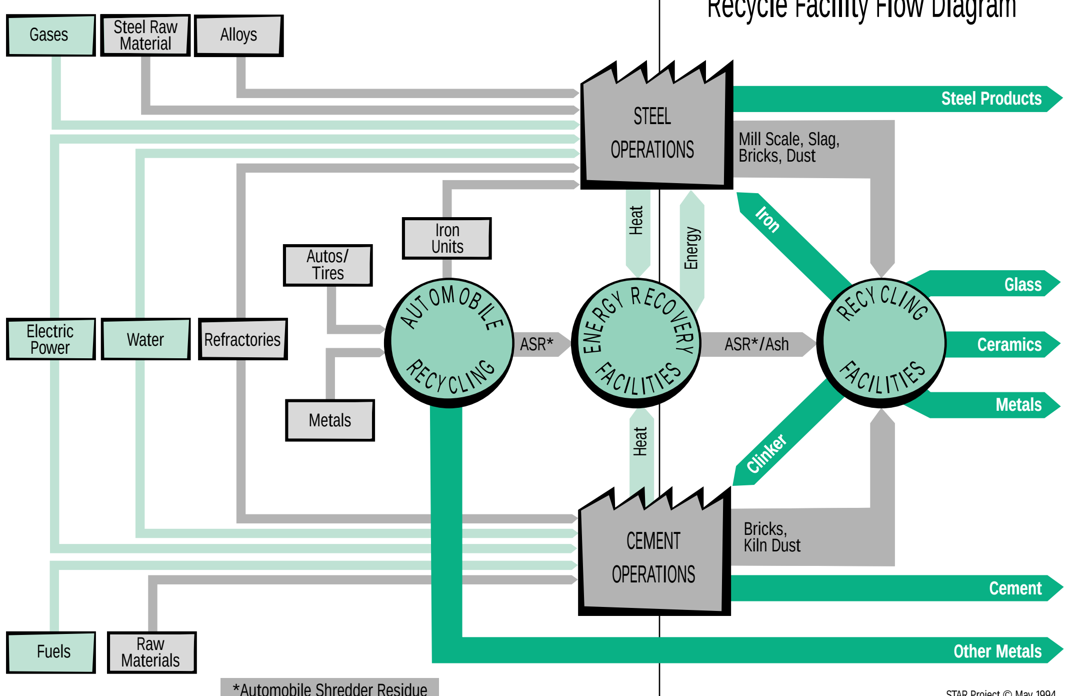
"Chaparral realized early in the STAR project that the company knew "very little about by-product, co-product and waste generation. When we asked ourselves a question—'How much slag, how much mill scale do we produce, and how many tons of landfill waste do we generate?' we got only estimates for an answer. It became clear that without a proper material balance we would not be able to manage this project." says Rostik.

"The principal philosophy is to identify every intake and every output, including

"We are in the recycling business, which is also the steel making business. We are accepting the environmental responsibility for what we do. This responsibility becomes the driving force for innovations and progress. And we make economic sense—to the delight of our shareholders."

"Proper and detailed material and energy balances before and after project implementation will prove the success of the project."

Recycle Facility Flow Diagram



[8]*Zero Waste Electric Arc Furnace Steel Making*, presented by Libor F. Rostik, Vice President, Technology and Development, Chaparral Steel Company, Waste Minimization/ Pollution Prevention Conference, Philadelphia, Pennsylvania, June 1996.

This by-product-to-resource conversion thus conserves natural resources while reducing energy requirements 10-15%. Furthermore, the value of the slag is increased 20 times, relative to its road construction value.

About collaboration, Libor Rostik says, "What is new is a desire to look over the neighbor's fence and develop a spirit of collaboration. The typical posture of 'do not tell me about my business' must give way to multi-industry views."

Chaparral only hires people who are comfortable with ambiguity and change. "Our company employs only people who can be motivated," says Rostik. There is no R&D function separate from production: "Everybody is in research and development," says Gordon Forward, President and CEO.

their quantities, and how much we pay either to purchase it or dispose of it. This exercise goes beyond the environmental concerns. It identifies the process steps and process requirements in such detail that it helps the operating people to become better managers. The overall map will show us the relationships plant-wide and, ultimately, will depict the activities of all three industries in very minute detail."

In the STAR project, Chaparral has successfully applied the principles of by-product synergy to its EAF slag by-product. It is currently exploring a new technology to achieve by-product synergy for its automobile shredder residue that is expected to expand to other applications. Other creative ways in which Chaparral recycles and reuses material or reduces pollution involve refractories, water, energy, mill scale, and kiln dust resulting in annual saving of millions of dollars. Some of these efforts are described in more detail below.

EAF Slag as a Resource for Cement Production: The CemStar Process

In 1993, Gordon Forward, Chaparral Steel's President and CEO, looked over his neighbor's fence and discovered a partner for EAF slag in TXI's adjacent cement plant. A joint team of operating, technical, and management personnel—including both Forward and Robert D. Rogers, TXI's president—collaborated in an effort to use the slag by-product produced by Chaparral as a resource for TXI's cement operations.

The result of this collaboration was "CemStar," a patented process that adds slag to the cement raw material mix, thereby yielding larger batches of high-quality Type I Portland cement without compromising its characteristics. Before this innovation, slag was cooled, crushed, and sold, generally to the road construction industry.

The upgraded slag magnetic separation process allows lower grade metallics to be recovered and recycled back to the furnace. The lower-grade iron slag is fed into the cement plant kilns, serving as a substitute for limestone. This by-product-to-resource conversion thus conserves natural resources while reducing energy requirements 10-15%. Furthermore, the value of the slag is increased 20 times, relative to its road construction value.

By increasing production capacity 9% in fiscal year 1995, CemStar has proven profitable as well. It has already produced several million dollars of pretax income for TXI's two cement plants on an investment of less than $1 million.

TXI believes that most cement kiln capacities can be increased 5-15% with a very small capital investment and very low incremental costs. While cement consumption now outpaces production, new plants are prohibitively expensive and time-consuming to build. TXI now plans to collaborate with other by-product synergy partners by licensing the process to other domestic and international cement producers for a royalty, with TXI providing the equipment, technical assistance, and, in some cases, the raw material.

The financial aspects of this project have also been well received on Wall Street. According to the September 18, 1996 issue of the *Wall Street Journal*: "CemStar, says Value Line's Mr. [Thomas] Plant, 'really accentuates the synergies between TXI and Chaparral Steel,' which accounts for two-thirds of the company's operations. Mr. Plant gives TXI stock Value Line's highest rating... 'With a situation like CemStar evolving, this could provide some meaningful increases to the bottom line.'"

A very significant benefit of the CemStar process is that its application reduces overall carbon dioxide (CO_2) production from the cement-making process. TXI therefore sees business opportunities for this technology in emission credit trading.

Eighteen months of theoretical studies, practical tests, and economic evaluations were required to prove that CemStar was indeed a viable by-product synergy project.

By-product Synergy for Automobile Shredder Residue and Beyond

Automobile shredding is an integral part of Chaparral's operations. About 700,000 obsolete cars are shredded every year, generating over 180,000 tons of residue that is currently landfilled. This residue stream includes aluminum, magnesium, glass, polyvinyl chloride (PVC), and rubber, as well as non-chlorinated plastics and other non-ferrous metals. In this stream, Chaparral recognized another opportunity for by-product synergy.

In 1990, Chaparral installed a sophisticated Automobile Scrap Residue (ASR) cleaning system, based on eddy current technology, to reduce the amount of ASR that must be landfilled. In a follow-up move in 1996, the company purchased exclusive rights to an innovative flotation separation technology after pilot tests indicated that Chaparral's ASR could be *economically* separated into essentially pure components. Unlike conventional separation by flotation techniques, this technology allows for high throughputs while using very inexpensive flotation media.

This capability means that the non-chlorinated plastics, rather than being landfilled, instead may be used as a highly efficient and clean fuel source. In fact, this technology will allow profitable mining of plastics from municipal landfills in the future. In addition, the separation process will yield aluminum, magnesium, and other materials so clean that Chaparral hopes to attract other processing facilities to its Midlothian site.

The facility, which is being constructed on the grounds of the steel mill, is expected to be operational by July 1997. The economic benefits are substantial. The sale of non-ferrous metals will pay for the plant in less than one year. The sale of clean plastics will generate revenues of up to $500,000 per year.

This technology may be applied, not just to ASR, but to a variety of waste streams from many different processes. Chaparral plans to market this capability throughout North and South America. As a result of its commitment to by-product synergy, Chaparral has identified a new business venture that promises to be very profitable while reducing the environmental impact of multiple industries.

This prospect has gained the support of the regulatory community. In a recent meeting with the Texas Natural Resource Conservation Commission (TNRCC) to describe this technology, the Commission offered not only to streamline the permitting process for these operations but to help Chaparral identify potential applications for this technology—a perfect example of industry-government collaboration. Rostik states, "The separation technology will revolutionize the recycling of obsolete automobiles. We are working very closely with all major automobile companies and their vehicle recycling partnership (VRP), and with the American Plastics Council (APC). This synergy will advance the recyclability of an automobile and further contribute to the environmental goals of automobile manufacturing worldwide."

This capability means that the non-chlorinated plastics, rather than being landfilled, instead may be used as a highly efficient and clean fuel source. In fact, this technology will allow profitable mining of plastics from municipal landfills in the future.

The CemStar project team was made up of people from all levels of both organizations—from presidents and vice-presidents to operations managers and operators. Rostik observes, "Creation of a dedicated team obliterates any problems related to two different company structures and cultures."

According to Rostik, "Environmental education and concern must become part of the company culture. The initial push came from the top. Results were achieved when roots were formed. It starts with a few visionaries but has to end with grassroots." This climate has fostered the innovation required to make by-product synergy successful.

Observations and Lessons Learned from Industrial Symbiosis Projects

David Cobb of Bechtel's Technology and Consulting Services, San Francisco, is project manager of the Brownsville project. He offers the following observations and "lessons learned" as a result of working toward by-product synergy.

"In discussions with industries about industrial symbiosis (IS), the focus should be on cost savings and easier permitting, rather than concentrating on environmental or socioeconomic benefits of industrial ecology."

"Some industries were at first reluctant to release waste stream data. Non-disclosure agreements alleviated this for the most part. Other industries do not yet see real economic advantages to materials exchanges. We hope that the IS tools and developed IS scenario will reveal multiple specific and quantified examples of such savings."

"BEDC staff have been most helpful in gaining industry cooperation. They were assisted in initial data gathering activities by Texas A&M staff. Their initial focus on pollution prevention proved counterproductive but a later focus on materials flows worked well."

The Bechtel Corporation: By-product Synergy through Industrial Symbiosis in the Brownsville, Texas Region

The Bechtel Corporation, a BCSD-GM member, provides technical, management, and directly related services to develop, manage, engineer, build, and operate installations for customers around the world. Since 1989, Bechtel has worked on more than 15,000 projects in 140 nations. Industries served include power, petroleum and chemicals, transportation, buildings, water supply and treatment, infrastructure development, pipelines, mining and materials, pulp and paper, advanced technology, environmental remediation, manufacturing, and telecommunications. At the end of 1995, Bechtel was working for 580 clients on almost 1,000 active projects and studies, some of which involve sustainable development.

The Brownsville, Texas Eco-Industrial Park (EIP) project is a community effort sponsored by the Brownsville Economic Development Council (BEDC), and supported by Bechtel, to promote industrial development in a way that minimizes industry's effect on the environment through increased manufacturing efficiency. The goal is to develop a workable community of manufacturing and service businesses in the Brownsville/Matamoros, Mexico region that enables companies with by-products and throw-away wastes to find other companies that might use these materials as raw materials—in other words, to practice by-product synergy.

By orienting companies to look at wastes as commodities to be sold or recycled, the eco-industrial park promises to boost companies' financial performance while reducing the demand for virgin feedstock materials, minimizing the cost of treatment and disposal of wastes, and reducing the adverse environmental effects of industrial development.

The Brownsville project will have two components: a physical site where companies can be located near one another and a virtual site where industries already in Brownsville/Matamoros can exchange materials without having to relocate. A strong candidate for the eco-park site is a brownfield at the Port of Brownsville that offers easy access to the port channel and the area's highway network, and is close to the existing industrial base and the international bridges leading to Mexico.

To reduce regulatory barriers to transporting materials involved in exchanges or recycling, regulatory innovation will be sought under the EPA's Project XL, a national pilot program in which EPA grants regulatory flexibility for innovative environmental projects.

With assistance from the Lower Rio Grande Valley Development Council, the BEDC and the City of Brownsville received a grant for a feasibility study in September 1995 from the U.S. Department of Commerce.

The preliminary research involves assembling a database of industries in the Brownsville area and identifying their input and output streams, production processes, disposal costs, and utility requirements. The industry database, being assembled by the Texas Engineering Extension Service (TEEX), will be used with a computer planning model, developed by Bechtel, to match industries by linking feedstock requirements with byproducts and waste streams.

Bechtel's planning model can be used to search the database to identify multiple possible materials exchange links within the Brownsville/Matamoros region. This regional IS will allow potential collaboration partners to be identified. The database includes both local existing industries (to identify current opportunities) and nonlocal industries (to identify potential opportunities that may attract new industries).

According to David Cobb, Bechtel "came up with the idea for IS planning tools when it became apparent that complex materials exchange webs will not likely "evolve" pair by pair. (Early participants will likely make their own deals with suppliers/receivers and agencies to allow them to get up and running. This reduces the incentive to modify practices later even though new opportunities arise.) Industrial designers need to be able to picture a "mature" materials exchange web up front. Tools to lay out these systems do not exist. Bechtel is developing them."

This research is expected to result in a workable IS scenario that BEDC can develop and market to regional participants and eco-industrial park tenants. The BEDC will take the lead in contacting local and new industries for whom materials exchange may be attractive.

The first IS scenarios, completed in late 1996, focus on mass flow and technical feasibility. Regulatory feasibility, cost/value analysis, and consideration of alternative process technology will be reflected in the final IS scenarios to be ready early in 1997.

The final IS scenario will help the BECD identify potential candidate industries and will help participants evaluate the risks and benefits of participating in a regional IS. It also will aid in identifying redundant suppliers of materials and receivers of wastes and byproducts, and will encourage innovative and accelerated regulatory solutions.

After the feasibility study has been completed, the BECD will understand what it will take to implement an eco-park in Brownsville in terms of facilities requirements, development costs, and the park's management structure. TNRCC will assist with the Project XL application to the EPA. In addition to BEDC and the City of Brownsville, the proposal is supported by the Port of Brownsville. "Profitability will be tracked internally by participants. The usual challenges to tracking environmental costs/ benefits exist. Bechtel will assist participants in developing accounting systems that more realistically track these costs," according to Cobb.

The next U.S. project for Bechtel is the development of a regional redevelopment plan, based on IS, that addresses the needs of a depressed industrial city in New England. This will involve increasing the utility and sophistication of the Brownsville tools, expanding the database, establishing a regional materials exchange brokerage, and providing planning services to regional communities and industries. A team consisting of city and regional planners, a major university, and other interested parties is now planning this project.

Overseas Bechtel projects for which IS is being planned include major industrial developments, an airport light industry park, several new cities, urban redevelopment, and integration of new industrial projects into existing communities.

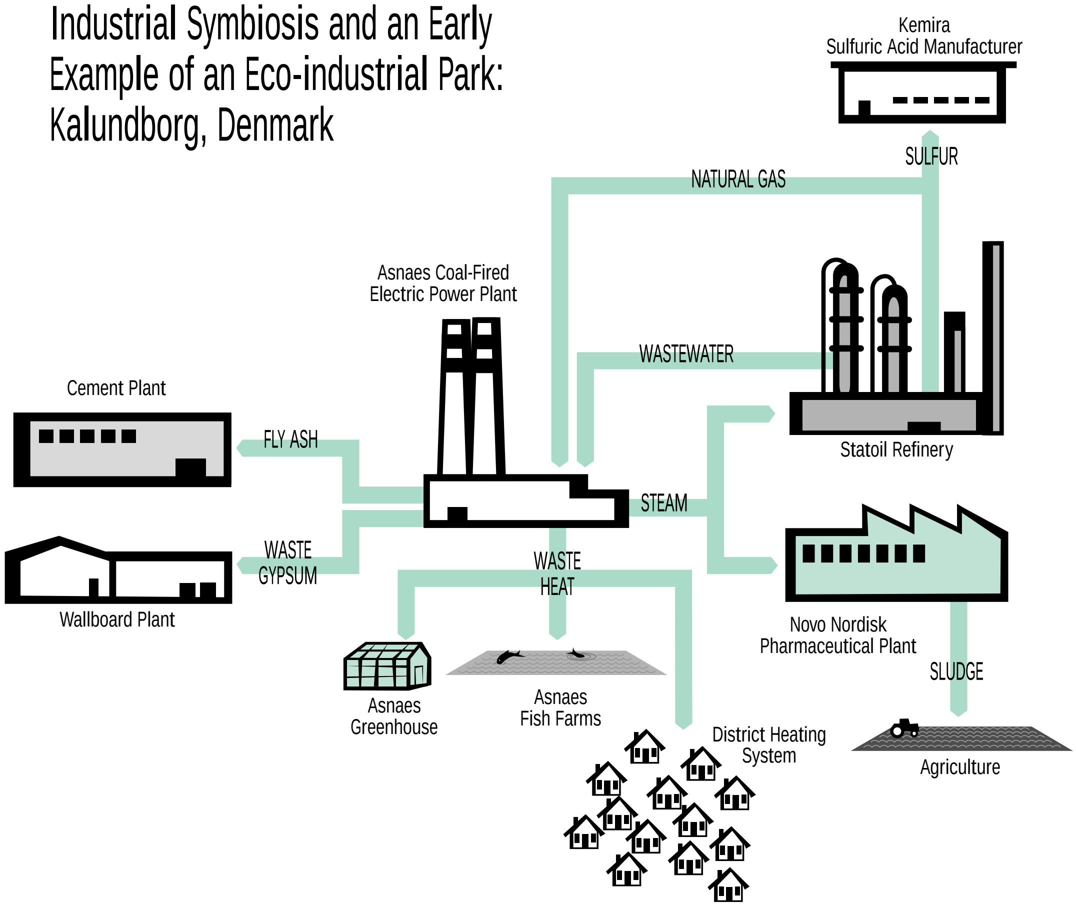
"We emphasize that the IS scenarios are intended to help individual participants make their own evaluations and come to their own conclusions. It is very important to consider the IS scenario as a planning tool, not a master plan. Detractors of the IS planning approach see it as the latter and back away."

"Communication was not always easy because of the greater interest in eco-parks compared to regional exchanges. Most interest has come from overseas developers whose vision is often of broad regional projects, most with difficult socioeconomic challenges that respond well to an IS approach. Bechtel feels that the 'eco-park' concept is unnecessarily restrictive, although such 'parks' may be a reasonable component of a much broader regional plan."

Internal Barriers: *"Materials exchange was viewed as having a strong 'green' base. It was necessary to demonstrate the potential economic benefits in order to effect really large-scale participation. Also, the planning tools needed to evaluate and demonstrate the consequences of large-scale materials exchange until recently have simply not existed. Lastly, the industry input/output/utility data necessary to drive such planning tools did not exist in a form that permitted systematic evaluation."*

External Barriers: *"Proponents focus on 'green' aspects rather than on economic incentives. There is a pervasive 'field of dreams' attitude that anything this good just 'has to happen.' Some have a misconception that a complex materials exchange web can evolve in the absence of a detailed vision of the overall make-up of the system. The severe constraints represented by lack of redundancy in both suppliers and receivers of materials streams potentially available to participants are not appreciated. Tools needed to identify these redundancies are unavailable."*

Industrial Symbiosis and an Early Example of an Eco-industrial Park: Kalundborg, Denmark



The eco-park concept probably first came widely to attention in "Industrial Ecology: An Environmental Agenda for Industry," a monograph by Hardin Tibbs, that told the tale of an IS in Kalundborg, Denmark, where a series of businesses formed a complex network of waste and energy exchange.

The Asnaes coal-fired electric power plant supplies steam to the Novo Nordisk pharmaceutical plant and the Statoil refinery, and waste heat to a district heating system serving 3,500 homes. The refinery removes sulfur from its natural gas, selling it to Kemira, a sulfuric acid manufacturer, resulting in a cleaner gas that is in turn bought by Asnaes. Asnaes sells fly ash to a cement plant and waste gypsum to a wallboard plant, and uses still more waste heat in the greenhouses and fish farms it operates. Sludge from Novo Nordisk becomes fertilizer for local agriculture, and refinery wastewater feeds the power plant.

Still successfully operating today, the Kalundborg eco-industrial park is viewed as a classic example of the IS approach to by-product synergy.

The Practice of By-product Synergy: A Case Study

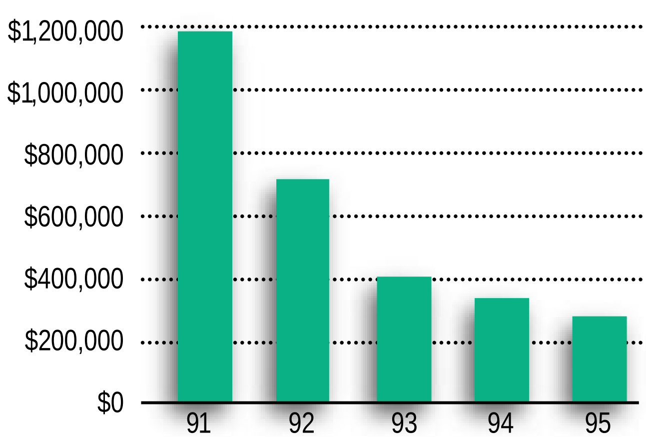
Florida Power & Light: By-product Synergy through Reclamation and Salvage

FPL Group, Inc. is the parent of Florida Power & Light Company (FPL), one of the largest investor-owned electric utilities in the United States. FPL serves 7 million people, or about half the population of Florida, in an area covering almost the entire eastern seaboard and southern third of the state. This region continues to experience strong growth, driven by Florida's tropical climate, natural beauty, and excellent quality of life. FPL Group's other operations include ESI Energy, a participant in the growing independent power business, and Turner Foods Corporation, one of the largest citrus producers in Florida.

For FPL, responsible environmental stewardship includes taking an active role in the development and application of sustainable development policies on the corporate, regional, and national levels. FPL's commitment to this policy at the corporate level is demonstrated by activities such as by-product synergy, pollution prevention, waste minimization and recycling efforts, and energy conservation/renewable energy programs.

Numerous by-product synergy and pollution prevention programs, including waste minimization and recycling initiatives, have been in place for several years at FPL locations system wide. Through these activities, and those of FPL's chemical standards and review board, FPL's fossil-fueled plants reduced the quantity of hazardous wastes generated from 145 tons in 1986 to just 41 tons by 1991. This was accomplished through product substitutions and segregation of waste streams

FPL Disposal Costs: A 77% Reduction from 1991-1995



Observations and Lessons Learned Through FPL's Reclamation and Salvage Projects

To ensure participation from the top down, FPL hired a full-time recycling coordinator in 1992 and created a waste minimization team to reduce waste volume and cost while increasing recycling efforts.

Through education and communication, employees have reduced waste using double-sided copying, electronic mail, and recycling.

FPL's Procurement Department has made significant contributions to reducing waste by collaborating with vendors to reduce packaging requirements and ordering materials with recycled content when possible.

To communicate the benefits of by-product synergy and other efforts, the waste minimization team circulates recycling awareness material. Items include posters, quarterly recycling statistics, annual video, newsletter, and a continually updated user's manual on the items to recycle.

To motivate its employees to participate, the Corporate Environmental Department sponsors a program that awards cash bonuses to employees for ideas and practices that have a positive environmental impact on the company.

According to Scott Freeburn, Recycling Coordinator at CRS, "There are still a lot of other things in our trash that we're looking to find new and creative ways to use or sell. Recycling is growing in a big way, and that means everybody wins—FPL, its customers, shareholders, and the communities we serve."

In a letter to FPL after a benchmarking visit to CRS, a municipal utility representative wrote, "We had heard about your operation during a visit to Kansas Power & Light. I was extremely impressed with their recycling center and the fact that they have generated over two million dollars. When I stated they had to be the best in the nation, they felt that your *company was on the cutting edge. During our recent visit, I learned why they felt that way. Your employees did not hesitate to share their recycling knowledge, which was quite extensive. The thing that impressed me the most was the way they all tried to encourage criticism and/or ask us to discuss what we felt might be weak points. Your company involves everyone in the recycling process. Could this be why your company has managed to advance so rapidly and so far ahead of the other recycling programs? This was the second benchmarking trip...that I have been involved in, and I must say that your company has a lot to be proud of."*

to avoid contaminating non-hazardous wastes with hazardous wastes.

Recycling is also a priority activity at FPL. In 1981, FPL's Central Reclamation and Salvage Department (CRS) was created to process scrap wire and cable. The CRS has since grown from a five-person scrap wire operation to a 50-person recycling center.

Each day, 17 FPL trucks drive throughout the state, bringing back materials from 72 locations: scrap cable and wire, waste wood, plastics, porcelain, concrete, paper, cardboard, toner cartridges, scrap pole line hardware, street lights, light bulbs, lead acid batteries, scrapped transformers, aerosol cans, and other types of scrap equipment and materials. Every FPL facility participates in the recycling program and each employee has an opportunity to recycle the materials in his or her workplace.

In 1994, FPL recycled 11 million pounds of metal, 5.1 million pounds of wood, 1.9 million pounds of paper and cardboard, 600,000 pounds of porcelain and concrete, 220,000 pounds of PVC, and 21,000 pounds of plastic stretch wrap. FPL's recycling activities are also estimated to indirectly reduce over 100,000 tons annually of greenhouse gas emissions.

FPL has worked to reduce costs for disposal of this scrap material from $1.2 million in 1991 to $281,000 in 1995, a 77% savings. Even more impressive is the revenue generated from these activities—$2,770,000 in 1994. CRS currently generates $1.8 million in profits annually, and expects to add $600,00 annually through new projects.

The two projects highlighted below are excellent examples of by-product synergy as practiced by FPL.

Scrap Porcelain and Concrete as Road Fill

Large quantities of porcelain, a waste stream somewhat unique to the utility industry, are generated from old insulators and electric equipment with porcelain bushings. FPL was sending this waste, together with scrap concrete from cracked transformer pads, pole guards, and old chambers, to a landfill at a rate of over 1,000 tons per year.

Three years ago, FPL's Corporate Recycling Coordinator, Scott Freeburn, recognized that the material might be useful in road construction. FPL contacted Eakins Construction Company. Eakins was interested, but did not want metal in the stream. FPL brokered an arrangement with a scrap dealer to pay Eakins for the scrap metal. One week later, after testing the porcelain/concrete blend, Eakins agreed to the partnership. Eakins now crushes the material and sells it to roadbuilders.

This project has reduced FPL's landfill costs by hundreds of thousands of dollars a year. Because the material is donated by FPL, it has reduced Eakins' raw material costs and provided a source of revenue through the sale of both the crushed porcelain/concrete blend and the scrap metal. And of course, significant amounts of landfill space are conserved.

Scrap Wood as Fuel for Sugar Mills

FPL was sending over 500 tons a year of untreated wood products such as damaged pallets, dunnage, and old spools to a landfill. Recognizing the potential fuel value of this wood, FPL approached a local sugar mill, Okeelanta Sugar Corporation, with the idea of burning the wood in boilers to provide process steam for sugar production. After testing the wood, which FPL mulched in a tub grinder, Okeelanta agreed to FPL's price and another successful by-product synergy collaboration was born.

FPL has not only eliminated its landfill costs for the scrap wood, but has converted this waste stream into a revenue source by selling it. In addition, significant amounts of landfill space are again conserved.

FPL's Other By-product Synergy and Pollution Prevention Projects

- Conversion of scrap wire insulation to fuel for the solid waste authority through burning;
- Conversion of used stretch wrap to a resource for a plastic lumber product made by Mobil Chemical;
- Return of wire reels to manufacturers for reuse;
- Refurbishment and reuse of hardware and equipment in lieu of scrapping;
- Testing and resale to Third World countries of old street lights and sodium bulbs that still have additional life but no longer meet U.S. specifications, thereby avoiding expensive and unnecessary disposal;
- Cleaning, granularizing, and sale of scrap PVC, polyethylene, and polycarbonate for reuse;
- Consolidation and use of unwanted paint, solvents, and degreasers;
- Harvesting and sale of aluminum and copper wiring from surplus transformers; and
- Donation of usable wood poles to local farmers for fencing.

1995 Distribution/Power Delivery Recycling Totals

Reclaimed Metals:	10,574,653 lbs.
Paper:	1,019,842 lbs.
Cardboard:	737,564 lbs.
Scrap Wood:	5,114,947 lbs.
Scrap PVC:	49,930 lbs.
Stretch Wrap:	21,540 lbs.
Scrap Porcelain & Concrete:	1,140,000 lbs
Refurbished Pole Line Hardware:	$218,492
Toner Cartridges:	1,818
Poles Back Hauled:	485
Used Oil Burned at Fuel Terminals:	234,609 gallons

Scrap plastic

Wire reels

The profitable conversion of by-products and wastes to resources requires creative collaboration among generators and consumers.

The Principles of By-product Synergy

Through the kinds of practical experience described in these case studies, BCSD-GM members have identified six fundamental principles for achieving success in by-product synergy: *collaboration, motivation, communication, innovation, participation,* and *evaluation*. Applying each of these principles does not mean that you'll succeed in overcoming all the barriers you may encounter, but neglecting these principles can lead to failure.

Collaboration

The profitable conversion of by-products and wastes to resources requires creative collaboration among generators and consumers. Whereas traditional pollution prevention activities focus on reduction, reuse, and recycling within a process, by-product synergy takes pollution prevention "beyond the fence-line" between different processes.

By-product synergy can occur:

- Among different organizations;
- Within an organization, but among different business or operating units; or,
- Within a business or operating unit, but among different process units.

By-products and wastes may be converted to resources by partners in one:one, one:many, or many:many relationships. Potential partners in by-product synergy project collaboration may be businesses, community organizations, and government agencies.

Motivation

"By-product synergy is successful not because of the technology, but because of the psychology," according to Andy Mangan, Executive Director of the BCSD-GM.

Because it crosses organizational boundaries and requires a change in the status quo, by-product synergy may be met with negative reactions including skepticism, cynicism, and anxiety. For a collaboration to be successful, all project stakeholders at all organizational levels must be motivated to support it.

Motivating people requires changing the organizational culture from one that resists change to one that embraces it. This change in culture must start at the top with the attitude of the organization's senior leadership.

Communication

To succeed with by-product synergy, good communication among all project stakeholders—businesses, communities, and government agencies—is essential. To identify, evaluate, and implement by-product synergy projects, information on the following topics must be freely 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.

Innovation

To overcome the numerous barriers to successful by-product synergy projects, innovation is often required, from the invention of new conversion technologies to the creation of strategies for overcoming regulatory disincentives and other barriers.

Participation

Successful by-product synergy requires active participation throughout the collaborating organizations, from CEO to factory floor worker, community leader to citizen. All organizational levels should be involved in identifying, evaluating, and implementing the project to ensure that all potential barriers to success are identified and overcome.

Evaluation

A by-product synergy project must be evaluated throughout its life cycle—before, during, and after implementation—to ensure that the economic, environmental, and social objectives of the project are being achieved. If not, corrective action must be taken.

To succeed with by-product synergy, good communication among all project stakeholders—businesses, communities, and government agencies—is essential.

The Problems of By-product Synergy

By-product synergy can be profitable as well as environmentally and socially beneficial, but it isn't always easy to achieve. Since it is better to understand potential problems early in the process, the BCSD-GM has identified numerous barriers you may encounter, including technical, economic, geographic, regulatory, legal, business, social, time, and informational ones.

Each project will have its own unique set of barriers. Although the BCSD-GM cannot offer specific guidance for every situation, we do believe that your chances of success are better if you understand the general by-product synergy principles that you should apply to overcome these barriers. The following table summarizes these guidelines.

By-product Synergy Barriers and Principles Needed to Overcome Them

Barrier Type	Question	Recommended Principles to Address Question
Technical	Is conversion of the by-product to the resource technically feasible?	Process technical experts should **participate** in project planning/implementation. All technical options should be **evaluated** (including patented processes). **Innovation** should be encouraged to develop new conversion processes.
Economic	Is conversion of the by-product to the resource economically feasible?	*True* project economics should be **evaluated** using life-cycle cost analysis and full-cost accounting tools.
Geographic	Can the by-product be safely and economically transported from its generator to its consumer?	Transportation options and economics should be **evaluated**.
Regulatory	Is transportation or use of the by-product regulated? Will the use of the by-product as a resource lead to additional regulation of the process (for example, by adding trace contaminants to the process)?	Potentially applicable regulations should be **evaluated** to identify issues. Regulatory experts should **participate** in project evaluation. There should be **communication** and **collaboration** with legislators and government agencies to achieve regulatory relief if necessary. **Innovation** is needed to create strategies for dealing with regulatory issues.

Barrier Type	Question	Recommended Principles to Address
Legal	Could the use of a "waste" in the process lead to increased liability? Is transportation or use of the by-product prohibited?	Potentially applicable laws should be **evaluated** to identify issues. Legal experts should **participate** in project evaluation. There should be **collaboration** with partners to share or reduce liability risks.
Business	Could the project lead to a loss of competitive advantage? Are partners willing to make a long-range commitment to the project? Is project funding available? Are reliable markets available for products produced via by-product synergy?	The competitive situation and market potential should be **evaluated.** Partners should **collaborate** to 1) protect intellectual property through patents, trade secrets, and other methods; 2) make long-range commitments through negotiated contracts; and 3) secure funding. **Innovation** is needed to identify new markets, alternative sources of funding, create unique business alliances, etc.
Social	Does the public mistrust the motives of the organizations involved in the project? Does the public have "Not in my back yard" syndrome? Will the public resist the purchase of products produced from "waste"?	There should be **communication** with community leaders and citizens about the project, emphasizing its environmental and social benefits. Where feasible, business, government, and communities should **collaborate** on projects.
Time	Is by-product synergy a low priority in the organization?	Employees/citizens should be **motivated** by senior organizational leadership to make by-product synergy a priority using performance goals and measures, and other incentive programs.
Informational	Is information about candidate by-product and resource streams available? Is information about potential partners available? Is information about conversion technology available?	Employees/citizens should be **motivated** by senior organizational leadership to increase availability of information using performance goals and measures, and other incentive programs. Potential partners and other stakeholders should **communicate** and **collaborate** to increase availability of information.

"...if there is a safe way to...sell [phosphogypsum]...or export it for profit, then the Florida economy and environment could be improved."

Tampa Tribune
September 9, 1994

Barriers to By-product Synergy: A Case Study

The following case study describes the Florida Phosphate Council's (FPC's) ongoing efforts to overcome regulatory barriers to by-product synergy projects involving phosphogypsum, an abundant by-product of the wet-process phosphoric acid fertilizer industry. This case was brought to the attention of the BCSD-GM by member company Florida Power & Light. Although FPC has not yet been successful, this example illustrates that, along with applying the principles of by-product synergy, patience, persistence, and perseverance are often required to make projects work.

Regulatory Barriers: Phosphogypsum in Florida

The Central Florida phosphate industry, one of the world's largest phosphate fertilizer producers, annually produces over 30 million tons of phosphogypsum, a by-product of wet-process phosphoric acid fertilizer production. Since 1979, the Florida Institute of Phosphate Research (FIPR), a state organization charged with "doing or causing to be done" phosphate-related research that can benefit the industry, the state, and the environment, has been actively developing uses for phosphogypsum. FIPR and other organizations believe they have demonstrated that phosphogypsum may safely and economically be used in building and road construction, agriculture, tile manufacture, and other applications.

However, in 1989, EPA imposed a ban on phosphogypsum use under the National Emission Standard for Hazardous Air Pollutants (NESHAP) because of concerns about $radium^{226}$, a radioactive isotope that occurs naturally as a trace element in the phosphate rock used to manufacture phosphogypsum. $Radium^{226}$ decays to radon gas, a potential carcinogen.

EPA's decision was based on what many believe was an overly restrictive interpretation of the then-available research results. Unfortunately, as a result of the ban, over 600 million tons of phosphogypsum are currently stockpiled in Florida alone and the stacks are growing at a rate of over 30 million tons each year. The fertilizer industry incurs significant expense to store phosphogypsum in vast storage fields, or "stacks." The phosphogypsum is transported to the stack in a slurry containing acidic process water. Eventually, the stack is closed by: 1) transferring the process water that collects on top of the stack to a recirculation system; 2) filling and grading the top surface; 3) capping it with a polyethylene liner; and 4) covering it with top soil and grasses (see photo at right).

To overcome this significant regulatory barrier to by-product synergy, the TFI and the FPC have been working diligently with industry members, business leaders, scientists (including the FIPR), government officials, environmentalists, farmers, and other private citizens with an interest in exploring environmentally and economically sound uses of phosphogypsum. The *Tampa Tribune* editorialized on September 9, 1994 that "...if there is a safe way to...sell it...or export it for profit, then the Florida economy and environment could be improved."

The following activities are now underway:

- The FPC has formed a Phosphogypsum Research and Utilization Task Force to provide public support for environmentally sound uses of phosphogypsum.

- TFI, the FPC, and the FIPR have met numerous times with EPA over the past two years to discuss this issue. In an April 5, 1995, letter to Carol Browner, EPA Administrator, David L. Batt, President of the FPL, wrote, "Having been with you on a number of occasions when phosphogypsum was discussed, including at the top of two phosphogypsum stacks, I know that you understand what is at issue. I urge you to expedite the reconsideration of the EPA ban. Within a few months, the State of Florida should have completed its compilation of scientific evidence to demonstrate the desirability and safety of using phosphogypsum to the fullest extent possible. I truly hope that EPA will be ready by then, if not sooner to fully concur." TFI has challenged the prohibition in federal court (TFI v. EPA, D.C. Circuit Court No. 92-1320.) According to G. Michael Lloyd, Jr., Research Director, Chemical Processing for the FIPR, some progress has been made with EPA. "It appears that an EPA-suggested approach may eventually allow the use of phosphogypsum in road building." At an EPA public hearing on August 1, 1996, to receive comments on a proposed rule to partially relax the standards, Jerome Guidry, a health physicist from Orlando, FL, said the risk of using phosphogypsum in this application is minimal. He compared it to being the same as "one pound overweight."
- The FIPR, together with a Canadian consulting firm, is evaluating the risk assessment methodology originally used by EPA in making the phosphogypsum ban decision. It believes that current risk assessment methodology will clear the way for the use of phosphogypsum in agriculture.
- Kai David Midboe, former director of the Louisiana Department of Environmental Quality, is attempting to form a nationwide Association of Phosphogypsum Affiliated Industries, a coalition of stakeholders from the 12 states that have stacks of phosphogypsum, to develop and present a compelling case for EPA to reevaluate the ban.

In a recent letter to the BCSD-GM, Mr. Lloyd of the FIPR observed, "We believe our experience has shown that regulation can be and often is the single greatest deterrent to innovative by-product utilization. We hope you are successful in prompting a more balanced evaluation of new approaches that can solve real problems."

Only time will tell whether these activities are successful in lifting the phosphogypsum ban.

Closed phosphogypsum stack

The Process of By-product Synergy

In this primer, you have learned about the principles and the problems of by-product synergy; and seen some concrete examples of increased profits and reduced pollution through its practice. But how do you do it yourself? The overall process of by-product synergy is outlined in the following table.

While the phases and many of the steps are the same as those for other process

Steps in the By-product Synergy Process

Phase	Step	Description
Phase 1 Planning/Organization	Step 1.	Obtain organizational leadership commitment to by-product synergy
	Step 2.	Set organizational goals for by-product synergy
	Step 3.	Define individual incentives for supporting by-product synergy
	Step 4.	Raise awareness about by-product synergy
	Step 5.	Form teams for participating in by-product synergy projects
Phase 2 Assessment/Prioritization	*Step 1.*	*Identify candidate waste, by-product, and resource streams*
	Step 2.	*Characterize candidate streams*
	Step 3.	*Identify and contact potential collaboration partners*
	Step 4.	Form joint teams with selected collaboration partners
	Step 5.	Identify technical, economic, geographic, regulatory, legal, business, social, time, informational, and other factors impacting project feasibility and estimate probability of overcoming them
	Step 6.	Do preliminary feasibility studies
	Step 7.	Review results and prioritize potential projects for further evaluation
Phase 3 Evaluation/Decision-Making	Step 1.	Perform detailed feasibility studies addressing technical, economic, geographic, regulatory, legal, business, social, time, informational, and other factors
	Step 2.	Define performance metrics by which project success will be measured
	Step 3.	Determine whether project is viable
Phase 4 Implementation	Step 1.	Obtain project funding
	Step 2.	Develop implementation plan
	Step 3.	Implement project
Phase 5 Monitoring and Improvement	Step 1.	Monitor performance metrics
	Step 2.	Evaluate project performance
	Step 3.	Take corrective action to improve project performance as necessary

Note: Specific guidance is provided in this primer for italicized steps improvement projects, other steps are specific to by-product synergy projects. This section of the primer provides general guidance for carrying out by-product synergy-specific steps involving identification of candidate streams, characterization of the streams, and identification of potential collaboration partners.

Guidance for Phase 2, Step 1: *Identify Candidate By-product, Waste, and Resource Streams*

To identify by-product, waste, and resource streams that may qualify for by-product synergy projects, start with a "50,000 feet view" of the process—a high-level process flow diagram—of the process (see figure) and then begin to "think outside the box."

For each incoming resource stream, *including energy and water*, ask the question:

> *Could the physical, chemical, or energy requirements of this stream possibly be met by a waste or by-product stream from another process—either as-is, or after undergoing some conversion process?*

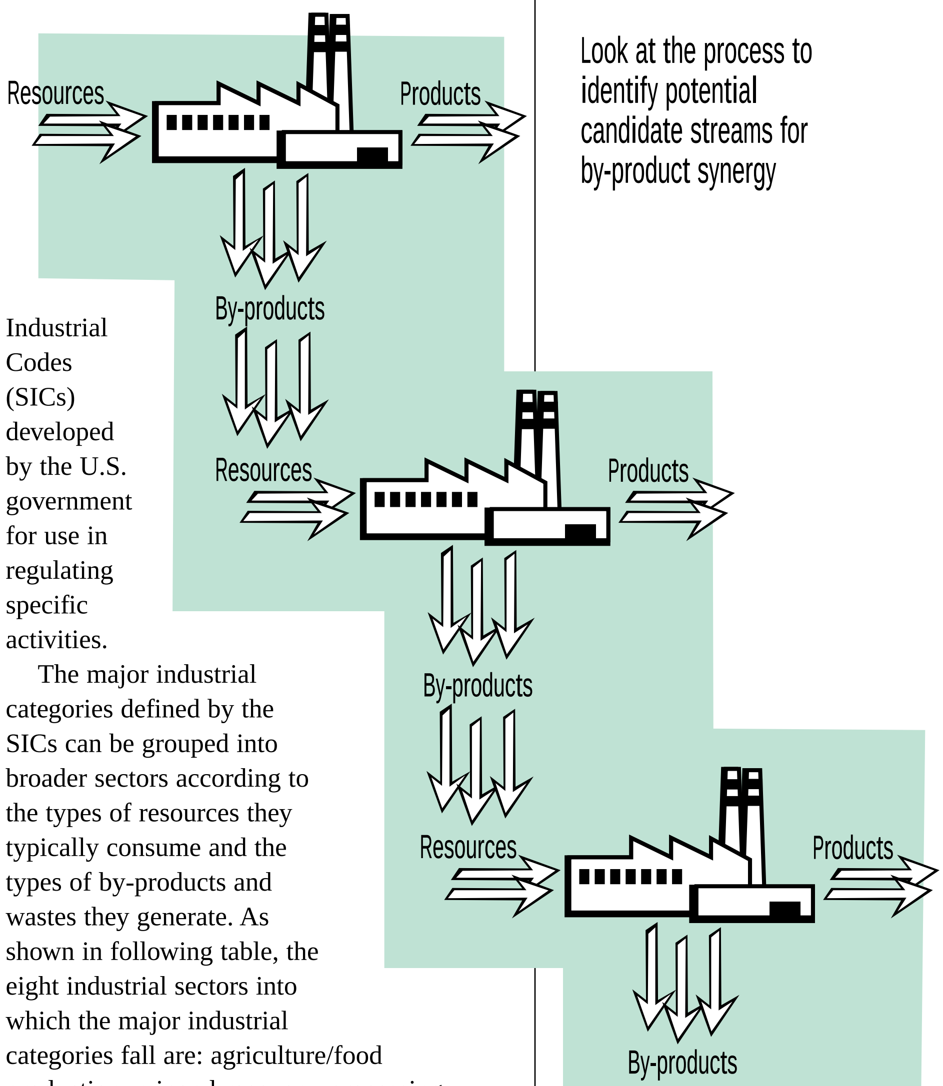
For each exiting by-product or waste stream, *including energy and water*, ask the question:

> *Could the physical, chemical, or energy attributes of this stream possibly meet the requirements of a resource stream for another process—either as-is, or after undergoing some conversion process?*

Unlike traditional pollution prevention activities in which both knowledge of and responsibility for the project reside within the process, by-product synergy projects will lead you into the potentially unfamiliar territory of processes in different industries. Resources like the *Kirk-Othmer Encyclopedia of Chemical Technology*[8] can provide general information on the resource requirements as well as the by-product and waste streams of most process industries.

To provide a starting place in identifying potentially synergistic processes for your project, the BCSD-GM has developed a general model of the structure of the economy based on the Standard Industrial Codes (SICs) developed by the U.S. government for use in regulating specific activities.

The major industrial categories defined by the SICs can be grouped into broader sectors according to the types of resources they typically consume and the types of by-products and wastes they generate. As shown in following table, the eight industrial sectors into which the major industrial categories fall are: agriculture/food production, mineral recovery, processing, transportation, construction, manufacturing, distribution/consumption, and office/clerical work.



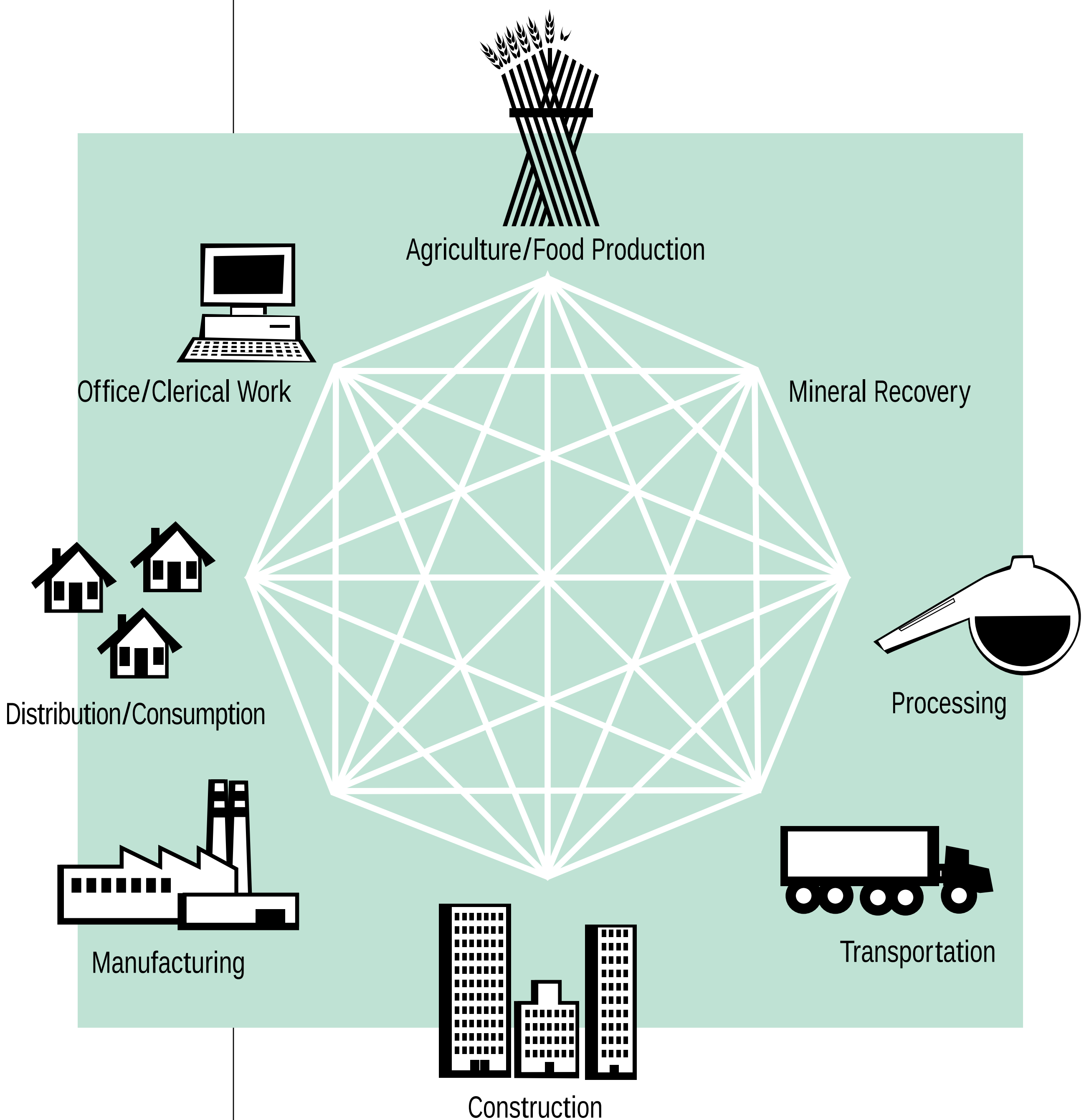
Look at the process to identify potential candidate streams for by-product synergy

[8]*Kirk-Othmer Encyclopedia of Chemical Technology*, John Wiley & Sons, Inc.

Use U.S. government standard industrial categories for insight into by-product synergy opportunities

Industrial Sector	SIC Code	Industrial Category	Examples of Sector Resources	Examples of Sector By-products and Wastes
AGRICULTURE/FOOD PRODUCTION	1	Agricultural Production—Crops	Seed, feed, fertilizer, pesticides, water, fuel	Chaff, sawdust, bagasse, manure, containers
	2	Agricultural Production—Livestock		
	7	Agricultural Services		
	8	Forestry		
	9	Fishing, Hunting, and Trapping		
	21	Tobacco Products		
	24	Lumber and Wood Products		
MINERAL RECOVERY	10	Metal Mining	Fuel, water	Overburden, tailings, water, drilling fluids, pipe, old equipment
	12	Coal Mining		
	13	Oil and Gas Extraction		
	14	Nonmetallic Minerals		
PROCESSING	20	Food and Kindred Products	Hydrocarbons, fibers, animals/vegetables, minerals, fuels, catalysts	Low grade energy (exhaust gas, low pressure steam, biodegradable substances, etc.), ash, slag, sludges, hazardous wastes, water with suspended, dissolved metals, obsolete mechanical equipment
	22	Textile Mill Products		
	26	Paper and Allied Products		
	28	Chemicals and Allied Products		
	29	Petroleum and Coal Products		
	30	Rubber and Misc. Plastics Products		
	31	Leather and Leather Products		
	32	Stone, Clay, and Glass Products		
	33	Primary Metal Industries		
	49	Electric, Gas, and Sanitary Services		
TRANSPORTATION	40	Railroad Transportation	Fuels	Used oils, hydraulic fluids, mechanical equipment, tires, batteries
	41	Local and Interurban Passenger Transit		
	42	Trucking and Warehousing		
	43	U.S. Postal Service		
	44	Water Transportation		
	45	Transportation By Air		
	46	Pipelines, except Natural Gas		
	47	Transportation Services		
CONSTRUCTION	15	General Building Contractors	Concrete, asphalt, lumber, steel, fill material, gypsum, rock, brick	Demolition debris, scrap
	16	Heavy Construction, Ex. Building		
	17	Special Trade Contractors		
MANUFACTURING	23	Apparel and Other Textile Products	Cloth, lumber, aluminum, steel, brass, copper, silicon, plastics, clay, energy, water	Offal, scrap, old mechanical equipment, wastewater, low-grade energy
	25	Furniture and Fixtures		
	27	Printing and Publishing		
	34	Fabricated Metal Products		
	35	Industrial Machinery and Equipment		
	36	Electronic and Other Electric Equipment		
	37	Transportation Equipment		
	38	Instruments and Related Products		
	39	Miscellaneous Manufacturing Industries		

Industrial Sector	SIC Code	Industrial Category	Examples of Sector Resources	Examples of Sector By-products and Wastes
DISTRIBUTION/ CONSUMPTION	48	Communication	Products, energy, paper, services, energy, water, paper	Packaging, used oils, discarded machinery, tires, batteries, plastics, municipal wastes–food, containers, glass, aluminum, packaging, yard refuse, newspapers, magazines
	50	Wholesale Trade—Durable Goods		
	51	Wholesale Trade—Nondurable Goods		
	52	Building Materials and Garden Supplies		
	55	Automotive Dealers and Service Stations		
	75	Auto Repair, Services, and Parking		
	76	Miscellaneous Repair Services		
	53	General Merchandise Stores		
	54	Food Stores		
	56	Apparel and Accessory Stores		
	57	Furniture and Home furnishings Stores		
	58	Eating and Drinking Places		
	59	Miscellaneous Retail		
	70	Hotels and Other Lodging Places		
	72	Personal Services		
	78	Motion Pictures		
	79	Amusement and Recreation Services		
	80	Health Services		
	82	Educational Services		
	83	Social Services		
	84	Museums, Botanical, Zoological Gardens		
	88	Private Households		
OFFICE/CLERICAL WORK	60	Depository Institutions	Paper, computers, energy, office furniture	Paper, obsolete equipment (plastics, metal, magnetic media)
	61	Nondepository Institutions		
	62	Security and Commodity Brokers		
	63	Insurance Carriers		
	64	Insurance Agents, Brokers, and Service		
	65	Real Estate		
	67	Holding and Other Investment Offices		
	73	Business Services		
	81	Legal Services		
	86	Membership Organizations		
	87	Engineering and Management Services		
	91	Executive, Legislative, and General		
	92	Justice, Public Order, and Safety		
	93	Finance, Taxation, and Monetary Policy		
	94	Administration Of Human Resources		
	95	Environmental Quality and Housing		
	96	Administration of Economic Programs		
	97	National Security and Intl. Affairs		
	99	Nonclassifiable Establishments		



By-product synergy collaborations may be formed within individual industries, industrial categories, or sectors; they may also be created across sectors, as illustrated in the "By-product Synergy Web" of potential connections shown in the figure above.

Some industries, such as pharmaceutical, semiconductor, and food processing, require very pure raw materials and clean processes. By-product and waste streams from these activities may be only slightly contaminated and therefore easily converted to resources by industries with less demanding requirements. At the other end of the scale, construction-related and other high-mass consumption activities have minimal specifications for fill material.

Guidance for Phase 2, Step 2: *Characterize candidate streams*

Once you have identified by-product, waste, or resource streams that may work in by-product synergy projects, characterize their key attributes to prepare for approaching potential collaboration partners. Examples of the kinds of information needed for each candidate stream include:

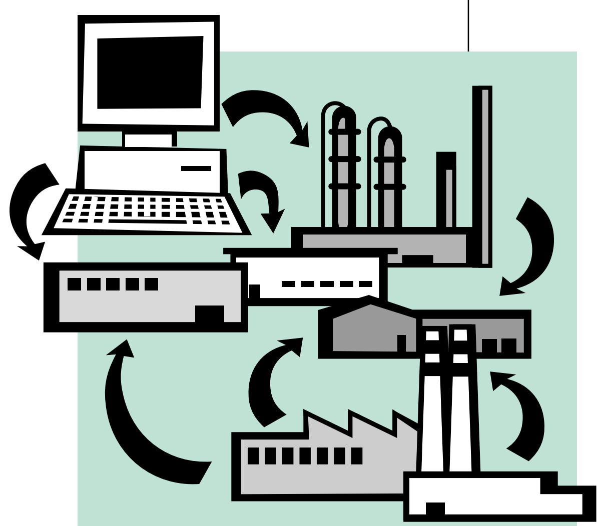
- Estimated physical and chemical composition, including concentration of primary and trace components;
- Regulated components;
- Estimated energy content;
- Estimated throughput;
- Estimated physical properties, like density, compressive or tensile strength;
- Geographic location; and
- Transportation options.

Guidance for Phase 2, Step 3: *Identify and contact potential collaboration partners*

One of the most challenging aspects of by-product synergy is finding collaboration partners—organizations with by-products that may be used as resources in your processes, or organizations that can use your by-products as resources in their processes. In addition to businesses, communities, and government agencies often have a stake in the project and sometimes may be partners in the collaboration.

Once you have identified target industries or sectors for by-product synergy, how will you find potential partners? The BCSD-GM (or your regional equivalent), the WBCSD, and other organizations devoted to sustainable development are the best place to start. Other places to look include the Internet, Chambers of Commerce, commercial and not-for-profit material exchanges, trade organizations, and trade shows and conventions.

When selecting potential partners, recognize that they must be as motivated as your organization is to make the project successful. And, they must be willing to collaborate, communicate, innovate, participate, and evaluate alongside your organization. In other words, they must be as committed as you are to by-product synergy as a strategy for sustainable development.



he power and the promise of by-product synergy lie in its ability to raise profits while reducing pollution and promoting sustainable development. Interest in by-product synergy is growing. The proof:

- It is cited as a strategy for achieving

Current BCSD-GM Members:

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Bechtel Corporation
Central & South West Corporation
Chaparral Steel Company
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