NJCAT TECHNOLOGY VERIFICATION

BY-PRODUCT SYNERGY PROCESS
CH2M HILL/APPLIED SUSTAINABILITY, LLC

(October 11, 2001)

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1. Introduction

1.1 NJCAT Program

The New Jersey Corporation for Advanced Technology (NJCAT) is a not-for-profit corporation that was formed to promote the retention and growth of technology-based businesses in emerging fields such as environmental and energy technologies in New Jersey. NJCAT provides innovators with the regulatory, commercial, technological and financial assistance required to bring their ideas to market successfully. Specifically, NJCAT functions to:

- Advance policy strategies and regulatory mechanisms to promote technology commercialization
- Identify, evaluate, and recommend specific technologies for which the regulatory and commercialization process should be facilitated
- Facilitate funding and commercial relationships/alliances to bring new technologies to market and new business to the state, and
- Assist in the identification of markets and applications for commercialized technologies.

The technology verification program specifically encourages collaboration between vendors and users of technology. Through this program, teams of academic and business professionals are formed to implement a comprehensive evaluation of vendor specific performance claims. If successful, suppliers obtain the competitive edge of an independent third party confirmation of claims.

NJCAT has developed and published Technical Guidance Documents containing a technology verification protocol that are consistent with the New Jersey Department of Environmental Protection (NJDEP) Technical Manual and the Interstate Technology and Regulatory Cooperation (ITRC) program technical and regulatory documents. This technology verification review is consistent with the NJCAT general verification protocol contained in the guidance documents.

Pursuant to N.J.S.A. 13:1D-134 et seq. (Energy and Environmental Technology Verification Program) NJDEP and NJCAT have established a Performance Partnership Agreement (PPA) whereby NJCAT performs the technology verification review and NJDEP certifies the net beneficial environmental effect of the technology. In addition, NJDEP/NJCAT work in conjunction to develop expedited or more efficient timeframes for review and decision-making of permits or approvals associated with the verified/certified technology.

The PPA also requires that:

- The NJDEP shall enter in reciprocal environmental technology agreements concerning the evaluation and verification protocols with the United States Environmental Protection Agency (USEPA), other local required or national environmental agencies, entities or groups in other states and New Jersey for the purpose of encouraging and permitting the reciprocal acceptance of technology data and information concerning the evaluation and verification of energy and environmental technologies; and

The NJDEP shall work closely with the State Treasurer to include in State bid specifications, as deemed appropriate by the State Treasurer, any technology verified under the energy and environment technology verification program.

1.2 Technology Verification Report

In March 2001, CH2M HILL, 1906 Apricot Glen, Austin Texas and Applied Sustainability, LLC, 4425 South Mopac, Building III, Suite 501, Austin, Texas (both organizations will be referred to as the Applicant) submitted a formal request for participation in the NJCAT Technology Verification Program. The proposed technology could be better described as a process. It called for the establishment of a program that would use a "facilitated interactive process" to assist industry in the discovery of new uses for waste streams "primarily as feedstock for other industrial processes." The request after pre-screening by NJCAT staff personnel (in accordance with the technology assessment guidelines) was accepted into the verification program.

This verification report covers the evaluation based on the performance claims of the applicant (see Section 4). A number of telephone discussions were conducted with the Applicant to solicit relevant materials and to refine the specific claim. Richard Magee and Rhea Weinberg Brekke were involved in the preliminary discussions with the applicant and obtained relevant materials. Subsequent telephone conversations and e-mails with the Applicant produced additional documentation and contacts. This evaluation is based on documents and discussions with key contacts as provided by the Applicant and related literature (peer reviewed and governmental).

1.3 Technology (Process) Description – By-Product Synergy (BPS)

1.3.1 Technology (Process) Status: general description including elements of innovation/uniqueness/competitive advantage.

By-Product Synergy (BPS) is defined as "The synergy among diverse industries, agriculture, and communities resulting in profitable conversion of by-products and wastes to resources promoting sustainability" (Radian 1998). While the genesis of reusing excess materials and wastes stems from practices that have been implemented since the industrial revolution, the application of a formal facilitated process was demonstrated across international borders in October 1997, by the Business Council for Sustainable Development – Gulf of Mexico (BCSD-GM) which launched a demonstration By-Product Synergy project in Tampico, Mexico with a group of 21 local industries (Young et al 1999). The project was suggested by several U.S. members of the BSCD-GM, who had reported individual successes with by-product synergies (Radian 1998) and who felt that a broader effort might identify additional opportunities, if approached in a more systematic manner. With a goal of promoting joint commercial development among economic sectors that mirrored the Industrial Ecology concept of one industry's wastes becoming another industry's inputs (Graedel & Allenby 1995), the project demonstrated that wastes could be reused as substitutes for raw materials. Potential benefits included savings related to avoidance of waste disposal, reduced demand for more costly raw materials, savings related to energy consumption, reduced environmental damage, and potential trade opportunities. The reuse of wastes as raw material substitutes or an additional feedstock component is not a new concept; in the United States for example, generators of hazardous waste must implement waste minimization plans that for the most part incorporate the principles of pollution prevention as well as reuse and recycling (Resch & Desrochers 2001).

One method of reuse and recycling involves transferring wastes or by-products to another user through waste exchanges. Waste exchanges have served as a passive outlet for industries that produce wastes and by-products that have a fairly consistent set of characteristics. Many waste exchanges operate in the United States (USEPA 2001a, b) with varying degrees of success. For example the California Materials Exchange (CalMAX), operated by the California Integrated Waste Management Board states that "since 1992 more than 650,000 tons of materials have been diverted from landfills and over 5.5 million dollars have been saved through CalMAX" (CalMAX 2001).

As economic systems, the efficiency and utility of waste exchanges are heavily dependent on information. Just as raw material characteristics must meet process specifications to ensure predictable product quality, so too must by-products and wastes that might be substitutes or added materials. Without consistent quality of inputs, manufacturers would be faced with not only the prohibitive costs of comprehensive testing prior to use, they would also be faced with the potential of unpredictable process fluctuations. In the chemical industry, unpredictability is intolerable. So, successful matches through waste exchanges depend on producer/suppliers who provide descriptions that are based on accurate characterizations and users who are knowledgeable enough about their process inputs to explore close potential matches. On its face, it would appear that producers should be able to provide the descriptions necessary for knowledgeable users to make preliminary determinations, and for organizations taken as whole this would be true. In practice, however, selling and buying process materials rarely involves people who have the knowledge or expertise to understand the underlying processes, rather it involves for the most part purchasing agents working from a specification produced by process engineers/research scientists. Purchasing agents' expertise reside in negotiating the best (cost and delivery time) arrangement to successfully complete the supply chain based on the specification. Rarely, would they initiate a change in the raw material specification or suggest a process modification.

In contrast to waste exchanges, BPS and similar facilitated processes appear to offer a forum where process knowledgeable experts can explore opportunities. As one BPS participant put it, the process established a culture of possibilities (McCormick 2001). In this context of information and process knowledge, BPS offers an active framework to examine the possibilities of by-product reuse. The Process generally progresses in the follow sequence: Commitment, Awareness, Data Collection, Analysis, Implementation, Evaluation, each phase is briefly described as follows:

- RECRUITMENT/COMMITMENT: Initially, organizers begin by seeking the support and commitment of a core group of participant companies at the senior management level. Project champions leverage their contacts with high-ranking officials in the participating companies. An initial informational meeting follows to explain the BPS concept, background on previous BPS successes, industrial ecology concepts, available resources, and the status of current waste management and clean-up efforts in the area. There is usually a geographic aspect to BPS since wastes and by-products costs tend to be influenced by transportation costs. Participants are asked to make a yearlong commitment during which they would systematically seek out profitable synergies among their operations. An up-front fee to defray technical support costs and to create a desire to seek a return on the fee investment is usually requested.
- AWARENESS: The BPS project manager then works through the corporate chain to explain the process. This step involves meeting with key technical people who would be likely representatives of their companies during the project. This stage can take considerable time, but BPS reports indicate that it is a critical step to create buy-in. Successful BPS projects require both "sources" and "sinks" for materials, necessitating diverse yet knowledgeable participants. In addition, extensive follow-up communication is often required to gain broad and consistent participation.
- DATA COLLECTION: In this phase each participant company creates an accounting of in-flows and out-flows of materials, commodities and utilities (energy, water, etc.). Each company is given a data template that is used by process and environmental engineers to identify material flows. This phase may be difficult; reports from the Tampico BPS indicate that most industries aren't accustomed to sharing process information, despite signed confidentiality agreements. Precise information may give way to rough material use quantities with little or no cost information; insufficient information had been identified as a barrier to performing subsequent economic evaluations (Young et al 1999). Follow up plant visits by the project staff may be needed.
- ANALYSIS: Data are analyzed by technical support personnel (typically a consulting engineering firm) to develop an overview of the materials within the group and a list of potential synergies (matches). In the Tampico BPS project, the technical analysis produced an initial match for raw material and waste flows within the group and also matched raw material and waste flows against company profiles based on the consultant's worldwide experience. During this phase, periodic (monthly or bi-monthly) group meetings are held with the participating company representatives group where facilitated brainstorming is used to maintain and advance the momentum established during the awareness phase; project consultants are typically used. The brainstorming process also establishes confidence and trust among the participants as well as generating enthusiasm for the project through an open exchange. Feasibility studies and barrier identification are conducted in this phase and may be carried into the implementation phase.
- IMPLEMENTATION: In this phase, identified synergies are implemented. It is perhaps the least predictable, because not only must coordination be established between supplier and user, internal management approval, processing changes (which could involve capital expenditures) at the user end must be completed before the first shipment of a material can be accepted. In addition, regulatory aspects, such as permit changes and other approvals, logistic aspects and transaction negotiations, final process evaluations which might include highly detailed and sensitive technical and process safety analysis must be

finalized. All of these aspects must enter into the cost benefit analysis that by-product users complete as a matter of internal procedure. While some of these aspects might begin well before implementation, the myriad of approvals varies from company to company.

- EVALUATION: An evaluation phase occurs after the implementation has begun to better understand and document the savings. Initial BPS projects utilized a combination of up-front payment and benefit sharing arrangement (based on a percentage of savings), so savings documentation was critical to the future of BPS projects. Post implementation information has proved difficult to obtain.

The timeframe for each of these phases varies from several months to a half of a year; however, project complexity, similarities with successful past projects would likely play a significant role in determining the actual time from start of the process to completion.

These steps, which varied from project to project, roughly follow the Primer developed by BCSD-GM (Radian 1998). The Primer called for Five Phases:

- Planning and Organization: This phase included leadership commitment, organizational goals, incentives, awareness development, and team formation.
- Assessment and Prioritization: This phase included waste and by-product identification and characterization, identification of potential synergies, team formation among collaborating partners, barrier identification and means to overcome them, development of preliminary feasibility studies, and priority setting.
- Evaluation/Decision Making: This phase involved detailed feasibility studies, economic analyses, and identification of performance metrics.
- Implementation: This phase involved funding, planning and implementing the project.
- Monitoring and Improvement: This phase involved monitoring performance metrics, evaluating the performance and taking corrective action to improve performance.

According to the Applicant's description of BPS in the Limited Preliminary Application (LPA), each BPS project involves "20 to 30 diverse companies in a given industrial region as fee-paying participants" (LPA, page 2). Three keys to this program's success are outlined in the LPA as:

1) diversity, companies that are brought together in these projects represent a wide variety of industries which are meant to broaden the markets in which participants find business opportunities;
2) communication, project provides a forum in which participants can share ideas while being encouraged to look beyond their company for opportunities - the BPS process seeks to build trust to foster open discussions of by-products and potential synergies;
3) partnership, relationships are leveraged with technical consultants, regulatory agencies, research organizations, and funding sources to assist participants in overcoming barriers to implementing the synergies that are identified.

In short, the BPS process takes the concept of a waste exchange, systematizes it using the structure of the proven Plan-Do-Check-Act cycle of management systems and adds facilitation to energize the process. In this process driven approach, there do not appear to be any favored technologies, industries, or economic sectors; all appear to be potential candidates for inclusion.

In the case of this application, NJCAT verification would add value to the BPS process by providing an independent evaluation that could help establish credibility with participants. The verification process would also serve as a mechanism to inform regulatory agencies of potential barriers (Wallace 2001).

1.3.2 Specific Applicability (to New Jersey)

According to the most recent national data, in 1999 more than 40 million tons of hazardous wastes were generated in the United States (USEPA 2001c), a reduction of about 1.5% over 1997 data. Of the top 15 states producing the most hazardous waste in terms of tons generated, New Jersey ranked 13th behind Texas, Louisiana, Illinois, Tennessee, Ohio, Mississippi, Kansas, Michigan, Massachusetts, Indiana, Arkansas, Idaho and ahead of New York and Alabama respectively. However, New Jersey ranks fourth among the number of large quantity generators located in a state behind New York, California, and Ohio and respectively. While these latest rankings reflect the changing nature of the economy of the Northeast, it also demonstrates that New Jersey continues to be among the manufacturing sector states. When adjusted for size, New Jersey ranks third behind Massachusetts and Louisiana in terms of tons of hazardous waste generated per square mile. In this respect, opportunities for waste reuse should be available in New Jersey. In addition, to the extent that closer geographic proximity (distance between generator and user) equates to more favorable waste exchange economics, the relative concentration of manufacturing within the state should produce more potential exchanges.

According to the United States Department of Energy (USDOE) the manufacturing sector consumed about 27.3 quads (or 10^{16} Btu) of energy in 1994 representing about 36% of domestic energy use (USDOE-EIA 1997). Although newer data suggest that total U.S. energy demand has increased to 94 quads in 1997 (USDOE-EIA 2000) manufacturing information is not as detailed. In 1997, energy demand for New Jersey was 2.6 quads (about 2.74% of the United States). The growth of the economy over the last half of the 1990's would suggest that energy consumption in the manufacturing sector has also continued to increase. Thus if 36% of domestic energy use could be considered a conservative estimate of manufacturing energy use, and the manufacturing sector remains significant in New Jersey, savings could represent a significant societal benefit in terms of reduced energy consumption and thus lower cost of goods for production and subsequent consumption.

In 1999, the New Jersey Chemical Industry Project had announced that it was encouraging chemical manufacturers to recycle wastes instead of discarding them (USEPA 1999). These nascent efforts received the encouragement of NJDEP and USEPA to examine recycling opportunities within the state. On another front, NJDEP had prepared a preliminary list of waste generation, type, quantity, company contact and net environmental benefit (Winka 2001) indicating that by-product/waste reuse potential exists in New Jersey. The list bore some similarities to opportunities identified by the Applicant, possibly due to the fact that the popular technical literature has highlighted some of the success stories despite the lack of critical peer-reviewed evaluation. Finally, The New Jersey Solid Waste Policy Group held a Solid Waste Summit in February of 2001 to build a leadership coalition for solid waste management and policy for the state (Rutgers 2001). All of these developments would suggest that the state is poised to take an active role in encouraging reuse, recovery, and recycling initiatives within and among industry sectors.

1.3.3 Range of Material Characteristics

The range of materials that could potentially be subject to BPS is without limit. The process could be applied to any generated waste or produced by-product provided a potential user finds the material to be of some value; which would likely be determined on a case by case economic value analysis basis. It is also likely that the value analysis would be performed between the two firms without third party assistance, since each firm's payback analysis would be based on company-specific Return on Investment and Payback targets.

1.3.4 Range of Industrial Characteristics

There are no actual industrial limitations. The theoretical limitations are likely to be related to the physical distance between industrial sites rather than industries themselves. Exceptions might include limitations based on neighboring characteristics of the plant that might prohibit certain transportation modes or physical plant restrictions. But, these limitations would be known well before the implementation phase of a potential project. In addition, depending on the potential value of the material exchange, the acceptable physical distance (as transportation costs) may be more or less; more if the value is high, less if the value is low. If the materials are regulated and the facility is not registered to accept regulated materials (for example, if a material exchange goes ahead initially as a waste stream with the hope of future delisting), a regulatory barrier might limit the use of the material (see Section 1.3.6 for more discussion).

1.3.5 Material Overview, Handling and Safety

Among the safety considerations that would be part of a potential BPS, the transportation, storage, handling and use would be likely candidates. Process Safety Management, Hazardous Materials Transportation and Hazardous Waste TSDF rules may require additional precautions and training before materials could be accepted for use. The specific aspects are case sensitive and are difficult to predict prior to a specific exchange agreement that identifies the materials to be used; however, it may appropriate to articulate the obligations of both parties to each other and the interests of the state if exchanges are to be sanctioned.

1.3.6 Regulatory Aspects

Perhaps the most significant regulatory barrier affecting by-product synergy implementation is the classification of materials as hazardous wastes. Regulatory and industry relationships have not always been collegial and the adversarial nature of these relationships has been well documented (Hoffman 1997). Participants of the Tampico BPS project felt that de-classifying waste materials based on their potential future use should be considered along with financial incentives (Young et al 1999). In the context of BPS, the use of the term "waste" is rare; synergies are represented by the term 'by-products' that are viewed as additional inputs to the raw materials supply chain. While this semantic distinction may ultimately be useful to demonstrate beneficial reuse, the history of waste disposal may limit its importance. Economic incentives, such as the cost of hazardous waste treatment and disposal are powerful drivers to reduce waste generation. For the unscrupulous, disposal costs are also a powerful avoidance incentive that has led to less than legitimate means; as well as the federal and state legal structure for the hazardous waste life cycle. Nevertheless, the potential for economic incentives to help distinguish waste from non-waste may be worthy of additional study even if it is beyond the scope of this verification. Ultimately, some level of state/federal recognition that the use of waste is beneficial will be needed in a form that modifies the cradle to grave regulatory structure without eliminating oversight.

1.4 Project Description

This project included the evaluation of documents provided by the Applicant, conference proceedings, Applicant company manuals and literature, and peer-reviewed literature. Discussions with Key Contacts and Applicant Suggested Contacts, see Sections 1.5 and 1.6, were also held. Documents provided by the Applicant that were included in this review were:

GENERAL INFORMATION ON BY-PRODUCT SYNERGY (BPS)

North Texas By-Product Synergy Project – 2000 Project Report. Prepared by Applied Sustainability, LLC. Private & Confidential Document – No Date.

By-Product Synergy: A Demonstration Project, Tampico, Mexico. Prepared by: Rebekah Young of Applied Sustainability, LLC, Susana Hurtado Baker and Federico Ortiz Lopez of Consejo Empresarial para el Desarrollo Sostenible – Golfo de Mexico. Mexico: CEDES-GM. August 1999.

By-Product Synergy: Cross-Industry Collaboration to Achieve "100% Product" Manufacturing. Prepared by Andrew Mangan of Applied Sustainability, LLC. Background paper – No Date.

NJCAT Verification Program Limited Preliminary Application.

Verification Claim Paragraph.

e-mails from Andrew Mangan.

CemStar® PROJECT

NO_x Control Technologies for the Cement Industry (Final Report under EPA Contract No. 68-D98-026, Work Assignment No. 2-28, EC/R Project No. ISD-228). Prepared by: Rebecca Battye, Stephanie Walsh, Judy Lee-Greco of EC/R Incorporated, 1129 Weaver Dairy Road, Suite AA-1, Chapel Hill, NC 27514. Research Triangle Park NC: U.S. Environmental Protection Agency. September 19, 2000.

Status Report on NO_x Controls for Gas Turbines, Cement Kilns, Industrial Boilers, Internal Combustion Engines, Technologies & Cost Effectiveness. Prepared by: James Staudt of Andover Technology Partners, North Andover, MA 01845. Boston MA: Northeast States for Coordinated Air Use Management. December 2000.

A Revolutionary Synergy – Steel Manufacturing By-Products in Cement Production. Prepared by Greg Mayes of TXI, 1341 West Mockingbird Lane, Dallas, TX 75247. Presented at the Portland Cement Association Materials Technical Committee, Fall 2000 Technical Session. September 19, 2000.

Summary of Fact Sheets entitled By-Product Synergy Results. No Date.

Confidential Fact Sheet: CemStar® Synergy – North Texas. No Date.

SPENT CAUSTIC – ALBERTA PROJECT

Alberta By-Product Synergy Project. Prepared by Applied Sustainability, LLC. No Date.

Confidential Fact Sheet: Spent Caustic Synergy – Alberta, Canada. No Date. (2 versions)

GRAPHITE-COPPER PROJECT

Confidential Fact Sheet: Graphite-Copper Synergy – North Texas. No Date.

AUTO SHREDDER RESIDUE PROJECT

Confidential Fact Sheet: Auto Shredder Residue Synergy – North Texas. No Date.

1.5 Key Contacts

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2. Evaluation of the Applicant

2.1 Corporate History

2.1.1 CH2M HILL (source: http://www.ch2m.com)

CH2M HILL is a nationally recognized environmental engineering firm, with global offices and more than 12,000 professional staff worldwide. Established in 1946, the consulting firm began as a professional partnership of H. Cornell, J. Howland, B. Hayes, & F. Merryfield (CH2M). In 1971, the firm merged with Clair A. Hill & Associates (established in 1946), to become CH2M HILL. In 1977, it merged with Black, Crow, and Eidsness (BC&E), a company originally established in 1951. In 1974 CH2M HILL Companies, Ltd. (CH2M HILL) was established to encompass the firm's subsidiary companies. CH2M HILL has capabilities in program management, planning, engineering design, technology, construction, financing and project development and provides these services across three business groups of Energy, Environment & Systems; Water; and Transportation. In addition, the firm includes: CH2M HILL Constructors, Inc. a construction services company, Industrial Design Corporation focused on high technology facilities design, construction, maintenance and operations; Operations Management International an operations and maintenance firm providing water, wastewater, and electrical and other utility services; and CH2M HILL Capital Services, Inc. a company focused on financing public and private infrastructure projects.

The company was ranked 8^{th} overall among Engineering News-Record's Top 500 Design Firms in 2001 based on 2000 revenues and 189^{th} overall among Forbes 500 Largest Privately Held Companies based on 1999 revenues.

2.1.2 Applied Sustainability, LLC

In 1999, the Business Council for Sustainable Development – Gulf of Mexico (BCSD-GM) created a for-profit company, Applied Sustainability, LLC, to administer By-Product Synergy (BPS) projects around the world (ASLLC 2000a; BCSD-GM 2001). Specifically, Hatch Associates Consultants, Inc., Texas Industries, Inc., Conoco, Inc. and Grupo IMSA, S.A. de

C.V., and the BCSD-GM formed Applied Sustainability, LLC and were members of the firm (BCSD-GM 1999). The corporate form of a Limited Liability Company operates much like a partnership, except that ownership takes the form of members instead of partners.

U.S. Members of the Gulf Council included Conoco, Inc., CSW International, Inc., Hatch Associates Consultants, Inc., Radian International, Temple-Inland, Inc., Thompson & Knight, Triangle Pacific, TXI, TXU, Vinson & Elkins, and Westvaco. Mexico Members of the Gulf Council included: Albright & Wilson Troy de México,Alpek Alfa, S.A., Campechana de Vehículos, S.A. de C.V., Celanese Mexicana, S.A. de C.V., Centro Empresarial de Tampioc, S.P., CROYINFRA, S.A. de C.V., DUPONT, S.A. de C.V., Grupo IMSA, S.A. de C.V., Grupo Primex, S.A. de C.V., ICA Fluor Daniel, S. de R. L. de C.V., Inmobilaria Interstarial, S.A. de C.V., NHUMO, S.A. de C.V., Petróleos Mexicanos.

Based on interviews with Hatch Associates Consultants, Inc. and CH2M HILL representatives, Applied Sustainability LLC was formally dissolved in the summer of 2001. Hatch Associates Consultants, Inc. will pursue existing BPS projects (Yates 2001), while CH2M HILL will lead the New Jersey BPS project (Danko 2001a, b). Subagent agreements had been developed with Hatch Associates Consultants Inc. and CH2M HILL for revenue sharing from referral fees received from TXI (the patent holder) to market CemStar® technology (ASLLC 2000a).

Andy Mangan, ASLLC's former president, is currently a subcontractor to CH2M HILL providing development and implementation services on the New Jersey BPS project. Andy Mangan, who may become an employee of CH2M HILL is also working with the firm on a long-term basis to develop enhancements to the BPS process and to create additional BPS projects in other states (Danko 2001a, b).

2.2 Organization and Management

The corporate offices for CH2M HILL are located at 6060 South Willow Drive in the city of Greenwood Village, Colorado; while the Applicant offices were listed as 1906 Apricot Glen, Austin, Texas and local offices (to New Jersey) are located at 1700 Market Street, Suite 1600 Philadelphia, Pennsylvania.

The principal office for Applied Sustainability LLC was located at 4425 South Mopac, Building III, Suite 501, Austin, Texas until its dissolution. Andy Mangan was its President and Gordon Forward served as its Chairman. In the past, partnering organizations that have participated in BPS projects along with the BCSD-GM and Applied Sustainability LLC were Bechtel and Hatch Associates Consultants, Inc.

2.3 Operating Experience with respect to the Proposed Technology (Process)

Prior to becoming President of Applied Sustainability LLC, Andy Mangan was Executive Director of the Business Council for Sustainable Development – Gulf of Mexico, the organization that sponsored By-Product Synergy projects. Based on interviews, his experience and expertise provided non-technical benefits (technical expertise in past BPS projects was provided by engineering consultants who became part of the team) including: promoting the BPS concept (Vavrek 2001), getting access to key company leadership, obtaining financial support, obtaining government interest, procuring appropriate sub-contractors to support BPS projects (Young 2001), publicizing BPS, building trust, supporting facilitation, and encouraging participation (Danko 2001b; Oliver 2001; Kay 2001).

CH2M HILL, which has just started its involvement with BPS (Danko 2001b; Wallace 2001; Campbell 2001), will provide the technical support for future BPS projects. It was mentioned earlier, that BPS would likely proceed on a number of fronts independent of CH2M HILL and Applied Sustainability LLC; for example, Hatch Associates Consultants, Inc. is proceeding with BPS in United States and Canada (Yates 2001).

The combined capabilities of Andy Mangan and CH2M HILL appear to be sufficient to support the phases of the process that are outlined in Section 1.3.1. In fact, a New Jersey BPS project was launched in July of 2001 (Mangan 2001).

2.4 Intellectual Property (Patents, Trademarks, etc.)

No patents apply to the BPS process.

The rights to the term By-Product Synergy (BPS) have been granted on a non-exclusive basis to the members of the Applied Sustainability, LLC, the company, and Andy Mangan; see Section 2.1.2 for a brief description.[1] In addition, without confirming documentation to clarify the assignment of intellectual property rights, it is not possible to determine the nature of the rights to the term By-Product Synergy that may or may not apply to all members of the Gulf Council (as a founding entity). Finally, according to BCSD-GM documentation, the underlying conceptual framework for By-Product Synergy may have stemmed from an USEPA grant to identify case studies and opportunities in “green twinning” a term which was coined in 1995 (Radian 1998; Hecht 2001), and may have brought the concept into the public domain.

It is unlikely that the technique of a facilitated process could be protected as intellectual property, since it is employed in many professions and has been in use for many years. However, to the extent that certain aspects of the facilitated process could be reduced to standard practice for the express purpose of waste reuse, there may be potential for intellectual property protection. Appropriate legal counsel should evaluate the intellectual property issues, if it is deemed critical to the verification.

2.5 Technical Resources Staff and Capital Equipment

CH2M HILL (http://www.ch2m.com) is a global environmental engineering, construction, and financial firm with sufficient resources (human and capital) to provide BPS support services. The application is premised on the environmental capabilities of CH2M HILL; furthermore, based on phone interviews, the firm has made a commitment to increase its process engineering capabilities (Wallace 2001).

[1] For example, Hatch Associates Consultants, Inc. as a former corporate member and director of Applied Sustainability, LLC (as well as a facilitator and technical resource for current and past BPS projects) is actively marketing the process in Canada and the United States (Yates 2001).

In fact, the BPS process has been implemented in full scale in the United States, Mexico, and Canada and is being explored in other parts of the world. Efforts to expand the use of By-Product Synergy processes are currently taking place under the auspices of Hatch Associates Consultants, Inc. (Yates 2001) and CH2M HILL (Danko 2001b, Wallace 2001, Campbell 2001). CH2M HILL has indicated, through interviews, that it intends to retain Andy Mangan as a staff member to build on his facilitation expertise and contacts. CH2M HILL expects to use its technical resources to create an online internet-based database to enhance the facilitation and data sharing aspects of BPS.

The resources of Applied Sustainability, LLC (http://www.as-llc.com) as a shell company are essentially non-existent. Financial information, although requested, was not provided in the second and third quarter combined report to members (ASLLC 2000a).

3. System (Process) Description

BPS, which generally follows the sequence of phases outlined in Section 1.3.1, is not documented in the peer-reviewed literature, per se; most of the documentation related to BPS was provided through Applicant prepared documentation and a primer prepared for the BCSD-GM by Radian Corporation with funding from USEPA (Radian 1998; Hecht 2001). However, the foundation on which the process rests was explored in related technical literature (peer reviewed and otherwise) from several perspectives: Pollution Prevention, Industrial Ecology (including Eco-Industrial Parks), Networks, and Waste Exchanges. Based on this review, as well as interviews with key representatives of participating companies that have benefited from BPS, there appears to be sufficient support to predict favorable outcomes.

Pollution Prevention

According to the LPA, By-Product Synergy builds on the foundation of pollution prevention, and expands it from a single company perspective to a multi-industry regional process. The broader perspective increases the possibilities for integration and collaboration; it also, however, increases the level of complexity for pollution prevention to occur. The Applicant believes, and results from past BPS projects appear to support this belief, that synergies can lead to reduced disposal costs, reduced use of virgin materials, lower energy consumption, and reduced air and water emissions; in addition to a potentially new revenue stream from the sale of by-products.

While quantification of disposal costs, virgin material purchases, and energy consumption savings would be case specific the underlying logic of expenditure reduction based on elimination of waste disposal costs is sound. As materials that would have been disposed or treated prior to disposal are used as substitutes or additional raw materials, environmental impact would be reduced, provided process yields are not reduced. In addition, peripheral costs related to liability of disposal could also be eliminated or reduced. The benefits that would accrue to pollution prevention initiatives would also accrue to BPS or similar waste to raw material substitution approaches.

Pollution Prevention programs and free technical assistance to implement pollution prevention practices have been at the top of the federal waste management hierarchy and available to industry and local municipalities for years (Adler & Kiepper 2001). In addition, as facility wide waste minimization efforts continue to be explored to reduce waste at the source, there is a growing awareness that regional cross industry as well as industry-specific coalitions have played and will continue to play an important role to recognize hidden value and help avoid landfilling (Resch & Desrochers 2001). BPS may offer an opportunity to leverage internal efforts at waste minimization and pollution prevention to broader coalitions that might offer technical solutions not previously apparent.

It is not clear, however, that savings among firms can be documented as easily as savings within a single company. Past BPS project participants admit that savings have been significant but were unable to document (or share information about) the savings that resulted from BPS. For some the belief that the project payback was positive was sufficient to term the project a success. In some respects, the lack of documentation may be related to how costs and expenditures to arrive at a mutually beneficial exchange are developed. For example, for the generating firm the benefit of the exchange may initially be the savings from avoiding the disposal cost, which might be significant. For the using firm the benefit of the exchange may initially be to reduce raw material purchases. But as transfer logistics, such as transportation, process modifications that might involve capital expenditures, and other factors such as quality guarantees are added, the cost picture on both sides of the transaction might change. Over time, the potential for further changes as the by-product value perception changes, the economics might change as well. In any event, the elimination or even reduction of pollutants that could enter the environment represents a positive contribution to environmental protection.

According to Applicant materials, BPS Synergy projects have resulted in environmental benefits such as reductions in NOx, CO_2, SO_2, hydrocarbons, energy savings, reduction in solids, reduction in liquid residues; see summary Table in Appendix 1 (ASLLC 2001a).

For one project, CemStar® (U.S. patents 5,421,880 and 5,494,515), NOx emissions were quantified on a relative basis in comparison to other technologies used in the cement industry (Battye et al 2000) and also included in a review of NOx control technologies for industrial boilers, gas turbines, internal combustion engines and cement kilns (Staudt 2000). The CemStar® process, which had been developed to increase plant capacity (Staudt 2000), is based on the addition of steel slag to the raw kiln feed; the relatively inexpensive steel slag has a low melting temperature and similar chemical characteristics to clinker. The conversion of steel slag to clinker requires much less energy input since a portion of the conversion reactions to form clinker have already occurred; thus the improved thermal efficiency of the process and decreased need for limestone calcinations contribute to lower NOx and carbon dioxide emissions. The process, which is currently being used at a number of cement facilities, has been estimated to be as cost effective as low-NOx burners and has achieved a 23 to 40 percent reduction in NOx emissions (Battye et al 2000). Similar results of 42% NOx reduction from baseline were reported for a 50-50 coal-gas fuel mix in a short term test and 19% NOx reduction from baseline for a 100% coal fuel mix in a long term test (Staudt 2000).

Industrial Ecology

There is no single accepted definition of Industrial Ecology. Among the first proponents, Frosch and Gallopoulos (1989) suggested that the concept of an industrial ecosystem should be adopted where "the consumption of energy and materials is optimized, waste generation is minimized and effluents of one process … serve as the raw material for another process." A more current view would call for treating the consumer society as an ecosystem (Lifset 2000). Both suggest that within an ecosystem framework, waste exchange/reuse, or more appropriately for this report by-product synergies, can find some philosophical support. The Industrial Ecology literature is growing and beyond this report to summarize; however, it is important to note that the tools of Industrial Ecology, Design for Environment and Life Cycle Assessment, bear some relevance to BPS or similar processes because they bring into focus its systems thinking basis. By taking a systems thinking approach, reductionism based linear thinking (single cause and single effect) "solutions" are placed back into a systems context to better understand consequences and question commonly accepted concepts such as "throw-away" decision-making (Senge 1990).

There are critics of Industrial Ecology who charge that it is actually a barrier to cleaner production because waste exchange is a fundamental tenet. Critics suggest that by recognition of waste exchange an affirmation of the value of waste (via the exchange) takes place as well and thus innovative solutions to eliminate the production of wastes in the first place are delayed (Baas 1999). This fear that Industrial Ecology enables the status quo, essentially elevates it above business cycles and economic forces. It presumes that Industrial Ecology can somehow freeze technology. In part, the misperception of Industrial Ecology stems from the ambiguity that surrounds it. It has come to mean many things to many people (O'Rourke et al 1996). As a result it serves as a large tent housing highly divergent views of change from incrementalism to total transformation; and ambiguity has been the means by which so many have adopted it as a valuable concept. Nevertheless, it has added another perspective that has in fact fostered new ways of examining environmental problems.

Eco-industrial parks are a manifestation of Industrial Ecology on a local scale and have received endorsement from the President's Council on Sustainable Development as well as USEPA as a promising development strategy for the 21st century (McGalliard et al 1997). These parks are the physical embodiment of two emerging industrial trends, flexible networks and inter-firm collaboration (Gertler 1995a), terms that could describe the BPS or similar cross-industry collaborative projects. USEPA lists several eco-industrial parks on its Internet site (USEPA 2000) one of which is a BPS North Texas project comprising a Steel Mill, Cement Plant, and Automobile Shredding facility. Planners have also taken note that industrial development can achieve "A community of businesses that cooperate with each other and with the local community to efficiently share resources (information, materials, water, energy, infrastructure and natural habitat), leading to economic gains, gains in environmental quality, and equitable enhancement of human resources for business and local community" (Deppe et al 2000). This definition places Industrial Ecology within the social fabric of community and the larger systems view mentioned above. Resources have begun to emerge to meet the growing interest in these parks, which may be suitable for brownfield applications (Cornell 2000).

Networks

In many respects, the potential for matches between generator and user is dependent on the number of participating firms; this is more commonly known as Metcalfe's Law after Robert Metcalfe the inventor of Ethernet (Gilder 1993). Metcalfe discovered how network capacity can be optimized. In simple terms, he stated that the "value" or "power" of a network increases in proportion to the square of the number of nodes on the network (Robertson 1996). Any network therefore increases its utility as it increases in size; if the nodes in the network could be equated to participating firms, then by increasing the number of firms the greater the potential for a useful connection inside the network. For example, if 10 participating companies increase to 11 the theoretical value of the network would rise from 100 to 121 for each participating company. Even if each participating firm had only one waste stream and one need, the number of potential matches rises significantly as the number of firms participating in the network increases.

Waste Exchanges

A long-standing mechanism that has been used to foster reuse of wastes and by-products has been through waste exchanges. Many states have linked their Internet sites to waste exchange programs of some sort (Dean & Frantz 1999). More recently waste exchanges were identified as an element of a plan to establish more environmentally sustainable economies in Oregon and the Pacific Northwest (Doppelt et al 1999). The Internet has enabled waste exchanges to expand their reach, accessibility, and cachet; the USEPA offers links to many local, regional, and national waste exchanges on its Internet site (USEPA 2001a, b).

Waste exchanges have had mixed success for a variety of reasons. The limitations stem from its passive nature, materials with limited information are posted and potential users must initiate a search process to identify potentially useful materials. The Applicant has termed waste exchanges "garage sales" that are limited by:

- lack of knowledge of the generator/producer of the material;
- limited information of the materials on the exchange;
- limited potential for specifying the material which may limit process applicability;
- uncertain supply chain (quantities, logistics, predictability)

Some exchanges have been quite successful, such as CalMAX (see Section 1.3.1) and RENEW while other have met with failure. The National Materials Exchange Network (EHP 1993), a cooperative effort to link more than 40 materials exchanges across North America, has apparently failed to survive the Internet era. Like CalMAX, RENEW which is the Resource Exchange Network for Eliminating Waste established by the Texas state legislature in 1987 "to promote the reuse and recycling of industrial wastes," is a regionally (Texas) focused endeavor (RENEW 2000). RENEW claims that it has listed 712 million pounds of material that has resulted in more than $6 million in disposal cost savings and earning more than $6 million from material sales. It is an Internet based resource offering lists of materials available and materials wanted. CalMAX is also a free service that is reserved for non-hazardous wastes; another free waste exchange CWE (the California Waste Exchange) is reserved for hazardous wastes and is operated by the California Department of Toxic Substances Control. Texas and California's experience would suggest that differentiating between hazardous and non-hazardous waste and with a regional concentration might aid in materials/waste reuse. In both instances, state assistance may help to avoid regulatory barriers or misinformation.

Andrews and Maurer (2001) conducted an exploratory survey of materials exchanges in the United States to find that few respondents indicated handling hazardous materials and most focus on pre-consumer items such as building materials or post consumer items. They found that non-profit organizations and governmental organizations have played an active role in this market, finding a place between scrap recyclers and used merchandise stores. They noted that a minority, 9 out of 63, respondents were involved with hazardous pre-consumer wastes; all of which acted only as a passive list-keeper of materials that were available. In the UK, Donaldson (1997) observed that waste exchanges had limited value because low-grade wastes dominated databases and companies experienced difficulties locating materials.

In BPS, facilitation among key technical personnel who are familiar with waste, by-product streams, and processes, in a confidential setting addresses some of the limitations described above. Although trust is not always immediately evident, based on former participant interviews, it is developed as the process continues, as is a sense of purpose to look for opportunities. The process may also identify process changes or opportunities that were not readily apparent before face-to-face meetings occur; in the Alberta BPS, the Caustic Soda Synergy project described in Section 5 Case Study 1 (below) the synergy occurred over a coffee break and had not been identified during a brainstorming session, consultant review of data, or other facilitated portion of the process (McCormick 2001). Had it not been for the "culture" of the process, the exchange that ultimately occurred between Weyerhaeuser and Husky would probably not have occurred at another event. Nor had it occurred through a waste exchange, which Weyerhaeuser admitted to have tried with little success, prior to the Alberta project.

4. Technical Performance Claim

Claim – By-Product Synergy (BPS), a facilitated interactive process involving a group of industries from diverse manufacturing sectors, has the potential to assist industries to discover new uses for their waste streams, primarily as feedstock for other industrial processes. When successful, BPS leads to measurable, verifiable environmental results in pollution prevention, waste reduction, energy efficiency and material use.

5. System (Process) Performance

The facilitation process that resulted in By-Product Synergies has been used on numerous projects; several are provided below as examples.

5.1 By-Product Synergy Case Studies

The four case studies supplied by the Applicant are presented in no particular order. Some of the case studies predate the formation of Applied Sustainability, LLC but are discussed as examples of the facilitation process that resulted in By-Product Synergies.

Case Study 1 – SPENT CAUSTIC – ALBERTA PROJECT (ASLLC 2000c, 2001b)

Two participants in the Alberta BPS project, a Weyerhaeuser Kraft pulp and paper mill in Grand Prairies, Alberta and a Husky Oil refinery in Lloydminster, Saskatchewan, discovered that spent hydrocarbon contaminated (oils, greases, perhaps some heavy metals) caustic produced at the refinery could be used in the Kraft process.

At the time of the BPS project the refinery was disposing the spent caustic (NaOH) by deep well injection at significant cost. The pulp and paper mill was purchasing virgin caustic from a chemical manufacturer; which was found to be ten times as costly as the spent caustic. Weyerhaeuser found that spent caustic could be introduced at the recovery boiler stage, where contaminants could be removed while producing a salt cake with the right chloride level to pass through the boiler without plugging; plugging involved several million-dollar washings per year prior to the synergy.

During *Pulping,* wood chips are cooked in caustic to form cellulose and black liquor, which is subsequently *Washed* through which cellulose is recovered as pulp. The black liquor, or spent caustic is concentrated through *Evaporation* and sent to a *Recovery Boiler* where it is incinerated; heat is recovered and smelt cake is formed. The smelt cake is dissolved with weak wash water from the recausticizing operation to produce green liquor (about 70% sodium carbonate and 30% sodium sulfide). During *Lime Burning,* calcium carbonate (lime/$CaCO3$) is burned in the kiln to produce calcium oxide (CaO) which is slaked to calcium hydroxide (CaOH). The calcium hydroxide is reacted with the green liquor to produce white liquor (NaOH) for the *Pulping* stage. Precipitated calcium carbonate is returned to the kiln to make new hot lime (CaO). Prior to reburning in the kiln, the lime is washed to recover chemicals; this is the source of weak wash water for dissolving the smelt from the *Recovery Boiler*. The Kraft process needs "make-up" chemistry to account for losses; NaOH is needed to make up for sodium losses.

In the first year of the BPS project Weyerhaeuser accepted 438 tons of spent caustic from Husky and in year two Weyerhaeuser began taking additional spent caustic from other suppliers. The facility can accept up to 1,400 tons of spent caustic per year. Extrapolating from the experience of one mill to other users (and suppliers) could yield significant savings between the two industries. However, even with the experience at one of its own mills, Weyerhaeuser has found it difficult to transfer the technology to other mills – which may be more of an indication of local priorities and investment decision-making than a technological barrier (Kay 2001).

The significant discovery that occurred during the BPS project, involved not only using the spent caustic to make up for sodium losses, but the introduction of the caustic at the black liquor stage that would allow the incineration stage to remove contaminants and avoid odors. The net savings between the two companies were estimated at about $1,500 per day. Both companies expressed satisfaction with the BPS process and have reported ongoing savings (Kay 2001; Vavrek 2001).

Case Study 2 – GRAPHITE-COPPER PROJECT – NORTH TEXAS (ASLLC 2000b, 2001c)

One of the North Texas BPS projects involved a graphite manufacturing facility and a metals recovery company. Poco Graphite Inc. manufactures premium graphite and electrode graphite products at its Decatur, Texas facility for aircraft and precision molding production processes. During the machining of copper-impregnated graphite electrodes, aqueous based cutting fluid is used to cool parts and to capture machining residue. The cutting fluid wastewater is treated through evaporation and a sludge containing about 50% copper is produced. About 37,500 pounds per year of sludge is purchased by Gachman Metals, a metals recovery company that in turn sells it to overseas customers.

Prior to this BPS project, Poco Graphite Inc. treated the wastewater by centrifugation and discharged 412,500 gallons of wastewater into the city's publicly owned treatment works while the sludge had been landfilled. Copper residues averaged about 4.5 ppm but had been recorded as high as 23 ppm in the wastewater. After implementation of the BPS project, Poco's wastewater copper content dropped to .035 ppm, which remains well within the 1 ppm limit of the company's new water permit from the city. According to a phone interview with a representative from Poco Graphite Inc. the company also received positive public relations value in addition to the disposal savings and new income stream (Oliver 2001).

Case Study 3 – AUTO SHREDDER RESIDUE PROJECT – NORTH TEXAS (ASLLC 2001d)

Another North Texas BPS project developed between an Auto Shredder facility located in Midlotheon, Texas and a steel mill owned by TXI. The Auto Shredder is capable of shredding up to one million automobiles per year, approximately one every nine seconds. The shredder produces between 120,000 and 130,000 tons of Auto Shredder Residue Fluff (ASRF) annually. ASRF is the remaining materials that are not recovered in standard recycling and typically accounts for 25 percent of the automobile, including mixed plastics, glass, rubber, etc. The ASRF was landfilled prior to the BPS project.

During the BPS collaboration process, the Auto Shredder and TXI discovered that a separation process employed in another industry might enhance recovery of metals from the ASRF. The float-sink separation process had been developed for the food processing industry to separate ripe carrots from overripe carrots. The technology could handle a high throughput of materials and it utilized an inexpensive floatation media, both important characteristics for the Auto Shredder processing facility. A trial run using ASRF proved successful and promised the recovery of additional non-ferrous metals streams; the metal stream alone made the investment in the technology economically feasible. As a result of full-scale implementation, by constructing a separation process adjacent to the steel mill in Midlotheon, Texas, recovery of about 15 percent additional metals from the ASRF was achieved. On an annual basis, approximately 18,000 tons of aluminum, copper, magnesium, and tin are reclaimed and sold back into the commodity markets replacing virgin metals. Energy savings and disposal avoidance were realized. This project continues to operate and generate positive revenues for the Companies involved (Mayes 2001).

Another potential BPS project that has not been implemented but continues to be pursued (Mayes 2001) involves an additional separation stage to concentrate the non-chlorinated, high calorific plastic from the ASRF. This additional stream accounts for about 80 percent of the total ASR stream, or about 98,000 tons annually. TXI is investigating the use of the plastic stream as an alternative fuel source; the ASRF-derived fuel has a calorific value of 14,000 btu/lb., the equivalent of a light bituminous coal. Although there are regulatory concerns, which have prevented implementation (average levels of 15 ppm PCB), the potential for use in high temperature furnaces and cement kilns, could cut CO_2 and SOx emissions. According to the Applicant, compared to a coal-burning furnace, the ASRF-derived fuel could reduce CO_2 emissions and virtually eliminate SOx emissions. As for fuel cost, the fluff which costs the steel company $10/ton or more to landfill, would be cheaper than coal. If implemented at an adjacent cement plant, the Applicant estimated that it would displace 66,000 tons of Wyoming and Colorado coal used to fuel the cement plant.

Case Study 4 – CemStar® (ASLLC 2001e; Mayes 2000; Forward & Mangan 1999; Mangan 1999)

When Dr. Gordon Forward, former CEO of Chaparral Steel, was asked by the parent company to run a cement plant that was proximate to the steel facility in the 1990's he realized that the slag produced by the steel mill was chemically similar to the clinker used to make Portland cement. Based on a collaboration of cement and steel engineers a patented process was developed to make Portland cement using the steel slag substitution. The CemStar® process is based on the substitution of steel slag for clinker through its addition into the raw kiln feed; the steel slag has a low melting temperature and similar chemical characteristics to clinker. The conversion of steel slag to clinker requires much less energy input since a portion of the conversion reactions to form clinker have already occurred; thus the improved thermal efficiency of the process and decreased need for limestone calcinations contribute to lower NOx and carbon dioxide emissions.

The reduced CO_2 and NOx emissions earned the company two Global Climate Change awards from USEPA. The CemStar® process, which was cited by the Applicant as an early BPS success story, was developed before the formation of Applied Sustainability LLC took place or the term BPS was defined. While this intra-company collaboration differs from the BPS model, it served as a framework for the cross industry sector collaboration that was eventually adopted by BCSD-GM in its definition of BPS. Both Forward and Mangan became affiliated with BCSD-GM prior to BPS. Discussions with a TXI representative, confirms that the process change has been successful and is being implemented at other cement facilities (Mayes 2001).

5.2 Verification Procedures

BPS has been applied numerous times over the past several years and current plans by CH2M HILL as well as Hatch Associates Consultants, Inc. indicate that BPS projects will continue. Some of these projects have resulted in Applicant or Participant generated publications or presentations, but none have been published in peer-reviewed journals and QA/QC procedures for the data presented are essentially unknown. However, sufficient information was derived from interviews to support verification of the submitted claim.

In each of the case studies described in Section 5, discussions were held with representatives of companies that participated in the BPS process, all affirmed that the BPS process resulted in the benefits described in Applicant documentation. The exception was CemStar® whose representative was unaware of Applied Sustainability LLC or the involvement of Andy Mangan.[2] Companies were unwilling or unable to provide specifics on savings or other financial benefits and literature on environmental benefits was scarce (with the exception of CemStar®); similar experiences were encountered during other BPS projects (Young 2001).

Of importance is that the approach of a facilitated process (and the broader sense of purpose to find exchange opportunities) resulted in waste or by-product matches that might not have occurred otherwise; and these matches resulted in material uses that had been destined for disposal. It should be recognized that essentially similar processes, which rely on facilitated dialogues among the participants to identify materials reuse opportunities, would likely yield similar results.

6. Technical Evaluation Analysis

6.1 Verification of Performance Claims

Based on the evaluation of the results from independent interviews (performed by the author) of personnel involved in field demonstrations of projects that were developed from the BPS process as well as other related documentation including that provided by the Applicant, it appears that sufficient evidence/data are available to support the Applicant's Claim.

6.2 Limitations and Barriers

Technical and Data: Solutions to technical barriers rest, for the most part, with the participating firms; who if sufficiently motivated will find them. In Tampico, for example, it was found that PVC residues were readily converted into shoe soles and polyethylene/polypropylene bags were transformed into plastic shipping palettes. In the Auto Shredding project, investigations into the feasibility of a synergy have gone on for many years because the participants continue to believe that beneficial outcomes are possible. While consultants have pointed to the lack of data as a barrier in the process – that is, not enough of it – company participants expressed the opposite viewpoint. Company experts felt that data development for its own sake wasted resources and was without purpose; they felt that more time should have been devoted to identifying potential supplier-user matches. They believed that once an opportunity for exchange was identified between participants, data generation was given a purpose and would proceed unimpeded. On the one hand, it may not have been possible to talk about opportunities without data; on the other hand, the success of the Alberta Spent Caustic project, which occurred without initial data, would suggest that data are not always essential to identify opportunities. Finally, once an opportunity is identified, the participant companies themselves will decide what data are needed to evaluate the opportunity.

Economic: Implementation of many of the identified synergies will depend largely on economics and participants will likely depend on in-house cost-benefit analysis to decide which projects will provide the returns to justify process changes. In some cases, the cost of commodity raw

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[2] CemStar® was one of the initial synergies developed by Chaparral Steel and TXI that led to the establishment of Applied Sustainability LLC by investors that included TXI. Gordon Forward, CEO of Chaparral Steel was Chairman of Applied Sustainability LLC.

materials is so low that the use of substitutes may be greater than virgin materials; in such cases it would be unlikely that synergies would develop. In Tampico, it was found that hydrochloric acid recovery was uneconomical given the virgin market at that time. Market fluctuation may change the economics of a synergy over time, particularly if decisions were borderline. Unfortunately, the costs of polluting remain for the most part as externalities (that is they are typically not adequately reflected in the economy) and therefore as long as polluting costs are low, prioritizing waste reuse or reduction will be the exception and may require government intervention. A common example is when competitive landfill costs (i.e., low prices) do not reflect the type of waste that is being disposed, such as high calorific wastes that may have value as an alternative fuel. When coupled with regulatory disincentives, beneficial waste options such as waste-to-energy conversions become unlikely.

Return on Investment Competition: Most synergies will require an initial investment of capital, human resources, process research or modification, pretreatment, or other out of pocket expense before a saving is realized. Most organizations utilize a payback analysis to justify expenditures of resources; faster/shorter paybacks will usually receive priority over longer paybacks. The initial investment must compete for the same internal funds with other projects, which may also be projecting quicker paybacks. In addition, funding cycles vary from company to company, and depending on the size of the funding request, funding may take place quickly or wait for a year or more for approval and budgeting. Before a company decides to invest, a comparison of the risks and benefits of a project are weighed against competing investment choices; so, even if a project has a net positive value (it will save money) and the rate of return is fast (say under one year) other options may be more favorable by returning more money per investment dollar. A related cost barrier may be retention of participating companies after a synergy has been implemented – how will continued interest and fees be justified once benefits have been realized (see also Networks below). The Alberta BPS exemplified the issue of continued participation; the group disbanded the formal process after the first phase and decided to continue meeting informally and without cost.

Corporate practice: Some visionary companies have attempted to introduce sustainability as a metric in the payback analysis. There are no currently accepted sustainability measures that can be applied across the board, although at least one organization has proposed institutional and private sector reforms to improve cross-border sustainability (Aspen 2000). In the private sector, qualitative factors that are used to filter projects (such as consistency with corporate practice in terms of the vision, mission, policy, etc. of a company) may be mechanisms that allow for social benefit to be introduced into investment and financial decision-making. There may be segmentation or differentiation factors that would allow a company to target a market (such as a green market) that it would not ordinarily be qualified for were it not for sustainable behavior. Until the ISO-9000 standard series became the default standard for quality, many companies used it to differentiate their products from their competition. Similarly, the ISO-14001 standard was first adopted by a few visionary firms, which allowed them to create new market segments, and is now being adopted by many companies around the world. Public image may be another substantial factor that can affect decision-making regardless of the internal return on investment. A decision that can improve a company's public image may lead to more favorable investment behavior, which in turn may create a more favorable climate for siting decisions. In addition, favorable impressions on external organizations can lead to improved workplace practices, as image becomes an important asset worth protecting. The pharmaceutical industry could be used as an example of this type of phenomenon; despite using the same chemistries as the chemical industry, it will often make decisions to guard its health-oriented image over short-term investment returns. This industry realizes that in the long term, the returns related to image may exceed those that are purely financially (which tend to be short term) driven. Many have become environmental/sustainability focused leaders that give more than passing attention to the life cycle of materials; after all, they must in the course of business practice be in a position to at a moments notice, be able to trace a product batch to a consumer if a product recall must be made.

Regulatory: Waste classification and the Resource Conservation and Recovery Act regulations have been cited as significant regulatory barriers by past BPS participants as well as others (Gertler 1995b). Once a material is defined as a waste, the full weight of the regulatory system to prevent environmental damage becomes engaged. Regulatory systems to track wastes from point of generation to point of disposal are an integral part of the hazardous waste regulations in the United States, addressing generator accumulation and storage, transportation, interim storage, treatment, and disposal. Often, spent materials become wastes either by virtue of their characteristics or by listing as a substance or listing as a process waste. The system is an important deterrent to mishandling wastes. It is also an important deterrent to handling wastes innovatively. Unfortunately, once a material becomes defined as a waste, it is difficult to modify the label; delisting is a cumbersome and untimely process to gain relief for reuse possibilities other than those outlined in the regulations. For example, in Tampico, used chemical drums were classified as hazardous wastes, so companies wishing to reuse them faced regulatory hurdles that proved insurmountable. If BPS or other waste-to-material processes are to become a viable alternative process, some accommodation must be made to allow for safe reuse; examining this question and developing policy alternatives for consideration by NJDEP, while important, are beyond the scope of this verification.

Risk: Whenever hazardous material is transported from one location to another, the potential for exposure increases and if risk is ultimately a function of hazard and exposure, then risk potential increases when transportation takes place. The potential for leaks and spills due to accidents during shipping and handling may represent a form of liability that will be negotiated between transaction parties. Some companies will not accept the risk of transporting waste materials if transport liability is greater (or more uncertain) than the benefits of waste disposal avoidance (in the case of generator arranged transportation) or the benefits of substitution (in the case of purchaser arranged transportation). Although, there may be other liability scenarios that develop between transaction parties, there may be an opportunity for legislative/regulatory institutions to define liability so that uncertainty is reduced. Risks, however, are not limited to roadway, rail, or sea; risk also may be realized at the recipient site, particularly if characteristics of the material change or are poorly understood. In 1992, a fatal accident occurred at the former Rhone-Poulenc Martinez, California acid regeneration plant despite the facility's familiarity with spent refinery sulfuric acid. Another accident occurred about a year later at General Chemical Corporation's Richmond, California site forming a 15-mile cloud of fuming sulfuric acid (oleum) that sent 20,000 people to hospitals and emergency facilities (http://www.igc.org/cbesf/chem.html). These are but two chemical accidents that occurred at facilities with employees who are trained to expect the unexpected. Risk may also be introduced in more subtle ways. As noted in Section 1.3.1, product quality is dependent on the quality of materials that are used to make the product.

Unlike virgin materials that are manufactured to an agreed upon specification, wastes or by-products may be subject to variability (changes in known characteristics or introduction or removal of characteristics) that could affect final product quality. Thus, risk whether on the road or at a plant site must be considered whenever new materials are introduced; in fact, the United States Occupational Safety and Health Administration's Process Safety Management Standard calls for safety reviews before process changes occur for covered processes. It may be prudent to extend such reviews when waste materials that are subject to characteristic variability are being considered. In any event, the liability questions related to waste use are not clear-cut and may represent another barrier between generator and user of the material. While this issue is ultimately between the transaction parties, it must be an explicit aspect of the transaction, which should not be ascribed to a third party, such as NJCAT if verification of the process were given.

Geographic: For the most part, BPS projects have had a geographic limitation, principally because waste materials have not been high value. The geographic region may be fluid depending on the material in question; it should however be large enough to allow for potential exchanges to be considered. In the case of CemStar®, a cement company and a steel company exchange of steel slag may be profitable up to a transportation distance of 250 miles. On the other hand some materials may call for greatly reduced distances; carbon dioxide is relatively expensive to transport; thus producers and users must be proximate to one another to make an exchange viable as in the case of Tampico where such a synergy is under development (Mangan et al NO DATE).

Trust: An apparent strength of BPS is the facilitated brainstorming process that promotes trust building and a sense of purpose. Companies in the process industries are typically reluctant to share process information with outside entities that might have contact with competitors irrespective of confidentiality agreements (which do provide some level of comfort when sharing written information). Process innovation is rarely written down and may only be recognized (the aha phenomenon) during a lively exchange among technologists. Only when trust has been established can breakthroughs occur in a spontaneous fashion. Similarly, once trust has been established open communication will take place. Getting to the trust point in the process may take time (more or less depending on the group of individuals involved).

Participant Time: Previous BPS project participants indicated that most companies assigned only one person (some had two people who shared responsibility) to represent their company during the project. Often these individuals have multiple responsibilities that may leave little time to devote to the project. If a single meeting is missed, where critical information is shared or brainstorming results in a breakthrough, the lost opportunity may be difficult to regain. Since so much of the potential for exchange is dependent on process knowledge, companies that involve the highest level of human resources stand to gain the most benefits. Neglect may lead to failure, if success is defined as synergy identification. In addition, the dilemma that firms with limited human resources face is that they may have the most to gain but for the limitations on staff time.

Network: As discussed in Section 3, the potential for matches between generator and user is dependent on the number of participating firms (Metcalfe's Law); the larger the number of firms (and processes within them) the greater the potential for matches. Thus even if each participating firm had only one waste stream and one need, the number of potential matches rises as the number of firms participating in the network increases. It also holds true that the lower the 'cost of participation' threshold the more likely that participation will take place. If entry costs are high, then few will enter, if entry costs are lower more will take the chance at a return. The optimal entry fee lies at some point above no cost; some cost is needed to justify human resources to follow the investment and obtain a return on the entry fee and the subsequent time that were invested. If state sponsorship through NJCAT or NJDEP were a desired attribute of a materials exchange process, then a not-for-profit or non-profit entity may be the most efficient form to administer the network and keep costs low. A related aspect of networking is the potential for activities to take place beyond the formal BPS process. In the Alberta BPS project group, several participant companies which had disbanded when a subsequent phase of funding was requested (either too much money or too great of a distance) continued to remain active in five sub-committees outside of the formal BPS structure (McCormick 2001; Kay 2001). This might suggest that once benefits are realized, entry/investment cost may become a barrier to continued participation. Finally, while the potential for matches is dependent on the number of firms and processes that comprise a network, this alone cannot be used to predict the number of matches that progress to implementation, as the Tampico BPS project illustrated. Among the 21 industries involved in Tampico, 199 inputs and 174 outputs were identified that yielded 63 potential synergies, of which 13 were selected for additional evaluation and from this group 2 or possibly 3 synergies had been reported as implemented (Young et al 1999).

6.3 Net Environmental Benefit

The New Jersey Department of Environmental Protection (NJDEP or Department) encourages the development of innovative environmental technologies (IET) and has established a performance partnership between their verification/certification process and NJCAT's third party independent technology verification program. The Department in the IET data and technology verification/certification process will work with any New Jersey-based company that can demonstrate a net beneficial effect (NBE) irrespective of the operational status, class or stage of an IET. The NBE is calculated as a mass balance of the IET in terms of its inputs of raw materials, water and energy use and its outputs of air emissions, wastewater discharges, and solid waste residues. Overall, the IET should demonstrate a significant reduction of the impacts to the environment when compared to baseline conditions for the same or equivalent inputs and outputs.

A limitation that is endemic to determining NBE around processes like BPS is that companies do not readily release information that could reveal process yield efficiencies because competitors could use such information to determine profit margins. Thus, only cursory estimates of NBE can be developed with limited information. Therefore, companies who choose to participate in the BPS process should be willing to provide data that would enable a more precise quantification of the NBE

For BPS, it could be argued from a qualitative basis that the substitution of wastes or by-products for virgin materials represents the potential for environmental benefits, a priori. Three broad categories of environmental benefits of BPS projects include disposal avoidance (such as land disposal avoidance on the part of the waste supplier), virgin material production avoidance (supplier energy and raw material and waste savings as well as user cost avoidance), and emission reductions (supplier and user). However, these categories represent only potential benefits because the actual exchanges (or synergies) would dictate the specifics of the case. It is entirely possible that no NBE could result from an exchange; for example, in the case of a marginal exchange where transportation and additional processing offset projected energy and emission savings. For illustrative purposes, estimates of CO_2 reductions are developed for two BPS case studies.

Spent Caustic Synergy

For the Spent Caustic Synergy (Section 5.1, Case Study 1) the Applicant reported that 438 tons of Spent Caustic was used in place of virgin material in the first year of implementation. Virgin caustic soda and chlorine are co-products of brine electrolysis, produced in roughly similar quantities (1.1 ton NaOH for 1 ton of Chlorine) through electrolysis, consuming between 2,530 to 3,450 kWh/ton per ton of chlorine gas dependent on the type of electrolysis cell used (Pellegrino 2000). Electricity is the greatest energy input into the electrolytic process. Thus, for 428 tons of spent caustic (assuming concentrations that are equivalent to virgin caustic) between 1 million kWh and 1.4 million kWh of electricity was saved through the substitution. If 1.2 million kWh is taken as the mid-point value, and a CO_2 equivalence factor of 1.1 pounds of CO_2 per kWh is used (average PJM grid emission factor for 1999), approximately 1.32 million pounds of CO_2 was avoided. If sulfur rich fuels were used to produce electricity, SO_2 reductions would also be expected. There are also CO_2 savings related to avoidance of fuel use for the transport of virgin caustic; however, this CO_2 reduction may be offset by emissions from the transportation of the spent caustic to the end user. In addition, 438 tons of spent caustic were not disposed through deep well injection by the generator.

Auto Shredder Residue

For the Auto Shredder Residue (ASR) Synergy (Section 5.1, Case Study 3) the Applicant reported that approximately 18,000 tons of aluminum, copper, magnesium, and tin are being reclaimed and sold back into the commodity markets. In this case, environmental benefits would accrue from avoidance of mining and beneficiation of these metals. According to various sources, the amount of energy saved through recycling may be as much as:

- 95% for aluminum (http://www.aluminum.org/default.cfm/0/4);
- 65% to 95% for copper (http://www.un.org/esa/sustdev/esa99dp3.pdf);
- 74% for tin (http://envirosystemsinc.com/alumfac.html);
- 95% for magnesium (http://www.nrcan.gc.ca/mms/cmy/content/1997/36.pdf).

Of course, the natural resource impact of mining is also avoided, which may be significant.

Based on previously reported (http://www.flash.net/~adherent/asr_economics.htm) ratios of aluminum, copper, tin, and magnesium in ASR residues, a possible distribution of these metals would be about 6,900 tons of aluminum, 9,600 tons of copper, 100 tons of tin, and 1,400 tons of magnesium. For the purpose of estimating the NBE, only aluminum, copper, and magnesium will be considered. Estimates of energy used for the production of these metals on a unit (tons) basis are provided as follows:

- Electrolytic reduction processes account for about two-thirds of the total energy input to the aluminum industry, representing about 6.8 kWh/lb or about 13,600 kWh/ton of aluminum produced. (http://www.eia.doe.gov/emeu/mecs/iab/aluminum/page2b.html).
- Copper production utilizes about 85 million btu of energy per ton of production (http://www.wws.princeton.edu/cgi-bin/byteserv.prl/~ota/disk2/1988/8808/880809.PDF).
- For magnesium, electricity demand ranges from 10 to 19 kWh/kg depending on the process employed. Using the mid-point, this represents about 15 kWh/kg or about 66,000 kWh/ton of magnesium produced (http://www.amm.com/inside/roskanal/1999/rk061899.htm).

With these values, and applying a CO_2 equivalence factor of 1.1 pounds of CO_2 per kWh (average PJM grid emission factor for 1999) and an average (natural gas and fuel oil) CO_2 equivalence factor of 139 pounds of CO_2 per 1,000,000 btu (USEPA 2001e) as well as a 95% energy savings factor from above, approximately 302,000,000 pounds of CO_2 are avoided through recycling the 18,000 tons of recovered material (See Appendix 2 for calculation). For comparison purposes, 302,000,000 pounds is approximately equivalent to 275,000,000 kWh (using the average PJM grid emission factor for 1999).

Caveats

Estimates of energy savings and CO_2 savings are highly case dependent. Actual NBE would be based on the assumption that materials that would ordinarily have been destined for disposal would be fully reused; therefore, representing potential environmental benefits from energy and materials savings. This implies that by reusing materials that require minimal processing, energy used during raw materials production could be saved. If additional processing is needed on the part of the user, savings may be affected. Finally, market forces will affect potential savings to supplier and user and the reuse potential of wastes or by-products.

It is also interesting to note that some have argued that waste material reuse may hinder environmental improvements by accommodating the status quo; the same charge has been leveled against Industrial Ecology, see also Section 3 (Baas 1999). The status quo charges seem to be premised on the notion that technology can be frozen with disregard for the fact that change is inevitable, driven by global, national, regional and local economic forces. If environmental benefits can be achieved, policy should encourage it.

7. Protection of the Health and Safety of Workers and the Public

The New Jersey Department of Environmental Protection requires that health and safety issues related to the development of innovative environmental technology have been addressed. The review process, which is based on documentation provided by the applicant, cannot address the adequacy of health and safety protections of this process a priori. Each facilitated arrangement to exchange waste will be unique between the parties of by-product provider and by-product user; therefore, the potential combinations are limitless. Consequently, by-product characteristics (including known and unknown contaminants) must be evaluated for compatibility with unit processes, operations, and materials of construction on a case-by-case basis by the supplier and the user.

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9. Abbreviations

ASRF – Auto Shredder Facility Fluff

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

BPS – By-Product Synergy

IET – Innovative Environmental Technologies

ITRC – Interstate Technology and Regulatory Cooperation

LPA – Limited Preliminary Application

NJCAT – New Jersey Corporation for Advanced Technology

NJDEP – New Jersey Department of Environmental Protection

PPA – Performance Partnership Agreement

TSDF – Treatment, Storage and Disposal Facilities

USDOE – United States Department of Energy

USEPA – United States Environmental Protection Agency

Appendix 1 - By-Product Synergy Results (ASLLC 2001a)

IMPLEMENTED SYNERGIES (all figures annual)	ENVIRONMENTAL BENEFITS				
	Ecological Biological	**Energy Savings**	**Solid Residues**	**Liquid Residues**	**Gaseous Residues**
CemStar® 130,000 tons of steel slag used in place of lime (single plant operation)	Biological benefits from reduced S02 (acid rain) from burning coal	11,800 tons of coal displaced; life cycle energy savings for coal mined & shipped to North Texas	130,000 tons of steel slag used as feedstock at cement plant		65,000 tons of C02; 800 tons NOx; 33 tons of total hydrocarbons reduced
ASR 120,000 tons of Auto Shredder Residue (ASR) mined for metal reclamation and possible fuel		18,000 tons of metals recovered from ASR and not mined (Al, Cu, Mg, tin)	18,000 tons of metal not mined		
ASR 98,000 tons of Auto Shredder Residue (ASR) separated as potential high energy fuel (14,000 btu).	Biological benefits from reduced S02 (acid rain) from burning coal	66,000 tons of coal displaced at Midlothian plant alone; life cycle savings for coal mined & shipped to North Texas	98,000 tons not landfilled if ASR used as fuel substitute from Midlothian shredder alone		SO_2 emissions reduced from subsitution of ASR for 66,000 tons of coal.
Graphite/Copper Sludge – 37,500 lbs. Graphite/copper sludge not landfilled or dumped in municipal water system	Landfill biota not destroyed (not quantifiable, but copper is toxic to landfill microbes)	Life cycle energy savings from 18,750 lbs. copper not mined; savings from avoided landfill trips	37,500 lbs. graphite & copper sludge not landfilled	412,500 gals. of graphite & copper laden wastewater	
Spent Caustic 438 tons spent caustic in place of virgin material; potential for three times that	Landfill biota not destroyed (not quantifiable, but caustic is toxic)	Life cycle energy saved from 438 tons of virgin caustic not manufactured	438 tons of spent caustic not deep well injected	Reduced chloride content by more than 200% in 2000 tons of saltcake per year	Destruction of spent caustic sulfurous odors in the mill recovery boiler

Appendix 2 – Calculation of ASR CO_2 Savings

Metal	% in Residue	Equivalent in tons	Rounded Value	kWh/ton	btu/ton	kWh total	btu total	CO2/kWh factor	CO2/mbtu factor	CO2	95%
Total	**13.1**	**18,000**	**18,000**							**318,288,000**	**302,373,600**
Aluminum	5.0	6,870	6,900	13,600		93,840,000		1.1		103,224,000	
Magnesium	1.0	1,374	1,400	66,000		92,400,000		1.1		101,640,000	
Copper	7.0	9,618	9,600		85,000,000		816,000,000,000		139	113,424,000	
Tin	0.1	137	100	n/a							
Average of CO2 per million btu					Equivalent kWh for 302,373,600 pounds of CO2 = 274,885,091, say 275,000,000						
natural gas	117										
fuel oil	161										
average	139										