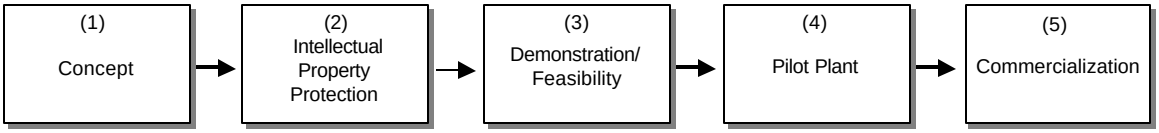
Pittsburgh Mineral & Environmental Technology, Inc.

A White Paper on the Technology Development Life Cycle

Introduction

Taking a technology from concept through commercialization requires an understanding of, and appreciation for, the full Technology Development Life Cycle. This life cycle consists of the following five stages:



Surprisingly few organizations understand and appreciate how to complete all of the above stages in a successful fashion; far fewer are able to do it in a repeatable way. Technology development, from concept through commercialization, is all too often a troublesome process. Under the best of circumstances, technology development is difficult; under the worst of circumstances, it is inefficient or downright dysfunctional. Technology continues to languish in universities, research institutes, and corporate laboratories.

As a successful technology development company, Pittsburgh Mineral & Environmental Technology, Inc. (PMET) is a notable exception to the rule. PMET's technological concepts have resulted in eight patents, with a ninth patent application currently in process. A number of these patents have produced what are arguably the "best" demonstrated solutions in their field, including one that the U.S. Environment Protection Agency (EPA) has identified as the Best Available Demonstrated Technology for removing mercury contaminants. And, perhaps most importantly, PMET's patented, demonstrated technologies have driven the construction and outfitting of revenue-generating pilot plant and production facilities.

Four representative PMET technologies – three that are commercialized, and one soon to be commercialized -- are summarized below:

PMET Technology	*(1) Concept*	*(2) IP Protection*	*(3) Demonstration/ Feasibility*	*(4) Pilot Plant*	*(5) Commercial-ization*
Brixx	Structural building blocks from fly ash	Patented May 30, 2000	PA Energy Harvest Grant	Built and operating onsite	Underway
Jet Mill	Cement additives from fly ash	Patented March 21, 2000	Ireland's Electricity Supply Board	Built and operating offsite	Licensing revenues
Carbon Separation	Carbon from fly ash	Patented March 30, 1999	Consortium for Premium Carbon Products	Built and operating onsite	Joint venture revenues
Mercury Recovery	Pure mercury from contaminated materials	Patented April 5, 1994	US DOE and Gas Research Institute	Built and later sold	Licensing/ operational revenues

The remainder of this white paper addresses each technology in turn, tracing its evolution from concept through commercialization. These are the "success stories" of a technology development company that has not only learned how to do it right, but how to repeat it.

Soon-To-Be Commercialized Brixx Technology

Researchers have sought to develop fly ash bricks for years, but only PMET knows how to produce a superior fly ash building product in an efficient, economical fashion.

(1) Concept. PMET's process for producing "Brixx" (i.e., construction brick, block and shaped building products) transforms fly ash and bottom ash into high quality products having properties equal to, or exceeding, those of competing brick, block or cement-based building products.

Brixx are manufactured using conventional forming and hydrothermal equipment. The process combines fly ash, bottom ash and a reactive mineral binder; compacts the mixture into the desired shape; and hydrothermally cures the shaped product under conditions that result in the growth of Tobomorite mineral crystals. These crystals bond tightly with nearby ash particles to create strong, durable building products.

Brixx contain up to 90% ash; consume far less energy during production than traditional building products; produce no secondary wastes; have precise dimensions; are available in a variety of colors; and may be solid, hollow or interlocking for structural integrity or decorative use. In addition to resisting weathering and absorption, they are equal in strength to fired clay brick and are superior in strength to concrete block.

(2) Intellectual Property Protection. The technology is protected by U.S. patent number 6,068,803, "Method of Making Building Blocks from Coal Combustion Waste and Related Products," which was issued on May 30, 2000.

(3) Demonstration/Feasibility. To demonstrate the commercial feasibility of Brixx, PMET recently received an $84,000 Energy Harvest grant from Pennsylvania's Department of Environmental Protection. PMET, which was the first recipient of an Energy Harvest grant, was one of 139 applicants requesting $45,000,000 in funding. The grant program is a new state initiative that mixes money from the Clean Air Fund, Growing Greener and the U.S. Department of Energy.

PMET has also submitted a proposal to the Ohio Coal Development Office, which co-funds technologies that can use high sulfur coal in an economical, environmentally sound manner.

(4) Pilot Plant. PMET's pilot plant for manufacturing Brixx produces full-size brick, block and paver products. The plant's flexibility makes it especially useful in comparing ash compositions, optimizing product chemistry and process parameters, and producing product for acceptance testing and field trials. The plant can compact single or multiple Brixx in sizes up to 8" x 8" x 4"; produce hollow, shaped and interlocking Brixx; and form up to three tons of Brixx per day under a wide range of conditions.

(5) Commercialization. PMET will soon begin commercializing its Brixx technology, which positions it to enter the domestic and global markets for structural building materials. Competitively, PMET's Brixx are a credible substitute for traditional products in terms of strength and cost-effectiveness. In addition, they are superior to fly-ash based products currently available (primarily in India and China), which incorporate a much lower percentage of fly ash, lack the crystalline characteristics required for strength and durability and involve technologies that are limited to specific sizes, shapes, and/or volumes. For PMET, bigger concerns than competition per se are the capital cost of constructing a high-volume building materials production plant and the need to obtain an appropriate marketing partner.

… And What's in the Commercial Pipeline? PMET is currently discussing the construction of full-scale Brixx production facilities with several prospective partners, including a development company that builds energy production facilities and a major manufacturer and supplier of lime and limestone products.

Commercialized Jet Mill Technology

PMET's innovative process for removing unburned carbon from fly ash results in an ash that is suitable for use as a cement additive.

(1) Concept. PMET's jet mill technology removes unburned carbon from fly ash based upon simultaneous fluid air-jet autogenous grinding and air classification. In this proprietary process, high-carbon ash is automatically introduced into the jet mill and autogenously ground by high energy particle-to-particle impacts. The ground material is then carried upward in a controlled velocity air stream in which the higher density, low-carbon ash falls to the bottom of the unit and the lower density, high-carbon ash is carried out of the system through a rotating classifier wheel. The desired carbon content of the ash is achieved by controlling the velocity of the upwardly moving air stream, the rotational speed of the classifier wheel and process time. Ash with a sufficiently low carbon content and a sufficiently small particle size is a viable replacement for Portland cement.

(2) Intellectual Property Protection. PMET's jet mill technology is protected by U.S. patent number 6,038,987, "Method and Apparatus for Reducing the Carbon Content of Combustion Ash and Related Products", which was issued March 21, 2000.

(3) Demonstration/Feasibility. PMET's jet mill technology is of potential interest to any fly ash supplier who wishes to produce cement additives with a carbon content of 3-4% (measured in terms of Loss on Ignition, or LOI) from fly ash with a carbon content of 12% LOI or less.

Ireland's Electric Supply Board (ESB) is a case in point. ESB sought to separate carbon from its fly ash and produce an ash of salable quality. Based on a review of all of the available process technologies, ESB selected PMET's jet mill process technology. Numerous tests were performed to support the required performance guarantees.

(4) Pilot Plant. An equipment vendor, Hosokawa Micron Powder Systems (HMPS), built and maintains a jet mill pilot plant at its facilities. This pilot plant is a small commercial unit used for testing and processing various types of ashes.

(5) Commercialization. PMET has an exclusive arrangement with HMPS to produce jet mill units for commercial use. Ireland's ESB signed a licensing agreement in 2001, at which point HMPS constructed ESB's jet mill unit.

…And What's in the Commercial Pipeline? PMET has provided information on its jet mill capabilities to several prospective customers, here and overseas. One prospective customer, a domestic marketer of coal combustion products, anticipates using PMET's jet mill technology to process ash sourced from its customer base. Another prospective customer, an international company headquartered in Switzerland, may augment its fly ash processing capabilities by purchasing a jet mill unit.

Two parties have committed capital to the construction of jet mill units, which cost $1.5 M apiece. At that price, jet mill technology represents a smaller capital investment than competing technologies such as Separation Technology, Inc.'s electrostatic separation technology or Progress Materials, Inc. Carbon Burn-Out (CBO) technology. PMET's technology enjoys a distinct competitive advantage over these other two technologies when capital spending is tight (as in the current environment), or when the plant in question is a smaller, older plant less likely to entertain a large capital investment.

Commercialized Carbon Separation Technology

PMET's carbon separation process for removing carbon from fly ash produces a high carbon product that is suitable for use as a reagent in steelmaking.

(1) Concept. PMET's carbon separation technology is a simple one-step process based upon classification (i.e., sorting), which selectively removes particulate matter from fly ash through centrifugal and gravitational forces. This technology provides a very low cost alternative for selected ashes that contain non-combined carbon and have a bimodal ash-carbon distribution. The high quality carbon extracted from the fly ash is a viable replacement for anthracite and coke breeze.

(2) Intellectual Property Protection. The technology is protected by U.S. patent number 5,887,724, "Methods of Treating Bi-Modal Fly Ash to Remove Carbon," which was issued on March 30, 1999.

(3) Demonstration/Feasibility. PMET investigated the feasibility of carbon separation techniques through the auspices of an industry-funded group, the Consortium for Premium Carbon Products from Coal (CPCPC). CPCPC engaged PMET to research the size and nature of the market for classifying (i.e., sorting) coal combustion products generated by cyclone boilers, relying on physical parameters such as grade and size.

(4) Pilot Plant. PMET built a fly ash utilization and carbon recovery pilot plant to assist power plant operators, ash distributors and other companies interested in converting coal combustion fly ash from a landfilled waste to a salable product. PMET's fly ash utilization and carbon recovery pilot plant includes alternative methods for separating the ash, including mechanical screening and air separation. The pilot plant also includes alternative methods for grinding ash in order to liberate adhered and entrapped carbon.

(5) Commercialization. PMET's first production-sized carbon separation plant is up and running at Reliant Energy's Niles plant. PMET formed an LLC with U.S. Natural Resources (USNR) to sell recovered carbon under the name, Pitt Carbon, to steelmakers and third party suppliers. In return for the rights to Niles' ash, the LLC partners will share 10% of their profits with Reliant Energy, and are splitting the remainder.

Niles generates approximately 50,000 tons of fly ash per year from its cyclone boilers. Based on a detailed characterization of ash samples from Niles, PMET expects to recover approximately 10,000 tons of carbon per year from the available ash. The recovered carbon has a delivered value of $100 per ton, or a total of $1,000,000 per year.

… And What's in the Commercial Pipeline? PMET anticipates building a second carbon separation facility at a power plant in West Virginia, with an expected volume three times that of Niles. Other possible sites include power plants in Colorado and Nebraska. PMET anticipates building at least one plant a year for the foreseeable future.

Commercialized Mercury Recovery Technology

In developing this technology, PMET's goal was to construct a universal process capable of solving a variety of mercury recovery problems in a variety of material and environmental settings.

(1) Concept. PMET's mercury recovery technology pulverizes mercury contaminated material; incorporates additives; heats the material; extracts all traces of mercury from resulting air and water vapor; and condenses mercury vapor to collect metallic mercury suitable for direct refining and recycling. The only materials leaving the system are clean air, clean steam, clean treated material, and a sellable mercury metal.

(2) Intellectual Property Protection. The technology is protected by U.S. patent number 5,300,137, "Method for Removing Mercury from Contaminated Soils and Industrial Wastes and Related Apparatus," which was issued on April 5, 1994. Additional foreign patents were issued in Australia, Canada, Great Britain, and Germany.

(3) Demonstration/Feasibility. PMET's flagship mercury recovery technology is considered the Best Demonstrated Available Technology (BDAT) by the U.S. EPA. Two benchmarking projects (one a government-funded project and the other an industry-funded project) reached similar conclusions.

The U.S. DOE's Office of Science and Technology funded the government benchmarking project. In this project, PMET demonstrated its mercury recovery technology on a mixed waste stream containing river sediment contaminated with both mercury and low level radioactive waste. PMET's technology successfully removed and recovered the mercury while leaving the radioactive contaminants behind in the sediment residues. In other words, the recovered mercury was not radioactive (and hence unusable), nor were there any radioactive emissions from the process into the atmosphere.

The Gas Research Institute (GRI) funded the industry benchmarking project to assess available mercury recovery technologies. In this project, PMET's technology and two competitive vendor technologies processed sample material provided by GRI, which concluded that PMET's technology was clearly superior with regard to mercury removal and recovery as well as the elimination of secondary wastes.

To date, the process has successfully removed and recovered mercury from numerous materials, including soils, chlor alkali wastes, by-products from smelting and refining copper and precious metals, waste water treatment sludges, catalysts, carbon products, batteries, and fluorescent bulbs.

(4) Pilot Plant. PMET built a mercury recovery pilot plant for processing sample batches of mercury contaminated materials. This plant is a scaled-down version of larger, two-ton mobile and fixed-site modular production units. Recently, PMET sold the pilot plant to a client for small-scale production use.

(5) Commercialization. PMET has licensed its technology in the United Kingdom, Germany, Australia, and Taiwan to remove and recover mercury from contaminated soils, debris, industrial wastes and mercury-containing products. Domestically, the company has operated its technology for clients such as El Paso Natural Gas and Cyprus Mining.

… And What's in the Commercial Pipeline? Three client proposals are pending (two in Brazil, one in Taiwan). In addition, PMET is developing a new but related technology for recovering mercury from activated carbon that coal-fired energy producers use to reduce emission levels of airborne pollutants. The company recently filed a patent application for its new technology, and has submitted a proposal to the U.S. Department of Energy (DOE) to demonstrate the technology's feasibility. PMET plans to commercialize the technology through a marketing agreement with ISG Resources, Inc., the nation's leading marketer of coal combustion products.