Eco-Industrial Parks

The Case for Private Planning

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An eco-industrial park (EIP) is a community of companies, located in a single region, that exchange and make use of each other's by-products or energy. Currently, EIPs are being promoted as a means of achieving sustainable development. Proponents argue that such a symbiotic community of businesses produces more environmental benefits than each company could realize on its own. Numerous EIPs have been planned in North and South America, Southeast Asia, Europe, and southern Africa (Ayres 1996; Gertler 1995; Indigo Development 1998; Lowe 1997).[1]

Advocates of EIPs consider the Danish coastal city of Kalundborg a model. There, the main industries and the local government turn by-products into raw materials by trading and making use of their waste streams and energy resources. Although the Kalundborg community and other similar cases developed entirely through market forces,[2] many policy analysts argue that public planners can copy and even improve on Kalundborg. Thus, Paul Hawken (1993) speculates: "Imagine what a team of designers could come up with if they were to start from scratch, locating and specifying industries and factories that had potentially synergistic and symbiotic relationships" (63). Similarly, Sim Van Der Ryn and Stuart Cowan (1996) suggest that the potential of planned industrial ecosystems is even greater than that of the indus-

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1. Although these communities of companies sometimes bear different labels—such as industrial symbiosis, industrial clusters, environmentally balanced industrial complexes, and localized industrial ecosystems—they all refer to the concept described in this article as *eco-industrial parks* (Lowe 1997, 64).

2. Other examples are located in the Austrian province of Styria, the Ruhr region of Germany, and the Houston Ship Channel (Garner and Keoleian 1995; Gertler 1995; Lowe, Moran, and Holmes 1996; and Schwartz and Steininger 1997).

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trial ecosystem that evolved in Kalundborg. Ernest A. Lowe (1997) points out that "while industrial ecosystems must be largely self-organizing, there is a significant role for an organizing team in educating potential participants to the opportunities and in creating the conditions that support the development" (58).

Despite such endorsements, the movement toward public planning of EIPs is misconceived. It rests on a misreading of the Kalundborg experience, and it reflects insufficient knowledge of how market forces historically have promoted resource recovery. In this essay, I show that Kalundborg is simply a contemporary example of how industrial loops have always worked. I compare private and public mechanisms in the development of industrial loops, and I argue that greater reliance on market forces would be a more effective way of replicating the Danish experience.

The Rationale for Planning Eco-Industrial Parks

Although some people consider all waste a hazard to health and the environment that must be destroyed or prevented, many others consider waste an economic resource (Sinha 1993). Many who view waste as a resource label themselves "industrial ecologists," drawing on an analogy with the natural world, in which living organisms consume each other's wastes. The premise of industrial ecology is that modern industrial economies should mimic the cycling of materials in ecosystems throughout the processes of raw-material extraction, manufacturing, product use, and waste disposal. Industrial ecologists view industries as webs of producers, consumers, and scavengers, and they encourage symbiotic relationships between companies and industries. The ultimate goal of industrial ecology is to reuse, repair, recover, remanufacture, or recycle products and by-products on a very large scale (Allenby and Richards 1994, Ayres and Ayres 1996, Frosch and Gallopolous 1989, Garner and Keoleian 1995, Graedel and Allenby 1995).

Some industrial ecologists and public planners envision EIPs as networks of companies and other organizations that exchange and make use of by-products. By integrating principles of industrial ecology with principles of pollution prevention and sustainable design, such regionally localized firms should, in the view of industrial ecologists, provide one or more of the following benefits, relative to traditional, nonlinked operations: reduction in the use of virgin materials; reduction in pollution; increase in energy efficiency; reduction in the volume of waste products requiring disposal; and increase in the amount and types of process outputs that have market value (Gertler 1995).

The Kalundborg Experience

Most industrial ecologists believe that Kalundborg, a small city on the island of Seeland, seventy-five miles west of Copenhagen, is the first recycling network in history (Garner and Keoleian 1995; Gertler 1995; Lowe, Moran, and Holmes 1996; Schwarz and Steininger 1997). In this city of twenty thousand people, the four main industries—a coal-fired power plant (Asnæs), a refinery (Statoil), a pharmaceuticals and enzymes maker (Novo Nordisk), a plasterboard manufacturer (Gyproc), as well as the municipal government and a few smaller businesses—feed on each other's wastes in transforming them into useful inputs.

This local synergy began to form in the 1970s and now operates as follows. The Asnæs power company supplies residual steam to Statoil refinery and, in exchange, receives refinery gas that formerly was flared as waste. The power plant burns the refinery gas to generate electricity and steam. It sends excess steam to a fish farm that it operates, to a district heating system that serves 3,500 homes, and to the Novo Nordisk plant.[3] Sludge from the fish farm and pharmaceutical processes becomes fertilizer for nearby farms. The power plant sends fly ash to a cement company, and gypsum produced by the power plant's desulfurization process goes to a company that produces gypsum wallboard. The Statoil refinery removes sulfur from its natural gas and sells it to Kemira, a sulfuric acid manufacturer.

A Gradual Development

Consultants did not design, nor did Danish government officials finance Kalundborg's industrial symbiosis. Rather, it resulted from many separate bilateral deals between companies, each of which sought, on the one hand, to reduce waste treatment and disposal costs and, on the other, to gain access to cheaper materials and energy while generating income from production residue. Even today, no higher level of administration exists to manage the interactions (Lowe 1997, 59). Jorgen Christensen, a spokesperson for Novo Nordisk, is explicit on that point: "I was asked to speak on 'how you designed Kalundborg.' We didn't design the whole thing. It wasn't designed at all. It happened over time" (qtd. in Lowe 1995, 15).

Henning Grann, a Statoil employee, reinforces the point: "The symbiosis project is originally not the result of a careful environmental planning process. It is rather the result of a gradual development of co-operation between four neighboring industries and the Kalundborg municipality" (qtd. in Garner and Keoleian 1995, 28). As Nicholas Gertler (1995) sums it up, the basis of the Kalundborg system is "creative business sense and deep-seated environmental awareness," and "while the participating companies herald the environmental benefits of the symbiosis, it is economics that drives or thwarts its development" (n.p.). Much of Kalundborg's "industrial metabolism" rests on the physical proximity of plants that are compatible in terms of their material flows, plus a few well-established and widespread industrial practices, including the cogeneration of electricity and heat, the hydrodesulfurization of gas, the heat-

3. Some residual steam was also sent to greenhouses that belonged to Asnæs, but this practice was abandoned after growers elsewhere in Denmark complained of unfair competition because the greenhouses in Kalundborg enjoyed especially low heating costs (Lowe, Moran, and Holmes 1996, C12).

ing of greenhouses from excess power-plant heat, and the use of standard transportation and purification technologies.

Using Kalundborg as the model, EIP advocates often argue that public planners, following a hierarchy of consciously chosen objectives, can outperform private agents, whose priority is to maximize profit rather than to promote sustainable development (Hawken 1993, Van Der Ryn and Cowan 1996). The idea of planning EIPs has garnered increasing support in academic, business, and political circles. Numerous EIP projects are now under way in North and South America, South Africa, Asia, and Europe. In the United States, the concept has won the support of the President's Environmental Technology Initiative (PETI), the President's Council on Sustainable Development (PCSD), and the Environmental Protection Agency (EPA), which created an Eco-Industrial Park Project in 1994. Several areas have been designated "demonstration sites" for EIPs in the United States.[4]

Reading Too Much into Kalundborg

EIP advocates fail to recognize that Kalundborg's industrial symbiosis is not self-sufficient and is not limited to the industrial park. For example, Statoil (sulfur) and Asnæs (fly ash and clinker), both located in Kalundborg, sell some of their by-products to Kemira and the Aalborg Portland cement company, whose plants are located on the Jutland Peninsula. Gyproc imports its supply of virgin gypsum, still a significant input, from 2,500 miles away in Germany and even from Spain, and in the early 1990s Asnæs fish farms exported to the French market most of the two hundred tons of trout and turbot they produced annually.

Furthermore, many of Kalundborg's plants are subsidiaries of foreign-owned corporations (for example, Statoil is a Norwegian firm, and Gyproc is owned by a Dutch company). In short, Kalundborg is a typical industrial city, a nexus of trade whose firms import and export numerous components and products on a worldwide scale (Gertler 1995, Lowe 1995, Lowe, Moran, and Holmes 1996, Tibbs 1992).

No Kalundborg company ever acted on its own to exploit opportunities that did not fit within its core business, no matter how environmentally attractive those opportunities were. And when government intervention forced a linkage, the venture lost money.[5] Moreover, even though each company considers the others when making

4. Designated sites include the Cabazon Resource Recovery Park (California), Cape Charles (Virginia), Chattanooga (Tennessee), Civano (Tucson, Arizona), East San Francisco Bay (California), Fairfield Park (Baltimore, Maryland), the Green Gold Initiative (Buffalo, New York), the Green Institute (Minneapolis, Minnesota), Londonderry (New Hampshire), Mesa del Sol (Albuquerque, New Mexico), Plattsburgh (New York), Riverside Eco-Park (Burlington, Vermont), Trenton (New Jersey) and Triangle J Council of Governments (North Carolina). See Indigo Development 1998.

5. The Danish government required Asnæs to initiate a fish-farming operation as a way to consume excess sludge. The operation lost money until the government allowed sale of the fish farm to an independent operator, who converted it into a profitable venture. As some observers noted, fish farming "just didn't fit" into Asnæs's line of business (qtd. in Lowe, Moran, and Holmes 1996, C12).

decisions, it still evaluates its own agreements independently. There is no "Kalundborg-wide" assessment of performance because participating companies believe that such performance would be a complex and unrewarding standard (Lowe, Moran, and Holmes 1996, C7). A final point that EIP planners should note is that the development of Kalundborg's "industrial ecosystem" required environmental regulatory flexibility.[6]

As interest in EIPs has increased, so has research, which has brought other examples of industrial symbiosis to light. In a research project tracking industrial loops,[7] Erich J. Schwarz and Karl W. Steininger (1997) documented the same phenomenon in the Austrian province of Styria. The authors concluded that, as in Kalundborg, cost calculations triggered the development of the Styrian structure. Those findings spurred further research in the Ruhr region of Germany, which resulted in qualitatively similar findings (Schwarz and Steininger 1997, 50). Scholars who study EIPs have also discovered that the same processes have been going on for a long time in major petrochemical complexes such as the Houston Ship Channel (Lowe, Moran, and Holmes 1996, A4). Is Kalundborg unique? No, the Danish city's experience is but a contemporary example of processes that are as old as cities.

Industrial Symbiosis in Historical Perspective

Industrial symbiosis—that is, exchange between firms in which by-products of one industry become the valuable inputs of another—is probably as old as civilization. Certainly long before the advent of modern environmental consciousness and regulation, documents and texts were published containing detailed illustrations of by-product reuse in different industries. Examples include *Waste Products and Undeveloped Substances: Or, Hints for Enterprise in Neglected Fields* (Simmonds 1862) and *The Recovery and Use of Industrial and Other Waste* (Kershaw 1928). Other examples can be found in patent records, graduate theses, and the serial *Waste Trade Directory,* which was published by the Atlas Publishing Company beginning in 1905. The same

6. Danish authorities approach environmental protection by requiring firms to submit plans detailing their continual efforts to reduce their environmental impact. According to Gertler (1995), the flexibility of this approach, coupled with the fact that the Danish Environment Ministry encourages attempts to find uses for all waste streams on a case-by-case basis, allows firms "to focus their energies on finding creative ways to become more environmentally benign instead of fighting the regulators" (n.p.). Also, the stricter environmental regulations that have been the driving force for some linkages have been performance standards rather than technology standards. Therefore, firms could choose technologies that rendered their waste streams usable as feedstock elsewhere. For a more detailed description of Danish environmental policymaking and especially of its flexible and personal approach as compared to the formulaic and procedure-driven U.S. approach, see Wallace 1995.

7. "The initial procedure was to choose a basic goods company since this could be expected to represent a supplier and recipient of various kinds of waste. Starting here, the waste streams coming into the plant site as well as originating from it were then followed. For each new supplier and recipient thus identified the procedure was repeated until the geographic system boundary was reached" (Schwarz and Steininger 1997, 50).

publisher's *Waste Trade Journal* covered "every aspect of the giant Secondary Materials Industry . . . of the Free World," and its monthly affiliate *Industrial Wastes and Salvage Journal* provided a "complete roundup of national and world markets in new and secondary materials" (407). These periodicals were "revised every year to include vital, complete, up-to-the-minute listings of Dealers, Consumers, Associations, Consultants, Processes and Processors, Equipment . . . covering the Continent and all 50 states" (Lipsett 1963, 407).

The importance of industrial loops was obvious to many commentators of the past. In his classic work *On the Economy of Machinery and Manufactures,* the English polymath Charles Babbage ([1835] 1986) wrote that preventing waste in industrial production often caused "the union of two trades in one factory, which otherwise might have been separated" (217). As Peter Simmonds (1862) observed a few decades later, "in every manufacturing process there is more or less waste of the raw material, which it is the province of others following after the original manufacturer to collect and utilize. This is done now, more or less, in almost every manufacture, but especially in the principal ones of the [United Kingdom]—cotton, wool, silk, leather, and iron" (2). Some years later, the authors of the *Descriptive Catalogue of the Collection Illustrating the Utilization of Waste Products* of the Bethnal Green Branch of the South Kensington Museum also noted that many ingenious persons were busily devising "means by which rubbish may be worked up into a useful product" and that there were "few . . . great manufactures now which have not one or more of these dependent industries attached to them. These secondary products are all examples of one form of the utilization of waste" (Bethnal Green Branch Museum 1875, 4).

Following World War I, some English commentators marveled at the Germans' ability to turn waste products into resources (Spooner [1918] 1974; Talbot 1920). Frederick Talbot (1920) wrote that "the German, when he encounters a waste, does not throw it away or allow it to remain an incubus. Saturated with the principle that the residue from one process merely represents so much raw material for another line of endeavor, he at once sets to work to attempt to discover some use for refuse" (19). Clearly, what is now termed *industrial symbiosis* was prevalent in advanced economies more than a century ago.

Cities as Industrial Loops

Many authors have noted the important role that cities historically have played in resource recovery (Rathje and Murphy 1992; Sicular 1981; Sinha 1993). For example, nineteenth-century Parisian writers such as Beaudelaire, Hugo, and Zola wrote moving tributes to the agricultural uses of the urban waste of the French capital (De Silguy 1989). The same processes were going on in all major European and North American cities (Bertolini 1990; De Silguy 1989; Sicular 1981). Catherine De

Silguy (1989) attributes the success of nineteenth-century Flemish agriculture, whose yields were three to four times those of French agriculture, to a richer supply of urban products used as compost (78). Countless other examples of resource recovery can also be found in old texts.[8]

Jane Jacobs ([1969] 1970) gives many similar examples from the second half of the twentieth century (107–17). She writes about one producer of book paper who referred to New York City as its "concrete forest," but she argues that viewing cities as "waste-yielding mines" might be a more appropriate metaphor. Jacobs notes, however, that unlike typical mines, whose resources may be depleted over time, cities will become richer the more actively and longer they are exploited because new veins, formerly overlooked, will be continually opened. She comments that "the largest, most prosperous cities will be the richest, the most easily worked, and the most inexhaustible mines" (111).

Viewing cities as mines has a history. For example, Bernhard Ostrolenk (1941) used it in a more literal sense in his classic economic geography textbook: "Even the sources of important raw commodities are changing. . . . The time is not far distant when New York, with its growing production of scrap iron and scrap copper from junked buildings, machinery, automobiles, etc., will be as important a source of raw material for metal industries as is the Mesabi Range or Anaconda" (21).[9]

In the 1920s, Rudolf Clemen noted the conditions necessary for commercially successful waste utilization. Historically, cities have fulfilled most of these stipulations: (1) a practical commercial process of manufacture; (2) actual or potential market outlets for the new proposed by-products; (3) adequate supplies of the waste used as raw material, gathered in one place or capable of being collected at a sufficiently low cost; (4) cheap and satisfactory storage; and (5) technically trained operatives (1927, 1).

Frederick Talbot's comments in the conclusion of his book *Millions from Waste* provide evidence that cities fulfill Clemen's third condition. Talbot (1920) notes that "co-operative and individual methods [of resource recovery] . . . can only be conducted upon the requisite scale in the very largest cities where the volume of material to be handled is relatively heavy. Waste must be forthcoming in a steady stream of uniform volume to justify its exploitation, and the fashioning and maintenance of these streams is the supreme difficulty" (303). Cities typically facilitate cooperation among individuals by facilitating the communication of tacit knowledge, whether technical or commercial, and the development of trust relationships (Desrochers 1998).

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8. "The worn-out saucepans and tin ware of our kitchens, when beyond the reach of the tinker's art, are not utterly worthless. We sometimes meet carts loaded with old tin kettles and worn-out iron coal-skuttles traversing our streets. These have not yet completed their useful course; the less corroded parts are cut into strips, punched with small holes, and varnished with a coarse black varnish for the use of the trunk-maker, who protects the edges and angles of his boxes with them; the remainder are conveyed to the manufacturing chemists in the outskirts of the town, who employ them in combination with pyroligneous acid, in making a black die for the use of calico printer" (Babbage [1835] 1986, 11–12).

9. According to a personal communication from an industry specialist, June 1995, New York City also became the premier copper mine in the world, as the advent of fiber optics made the old copper lines useless.

The recovery of perishable industrial waste illustrates the historical function of the city in resource recovery. Some of the oldest urban archeological evidence of resource recovery comes from the late Stone Age city of Çatal Hüyük, in central Turkey. It appears that workers who specialized in recovering bones made awls, punches, knives, scrapers, ladles, spoons, bows, scoops, spatulas, bodkins, belt hooks, antler toggles, pins, and cosmetic sticks (Mellaart 1967, 214–15). Some texts written in the Roman era describe shops located near slaughterhouses that turned bones and ivory into items such as pins, tokens, buttons, components of hinges, and wall fittings (Chevalier 1993).

In the early history of eastern U.S. cities, swine were frequently raised near liquor distilleries, where they were fed on the mash (Bogart 1936, 300). One could observe the same phenomenon in Belgium, where beginning in the early nineteenth century most distilleries relocated from the countryside to cities in order to secure markets for their by-products (Dechesne 1945, 51). In 260 New York City stables, cows living on the swill of local distilleries produced most of the milk for the city (Miller 1998, 78).[10]

In his classic study of "the economic basis of urban concentration," conducted in the early twentieth century, Haig (1926) explained why, despite the advent of artificial refrigeration, perishability remained an important factor in determining the location of certain fabricating functions: "Thus if articles which spoil quickly are to be preserved by drying or canning, these processes are usually best performed near the point of extraction. New York City's canneries prove, upon analysis, to be, for the most part, salvage plants designed to preserve the surplus supplies of temporary glutted markets, supplies which would otherwise decay and be wasted. Perishability during some intermediate process of fabrication tends to bind processes together at one place" (191).

Trade and the Open Nature of Urban Industrial Loops

Although urban history supports the idea of industrial ecology, proponents of EIPs often fail to consider that those industrial loops existed because of trade. That is, cities have never been closed or self-sufficient systems, but rather open systems where various inputs and by-products are imported and exported. For example, most of the raw materials used in Çatal Hüyük—with the exception of clay, reeds, and wood—were not locally available (Mellaart 1967, 212).

Other examples of urban recovery in the last two centuries support the linkage of trade and industrial loops. The United Kingdom imported more than six thousand tons

10. Of course, the same phenomenon may be seen today: "Brewing is an example of recycling. Grains are malted and fermented and the extract made into beer. The spent grains from the breweries in our large cities are transported to central plants where they are dewatered, dried, and prepared for animal feed, particularly for milk farms not too far distant, serving the same central population. The grains after drying are high-protein feed" (Mantell 1975, 753).

of horns and hoofs and approximately ninety-two thousand tons of bones from giraffe, elephant, horse, ox, buffalo, and whale each year in the 1870s for remanufacture (Simmonds 1875, 133–47). Those imports added to a domestic production of bones thought to be between seventy thousand and eighty thousand tons (Bethnal Green Branch Museum 1875, 49).[11] Most of the imports went to London, Birmingham, and Sheffield (Simmonds 1875, 133–47). For example, every year in Sheffield about two million shank bones of oxen were turned into knife handles, spoons, nail brushes, combs, fans, bone flats for button molds, and various other miscellaneous articles. This production was, however, only part of their use.[12]

Much the same process was going on in major cities around the world. In the middle of the nineteenth century, some 375,000 animals a year were slaughtered in New York's "animal district," located a few hundred feet from Times Square. Although the area was probably extremely unsanitary by today's standards, it was yet another prototype of EIP, in which no potential resource was wasted. Bones became handles, buttons, and inputs in textile coloration. Entrepreneurs converted marrow into tallow that chandlers, soap makers, and the rapidly expanding chemical industry found valuable. Sugar refiners and fertilizer producers made use of residual blood. Hooves became gelatin and "Prussian Blue"; hides and hair were valuable commodities; and whatever remained was hog food (Miller 1998, 82). Not just locally produced bones became valuable commodities; many railway cars loaded with buffalo bones arrived in the metropolis for transformation into button molds, knife handles, and other objects (Simmonds 1875, 98).[13]

With the advent of the Chicago stockyards, the supply of animal by-products became so regular and important that chemists set about creating new and different products (Clemen 1927). The earliest innovative work of chemists focused on food products such as oleomargarine and beef extract, but eventually the chemists turned to more distant fields such as pharmaceuticals, explosives, lubrication oils, and cosmetics (Clemen 1923). Before long, "Packingtown" became a model EIP as a number of separate satellite industries that bought unfinished by-products grew around the mammoth slaughtering plants. Large refineries took the nonuniform, steam-rendered lard of packers, refined and bleached it, and sold it on the open market. Soap factories bought various grades of tallow. Glue works made glue from bones, sinews, and various other packing-plant materials. Butterine manufacturers used neutral lard and oleo oil from packing plants to manufacture oleomargarine. Fer-

11. Actually, the demand for bones was so important in the nineteenth century that some merchants had the bones on the battlefields of Waterloo and Crimea picked up and sent to England to be turned into fertilizers (De Silguy 1989, 78).

12. See also Simmonds 1862, 352–60.

13. It must be pointed out, however, that St. Louis was probably the major hub in the buffalo-bones trade (exhibit at the Museum of the Rockies, Bozeman, Montana, July 1999).

tilizer plants carted off the pressed tankage and raw or pressed blood, dried it, and sold it as such or manufactured mixed fertilizer (Talbot 1920, Clemen 1927).

These by-product manufacturers, whether or not they were formally affiliated with a giant meat-packing firm, bought their materials in part from packers and in part from outside concerns. For example, in the manufacture of compound lard, the purchase of vegetable oils was necessary. Similarly, the soap industry needed many materials that were not necessarily by-products of the meat-packing industry (Weld, Kearney, and Sidney 1925, 141). The livestock supply that went into the Chicago packing plants came from twenty-seven states (137), and the output was marketed throughout the United States, either directly by the packers or through various brokers (169).

Private Planning in the Creation of Eco-Industrial Parks

Even though all successful localized industrial parks developed through the normal course of business, many scholars and planners contend that nowadays public intervention is necessary to create EIPs (Hawken 1993; Indigo Development 1998; Lowe 1997; Van Der Ryn and Cowan 1996). The American response largely has been to look to the Danish example as illustrative and to seek more proactive ways to model and imagine eco-industrial possibilities. However, public planning efforts are not likely to outperform market forces. To understand why, it is useful to compare the characteristic features of private and public planning.

Markets are spontaneous orders sustained by an institutional framework consisting of private property rights and the pricing process. Private planning through a market relies heavily on decentralized decision making and a trial-and-error process of discovery and improvement. Unlike public planning, the market itself has no specific purpose and is essentially an arena of voluntary exchanges in which the private goals of individual actors tend to be coordinated (Ikeda 1995). The creation of localized industrial symbiosis is a fairly common outcome of those processes. The reasons can be summarized by examining the relationship of prices and technical innovation to industrial symbiosis.

Prices and Industrial Loops

To understand how private planning leads spontaneously to the creation of industrial symbiosis, one must keep in mind that the ultimate goal of all market actions is to produce marketable goods and services using the least-cost combination of inputs. Firms cannot survive if they waste too many potentially valuable inputs. The history of resource recovery indicates that the goal of cheap production has driven much of it. Babbage ([1835] 1986) observed that "the care which is taken to prevent the absolute waste of any part of the raw material" (217) helped to reduce production costs and encouraged additional investment. A few decades later, the British authors of the *Descriptive Catalogue of the Collection Illustrating the Utilization of Waste Products* also noted that industries were paying attention to the "utilization of waste materials." They wrote, "As competition becomes sharper, manufacturers have to look more closely to those items which may make the slight difference between profit and loss, and convert useless products into those possessed of commercial value, which is the most apt illustration of Franklin's motto that 'a penny saved is twopence earned'" (Bethnal Green Branch Museum 1875, 4).

More than a generation later, the German engineer Theodor Koller ([1902] 1918) observed that "competition is so keen that even with the most economical—and therefore the most rational—labour it is difficult to make manufacturing operations profitable, and it is therefore only by utilizing to the full every product which is handled that prosperity for all may be assured" (vi).

Of course, the tendency of a company to reduce its manufacturing expense by creating new credits for products previously unmarketable is observed today in countless industries (Ayres, Ferrer, and Van Leynseele 1997; Florida 1996; Saunders and McGovern 1993). Market forces promote resource recovery because reused, remanufactured, and recycled materials are generally cheaper than virgin materials for at least three reasons: (1) the value of some residuals can be close to nothing for their producers but of much greater value to somebody else; (2) much processing has already been done in the production of residuals, thereby lowering further processing costs; and (3) residuals are often produced much closer to their potential buyers than virgin materials, thus lowering transportation costs.

So the pricing process, in a context of well-enforced private property rights, serves as a powerful feedback mechanism to prevent the waste of valuable inputs or to find productive uses for by-products. Faced with competition from other producers, all entrepreneurs and managers have no choice but to reduce waste and create industrial symbiosis either within their firms or with other businesses. As Max Muspratt, a past president of the Federation of British Industries, put it in 1928:

> In the days of my childhood, "waste not, want not" was a lesson inculcated upon all young people. Whether there was at once a suitable response in the nursery I am now too old to remember, but the same wise saying has had the constant consideration of every progressive manufacturer for at least a century. . . . Every up-to-date factory has its experts who understand the problems of their particular processes and the character of the waste produced, but it may readily happen in the future, as in the past, that the waste of one industry has no interest for that particular industry and is neglected, but it may be capable of utilisation in some entirely different industry. (qtd. in Kershaw 1928, vii)

Private Property Rights and Industrial Loops

Owners must have reasonably secure expectations of continued ownership if they are to improve or conserve resources. Private property rights are therefore essential to a free-market regime. Less understood is the notion that a private property–rights regime, backed by the common law, historically has been an efficient way of protecting the environment through legal actions for trespass and nuisance (Devlin and Grafton 1998; Meiners and Yandle 1999; Smith 1995). Thus, private owners can often achieve the environmental goals that EIP planners seek through public guidance, and they can do so without creating the drawbacks that accompany regulation.

Liability makes a firm accountable for damages caused to others, including damages caused by pollution. This property-rights framework creates clear incentives for firms to find the cheapest way of reducing their level of discharge into the environment. For example, the early Chicago meat packers initially dumped a significant portion of the nonedible parts of animals into the South Branch of the Chicago River, but the current proved too weak to carry away the by-products. The packers were sued and eventually forbidden to dispose of their refuse that way. They therefore had to transport wastes to a location sufficiently far from the city to be buried, an operation entailing considerable expense. In time, however, new uses were found for these by-products (Clemen 1923).

Of course, the common law is not flawless as an instrument of environmental protection. Multiple polluters, each inflicting small amounts of damage, are unlikely to be held liable, especially when many parties share the damage. Injuries and harms that come after long gestation periods present another challenge. Although parties who can show evidence of injury or imminent harm may have a common-law cause of action, efforts to obtain injunctions for speculative harms such as future cancer are not generally successful. However, where the common law does foster environmental protection, there is no arbitrary distinction between a useful material and a waste, as there often is in regulatory schemes.

As Supreme Court Justice George Sutherland wrote in a famous case in 1926, "Nuisance may be merely a right thing in a wrong place like a pig in the parlor instead of the barnyard" (qtd. in Meiners and Yandle 1999, 926). Similarly, in some instances, "waste is merely raw material in the wrong place" (Talbot 1920, 11), and countless toxic wastes have become useful inputs within the institutional framework of prices and private property (Bethnal Green Branch Museum 1872, 1875; Koller [1902] 1918; Simmonds 1862, 1875; Talbot 1920).

Technical Innovation and Resource Recovery

"Resources are not, they become" (De Gregori 1987, 1241); that is, they are created partly through technical innovation. The same is true of resource recovery. As Charles Lipsett (1963) has stated, "Yesterday's waste has become today's new product or chemical or food, with its own waste which through research and development will become tomorrow's new economic resource" (355). Because of technical innovation (among other things), the market process is in continual flux. Old products and markets disappear, while new ones emerge and make creative use of what were formerly waste products.

Writing about the manufacturing applications of horns, Simmonds (1875) noted that "While many of the former uses of horns for glazing purposes, for drinking cups, for horn-books, and for the bugle of the bold forester, have passed away, other and more elegant and varied applications have been found for this plastic and durable substance" (138). In his 1939 address to the American branch of the Newcomen Society, Oscar G. Mayer, an industry executive and past president of the Institute of American Meat Packers, pointed out that in addition to familiar animal by-products, such as leather, wool, soap, and oleomargarine, new discoveries utilizing animal by-products in the pharmaceutical field were being made almost every year: "What is the value to humanity of such products as pepsin, adrenaline, pituitrin, ovarian extract, pineal extract, insulin and liver extract? . . . Many other compounds of incalculable value will be discovered, for the packer's raw material is an inexhaustible biological well" (Mayer 1939, 18). New uses for waste products are more likely to be found in advanced economies because the sheer diversity of the technical, managerial, and professional capacities of their inhabitants fosters many different ways of turning residuals into resources, while also providing many different potential markets.

Public Planning and Industrial Symbiosis

Public agencies, nongovernmental organizations, and university teams, rather than businesses, lead most formal EIP development efforts. These organizations have taken several approaches. One is to develop an EIP from scratch or build it around a few existing industries by providing a physical site where companies can be located near one another. Another is to create "virtual EIPs"—that is, networks of firms within a region that can exchange by-products without having to relocate (Business Council for Sustainable Development 1997, Kincaid 1999).[14] In either case, such governmental or bureaucratic managers, unlike private agents, must ultimately rely on some form of command and control because even though public planners operate in mixed economies, they do not use the profit-or-loss test to evaluate their performance.

Some authors contend that an EIP development team could outperform market processes. Analysts and consultants have therefore identified various tasks to help create EIPs. These tasks include, for example, recruiting companies to fill a void that may occur when key suppliers or customers move or go out of business, modeling the

14. These arrangements are said to differ from traditional waste exchanges such as Recycler's World, the National Materials Exchange Network, and the Global Recycling Network or from commodity-specific financial exchanges such as the Chicago Board of Trade market for scrap materials in that they are much more proactive in identifying by-products and creating connections (Kincaid 1999).

network of exchanges to reveal new opportunities, and researching technologies and markets for currently unmarketable by-products (Martin et al. 1996, 6–32).

To assess whether EIP developers can outperform private company employees, one must consider the outlook and incentives facing both public planners and private employees. The first difference between the two groups is the manner in which they view the activities of a firm. EIP planning-team members typically view private firms as producers of particular wastes or users of established by-products (Martin et al. 1996). Private company employees, on the other hand, are paid to create the most value from given inputs, not merely to produce a regular supply of waste products. As Henry Ford put it in 1926, "You must get the most out of the power, out of the material, and out of the time" (qtd. in McDonough and Braungart 1998, 83). Therefore, we can expect firms, absent regulatory constraints, typically to reduce their waste flows or to find more productive uses for their waste. Attracting a power plant to a specific location does not ensure that its by-products will be used in the way that public planners imagine. The managers and designers of a power plant may find a more efficient way to extract energy and in the process reduce or eliminate by-products that an older plant might have found profitable to sell. Innovative substitute inputs might become available for a given production process, emitting fewer by-products. Entrepreneurs might develop new and more financially rewarding uses for by-products. The rise of an input price or the lowering of the production costs of alternative producers may make the power unprofitable. Inevitably, the public planners' choices will reflect past experience, not future possibilities. To plan localized waste flows as if they are intrinsically part of the internal structure of firms or not subject to change simply does not accord with historical evidence or with the logic of market processes.

Knowledge of by-products and of production processes—that is, expertise—and how this knowledge affects resource recovery would also differ between a development team and private company employees. As noted previously, at least one author believes that a team of designers could come up with better symbiotic relationships if it started from scratch, locating and specifying industries and factories according to a grand scheme (Hawken 1993). Others argue that an EIP development team can gain a better overview of the waste currently produced than private agents (Schwarz and Steininger 1997, 55). F. A. Hayek (1980) called such faith in the superiority of central planning over decentralized decision making the pretense of knowledge. According to Hayek, the most important knowledge in a market economy is that which people acquire under the particular circumstances of time and place. In a market economy, individuals confronted with specific problems can better tap into such decentralized knowledge because they always know more about the particularities of a given situation in which they are directly involved than does a distant planner.

Even though the EIP experiments are still in their infancy, there is good reason to believe that they cannot avoid certain pitfalls of central planning, especially considering that a fundamental reason for the success of the Kalundborg industrial symbiosis is the "knowledge of the local situation that was not available to staff at corporate headquarters" (Lowe, Moran, and Holmes 1996, C12).

The only kind of knowledge that EIP developers can acquire is a synthesis of what they learn about various by-products from individuals working within firms. The planners classify this information according to broad Standard Industrial Classification (SIC)[15] specifications and then look for possible localized matches by pondering the best-known uses of these by-products. In contrast, in a private firm, employees who have to deal with by-products will typically look at a much smaller set of waste products. In so doing, they can explore more reuse possibilities and contact a larger number of potential customers. Consider, for example, some observations Kincaid (1999) made in a recent by-products survey of producers located in and around North Carolina's Research Triangle area: "Another means of increasing creative thinking about by-products was to foster interaction with people from outside individual facilities. When the interviewers sat down to review the survey booklet with facility representatives, the discussion usually resulted in the identification of promising items to add to survey responses. When the interviewer was able to take a tour of the plant, yet more reusables were usually identified. The creative process was further boosted by discussions between two or more potential partners" (93). Kincaid went on to identify two examples of excited brainstorming that resulted from such meetings:

> Two representatives from a tool manufacturing company visited an amino acids manufacturing plant to discuss a potential acids partnership. After they determined that an acids exchange might be feasible, the tool manufacturing company representatives asked, "What also do you have that we might be able to use?" This query resulted in a walk to where waste fiberboard drums were stored. These drums were lined with plastic bags, and they were originally packed with pouches of desiccant inside to keep the contents dry. The tool manufacturing representative thought his company might be able to use some of the drums, and the two men started enthusiastically brainstorming about who else might be able to use the plastic bags and desiccant pouches. The tool manufacturer suggested the Adopt-A-Highway program for the plastic bags and marinas for the desiccant.
>
> At a sawdust partnership meeting, a cabinetmaker and a hazardous waste management company representative determined that the latter's company could use the cabinetmaker's sawdust to pack hazardous waste bound for an incinerator. The two men went on to discuss how the sawdust might be used

15. The traditional SIC is currently being replaced by the new North American Industrial Classification System (NAICS).

> as a spill absorbent as well. This led to animated brainstorming about ways to make socks filled with sawdust for this purpose. (1999, 93)

In short, the SIC, or formal and documented, type of information acquired by conducting by-products surveys in one area is no substitute for direct interaction between technical experts.

An EIP development team typically tries to recruit companies to fill by-product niches (Martin et al. 1996). Private company employees, on the other hand, must factor in many other variables, such as finding adequate labor, materials, and energy supplies, proximity to markets, quality of life and amenities, business climate, capital availability, the need for frequent face-to-face interaction between producers and suppliers, and so forth. Central or EIP planners can never know all these factors in their totality. By-products will be crucial in location decisions only if they are the most important inputs of a firm. In that case, no public planners would be needed to lure a waste-producing or receiving firm because economic incentives would provide sufficient stimulus, as much historical evidence demonstrates.

Another consideration when comparing an EIP development team to private company employees is performance evaluation. The effectiveness of EIP developers will have to be measured, one way or another, by their capacity to create *localized* industrial loops. A private firm evaluates its employees by their capacity to transform inputs into the most valuable output, and attention is not restricted to local markets. One can imagine a situation in which two potential industrial loops are available, one that is local but less financially rewarding, another that is more lucrative but involves shipping by-products to a more distant location. The private employees would send the by-products to the location that pays more, the place where it would be used more productively, thereby saving on the use of other resources. The course of action an EIP development team selects would depend on how the team was to be evaluated. If the team members' performance evaluation were based on a demonstrated capacity to create localized loops, they would have little incentive to use the by-products in the most efficient way by sending them far away.

Ultimately, the justification for a public EIP development team rests on the tenet that private employees will not gather relevant information to create industrial loops. In some situations, of course, they might not. Breaking with an established daily routine is difficult; most company employees have an inward-looking focus, and they may not know what information is available or where to find it or may simply not have the time to get it (Côté and Smolenaars 1997, 72). However, if competition is allowed to reign, the most dynamic firms will get ahead, perhaps driving their less-innovative competitors out of business. Besides, it is a mistake to think that only employees of private manufacturing firms will seek to create industrial loops because numerous brokers historically have been and today still are involved in resource recovery. Both the insiders and outsiders of a firm would, in all likelihood, cover the tasks performed by an EIP development team.

An EIP development team can certainly spot a few business opportunities that have so far escaped the attention of market participants, but it is unlikely that such events would occur often in an industrial setting if employees currently paid to ensure regulatory compliance were instead working on finding creative uses for by-products. If "by-products" and "wastes" could be regarded as any other manufacturing outputs—that is, for their chemical composition and potential uses, not for their place in the industrial pecking order—the private sector would spend much more energy on the creation of industrial loops.

Some company employees and private brokers would almost certainly be charged with finding markets for by-products, much as they find markets for other outputs. They would gather data on possible customers, arrange meetings, hire outside consultants, attend trade shows, subscribe to industry publications, and so forth. They would negotiate deals and sign contracts to transfer by-products, covering in the process standard issues such as quality of supplies, mode and timing of delivery, and legal recourse for failure to comply with previous agreements. Ultimately, market participants not only have more experience and knowledge about particular production processes and by-products than EIP planners, they also have more financial incentives to seek relevant information and to make correct decisions.

Regulatory Obstacles

One of the major reasons that all the actions just described might not occur in the private sector is not the unwillingness of private parties but the regulations that the government imposes in the name of environmental protection. Current environmental regulations are fragmented and inconsistent. Firms collect copious amounts of technical information and data for regulators who enforce compliance with government-mandated standards. Such a framework typically leads to a rigid rule orientation inherently hostile to making allowances for the differences in particular circumstances that unforeseen conditions or changes might occasion (Ikeda 1995; Wallace 1995). The bureaucrats involved in the process typically have no vision of the whole. They concern themselves almost exclusively with their specialty, creating a situation in which compliance with rules and requirements often precludes the realization of economic benefits that companies might generate by trading by-products.

Many analysts now argue that some of these regulations are unenforced or are unenforceable, inefficient, contradictory, and counterproductive; that others have instituted pervasive structural biases against new technology; and that ultimately most have proven extraordinarily costly with little benefit to show for them (Ayres and Ayres 1996; Crandall 1992; Frosch 1995; Heaton and Banks 1997; Landy and Cass 1997;

Wallace 1995). Donald Geffen and Alfred Marcus (1994) note that compliance problems tend to take up a great deal of U.S. managers' time because regulations keep changing; moreover, so much effort goes into staying abreast of regulation that little time is left for pollution prevention. George Heaton and Darryl Banks (1997) write that "environmental innovators uniformly lament their treatment in the regulatory process, in which delay, uncertainty, red tape, and skepticism about new compliance techniques are widely acknowledged problems" and that "the most creative segments of the industrial community—new companies, small firms, entrepreneurs—are uniquely disadvantaged by an overall regulatory framework that erects entry barriers against new ideas" (24).

Regulatory Definitions as Barriers to Resource Recovery

By far the most glaring regulatory problems in the creation of industrial loops are the definitions of *solid waste* and *hazardous waste*[16] under the Resource Conservation and Recovery Act (RCRA), which contains more than six hundred pages of complex and intricate regulations.[17] Under the RCRA, a by-product can be a solid waste or a hazardous (solid) waste, or it can avoid a solid waste label. As Gertler (1995) has pointed out, this legal approach has led to a circular definition: "Solid waste is a discarded material, a discarded material is anything inherently waste-like, such that a solid waste is anything inherently waste-like. (Since the three criteria for defining something as a 'discarded material' are connected by 'or' and not 'and,' meeting any one of them results in the substance in question being 'discarded.') Perhaps more importantly, it is somewhat perplexing that recycled materials are defined as discarded, since to 'discard' has the common meaning 'to throw away'" (n.p.).[18] RCRA considers a solid

16. The RCRA defines a solid waste as "any garbage, refuse, sludge from a waste treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities." EPA officials have encountered difficulty in establishing when a material is "discarded" and have consequently redefined solid waste as "any discarded material not otherwise excluded by regulation or variance"; a discarded material is then any material that is "abandoned," "recycled," or "inherently waste-like."

RCRA defines hazardous waste as a "solid waste, or combination of solid wastes which because of its quantity, concentration, or physical, chemical, or infectious characteristics may [a] cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible illness; or [b] pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed" (42 U.S.C., Sec. 1004[27]).

17. For a much more detailed treatment of this issue, see Dower [1990] 1995; Frosch 1995; Gertler 1995; Landy and Cass 1997; Lowe, Moran, and Holmes 1996; Martin et al. 1996; Powers and Chertow 1995; and Volokh 1995. It must also be noted that in addition to the RCRA, statutes such as the Toxic Substances Control Act (TSCA), the Clean Air Act (CAA), the Asbestos Hazard Emergency Response Act (AHERA), and the Clean Water Act (CWA) also affect the management of solid and hazardous waste (Martin et al. 1996, 5-5).

18. Gertler (1995) also adds that the "reason for all this intrigue is apparently that recycling status exempts a process from the bulk of RCRA regulation, making attaining such a status very attractive to those generating waste. EPA has thus endeavored to separate 'sham recycling,' which is essentially a show at recycling made by generators of hazardous waste in order to avoid the costs of mandated disposal, from 'true recycling'" (n.p.). Needless to say, such an approach ultimately works against resource recovery.

waste "hazardous" if it is ignitable (that is, burns readily), corrosive, or reactive (for example, explosive), or if it contains certain amounts of toxic chemicals (Gertler 1995). In addition to these characteristics, the EPA has developed a list of more than five hundred specific hazardous wastes. So the "hazardous" label refers not only to the inherent properties of a substance, but also to its history relative to its "discarded" status (Frosch 1995, Gertler 1995, Volokh 1995).

The ambiguity surrounding solid wastes, hazardous wastes, and secondary materials in the language of the RCRA means that all waste or by-products falling under the statute's definition of solid or hazardous waste are subject to RCRA requirements. Classification of a by-product as solid waste sets in motion a costly permitting process, and the label "hazardous waste" virtually prevents the reuse of the targeted substance, even though it might be chemically identical to or even less hazardous than a "virgin" product. For example, strict environmental laws will likely control a manufacturer that produces waste containing cyanide, a toxic hydrocarbon, or a heavy metal. Unless the firm's managers are willing to invest a great deal of resources in overcoming extremely long and complex bureaucratic barriers (getting permits, collecting data, writing timely reports, being subjected to increased liability, and so forth), the RCRA will most likely prevent the firm from processing that material into a salable product or even transporting it, except to a disposal site.

The automotive industry's anticorrosion measures to protect cars illustrate the negative effects of the RCRA. The anticorrosion process typically creates wastewater rich in zinc. In the past, producers of the sludge from this wastewater sent it to a smelter that recovered the zinc for reuse. But once government regulations in the mid-1980s designated this residual as "hazardous," the regulatory requirements became so stiff that the smelter could not accept it anymore. The zinc now ends up in a landfill, and its required handling gives rise to both an additional cost for its producers and a waste disposal problem for the rest of society (Frosch 1995, 181).

One can also look at a residual from aluminum production, the "potliner" (steel shells lined with insulation and carbon) used in the electrolytic process that converts alumina into aluminum. Such potliners are typically replaced after three to seven years and contain a mixture of carbon, aluminum, sodium, fluoride, silicon, calcium, and trace amounts of cyanide and iron. Historically, various industries reused potliner materials. Mineral wool plants used them as a source of fluoride and as a fuel substitute for coke. Cement kilns used them as a fuel supplement to replace 2 to 5 percent of their coal. Steel plants used the carbon as a fuel source and the fluoride as a substitute for the fluxing agent fluorspar. All this reprocessing ended in 1988, however, when spent potliner was first classified as a solid waste—and eventually as a hazardous waste—despite lack of scientific evidence proving that the previous industrial practices posed any threat to human health (Volokh 1995, 19–20). As an EPA assistant administrator for the Office of Solid Waste and Emergency Response has put it, the RCRA is "a regulatory cuckoo land of definition" where a substance that "wasn't hazardous yesterday . . . is hazardous tomorrow, because we've changed the rule" (qtd. in Volokh 1995, 3).

In short, the regulations governing hazardous waste management impose onerous burdens and responsibilities on those who generate, handle, treat, and dispose of such materials. It is therefore not surprising that very little hazardous waste is recovered. As Alexander Volokh (1995) has pointed out, although about one hundred thousand to one million tons of hazardous waste are recycled in the United States each year, another thirteen million tons are dumped into hazardous-waste landfills. Many analysts therefore view environmental regulation as the single greatest deterrent to the innovative use of by-products.

CERCLA (Superfund)

Whereas the RCRA deals with the regulation of waste-control practices at current manufacturing, transport, and disposal facilities, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)—more commonly known as Superfund—was enacted in 1980 to deal with the cleanup of abandoned sites.[19] This law has a critically detrimental impact on the development of EIPs in old industrial areas.

The enforcement of CERCLA often imposes the legal doctrine of "joint and several strict liability" on everyone having anything to do with the siting and storage of hazardous wastes on so-called "brownfields" (formerly used industrial sites). In practice, this doctrine means that the government can hold anyone who is even peripherally responsible for any portion of the material at a Superfund site financially responsible for the entire cleanup. Restoring a Superfund site usually costs many millions of dollars and may involve decades of litigation. As Rose Devlin and Quentin Grafton (1998) put it, "Technically speaking, all of these firms/individuals are liable to pay up to the full costs of clean-up or any costs stemming from damages to natural resources incurred by the federal or state governments from a hazardous waste site . . . irrespective of whether their actions actually caused the accident" (115).

As a number of difficulties arose from this practice, the 1986 Superfund Amendments Reauthorization Act gave the party that paid for the cleanup costs the right to collect from any others who might have contributed to the damages. Superfund therefore has a major impact on firms' decisions regarding location and handling of by-products.

General Motors is a case in point. The firm is often reluctant to transfer regulated waste to brokers, waste exchanges, and potential users because it cannot get rid

19. For a much more detailed treatment of this issue, see Dower [1990] 1995; Gertler 1995; Landy and Cass 1997; Lowe, Moran, and Holmes 1996, appendix D; Segerson 1995; Stroup 1996; Viscusi 1996; Viscusi and Hamilton 1996; and Volokh 1995.

of the legal responsibility for the material, and it is not sure it can trust downstream users (Gertler 1995). Besides, the cleanup standards associated with Superfund are generally acknowledged to be unrealistically strict and therefore unnecessarily costly (Stroup 1996). Consequently, developers often fear that if they take on a cleanup effort, not only will they have to spend money to eradicate the last stray molecule of a given substance, but they will also be sued by a future user of the property to clean up contamination that they did not cause. Because the liability scheme of CERCLA is so menacing, land near hazardous-waste sites that has been or might be designated a Superfund site becomes virtually unsalable, despite potential advantages such as location and existing amenities. Vast stretches of urban real estate have been written off for development because of Superfund, in the process starting a cycle of urban blight and promoting "green field" development in distant suburbs (Landy and Cass 1997, 207). Thus, many opportunities for the natural evolution of eco-industrial parks never see the light of day.

In sum, expensive and obtrusive government regulations that have minimal positive effects on public health make the reuse of materials so difficult that in practice a larger waste flow is encouraged. Unlike the common-law approach, environmental and other regulations have resulted in the erection of numerous barriers to resource recovery.

Had Superfund-like rules been in effect in Denmark, the Kalundborg industrial symbiosis would have been a very difficult, if not impossible, task. For example, the flue gas that Statoil pipes to Gyproc and the liquid sulfur that Statoil sells to Kemira probably would not have been approved in the United States because both substances would be classified as "hazardous waste," and the new resources created from these by-products also would have been treated as hazardous under the "mixture and derived from" rule (Gertler 1995, n.p.). Furthermore, the movement of sulfur from Statoil to Kemira and the movement of scrubber-ash gypsum from Asnæs to Gyproc would violate another rule, the ninety-days-storage rule, which again in all likelihood would prevent the profitable reuse of these by-products (Gertler 1995).

Of course, local, national, and international environmental regulations are only one type of public policy that affects the propensity of managers, engineers, and technicians to find creative new uses for their by-products. Antitrust statutes, too, can effectively bar the agglomeration of enterprises necessary to create EIPs; consumer-protection statutes relating to government procurement practices and safety regulations can prevent the use of by-products; and laws governing international trade may prevent their transportation. Zoning ordinances, subdivision regulations, permits for various construction phases, and growth management may also prohibit certain activities. Subsidies targeted at the extraction and transportation of virgin materials discourage the use of by-products (Crandall 1992; Devlin and Grafton 1998; Graedel and Allenby 1995; Lowe, Moran, and Holmes 1996; Roodman 1998; Wernick and Ausubel 1997).

Conclusion

Planning a regional community of companies that exchange and reuse by-products or energy has been advocated in academic, business, and political circles. The examples used to justify such an approach, however—such as Kalundborg, Denmark—resulted entirely from market forces. The claim that a more proactive approach would achieve better results than market processes rests on the claim that public agents are more likely to identify and achieve a goal such as the creation of an EIP than private agents whose priority is to maximize wealth. This claim presupposes that public planners are capable of centrally planning and coordinating the activities of numerous public and private agents to conform with their specific objectives. That they can actually do so successfully is doubtful.

Private agents working in competitive businesses tend to minimize the amount of waste they produce, either by using their inputs more productively or by finding new uses for their by-products. The market process, unlike regulation, is a mechanism that inherently and systematically corrects its own errors and encourages innovation. Within a market framework, trading by-products is not a good in itself if a more effective waste solution exists upstream. Where such a solution does not exist, trade is likely to occur.

Ultimately, support for an EIP development team stems from a perception of market failure in developing industrial loops. This perception, however, presupposes that in a market economy, firms have more incentive to cover the costs of by-product disposal than to eliminate them at the source or to find new markets for them. This belief also requires that firms' employees cannot gather useful information as well as an EIP development team would. Both postulates are manifestly false, logically and empirically. Furthermore, current attempts to create EIPs are too narrowly focused and fail to consider that firms are in business to create products that consumers want, using the least-cost input combination, and therefore that firms making locational choices will evaluate many factors besides the proximate reuse of by-products.

Promoting resource recovery where it is economically feasible and environmentally sound is a commonsense action, but the current movement to plan and create EIPs rests on many errors of reasoning and of fact. Greater priority should be placed on removing barriers to reuse of materials. Otherwise, proposals to create EIPs will remain mere academic or public relations exercises.

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