Part II: Strategies and Opportunities

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ABSTRACT
The primary objective of this analysis is to apply the concepts of industrial ecology and eco-industrial parks (EIP) to the future development plans of Connecticut Newsprint LLC, a newly formed company based in Bridgeport, Connecticut. At the request of Connecticut Newsprint’s President and Chief Executive Officer, James L. Austin, our principal task was to evaluate alternative means to utilize the company’s short-fiber sludge, a byproduct of the recycled newsprint operation. Our group has evolved the “problem” of sludge disposal in the short-term into an “opportunity” for significant business development and diversification over the long-term. The present analysis proposes a development plan that uses the recycled newsprint facility as the basis for forming an EIP.

INTRODUCTION

Industrial Ecology and the Eco-Industrial Park (EIP) Concept
In recent decades, environmental issues have leapt from the status of peripheral concern in the minds of corporate managers to become significant factors in the design, operation, and eventual disassembly of industrial processes and products. Internal evaluation of industrial environmental performance began as a response to achieve compliance with legislation (i.e. the Clean Water Act and Clean Air Act) created during the environmental movement of the 1960s and 1970s. More recently, several industries have evolved to view environmental considerations as an opportunity to critically re-evaluate material flows, energy and water use, and product or process design in order to improve efficiency and bolster company performance.

As a result, an entirely new academic discipline has emerged – industrial ecology. Central tenets of the new field include design for the environment (DfE), life-cycle analysis (LCA), and dematerialization, which, when considered in aggregate, describe business as an independent organism possessing “industrial metabolism” (Graedel 1995). Understanding the nature of a facility’s input and output streams along all phases of the product/process life-cycle (from resource extraction to end-of-life) can provide a competitive advantage to companies in the form of technological innovation, reduced waste disposal costs, and product differentiation.
The EIP concept represents the fullest application of industrial ecology principles. EIPs incorporate multiple businesses on the same industrial site (or on separate sites, but inter-linked as a “virtual EIP”) in order to facilitate synergistic relationships for resource streams. The EIP “mirrors natural systems” in that the waste of one process serves as another facility’s raw materials (Cohen-Rosenthal et al. 1996). Water, energy, and general overhead costs are shared among participants. Even environmental permitting can be coordinated to some extent via “umbrella” permits granted to the operations of the EIP as a whole (Cohen-Rosenthal et al. 1996).

Connecticut Newsprint Company Profile

Connecticut Newsprint, LLC plans to build a 100% recycled newsprint manufacturing facility, which is scheduled to begin operation in the fourth quarter of 1999. Tentatively, the plant will be constructed on a 50-acre site in Bridgeport, Connecticut, although other sites are being considered. James L. Austin, President and Chief Executive Officer, leads the development plans for the company and coordinates a consortium of both private sector and government entities, each of which contributes to the design, construction, or financing of the project. The Development Team includes:

- City of Bridgeport
- Raytheon Engineers and Constructors
- Bridgeport Port Authority
- State of Connecticut
- Office of Policy and Management
- Connecticut Development Authority
- Carpenter Technology
- Papierfabrik Palm
- Thompson Avant International
- Environmental Risk Limited
- Wright Investor Services, Inc.
- Mid-Atlantic Development Corporation
- Hayne and Curley
- Pullman & Comley, LLC
- Frankel and Thornberry
- People’s Bank
- United Illuminating Corporation
- Logistec, Inc.

Raytheon Engineers and Constructors, Inc. leads the design and equipment procurement aspects of the project. Financing is provided by multiple sources, including the State of Connecticut, which has approved a $500,000 economic development grant for the project. Bond financing will be provided by Morgan Stanley and Co., Inc. and Greenwich Partners, LLC. Altogether, the Connecticut Newsprint project involves approximately $380 million in capital costs and another $70 million in soft-cost financing.

1 The location of other candidate sites is proprietary information and cannot be discussed at this time. It is worth noting, however, that other sites possess significant advantages for the long-term scenario proposed in the present study. Among other benefits, these sites are significantly larger in acreage, allowing for potential on-site facilities expansion to include factories manufacturing products that utilize the newsprint plant’s sludge as a raw material. Due to the uncertainty involved in the location of the site, a discussion of specific modes of transportation, site conditions, and site layout are generally avoided in the current analysis.
In keeping with being an environmental company in its overall product focus, the proposed Connecticut Newsprint facility will use approximately one-half the energy of a conventional newsprint plant. Moreover, the recycled newsprint manufacturing facility will have a significantly reduced waste stream relative to virgin newsprint plants because the primary source of solid waste from conventional plants is the de-barker (Springer 1994). Another important environmental consideration is the product life-cycle. Having a “lifespan” of only twenty-four hours, a newspaper can potentially be recycled back into the production process in a short period of time (see section on Long-Term Development Plan).

It is estimated that Connecticut Newsprint will have the capacity to process 725 metric tons of raw materials per day. Raw materials consist of approximately 60% old newsprint (ONP), 30% old magazines (OMP), and 10% telephone directories. The raw materials are processed into approximately 630 metric tons per day of high-quality newsprint. At this production level, Connecticut Newsprint aspires to provide 8% of the annual demand in the newspaper-hungry markets of New England and the mid-Atlantic states. Another significant output from the production process is the focus of our analysis – 250 metric tons of short-fiber sludge per day.

Connecticut Newsprint Sludge Characteristics
The process of re-pulping the raw materials includes a de-inking and screening stage (see Figures 1 and 2) from which there is an estimated 15% yield loss in the form of short fibers. This equates to nearly 250 metric tons per day of inorganic sludge as a byproduct of newsprint recycling. The sludge itself consists of short fibers, filler (clay and ash), and inks, which are unusable and therefore removed in the production process. Connecticut Newsprint anticipates that the sludge will exhibit the general physical and chemical composition displayed in Table 1 below.

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>COMPOSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash, dry basis</td>
<td>20–30%</td>
</tr>
<tr>
<td>Heat value</td>
<td>5000–6000 BTU/oven-dry lb</td>
</tr>
<tr>
<td>Calcium</td>
<td>5000–8000 mg/kg</td>
</tr>
<tr>
<td>Chloride</td>
<td>10–80 mg/kg</td>
</tr>
<tr>
<td>Chromium</td>
<td>0–12 total, mg/kg</td>
</tr>
<tr>
<td>Copper</td>
<td>25–200 total, mg/kg</td>
</tr>
<tr>
<td>Lead</td>
<td>0–10 total, mg/kg</td>
</tr>
<tr>
<td>Magnesium</td>
<td>750–1250 mg/kg</td>
</tr>
<tr>
<td>Nickel</td>
<td>5–14 mg/kg</td>
</tr>
<tr>
<td>Potassium</td>
<td>200–400 mg/kg</td>
</tr>
<tr>
<td>Sodium</td>
<td>1000–1400 mg/kg</td>
</tr>
<tr>
<td>Sulfate</td>
<td>150–250 mg/kg</td>
</tr>
<tr>
<td>Zinc</td>
<td>20–45 mg/kg</td>
</tr>
<tr>
<td>PH</td>
<td>Adjustable</td>
</tr>
</tbody>
</table>
Figure 1: Connecticut Newsprint De-Inking Process System

- Trommel Screen
- Helidyne Pulper
- News Chest
- Magazine Chest
- Blend Chest
- High Density Cleaner
- Ultra Fine Screening
- Forward Cleaning
- Reverse Cleaning
- Disk Thickener
- Diskperser
- Screw Press
- High Consistency Bleach Tower
- High Density Storage Tank
- Medium Consistency Pump
- Flotation Cells
- Coarse Screening
- High Consistency Bleach Tower
- To Stock Preparation System
After passing through screwpresses, the sludge remains 45% solid if further de-watering processes are not applied. As will be discussed in detail later, the composition (especially water content) of the sludge determines its potential uses as a raw material for other products.

POTENTIAL PULP AND PAPER SLUDGE APPLICATIONS
Various applications for pulp and paper sludge are well documented. Among the many potential uses or disposal methods are:

- Landfill disposal
- Landfill clean-capping
- Combustion to generate Btu value
- Composting
- Land application as a soil amendment
- Engineered soils for specific uses
- Cat litter
- Construction materials such as bricks or eco-blocks
- Fuel additive to burn with coal-fired power plants to reduce NOx
- Linerboard feedstock
- Lightweight aggregates

Each of the above options was evaluated in the context of Connecticut Newsprint’s particular sludge characteristics. Particularly helpful to our analysis was the Beneficial Use Technologies matrix created by BES Technologies (see Table 2). This matrix evaluates the viability of various beneficial use options based upon solid content. From the suite of choices, our group has selected several viable alternatives for sludge disposal, beginning with those most appropriate for the short-term.

ANALYSIS OF SLUDGE APPLICATION OPTIONS
We employed three primary criteria in evaluating Connecticut Newsprint’s alternatives for sludge disposal: 1) sludge characteristics, 2) on-site sludge processing requirements, and 3) transportation costs. Based on these criteria, we analyzed each option to determine the most economically efficient and environmentally friendly utilizations for the byproduct.

The characteristics of sludge include its composition as well as its physical state. The presence of trace metals varies, depending on the particular raw materials used in production. Magazines printed using chemical-based inks produce more potentially harmful residuals than magazines made using a soy-based ink product. Similarly, ash, fiber, and clay content all vary according to the specific inputs. Perhaps most important to our analysis of disposal options is that the solid content of a specific sludge depends on the type of de-watering technology employed in the manufacturing process. Whereas composition may be the sludge characteristic most relevant to environmental concerns, the physical state of the sludge (i.e. percentage of water content) relates more closely to economic considerations.
Figure 2 Connecticut Newsprint Stock Preparation System

Refining

Machine Chest

Blend Chest

Deculator

Silo

To Headbox

Cleaners

Rejects

Headbox Screening

To Headbox
Each disposal option requires a different level of sludge processing. For example, sludge which is used as landfill daily cover can be shipped to the landfill as is, where it can be immediately applied without further treatment (BES Technologies 1995). On the other hand, the use of sludge as compost material often requires the addition of significant amounts of nitrogen, or even microbial agents (EarthCare website). However, processing does not necessarily need to be completed by Connecticut Newsprint prior to shipping, since many companies that use sludge as an input for their product will buy unprocessed sludge and bear the cost of processing it themselves (BES Technologies 1995).

Once the sludge characteristics and processing requirements are determined, economic factors need to be considered. Foremost among these are transportation costs, which often account for a majority of total disposal costs.

<table>
<thead>
<tr>
<th>Beneficial Uses</th>
<th>Low Solid Content 0.5 – 24%</th>
<th>Medium Low Solid Content 25 – 39%</th>
<th>Medium Solid Content 40 – 59%</th>
<th>Medium-High Solid Content 60 – 75%</th>
<th>High Solid Content 76 – 100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Spreading</td>
<td>Minimum*</td>
<td>Target**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mine Land Reclamation</td>
<td>Minimum</td>
<td>Target</td>
<td>Maximum***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landfill Daily Cover</td>
<td>Minimum</td>
<td>Target</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydroseeding</td>
<td>Minimum</td>
<td>Target</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay Cap (as is)</td>
<td>Minimum</td>
<td>Target</td>
<td>Maximum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineered Soil</td>
<td>Minimum</td>
<td>Target</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compost/Mulch</td>
<td>Minimum</td>
<td>Target</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Animal Bedding &amp; Agricultural Products</td>
<td>Minimum</td>
<td>Target</td>
<td>Maximum***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absorbents</td>
<td>Minimum</td>
<td>Target</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay Recovery for Capping</td>
<td>Minimum</td>
<td>Minimum</td>
<td>Target</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cements &amp; Binders</td>
<td>Minimum</td>
<td>Minimum</td>
<td>Target</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lightweight Aggregate</td>
<td>Minimum</td>
<td>Minimum</td>
<td>Target</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molded Fiber &amp; Construction</td>
<td>Minimum</td>
<td>Target</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay Recovery, Bleaching &amp; Reuse</td>
<td>Minimum</td>
<td>Minimum</td>
<td>Target</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical Products</td>
<td>Minimum</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel &amp; Gasification</td>
<td>Minimum</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Depending on the location of the plant, the sludge may be shipped by truck, rail, or barge, with each mode of transportation entailing distinct cost advantages relative to site selection. Given these considerations, company President James Austin prefers that short-term sludge disposal operations (of the facility’s current 45% solid sludge) occur within roughly a 100 mile radius of Connecticut Newsprint.

Short-Term Scenario
For the short term (during the first 2-3 years of plant operation), our primary consideration was to determine a sludge use which would have low transportation costs and would not require significant on-site processing. We recommend the consideration of two beneficial sludge uses: 1) as a soil amendment (land application) and 2) as landfill capping material.

Land Application
Land application entails spreading or disking sludge over agricultural lands. Pope & Talbot, Inc., of Eau Claire, Wisconsin, has experimented with land application of de-inked sludge for several years, having spread its sludge over 5,000 acres of farmland since 1987 (Cardwell 1994). The Wisconsin Department of Natural Resources permits the company to spread sludge over 800 acres per year, but not to spread repeatedly on the same fields. Because this technology is still in its trial stage, sludge application is limited to acreage planted with cash crops such as field corn, soybean, and hay – not fields which are used to grow crops that will be directly consumed by humans (Cardwell 1994). Despite these regulatory limitations, Pope & Talbot was able to land spread 42,900 wet tons of sludge in 1993 (approximately 200 tons per day based on a 225 day growing season).

The most beneficial aspect of the program from Pope & Talbot’s perspective is the realized saving in disposal costs. Traditional landfill disposal costs approximately $45 per ton. Alternatively, Pope & Talbot spends only $4-5 per ton to haul and spread the sludge onto farmland. This difference equates to a savings of over $1.5 million annually.

We believe that Pope & Talbot has set a standard which Connecticut Newsprint can mimic to reduce its own sludge disposal costs. The sludge produced by both companies is similar – each is approximately 45% solid and has substantial fiber content. According to BES Technologies, the target solid content for land spreading is 25-39%; therefore, Connecticut Newsprint sludge represents a close match for this use (see Table 2). Much of central Connecticut is rural, providing ample opportunity for trial applications, and the growing season is similar in length to that of Wisconsin. Moreover, a substantial portion of local cropland is used to grow feedstock or other non-human consumed products (i.e. sod). Extensive studies need to be carried out regarding the long-term effects of the sludge as a soil amendment, but we feel that a short-term alternative similar to that demonstrated by Pope & Talbot should be considered.
**Landfill Capping Material**

The potential use of sludge as a landfill capping material has recently been explored. While direct application is often allowed, physical and chemical processing is sometimes necessary to gain required capping material characteristics. Technology Development Corporation (TDC) of Fairfield, Ohio, holds patents for a process which converts paper mill wastes containing ash into clays for recovery and reuse. Generally, the process requires 45-50% solid content and at least a 20% ash content (BES Technologies 1995). Its product is then sold to private and municipal landfills as capping material. Due to the potential market which exists in the northeast, TDC is exploring the possibility of building a regional plant in New York State, which would handle up to 750 wet tons of sludge per day. Connecticut Newsprint’s byproduct fits TDC’s ash and solid content requirements, and could potentially supply approximately one-third of the processing plant’s daily demand.

As suggested earlier, sludge is often sold directly to a landfill operator. According to the BES matrix (see Table 2), the suggested solids content for clay capping (as is) is 40-59%, so Connecticut Newsprint falls within the target range. Connecticut Newsprint has arranged preliminary agreements with municipalities in Connecticut and Pennsylvania regarding the use of its sludge in landfill closure projects. However, the costs for use as capping material can often approach those for landfiling itself. Quotes from the two municipalities have averaged $4 million per year for disposal. Therefore, we recommend that Connecticut Newsprint employ landfill capping as a last resort in the short-term.

**Medium-Term Scenario**

For the medium-term, we took into consideration the desire to further reduce transportation costs, which are a function of weight (largely determined by water content) and shipping distance. We identified available technologies for further sludge de-watering, with the goal of reducing transportation costs by increasing solid content.

**De-watering Technologies**

Currently, Connecticut Newsprint plans to employ only screwpresses in their de-watering process, which would yield a 45% solid content sludge. The potential next step would be to add another mechanical de-watering device to the process, namely, a tech drier. This technology costs approximately $4 million and would raise residual solid content to 80%. This would significantly reduce overall transportation costs and would allow for alternative disposal options based upon its altered physical state.

If further de-watering is desired, the next step would be to incorporate a fluidized bed boiler into the production process. This technology incinerates the sludge, reducing it to 100% ash content. Employing this technology provides several advantages, namely that the incineration generates a heat
value of approximately 5000 Btu per oven-dry pound (see Table 1). A fluidized bed boiler would also produce 30-40% of the plant’s steam demand of 250,000 pounds per hour, reducing the need for outside energy sources. However, this technology also possesses disadvantages, namely the $10 million capital costs. Moreover, the on-site incineration process may elicit public discontent as a NIMBY (Not In My BackYard) issue. If either of these technologies are installed, the water content of the residual material will change and a new suite of medium-term options will arise.

Sludge Composting
In the Connecticut Newsprint context, composting could involve the mixing of inorganic sludge with a variety of organic wastes, including municipal sludges and food and fish processing waste. Resource Conservation Services (RCS), a small company in Maine, has worked with several de-inking mills in New York and Maine over the past several years to develop marketable compost products (Recycled Paper News 1992). The products have been sold primarily for commercial use, including roadside re-vegetation projects, golf courses, and commercial landscaping. Although RCS has not experienced any incidents of heavy metal or PCB contamination when using the sludge, they maintain a strict policy of not selling their product for agriculture or home vegetable garden applications. Many smaller companies exist in the market, such as Grow-Rich, in Niagara Falls, Ontario, but their low production volumes often restrict them to selling only to local horticultural markets.

We recommend the exploration of composting as a strategy for local disposal. When adjusted by the addition of a tech drier, Connecticut Newsprint’s sludge solid content would approach 80%, which closely corresponds to BES’s target window of 60-75% (see Table 2). We have identified firms in New York, New Hampshire, and Connecticut, which specialize in marketing sludge-based compost (see Appendix). Because the facility’s daily sludge output likely exceeds any small composting company’s daily input requirements, we have explored additional on-site composting options.

Building and Construction Materials
Another option for our de-watered sludge is its use as building and construction materials. The use of fibers in cementious products is not a new concept in the paper industry. Scott and Smith (1995) state that sludge use in cementious products generally improves physical characteristics such as plasticity and workability. Tiles containing 13% high-ash sludge possess the required durability needed for commercial use. Similarly, sludge with a 20-30% ash content may be used to produce a commercial facing brick. The advantages of these bricks include better compression rates and increased water permeability. Based on preliminary experimental results, Thomas et al. (1987) concluded that a marketable composite material (potentially useful in building blocks, wallboards, panels, shingles, and fire retardant and filler materials for fireproof
doors) could be produced by combining Portland cement with sludge from de-inking mills.

One facet of building materials fabrication involves the formation of aggregates. An aggregate is a collection of materials used as filler in construction products, such as concrete, building blocks, and asphalt (NCASI 1993). Light-weight aggregates (LWA) are a specific subsection of these materials that are used to make composites with increased strength properties and reduced density (NCASI 1993). The use of paper sludge in the production of aggregates has not been well documented, but recent technological and entrepreneurial innovations allow for increased incorporation of paper-based sludges into the building materials industry.

Greengrove Corporation and the Natural Resources Research Institute (NRRI) have explored the use of paper sludge and ash in the formation of a lightweight aggregate through a proprietary mixing process named AgrecellTM (see Figure 3). Greengrove states that the paper sludge component alone does not contain enough fusible material to form the strong ceramic pellets which are necessary for the LWA. However, when mixed with the ash component, the compound exhibits sufficient strength properties (NCASI 1993).

Figure 3 Agrecell Process for Lightweight Aggregate
A pilot-scale production of 20 tons of LWA was completed and test marketed. After receiving encouraging results from the field evaluation, the company planned construction of a new plant in Kaukauna, Wisconsin that would produce 250 tons of LWA per day from 700 wet tons of paper mill sludge and 125 tons of ash per day (NCASI 1993).

Reusable Resources, Inc. developed a different process that thermally treats paper mill sludge to produce an aggregate that can be used as filler in asphalt, roadbeds, cement blocks, and also as a feedstock to cement kilns. The process has been pilot-tested at a site in Middletown, Ohio (NCASI 1993).

Yet another use for sludge in the construction materials industry is the production of eco-blocks. The Paper Science and Engineering Department at Miami University in Ohio is conducting experimental work which entails compressing the short-fibers from newsprint sludge into wood-like blocks to be used for construction purposes. Initial experiments show that newsprint sludge is a suitable substitute for common industrial sludge and therefore could be used in the production of eco-blocks (Miller et al. 1997).

Assuming that Connecticut Newsprint employs additional de-watering technologies, the ideal 76-100% solid content desired for building and construction materials will be achieved. With a rapidly growing market for sludge-based construction materials, Connecticut Newsprint should have little difficulty forming business partnerships (see Appendix for a listing of possible companies). Additionally, the reduced water content of the sludge will foster the opportunity to develop relationships with more distant companies since overall transportation costs will decrease.

**Engineered Soils**

Another means of utilizing Connecticut Newsprint sludge is selling it as feedstock to soil engineering firms. One company, N-Viro International Corporation, incorporates wastewater sludge into its formulation of N-Viro Soil™, which is used as a agricultural liming agent and as a soil blend component (N-Viro International Corporation website). The firm treats and augments the sludge, tailoring the end-product to the specific consumer need. Although N-Viro Soil is not made using newsprint sludge as a raw material, its success in the market as a sludge-based product provides optimism for the prospects of engineering soils from Connecticut Newsprint byproducts.

An example of a company which specifically uses newsprint sludge is BFI, Inc., which employs a proprietary blending technology to manufacture BioMix™. This product is sold as engineered topsoil and is used in projects such as mine reclamation and capping, landfill closure, roadside construction, and sports field improvements. BFI was contracted in 1991 to offer alternative sludge disposal solutions to American Fiber Resources (AFR), which operated a recycled paper plant in West Virginia (“Recycling Paper...” 1996). AFR’s byproduct is similar in content to Connecticut Newsprint’s 45% solid sludge, suggesting the possibility that a similar resource exchange could take place between BFI and Connecticut Newsprint.
Based on these examples and the aforementioned reduced transportation costs, an opportunity exists for Connecticut Newsprint to develop industrial synergies with soil engineering firms. The marketability of the short-fiber sludge for this growing technology is, again, contingent upon the percent solid content of the byproduct. The BES matrix indicates that the target solid content ranges from 40-59% for sludge to be used as engineered soil. Therefore, this alternative will best suit Connecticut Newsprint in the medium-term (along with the continuation of short-term alternatives) should it decide not to invest in the de-watering technologies previously described. Moreover, this additional alternative enables Connecticut Newsprint to further diversify its sludge disposal options as markets for each technology develop uniquely over time.

Long-Term Scenario
As we move from medium to long-term recommendations, our focus shifts from eco-industrial material flows toward our ultimate goal of an EIP. The concept of bringing raw material suppliers, manufacturers, and consumers together is based on a more efficient use of resources. The plan includes the expansion of operations to include on-site sludge utilization facilities, the attraction of a newspaper publisher to the site, and the development of an on-site raw material recovery center. The details of our long-term scenario are described below as part of our vision of a development plan.

LONG-TERM DEVELOPMENT PLAN
The future of Connecticut Newsprint is very promising, both ecologically and economically speaking. Part of our environmental strategy involves viewing the firm from an evolutionary and incremental perspective, each step building upon the suggestions put forth in the short and medium-term scenarios. The long-term scenario can be further subdivided into stages of growth that allow the incorporation of EIP principles. Our analysis culminates in the development of an EIP with the newsprint facility as its hub. The opportunity to form a virtual EIP is viable as well, given the local market for resource exchange. The first phase of our long-term development plan involves the development/recruitment of sludge-utilizing industries to our site.

On-Site Sludge Utilization
The on-site utilization of sludge will be vital to our long-term scenario. Making use of the sludge on-site will facilitate the management of approximately 250 metric tons of the short-fiber sludge per day. This will reduce the total amount of the byproduct needed to be handled off-site, and therefore decrease the cost of transporting the sludge. The following list of suggestions is by no means exhaustive; however, based upon our sludge use matrix and the physical and chemical attributes of the newsprint sludge, these three processes seem to be the most viable options for Connecticut Newsprint:
• installation of cement products equipment (building materials fabrication);
• on-site composting;
• development of a soil engineering program.

Two of the options (building materials and composting) can be incorporated into the newsprint production process under the currently planned design, while the other option (engineered soils) would likely require some additional infrastructure development.

**Building Materials Fabrication**

Given that many alternatives within the building materials industry are still in the experimental stage, our recommendation is to research further the incorporation of cake sludge processing (CSP) equipment into the Connecticut Newsprint production process (see Figures 4 and 5). We have found one such company that sells CSP machinery to businesses. CemenTech, Inc. offers a CSP series that is designed to accurately proportion and blend waste-water cake sludge (ranging from 12% – 40% solid content) with a combination of alkaline materials at output rates from 5–50 tons per hour of total mixed material (CemenTech website).
The company reports that the output material readily meets U.S. EPA Class A or Class B standards. In addition, most of the biosolids processed by CemenTech CSPs are sold to the public. The process includes de-watering the sludge and then loading it into the CSP or holding bin using a conveyor or endloader (CemenTech website). CemenTech has installed CSP equipment in over 25 locations worldwide, providing several examples of functioning systems that Connecticut Newsprint could use as a model for its own CSP installation.

**On-Site Sludge Composting**

Depending on the final site location selected for the Connecticut Newsprint operation, the potential market for selling compost as an agricultural fertilizer is significant. It is likely that only a small fraction of the 250 metric tons of daily sludge output could be channeled to on-site composting. One simple way to introduce organic material into the composting waste stream is to encourage company employees to dispose of coffee grounds and food wastes along with the sludge for composting. The benefits of applying an explicit composting technology obtained through a company specializing in compost processes (such as EarthCare Technologies, Inc.) is that such companies can provide the following additional services (EarthCare website):

- Analysis of waste streams and methodologies;
- Investigation of suitable areas;
- Production of design specifications;
- Development of infrastructure cost estimates;
- Formulation of operational cost estimates;
- Identification of equipment sources;
- Oversight of site development;
- Acquisition of site permitting;
- Establishment of a compost quality assurance program;
- Production of overall site management plan and operational parameters;
- Implementation of required personnel training programs;
- Operation and management of the site in accordance with the bioremediated, active, thermophilic, windrow composting technology;
- Marketing of the stabilized compost product.

These services can aid in the successful and efficient development of an on-site composting facility. Assuredly, EarthCare Technologies, Inc. is not the only company engaged in this type of operation. Connecticut Newsprint should further survey the array of composting technology companies before selecting a business that will facilitate a sustainable on-site composting program.
Soil Engineering

Recruiting a soil engineering company such as BFI or N-Viro Technologies to the EIP site would allow Connecticut Newsprint to further diversify disposal options. As with the on-site composting program, it is unlikely that the entire 250 metric tons of sludge produced per day will be needed by a single on-site soil engineering firm. Therefore, we recommend that any off-site soil engineering contracts developed during the medium-term scenario be continued as part of a virtual EIP for the long-term.

On-Site Newspaper Publisher

Old newspapers (ONP) are the second most recycled paper product in the United States. In 1995, more than six out of every ten newspapers in circulation were recovered via municipal or commercial recycling. From the recycled paper stream, approximately 36% of ONP is rechanneled into the production of more newsprint (American Forest and Paper Association website). These statistics accentuate the fact that newspapers have a short product lifespan. Technically, a newspaper has a twenty-four hour product life-cycle; therefore, the product can be readily reintroduced into the input stream of the recycled newsprint firm. Furthermore, the newspaper market continues to grow, with nearly 35 million tons produced on a global basis. Per capita consumption in the United States is approximately 44 kilograms per year. European per capita newspaper consumption exhibits a growth potential of 2% per year based on the current demand for approximately 23 kilograms per year. Moreover, it has been forecasted that Asia will soon become a net importer of newsprint (Norske Skog, Inc. website). These statistics support market entry and the development of an on-site newspaper publisher with potential for product exportation.

We propose two alternatives for Connecticut Newsprint: 1) develop and construct a printing/publishing firm or 2) recruit an outside printing/publishing firm to co-locate on the Connecticut Newsprint site. Connecticut Newsprint plans to produce approximately 630 tons of high-quality newsprint per day. It is unlikely that the on-site printer could feasibly utilize this large outflow of newsprint by itself; therefore, Connecticut Newsprint would need to maintain outside contracts for delivery of its finished product.

According to a 1993 EPA Cluster Profile on Printing, Publishing, and Allied Industries, there are 7,465 newspaper printing companies in existence, 2,617 of which employ twenty or more people (EPA website). These statistics suggest that it is plausible that there are several candidate printing/publishing companies that could be recruited to co-locate with Connecticut Newsprint. However, there are environmental considerations relating to on-site printing that will be examined more closely in sections below.

The idea of recruiting an on-site newspaper publisher stems from the overarching goals of industrial ecology. The process of examining the entire life-cycle of the product can contribute significantly to overall cost reduction and increased efficiency of the Connecticut Newsprint operation. For instance,
co-locating the printer/publisher on-site merges two stages of the product life-cycle process by creating feedback loops between the finished product distribution stage and raw materials extraction stage (see Figure 6). Finished product distribution to an on-site publisher would greatly diminish the total transportation and energy costs associated with delivering the newsprint to an off-site publisher. Moreover, the raw materials “extraction” occurs following a twenty-four hour product life-cycle with a continuous daily turnover. This rapid turnover rate is the impetus for our next evolutionary step – the creation of an on-site raw material recovery facility.

On-Site Raw Material Recovery Facility
The proposed recovery facility would have three broadly defined objectives. The first would be to harness the potential of existing material recovery infrastructure by encouraging community recycling centers to enhance their newspaper recovery programs. The centers also should increase the recovery of magazines, which often are not recognized as recyclable material by the public. Contrary to public perception, magazines are in high demand for the newsprint recycling industry. Flotation technology, a recycling process commonly used in Japan and Europe (and recently introduced in North America), requires that newsprint be combined with coated paper such as that found in old magazines (typically 70% newsprint and 30% coated paper) to produce recycled pulp (Canadian Magazine Publishers Association website). The clay filler used in coated stock enhances product quality in several ways—assisting in the flotation operation, adding opacity and brightness to the recycled product, and strengthening the recycled newsprint (Canadian Magazine Publishers Association website). Given that Connecticut Newsprint employs flotation cells in its de-inking process (see Figure 1), we believe that the quality of its finished product would benefit from continual magazine recovery.

The Canadian Magazine Publishers Association (CMPA) estimates that North American recycled paper mills could require one to three million tons of coated stock per year by the year 2000. Coated stock is used in a number of products in the U.S.:

- 33.3% is used in magazines
- 24.4% in catalogs
- 20.6% in commercial printers
- 11.9% in inserts/flyers
- 4.6% in books
- 4.2% is used in labels

The CMPA states that even if every magazine in Canada were collected for recycling, only about 35% of the demand for old coated paper required by Canadian newsprint recycling facilities would be met. High demand and low supply have inflated the price of old coated stock. For example, prices increased from $120 to $280 (Canadian dollars) per ton, during a recent six-month period. Current estimates state that only 6–10% of available coated stock is
being captured by residential recycling programs (CMPA website). Connecticut Newsprint is uniquely situated to take advantage of its market position as an industry leader if it incorporates a raw material recovery program into its long-term plans.

The second objective of an on-site recovery facility should be to develop additional collection infrastructure. Critical to the success of this recovery effort is the formulation of a sound public relations strategy, which increases consumer awareness regarding magazine recyclability. Our proposed recycling facility would have receptacles for used magazines and newspapers both on site and in the community, modeled after the Salvation Army clothes drop-off bins. Possible locations include transportation hubs such as train stations or bus terminals. The recycling facility should also investigate market incentives (i.e., deposit/refund mechanisms) to promote recycling of magazines and newspapers. Incentives can also be created through community work, such as encouraging schools to compete in assisting community recycling efforts in their respective neighborhoods, with the winning school receiving new equipment, such as computers.

The third objective of the facility should be to attract media attention to plant operations and associated recycling issues. The recycling facility could coordinate some positive, media-related activities like community-based cleanup efforts and educational programs about recycling, perhaps through children’s programs that involve teaching about the recycling process and giving tours of the site. A favorable standing within the community will benefit Connecticut Newsprint in the long-run. If Connecticut Newsprint has a positive environmental reputation in the community, major construction at their facility – like the installation of a fluidized bed boiler – would likely be viewed more favorably.

Environmental Considerations for On-Site Sludge Utilization Facilities

In order to present a comprehensive analysis, it is necessary for us to consider the environmental impacts not only of our primary facility, but also of those industries that are on-site in our long-term scenario. Co-location of other industries with Connecticut Newsprint in an eco-industrial park presents numerous additional opportunities for coordination of material flows. Conversely, the assemblage of these industries at one site necessarily entails additional environmental impacts, as each facility recruited to the EIP brings its own set of material flows.

Several environmental considerations are common to each of the three industries we have proposed for the Connecticut Newsprint EIP. All on-site sludge-utilizing companies will require significant water and energy use. Therefore, the potential exists to minimize redundancy in capital infrastructure associated with these resources. For example, a single water intake system could service the needs of all on-site facilities. It is also possible that
the industrial wastewater from one plant (i.e., the diluted caustic soda used in the recycled newsprint process) may be useful in the production processes of a second facility, thereby reducing the need to cleanse and filter the water as it leaves each plant.

In addition to the shared environmental considerations, each industry has its own environmental issues because of its particular processes. For example, composting may introduce concerns of groundwater contamination via leaching of residual metals from the de-inking process. Soil engineering may involve the formation and use of chemical intermediates that may create their own waste disposal problems. Bringing a publisher on-site poses many industry-specific environmental concerns, as outlined below (Huth 1997):

- A potential impact arises from the chemical properties of the inks used in the printing process. We would recommend that the publisher employ soy-based inks which will reduce heavy metal concentrations when the newspaper is reclaimed in the raw material input stream.
- When locating an off-site publisher, Connecticut Newsprint should try to recruit newer firms since most of the letterpress equipment still in service is now more than 30 years old. This older equipment may have environmental problems related to energy efficiency, cleaning and maintenance, and adaptability to new improvements (i.e., soy-based inks and keyless inkers).

Additional Recommendations for Infrastructure Expansion

Our recommendations for Connecticut Newsprint and associated industries have been primarily process-related. We propose additional recommendations that focus on the construction of the facilities themselves using design for environment (DfE) principles. Our first suggestion is to encourage the use of recycled building materials (perhaps made of sludge or other industrial byproducts) in the construction of the plants. We also recommend that the new facilities participate in the EPA Energy Star program, which identifies ways to make companies more energy efficient. It is plausible that alternative energy technologies such as solar panels and co-generation plants could improve energy efficiency while enhancing environmental performance. Finally, we concur with Mr. Austin’s suggestion that land within the site (contingent upon final site selection) should be set aside as a land preserve.

Long-Term Conceptual Model

In our long-term conceptual model (see Figure 6), we depict the organizational structure of some of the material flows discussed, and hope to achieve the industrial ecologist’s ideal in the form of an eco-industrial park centered around Connecticut Newsprint. In its most complete form, the EIP would attempt to close the energy and waste loops associated with the newsprint facility and its peripheral industries. This creates a cyclical and complex web of interactions between the various EIP components.2

2 Not all material flows are depicted in our conceptual model due to uncertainty regarding certain feedback loops stemming from the peripheral industries. In addition, quantities are largely omitted from the diagram due to forecasting uncertainties. Common environmental considerations such as shared water and energy resources are also left out of the model.
Figure 6  Long-Term Conceptual Model

Connecticut Newsprint, LLC
725 TPD raw materials
250 TPD sludge
630 TPD newsprint

Used newspapers
Recycling facility
Off-Site Publisher
On-Site Publisher
Consumer

Building Materials
Composting
Engineered Soils

Long Term Conceptual Model
Reviewing the series of material flows, we begin with the input of 725 metric tons of raw material per day (ONP, OMP, and telephone directories) coming into Connecticut Newsprint from the recycling stream. Connecticut Newsprint then processes this raw material into 630 metric tons of high-quality newsprint per day. This product will then be transformed into printed newspapers and magazines by means of the on-site publisher. As mentioned previously, it is likely that our on-site publisher will not be able to handle the entire 630 metric tons of newsprint on a daily basis (which is contingent upon circulation and newsprint demand); therefore, a portion will be transported to off-site publishers. All publishers (both on and off-site) distribute the finished product to the consumer, who will (ideally) return the used products to our recycling bins facilitated by our recovery program. These steps will close the loop between the product end-life and raw material extraction phases. In addition, Connecticut Newsprint must explore marketable uses for its newsprint sludge. The anticipated 250 metric tons of sludge per day will be distributed among the three aforementioned on-site processes – construction and building materials, composting, and soil engineering.

The gamut of recommendations we have offered in this analysis must be qualified by saying that the sludge technology field is young and evolving. Our suggestions are therefore based upon currently available literature and the general concepts of industrial ecology rather than on actual market feasibility studies (e.g. present value analysis).

ACKNOWLEDGEMENTS
We would like to thank Connecticut Newsprint CEO Jim Austin for the opportunity to work with Connecticut Newsprint and for his willingness to explain the finer details of the recycled newsprint industry. In addition, we thank Jim Lewyta of Hydrofuser Technologies, Inc. for providing substantial materials pertinent to our research.

REFERENCES
EarthCare Technologies, Inc. website. http://www.ecticompost.com


FURTHER INFORMATION


## APPENDIX

### BENEFICIAL USE TECHNOLOGY COMPANIES

<table>
<thead>
<tr>
<th>APPLICATION/TECHNOLOGY</th>
<th>COMPANY NAME</th>
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Source: BES Technologies