Recology: Value in recycling materials

Research and Findings

FINAL VERSION (MAY 13, 2010)

MIT Sloan Sustainability Lab Team:

David Britz, Yoshi Hamaoka, Jessica Mazonson

Faculty Advisor:

Professor Slaughter

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Project introduction and objectives

Recology, the leading resource recovery company, headquartered in the San Francisco Bay Area, asked our S-Lab team to evaluate strategies for diverting materials from landfills while increasing their resale value. By 2009 Recology had achieved approximately 75% diversion of waste from landfills, significantly higher than the national average, but the company is still challenged by its goal to achieve “zero waste”. Currently, Recology provides comprehensive MSW collection and recycling services, including construction and demolition debris, large scale composting of food and organic waste, transfer and landfill operations and green planning services.

Initially our team considered a number of different materials to review, from e-waste to food scraps, but settled on three different materials that would cover a range of Recology’s activities and support landfill diversion, reduction of environmental impacts, and ideally increasing profits. The three materials we selected were plastic, paper and gypsum board. The goal of our project was to provide a framework to evaluate opportunities both from an environmental and profit perspective. This report provides an overview of our approach to analyzing each opportunity, findings, and recommendations based on our analysis. To achieve this we looked at industry dynamics, environmental benefits (material flows, embodied energy, and water usage), and new market opportunities while capturing more value in the marketplace for recycled materials.

Research methodology

The company asked our S-Lab team to investigate specific materials that have a large impact on the environment. We were asked to focus on material flows, embodied energy, and water intensity of virgin materials as a means to find strategic intervention points. We were to use a variety of resources to study the manufacturing, use, disposal, and post-consumer markets of these materials.

Materials Selection

Three classes of waste materials were identified:

1. Plastics
2. Commingled paper
3. Construction debris

Plastics were identified as an important material because they are generally recyclable, but they also pose significant environmental issues when disposed of in landfills or offshore. One issue mentioned by Recology was the Great Pacific Garbage Patch. A rotating ocean current has caused the collection of marine litter in the central North Pacific Ocean[1]. The patch contains a high concentration of plastic and is reported to be toxic to marine life.

We focused our search on PET, since it was found to be a major constituent in the waste stream and also because it has a wide range of uses as a recycled material. Corn-based plastics are rapidly emerging in the market, but their influence on municipal solid waste (MSW) recycling has not yet been widely studied.

Recology noted that paper is the largest volume material that is discarded[2]. It is unclear why this paper is landfilled, but implicit in the project is that waste paper has either poor demand or such low prices that selling or sorting is not economical.

Construction debris was also identified as a separate waste stream coming in from construction, renovation, and demolition customers. Two specific materials identified were gypsum board and asphalt shingles. The S-Lab team focused on gypsum board because it represents a significant volume percentage of currently unrecovered construction waste.

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[1] http://en.wikipedia.org/wiki/Great_Pacific_Garbage_Patch

[2] http://www.epa.gov/osw/nonhaz/municipal/pubs/msw2008rpt.pdf

Research Methods

The S-Lab team used several resources to holistically understand each material. We analyzed several aspects of each material:

- **Virgin Material Market**: Market size and growth, suppliers, pricing, availability, raw materials, end users.
- **Environmental Impact**: Material flows, embodied energy, water intensity, waste products, other environmental impacts.
- **Recycling of Virgin Materials**: Recycling rates, methods of processing, pricing, purchasers.

To understand markets, we primarily focused on industry reports through IBIS World and S&P Industry Reports. Industry-specific publications for paper and pulp, plastics, and gypsum and construction gave timely analysis into market trends, research and development, and major players.

Environmental impact associated with each material was derived from LCA databases, academic articles and books, patents, and other industry-specific publications. Material flows were relatively easy to identify from LCA databases, patents and publications. Energy and water required relying on a third party analysis of a material that made assumptions about material origin, transport, end use, and other factors. These assumptions inevitably affect the accuracy and applicability of these calculations, but likely provide guidance for interventions. Other environmental impacts were sought through organizations like the Environmental Defense Fund and Conservation International.

Recycling of virgin materials was researched primarily through recycling industry reports, including the EPA and recycling interest groups. Recycling was frequently addressed in many of our other sources of information. Finally, we spoke with industry experts to learn about recycling of specific materials. These conversations created a more detailed picture of consumer demands for recycled products and market and technical factors associated with the use of recycled materials.

Sustainability Frameworks Applied to MSW

We focused on three specific frameworks: material flow analysis, embodied energy, and water intensity. These frameworks focus primarily on the manufacture of materials, rather than on consumer use. Each of these frameworks provide information, whether it be on profits, energy or water.

Material Flow Analysis is a process by which a product is studied from the perspective of material inputs and outputs. Using the basic notion of conservation of mass, a simple equation can be considered: *material inputs* = *product* + *waste*. The mass of all material inputs, including liquids, solids, and gasses, must equal the mass of the product plus the mass of all liquid, solid, and gaseous waste. Scarce, expensive, and nonrenewable resources can be identified as inputs, and potentially toxic or valuable waste streams can be identified.

Embodied energy analysis is the process of measuring all energy expended in each step of producing a product. Using the principle of conservation of energy, *energy input* = *energy stored in product* + *energy stored in waste* + *energy released to the environment*. These steps can include farming, mining, gathering, harvesting, or otherwise acquiring a material, transportation and processing, assembly, and processing waste streams. Embodied energy analysis isolates each step in the process, enabling the identification of particularly high energy materials or steps that can be modified, reduced, or substituted.

Water intensity is the study of how much water passes in and out of a product as it is manufactured. Water intensity, as understood by the S-Lab team is more nebulous than embodied energy or material flows. For example, water intensity could focus on molecular water, regardless of source, or it could focus on potable water. In our analysis, we generally viewed water intensity as the use of water in production that turns potable water into water vapor or unpotable water.

Analysis and results

Plastic

In the U.S. alone we currently consume about 11 billion pounds of PET per year, one of the seven designated resin types in the plastic industry. Of that 11 billion, over 50% is used to manufacture bottles.[3] In 2003 American households generated 26.7 tons of plastic waste, yet plastic recovery for recycling was only 6.3%.[4] While advances are being made in bioplastics and technologies to make plastics from renewable resources, the vast majority of the plastic generated today is comes from a nonrenewable resource, oil. This section provides an overview of market trends in the recycled plastic industry, environmental benefits of recycled plastic, technological challenges of the recycling process, key industry players and opportunities.

Industry overview / market trends

According to a 2010 IBISWorld Industry Report on plastic bottle and container manufacturing, plastic demand is highly sensitive to consumer spending habits, and therefore, economic downturns. For five years up to 2010, industry revenue for plastic manufacturing declined at an average of .2% per year.[5] Furthermore because plastic container manufacturing is a mature industry, large players are fighting for market share gains through mergers and acquisitions. Since 2004 the US has been a net importer of plastic bottle containers, with net imports expected to be greater than $70 million in 2010.[6] Since U.S. companies cannot compete with generic plastic products imported from Asia in terms of price, they are forced to differentiate on quality. As mentioned above, the industry is driven by consumer demand primarily in beverages, food, dairy, and household and automotive chemicals. Although soft drink bottles hold the largest percentage of the plastic market, the industry is declining as consumers shift away from

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[3] Graves, Beverly, "Breakthrough in Total Closed Loop Recycling", Products Finishing, August 2003
http://www.allbusiness.com/machinery-manufacturing/general-purpose/624873-1.html

[4] Wilson, Michael, IBISWorld Industry Report 42193 Recyclable Material Wholesaling in the US, January 2010

[5] Samadi, Nima IBISWorld Industry Report 32616 Plastic Bottle & Container Manufacturing in the US, March 2010

[6] Samadi, Nima IBISWorld Industry Report 32616 Plastic Bottle & Container Manufacturing in the US, March 2010

plastic bottled beverages. However, the dairy and automotive parts wholesaling industries have been increasingly using higher concentrations of recycled content and both segments are growing. For example, industry sources estimate that 5-10% of the plastics in GM vehicles in 2010 were sourced from recycled materials, up from a negligible amount a decade prior.[7]

Because of a supply surplus of virgin resin and the relative higher quality of virgin material over recycled resin, the price for recycled plastic is weak in comparison. One of the main drivers of growth in the recycled plastic industry, however, has been export to Asia, especially China, where approximately 30% of all recycled PET (rPET) collected in the US is sent.[8] Although recycling of plastic materials has been increasing, it still lags far behind the production of virgin resin. Recovery rates for various types of plastic have not been overwhelmingly high, in part due to a need for advances in technology to sort and clean different resin types so they can be remanufactured into rPET. In 2003 the recovery rate for plastic was 6.3% of all material produced.[9] Plastic accounts for 2.9% of recycled material by volume and in 2006 957, 500 tons of plastic bottles were recycled in the US.[10]

Simply collecting plastic does not necessarily mean that there will be a buyer for the raw material. Oftentimes it is easier, and sometimes cheaper, to make plastic containers from nonrenewable resources. Nonetheless, various markets exist for different grades of recycled plastic. While the food packaging industry demands higher-grade flaks and pellets that have gone through a purification process, colored flakes have a market in other applications. Because plastic resin degrades every time it is reheated, most plastic is only reprocessed once before it goes to a landfill. Although there is an increasing demand to incorporate rPET into beverage and other containers, most often recycled plastic resin is downcycled into jacket fill, fleece, carpet, plastic lumber, toys, and other such products. The table below shows some of the uses of recycled plastics:

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[7] Wilson, Michael, IBISWorld Industry Report 42193 Recyclable Material Wholesaling in the US, January 2010

[8] Wilson, Michael, IBISWorld Industry Report 42193 Recyclable Material Wholesaling in the US, January 2010

[9] Wilson, Michael, IBISWorld Industry Report 42193 Recyclable Material Wholesaling in the US, January 2010

[10] Wilson, Michael, IBISWorld Industry Report 42193 Recyclable Material Wholesaling in the US, January 2010

Table 1: Uses of recycled plastics

Industry	Products
Construction	Damp proof membranes, drainage pipes, scaffolding boards, roof insulation, flooring
Landscaping / home	Walkways, decks, jetties, fences, signs, carpets
Textiles	Polyester fleece, duvet / coat filling
Transportation	Automotive parts : 9% of all recycled HDPE used in auto parts in 2008
Packaging	Plastic film, carrier bags, refuse sacks, plastic bottles

Increasingly large CPG and retail companies are interested in incorporating recycled plastic into their products which will add to the momentum of the recycling industry. For example, at the Winter Olympics in Vancouver, Coca Cola supplied their representatives with outdoor wear made from 100% rPET and Nike has announced that it is supplying 9 World Cup football teams in South Africa with official strips made entirely from rPET. These teams' replica strips will also be made from the same rPET-derived fabrics. Nike estimates it will use 275,000 tons of rPET in this application.[11] Achieving food grade recycled PET to use in bottles themselves continues to be a challenge.

Environmental considerations

Energy: According to the Institute of Scrap Recycling Industries (ISRI), using recycled material vs. virgin resin uses 80% less energy.[12] A recent material flow and embodied energy study on PET bottles revealed that the production of 1kg of flakes of recycled PET requires a total amount of gross energy that is between 42 and 55 MJ. The same quantity of virgin PET requires more than 77 MJ. [13] Another life cycle assessment of PET bottles indicated that producing virgin PET resin requires 70-83k MJ/ton and turning it into bottles required an additional 20k MJ for a total of 100k MJ/ton of energy. The same study suggested that in 2007 3.8 million tons of PET were required to produce the 100 billion liters of bottled water containers globally. Producing PET bottles to satisfy global bottled water demand thus required

[11] http://webserver.petcore.org/content/uses-recycled-pet-petcore-column-petplanet

[12] Wilson, Michael, IBISWorld Industry Report 42193 Recyclable Material Wholesaling in the US, January 2010

[13] http://www.springerlink.com/content/76466372964h1810/fulltext.pdf

approximately 300 billion MJ of energy. Given that a barrel of oil contains 6000 MJ, this is equivalent to approximately 50 million barrels of oil per year.[14]

Water: Although recycling plastic saves energy, common water separation practices are estimated to dispose of up to 100k gallons of water per day at each plant.

Health: In addition to environmental degradation and nonrenewable dependence, the production of virgin plastics also has damaging health consequences. Plastic releases toxic chemicals such as benzene and vinyl chloride (in the case of chlorinated plastics), which can cause cancer. Polyvinyl chloride (PVC), which is used in plastic piping, shrink-wrap and other uses, releases dioxins, a known carcinogen into the air during production.[15]

Technological challenges

Despite increasing market demand for recycled plastic, the process for achieving high quality recycled materials continues to prove challenging. Despite the seven designated resin codes, different combinations of dyes and additives lead to changes in the melting point and other properties even within the same resin code. While demand is increasing for uniformly sorted plastic, and doing so creates a higher value product, technological challenges make sorting difficult.

Current research into plastics recycling is looking at ways to break down plastics into their monomers so they can be re-manufactured into new plastics. Optical scanning technology to sort different plastic types, which uses scanners that identify the light wavelengths reflected off of different materials, is one such technology used to improve the sorting process.

Recycling process

The most common mechanical recycling process for plastics is outlined below:

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[14] http://www.springerlink.com/content/76466372964h1810/fulltext.pdf

[15] http://www.eurekarecycling.org/PDFS/Recycling_Plastic_Complications.pdf

- Plastics are sorted (usually manually) into polymer type and/ or color
- Following sorting, the plastic is either melted down directly and molded into a new shape, or melted down after being shredded into flakes and than processed into granules called regranulate
- Technology is being introduced to sort plastics automatically, using various techniques.

Because the quality of the recycled product depends on the consistency of the resins that make it, technological improvements of sorting capabilities is critical.

Additional end of life options

Although Recology currently landfills plastic waste that is not baled for recycling, additional options for waste disposal could prove beneficial. While Recology currently does not incinerate waste and some research shows that incineration emits harmful chemicals, some scientific studies have shown waste-to energy-incineration plants to be an environmentally safe option when using emission control technology and high combustion temperatures. Furthermore, because of plastic's high energy content, the entire waste mix can burn hotter and generate more energy when plastic is included. Because incineration is controversial, this may not be a viable energy generation mechanism for Recology.

Key industry dynamics

Many recyclers are adding value to their product through vertical integration into fibers, thermoformable sheets, and compounding into alloyed products, which creates a stronger combined product, increasing the value of the resin and avoiding direct competition with virgin PET.[16] In addition, many successful PET processors are vertically integrating into product manufacturing, including Image Industries and Wellman Inc. Wellman Inc is the second largest producer of PET resin the US, with over 1 billion pounds of capacity. Products from polyester carpet to thermoformed sheets to T-shirts to car parts are all made by companies that manufacture products using PET they have recovered and remanufactured. The main attraction behind vertical integration into product manufacturing is the cost savings it offers. Prices for clear PET flake material range between $.31-35 / lb and $.42-.46/ lb for pelletized material while the cost for

[16] http://www.azom.com/Details.asp?ArticleID=748#_Price_Fluctuations

production is estimated at $.07 -.15 / lb, representing a savings of 25-35% of the purchase price of material from another PET reclaimer.[17]

Paper

Industry overview

Paper mills manufacture paper from virgin pulp and waste paper. In the United States, 57.4% of all consumed paper was recycled in 2008[18]. It is challenging to increase the recycling percentage. Every time paper is recycled, its fibers become shorter than the original materials. In addition, office shredder machines destroy the fibers, making them even more challenging to recycle. Such short fibers make paper weak in structure and limit its applications. However, chemical processes can improve the quality of paper made from recycled materials. For example, Hercules developed a chemical product that contains polyamines that can form both hydrogen and ionic bonds with the fibers and the smaller particles of cellulose[19]. Other chemical products are used to bleach (de-ink) collected paper. Paper mill companies have increased use of such chemical products to increase the recycling rate.

The market demand for paper increases mainly from growth in developing countries. In 2008, China was the world's largest manufacturer, producing 16.9% of the world's total output, followed by the US at 16.4%[20]. This high demand in China stimulates imports of recycled papers from the world[21], especially of unbleached wastepaper, which is mainly used for recycled packaging. This grade of paper has been rapidly growing at a 41% annual average, increasing from 2.6 million tons in 2002 to 10.4 million tons in 2006.

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[17] http://www.azom.com/Details.asp?ArticleID=748#_Price_Fluctuations

[18] IBISWorld Industry Report 32212 Paper Mills in the US

[19] "The Paper Chase", http://pubs.acs.org/cen/coverstory/88/8816cover.html

[20] IBISWorld Industry Report 32212 Paper Mills in the US

[21] "China's Wastepaper Imports and the Environment", April 2007, Issue 7, Information Bulletin China and East Asia

Paper has many applications including newspaper, reams, paper roll, packaging, paper boards, etc. The real paper price index (PPI) grew at only a 0.6% annual rate from 2005 to 2010. It is partially due to the weaker US dollar exchange rate, but competitive paper production market stabilizes the price even under strongly increasing demands.

Life Cycle Analysis

The life cycle of paper has been researched by many organizations, including the paper calculator project[22] supported by Environmental Defense Fund (EDF). This web-based tool can calculate the ecological impacts of the total life cycle from manufacturing to landfills for various kinds of paper such as uncoated or coated free sheet, paperboards, etc. To show its application, this section reviews a case study of commercial products.

This case study compares the two consumer products sold by the Staples, Inc. At its website www.staples.com on May 4th 2010, you can buy 500 reams of multi-purpose papers. One is 100% recycled multipurpose paper for $9.99 and the other is non-recycled paper for $6.99. Figure 1 shows their package pictures.

Figure 1: Packages of commercial multipurpose printing papers[23]

By setting the exact weight and recycle rate of each product to the paper calculator tools, we compared the ecological impacts of the two products. Table 3 shows the results of the comparison.

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[22] Paper Calculator, Environmental Defense Fund, http://www.edf.org/papercalculator/

[23] Staples. Inc Web Site, www.staples.com

Table 2: Comparison of ecological impacts of commercial printing papers.

Recycle	Wood Use (ton)	Net Energy (M BTU)	GHG (lbs/CO2)	Water waste (gal)	Solid waste (pounds)
100%	0.000	0.200	31.0	94.1	10.8
0%	0.036	0.272	53.4	207.9	17.3
Beneficial Impact	**Infinite**	**36%**	**72%**	**121%**	**61%**

The paper calculator has five metrics: wood use, net energy, GHG, water waste, and solid waste. While 100% recycle paper uses no wood at all, non-recycled paper uses 36 kg of wood, which is more than three time heavier than the weight of the product. In addition, the paper manufacturing process wastes significant water. Non-recycled paper wastes over 200 gallons, which is 121% more than the 100% recycled paper wastes. To reduce the ecological impact, it is critical to close the water usage loop. However, the reuse of water is challenging because paper making processes require very clean water. Chemical products are also useful to remove contaminants such as bacteria, waxes, and adhesives[24].

Value Chain Analysis

The value chain of paper from manufacturing to landfills is described in Figure 2. The paper mill companies use both virgin pulp from forest woods and recycled paper for raw materials to manufacture paper and then they ship to customers such as Staples, Inc, through wholesale companies. Customers sell final paper products such as copy paper to end users. After they are consumed, they are disposed of in trash boxes, mixed with other types of trash. The waste is then collected by a resource recovery company in the region (i.e. by Recology in San Francisco). The waste paper is picked up from a pool of trash and is recycled.

Recology is trying to increase the recycling rate, but the low price of recycled paper makes the goal challenging. Although the market for recycled paper is fragmented geographically and the price information is not open to public in general, one available source indicates that the market price of waste

[24] "The Paper Chase", http://pubs.acs.org/cen/coverstory/88/8816cover.html

paper is only $14 per ton[25]. Such a low price may not necessarily justify the sorting cost. Suppose that one hourly wage (for $9 hourly) worker can collect 0.6 ton of papers per hour (i.e. about 500 letter-size papers per minute), the wage costs $15 per ton. Although waste management companies have not been able to capture the value, the retail price of printing paper is about $800 per ton, equivalent to $8 per 500 pages of letter size.

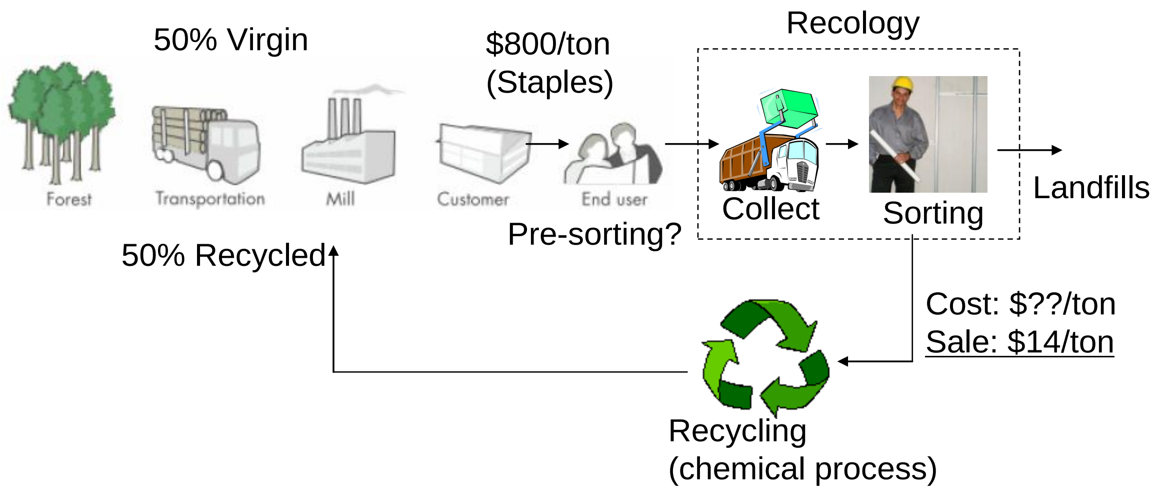

Figure 2: Value chain of paper materials.

Gypsum

Gypsum board (a.k.a. wall board, drywall, sheetrock) is approximately 93% gypsum and 7% paper[26]. It is manufactured by several companies in the US, including National Gypsum, USG, Georgia Pacific, and Certainteed[27]. Manufacturing of gypsum board is distributed across the US to be close to mines and also to consumer demand.

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[25] "The Paper Chase", http://pubs.acs.org/cen/coverstory/88/8816cover.html

[26] http://www.calrecycle.ca.gov/condemo/wallboard/

[27] "Gypsum Product Manufacturing in the US," IBISWorld Industry Report 34742, Anthony Kelly, January 2010.

Gypsum (chemical formula: $CaSO_4 \cdot 2H_2O$) is an inert chemical found across the US. Gypsum mining in the US represents an $80 million industry[28]. At a sale price around $8.80 per ton, gypsum is a low-value commodity. An increasing source of gypsum is a byproduct of coal fired power plants, FDG (flu desulfurization gas) gypsum. FDG gypsum has a market size of $3 million and is expected to grow. Current sale prices of FDG gypsum are around $3 per ton, reflective of the increased transportation distance and cost to wall board manufacturing sites.

Gypsum is typically mined and then crushed to form a fine powder. Gypsum is then calcined (heated in a very high temperature, dry oven) to drive off water. As a next step, calcined gypsum is combined with water and other additives to form a slurry. The slurry is cast between two sheets of paper, then sets and dries in an oven. This addition of water to make the slurry causes dehydrated gypsum to chemically convert back to a hydrated form and then set into a strong, rigid sheet.

Gypsum waste comes in two forms, though the focus of most gypsum recycling efforts is scrap from drywall cuttings, which makes up about 12% of all new drywall. The other form of drywall waste is from demolished buildings and includes a higher content of nails, paint, and other contaminants. Approximately 4 million tons of drywall are landfilled annually, of which 64% is construction scrap.

Gypsum recycling has progressed and is currently used by gypsum board manufacturers. Companies, such as Gypsum Recycling International, have designed fully integrated systems for recycling gypsum board. This includes collection, storage, and processing of gypsum scrap. New gypsum boards can use up to 20% recycled gypsum content. Their target customers are large drywall manufacturers who want to increase recycled content of gypsum in their products.

[28] "Gypsum," USGS Minerals Yearbook, Robert Crangle, 2007.

Gypsum production: Sustainability Frameworks

Gypsum's material flows, embodied energy, and water intensity were determined[29] are presented below.

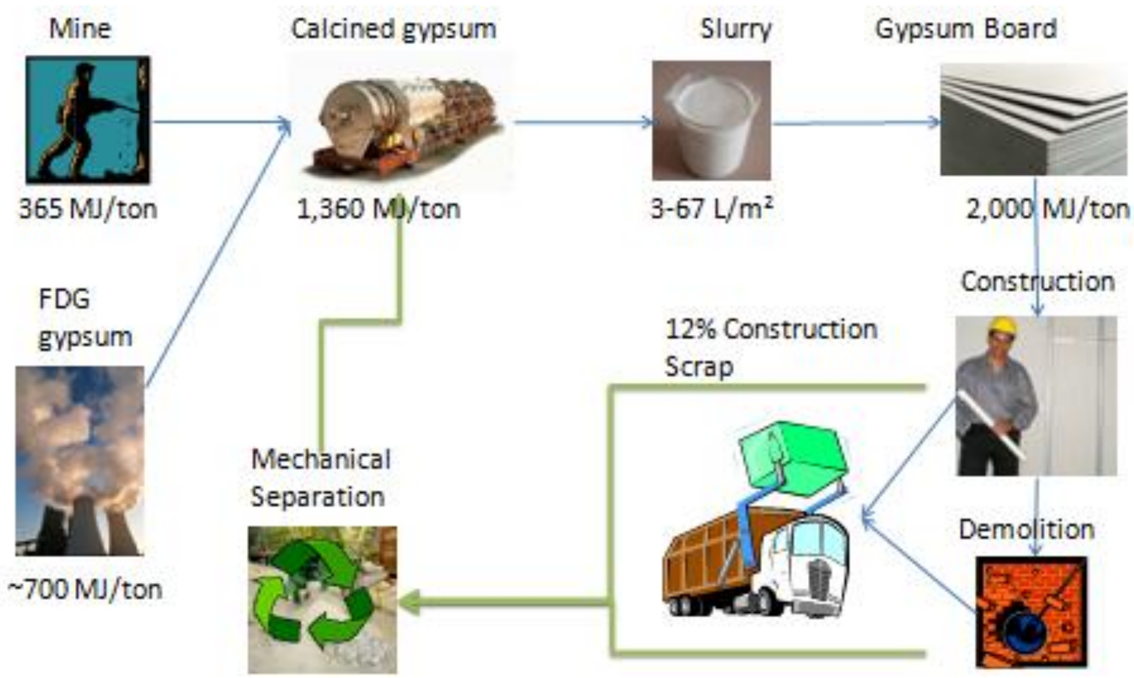

Figure 3: Life cycle, embodied energy, and water intensity of gypsum board manufacturing.

As can be seen from the figure, the largest energy contribution in gypsum manufacturing is in the calcination of gypsum power and final gypsum board manufacturing. Transportation is not taken into account and could make up a significant portion of embodied energy, as gypsum is a bulky material that is usually transported by road. In total, it was calculated that virgin gypsum requires approximately 4,000 MJ/ton of gypsum board. The calculation for energy use in manufacturing was cross-checked with patents[30] on gypsum board manufacturing. Gypsum board manufacturing uses a moderate amount of

[29] "Ecologically Sustainable Development: Approaches in the Construction Industry," Robert Omahen, Faculty of Economics, University of Regensburg, Germany, 2002.

[30] See US patent number: 6435770 for example.

water: 3-67 Liters per square meter of board[31]. This water is chemically bound to the gypsum and also is released from the gypsum board as water vapor during drying.

Environmental Impacts of Gypsum

The team searched for specific environmental impacts of mining of gypsum. Mining practices vary by country[32], but the US and Canada tend to use surface mining[33]. In general, surface mining can cause erosion, formation of sinkholes, loss of biodiversity. Because gypsum is inert and does not require chemicals to remove it, it has relatively minimal direct effects on local water sources. Mining equipment can leak oil or fuel, contaminating water and soil.

Gypsum in landfills could have adverse effects to human health and has been reported to evolve hydrogen sulfide gas through anaerobic decomposition in landfills[34]. Hydrogen sulfide is not a greenhouse gas, but could cause lung and eye irritation at low levels, and central nervous system damage or cancerous lesions at higher and prolonged concentrations[35]. It has been recommended that aerating landfills will prevent the formation of hydrogen sulfide. It is unclear if no gas would be evolved or if sulfur dioxide would evolve[36].

Gypsum Recycling

Since gypsum is an inert, nondegradable material, it is 100% recyclable, in principle. Gypsum board from demolition contains nails, staples, paint, and wallpaper and may contain lead paint and other toxic contaminants that limit its recyclability. Recycling equipment separates paper from gypsum mechanically, resulting in powdered gypsum that is >99% gypsum and <1% paper. The 1% contamination is one of the

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[31] See US patent number: 5342566 and 4965031.

[32] British Geological Survey- Mineral Planning Factsheet- Gypsum, 2006.

[33] "Environmental Effects of Mining", Ripley, Redmann, and Crowder, 1996.

[34] Plaza, Christine, Xu, Qiyong, et al. 2006, “Evaluation of alternative landfill cover soils for attenuating hydrogen sulfide from construction and demolition (C&D) debris landfills.”

[35] http://www.who.int/ipcs/publications/cicad/en/cicad53.pdf

[36] Plaza, Christine, Xu, Qiyong, et al. 2006, Evaluation of alternative landfill cover soils for attenuating hydrogen sulfide from construction and demolition (C&D) debris landfills.

reasons why recycled gypsum can only constitute 20% of new gypsum boards; the residual paper apparently affects the fire rating of the board.

Usage of recycled gypsum also does not significantly affect the embodied energy in drywall, since 20% recycled content usage would cause only a 3% reduction in energy. It also does not have a significant effect on water intensity. It also should be noted that the gypsum industry is contracting, with some mines closing and board manufacturing facilities idling[37].

General Recommendations

We identified several areas that could benefit Recology as a company. These include improvements in technology, storage of materials, partnerships and new relationships.

As a corollary, improvements in technology can assist in increasing the value of MSW. Technologies that increase the automation and effectiveness of separation and sorting can reduce marginal costs while simultaneously yielding higher value products. Since several manufacturers exist for separating specific materials, Recology should evaluate equipment from several vendors before purchasing.

[37] "Gypsum Product Manufacturing in the US," IBISWorld Industry Report 34742, Anthony Kelly, January 2010.