

## **Bibliography on Gypsum Drywall**

Prepared by John Reindl, Recycling Manager  
Dane County Department of Public Works  
1919 Alliant Energy Center Way  
Madison, WI 53713-1400

### 1. BioCycle

#### *a. "The Gypsum Wallboard Problem", March 1992, page 35*

30 million tons of drywall are made per year in North America; 3 - 5% wasted in manufacturing, 10-12% wasted in installation. Rule of thumb for the generation from single family construction is 1 pound of waste per square foot of floor area. Estimate is that remodeling waste totals 1/6 th that of new construction. In 1984, the Greater Vancouver Regional District banned the landfilling of gypsum because of the potential to produce hydrogen sulfide gases and metallic sulfide leachates.

#### *b. "Recycling Gypsum From C&D Debris", March 1992, pages 34-36*

New West Gypsum of Vancouver, BC recycles gypsum drywall and has set up plants in 3 other cities, with a 4th to be developed soon. The business was prompted by the local government's ban on the landfilling of gypsum drywall. The company developed machinery to pulverize the gypsum core and remove the backing paper, which is 8-12% of the finished wallboard, by weight. The company's process reduces the paper content to less than 2%, and the gypsum is sold back to the drywall manufacturers to produce new drywall, with between 7 and 33% recycled gypsum. The firm is also working on a process to clean up the paper to the point where it can also be recycled and a market has expressed interest in the pulp.

The company receives 99% of its revenues from tipping fees charged for the drywall it takes in, charging contractors \$75 a ton. The recovered gypsum is sold to drywall manufacturers for \$1 a ton, compared to \$19 to \$29 a ton for virgin gypsum.

The company feels that the reclamation of gypsum for agricultural purposes will be limited due to the contaminants in the wallboard (including dioxins and furans in the paper, and the various additives), and because the pH is too high.

The company plans to build a recycling facility in New Jersey as well.

#### *c. "Recycling Debris from Construction Projects", August 1992, pages 62 to 63*

The article describes a firm in McHenry County, IL which collects construction debris 'curbside' from construction projects. Drywall is not recycled; a waste audit found it is 14% of the material produced. (Waste quantities were: wood - 33%, cardboard - 33%, drywall - 14%, metals - 10%, miscellaneous - 10%.)

#### *d. "Construction Drywall As A Soil Amendment", Edwin H. White and Mark E. Burger July 1993, pages 70-71*

An estimated 1.7 million tons of drywall were disposed in 1990 from construction sites. Tests were done at SUNY at Syracuse of the composition of drywall for pH, calcium, magnesium, arsenic, barium, cadmium, chromium, lead, mercury, selenium and silver. It was found that the heavy metals were very low. Corn yields and soil fertility increased when drywall was added in amounts that did not exceed recommended doses for agricultural gypsum, but there was a negative effect if excessive gypsum was applied.

#### *e. "Innovators in C&D Recycling", January 1994, pages 30-33*

During the construction of a 2,000 square foot house, about 3,000 pounds of scrap gypsum wallboard is produced. Gyp-Pack Container of Tonowanda, NY has patented a mobile processing unit for gypsum wallboard. Over 65 machines have been sold so far. Prime markets for the recovered material are wallboard factories and agricultural uses, with the recycled gypsum selling for an average of \$25 a ton. Research done at SUNY found that gypsum has a positive effect on the yield of corn and soil fertility.

### 2. Resource Recycling

#### *a. "Managing Construction and Demolition Materials", August 1992, pp 50-61*

Article says that a 300-350 tons per day gypsum recycling plant would cost about \$2 million, and would only be economical in areas that have landfill tipping fees of \$50 a ton or more. Revenues for recovered gypsum are \$0 to \$5 a ton for use to make wallboard, and \$100 a ton for agricultural gypsum.

#### *b. "Recycling in the New West", August 1992, pages 33-34*

New West Gypsum is currently processing 115,000 tons of gypsum wallboard at 3 facilities and is building new plants in 2 other locations. Materials are brought to these plants from locations as far away as 135 miles through transfer stations. They accept both construction and demolition drywall, although it must be clean and free of lead paint, tape, asbestos and PCBs. The facilities charge \$35 to \$55 a ton. The firm is building a new plant to recycle the linerboard, thus improving both recovery rates and the economics.

### 3. "C & D Debris: A Crisis is Building", Waste Age, January 1992, pp 26-36

This article reviews systems across the US. It notes that Kimmins has 4 C & D recycling plants in Florida, with a 5th under development. While drywall is accepted at all plants, and is 15% of the input by volume, none is being recycled.

In 1989, a drywall recycling plant was established in Windsor, VT with the name of New England Gypsum, Inc. Drywall is chipped for reuse as oil-spill absorbent, cat litter and soil amendment; a fireproofing product is under development. The plant handles 120 tons per day. The operators found that drywall is 12-15% of C & D waste; only wood has a higher percentage. Michael Czok, the plant operator, says that drywall can decompose to produce hydrogen sulfide if (illegally) disposed with sewage sludge and water, but only under unusual conditions.

The article references a company known as National GypChipper of Pflugerville, Texas that makes a machine to chip gypsum board, but I was not able to locate this firm through directory assistance.

4. "C & D Debris: Construction & Dismantling", Waste Age, April 1994, pp 26-36

In the wake of Hurricane Iniki in 1992, the demolition waste was subdivided for recovery. The plan for gypsum drywall is to crush it and use it as an amendment for Hawaii's highly acidic soil.

5. "The Deconstruction of C&D Waste: Nailing Down the Numbers", World Wastes, June 1994, pages 36-38

While good data are not available on the quantity of C&D debris, more and more attention is being directed towards this waste stream. In studies done by the University of Illinois at Chicago, the amount of drywall from the construction of a single family house and a 6-unit apartment building were both found to be 25% drywall, the second largest component, with the quantity being 3,760 pounds from a 2,060 square foot house and 8,500 pounds from the 9,000 square foot 6-unit apartment.

6. "New-Style MRFs Recycling Construction and Demolition Debris", Solid Waste & Power/Solid Waste Technologies, October 1991, pp 45-49

Kimmins Recycling Corporation has built 3 C & D recycling systems in Florida since December 1989. They report that drywall is a frustrating material to handle, producing lots (intolerable amounts) of dust, and having limited markets.

7. "Two Gypsum Wallboard Recycling Plants to Open in New Jersey", Recycling Times, July 14, 1992

Reclamation Technologies, Inc. (RTI) plans to open two waste gypsum wallboard recycling plants in New Jersey in the near future. The company will license its patented technology to others. Both plants will have the ability to process 100 tons of material per day of not only gypsum, but also waste paper, wood, plastic and glass. RTI had previously spent 2 years researching machinery and chemical technologies for converting the gypsum into a variety of products, and has found several alternatives for both the agricultural and construction industries.

8. Recycling Construction and Demolition Waste in Vermont. Final Report, C. T. Donovan Associates Inc., December 1990

There are no known recyclers of gypsum drywall in the Northeast at the time of publication, although a firm (New England Gypsum) is planning to establish a 100 ton per week facility in Randolph, VT, with an unknown time schedule.

SIC codes of drywall generators include:

- 1521 - General Contractors - Residential, single family
- 1522 - General Contractors - Residential, other
- 1531 - Operative Builders
- 1541 - General Contractors - Industrial Buildings and Warehouses
- 1542 - General Contractors - Nonresidential Buildings, other
- 1742 - Plastering, Drywall, Acoustical, and Insulation work
- 3275 - Gypsum Products (Manufacturer)
- 5032 - Brick, Stone, and Related Construction Material

9. Summary of Construction and Demolition Waste Reduction Contracts Completed During FY 92-93, Metro, Portland, OR

In waste composition studies done at ten residential construction sites by an organization known as Clean It Up Mark, it was found that drywall was the second largest source of waste (behind wood), comprising between 17% and 32% on a weight basis. Total waste generation was 3 to 4.6 pounds per square foot.

Another study of construction sites involving 3 waste audits found that waste generation was between 3.7 and 4.5 pounds per square foot, with drywall again being the second largest category at 12 to 27%.

10. Telephone conversation with Drywall Decorators Repair Service, Plover, Wisconsin, March 15, 1994

In a phone conversation on March 15, 1994 with Drywall Decorators Repair Service, the owner said that he pays his brother-in-law who has a tree service to take the scrap drywall. The brother-in-law grinds up the scrap and mixes it with the mulch that he uses in planting trees. He got the idea from the drywaller, who told him that the lawn grew really well in the spots that he cleaned out his drywall buckets. These companies are in Plover, near Stevens Point.

11. Request for Markets from Dane County, Wisconsin Farmers

In early March, 1994, a letter to the editor was sent to 15 local rural papers, asking farmers who were interested in using ground up drywall for soil amendment to contact me. As of March 30, 1994, no farmers have responded. The following papers carried the letter:

- Deerfield
- Mount Horeb
- Oregon
- Stoughton

12. Searched the following databases at UW libraries on March 15, 1994:

- Agricola, 1984-1993
- Applied Science and Technology, 1983-1993
- CAB Abstracts, 1984-1992
- Dissertation Abstracts, 1988-1993
- Engineering Index, 1992-1993
- Environmental Periodicals Bibliography
- GPO, 1976-1993
- NTIS, 1985-1993
- Science Citation Index, 1991-1993
- UW Card Catalog, both computerized and paper Search phrase was (gypsum or drywall or wallboard) and (reuse or recycle or recycling).

Found references to articles I already had along with:

"Waste Management for the Construction Manager", Transactions of the American Association of Cost Engineers, 1992 (the association would not photocopy this article for me, but instead, I would need to buy the entire transactions, at a cost of \$124.50)

"Gypsum Firm Cuts Costs, Recycles Waste Board", Rock Products, July 1989, pp 36-37

Also found references to recycling gypsum produced from flue gas desulfurization systems.

13. Survey of Dane County, Wisconsin drywall contractors

On March 16, 1994, a short survey was sent to 41 drywall contractors in Dane County. A self-enclosed, stamped envelope was included to increase response.

As of June 9, 1994, 19 responses have been received. Average scrap rate is about 10-15%, although some are as high as 25%.

Some ideas for recovery of the drywall are:

- Use for agricultural use for the lime value
- Manufacturer (USG) will be taking it back (from Wick Homes)
- Could be used as a fertilizer or mulch
- Farmers want it if it is clean
- It's a very absorbent material, but with neutral pH
- Would like to see it recycled back into drywall; I would use this drywall if it's as good as the original
- Use it for lawns
- Make it mandatory. Charge what the disposal sites charge or a little more; the drywallers will need to adjust prices accordingly.
- Provide a dumping area for drywall only.
- Make it inexpensive.

Some problems reported are:

Cost of disposal

- DNR said it's against the law to landspread on agricultural land
- Other contractors contaminate drywall in dumpster, making it unusable for farmers

In response to my inquiry of existing recycling operations, several said that Hallmark Drywall had a recycling operation; other recyclers included Louisiana-Pacific in Minneapolis.

14. Telephone conversation with New Jersey Department of Environmental Protection

In a March 17, 1994 telephone conversation with Tony Cavalier of the New Jersey Department of Environmental Protection and Energy, (telephone (609)530-8885) I was told that no gypsum recycling plants have been built in the state. The companies were unable to identify markets, and the state would not allow the plants to be built without markets. Proposals for markets included mixing with concrete for fill and agricultural use. However, faculty at Rutgers said that drywall gypsum was unsuitable for agricultural use because of the hydrogen sulfide generation. Mr. Cavalier said he would send me the Rutgers analysis; however, the paper I received was instead a calculation on the liming value of aglime chemicals that [incorrectly] referred to  $\text{CaCO}_3 \cdot 2\text{H}_2\text{O}$  [calcium

carbonate] as gypsum. I called Mr. Cavalier on March 28, 1994 to see if I could get a copy of the paper on hydrogen sulfide generation and left a message for him.

15. Telephone conversations with Robert Wessel, The Gypsum Association, 810 1st Street, NE, Suite 510, Washington DC, 20002, (202)289-5440, April 19, 1994 and July 12, 1994

The Gypsum Association doesn't have composition data; need to contact manufacturers. Type X (fire retardant) wallboard, as compared to normal wallboard, contains more gypsum (less limestone), vermiculite, and fiberglass. The association is starting a project to review potential to recycle, principally agricultural uses. They will be looking at landscaping uses, such as sod grass, and will issue RFPs to universities across the US. Some companies make claims against the use of gypsum (such as the dioxins) that are unfounded, and seem to be an effort to corner the market to recycle it back to the drywall manufacturers. They have heard from the paper trade association on the dioxin content, and it is very low. However, because of the environmental concerns, they will focus on non-food applications. In California, ground up gypsum drywall has been applied to grapes for over 25 years. The State of Colorado allows drywall to be ground up and applied to the land. The economics of making it back into drywall are questionable, both financially and from an energy viewpoint.

As of July 12, 1994, the RFP was still under preparation. The Gypsum Association has been meeting with staff of the US Department of Agriculture, which has both done work on the recycling of gypsum products and is interested in the proposed RFP. The USDA believes a mixture of up to 75% gypsum with 25% soil may be suitable for sod grasses. The USDA may do the additional work at no cost to the association, in which case the RFP will not be issued. Mr. Wessel recommended that I forward the names of interested researchers to him for the mailing list for the RFP, although the association would rather focus on a location nearer their headquarters.

16. Telephone conversation with Michael Gardner of the Association of the Wall and Ceiling Industries-International (formerly the International Gypsum Drywall Contractors Association), (703)534-8300

I spoke with Mr. Gardner on March 28, 1994. His association does not have detailed information on the composition of drywall. However, he said that there are materials in drywall that would pose potential problems for land application, including fiberglass and asphalt. Asphalt is used in both "greenboard" and sheathing. He did not know of any recycling projects, but has only been with the association for about 4 or 5 months. One stumbling block will be the low price of virgin ore, as well as the supply of synthetic gypsum, such as from flue gas desulfurization systems. He will send me some articles on gypsum drywall recycling; I in turn will send him my notes.

17. "Gypsum", chapter in Mineral Facts and Problems, 1985 edition, US Dept of the Interior, Bureau of Mines

Gypsum is the most common of the naturally occurring sulfate minerals, and is 79% calcium sulfate and 21% water ( $\text{CaSO}_4 \cdot \text{H}_2\text{O}$ ). In addition, gypsum is a chemical byproduct of manufacturing processes for making phosphoric acid, citric acid, etc as well as from sulfur scrubbers from power plants. The US is the world's leading producer of gypsum, producing 15% of the world's output. However, domestic demand exceeds domestic production, and net imports account for 40% of the demand.

One of the largest uses for gypsum is to make gypsum wallboard, with the manufacturing plant often at the minesite. There are three main areas of gypsum deposits in the US -- the Great Lakes, Texas/Oklahoma, and California. The leading producer states are Texas, Iowa, Oklahoma, California, Michigan, and Indiana and account for over 65% of US production. Calcined gypsum (manufactured by heating the gypsum to 350°F to drive off 3/4 of the water) is used to make products such as drywall, and the largest producer states are Texas, California, Iowa, Florida and New York, which account for 43% of the US production. (The big Iowa bed is in Webster County in north central Iowa; in Michigan, the deposits are in 6 counties -- Kent, Ionia, Eaton, Mackinac, Iosco and Saginaw, with the biggest deposits in northeast Michigan -- and said to be "practically inexhaustible"; while in Indiana, the article simply says that there are large deposits, with the map showing the biggest deposits in the far southern part of the state.)

Crude gypsum is marketed for use in cement, agriculture and fillers. In portland cement, gypsum is used to retard the setting of the concrete. In agriculture, gypsum is used to treat alkaline and saline soils, improve the permeability of argillaceous (silicate clay) materials and to provide sulfur and catalytic support for maximum fertilizer utilization and leguminous productivity. Tonnages for 1983 were: cement retarder (SIC 3241) - 3,955,000 tons (72%); agriculture (SIC 2875) - 1,309,000 tons (24%); and filler and miscellaneous - 197,000 tons (4%). Byproduct gypsum was sold for agricultural purposes in both California and the South Atlantic regions in 1983 (these two areas use 90% of the agricultural gypsum), with total sales of 760,000 tons for \$7.1 million (\$9.34/ton). Only a small amount of byproduct gypsum is reclaimed.

The trend of uses of crude gypsum from 1973 to 1983 has been relative stable, with agricultural use going from a low of 1,301,000 tons to a high of 1,714,000 tons. The year 2000 forecast is for agriculture use to be about 1,700,000 tons, with cement use at 4,800,000 tons and filler and miscellaneous use at 260,000 tons. For cement use, gypsum is crushed to minus 1.5 inches to plus 3/8 inches, while for agricultural and filler purposes, it is ground to 100 mesh or finer.

Calcined gypsum, on the other hand, is used as plaster (a non-growing sector) and various construction products (especially wallboard, which is growing rapidly), and in 1983, 16,382,000 tons were used for these purposes. The forecast for the year 2000 is that prefabricated products (primarily drywall) will consume 27 million tons of gypsum, with plaster consuming 600,000 tons. The demand for Type-X drywall, which is used in large quantity for nonresidential high-rise apartments and commercial buildings, is extremely cyclical.

Gypsum is a low cost material. From 1963 to 1983, the price per ton rose from \$3.67 to \$7.87; adjusted for inflation, the price actually dropped by 29%.

18. "Gypsum", an article in 1991 Minerals Yearbook, US Dept of the Interior, Bureau of Mines

Because of decreased construction activity, the demand for gypsum in 1991 was down 15% from 1990, to a total of 22 million tons. Lead states were Oklahoma, Iowa, Michigan, Texas, California, Nevada, and Indiana, which jointly accounted for 76% of the US production. Large individual mines include USG's Sperry Mine, Des Moines County, Iowa, USG's Fort Dodge Mine, Webster County, Iowa, National Gypsum Company's Tawas Mine, Iosco County, Michigan, and USG's Alabaster Mine in Iosco County, Michigan. Iowa was the second leading state in the production of calcined gypsum at the two mines listed above.

For crude gypsum, in 1991, 63% was used in cement, with the remainder largely used in agriculture.

The 1991 prices per ton, f.o.b. the mine or plant, for gypsum were: crude - \$6.09; calcined - \$15.67 and byproduct - \$4.49.

The consumption of prefabricated gypsum products in 1991 was:

Material	Reported		My calculation	
	Million Ft2	Thousand Ton	Lb/Ft2	Lb/Yd3
3/8"	622	517	1.66	1,430
1/2"	8,861	7,928	1.79	1,160
5/8"	1,389	1,450	2.09	1,080
1"	93	104	2.24	725
Type X	4,555	4,838	2.12	-
Other	124	105	1.69	-

All other products 1,921 to 1,755

Type-X wallboard is fire resistant.

19. Construction Materials Recycling Guidebook. A Guide to Reducing and Recycling Construction and Remodeling Waste Including a Directory of Twin Cities Area Recycling Markets, Innovative Waste Management, (Minneapolis?), March 1993 Page 12 has 5 paragraphs on gypsum wallboard recycling, including 2 describing the New West plants in Canada.

The study says that the founder of the New West facilities believes that to be economical, a gypsum recycling plant will require the supply of gypsum generated by a population of a million people, and close (how close it doesn't say) proximity to a gypsum wallboard manufacturer as an outlet for the recovered gypsum. A tipping fee at the recycling plant will be necessary; having high landfill costs or a ban on the land disposal of drywall are both factors that assist the economics.

An agricultural use of gypsum is as a soil amendment for low pH or sulfur deficient soils. An analysis of gypsum wallboard material (type of wallboard, with or without paper, etc not stated) showed high calcium content, and heavy metal levels comparable to those in commonly-used ag lime. The study notes, however, the concern about other materials, such as adhesive-content, soluble salts, and economics. A contact is Tom Halbach, assistant state specialist for waste management with the Minnesota Extension Service at (612)625-3135.

Finally, the report says that Dynamic Homes of Detroit Lakes is seeking funding to develop a processing facility for turning wallboard into a soil amendment and Empire Organic Greenhouses in Rosemount uses scrap wallboard in its compost.

20. Telephone conversation with Georgia Reay, Wisconsin DNR

Georgia Reay is the compost specialist with the Wisconsin DNR and is from the Twin Cities area. I asked her about her knowledge of operations to recycle drywall into agricultural products in either Wisconsin or elsewhere. She was unaware of any operations in Wisconsin, but said that in Minnesota, Empire Organic Greenhouses was composting grass clippings with drywall to produce a product that is sold nationally through K-Mart. She suggested I call Gayle Prest, the recycling coordinator for Dakota County at (612)891-7025. Also in Dakota County, a hauler by the name of Kuntsen was recovering drywall, she thought. She further suggested I call the Minnesota Pollution Control Agency to find out about their standards for recycling drywall for agricultural purposes, and call Zieg Shurly (phonetic spelling) at (612)296-6300.

21. Telephone conversation with Art Peterson, UW-Madison Soils Department

On March 17, 1994, I talked with Art Peterson, Professor of Soil Science at UW-Madison about gypsum from drywall.

I told Art that some articles had talked about the benefits of using gypsum as a liming agent on low pH (acid) soils, while others said it was a benefit on high pH (alkaline) soils. Art said neither is true; gypsum is a neutral salt and has no impact on soil pH.

Gypsum as a soil amendment has three potential benefits. First, in high sodium soils, it will replace the sodium. High sodium soils (such as at canneries that have land applied material for many years) have poor water absorption abilities, and the gypsum can restore this ability. Dane County soils would not benefit much from gypsum for this issue, but coincidentally, Art had just talked to Seymour Canning west of Green Bay, which needs to get gypsum by the boxcar load to solve a high sodium problem.

A second benefit is the sulfur in the gypsum. Sulfur is needed on many types soil, especially the lighter soils, and alfalfa fields, to help utilize the fertilizer. When acid rain was more of an occurrence, more sulfur was added through precipitation. But now, some farmers are finding that there's not enough sulfur in the soil or the fertilizers they are adding, and they need to add more. Art suggested I talk to Sherry Combs of the Soil & Plant Analytical Laboratory at 262-4364 to find out what recommendations are being made for this area for adding sulfur.

A third potential benefit is for soils that need extra calcium, without changing the pH. Potato growing areas in the central part of the state, for example, use gypsum for this need.

22. Telephone conversation with Sherry Combs, March 18, 1994, UW-Madison Soil & Plant Analysis Laboratory

Sherry Combs, Soil & Plant Analysis Laboratory of UW-Madison, said that the recommendation for sulfur addition depends on the crop and other sources of sulfur, such as precipitation, manure, and what's already in the soil. Farmers that grow alfalfa may need sulfur. She did not think gypsum is a good source of sulfur as it has low solubility, except in low pH soils, which is not the case in Dane County. Gypsum would not eliminate a sulfur deficiency in Dane County soils in the year that it was applied. Gypsum is a good source of calcium in low pH soils where it is desired not to alter the pH (such as for potatoes). It can loosen hard soils, which is true for sodic soils (those that are high in sodium). Gypsum has no effect on soil pH. She thinks that soil application of gypsum drywall would be a good form of reuse.

23. Telephone call with Tom Halbach, Minnesota Extension Service, (612)625-3135

In a phone conversation on March 21, 1994, Mr. Halbach said that he took samples of drywall and did chemical tests. He said that the results differed greatly by the age of the drywall and the material applied to the surface. For example, older drywall, especially with plaster on it, had high levels of some of the heavy metals. Newer drywall had low levels of heavy metals, but did have high levels of sulfur and boron salts. His conclusion was that new drywall could be safely applied to the land as an agricultural product. He said he would send me the test results. He also noted that he has received about half a dozen phone calls on this topic.

24. Gypsum, US Dept of the Interior, Bureau of Mines

This is a monthly compilation of gypsum supply and demand data; the preliminary data for 1994 has cement use at 3.8 million tons and agricultural and miscellaneous use at 1.6 million tons.

25. Soils. An Introduction, 2nd edition, Michael Singer and Donald Munns, 1991

Gypsum is listed as an inorganic fertilizer, with no nitrogen, phosphorus or potassium, but 18% sulfur, and a good source of calcium. Gypsum is also useful as an additive for soils with high levels of sodium. Gypsum tends to leach out of all but arid soils, and natural quantities of gypsum are not usually an important source of sulfur.

Sulfur and calcium are macronutrients needed for plant growth.

26. Industrial Waste Diversion Program: Final Reports No. 6: A Demonstration of Applying ATS Thermal Screw Technology to the Processing of Separated Construction and other Waste Materials, Ontario Ministry of the Environment, Toronto, 1991, 131 pp

The ATS thermal screw system was developed by a firm in Switzerland and recently bought out by a Canadian firm, Thermofriction Waste Recycling (TWR). The system is primarily used in the agricultural and forestry industries, for making animal feed briquettes or fuel briquettes. This study tested the system on various types of construction and demolition waste and other wastes such as tires and yard waste. Basically, the system uses two parallel screws, rotating in opposite directions at either 55 or 83 rpm to push the feedstock through several chambers that have adjustable plates. As the waste is moved by the screws against the plates, it is crushed, mixed, granulated, compacted, heated, and dried. At the back end of the system, the material can either be forced through dies to form pellets, or, without the dies, left as a flake. A 1,000 tonne sample of construction waste was analyzed. Largely from residential and high-rise construction, its composition was:

garbage	25%
concrete	25%
wood	11%
wallboard	11%
metal	9%
cardboard	3%
finer	16%

For drywall, the machine as equipped with 110 KW electric motors could handle 3 tonnes per hour. A profit/loss analysis estimated that to handle 15,000 tonnes per year would have a net cost of \$28.30 per tonne, before revenues (note: this includes a \$8/tonne royalty; labor rates were \$20 an hour; there were two shifts, with 1 employee each shift; the machine was operated 5,160 hours per year, electricity was 4 cents per kwh; interest was 13%, depreciation was 5 years, and there was no cost for property taxes).

27. Strategic Analysis of Waste Gypsum Wallboard Reprocessing in British Columbia, Peat Marwick Stevenson & Kellogg, 1991, 34 pp

This study was commissioned by the British Columbia Ministry of Environment to ascertain four objectives:

- the availability of gypsum drywall as potential feedstock to existing and proposed drywall recycling systems
- the existing and required infrastructure supporting collection and transportation of the scrap drywall
- the commercial viability of expanding drywall reprocessing facilities in British Columbia
- recommended options to improve the recovery and recycling of scrap gypsum drywall

Four sources were identified as generators of scrap gypsum drywall in British Columbia:

- construction sites, 64% or 48,000 tonnes per year
- demolition sites, 14% or 10,800 tonnes per year (It is estimated that about 1% of demolition waste is gypsum drywall. This percentage is likely to increase as more building built with drywall are demolished in the future.)
- production facilities, 12% or 9,000 tonnes per year from 2 plants
- renovation projects, 10% or 7,300 tonnes per year

It is estimated that 54% of all gypsum scrap generated in British Columbia is recovered annually. In the Lower Mainland the rates of recovery are 90% of production waste, 65% of renovation waste and 57% of construction waste. No demolition drywall is recovered.

British Columbia has one firm that recycles gypsum drywall -- New West Gypsum. The process they developed is based on a compaction device they built to reduce transportation costs for ocean disposal of scrap gypsum. The compaction removes the paper from the gypsum. The process is said to be not complex from a technological viewpoint, but effective. Delivered material is hand-cleaned of metal edging, plastic and other debris, and then crushed into small pieces with a loader. The pieces are then fed into a grinding machine that separates the outer paper from the gypsum. A magnet retrieves any nails, screws or other metals that were missed in the initial cleaning. The gypsum is now a coarse powder and is hauled to the two local drywall manufacturers for remanufacture into drywall.

Several companies have indicated plans to set up competing operations. Four primary barriers to entry into this field were identified by the authors:

- supply of scrap drywall
- availability of end markets
- transportation economics
- limits on recycled content in drywall due to the paper in the recovered gypsum reducing fire resistance

The authors conclude that the barriers to entry of a new firm in this area of British Columbia are "high".

The infrastructure for drywall scrap collection and transportation is defined as having three alternatives:

- contractors collect and haul their own scrap
- "scrappers" clean the site and haul the waste
- disposal companies are hired to collect and transport

The report notes that most scrap is collected and hauled by the drywall contractor. In addition, there is a firm that serves as a transfer station for drywall, with the material ultimately going to New West, and another firm that is storing drywall, claiming that they will eventually recover the material. The development of an infrastructure to handle scrap drywall depends on a ban on landfilling the scrap.

Markets for the recovered gypsum are largely the two drywall manufacturers in the area -- Domtar and Westroc. The amount of recycled material they can use is limited both by fire ratings and manufacturing processes. New West says that the paper component of the recovered gypsum is 1%. In turn, Domtar says it can use 20% recycled gypsum and Westroc says it can use 15%. Both firms say that they are working to increase this amount. Domtar pays \$19 a tonne for virgin gypsum, while Westroc pays \$29 a tonne. New West is paid \$12 a ton for the recovered gypsum and therefore charges suppliers \$75 a tonne to accept scrap gypsum. In 1990, New West sold these two firms almost 32,000 tonnes of recovered gypsum.

Three other potential markets were identified:

- mushroom growers, which use 1,750 tonnes per year of virgin gypsum in British Columbia annually
- agricultural fertilizer -- New West sold 260 tonnes in 1990; the total market is estimated a few thousand tonnes per year
- cement manufacturers. However, the gypsum may contain additives which would be detrimental to its use in cement. The potential market in British Columbia is quite large, about 100,000 tonnes a year.

New technology to provide cleaner recovered gypsum would both expand the market for the recycling into drywall and the use in the cement industry.

New West is planning to build several new recycling operations, using better technology, and expanding the size of the facilities.

The authors also interviewed reprocessors in other areas. One firm in Ontario said that they recover drywall for secondary markets, including kitty litter and fertilizer. Other Ontario reprocessors said that the recovery plant must be within a two hour drive of the end market to be economical.

Recommendations to improve the rates of gypsum drywall recovery in British Columbia include:

- restrict landfilling, and long-term storage of scrap drywall
- provide inspection of construction and renovation sites to insure that drywall scrap is being properly managed
- establish fines for improper disposal

28. Telephone conversation on March 28, 1994 with Andrea Cohen of the Vermont Recycling & Resource Conservation Section, (802)241-3444

I asked about the status of the gypsum recycler New England Gypsum, reference in a report and a magazine article as building gypsum recycling plants in Vermont. Ms. Cohen said that this firm was out of business. She had her staff person (Carolyn, did not get the last name) call me back on April 5th. She told me that the company was unable to find markets for the material, but did not know what the markets were going to be.

29. A Feasibility Study and Cost Analysis of Recycling Construction Site Gypsum Wallboard Waste, MS thesis, Peter Yost, University of New Hampshire, September, 1993, 163 pages

This thesis looks at the feasibility of recycling drywall from local drywall contractors back into drywall at the Domtar Gypsum Newington, NH plant. When this plant was constructed in 1989, a recycling operation was incorporated into the plant to handle the large amount of scrap drywall that was produced in getting the plant on line. Now, there is excess capacity in the recycling system, and the capacity to handle 600 tons per week of drywall generated from outside sources. In addition, the raw gypsum must be imported at a relatively high cost (\$13.78 a ton in 1991, versus the average domestic value of \$7.29 a ton), making recycling more economically attractive. As an alternative, it is estimated that for a cost of \$10,000, the recycling system could be shipped to Domtar's plant in Grand Rapids, Michigan to recycle the several million tons of scrap gypsum board that has accumulated at that plant. The system does not remove the paper from the drywall in order to recycle the gypsum.

Only construction drywall was examined, there are no known systems to recover demolition drywall and Domtar can only recycle drywall with very low levels of contamination.

Rules of thumb for scrap drywall generation were noted as 1 lb per square foot for residential construction, with an unknown quantity for commercial and industrial construction; alternatively, scrap generation is about 10% of the amount purchased. This study investigated the rules of thumb and used an estimate of 1.62 pounds per square foot of for gypsum drywall. Three studies (Toronto, McHenry County, IL, and Portland, OR) found gypsum to be 15 to 21% of the waste from residential construction. While the rule of thumb of 1 lb of scrap gypsum per square foot of new residential construction was confirmed, it was not possible to derive estimates for remodeling projects or commercial projects.

According to data from Domtar, the composition of drywall at "setpoint" is:

Component	Percent
Stucco	52
Waters (1)	42
Paper	4-5
Gypsum	0.6-0.7
Starch	0.15-0.45
Disal	0.1
Potash	0-0.35

1. Can contain Soap, fiberglass

Note: the setpoint is the point at which the slurry comes off the feedhead and is fed between the paper face and backing. Approximately 35% of the water is driven off and replaced by air.)

Besides recycling drywall scraps for reuse in manufacturing drywall, other potential uses included as a soil amendment for calcium for potatoes, cranberries, and peanuts, or sulfur for alfalfa, corn, cotton and wheat. There is a potential problem of contamination from Type X and MR (moisture resistant) drywall.

The disposal of gypsum can lead to the generation of hydrogen sulfide. For this to happen, several conditions need to occur: there must be sufficient moisture, it must be an anaerobic condition, the pH must be correct, the temperature must be proper, and there must be sufficient organic material for the sulfate-reducing bacteria. These conditions do not exist in most C & D disposal sites.

In 1990, the Washington State Department of Ecology compared four alternatives to landfilling gypsum (ocean dumping, incineration, agriculture, and remanufacture into new drywall), using seven criteria: (1) integration with existing state waste management priorities, (2) environmental impacts, (3) health impacts, (4) cost/economic viability, (5) avoided costs per ton, (6) availability/feasibility, and

(7) technical viability. The resulting ranking was: first - remanufacture of new drywall; second - agriculture; and third - after proper landfilling, ocean dumping and incineration.

The study found that Kittery, Maine requires that drywall be separated from other (construction?) waste, and ground and reused as a soil amendment along the sides of town roads to help leach out the salt applied to the roads and washed onto the roadsides. Hooksett, NH requires the separate disposal of drywall waste.

The cost of recycling was broken down into Domtar's costs and the costs of the contractors or others to provide the drywall to the Domtar plant. Domtar did not release exact data, but stated that the equipment cost about \$750,000 and that daily costs were to be assumed fixed at \$600. The author notes that the capacity of Domtar is to recycle 200 tons of material a day; thus costs could be as low as \$3 a ton. For the contractors, costs depended on their current method of handling the scrap, but it was noted by many contractors that there would be no separation costs, and for some, since they already hauled the scrap in their own vehicles to a disposal site, no added cost for a container or in some cases, transportation. While the thesis gives equations for calculating the costs to these two parties and gives examples of the breakeven tonnages (for Domtar) and mileages (for the contractors), no conclusions were described.

In an analysis of contamination, the level in scrap drywall brought in to a recycling collection center was found to be about 0.19%, which is lower than that obtained in raw gypsum ore. All of the material was from drywall contractors hauling their own material. A concern still remains on the level of contamination to be expected from a private hauler bring in drywall.

A mail survey of drywall and general contractors in the area resulted in return rates of only 26% and 30%, respectively. Some results are:

Type of Contractor	Drywall	General
Average landfill tipping fee/ton	\$61.70	
Fee willing to pay for recycling/ton	-\$1.80	\$2.83
Miles willing to drive if \$0/ton	18	18
% who disposal of own drywall	42%	78%
<b>Who's responsible for disposal</b>		
mostly commercial jobs	6%	94%
mostly residential jobs	79%	21%

The thesis concludes that:

- there is sufficient drywall scrap available within a 50 mile radius to make it economically attractive for Domtar to setup a recycling collection system at their plant and accept the drywall at \$0 a ton
- drywall contractors for residential sites could economically haul a ton of drywall an additional 71 miles round trip to dispose of their drywall at \$0 a ton, while for commercial jobs, the distance becomes 246 miles. With the Domtar plant just 20 miles from the major landfill accepting gypsum scrap, the economics for contractors look very favorable.
- a potential exists for drywall scrap to come from longer distances if the transportation costs can be kept low. One alternative is to have collection sites at the drywall distributors, with the scrap backhauled in the trucks making the deliveries from the manufacturers. A local distributor is setting up such a facility.

The state of New Hampshire has developed a program to provide information on gypsum wallboard recycling, disseminating information through the Governor's Recycling Program and the Business and Industry Association. A technical bulletin from the Solid Waste Division of the Department of Environmental Services has also been prepared. The state of Massachusetts is also informing transfer station operators in the northeastern part of the state about the opportunities to recycle gypsum drywall at Domtar.

(Note: As of March 1994, the author of this thesis was working for the National Association of Home Builders. He provided his thesis in response to my general call asking for information.)

### 30. Discussions with Dane County Public Works staff

Drywall is usually generated at a building site over a short time frame, typically over a few days, with the contractor usually handling their own waste.

### 31. Discussion with Robert Walther, 259-9235 (now 244-4332)

In his study of residential construction waste management in Dane County in the summer of 1993, Rob learned that most drywall is disposed of in a separate container from other construction debris. He also said that Louisiana-Pacific was looking into setting up a drywall recycling system in Wisconsin.

### 32. Letters sent to Gypsum Wallboard Manufacturers

On March 14, 1994, letters were sent to the following gypsum wallboard manufacturers, as located in the Thomas Register, asking for information they have on the recycling of drywall and the composition of the drywall that they make:

*Boise Cascade Corporation*

*Boise, Idaho*

No response.

*Char Corp*

*Hiialeah, Florida*

Returned by post office.

*Celotex Corp*

*Tampa, Florida*

No response.

*Domtar*

*Ann Arbor, Michigan*

Domtar sent both a brochure on the environmental issues of gypsum wallboard and a Material Safety Data Sheet (MSDS) on the drywall.

The brochure says that the paper facing is made from 100% recycled newspaper and corrugated cardboard. Gypsum wallboard can be recycled, both from the manufacturing process and from construction sites (if it is clean). Domtar can use between 5 and 20 percent recycled drywall in the manufacture of drywall. They currently accept construction site drywall for recycling at 6 of their plants, but not at their only Midwest plant in Grand Rapids, MI.

The MSDS did not describe which type of drywall it was for: regular, moisture resistant or fire-retardant. It listed four hazardous ingredients: (1) gypsum at 71-89%, (2) limestone at 2-19%, (3) paper at 5-6%, and (4) crystalline silica at 0.1-2%. The pH is give at 7.5, while the solubility in water is 0.2% by weight. hazardous combustion products are carbon monoxide and carbon dioxide, while conditions to avoid are strong acids, which will cause the production of carbon dioxide. Toxicologically, the routes of entry are eye contact and inhalation; acute exposure is irritation of nose, throat and lungs from excessive exposure to dust, chronic exposure is from dust containing respirable sized crystalline silica, which can lead to silicosis, and is a possible carcinogen. Preventive measures include gloves, goggles, and dust masks.

*Georgia-Pacific*

Brian Randall (phone (404)987-5190, ext 222) faxed me a chart on the typical composition of gypsum wallboard. The non-gypsum materials include:

<b>Paper</b>	<b>4-6%</b>
Water Resistant Additives	0-8%
Organic Binders	<1%
Soap for Foam	<1%
Organic Dispersant	<1%
Glass Fiber	<1%
Gypsum Crystal Modifiers	<1%

The chart lists the gypsum crystal modifiers as fine ground gypsum, potassium sulfate, aluminum sulfate, boric acid and organic retarder.

In a phone conversation on June 10, 1994, Mr. Randall didn't believe that the composition of the drywall would be of concern for agricultural use. He noted that the water resistant additive that Georgia-Pacific uses is silicone, while some of the other manufacturers use an asphalt-wax emulsion. The binders are starches and sugars.

*Louisiana Pacific*

*Portland, Oregon*

Louisiana Pacific makes gypsum board products for use as underlayment in floors, exterior wallboard and interior wall board. 100% recycled newsprint is used to make the cellulose fiber.

The Material Safety Data Sheet (MSDS) lists the composition as: (1) gypsum - 63%, (2) paper - 15%, (3) perlite - 13%, (4) water - 7% and (5) other - less than 2%. It is noted that both the gypsum and the perlite can have naturally occurring crystalline silica as a trace, usually at less than 1%. Health hazards relate to the dust; the crystalline silica is classified as a probable human carcinogen by some health agencies, but not others.

*National Gypsum*

*Charlotte, North Carolina*

David Drummond of National Gypsum (telephone (704)365-7474) called me on April 4, 1994 in response to my letter. He said that National has 18 drywall manufacturing plants. While the firm is developing systems to recover their in-plant scrap (3-6%), he does not envision that they will accept outside scrap in the foreseeable future. National Gypsum also does not have a company policy on the use of scrap gypsum from drywall for agricultural use, because of the varying conditions that the scrap would be in and the uncertainty of how it would be processed and land applied. However, his personal belief was that beneficial application to the land was

a good method of reuse. The company has had its wallboard tested at its research center in Buffalo, and Mr. Drummond said that there were no materials in the drywall that would make it unsuitable for land application, regardless of whether it was normal, moisture resistant or fire retardant drywall. He would both fax me the MSDS and have Larry Kingston of the laboratory give me a call. Mr. Drummond believes that with increasing landfill fees, drywall contractors will also have more financial incentive to reduce the amount of scrap that they generate.

The MSDS provided little information, only saying that drywall has gypsum, quartz as a naturally occurring component, and cellulose.

Larry Kingston (telephone (716)873-9750, extension 253) said that he had the firm's drywall tested several years ago for leachable materials under the EPA EP tests, and no toxic materials were detectable. Based on his knowledge of how drywall is manufacture, he cannot think of any materials that would be a problem for agricultural application of the recovered drywall. The problem seems to be that although virgin gypsum has been used as an agricultural product for centuries, only recently has scrap drywall been looked at for this use. National Gypsum is hesitant to endorse the use of scrap drywall for agricultural use until the government sanctions its use. California has recently approved the use of scrap drywall for agricultural use and Mr. Kingston hopes that a proposed US DOE/University of Ohio study of the use of gypsum to help restore some barren land in Ohio will also investigate the use of scrap wallboard. Mr. Kingston noted that even though Wisconsin doesn't use much gypsum, that there would be some agricultural and hence economic value for the use of gypsum for farmers, although it might not be near the price that virgin agricultural gypsum sells at. Mr. Kingston would be glad to help us in any efforts we take to recover drywall, including meeting with us if we test the land application. For the potential of taking scrap wallboard back to the manufacturers, Mr. Kingston said that it would need to be clean and that the logistics would need to be worked out. At National Gypsum, all of the in-plant scrap is now being recycled.

*United State Gypsum  
Chicago, Illinois*  
No response.

33. Telephone Conversation with Steve Brachman, City of Milwaukee Resource Recovery Manager, March 15, 1994

Steve was unaware of any drywall recyclers in the Milwaukee area, but said a firm by the name of Shoreline of Wisconsin was in the business of crushing construction and demolition concrete and other rubble. Steve was not sure that this business would survive.

34. Telephone Conversation with Dave Eger, Waukesha County Solid Waste Manager, March 15, 1994

Dave was unaware of any drywall recyclers in Waukesha County, but said that Shoreline of Wisconsin is expanding its business and would like to get involved in more aspects of construction and demolition debris recycling, including drywall. Currently, it crushes concrete for aggregate and shoreline erosion control as well as recovering metal from C & D waste. The Waukesha County solid waste staff and board are impressed with the company's operation.

In addition, there is a firm in Waukesha known as Cotton Disposal that has a transfer station that it uses as a picking floor to hand pick out recyclables from C & D debris.

35. Telephone conversation with and literature from Gyp-Pack of Tonowanda, NY, March 21, 1994

They will send me information on their equipment to process drywall for recycling and the potential uses for processing drywall; they noted that they have been getting a lot of calls on this recently (they were described in a January 1994 article in *BioCycle*). Literature was minimal; showed a truck and text says that system grinds and separates the paper. The firm also has GypCube, which is a container made primarily of gypsum drywall into which gypsum scraps are placed for transportation back to the drywall manufacturer for recycling.

36. Telephone conversations with two fertilizer retailers in Madison, March 22, 1994

Neither company sells gypsum at their Dane County stores; one said that he had never before had a call for it. One firm looked up the price in their catalog (they could get it if desired; they sell it at other operations in the state). It is sold in 50 pound bags, with the price declining as the number of bags purchased increases. For example, a truckload of 840 50-pound bags would cost \$4.08 a bag (\$163 a ton), while a smaller order would be priced at \$4.76 a bag (\$190 a ton).

37. Telephone conversation with Scott Cahail, Iowa Department of Natural Resources, March 22, 1994

Mr. Cahail was not aware of any drywall recycling operations in Iowa. Sperry (a drywall manufacturer) had applied for a DNR grant to install recycling equipment in their plant, but DNR denied the application, concluding that the recycling system would be economical without the grant. Several drywall contractors have approached the state about grinding up drywall to use as fill material on construction sites, but have not followed up with these proposals and when DNR has tried to contact them, have not responded.

38. Telephone conversation with Mary Rothenmaier, DNR Southern District, early March 1994

Ms. Rothenmaier was contacted to find out if there are any farmers in the area that reclaim drywall for agricultural use. She said that there weren't any that the DNR knew about; and that DNR approval would not be required.

39. Telephone conversation with Georgia Reay, DNR central office, March 22, 1994

Ms. Reay thought that DNR approval would be required to apply drywall material to agricultural land and that NR 518 would probably need to be followed. However, she also said that the Districts have at their discretion whether or not approval would be required. She advised me to contact Gene Mitchell of the central office for a better reading on this.

40. Conversation with Jim Downing, Badgerland Supply, Inc., March 22, 1994

Mr. Downing is President of Badgerland, one of 3 drywall wholesalers in Dane County, and probably the biggest. He said that the drywall contractors have a big problem with scrap drywall, primarily because of the cost of disposal. Drywallers estimate it costs them between 1.5 and 2 cents per square foot of purchased drywall to dispose of the waste (for example, for a job of 10,000 square feet of drywall, about \$200). Almost all the contractors handle their own scrap. While the manufacturers understand that there's a problem with handling the scrap, Mr. Downing does not feel that they have provided solutions. For recycling, the manufacturers will want the gypsum only, not the paper. He noted that Domtar, which will accept drywall pieces with the paper, does not sell much, if any, drywall in Wisconsin. He buys his drywall from National Gypsum in Waukegan, Illinois, which barges their gypsum in from Michigan. Mr. Downing has been asked by the contractors to be a dropoff site to handle the scrap; he doesn't feel this is practical, partially because this wouldn't provide the service to all the contractors. He believes that the County or the State will need to provide some leadership to facilitate drywall recovery. He said a special problem the wholesalers have is with dunnage, a special block made by the manufacturer to facilitate shipping of partial loads. He minimizes the problem by buying full loads, which he estimates have 23,000 to 24,000 square feet of material and 43,000 to 45,000 pounds. He estimates that half of his material is 1/2 inch and the other half is 5/8 inch, Type-X. He also takes his scraps to Ted Belanus at Hallmark Drywall for recycling. He believes that Menards and Fish both sell a lot of drywall, but only to the general public, not to the contractors. He suggested contacting Knight Manufacturing in Brodhead about a grinder for processing drywall for agricultural use, and Walls & Ceiling magazine for information from the industry. Contacts at the other two wholesalers are Jack Schroeder at Gypsum Supply and Dick Klein at Wisconsin Drywall.

41. Conversation with Bob Mandt, Oregon, WI, March 22, 1994

Mr. Mandt owns a sand pit into which drywall waste is disposed. He has been doing this for several years, primarily as a service to the contractors, as they buy the sand from him. His DNR approval is for clean drywall only, without metal such as screws or nails. He believes that materials should be recycled, and not disposed, but doesn't have a machine to grind up the drywall. He believes a two-stage crushing grinding operation would be needed. He says the farmers will take the material, but he doesn't believe that they will pay for it.

42. Conversation with Lynn Hummel, DNR, March 24, 1994

Was unaware of Mandt disposal site. Said he didn't believe the environmental impacts of disposal would be significant enough to warrant much of his attention in comparison to other problems he is concerned about. Will get back to me with more information; it will probably take awhile.

43. Conversation with Mindy Habecker, Dane County UW Extension, March 22, 1994

Mindy said that she had done some work on the potential to recycle drywall for agricultural use. One of the concerns was with the fiberglass in Type-X drywall, but the conclusion was that if the drywall was incorporated into the soil, it would not be a health hazard. [Editor's note: crystalline silica from sand can lead to silicosis, a dangerous lung disease and may be a human carcinogen. However, glass is amorphous and researchers have found that it doesn't pose the same level of risk as crystalline silica in sand. Crystalline silica will be also be present in gypsum as a natural occurrence in small amounts.] Mindy thought that farmers would use the drywall if they had data on the chemical composition and it was conveniently available.

44. Conversation with Lee Gross, Dane County UW Extension crop agent, early March, 1994

Mr. Gross did not have any leads of farmers who wanted to use gypsum from drywall.

45. Telephone conversation with Dick Klein, Wisconsin Drywall, March 22, 1994

His firm is owned by United States Gypsum through an intermediate corporation known as L & W Supply Corp. USG realizes the need to find a way to recover the scrap drywall; many landfills no longer will accept it for disposal. He suggested calling Mike Lorimer at (312)606-3717 for information on recovery. From his operation, they have little scrap; the dunnage is stockpiled and then sent back to USG.

46. Telephone conversation with Jack Schroeder, Gypsum Supply Co. of Wisconsin, March 22, 1994

Mr. Schroeder's firm gets its drywall from the USG Sperry and Fort Dodge, Iowa plants and the National Gypsum (Gold Bond) Waukegan, Illinois and Fort Dodge, Iowa plants. The main problem with gypsum waste management seems to be the cost of disposal for the drywall contractors. At his wholesale operation, he ships most of the dunnage back to the manufacturers, although he has sent some to Hallmark Drywall for grinding and farm application.

47. Survey of Dane County drywall wholesalers, March 22, 1994

A survey of the three drywall suppliers (Badgerland, Gypsum Supply and Wisconsin Drywall) produces an estimate that there are approximately 21 million square feet of 1/2 inch and 26.4 million square feet of 5/8" drywall sold by these three firms in a year. My calculation of weight is about 90 million pounds, or 45,000 tons.

48. Telephone conversation with Warren Wilson, Dakota County, Minnesota, March 28, 1994

Warren responded to my call to Gayle Prest. He was unaware of any drywall recycling operations in Dakota County, MN, although several alternatives had been examined, including use as kitty litter, floor dry and as an admixture with the composting of grass clippings. This last project was being examined by Empire Organic Greenhouses, which did not pursue this because they believed the gypsum would be a liming agent and alter the pH.

49. Telephone Conversation with Michael Koran, Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP), March 28, 1994

Mr. Koran said that in an average year, approximately 5,000 tons of agricultural gypsum are used in Wisconsin, mostly by the potato farmers, who are after the calcium. In 1993, however, only 3,118 tons were used, while in 1992, 4,828 tons were sold. DATCP requires gypsum sellers to be licensed if they make claims for the benefits of their products, however, no licenses are required if they only state that the gypsum is a source of calcium and sulfur.

50. Telephone conversation with Mindy Habecker of the Dane County Extension Office, March 28, 1994

I asked Ms. Habecker how to calculate the amount of calcium or sulfur that would be needed on agricultural land and how much gypsum would need to be applied to meet that need. Mindy said that when a soil analysis is done, the type of crop to be grown would be indicated. The analysis then recommends how much of the nutrients are needed per acre, and the calculation is done based on the amount of the nutrient in the fertilizer. For fertilizers such as gypsum that are relatively insoluble, it may be necessary to add the fertilizer in the preceding year, and/or use a more soluble material. Mindy will send me UW-Extension fact sheets on both calcium and sulfur for agriculture.

51. Conversation with Gene Mitchell, Wisconsin Department of Natural Resources, March 29, 1994

Gene has been getting several requests for approval of projects to land apply gypsum from drywall. The Department would like to provide a blanket approval, if possible, and we talked about the potential to recycle gypsum on agricultural land and possible contaminants.

Gene also said that the Department had given the Kohler company approval for the recovery of scrap gypsum from their molding process. The gypsum is of high quality and is ground up for application to potato farm land.

52. Telephone conversation with Mike Carpenter, Carpenter Construction, Middleton, 831-8228, March 29, 1994

Mr. Carpenter said that his firm has been contemplating setting up a construction and demolition recovery system for several years, especially for wood and drywall. For drywall, his thought was to go to construction job sites and collect the drywall for a fee, bringing it back to a central place where it would be ground and then shipped back to the manufacturers. For remodeling jobs, it would probably not be economical to collect the drywall except at large job sites, but instead, the drywall could be brought to the processing plant. Mr. Carpenter had talked to the suppliers several years ago; there seemed little interest in taking back the scrap drywall to make new product.

53. Telephone survey of DNR list of drywall recyclers, March 31, 1994

Gene Mitchell gave me a list of 6 firms that the DNR recycling database had listed as recyclers of drywall, dated January 18, 1994. I called each of these firms and found that none had every recycled drywall. However, Gene also gave me contacts of two firms that have recently approached DNR to establish drywall recycling projects:

Vicky DeLong  
Land Management, Inc.  
8339 E. County Road X  
Clinton, WI 53525  
(608)676-5846

Scott Karcher  
Scrap Material Handling Co.  
320 Sunny Avenue  
Delavan, WI 53115  
(414)728-8973

In addition, Gene gave me a contact in the US SCS, who has been corresponding with Gene on this topic:

Mary Jane Reetz  
District Conservationist  
Soil Conservation Service

512 C Street, NE  
Brainerd, MN 56401

Ms. Reetz reports that New West Recycling in Tacoma, Washington said that chickens would eat bedding made of gypsum, and thus build up dioxins in their bodies (apparently from dioxin in the glue, which she said others claim there is both little glue used and little dioxin in the glue). Furthermore, she also spoke with a researcher at the University of Washington who said that chickens and turkeys don't eat much of their bedding and this should not be a problem.

54. Potential of Pulverized Construction Drywall Waste as a Soil Amendment, MS thesis, Mark E. Burger, State University of New York, Syracuse, NY, December, 1993, 143 pages [also see reference 1d]. Email address as of March 1998 is meburger@juno.com

Tests were done against the hypothesis that "... on-land disposal of pulverized regular construction drywall waste would have a beneficial, non- detrimental effect to soil and crops."

Currently, there are some major limitations to the landfilling of gypsum drywall -- it is bulky, hard to compact, takes up valuable space, and in certain circumstances, can produce hydrogen sulfide gas, which is both offensive in odor as well as being toxic and explosive in high concentrations. Hydrogen sulfide gas will only be produced, however, if all of the following conditions hold:

- presence of desulfovibric bacteria
- availability of organic material
- source of SO<sub>4</sub> ions
- liquid water
- anaerobic conditions
- pH between 4 and 9
- temperature between 30 and 38 degrees C

Alternatives for the reuse or disposal of scrap drywall include recycling into drywall, which is limited because of the need to keep contamination low, ocean disposal, which has been done in the Pacific Ocean in Canada, incineration, for which there are no known literature references, and land application. For land application, some of the materials used in the manufacture of drywall are of concern, including:

1. Boron, which can result in soil toxicity. Drywall has about 0.15 g per kg B.
2. Asphalt-based wax emulsions. It is only in drywall that is enhanced for water resistance and therefore will not be a problem with regular drywall.
3. Fiberglass is used in the manufacture of fire-resistant drywall, at a rate of about 19 kg per 924 square meters. It is not present in regular drywall.
4. Starch-based glues should not be a problem since they are made of animal by-products or corn.
5. Organics are also not known to be of any concern based on the Material Safety Data Sheets provided by the manufacturers if the drywall is applied at a rate of 16 to 22 Mg per hectare.
6. Other compounds may include pentachlorophenol (PCP) which has been found in low concentrations of the paper backing of some drywall. However, the PCP may have come from contact of the drywall with a wood deck treated with PCP.

The author concludes that none of these materials should result in detrimental effects for drywall applied at agronomic rates.

Gypsum has been used as for agricultural purposes for hundreds of years, with recorded uses beginning in the mid 1700's. It has been used on sodic and irrigated soils to ameliorate the effects of poor soil physical properties on vegetation growth by enhancing flocculation and aggregation of soil particles, to reduce soil crusting and sediment erosion while increasing water infiltration and soil aeration, as a fertilizer source of sulfur and as a flocculating agent of clay soil particles in muddy ponds.

Gypsum is 79% calcium sulfate and 21% water. It has 23% calcium and 18% sulfur. Its solubility is about 150 times that of limestone. With the implementation of federal clean air laws, the amount of sulfur added to the soil through atmospheric deposition has declined, and deficiencies could develop in soils to the detriment of crop yields, especially for alfalfa and clover. In the northeastern US, gypsum could also help farmers that have wet soils by increasing water infiltration and soil aeration. Gypsum could also be used to treat soil that has had excessive amounts of road salt, clay soils, muddy pond water and to "fix" ammonia in manure.

Liming of soil is common in humid areas to neutralize soil acidity. It has used since as least 45 A.D. The effectiveness of various materials as liming agents is defined by their calcium-carbonate equivalent (CCE) and their effective-neutralizing value (ENV). The ENV is the fraction of lime, expressed as pure CaCO<sub>3</sub> that is expected to react in the first year after application. Generally, the smaller the particle size, the more rapidly the lime will react with the soil, but the additional grinding adds cost to the material. Applying too little lime to soil may produce little or no return, while applying too much lime can be injurious to the plants by inducing deficiencies of Fe, Mn Cu, Zn, or Mg, reducing the availability of PO<sub>4</sub> and/or restricting B uptake.

The field test consisted of 15 test plots of 6 meters by 6 meters, with 5 treatments of three replications each:

- a control

- agricultural limestone to increase pH to 7.0 (29.8 Mg per hectare)
- agricultural gypsum at 29.5 Mg per hectare to give the same level of Ca as the agricultural limestone
- pulverized drywall at 24.6 Mg per hectare to again provide the same amount of Ca as the agricultural lime
- pulverized drywall at twice the rate of Ca as the agricultural lime (that is, 49.3 Mg per hectare)

The material was applied in the late fall of 1990 and corn was planted in the spring of 1991.

Sampling was done of the materials applied to soil, the soil before the treatments (October 1990) and in the fall of 1991. Soil solutions were sampled every two weeks between June and November of 1991. Plant tissues were analyzed from material collected in July, September and October 1991.

The data for the gypsum from the drywall was as follows:

Material	Composition
pH	8.0
Ca	260.0 g/kg
Mg	22.0 in.
Na	0.20 in.
P	0.20 in.
K	0.50 in.
S	116.0 in.
As	<10 mg/kg
Ba	19.7 in.
Cd	<1 in.
Cr	59.0 in.
Pb	<10 in.
Hg	26.0 in.
Se	<10 in.
Ag	<2 in.

The tests concluded that the land application of both levels of gypsum from construction drywall had a beneficial, non-detrimental effect on the soil and on corn grain production. Grain yield was 25% higher on the plots receiving the construction drywall gypsum than on the control plots, and similar to the yields on the plots that received either agricultural gypsum or agricultural lime. The drywall increased the soil concentrations of exchangeable Ca, Mg and SO<sub>4</sub> and the base saturation within the 0-15 cm soil depth. The construction drywall gypsum did not affect the soil pH (which is 5.1 in the top 15 cm), although the agricultural gypsum did raise it slightly, and the agricultural limestone raised the pH considerably. For the plots with the drywall treatment, the ear leaves had higher levels of Ca, Mg and S, while the levels of As, Ba, Cd, Cr, Pb, Hg, Se and Ag were either below detectable limits or not higher than the other plots. In the grain, the concentration of Mg was 15% higher (0.10 g/kg) than in the control, while S was 28% higher (0.6 g/kg) than the control. There were no differences in the concentrations of N, P, K, Ca, Na or Cr in the grain. The concentrations of As, Ba, Cd, Pb, Hg, Se and Ag were below detectable limits. The thesis has detailed tables of the results.

55. "Understanding Plant Nutrients. Soil and Applied Calcium", K. A. Kelling and E. E. Schulte, UW-Extension fact sheet A2523, (1992?)

Generally, Wisconsin soils with a pH above 6.0 have sufficient calcium for agronomic crops. When calcium is applied to soil, the predominate source of the calcium is limestone, which has 300-400 pounds of calcium per ton of limestone. Gypsum contains 20-22% calcium and is not recommended as a source of calcium except for soils with a low cation-exchange capacity supporting crops that require an acidic soil. Research has shown that potatoes and apples may benefit from added calcium when grown on sandy soils with low calcium levels. For potatoes, the additional calcium improves resistance to bacterial soft rot and internal brown spot and consistently improves potato grade. Available calcium is estimated by measuring exchangeable calcium. Optimum soil-test levels for exchangeable calcium are 400-600 ppm for sandy soils and 600-1000 ppm for silty, clayey, and organic soils.

56. "Understanding Plant Nutrients. Soil and Applied Sulfur", E. E. Schulte and K. A. Kelling, UW-Extension fact sheet A2525, (1992?)

Sulfur is an important plant nutrient, but is often not recognized as such because it is not often deficient in the soil. The sulfur cycle is similar to the nitrogen sulfur. Most soil sulfur is unavailable to plants and is part of the organic matter in the soil. It becomes available either through bacterial oxidation of the unavailable sulfur, or in wet soils, sulfide sulfur can combine with oxygen as the soil warms or has increased aeration.

Sulfur is removed from the cycle through both the harvesting of plants as well as leaching. Legumes and corn silage have the highest sulfur removal rates of crops; corn silage removes 25 lbs per acre for 15 tons per acre of silage, while an alfalfa crop of 4 tons per acre removes 23 pounds of sulfur per acre. Potatoes (400 cwt) and corn grain (150 bu) remove 10 pounds of sulfur.

Sulfate sulfur is not readily held by soil particles, except for acid clays, so in most soils, it can be leached below the root zone.

Soils commonly contain 200-600 pounds of sulfur per acre, nearly all in the unavailable organic form. As the organic material decomposes, a small portion of this sulfur is converted into the available form of sulfate sulfur. Approximately 2.8 pounds per acre are made available annually from each 1% of organic matter in the soil. A second source of sulfur is through atmospheric deposition, with the southeastern portion of the state receiving 20 pounds per acre or more per year. Manure is a third source of sulfur. About 55% of the sulfur in manure is becomes available to the plants in the year that the sulfur is applied. The amount available varies from 0.8 pounds of sulfur per ton of dairy manure to 1.8 pounds of sulfur per ton of poultry manure. The fourth natural source of sulfur is the subsoil; clayey, acidic subsoils can have substantial amounts of plant-available sulfate sulfur. Sandy soils, on the other hand, may require annual applications of sulfate forms of sulfur, because the sulfate leaches through these soils relatively rapidly.

The need for sulfur is determined by calculating the sulfur availability index, which is a combination of sulfur released by the organic matter in the soil, sulfur from precipitation, subsoil sulfur, and sulfur in any applied manure. At 40 or above, adding more sulfur is not likely to produce any benefit; at 30 or less, sulfur should be added; while at 30-40, further plant analysis should be done.

Gypsum is listed as a slightly soluble sulfur fertilizer, with sulfur content at 17%.

57. Telephone conversation with Jeff Eveland, Wick Homes, Mazomanie, WI, (608)795-2261, ext 266, April 13, 1994; followup September 20, 1994

Mr. Eveland responded to my survey of drywall contractors, noting that Wick Homes will have its scrap drywall recycled by having it taken back by the manufacturer, United States Gypsum (USG). He said that their project with USG is in its infancy; they are still in the talking stages and haven't worked out anything yet. Wicks will be a pilot project for USG (Sperry, Iowa plant); USG is not currently recycling contractor scrap at this plant. The storage or processing needs for Wick Homes has not yet been discussed, nor the method of transportation or the cost or revenues. USG ships drywall to Wick Homes by contract carrier, who then backhauls other materials.

In a followup call on September 20, 1994, Wicks said that they have gone ahead with this project, and it is working out very well. Wicks pays to have its gypsum sent back to USG; the cost of shipping it back is the same or less than the cost to send the drywall to the landfill. USG feels that it can use up to 10% scrap in making new drywall as long as it does not have drywall mud or drywall tape on it.

58. MSDS from USG

In their Material Safety Data Sheet dated September 3, 1992, United States Gypsum gives the composition of their gypsum panels as:

<u>All Panels</u>	
Gypsum	85-95%
Paper	3-9%
Starch	0.3-1%
Glass Fiber	0-1%
Sucrose	0-1%
Lignin Sulfonates	0-1%
Sodium Naphthalene Sulfon	0-1%
Polyvinyl Alcohol	0-0.10%
Calcium Stearate	0-0.01%
Alkyl Ether Sulfate	0-0.01%
Diethylen Triamine	
Penta-Sodium Salt	0-0.01%
Boric Acid	0-0.01%
Glycerin	0-Trace
<u>Additional Components of Specialty Boards</u>	
Waste Resistant Panels	
Wax, Paraffin	0-2%
Type X Firecode and ULTRACODE™ Vermiculite	0-7%
Foil Backed Aluminum Foil	0-1%
Vinyl Covered Panels	
Polyvinyl Chloride	0-10%

59. "Treatment and Disposal of Gypsum Board Waste. Industry Position Paper", Construction Dimensions, February 1992, pages 5-6, 29-30

A general overview of landfill limitations and recycling alternatives is given. The gypsum industry supports alternatives for recovery and is working on methods to recover scrap wallboard back into new wallboard.

60. "Treatment and Disposal of Gypsum Board Waste. Technical Paper. Part II", Construction Dimensions, March 1992, pages 58-63

This is a continuation of the article in the February 1992 issue. This article focuses almost exclusively on the conditions under which hydrogen sulfide gas can be formed. Hydrogen sulfide is a toxic and explosive gas, produced in nature by the anaerobic decomposition of sulfur compounds by bacteria. To be created, the following conditions must all be satisfied:

1. There must be liquid water present.
2. There must be organic material available to provide the carbon necessary for the bacteria.
3. There must be sulfates available.
4. There must be an absence of oxygen.
5. The sulfate reducing bacteria must be available. These bacteria are present in a wide variety of materials.
6. The pH must be between 5 and 9, with optimal conditions of between 7 and 8. At a pH above 9, soluble iron will precipitate, depriving the bacteria of this needed material.
7. The optimal temperature is between 30 and 38 degrees C, or 54 and 100 degrees F. Bacterial action stops at temperatures below freezing and above 45 degrees C (113 degrees F).

One possible method to eliminate hydrogen sulfide production from the disposal of gypsum is to add lime at a rate of 3-5 pounds per ton of gypsum. This raises the pH above what the bacteria can survive at.

61. Telephone conversation with state of Illinois recycling office, March 31, 1994

They were not aware of any programs recycling drywall in Illinois; I was referred to Steve Clements, who has a C & D recycling program in McHenry County, Illinois.

62. Telephone Conversation with Steven Clements, CornerStone Material Recovery, (815)653-1972, April 7, 1994

He does not recycle drywall, but would be interested in doing so if he either had the land to apply it to or if he was able to get farmers in his area that would take it. One potential problem is over regulation by state agencies; North Carolina has an approval process already that requires the material be ground to the point where 70% is less than 100 mesh, the state sets limits to the amount that can be land applied, along with a requirement for a best management practices plan.

63. Telephone conversation with Louisiana-Pacific of Minneapolis, (612)339-4201

Will return call. Based on talks with Rob Walther and survey of local drywall contractors, it has been said that Louisiana-Pacific has a drywall recycling operation in Minneapolis and is interested in setting up a system in this part of Wisconsin.

64. Telephone conversation with Department of Public Works, Kittery, Maine, March 31, 1994

Contrary to what has been published elsewhere, Kittery does not require that drywall be ground up and applied to roadsides. However, what they do limit is the quantity of drywall that can be brought to the city transfer station, with a maximum of 3 cubic yards per week. Most of the contractors thus do not use the city transfer station, and either haul it to the landfill themselves or to the Domtar drywall plant in Portsmouth, NH, (across the river from Kittery) for recycling. Domtar does not currently charge to accept this drywall. For the smaller generators, the city will take the excess quantities of drywall and grind it up, mixing it with loam, city produced compost from leaves or sewage sludge, and street sweepings to produce a material that is used as a soil in city projects. Since the area has a lot of clay soil, the city produced soil helps the structure of the natural soil. The city will take all three types of drywall; they receive little moisture resistant or fire retardant drywall. They will also take drywall from demolition projects; the city believes that there is little leaded paint or asbestos in this material as both substances were banned by the time drywall was being installed. Gold Bond helped the city of Kittery set up this program, providing technical advice.

65. State of Wisconsin Blue Book, 1993-1994, page 616

In 1991, Dane County had 3,020 farms with an average size of 202.3 acres, for a total of 280,000 acres of farmland.

66. Telephone conversation with Wayne Pauly, Dane County Parks Department, April 14, 1994

Wayne was not aware of any roadsides that had salt damaged soil; he suggested I talk to the Highway Department. He also felt that Dane County soils, being both rich and with a lot of limestone, might not be very susceptible to salt damage. He also believes that it may not be a problem because the road salt would tend to be in the soil nearest the road, where the highway department does not want vegetation. He also said that the trees (such as evergreens) that show signs of salt damage (often quite far from the road) are suffering

from direct surface exposure to salt spray, and not from high levels in the soil. He thought that urban areas might have more of a problem, such as terrace areas of lawns on feeder streets.

#### 67. Observation

The grass on the edges of boulevard strips in Milwaukee often look "burned out" in the spring. Is this due to salt from the roads that might benefit from gypsum? What's the situation in Dane County?

#### 68. Telephone conversation with Pat McCann, Caledonia, WI, April 15, 1994

Mr. McCann is involved in the cleanup of construction sites, recycling as much of the material as possible. He does not recover drywall, and, while not aware of any recycling potentials, has heard that others in his area have outlets to recover it.

#### 69. Patent 5,141,109, August 25, 1992

This patent is for a shipping container composed of scrap gypsum drywall, and then filled with scrap drywall, used for shipping the scrap to drywall manufacturers for recycling of the scrap. It was invented by Louis Bergeron, Sr. of Tonowanda, NY.

#### 70. Patent 5,100,063, March 31, 1992

The patent is for a device to separate gypsum drywall into the paper and gypsum by crushing the drywall between two rollers and then screening out the gypsum pieces from the larger pieces of paper. Invented by Fred Bauer of West Fab, Inc. of Salem, Oregon. The telephone operator was unable to find a listing for this firm, but did give me a home number of (503)463-7021, at which I reached an answering machine and left several messages. The Madison Public Library gave me a number for West Fab, Inc., but, when called, the phone had been disconnected. The Salem, Oregon phone book did not have a listing for a Fred Bauer.

#### 71. Patent 5,183,213, February 2, 1993 and 5,238,195, August 24, 1993

These patents use a rotating barrel with loose metal weights to separate gypsum from paper to recycle drywall. The process is said to remove 90 to 95% of the paper, leaving less than 1% paper in the recovered gypsum, which has been found to be adequate for use in making drywall. The latter invention also then incorporates up to 40% recycled gypsum into virgin gypsum for the manufacture of drywall. One of the advantages of using recovered gypsum is that the recovered material contains the additives used in manufacture of drywall, reducing the need to add these materials. Invented by John Knez, Jr. of Knez Building Materials Company, Tigard, Oregon.

#### 72. Patent search, April 20, 1994

The key words searched and the number of patents found were "gypsum" - 433, "wallboard" - 149, "drywall" - 112 and "gypsum and cement" - 25. For the category of gypsum and cement, the patents were focused on lightweight building products, fireproof products, and shaped products, such as molds and models. None of the patents under wallboard or drywall appeared to be of interest. For the listings under gypsum, besides the patents listed above, the following patents may have some interest:

5266210	Process for removing heavy metals from water
5262006	Paper manufacturing process, and papers obtainable by means of that process
5227100	Process for producing gypsum building materials
5223035	Pozzolan blends
5193936	Fixation and stabilization of lead in contaminated soil and solid waste
5183506	Modified flux composition for cement
5177924	Lightweight building component
5171366	Gypsum building product
5135805	Method of manufacturing a water-resistant gypsum composition
5120355	Water-repellent composition
5116671	Gypsum board
5116555	Method of and apparatus for controlling the manufacturing process in the continuous production of gypsum-cemented workpieces
5112499	Process for treating pond water
5100063	Recovery of components of waste plasterboard
5021093	Cement/gypsum composites based cellulose
4927463	Aqueous dispersion of gypsum and its use as a filler and coating pigment in the production of paper and cardboard
4858402	Building board, particularly gypsum plasterboard
4645548	Process for producing non-combustible gypsum board and non-combustible laminated gypsum board
4612173	Method of purifying by-product gypsum
4564544	Fire-resistant gypsum board
4557973	Fire resistant gypsum board containing mineral wool fibers and method
4328178	Process of producing a building product of gypsum, particularly a gypsum slab
4258102	Silicone compositions for treating gypsum board
4238546	Lightweight gypsum products and methods of making same
4142471	Pallet having reinforced gypsum structural members
4048337	Gypsum dust diluents for use in pesticides and fertilizing products

3998596 Apparatus for treating by-product gypsum to be used as an inhibitor for setting of cement  
3855391 Sludge stabilization with gypsum  
3582376 Quick-setting cement composition containing portland cement, alpha gypsum and a dispersant

73. Telephone conversation with John Norwell, Dane County Highway Commissioner, April 22, 1994

Mr. Norwell was unaware of roadside salt damaged soil. He noted that Dane County uses less salt than other areas of the state.

74. Telephone conversation with David Vitale of the New York Department of Environmental Conservation, April 25, 1994

Mr. Vitale was unaware of any gypsum drywall recycling operations in New York; he was also unaware of Gyp-Pack of Tonowanda, NY. I told him that I would send him what I had found.

75. Telephone conversation with John Knez, Jr., Knez Building Materials Company, Tigard, OR, April 25, 1994

Using his invention, his company is currently processing gypsum drywall for reuse/recycling. His company charges \$60 a ton, while landfills are at \$92 a ton. His markets are cement compounders (Mr. Knez says that problem with this market is that they need such a large supply), the gypsum drywall manufacturers (Domtar in his area is using 14% to 25% recovered material) and farmers, especially dairy farmers who use the gypsum chips in with other bedding material for the moisture absorbent qualities (1/3 gypsum, 2/3 paperboard, other materials). Mushroom farmers can also use gypsum from drywall. He also sells his system; cost is about \$150,000; capacity is 45 cubic yards every 20 minutes. [Drywall has a density of about 1,000 pounds per cubic yard. If the infeed is half air, half drywall, the capacity would be equal to about 34 tons per hour.]

76. Telephone conversation with Elaine Cordis (phonetic spelling), Oregon Department of Environmental Quality, May, 1994, (503)229-6046

Will call back; will ask about companies recycling gypsum drywall.

77. Telephone conversation with the purchasing agent of Medusa Cement, Manitowoc, WI, April 26, 1994

Medusa has discontinued manufacturing cement at this plant; there are not manufacturers of cement in Wisconsin.

78. Telephone conversation with the Portland Cement Association, April 27, 1994, (708)966-6200

The closest cement manufacturers to Wisconsin are LaFarge and Medusa in the Upper Peninsula of Michigan and Holman of northeast Minnesota. (Exact locations were not known.) A message was also left for information on what step in the manufacturing process gypsum might be added, whether by the cement producer or by a compounder.

79. Meeting with Ted Belanus, Hallmark Drywall, April 27, 1994

Mr. Belanus has been working on a project to recycle gypsum drywall for the past 6 years, grinding it up, removing the paper and applied it to farm land, including his own farm. He has done extensive work to produce a machine to grind up the drywall and separate out the paper; the biggest problem has been that it's difficult to separate the paper, which both clogs up the field spreaders and creates a messy situation if the paper is on the farm field. He has found the gypsum not only helps his crops, but also loosens up the clay soil. He also said that gypsum would be good for mushroom growers, who each year form a new media of horse manure and gypsum, and that there are mushroom growers near Cambridge, Wisconsin Dells and Fond du Lac. He is interested in assisting the County and the University in field testing the gypsum on agricultural land.

80. "Mushroom Growing". UW-Extension Fact Sheet A2760, February 1976, 6 pages

Mushrooms can be grown in most parts of the US, except in the Deep South, where the high temperatures make it impractical. Most commercial mushrooms are grown inside of buildings near major metropolitan areas, although eastern Pennsylvania is the largest mushroom growing region in the US. Mushrooms are grown in a prepared medium that usually includes gypsum. For example, one recipe for the media adds 30 pounds of gypsum per ton of horse manure; another recipe is for 15 tons of corn cobs, 7 tons of meadow hay, 4 tons of clover or alfalfa hay, 1/2 ton of gypsum, and various other materials.

81. Regional Trends Summary, Dane County, Wisconsin 1993, Dane County Regional Planning Commission, May 1994

On page 1, there a graph shows the number of new housing units built from 1984 through 1993. In 1990 and 1991, a relatively low number of about 2,800 units were built each year, with 1992 data at 3,200 units and 1993 at 3,978 units.

82. The Harris Directory, October 1994

The Harris Directory is a list of recycled building products prepared by The Stafford Architects in Seattle, WA. It lists the following companies and products with recycled gypsum:

Domtar Gypsum  
P.O. Box 543  
Ann Arbor, MI 48106  
(313) 930-4700

Gyproc Wallboard 20% or more post consumer gypsum and 10% post industrial gypsum.

Reclamation Technologies Inc.  
283 North Harold St.  
North Plainfield, NJ 07060  
(908) 769-0600

Gypco - interior and exterior Waterproof textured coating 95% post consumer gypsum wallboard.

Luvit Sprayed or spread applied organic soil supplements. 100% post consumer gypsum.

Thermobloc Roofing - spray applied basecoat with waterproof topcoat

97% post consumer gypsum wallboard.

The Harris Directory also listed several products that are made with gypsum and other products (such as newspaper), where it appears that only the other products are made from recycled material. In some cases, the firm is researching methods to use recycled gypsum; in other cases, it appears to the editor that recycled gypsum might be usable. These products include cellulose insulation, roofing sprays and artificial stone.

83. Keeping C&D Materials Out of Landfills. Conserving Resources and Minimizing Waste in the Construction Industry, A Report by the Ontario Construction and Demolition (C&D) Waste Reduction Strategy Team, Ontario Ministry of Environment and Energy, October 1993, 85 pages

On page 24, a short description of the opportunities to recycle gypsum drywall says that the Ontario Waste Exchange reported that there were at least 15 firms operating waste drywall collection and recycling businesses in the Greater Toronto area in 1991, while currently (1993), there are three major players dominating the drywall recycling market.

84. Toronto Telephone Books, June 1991-June 1992

Only one firm was listed in the Toronto telephone books as a recycler of gypsum drywall -- New West Gypsum Ontario Inc.

85. "Gypsum Remedies Winter Salt Kill of Highway Grasses", Better Roads, June 1975, pages 24-25

Research is underway in two states to determine the best ways to avoid and fix road salt kill of vegetation. One recently completed project was a three year study in Maine to use finely ground gypsum to alleviate the effects of the salt. Gypsum was found to be effective, with the amount of gypsum to apply determined by the level of salt in the soil. The sodium is replaced by the calcium from the gypsum and the sodium sulfate leaches out of the soil. A linear relationship was found for the salt concentration and the amount of gypsum needed; for example, at 920 ppm of sodium, 3.4 tons of gypsum is applied per acre to a depth of 6". Besides this research in Maine, another three year test project is underway in Maryland.

86. "Waste Management for the Construction Manager", 1992 American Association of Cost Engineers Transactions, Hal Johnston and William R. Mincks, pages J5.1 to J5.13

Using a 1976 report, the authors say that demolition waste is about 14% of all waste in the US (25 million tons out of 192 million tons a year), while with the waste from building construction, the total is over 20%. For residential construction, a 1989 report from Toronto (Making a Molehill out of a Mountain), the composition is approximately as follows:

Material	Percentage
Wood	35
Dimensional Lumber	(25)
Manufactured	(10)
Drywall	15
Masonry & Tile	12
Corrugated Cardboard	10
Asphalt	6
Fiberglass	5
Metal	4
Plastic & Foam	4
Other Packaging	4
Other	5

One of the authors did his own study of residential waste composition and similar data, except that the percentage of drywall was double the Toronto data.

For drywall, the "traditional" disposal technique is given as landfilling, while alternative methods include ocean dumping, recycling back into drywall, agricultural use, and kitty litter.

In addition, the generation of drywall waste can be minimized by several methods:

- Order and supply various lengths of drywall according to the dimensions of the project, rather than using only the largest sizes of drywall. For example, instead of just using 12 foot lengths, lengths of 10 or 8 feet can be used to minimize waste.
- Design projects in modular dimensions according to drywall sizes. This is often done already for other building materials, such as masonry.
- With rising landfill and other disposal costs, the cost of using smaller pieces of scrap drywall with the added labor cost of taping the joints must be compared to the cost of disposing of the scrap.

It is believed that the quantity of scrap can be reduced by 50% over current practices.

Necessary elements to develop a waste reduction program are said to include:

- Economic incentives
- Realization of the economic incentives
- Education on techniques for waste reduction in the drywall industry

Revised awareness of gypsum wall waste reduction in apprenticeship and training programs should help utilize waste on the jobsite.

87. "The Relationship of Road Salt Applications to Sodium and Chloride Ion Levels in the Soil Bordering Major Highways", F. E. Hutchinson and B. E. Olson, Highway Research Record, 1967, Paper 193

Road salt increased both the chloride ions and sodium ions along roads which had had salt applied. The ion concentrations were highest nearest the road, but a measurable increase was detectable up to 60 feet from the edge of the road.

88. "Effect of Sodium Chloride on Grasses for Roadside Use", Eliot C. Roberts and Edward L. Zybura, Highway Research Record, 1967, Paper 193

In tests along I-80 in Iowa, salt damage to vegetation was observed up to 10 feet from the highway, with the greatest damage being in heavy soils with little organic material. While salt levels of up to 600 ppm stimulated the growth of grass, injury became evident at 1,000 ppm and increased as levels increased to 5,000 ppm.

89. "Leaching Losses of Sulfur During Winter Months When Applied as Gypsum, Elemental S or Prilled S", R. D Rhue and E. J. Kamprath, Agronomy Journal, Vol 65, July-August 1973, pages 603-605

In the southeastern US, sandy soils are often deficient in sulfur, and applied sulfur is readily leached from the soil. A test was done to determine the rates of sulfur leaching over a winter in both sandy soil and clay soil, comparing sulfur provided in gypsum, finely ground elemental sulfur and as prilled sulfur formed with bentonite.

In the sandy soil, the gypsum provided the highest content of sulfate sulfur in the top later of the soil shortly after it was applied until about 140 days after application. For example, at 40 days, the gypsum soil had about 25 ppm sulfate, while the elemental sulfur soil had about 9 ppm and the prilled sulfur soil had about 5 ppm sulfate, while at 100 days, the levels of sulfate sulfur were 15 ppm, 6 ppm and 4 ppm respectively. After 140 days, the sulfur level of all three forms of material was about equal at about 3 ppm [editor's note: it looks like the sulfur levels returned to the background level]. Studies of the subsoil found that the sulfate sulfur from the gypsum migrated fairly quickly to the subsoil; the elemental sulfur migrated to the subsoil somewhat slower.

In the clay soil, the element sulfur provided the highest level of sulfates (at 160 days, the level was about 22 ppm compared to 12 ppm for gypsum and 9 ppm for prilled sulfur). In the clay soil, the sulfur content remained high for the 220 days of testing.

90. "Economics of Gypsum and Elemental Sulfur as Fertilizers on Subclover-grass Pastures in Northern California", D. M. Center and M. B. Jones, Journal Range Management, 38(3):378-381, May 1983

In California, the rangelands often have a deficiency of sulfur, and the use of sulfur fertilizers improves the quantity of forage produced, for both legumes such as clover and grasses. This report uses data developed in other studies and calculates the economic benefit of applying sulfur either as elemental sulfur or as gypsum.

Both elemental sulfur and gypsum resulted in increases in the forage production, following a negative exponent function of the form:

$$\text{forage } A * [1 - \exp(-C * \text{amount of sulfur added})].$$

In the first year, both the elemental sulfur and the gypsum produced similar results, with production rapidly increasing up to about 60 kg/ha S, after which the production flattens out quickly. Elemental sulfur produced a higher forage yield a slightly higher production rate in the first year. (For example, for gypsum, the first year production at 400 kg/ha of sulfur was 4,400 kg/ha compared to 4,500 kg/ha for elemental sulfur). However, in the subsequent years, the residual effect of the gypsum was higher than that of the elemental sulfur, and the gypsum had a substantially higher cumulative production over a 3 year period for sulfur applications of excess of about 120 kg/ha. (For example, for gypsum, the discounted 3 year production at 400 kg/ha sulfur was 16,600 kg/ha compared to 14,100 kg/ha for elemental sulfur.)

Optimal quantities of sulfur to apply -- and the type of sulfur to use -- depend further on the quantity of winter forage desired. The growth of winter forage was benefited more by elemental sulfur than by gypsum, and there was no observed residual impact.

The optimal schedule for reapplication of sulfur was not determined by this study. However, the authors have an intuitive conclusion that the optimum reapplication schedule for total forage would be greater than 3 years, noting that the low cost of the fertilizer (\$66.15 a ton for gypsum, or \$0.352/kg S and \$119.07/ton for elemental sulfur, or \$0.119/kg S) as compared to the cost of applying the fertilizer (\$4.00 per acre or \$9.88/ha). However, if winter forage is critical, reapplication should be annual, since there is no residual effect for winter forage. It is recommended that application rates be established in either situation using tissue analysis of the subclover.

91. "Use of Gypsum on Soils: A Review", I. Shainberg, et. al., in Advances in Soil Science, Vol. 9, B. A. Stewart, ed., 1989, pages 1 - 111

The main purposes of this report are to both document the wide ranges of uses of gypsum for agronomic applications and to describe uses and effects under active research and/or needing research.

Several of the agronomic uses of gypsum are well known, including reclamation of sodic soils, or as a nutrient source for Ca (for peanuts, potatoes, apples, and avocados) or S, while "... current research is suggesting a much more widespread potential for use on dispersive and/or highly acid soils. On crusting soils, particularly in semiarid or marginal rainfall areas, gypsum may significantly increase water availability, emergence, or both, and prove to be at least a short-term solution to a serious limitation in production. On acid soils, the improvements in subsoil fertility with gypsum amendment, and subsequent yield increases, offer a significant new approach to managing these soils, which often show poor or variable yields as the result of restricted rooting. The combination of effects on some soils may improve yields and production efficiency synergistically by allowing more water to infiltrate and encouraging roots to exploit water that is stored in subsoils horizons." Part of the problem of acidic subsoils is the toxicity of aluminum in these subsoil. Gypsum appears to ameliorate this problem by decreasing the level of aluminum. Research is needed in particular on the chemistry of gypsum reactions with acid soil.

92. "Suitability of Ground Gypsum Board as a Source of Agricultural Gypsum for Application to Croplands", Robert C. Dixon, Certified Professional Agronomist, 2719 Sheridan Way, Stockton, CA 95207, 15 pp. ca 1984

This report looks at the suitability of using waste gypsum board from the Domtar Gypsum America Inc. manufacturing plant in Antioch, California as an agricultural gypsum in an area of north-central California. The major concern was the level of boron, although the study also examined heavy metals. Boron is an additive in the manufacture of gypsum drywall. Boron is an essential trace element for plant growth, although too much boron is toxic to plants. In the gypsum sampled, the quantity of boron ranged from 92 to 156 ppm, with an average of 120.4 ppm or 0.241 pounds of boron per ton of gypsum. Gypsum applications in the geographical area of study are typically 1 to 4 tons per acre, although application rates can be as high as 6 to 8 tons per acre where saline/alkali soil conditions are severe. Limits for boron in soils as analyzed by the University of California Agricultural Extension Laboratories as:

Below 0.5 ppm	Satisfactory for all crops
1 ppm	Sensitive crops may show visible injury
5 ppm	Semi-tolerant crops may show visible injury
10 ppm	Tolerant crops may show visible injury

Besides the application rate, the amount of leaching must also be considered. It is noted that irrigation water of up to 0.75 ppm of boron can be applied to the soil year after year without causing toxicity problems for any crops.

The conclusion was, for most croplands, the amount of boron in the gypsum was low enough to not cause a boron-toxicity problem, although for land irrigated with high boron water, the amount of gypsum applied could be limited by the boron content. Heavy metals were also not a problem.

93. "Construction Site Recycling. A Guide for Architects, Builders and Developers", Metro, Portland, OR, January 1993, 32 pages (brochure)

There are three companies in the Portland area listed as recycling scrap drywall, with the fee they charge to accept scrap drywall:

Gypsum Wallboard Recycling  
11120 SW Industrial Way, Bldg. 9  
Tualatin, OR 97062  
(503)691-9765  
All drywall-related waste, both old and new. \$45/ton

Knez Building Materials  
12301 SE Highway 212  
Clackamas, OR 97015  
(503)655-1991  
New scrap and used scrap installed after 1979. For fee, call.

United Pacific Recycling  
1000 SE Frontage Road

North Plains, OR 97223

(503)647-5840

New scrap. \$30/ton

94. "Gypsum Prices Have Gone Through the Roof", Engineering News-Record, August 15, 1994, page 79

According to a chart of gypsum prices since the 2nd quarter of 1992, in the second quarter of 1994, gypsum prices went up 12%. Since the 2nd quarter of 1992, gypsum prices went up 7 times for a total of (uncompounded) 34%; prices went down twice for a total of 1\_%.

Prices for gypsum drywall (per msf [thousand square feet]) are listed as:

Prices as of August 15, 1994

Size	Kansas City	Los Angeles	Minneapolis	New Orleans	New York
1/2"	\$146.00	\$135.00	\$170.00	\$100.00	\$165.00
5/8"	\$177.00	\$160.00	-	\$120.00	\$170.00

An average price for 20 cities is \$140.57 for 1/2" and \$159.72 for 5/8" gypsum, increases of 9.6% and 5.1% over corresponding prices a year earlier. The data are from the US Bureau of Labor Statistics.

94a. "Gypsum Prices are up 27% Over a Year Ago", Engineering News-Record, November 21, 1994, page 131

Gypsum drywall prices went up in the 3rd quarter of 1994 by about 5%; some prices are:

Prices as of November 21, 1994

Size	Kansas City	Los Angeles	Minneapolis	New Orleans	New York
1/2"	\$156.00	\$138.00	\$180.00	\$100.00	\$165.00
5/8"	\$187.00	\$159.00	-	\$120.00	\$170.00

An average price for 20 cities is \$149.68 for 1/2" and \$167.42 for 5/8" drywall.

94b. "Another Huge Hike for Runaway Gypsum Prices", Engineering News-Record, August 21, 1995, page 77

In their graph, ENR shows prices increases for gypsum in each of the last 9 reporting periods. In 1995, there was a 1st quarter increase of about 3% and a 2nd quarter increase of about 5%. However, the 20 city average is less than what was reported in February, at \$149.92 for 1/2" and \$166.42 for 5/8".

94c. "Construction Economics", Engineering News-Record, August 19, 1996

Gypsum drywall prices are reported as follows:

Prices as of August 19, 1996

Size	Kansas City	Los Angeles	Minneapolis	New Orleans	New York
1/2"	\$184.00	\$130.95	\$195.00	\$100.00	\$146.00
5/8"	\$215.00	\$150.86	-	\$120.00	\$170.00

94d. "Construction Economics", Engineering News-Record, December 15, 1997

Gypsum drywall prices are reported as follows:

Prices as of December 15, 1997

Size	Kansas City	Los Angeles	Minneapolis	New Orleans	New York
1/2"	\$227.92	\$158.00	\$220.00	\$100.00	\$160.00
5/8"	\$290.60	\$162.49	-	\$120.00	-

The 20-city average was \$167.80 for 1/2" drywall and \$173.73 for 5/8" drywall.

94e. "Construction Economics", Engineering News-Record, December 18, 1998

Gypsum drywall prices are reported as follows:

Prices as of December 18, 1998

Size	Kansas City	Los Angeles	Minneapolis	New Orleans	New York
1/2"	\$230.00	\$158.00	\$220.00	\$100.00	\$163.00
5/8"	\$260.00	\$165.25	-	\$120.00	-

The 20-city average was \$165.60 for 1/2" drywall and \$170.12 for 5/8" drywall.

94f. "Construction Economics", Engineering News-Record, September 20, 1999

Gypsum drywall prices are reported as follows:

Prices as of September 20, 1999

Size	Kansas City	Los Angeles	Minneapolis	New Orleans	New York
1/2"	\$306.00	\$180.00	\$310.00	\$184.00	\$320.00
5/8"	\$260.00	\$175.00	-	\$203.20	-

The 20-city average was \$231.98 for 1/2" drywall and \$195.42 for 5/8" drywall, increases of 36.0% and 14.6% respectively, from a year earlier.

94g. "Construction Economics", Engineering News-Record, November 20, 2000

Gypsum drywall prices are reported as follows:

Prices as of November 20, 2000

Size	Kansas City	Los Angeles	Minneapolis	New Orleans	New York
1/2"	\$240.00	\$205.00	\$250.00	\$188.00	\$152.00
5/8"	\$310.00	\$187.00	-	\$205.50	-

The 20-city average was \$206.22 for 1/2" drywall and \$208.27 for 5/8" drywall, a decrease of 12.8% for the 1/2" drywall and an increase of 5.6% for the 5/8" drywall from a year earlier. A chart of materials prices indexes shows that with 1992 as 100, gypsum prices have gone down from about 200 in February of 2000 to under 175 in November 2000.

94h. "Construction Economics", Engineering News-Record, November 19, 2001

Gypsum drywall prices are reported as follows:

Prices as of November 19, 2001

Size	Kansas City	Los Angeles	Minneapolis	New Orleans	New York
1/2"	\$235.00	\$209.76	\$215.00	\$220.00	\$155.00
5/8"	\$235.00	\$195.58	-	\$219.0	-

The 20-city average was \$199.96 for 1/2" drywall and \$216.31 for 5/8" drywall, a decrease of 3.0% for the 1/2" drywall and an increase of 3.9% for the 5/8" drywall from a year earlier. A chart of materials prices indexes shows that with 1992 as 100, gypsum prices have gone down from about 173 in February of 2001 to 168 in November 2001.

95. Engineering News-Record, August issues, 1975, 1980, 1985, 1990, 1992

The prices for \_" gypsum drywall (per msf) are given as:

Year	Kansas City	Los Angeles	Minneapolis	New Orleans	New York
1975	\$70.00	\$56.00	\$85.00	\$61.00	-
1980	\$119.00	\$116.00	\$140.00	\$114.00	\$125.00
1985	\$157.00	\$114.00	\$165.00	\$140.00	\$232.00
1990	Not given;				
1992	\$111.00	\$115.00	-	\$120.00	\$105.00

96. Madison Public Library Reference Service

The Consumer Price Index for the United States for all items was the following, with a 1982 base:

July 1975	54.0
July 1980	82.6
July 1985	107.7
July 1990	130.6
July 1992	140.6
July 1994	148.4

[Two conclusions: (1) since 1975, the CPI has increased by 175%, while gypsum drywall prices increased between 66% and 141% (ie, less than the CPI); (2) from 1992 to 1994, the CPI increased by 5.7%, while gypsum drywall prices decreased 17% in New Orleans, and increased in the other cities from 17% to 57%, or more than the CPI.]

97. Telephone conversation with Ted Belanus, Hallmark Drywall, Madison, WI, September 20, 1994

Mr. Belanus said that the price of drywall has gone up about 25% in the last two years; with low interest rates, there was a boom in construction and hence the demand for drywall. In previous years, there had not been much of a price increase in drywall, so the price increases in the last two years has been partially compensating for the lack of previous increases. With the recent increase in interest rates, he expects construction to slow down and that drywall prices will either hold or perhaps decline.

98. Message from Colorado Recycling BBS, Kari Anderson, April 26, 1994

In response to a request for information I posted on this BBS, Kari Anderson wrote that she knew of two entities recycling gypsum from scrap drywall.

In Boulder County, CO, the Builders Environmental Recycling Program (Don Evans, (919)767-7060) is organizing a materials recycling facility (MRF) to recycle untreated wood and drywall. The facility wood break these materials into their basic components (wood, fiber, gypsum and paper) and then manufacture products, including gypsum prills.

In California, Recycling Earth Products Inc., (1025 Service Place, Suite 209, Vista, CA 92084, (619)726-7232) apparently converts recovered gypsum into powdered and pellet (prill) form. The powdered gypsum is sold in bulk or bags; 1/16 to 1/8th inch prills are sold in bags. The bagged gypsum is sold to agricultural sources and landscaping businesses in California as a soil amendment. The company claims the prill is ideal for golf courses and orchards because other organic compost and nutrients can be blended in with the gypsum prill.

99. Telephone conversation with Don Evans, Research Econometrics re: Boulder, CO Builders Environmental Recycling Program, (919)676-7060, September 29, 1994

His firm does analyses on the costs and benefits of various projects, including waste recovery projects. For gypsum, he started with a project in Boulder, CO; in doing his research, he learned of Recycling Earth Products. In visiting his facility, he was very impressed and relayed his information on to the NC Office of Waste Reduction (Gary Sutton). The state of North Carolina and Mr. Evans will be working on a gypsum recycling project for the entire state of North Carolina.

100. Telephone conversation with Joe Jaoudi, President, Recycling Earth Products, Vista, CA, (619)726-7232/552-9191, September 22, 1994

Have collected over 40,000 tons, have been processing material for over 2 years. Has also been invited by the State of North Carolina to set up three plants. Developing systems to handle a broad range of construction materials, specialize in California in drywall. They received a "soft loan" of \$500,000 from the State of California and \$170,000 from the County of San Diego. Needs about 10,000 to 12,000 tons of drywall a year to have a successful operation. Uses mobile equipment, would aggregate 2,000 tons or so on a site, and then bring in their equipment to process it. In California, the strawberry growers use a lot of gypsum; the strawberry farms are often near the ocean, and the soils have high sodium levels. He said that strawberries (and other crops such as tomatoes, almonds, peanuts and cotton) also need a lot of calcium. He ships materials over 300 miles. Says drywall manufacturers can use up to 30% recycled gypsum in new drywall. In California, the demand for agricultural purposes is so high that they sell all they can produce to farmers. Also starting to make gypsum to sell to golf courses. Won't be a major outlet, but the price will be close to \$200 a ton versus \$27 a ton for agricultural purposes. Says that California will be banning drywall from landfills as more facilities are available to recycle the material.

101. "1993/94 Gypsum Market Profile". Metro Solid Waste Department, Portland, OR, August 1994, 3 pp

The first gypsum recovery business in Oregon began operating in 1992, and recovered about 4,000 tons. In 1993, total recovery was just under 17,000 tons or about 40% of the estimated generation. There are at least five businesses now recycle gypsum drywall scrap in the metropolitan Portland area:

Knez Building Materials receives unpainted scrap at its processing facility which is at the same location at which it sells building materials. It processes the drywall for agricultural purposes.

Gypsum Wallboard Recyclers accepts painted and wet material. Painted material is tested for lead, and, if present, landfilled. Good quality material is sent to New West Gypsum in Fife, WA, where it is processed for reuse by Domtar to make new wallboard.

United Recycling processes clean, unpainted scrap into a prilled soil amendment.

Energy Recovery Inc. is a new facility that processes material from mixed loads as well as source separated drywall.

Tualatin Valley Waste Recovery is a drop site for separated dry materials, and is located adjacent to a limited-purpose landfill.

The facilities all charge a tipping fee, between \$30 and \$60 a ton. The processes used to recycle the material are proprietary, but involve removing the paper and then converting the gypsum into granules or powder, depending on end use.

Virgin gypsum for agricultural or manufacturing processes in the Pacific Northwest is mined in either Mexico or the Southwest, and, although the material itself is low cost, transportation costs are increasing. The value of the recovered gypsum is similar to virgin gypsum, although contamination is a concern, especially for toxic materials for gypsum that is destined for agricultural use.

Recovery of gypsum is expected to increase in the Metro area due to increasing awareness and technological developments. The economics are limiting, as the cost to recover gypsum must compete with limited-purpose landfills.

102. Chemical Analysis of Gypsum Drywall, UW-Extension Solid and Plant Analysis Lab

A sample of ground drywall obtained from Ted Belanus of Hallmark Drywall of Madison, WI was tested as a prelude to a possible University test of gypsum drywall as a soil amendment. The sample included both regular and Type-X drywall. One sample was

analyzed on June 1, 1994 and includes the data on first 12 items, (P through Na), a second test was done on June 7, 1994 and includes 13 items (Cd through Se, plus Cu, Zn, Fe and Mn), while a third test done on June 8, 1994 includes N and Cl. The data from the analyses are:

Material	Composition (ppm)
P	<21.7
K	<62.1
Ca	160,360
Mg	8,475
S	133,821
Zn	11.49, 16.63
B	42.45
Mn	44.45, 45.64
Fe	857.9, 941.8
Cu	7.06, 11.62
Al	294.6
Na	<61.2
Cd	3.08
Cr	11.61
Co	9.17
Mo	2.65
Ni	20.10
Li	<2.49
As	<27.9
Pb	15.60
Se	<19.0
N	280.0
Cl	193.5

103. Letter from Dexter Matthews, State of North Carolina Department of Environment, Health and Natural Resources to Bonny Moellenbrock, Orange Recycling Services, Durham, NC regarding an approval to reuse gypsum drywall for soil application, December 13, 1993, 2 pages

Approval is given for the land application of gypsum recovered from scrap drywall. The following conditions are approved for the Orange County, NC area:

- For residential lawns, the application can be up to 50 pounds per 1,000 square feet, or about 1 ton per acre.
- In nursery potting medium, the application rate can be 6 to 8 pounds per cubic yard.
- As a greenhouse fertilizer, superphosphate (0-46-0) can be mixed with the ground wallboard to form 0-46-0-Ca.

In all cases, the drywall must be unpainted material from new construction. The drywall must be ground to a fine particle size, with 70% passing a 100 mesh screen. A Best Management Practices Plan must be developed and approved by the Solid Waste Management Section and distributed to all who will be land applying the material. Finally, an annual report must be submitted to the state indicating how much gypsum wall has been reused and how it was reused.

The State would consider expanding its approval if additional information is submitted on possible other beneficial reuses.

104. Telephone conversation with Bonny Moellenbrock, Orange Recycling Services, Durham, NC (919)688-5660, September 26, 1994

Haven't proceeded on the project to recycle gypsum from drywall for land application; got a grant from a local municipality to test a machine, but the machine didn't work. The State Cooperative Extension Service is preparing a Best Management Practices guide; contact is Craven Hudson, (919)560-0525. NC Office of Waste Reduction is studying possible application to peanut crop.

105. Note from Reuben Damm, member, Council on Recycling and Columbia County, WI Board of Supervisors, and semi-retired farmer, April 13, 1994

Columbia County [which is adjacent to Dane County] has two commercial potato growers, Alsum Produce and Slinger Brothers. Although he did not check them out, he believes that they have considerable acreage. [Most Wisconsin potato farms are much further north; I had asked Mr. Damm about potato growers in Columbia County as possible potential markets for gypsum that are closer.]

106. Telephone call to Craven Hudson, Durham County, NC Cooperative Extension Service, (919)560-0525, September 29, 1994

I called Mr. Hudson to find out if I can get a copy of his Best Management Practices for using gypsum drywall on agricultural land, but learned that it is still under preparation. The NC Extension is also looking at the potential to use gypsum from drywall on construction sites as part of the landscaping.

107. Telephone conversation with Scott Mouw and Gary Sutton, NC Office of Waste Reduction, (919)571-4100, September 27, 1994

North Carolina has looked at the potential to recycle gypsum from drywall for agricultural purposes. Gary Sutton is the person directly working on this study. They did trials on peanuts; peanuts need calcium. The trials went very well and the final report under preparation. Other crops that could use calcium include tomatoes and blueberries. Their office has talked with Recycling Earth Products of California about setting up a gypsum and construction debris recycling system in NC; the company's president will be visiting NC in two weeks to visit urban areas and construction firms to see about setting up a system in NC.

Gary Sutton feels biggest problem will be the stockpiling of the drywall at the construction sites; Recycling Earth Products will eliminate this problem because they do the cleanup at the construction sites and thus do the source separation with no extra effort from the construction workers. Mr. Sutton does not believe that the fiberglass in Type X drywall will be a problem either in the processing of the drywall or in the agricultural application. A tub grinder works well to grind up the drywall, pulverizes the paper to such a fine extent that it disappears in the first rain. The only problems with tub grinders have been the slowness of the processing and the dust. In North Carolina, 100,000 tons of gypsum are used annually for the peanut crop; this is equal to the amount of scrap gypsum that is estimated to be generated annually. Gypsum is also used on berry crops and on golf courses, and North Carolina has a lot of golf courses. Thus, there should be strong good demand for gypsum recycled from drywall. Mr. Sutton is also talking with the drywall manufacturers about getting scrap drywall recycled back into new drywall.

108. Telephone conversation with Don Steinmetz, Jr., City of Madison Parks Department, Yahara Hills Golf Course Greens Superintendent, 838-6570, September 29, 1994

Mr. Steinmetz said that they do not use gypsum on their golf course, and he is not aware of any golf courses in Wisconsin that do use gypsum. He has heard the use of gypsum discussed at conferences, but didn't think that it offered any advantages in Wisconsin; our soils don't need the benefits that gypsum would provide (he thought the major use would be for the calcium).

109. Characterization of Construction Site Waste. Final Report, Mark McGregor, et. al., report to Metro, Portland, OR, July 30, 1993, 29 pages (also see reference 9)

Waste characterizations studies were done at several construction sites. For 34 single family homes, the total waste generation was found to be from 3 to 4.9 pounds per square foot, with gypsum scrap ranging from 17 to 32% on a weight basis. On a square foot basis, drywall amounted to 0.49 to 1.48 pounds per square foot of floor space.

110. Construction Industry Recycling Project. Final Report, Palermi & Associates, report to Metro, Portland, OR, July 30, 1993, 48 pages (also see reference 9)

Waste audits were done on the construction of three homes. Drywall was between 12 and 28% of the total waste on a weight basis, and between 0.49 and 1.27 pounds per square foot of floor space.

111. Telephone conversation with Gina Dennis, B A D Drywall Scrap Service, Waunakee, WI, January 4, 1995

Ms. Dennis and her husband have started a drywall scrap removal business to pick up drywall waste from construction sites. They serve south-central Wisconsin. Their business name and address is B A D Drywall Scrap Service, 806 Lexington Drive, Waunakee, WI 53597.

112. "Source Evaluation of Solid Waste in Building Construction", Rafael M. Gavilan and Leonhard E. Bernold, Journal of Construction Management, vol 120, number 3, September 1994, pp 536-552. Also, An Analysis of Construction Solid Wastes, Rafael Miguel Gavilan, M.S. Thesis, North Carolina State University, 1992, 264 pp

Drywalling is identified as a two-step process: hanging the drywall, and finishing (tape, float, skim and sand the joints). Typically, the goal is to minimize the number of joints to minimize the cost of finishing and cracking. However, this does not minimize the amount of waste. Graphing out these costs and adding the individual costs to total costs produces shows the point at which total costs are minimized. Using scenarios of low and high landfill costs, the authors conclude that low disposal costs result in more waste. The graphs differ in the article and the thesis.

113. Recovery, Recycle, and Reuse of Industrial Waste, Kenneth Noll, et. al., Lewis Publishers, 1985, 196 pages

On page 63, it states that gypsum drywall scrap has been reused for soil conditioner, with the assistance of waste exchanges, although the specific waste exchanges that facilitated the exchanged are not listed.

114. "Gypsum", Garn Wallace and Shelly Stiles, National Gardening, March/April 1995, pages 84-87

Gypsum is one of the best sources of calcium for plants, and is both a plant nutrient as well as a "balancing" element that protects against nutrient excess or deficiency, problems of high or low pH, or heavy metal contamination. Calcium is most often deficient in high rainfall, acid soil areas, such as the Pacific Northwest and areas east of the Mississippi River.

Gypsum also provides sulfur, which is essential for nodule formation on the roots of legumes. Sulfur deficiencies are less common than calcium deficiencies, but can occur throughout North America.

Gypsum also helps sodic soils, leaching out the sodium.

Generally, gypsum does not affect soil pH; an exception being soil that is alkaline because of high bicarbonate ions. In this case, the calcium in the gypsum can react with the bicarbonate to form insoluble calcium carbonate, and the pH of the soil can change from 7.5 to 7.8.

Gypsum also reduces the absorption of heavy metals by plants.

Natural mined and finely milled gypsum is available for home gardens at a cost of about \$3 to \$4 a 10 pound bag.

115. Design and Control of Concrete Mixtures, 13th edition, Portland Cement Association, 212 pages, 1988

Gypsum is typically used as a component of cement to retard setting times; tricalcium aluminate reacts with the gypsum and water, to form calcium monosulfate hydrate, liberating a large amount of heat during the first few days of hydration and hardening, contributing slightly to early strength. Diagrams for the manufacture of cement show the gypsum being added in the final manufacturing stage.

[See also reference 17; the use of gypsum in cement manufacture is the largest use of crude gypsum; the gypsum used is generally in sizes of minus 1.5" to plus 3/8".]

116. Telephone conversation with Robert Wessel, The Gypsum Association, 810 1st Street, NE, Suite 510, Washington, DC 20002, (202)289-5440, June 28, 1995

The Gypsum Association has contracted with the US Department of Agriculture at Beltsville, MD for research on the use of gypsum drywall scrap on both sod grass and tomatoes. The gypsum being applied is from a mixture of regular drywall, moisture resistant drywall and fire retardant drywall. Currently, the visual appearance of the grass looks good, but there has been no analyses of the clippings nor of leachings from columns of the drywall. The tomato samples are specifically included to determine if there is a problem with boron. These tests are behind schedule due to some greenhouse problems. A report should be available on this project by early fall of 1995.

117. "Clean Washington Center Sees Potential for Northwest C&D Markets", Recycling Times, June 27, 1995, page 13

According to a study done by GBB and two local consultants for the Clean Washington Center, there is already an annual recovery of 55,000 to 60,000 tons of scrap gypsum drywall back into new drywall from a waste generation of 70,000 to 90,000 tons. Additional material could be recovered if new technology can ease the removal of the paper backing on the wallboard and if regulations are developed to encourage recycling rather than stockpiling of the scrap drywall.

118. "BFI buys Calif. C&D Recycler", Waste News, page 1+, July 10, 1995; "Recovery Options for Wood and C&D ", BioCycle, July 1995, pages 30-33

BFI recently purchased Conwaste of Bakersfield, CA, a construction and demolition waste recycler. The firm recycles gypsum drywall by removing the paper backing and selling the paper backing for hydroseeding applications and selling the gypsum to the farming market for a soil amendment.

119. Telephone conversation with Myrna Riegel, Adams County, WI solid waste department, (608)339-9178, July 24, 1995

In Adams County, there is a firm that makes manufactured housing; Ms. Riegel is examining methods to divert drywall and wood waste from this firm from the landfill. At the present time, they have not found a method to recover the drywall.

120. Telephone conversation with PCR, Inc., Coon Valley, WI, (608)452-3651, July 24, 1995

PCR, Inc. has built and sold a machine to a local drywall contractor/farmer to grind up the scrap drywall for application to his land. His name is Mike Early at (608)784-5611.

121. "Proposal for Recycling Gypsum Board for Agricultural Uses", Bill Brey, Cycle Farm, Sturgeon Bay, WI, January 30, 1995, submitted to the WI Department of Natural Resources, 20 pages

This proposal is for the testing of gypsum drywall on both alfalfa and corn cropland in Door County, WI, which has sandy soils. The amount of gypsum to be applied will be based on soil tests and crop requirements, with the gypsum to be applied in both 1995 and 1996. Approximately 350 tons of gypsum is expected to be used, ground in a TMR mixer with 4 augers, and spread with a lime spreader designed by Chandler Equipment Company.

122. Telephone conversation with Pete Van Rueden, Clyman, WI, (414)696-3880, (414)791-5820, August 24, 1995

Mr. Rueden has a business in southeastern Wisconsin (primarily Waukesha County) to pick-up and dispose of drywall waste called U Call, We Haul. His firm handles 7-10 tons of drywall waste a day. He has the design for a machine to grind up the drywall scrap; he is looking for markets for the ground up material.

He also said that there is a person in the Reedsburg area who is sell drywall scrap for reuse.

123. Telephone conversation with David Penofsky, Bureau of Solid and Hazardous Waste Management, Wisconsin DNR, (608)267-3540, August 10, 1995

DNR has not yet given a formal approval to Bill Brey of Cycle Farms to apply gypsum from scrap drywall onto farm land. However, they have given him verbal approval to do so as part of his demonstration project (see item 121) on his own land.

124. Construction, Demolition & Landclearing Debris Research & Assessment. Final Report, GBB Solid Waste Management Consultants for The Clean Washington Center, May 1995, 470 pages

For the State of Washington, this report reviews the quantity of various components of construction, demolition, and landclearing (CDL) debris, looks at the current status of recovery, opportunities and barriers for increased recovery, and recommendations for state action.

The 1993 US consumption of gypsum wallboard is given as 20.7 billion square feet, and 17.4 million metric tons. About half of this is 1/2" regular wallboard, with another 25% being Type X wallboard and 10% being 5/8" regular wallboard.

While data on generation are sketchy, the best estimate is that some 70,000 to 80,000 tons of drywall scrap are generated annually in the state, with some 55,000 to 60,000 tons recovered annually, almost all back into new drywall, but also for agricultural uses, including animal bedding and agricultural soil amendment.

The best opportunities for further recovery of drywall include both the existing markets and new products, including its use for crops that need gypsum (such as mushrooms), or as an additive for partition blocks and other non-structural applications.

For its recovery back into drywall, one of the biggest barriers is the quality control issue from the paper backing and other additives. For agricultural products, the major concern is that there are chemicals in the drywall that may be harmful to the environment, including dioxins, fiberglass, lead, foaming agents, dispersants, fungicides, and preservatives. However, Domtar, a manufacturer of drywall, has produced and sold agricultural gypsum from wallboard scrap since 1990, currently marketed under the name of Domtar AG II Agricultural Soil Conditioner. It is recommended that an agricultural-based product task force be set up at the state level to investigate the technical facts surrounding ground gypsum wallboard application.

125. Telephone call to Craven Hudson, Durham County, NC Cooperative Extension Service, (919)560-0525, August 31, 1995

In followup to a phone conversation in September 1994 (see reference 106), the NC Cooperative Extension Service decided not to prepare a Best Management Practices manual for the use of scrap drywall on agricultural land, but instead are preparing a fact sheet, which is currently at the printer, and will be sent to me when available. Montgomery County, NC is working with a private firm (Joe Jaoudi, Recycling Earth Products, Vista, CA), to develop a drywall recycling program.

126. "Use of Gypsum on Soil Where Needed Can Make Agriculture More Sustainable", Arthur Wallace, Communications in Soil Science and Plant Analysis, Volume 25, Numbers 1&2, 1994, pages 109-116

Saying that "... gypsum can be considered to be a farmer's best friend", the author notes that over 30 benefits to the use of gypsum on land have been documented (some of which overlap), and lists the following:

- improves soil structure by flocculating clay
- helps reclaim sodic soils (where the exchangeable sodium percentage (ESP) is too high)
- prevents soil crusting and aids seed emergence
- increases the solute concentration of low-solute irrigation water
- helps to break up compacted soil
- makes slightly wet soils easier to till
- stops water runoff and erosion
- decreases pH of sodic soils
- decreases swelling and cracking of some clays (montmorillonite- type clays with high levels of exchangeable sodium)
- reduces waterlogging of poorly drained soils
- helps to make stable organic material
- makes water-soluble polymer soil conditioners more effective
- makes magnesium non-toxic
- corrects subsoil acidity
- increase waste-use efficiency of crops
- creates favorable soil buffered solute concentration (EC)
- makes in possible to use irrigation water with a high sodium adsorption ration (SAR)
- decreases dust erosion
- helps plants absorb plant nutrients
- decrease heavy-metal toxicity
- increases the value of organics in the soil

- improves fruit quality, prevents some plant diseases
- provides sulfur
- helps prepare soil for no-till management
- decreases bulk density of soil
- decreases the toxic effect of NaCl toxicity
- multiplies the value of other inputs (such as fertilizer)
- can improve (decrease) the pH of the rhizosphere
- keeps clay off tuber and root crops
- decreases loss of fertilizer nitrogen to the atmosphere
- can be a source of oxygen for plants
- helps earthworms to flourish
- can increase crop yields

Gypsum can help soil if any of the following conditions apply:

- pH is over 8.2 (sometimes even if it is less)
- ESP is over 9 (sometimes even if it is over 3) - water puddles on the soil
- soil particles slake or disperse when added to water
- the subsoil pH is less than 5
- there is waterlogging in the soil
- there is a crust on the soil after rain or irrigation
- there is excessive cracking of the soil after rain or irrigation
- the soil contains clay which is dusty when dry
- irrigation water contains substantial amounts of bicarbonate
- intense rain falls on soil that is not acid and where all solutes may be leached from the soil surface
- no-till is used

127. "The Roles of Gypsum (Calcium Sulfate) in Agriculture", Adolph Mehlich, and G. P. Tewari, United States Gypsum, 1974, 158+ pages

Only the table of contents and a few pages were provided. The report has six chapters as follows:

1. Calcium Sulfate in Perspective
2. Certain Aspects of Fertilizer Use in Crop Production
3. Comparative Value of Calcium Sulfate and Lime as Sources of Calcium for Agricultural Crops
4. Calcium Sulfate as a Source of Sulfur
5. Use of Calcium Sulfate in Crop Production
6. Other Important Uses of Calcium Sulfate

In Chapter 5, subheadings include pasture and forage crops; sugar, fiber and oil crops, cereals, vegetables and other crops; forest crops; turf crops; and peanuts.

In Chapter 6, subheadings include soil-conditioning effects of calcium sulfate; use of calcium sulfate to counter the harmful effects of ammonia; and role of calcium sulfate in animal and human nutrition.

Mr. Walker is the Executive Director of the Gypsum Association. He notes that gypsum has value as an agricultural soil amendment and that tests done at Syracuse University found that gypsum applied to corn crops did no harm and probably increased production. He believes that gypsum recycling must be driven by economic considerations and that government mandates and pressure from recyclers.

He goes on to say that the gypsum industry is serious about recycling.

129. "Gypsum Board - An Environmental Pioneer", Gypsumation, in Walls & Ceilings, Robert Wessel, October 1995, pages 1-2

Mr. Wessel is an employee of the Gypsum Association. He notes that gypsum drywall has been manufactured with recycled paper facing since the 1940's, and that currently, increasing amounts of new construction and in-plant drywall are being recycled into new gypsum board and research is underway to find alternative uses for new construction waste.

Among other uses, gypsum is used for agricultural purposes, to settle suspended solids in lakes, as a dietary supplement in foods, to neutralize natural acids in foods, including canned vegetables, to control tartness in wine, and as an additive in flour, white bread, ice cream, cheese and other foods.

130. "A Technique to Recycle Gypsum", C&D Debris Recycling, Byron Harker, Fall 1995, pages 8, 13-15

The author's firm -- New West Gypsum -- has developed a process for scrap gypsum, primarily for remanufacture into drywall. They currently have plants in Vancouver, BC, Seattle, WA and Toronto, ON, and are exploring the development of facilities in New Jersey, California and Florida. One of the keys to the successful reuse of scrap drywall by manufacturers is the removal of the paper from the

scrap. Once the paper is removed, manufacturers can typically use 15% to 20% recycled material, although test runs have been done using recycled material for a third of the feedstock.

As a sidebar, several "ghosts" of gypsum recycling were discussed, including asbestos, lead, mercury and hydrogen sulfide. Asbestos has been used in joint compound, but the quantity is small (under 1%) and the asbestos is encapsulated. Lead was present in paints in the past, but New West Gypsum has not found lead in any of the demolition drywall they've tested. Mercury was used as an anti-fungal product, but its use was discontinued in 1990. The firm has found mercury only in one load of demolition material. Hydrogen sulfide is formed only in the disposal of gypsum in anaerobic conditions; recycling is a solution to its generation.

131. Telephone Conversation with Jean Luce, Adams Co., WI UW-Extension, (608)339-4233, October 24, 1995

Ms. Luce was looking for information on the recycling of gypsum drywall; there is interest in her county in recycling about 20-25 tons of gypsum drywall generated daily by a modular home builder.

132. "Water Quality for Agriculture", FAO Irrigation and Drainage Paper 29, R. S. Ayers, and D. W. Wescot, 1985, pages unknown

Only a portion of this paper was provided to me, including those parts dealing with the use of gypsum. It is an update of a report of the same name and authors published in 1976. Gypsum is called the most commonly used and widely available amendment for both soil and water, being used for the treatment of sodic soils, problems with infiltration due to salinity of the irrigation water ( $EC_w$ ) and problems of infiltration due to sodium adsorption ratio (SAR). Gypsum can either be incorporated into the soil or added to irrigation water.

133. "Recycled Sheet Rock: Revolutionary Solution to Swine Waste Concerns?", David Williams, NC Office of Waste Reduction, Recycling Works (newsletter of the North Carolina Small Business Assistance Center), October 1995; "Gypsum Eliminates Odors from Swine Operations", Recycling Today, January 1996, page 20

The North Carolina Recycling Business Assistance Center is exploring the use of processed scrap drywall to reduce the odors from swine manure. The work is based on the ability of gypsum to chemically react with the ammonia in the manure to form ammonium sulfate, which is odor free. The research is being done under a three phase process of laboratory work, a prototype operation and then an actual farm operation. No timeline was presented in the article.

134. Wisconsin Department of Administration Procurement Guide, December 6, 1995

A private firm makes an industrial absorbent from 100% recycled gypsum drywall. Called Absorbee, the manufacturer is:

10313 Morse Lake Road  
Alto, MI 49302  
(616)891-9110

135. "Use of Ground Sheetrock (Gypsum) as a Soil Amendment", J. P. Zublena, A. R. Rubin and D. A. Crouse, Soil Science Notes, [North Carolina Cooperative Extension], April 1995, 2 pages

Gypsum is used for agricultural purposes as a source of calcium and sulfur. It can also remediate soils high in sodium, reduce soil crusting and treat acidic soils that are high in aluminum and low in calcium.

For use as an agricultural product as a source of calcium or sulfur, it is recommended that fertilizer dealers be contacted to determine the quantity needed and the particle size desired. Typical application rates [in North Carolina] are between 500 to 2000 pounds per acre.

High sodium conditions can cause clay particles to disperse, minimizing aggregate size, and in extreme situations destroy the soil structure completely. Water permeability is reduced because of the loss of large pore spaces in the soil. This can be remediated by adding sufficient calcium to replace the sodium. Gypsum is a preferred source of calcium, since it has no direct effect on the soil pH. Application rates are based on the soils cation exchange capacity and the amount of sodium that needs to be replaced, with rates of a few hundred pounds to two or more tons per acre.

Soil crusting is generally caused by highly dispersible clay particles that remain suspended in water for a considerable amount of time, and then seal the soil when they settle. This can prevent rapid water infiltration and promote water runoff, as well as preventing plant emergence. Gypsum applied at a rate of 500 to 2000 pounds per acre after seed bed preparation has been shown to be effective in preventing soil dispersion and surface sealing. Because the gypsum will dissolve and penetrate the soil, additional applications may be necessary whenever freshly prepared soil is exposed to rain. To be effective, the gypsum should be less than 1/16 inch in size.

Acid subsoils can often have high amounts of aluminum and low amounts of calcium. Because the aluminum is toxic to plants, this condition forms a barrier to root penetration. Lime can both raise the pH and provide calcium, but excess lime can change the pH to the point where other soil nutrients are no longer available to plants. Gypsum, however, can be used to add more calcium to the soil, but without affecting soil pH.

Although gypsum is a valuable agricultural product, the authors also note that drywall contains other substances, and the composition of the drywall must be taken into account.

136. "Browning-Ferris Acquires Most of ConWaste", C&D Debris Recycling, Fall 1995, page 3

BFI has purchased ConWaste of Bakersfield, CA, which specializes in recycling construction waste, including the recovery of gypsum from wallboard. The gypsum is recycled for agricultural purposes.

137. Usage Application of a Machine for Recycling Gypsum Plaster Board, patent 5,433,388, issued July 18, 1995; IBM Patent Website, <http://www.patents.ibm.com>

This patent is a German (Gebrüder Lödige Maschinenbaugesellschaft mit, beschränkter Haftung) application of a previously developed machine for use in the recycling of gypsum for use in manufacturing new drywall.

In the current state-of-the-art in recycling manufacturing waste back into drywall, two main processes were used -- coarse pulverization which was fed into the calcination process and coarse pulverization followed by introduction into a mill with natural gypsum. Neither process has worked very well, because of problems associated with the paper backing on the drywall, and subsequent problems during the calcination process.

In the new process, the coarsely-ground scrap drywall is fed into a continuous-operation machine known as a wetting-mixer, which rapidly processes the material (dwell times of 15 to 150 seconds), producing a product of uniform size, with the paper ground up to the point that it no longer causes problems with calcination.

138. "Clean Gypsum Wallboard Recycling with Agronomic Application to Potato Growing in the Central Sands Region", proposal made to the UW Solid Waste Recovery Research Program, Kathleen Daniels, Adams County, WI, 20 pages, December 18, 1995

This is a joint proposal of the Modular Housing Industry and the Potato Growers of the Central Sands Region of Wisconsin to test the use of gypsum drywall from the manufacture of modular housing for application to potato fields.

Virgin gypsum has been used for agricultural purposes since the mid-1700's, and by local growers for the last 15 years, who apply an average of 500 to 1,200 pounds of gypsum per acre. For potatoes, gypsum promotes stronger cells, more uniform potatoes, decrease "internal brown spotting", and increases storage.

Three levels of treatment will be tested, including a control, 1,000 pounds of drywall per acre, and 4,000 pounds of drywall per acre. The research is to be done on the Wallendal farms in Adams County, WI.

The research is to go until December 1996.

139. Telephone conversation with Bill Brey, BCF, Sturgeon Bay, WI, January 9, 1996

Mr. Brey has been testing the using of gypsum drywall scrap on his farm, including both alfalfa and corn. The results have been very positive and very obvious on the alfalfa, less obvious on corn. He is using a tub grinder to process the scrap to a size of under 1/8". He leaves the paper in the mixture; it helps in the application. His two biggest problems are getting more drywall to process, and in the spreading of the gypsum, for which a more accurate and higher volume machine is needed. He is working with a firm develop a better spreader, which he feels is 6 months away.

Mr. Brey uses a spreading rate of 1 ton of gypsum per acre. He is applying the gypsum for the sulfur, and this rate provides 17 pounds of sulfur per acre. Alfalfa and corn need about 25 pounds of sulfur per acre, and the soil provides about 8 pounds.

Mr. Brey said that farmers have traditionally gotten the sulfur they needed from purchased fertilizer as a filler and from acid deposition. However, beginning in about 1981, the fertilizer manufacturers stopped including sulfur in most fertilizers and acid deposition has decreased due to pollution controls. Some farmers are now buying elemental sulfur, but it doesn't work as rapidly as gypsum, instead having a year's delay in effectiveness.

140. "Wallboard on the Reuse Path", BioCycle, January 1996, page 46

New West Gypsum near Tacoma, WA is now recycling about 75 tons of gypsum drywall a day, charging \$50-\$55 a ton, which is \$20 a ton less than local landfills. Their process crushes the drywall, removes most of the paper and then the material is sold to Domtar to manufacture new drywall with between 12 and 15% recycled content.

141. Telephone Conversation with Scott Karcher, K & K Drywall/Wisconsin Reductions, Inc., 320 Sunny Avenue, Delavan, WI 53115, January 23, 1996

Mr. Karcher's business is processing scrap drywall which is then recycled by National Gypsum.

142. Meeting with Peter Wallendal, et. al., January 22, 1996

Mr. Wallendal is a potato farmer in central Wisconsin. He found, by accident, that using extra gypsum on his fields reduced the occurrence of brown spots and extended the storage life of potatoes. He currently uses about 5 times what other farmers use, about 1200-1500 pounds per acre. The gypsum is broadcast and then plowed over to form hills. Mr. Wallendal also will only buy seed potatoes from sources that either have naturally high levels of calcium or who add calcium. (See reference 138)

143. "Dayton Farmers Says [sic] Gypsum Improves Soil and Pigs' Health", Gloria Hafemeister, Wisconsin State Farmer, March 15, 1996, page 1, Section B

Jim Kramer has used gypsum both on his alfalfa fields and in the pig barn with beneficial results. On the alfalfa, it has produced plants with solid, healthy stems. In the barn, gypsum has been applied to the floor, and it has helped reduce scouring in the pigs, and he says that neighbors have used gypsum with success in the cow barns. He believes that the sulfur in gypsum helps the animals, similar to the use of sulfa drugs.

144. According to a flurry of messages on various newsgroups in April 1996, gypsum can be used to 'neutralize' the effects of dog urine on grass. (see rec.gardens)

145. Internet message from Kurt Vogel (tokyovogel@twics.com), April 15, 1996

Mr. Vogel's firm is researching ways to recycle gypsum; in a previous owned manufacturing plant, the plant waste was recycled into new product, along with using a lot of FGD and other chemical gypsum. Central Research Laboratory is researching the use of recycled gypsum to make new board, but is having a problem with too much paper. His firm is interested in hearing more about equipment and processes to use scrap to make new board.

146. According to a number of messages on Internet newsgroups in April 1996, gypsum is one ingredient used in making beer. Various recipes were provided in the rec.crafts.brewing newsgroup.

147. In an Internet newsgroup message from Oklahoma, there was a short description of the use of gypsum as a lawn fertilizer. Soil tests done at Oklahoma State University include recommendations on the application of gypsum based on the soil analysis. (see rec.gardens).

148. Email messages from Damion Babler, May 14, 1996 (Damion@caelab1.cae.wisc.edu); September 23, 1996

Mr. Babler wrote a paper on the use of gypsum for agricultural purposes in early 1996. He says that his father uses gypsum on his farm outside of Belleville (288 Primrose Center Road, Belleville, WI 53508). As part of the bedding for cows, it keeps the area drier and they have fewer mastitis cases.

149. Email message from Brent Walston (bonsai@pacific.pacific.net), May 19, 1996

Mr. Walston made a saturated solution of gypsum and distilled water and found that it had a pH of 6.4, or slightly acidic. He says that this is in accordance with what he had learned in basic chemistry -- a salt of a weak base is an acid. He says that gypsum can be viewed as a salt of calcium hydroxide and sulfuric acid (and that's it's actually more complicated than this, but holds for the purpose of argument), and calcium hydroxide is a weak base, while sulfuric acid is a strong acid.

150. "The Use of Crushed, Recycled, Construction Drywall as Animal Bedding and as an Animal Feed Additive", proposal to the UW Solid Waste Recovery Research Program by Gary Splitter, UW-Madison, Spring 1996, 14 pages

Based on anecdotal information from farmers on the benefits of gypsum (see reference 143), this study will test the use of gypsum for four purposes:

1. Scours (a life-threatening diarrheal disease in newborn pigs and calves) in pigs bedded in recycled drywall.
2. Somatic cell counts and teat swab bacterial counts from dairy cows bedded with recycled drywall.
3. Fly counts in barns with drywall used as animal bedding.
4. Feed conversion ratios when feeder pigs are fed drywall supplements.

The proposal notes that virgin gypsum is already used for several of these purposes; for example, Domtar and Prince Agriproducts are two companies that sell gypsum animal feed supplements, and a local retailer sells gypsum animal feed for a price of approximately \$7 per 50 pound bag, adding it at a rate of 100 to 250 pounds per ton of animal feed.

The research will be conducted through June 1997, with the results available in shortly thereafter.

151. Internet message on mushroom compost in rec.gardens, June 1996

The writer says that she uses mushroom compost 'all the time'; it includes aged cow manure, compost and other materials. She buys it for \$1.99 a bag, and says it's great for improving the soil texture.

152. Internet messages August 1996.

In the sci.chem.coatings newsgroup, Dan Borse of Chemica Technologies, Inc. (dbrose@cehmica.com) wrote that he is interested in making joint compound out of recycled drywall, and asked if this was currently being done.

Paul Palmer of Sonoma County, CA (paulp@sonic.net) wrote back that he wasn't aware of this use, but that recycled gypsum from wallboard was widely used as a fertilizer, and that a friend of his uses recycled gypsum wallboard on his organic winery and could not otherwise gets the results he does.

153. Email messages with Annamarie Velic, RMT Inc. (annamari@rmtaam.rmtinc.com), August and September, 1996

RMT is a consulting firm and is researching methods of recycling gypsum drywall for the use in remanufacturing drywall board for one of their clients.

154. Email message with Allen Williams (Allen-Williams@msn.com), September 11, 1996

Mr. Williams was an employee of National Gyp Chipper, manufacturer of gypsum grinding equipment, until the firm went out of business. He then acquired the rights to the manufacture the machines, including the patents. He now markets the machine under the name of Multi Chipper. This equipment was installed in a facility in California designed to handle 100 tons of scrap a day, but didn't succeed, as the system could not keep up with the grinding equipment. He is now located in Texas, and hopes to market the machine again, and will send me information on the equipment.

155. "Gypsum Paper Separation", product description from C&D Debris Recycling, Spring 1996, page 21; literature and video from J.C. Steel & Sons, PO Box 1834, Statesville, NC 28687, (704)872-3681, October 15, 1996

A system to separate paper from gypsum is described, with capacities in excess of 30 tons per hour. The system consists of three basic components -- a chopper feeder that reduces the drywall to -5" pieces, a disintegrator roll crusher, and a screen. In a test of the system, it was reported that 85% of the input wallboard was recovered as gypsum, with a purity of over 99%.

156. "German Wallboard Line Should Open in Mid-1996", C&D Debris Recycling, Spring 1996, page 3

Rigips GmbH of Düsseldorf, Germany, plans to open a drywall manufacturing plant just outside of Berlin that will include the use of about 13 metric tons per hour of scrap plasterboard. Ground plasterboard will be mixed with DSG in cage mills, deagglomerated, and dried at about 50 metric tons per hour in preparation for the wallboard process.

157. "Maxigrind Recycles Gypsum Wallboard", Recycling Today, September 1996, page 22

All Seasons Enterprises of Fort Dodge, Iowa, has developed a process for recycling drywall manufacturing scrap, including removal of the paper covering. The firm uses a Maxigrind 425 horizontal rotary grinder from Rexworks Inc., of Milwaukee.

158. "Effects of Gypsums Use in Agriculture", Damion Babler, May 7, 1996, 11 pages (also see reference 148)

Jim Kramer, a farmer in Dayton, WI, has been processing scrap gypsum both for his own use as well as selling it to local farmers. This goal of this paper is to review the effects of gypsum for use as an agricultural product not only for soil amendment, but also for bovine and swine use and to provide recommendations for the use of gypsum in agriculture.

Historically, gypsum has been used as a fertilizer since the Greek and Roman periods, with the first published account of its effect on crop production being written in 1768 by a German clergyman. An article by G. Hayden in 1807 described the fertilizer impacts of gypsum on clover, saifoin, alfalfa (lucerne), other grasses, corn, potatoes, cabbage, cauliflower and bulbous root plants. It further noted that it was also being used to dust vegetables to get rid of pests.

As a soil amendment, three factors are examined in this paper - soil acidity, soil structure and nutrients.

While gypsum is chemically neutral, it does reduce soil acidity by affecting the free aluminum and iron in the soil. This can be an important factor in saline soils, but not generally in Wisconsin soils.

Soil structure is improved by gypsum by reducing the tendency of a soil crust to form as well as increasing penetration in subsoil hardpans.

Gypsum also adds the nutrients of calcium and sulfur to the soil; sulfur deficiency is becoming more prevalent in the US, increasing from occurring in 13 states in 1962 to 48 states in 1991.

Gypsum has also shown beneficial results when used as part of the bedding for dairy cattle and hogs.

In a survey done by the author, the dairy farmers reported that the gypsum helped to absorb liquids, keeping the cows dryer and reducing mastitis along with illness among the younger animals. The two drawbacks were increased dust on the animals that were in the barn for a winter (but which washed off after a rain) and that the gypsum became slimy after being waterlogged, compared to lime, which retains its grittiness.

Hog farmers also reported improved health in their animals, attributed to less bacteria due to gypsum's moisture absorption.

The purchase economics of gypsum was much less than lime, \$37 a ton versus \$50 a ton, but gypsum does require up to about 3 times the storage volume as lime.

In conclusion, the author recommends the use of gypsum both as a soil amendment as well as in animal barns.

159. "Demonstration of Land Application of Crushed Gypsum Wallboard Waste for Alfalfa", Richard Wolkowski, Department of Soil Science, University of Wisconsin-Madison, grant application to the Wisconsin Department of Natural Resources, July 29, 1994, interim reports October 6, 1995 and October 22, 1996

A three year test is being done of the use of gypsum recovered from drywall at four Wisconsin Agricultural Research stations growing alfalfa, along with control plots of no material, and plots with commercial gypsum fertilizer, elemental sulfur fertilizer, potassium sulfate fertilizer, and potassium magnesium sulfate fertilizer.

Chemical analyses were done of the gypsum prior to the application for the grant. The gypsum had agriculturally beneficial amounts of calcium, sulfur and boron, with much lower values of magnesium. Metals content was found to very low, and the cumulative load of 10 metals monitored under EPA 503 rules would not be exceeded in many years of continuous application of material at reasonable levels. The Neutralizing Index was 5.7, indicating little or no liming value.

In 1995, three treatments of gypsum drywall were used:

1. Preplant incorporation, 1 ton/acre
2. Preplant incorporation, 4 tons/acre
3. Preplant incorporation, 16 tons/acre

Each application was made in 1995.

In this first year, there was little effect on crop yields. Soil pH was lowered, especially at higher rates of application (16 tons/acre). This is believed to be due to a "salt effect", and the study will examine whether or not this a long term effect. The amount of calcium and sulfur increased with increasing applications of drywall, but the quantity of magnesium decreased, probably due to leaching of magnesium from the calcium. Boron levels did not change.

A variety of treatments were used for the plots with gypsum from drywall; in 1996, seven different treatments were used:

1. Preplant incorporated (1995), 1 ton/acre
2. Preplant incorporated (1995), 4 tons/acre
3. Preplant incorporated (1995), 16 tons/acre
4. Top dressed, 250 lbs/acre
5. Top dressed, 500 lbs/acre
6. Top dressed, 2,000 lbs/acre
7. Preplant incorporated, 4 tons/acre plus top dressed, 250 lbs/acre

Yields were highest on the plots with the 16 tons/acre preplant treatments, however, the increase was statistically significant only at one of the four research stations. As was found in 1995, soil pH slightly decreased, calcium and sulfur generally increased, while magnesium decreased (to a point of near Mg deficiency at one site for the 16 tons/acre application). Boron levels only changed at one of the four sites. No harmful effects on the soil were seen and the level of other soil nutrients did not change significantly.

The project is to continue for one more year, with the final report due in the fall of 1997.

160. "Use of Waste Gypsum in the Revegetation on Red Mud Deposits: A Greenhouse Study", J. W. C. Wong and G. E. Ho, Waste Management & Research, Volume 11, pages 249-256, 1993

Waste gypsum produced in the manufacture of phosphate fertilizer was tested in the revegetation of red mud produced from the manufacture of bauxite.

Red mud has high alkalinity, salinity and sodicity, as well as low permeability, preventing the growth of most plants. It was found that the addition of 5% or more gypsum reduced the pH, electrical conductivity and sodium and aluminum content of the soil, as well as providing a continuous supply of calcium ions, thus reducing the exchangeable sodium percentage, and was effective in treating the soil to permit revegetation by *Agropyron elongatum* (tall wheat grass) and *Cynodon dactylon* (Bermuda grass).

161. Avfallsreduksjon og Kildesortering i Byggebransjen [Waste Reduction and Source Separation in the Building Industry], Statens Forurensningstilysyn, Oslo, Norway, 1994, 61 pages plus 11 appendices

Waste reduction and source separation recycling were tested on two building projects in Norway -- the Norwegian Institute for Atmospheric Research (Norsk Institutt for Luftforskning, NILU) and the Nursing Technical College in Oppland County (Sykepleierhøyskolen i Oppland, SHO).

The goal of each project was to reduce the amount of waste generated from an estimated normal average of 30 kg/square meter to less than 20 kg/square meter, with recovery at a minimum of 40%. For the NILU project, total generation was 16.7 kg/square meter, of which 44% was recovered, while for the SHO project, 50% was recovered, but the amount produced was 22.2 kg/square meter. Both projects were built by the same construction firm.

As part of this work, the reuse and recycling of gypsum drywall was studied. For the NILU project, gypsum accounted for 16.6% of all waste on a weight basis, or 18.2 metric tons, for a project of 6,540 square meters. However, for the SHO project, gypsum amounted to only 1.0% of the waste, or 0.6 metric tons, with a project size of 2,665 square meters.

At the NILU project, which used an extensive amount of drywall, 246 tons of board were delivered, along with 11 tons of spacers. The waste amounted to 18.2 tons, of which 11 tons were the spacers and only 7.2 tons were from the board, amounting to a waste

generation rate from the installation of drywall at just under 3%. This material was recycled by being returned to the manufacturer, which has for many years reused its own scrap, but for which this was the first time that building scrap was recycled.

The SHO project used far less drywall board, instead using a gypsum bound particle board, known as Nesporex, which is heavier than gypsum board. For the drywall, much of the generated waste could be used in a wall, and only 0.6 tons of waste were generated, which was returned to the manufacturer for recycling. However, in addition, 9.8 tons of the gypsum chipboard waste were generated (13% of the quantity delivered), and this had to be landfilled because there is no way currently to recycle it. The quantity of waste produced with the gypsum chipboard was high because of there needed to be many cuts made for windows and doors.

For both projects, the total cost of handling waste declined due to the waste reduction and recovery program. For the gypsum drywall, the cost to transport it back to the manufacturer (which neither paid nor charged for taking this material) was less than the cost to take it to the landfill.

162. The Effects Of Gypsum and Sewage Sludge on Plant Growth and Nutrition on Alkaline, Saline, Fine-Textured Bauxite Residue, Margit Antje Bucher, MS Thesis, Duke University, 1985, 100 pages

An examination was done on the ability of gypsum and sewage sludge to foster plant growth on bauxite residues produced in the aluminum refining process. These residues are highly alkaline (pH of 10-11), highly sodic, with a toxic level of soluble aluminum, and a lack of nutrients.

Hypotheses studied included:

1. The addition of gypsum and sewage sludge will decrease pH, lower the levels of soluble Al, and increased solubility of Ca and Mg, with higher levels of gypsum producing greater change.
2. Increase nutrient availability in bauxite residue amended with gypsum and sewage sludge will enhance plant growth, increasing the uptake of Ca, Mg and P, while decreasing the uptake of Al.

Gypsum was added at the rates of 40, 50, and 60 tons/hectare, with bauxite to sludge ratios of 1:1 and 1:2.

It was found that the amount of gypsum added did not affect the pH of the soil, although the amount of sludge added did have a measurable impact initially; as time went on, however, all samples had statistically indistinguishable pHs of 8.50-8.76. The gypsum increased the solubility of Na and the availability of magnesium in the high sludge applications.

The gypsum also resulted in increased biomass in both *Agropyron elongatum* (tall wheatgrass) and *Distichilis spiata* var. *stricta* (desert salt grass). For *Agropyron*, the increase appears to be related to the increased Ca availability.

163. Scrap Construction Gypsum Utilization, Ron Korcak, US Department of Agriculture, Final Report to The Gypsum Association, 54 pages, July 31, 1996

This study looked at the utilization of scrap gypsum drywall from new construction as a beneficial soil amendment at the construction site.

Studies were done on application rates of 5 and 10 tons of drywall per acre, to correspond to the amount of drywall that might be available from a typical home construction project. A typical residential building generates an estimated one pound of drywall scrap per square foot of floor space. Thus, a 2,000 square foot home with an eight of an acre usable for the incorporation of drywall scrap would result in an application rate of 8 tons per acre, while a one acre usable lot would have an application rate of 1 ton per acre.

The author notes that gypsum has been used as a soil amendment for over 200 years, and that numerous reviews have been done to outline the beneficial uses of gypsum in agriculture and horticulture. However, a concern with drywall is that there are other additives in drywall besides gypsum, including asphalt-based wax, starch-based glues, organics, boron and other compounds. The asphalt material is in water resistant drywall and no direct research was found on its degradation. The starch-based glues and dispersing agents should be biodegradable. Boron is an essential plant nutrient, with an optimum level of concentration species specific, and toxic in elevated concentrations. However, at levels of 5 to 10 tons per acre of drywall, boron toxicity should not be a problem.

The report reviews research done for drywall as a soil amendment, for moisture control in animal bedding, and as a additive for composting.

In this project, three separate experiments were done, comparing gypsum from drywall with a control and with agricultural gypsum:

1. application to an established turf field
2. soil column leaching
3. vegetable growth on amended soil in pots

Background testing was done of the constituents of drywall as compared to agricultural gypsum. compared to agricultural gypsum, the drywall had lower amounts of boron and strontium, and higher amounts of potassium, magnesium, manganese, aluminum, zinc, copper, iron, barium, cadmium, chromium and arsenic. The levels of the fertilizer nutrients (K, Mg, and P) were so low to be of minimal if any impact on crop nutrient needs, while the remaining trace element concentrations were within the normal concentration

ranges of soils. Tests done on TCLP (toxic concentration leaching procedure) metals and dioxins resulted in values below the detection levels.

For the experiments with the turf field, the three different experiments were duplicated 4 times. Most significant, it was found that the addition of drywall produced a beneficial impact on calcium status in both the plant tissue and the soil without a significant change in soil pH and no indication of trace element problems. However, there was no significant effect on turf grass biomass production.

For the soil leaching columns, the overall result was that the equivalent of 10 tons of drywall per acre produced the same results as agricultural gypsum: enhanced mobility of calcium and sulfate-sulfur from the gypsum and potassium, magnesium and manganese from the soil, without any increased mobility in trace elements that would raise groundwater contamination concerns.

In the tests of vegetable growth on amended soil in pots, 5 replicas were performed. Both tomatoes and broccoli were grown.

For the tomatoes, the control produce earlier ripened fruit, while the gypsum amended pots had larger fruit. The drywall treated soil produced fruit with higher levels of calcium and cadmium than the control or agricultural gypsum treated soil, and higher levels of cobalt as compared to the control soil. Copper levels were higher in both gypsum treatments than in the control, although the drywall produced less of an increase than the agricultural gypsum. It was noted, however, that the differences in cobalt, copper and cadmium were numerically small. The author concludes that the application of the equivalent of 10 tons of drywall or agricultural gypsum to the soil had limited effect on tomato production, with a slight increase in cadmium and cobalt in the fruit, but at levels that should not impose any limitation on the utilization of pulverized wallboard.

For the broccoli, deer damage prevented studies of the broccoli heads, and only leaf data were available.

While leaf material was greatest in the drywall amended soil, the results were not statistically significant.

The author provides three recommendations for the use of scrap drywall as a soil amendment to show beneficial use:

1. Obtain an elemental analysis of the drywall, either from the manufacturer or by establishing a database of information of the various products.
2. Develop a biological 'quick test' to show if gypsum is beneficial in a particular soil.
3. Develop predictions of the beneficial value of gypsum based on Soil Survey soil types.

164. Patent 5,100,063: Recovery of Components of Waste Plasterboard, from IBM Patent Website, <http://www.patents.ibm.com>

This patent was granted to Fred Bauer of West Fab, Inc. of Salem, OR in 1992 to remove the paper from gypsum drywall. A system of rollers crushes the drywall and the paper and gypsum are separated by a vibrating screen.

165. Patent 5,304,276: Method and Apparatus for Reclaiming Gypsum from Waste, from IBM Patent Website, <http://www.patents.ibm.com>

This patent was granted in April 1994 to Bruce MacLeod and Keith Burley of G. P. Research Ltd of Canada to separate the paper from gypsum drywall. A roller and a plate are used, with the plate located at a position from the roller to create a fracturing surface between the gypsum and the paper. The wallboard is compressed as it moves through an aperture, crushing the drywall and thus separating the paper from the gypsum core.

166. Patent 5,413,284: Method of an Apparatus for Treating Plasterboard-Production Scrap, from IBM Patent Website, <http://www.patents.ibm.com>

This is a German patent issued to Babcock BSH Aktiengesellschaft, formerly Buttner-Schilde-Hass and to Gebrüder Lödige Maschinenbaugesellschaft mbH in May 1995 to reduce gypsum wallboard scrap into uniform pieces of material such that it can be re-calcined for manufacturing new wallboard. The wallboard is processed in a cylindrical tube with radial arms (also see item 137 above).

167. Patent 5,593,096: Method and Apparatus for Separating Adhered Paper from Paper Covered Gypsum Board, from IBM Patent Website, <http://www.patents.ibm.com>

This patent was granted in January 1997 to Byron Harker and John McCamley of New West Gypsum of Langley, British Columbia for a machine to separate adhered paper from gypsum drywall by hammermilling the relatively damp gypsum board through holes of a hammermill grate, followed by screening of the material.

168. Patent 5,577,672. Method and Apparatus for Disintegrating Wallboard, from IBM Patent Website, <http://www.patents.ibm.com>

This patent was granted in November 1996 to William Holmes of Continental Tire Recyclers of Geneva, IL. The machine feeds individual sheets of stacked wallboard to a shear, which then cuts off pieces of drywall, which then go into a shredder to be ground into small particles, said to be capable of being recycled.

169. Email message from Sean Kluey, [skluey@passport.ca](mailto:skluey@passport.ca), Ontario Recycler, January 30, 1997

This firm has patented an inexpensive way to process drywall for recycling. More information can be obtained from the General Manager, Paul Kitchen at (705)325-8163.

170. Email message from Recyclewfb.aol.com, March 17, 1997

The writer said several drywall manufacturers take back new, unpainted scrap. According to the writer, the Northeast Resource Recovery Association in Concord, NH would soon have more information available on the potential to recover drywall.

171. Email message from Brian Cole, bmc2@axe.humboldt.edu, March 19, 1997

His company's drywall scrap was being taken for recycling by a worm farm. However, the worm farm recently stopped taking the scrap because they had seen a study done some five years ago that said that drywall has dioxin in it. He was looking for information on the presence of dioxin in drywall scrap.

172. Internet Site <http://www.roskill.co.uk/gypsum.html>, April 17, 1997

A 1994 report, Gypsum - Market Update, Analysis and Outlook, is available from Roskill, a British firm for \$440. It includes production and use data for individual countries and the world. The use of gypsum is divided into the following categories:

- Plaster and Plasterboard
- Cement
- Agricultural Uses
- Soil Conditioning
- Pesticides and Herbicides
- Fertilizers
- Filler and Pigment Uses
- Glassmaking
- Chemicals

173. Internet Site <http://www.reusetech.com/rtssprod.htm>, April 18, 1997

Encore Horticultural Products lists a number of organic products that they market, including GypSyn, a calcium and sulfur supplement made from gypsum, and Buckshot, a gypsum product made from 100% recycled materials, which it says has proved applications for peanuts, Christmas trees, potatoes and turfgrass. The company's name is given as ReUse Technology, Inc., 100 Chastain Center Blvd, Suite 155, Kennesaw, GA 30144, (770)425-7676.

174. Personal conversation with John Andes, Anaholo, HI, May 27, 1997

Mr. Andes is developing a machine to process gypsum drywall at construction sites. Previously, Mr. Andes worked for Gyp-Chipper of Austin Texas. Using liquid as part of the process, it creates no dust. He is currently working with possible investors. Mr. Andes can be reached at PO Box 749, Anaholo, HI 96703.

175. Personal conversation with Ronald Seyferth, Racine Painting & Decorating, 1012 State Street, Racine, WI, (414)635-8344, May 29, 1997

Mr. Seyferth has been in the painting and drywalling business for many years and has invented a small, portable machine to grind up drywall on the job site. Using used parts from lawn aeration equipment, his machine costs around \$2,000 to build; he noted it did create a lot of dust. He said he would invite me down to Racine to see his machine when he has some time.

176. Email message from Jim West, First American Scientific Corporation, June 27, 1997, [mpage@axionet.com](mailto:mpage@axionet.com)

First American Scientific Corporation has developed a process to cheaply recover drywall into dry reusable gypsum. They are interested in joint venture partnerships on this process. More information is available on the Internet at <http://www.fasc.com>.

177. Internet site <http://www.fasc.com>, July 14, 1997

First American Scientific Corporation is the exclusive licensee of a technology to use sound in combination with other processes to produce material as fine as -400 mesh. Called the Micronizer, they have a pilot plant in operation in Bakersfield, CA to produce agricultural fertilizers and soil supplements, and are looking to expand their processing of gypsum and limestone. They are focusing on the California market in the US because of the high amount of irrigation in California and the subsequent salinity problems of the soil. The microfine sized materials that they produce can be delivered through micro-drip injection irrigation systems.

178. "Study of the Potential Groundwater Impacts from Land Spreading Clean Waste Wallboard Through Soil, Vadose Zone, and Groundwater Analysis", proposal to the University of Wisconsin System Solid Waste Recovery Research Program, April 15, 1997, by Robert E. Lee & Associates, Green Bay, WI

The proposers worked with DCF Drywall in experimenting with the use of drywall as a soil amendment. As part of their work, they received a list of parameters that the state Department of Natural Resources wanted characterized, but the proposers could not find any data on the impacts of drywall as a soil amendment on groundwater. This proposal, then, is to develop some data on the impact of gypsum drywall used as a soil amendment on groundwater, with an emphasis on those parameters that are most likely to negatively impact groundwater quality.

(Compiler's note: this project was not funded.)

179. "Tipping Fees Tip Canada's C&D Market", Curt Harler, Recycling Today, June 1997, pages 54, 103-108, 145

Increased landfill fees and a generally healthy economy are leading to increased interest in waste reduction and recycling of C&D debris in Canada. As an example, in Edmonton, the Partners in Clean Construction (PICC) found that the amount of drywall landfilled from new home construction decreased from 78 kg per 100 square meters of floor space to 75 kg/100 m<sup>2</sup>. British Columbia has an active drywall recycling industry due to its landfill ban, although some drywall is also shipped from British Columbia to the neighboring province of Alberta for disposal. The Edmonton, Alberta landfill welcomed the drywall as a means of neutralizing oil patch waste. A group known as Action on Waste is looking at alternatives for recovery.

180. "Construction Waste: An Economic Opportunity", Bobbi Tousey, NRC Connection, page 6, 1997

The North Carolina Recycling Business Assistance Center (RBAC) has contracted with the North Carolina State University Department of Animal and Poultry Waste Management Center to investigate the feasibility of using gypsum as part of a dry bed system in swine houses. Gypsum is known to have the capability to absorb odors and liquids. For more information, contact Bobbi Tousey at the NC RBAC at (919)715-6500.

181. Principles of Gypsum Use as a Soil Amendment, M. E. Sumner, et. al., Agronomy Division, The University of Georgia, publication MP-373, October 1989, 6 pages photocopied from a document

Gypsum is a neutral, slightly soluble (0.2%) crystalline salt that, when ground to fine powder, is used in the manufacture of wallboard, as a cement additive and as a soil amendment. In addition to supplying the essential elements of calcium and sulfur, gypsum can have profound effects on both the physical and chemical properties of certain soils. For example, it has been used as an ameliorant for saline and sodic soils.

Recent research in Georgia and elsewhere has shown that gypsum can have a significant influence in modifying the properties of many highly weathered soils, vis-à-vis (1) surface crusting, (2) subsoil hardpans, and (3) acid subsoils.

Soils which form surface crusts have both poor water penetration, are especially prone to erosion and prevent the emergence of germinating seedlings. Gypsum has been found to be very effective in preventing soil dispersion. Potentially responsive soils can be identified by conducting a dispersion test. A level teaspoon of soil is mixed with 1/2 ounce of distilled or rain water in a test tube and then allowed to stand for 2 hours or more. If the upper liquid remains cloudy, the soil is likely to respond to an application of gypsum. The gypsum should be applied to the surface at a rate of 0.5 to 1.0 tons/acre and not incorporated into the soil.

Subsoil hardpans often restrict the penetration of roots into the subsoil, thereby limiting the amount of water readily available to the crop. Gypsum can improve root penetration. Potentially responsive soils can be determined by digging a pit down to the suspected soil. If a hardpan is detected and root penetration appears impeded, the chances for a response to gypsum would be good. From 2-4 tons/acre gypsum should be applied and incorporated into the top 4-6 inches of soil. It will take 2 years or more for the gypsum to migrate to the hardpan.

Many highly weathered soils have very acid subsoils which contain high levels of soluble aluminum and low levels of soluble calcium. The aluminum is toxic, and the calcium is needed for roots at their points of elongation. Thus, this combination restricts root proliferation in acid sensitive crops. Gypsum can be effective in reducing soluble aluminum while increasing the amount of soluble calcium, without changing soil pH. A chemical test to determine the suitability of soil to gypsum treatment is available on request from the Soil Test and plan Analysis Laboratory at the University of Georgia. As with the treatment for hardpan, from 2-4 tons/acre gypsum should be applied and incorporated into the top 4-6 inches of soil. It will take 2 years or more for the gypsum to migrate to the hardpan.

Potential problems can occur if excessive gypsum is applied to sandy soil, causing a depletion of magnesium (Mg) and potassium (K). For greatest economy Mg and K can be added back to the soil at least 6 months to a year after the application of gypsum to allow the gypsum to move into the subsoil.

It is emphasized that gypsum treatment is not a substitute for lime treatment.

182. "Demonstration of Land Application of Crushed Gypsum Wallboard Waste For Alfalfa", interim progress report of Richard Wolkowski, Department of Soil Science, University of Wisconsin- Madison, to the Waste Reduction and Recycling Grant Program of the Wisconsin Department of Natural Resources and the Dane County Department of Public Works, May 23, 1997, 12 pages (see also item 159)

This report summarizes the results of two years of application of gypsum to alfalfa at four sites in Wisconsin. Gypsum was applied in 1995 prior to the seeding of alfalfa and as a top dressing in 1996 at rates of up to 16 tons/acre for preplant application and 1 ton/acre for top dressing.

No harmful effects were seen at any site for any of the application rates. The highest application of preplant gypsum showed a positive trend for increase yield of alfalfa at three of the four sites, but these results were generally not statistically significant. The stand was not affected. The soil pH slightly decreased, soil Ca and S increase and soil test Mg decreased where gypsum was applied. Increases in forage nutrient concentration were consistent with treatment application.

One more year of research is to be done on this project, with a final report after the 1997 growing season.

183. "Clean' Gypsum Wallboard Recycling with Agronomic Application to Potato Growing in the Central Sands Region", fact sheet by the Solid Waste Recovery Research Program of the University of Wisconsin, Spring 1997, 1 page (see also items 138 and 142)

In this project, finished in March 1997, gypsum scrap from a manufacturer of modular homes was used as a soil amendment on potatoes. It was found that crushed gypsum wallboard can significantly reduce the incidence of internal brown spot and soft rot in the Central Sands Region of Wisconsin. The full report of the research results has not yet been published.

184. "Recent Developments in Agricultural Uses of Gypsum", K. K. Ritchey, et. al., 5th International Conference on FGD and Synthetic Gypsum, May 11-14, 1997, Toronto, Canada, ORTECH Corp., Mississauga, Ontario, 20 pages

Approximately 20 million tons of FGD (flue gas desulfurization) residue are produced annually in the US. These materials are high in calcium sulfate (gypsum) or can be easily converted to calcium sulfate. Currently, about 7% is recovered and the rest is either stored in lagoons or landfilled.

While gypsum does not neutralize soil acidity in the way of, say, limestone, it can produce beneficial effects for plant growth on acidic soil, particularly as toxic aluminum ions are replaced with calcium ions. Gypsum can also reduce erosion, reduce P runoff, and treat soils with high Mg. However, there are other concerns with the use of calcium sulfate, including a possible deficiency of Mg caused by replacement by Ca, excessive S in the plants, decreased P availability, increased levels of Al in ground or surface waters due to leaching from the soil, and contamination from impurities within the gypsum, such as B or heavy metals.

185. "Utilization of Crushed Gypsum Drywall Waste For Potato Production in Wisconsin", grant application by Richard Wolkowski, UW-Madison Department of Soil Science and the Adams County (WI) Rural and Industrial Development Commission to The University of Wisconsin System Solid Waste Research Program, February 1997

Previous research on the use of scrap wallboard on potatoes in the central sands of Wisconsin found that gypsum application improved the quality of the potatoes. This study will expand upon that work and will include additional levels of gypsum wallboard usage to determine any impacts on yield and grade out, and to expand the database of information to respond to potential concerns of the food processors. This project was funded and final results are expected in the spring of 1998. (Also see items 138, 142 and 184 above.)

Gypsum contains both Ca and S, which are essential plant nutrients, although Wisconsin soils are generally not deficient in either element. However, potatoes grown in sandy, acid soils are one possible beneficiary of the calcium.

186. "Mined Gypsum is Up, Sales are Down", Recycling Today, July 1997, page 22

Producers mined 1.46 million metric tons of gypsum in March, 1997, 6% more than in March 1996. Sales of board products were 2.2 billion square feet, 6% more than the previous year, while the output of calcined gypsum was 944,000 tons, 28% less than a year ago. Uncalcined gypsum sales for used in portland cement and agriculture were 454,000 tons, down 3% from a year earlier.

187. "Open and Shut", Waste News, December 2, 1996, page 9; "Deal to Divert Million Tons of Gypsum", Waste News, July 28, 1997, page 20

The United States Gypsum Company has signed a deal with Louisville (Kentucky) Gas and Electric Co. to use the synthetic gypsum from the utility's air pollution control system to make gypsum drywall. When this facility comes on line, over a million tons a year of synthetic gypsum are expected to be used by USG at several plants and diverted from landfills. The wallboard plant is to be built in Bridgeport, Alabama and is expected to be operational in 1999, with production estimated at 700 million square feet a year.

188. Email message from Duane Roskoskey at the Michigan Department of Environment Quality, Roskoskd@state.mi.us, August 4, 1997

Mr. Roskoskey is working on a project to facilitate the recycling of drywall. He will be concentrating on the recycling back into new drywall, but will also be looking at agricultural uses, as a compost additive and other uses.

189. Wisconsin Department of Natural Resources Approval for Landspreading Waste Gypsum Wallboard as Soil Amendment, Len Polczinski, July 17, 1997, 14 pages, (For more information, contact David Sommi Panofsky, (608)267-3540, Panofd@dnr.state.wi.us)

The Wisconsin DNR granted approval to BCF Drywall Recycling of Sturgeon Bay, WI to collect, process and landspread gypsum drywall as a soil amendment. This approval covers clean construction regular drywall only and does not include specialty wallboard products, such as 'greenboard', water-resistant board or fire-resistant board.

BCF Drywall Recycling received a DNR demonstration grant in 1995 to collect and process clean construction and to land apply this material. Approximately 200 tons of material were processed in an 18 month period and a final report was submitted to the DNR in the fall of 1996.

The approval includes the following conditions:

- The approval is a conditional grant of exemption that will expire in 5 years unless extended
- The approval is limited to new and clean construction scrap primarily free of tape, joint compounds, paint, nails, screws and other contaminants and shall be limited to regular drywall.
- The wallboard shall be processed to a maximum particle size of 3/4 inch dry sieved. Dust from the processing of the drywall shall be controlled in accordance with rules of DNR's Air Management program.
- Storage of unprocessed or processed material shall be done in a nuisance-free manner and limited to no more than 1000 tons of material.
- Processed material shall be applied to the soil in accordance with good agricultural practices.
- The processor is to inform any users of the processed material of these conditions and provide printed user guidelines or instructions.
- The processor is to provide the DNR with annual reports each December 1, including amount of material processed, the amount landspread, difficulties encountered and the advantages or benefits of landspreading the material.

190. "Cropland Utilization of Ground Drywall", David A. Munn and James Carr, BioCycle, July 1996, page 57

Ground scrap drywall could be used as a source of agricultural nutrients as well as a soil amendment, with rates of up to 10-25 tons of drywall per acre, or the equivalent of the scrap from 10-25 average new home construction projects. Such applications could be repeated every 10 years or more frequently, especially if lower application rates are used.

A study done at the Ohio State University Agriculture Technical Institute used residential drywall scrap run once through a commercial chipper to soybeans at rates of 14.7 and 29.4 tons per acre. The drywall was tested for trace elements, and only boron raised concerns, with the boron levels at 9.6 pounds per ton of drywall.

Grain yield and test results were not significantly related to application rates, although there was a slight positive trend. The soil exchangeable Ca level was significantly and positively affected by application rates, and a modest reduction in soil penetrometer resistance readings. The boron levels did not appear to cause any damage and the paper backing from the drywall all appeared to have decomposed within 11 months.

191. Telephone conversation and email correspondence with Chuck at Georgia-Pacific Corporation, Antioch, CA, (510)757-2870, cncneese@inreach.com, September 12, 1997

He is investigating the feasibility of recycling scrap drywall at his plant and is looking for a machine to grind up the drywall for recovery.

192. Residential Construction Waste Management. A Builder's Field Guide. How to Save Money and Landfill Space, Peter Yost and Eric Lund, NAHB Research Center, 400 Prince George's Blvd, Upper Marlboro, MD 20774-8731, (301)249-4000, c. 1997, 30 pages

The thrust of this guide is for all types of residential construction debris, but highlights three strategies for the management of gypsum drywall: (1) using pulverized drywall for a soil amendment or as a compost, (2) take-back of the scrap by the wholesaler and manufacturer to use to produce new product, and (3) storage of scrap drywall in empty wall cavities.

Drywall generation in residential construction is estimated at 1.0 to 1.2 pounds per square foot of home space, the second largest component of construction debris by weight (26%) and 11% by volume.

Recycling drywall as a soil amendment is based on research of the US Department of Agriculture funded by the Gypsum Association [see reference 163] which showed that it can have beneficial effects by increasing the available calcium and sulfur, improving soil tilth and root penetration, particularly in clayey soils, and by treating salt problems in sodic soils. Application rates can generally be in the range of 2-8 tons an acre, avoiding the use of Type X or moisture-resistant wallboard. It is estimated that an on-site grinding machine will cost about \$100-\$150 an hour and can process 3-5 tons an hour. A case study of on-site incorporation into the soil of a building site is a Habitat for Humanity project in Americus, Georgia in which 100 cubic yards (15 tons) was recovered at a 20 home project.

Take back programs is said to be perhaps be the most efficient way to handle the recovery of some building products, with the key being a backhaul to eliminate transportation costs.

A third approach is the cutting up and storage of drywall scraps in vacant wall cavities. While not reuse or recovery *per se*, it does temporarily divert the drywall from landfills until the house is torn down in 50 to 100 years. The extra time is estimated at about 2 hours for a 2,000 square foot home, with an estimated diversion of 80-90% of the drywall scrap. The scrap should be toe-nailed into the cavities to prevent rattling, it should not be put into cavities that have insulation, wiring or HVAC. The scrap is not known to provide any insulation, sound proofing or fire resistance.

193. Creating Local Jobs From Environmental Protection. Focus on Recycling and Small Business, T. Paul Robbins, Austin, TX, March 1992, pages 16-17

As an alternative to gypsum wallboard, a product known as Pan Terre was developed in Belgium from recycled organic materials without the use of synthetic chemicals. Manufactured out of equal parts of mixed scrap paper and agricultural waste (such as wheat

straw, rice husks, peanut shells or bagasse), the product is manufactured with air pockets to provide insulation and reduce the transmission of sound. It weighs only 1/3 of sheetrock, but has 4 times the insulation value of wallboard.

Opening a new plant to produce Pan Terre would cost approximately \$3.2 million for equipment, \$0.5 million for operation and maintenance and \$0.8 million for land, employing 40 people and using 4,200 tons of scrap paper a year.

193. "Demonstration of Land Application of Crushed Gypsum Wallboard Waste for Alfalfa". Richard Wolkowski, Department of Soil Science, University of Wisconsin-Madison, interim report October 27, 1997 [also see references 159 and 182]

This is a summary of the third year of results from an experiment on the use of gypsum drywall on alfalfa at four agricultural experimental stations in Wisconsin.

In general, the application of crushed gypsum drywall did not affect yield or stand at any of the four locations at rates of application of up to 16 tons per acre. Soil pH, and levels of soil calcium, magnesium and sulfur were affected as expected. Soil pH was reduced (that is, became more acidic) at the application rate of 16 tons/acre, apparently due to a "salt effect" [drywall is chemically near neutral in pH], Mg was reduced at all locations with a 16 ton/acre application, while the Ca and S content of the soil were increased by the addition of drywall.

A final report expected in May 1998 will both summarize the results of the 3 years' of work and include data on plant tissue analyses.

194. "The Real "Home Improvement" Show", Resource Recycling, January 1997, page 16

Much of the scrap drywall from the renovation projects done on the television series "This Old House" are recycled by Dana Wallboard Supply Co of Tyngsborough, MA, the supplier of the drywall. Dana also has a drop-off container at its facility for others to bring back scrap to be recycled. The drywall is recycled at an unnamed manufacturer in Newington, New Hampshire.

195. Email message from Bob Carpenter, September 24, 1996, carp@primenet.com, phone (520)445-0449

He is working on developing a soil cement called Cast Earth and is looking into the use of gypsum as a stabilizer. I wrote to him in December 1997 for an update.

196. Equipment of Andela Tool & Machine, Inc., on Web page <http://www.recycle.net/recycle/equip/andela>, December 8, 1997

Andela Tool & Machine Inc. makes pulverizing machines for a variety of products, including gypsum drywall. The machine is said to have all weather protection, control dust emissions, separate out contaminants and provide for safety for the workers. A system of magnet removal and trommel screening produces a final product of fine gypsum of 1/8" minus and coarse gypsum of 1/2" minus, along with separation of paper waste and contaminants. Processing capacity is put at 10 tons per hour. The company is located at 493 State Route 28, Richfield Springs, New York 13439, telephone (315)858-0055, fax (315)858-2669, email [andela@recycle.net](mailto:andela@recycle.net).

197. "Richmond Landfill Pollution Prevention Plan", Stuart Somerville and Graeme Bethell, 19th Canadian Waste Management Conference, September 16, 1997, on Web page <http://www.ecowaste.com/p2plan.htm>, December 8, 1997

The Richmond, BC Landfill is a demolition, land clearing and construction waste landfill owned and operated by Ecowaste Industries, Ltd. in the Greater Vancouver, BC area. Gypsum drywall is recycled, with over 1.2 million kilograms (1300 tons) recovered from 1993 through 1996. According to information on other parts of Ecowaste's web pages, the material is transferred to New West Gypsum for recycling. The landfill charges \$20 per cubic yard to handle the material, with a maximum load of 10 cubic yards. Larger loads can be delivered directly to New West Gypsum.

198. Email messages in the archives of GRN on Web page <http://grn.com/grn/mail/archive>, December 9, 1997

A list of firms recycling gypsum from the library of EPA-New England includes the following:

New West Gypsum -- British Columbia; Toronto, Canada and Seattle, WA  
Energy Reclamation, Inc. -- Portland, OR  
Domtar -- Newington, NH  
Jet-A-Way -- Boston, MA  
Ghis Supply -- Saco, ME

199. "Construction & Demolition Recycling Program. Drywall Recycling", California Integrated Waste Management Board, May 28, 1996, 6 pages, on the Web page [http://www.intranet.ciwmb.ca.gov/mrt/cnstdemo/factsht/dwall\\_t5.htm](http://www.intranet.ciwmb.ca.gov/mrt/cnstdemo/factsht/dwall_t5.htm)

This fact sheet is part of a series on C&D materials produced by the California Integrated Waste Management Board. It has three purposes: (1) to help create business opportunities, (2) to save money for those handling gypsum scrap and (3) to help local governments meet their 50% landfill diversion goals.

It is noted that landfilled gypsum can produce toxic hydrogen sulfide gas in certain circumstances, while if incinerated, it can produce toxic sulfur dioxide gas.

The first step in diverting gypsum drywall from landfills is to reduce its generation. Three steps are recommended: (1) constructing standard sized walls and flat ceilings, (2) ordering custom-sized panels for non-standard walls and (3) finding reusable substitutes, such as modular 'demountable partitions'.

Existing markets for drywall scrap include donation (such as to Habitat for Humanity), remanufacture into new drywall, as a soil amendment, and in lightweight concrete.

Remanufacture is limited by the presence of paper, but paper removal processes are moving forward.

Agricultural uses include a wide variety of applications, from general agriculture to mushroom growing to nurseries to golf courses.

Scrap gypsum is also currently being used by one company to make lightweight concrete.

Other existing and potential markets for scrap gypsum include the following:

- Cement production
- Stucco additive
- Sludge drying
- Waster treatment
- Salty soil treatment
- Manure treatment
- Animal bedding
- Flea powder
- Grease absorption
- Athletic field marker

Demolition drywall can be recycled into some non-agricultural uses, but the following types of contamination must be dealt with:

- Nails
- Joint tape
- Joint compound, especially those with asbestos
- Paint, especially lead-based paint

The CIWMB also has an on-line searchable database of markets for C&D materials, including drywall, as part of this Web page.

200. Homepage of GYPROC AS, a Norwegian manufacturer of gypsum drywall. <http://www.gyproc.no/>. December 8, 1997

As part of their goal to promote sustainable development, GYPROC AS has developed environmental management systems in conformance with ISO 14000, as well as using ISO 9000 as a basis for overall management. The firm uses four sources of gypsum in its products (1) mined gypsum, (2) synthetic gypsum from the air pollution control systems of coal burning power plants, (3) internal scrap, and (4) scrap from construction products. Under the firm's goals for improving the environment, it has goals to both reduce the amount of scrap drywall generated at jobsites and to help set up systems for the collection and return of scrap to the factory for recycling. In addition, the homepage notes that scrap drywall can be used to as a sound barrier (presumably within building construction), as a fertilizer and as a soil amendment. However, no details on these uses in Norway are provided.

201. "USG Plans to Open PA. Gypsum Plant", Jim Johnson, Waste News, April 13, 1998, page 2

USG plans to build a \$112 million gypsum drywall plant in Aliquippa, PA, utilizing synthetic gypsum from the sulfur dioxide removal systems of power plants. Currently, this material is being landfilled. Production will be approximately 700 million square feet of drywall a year, the largest of USG's plants. No estimate was available on the quantity of gypsum that will be used a year. The company was attracted to this site because of low cost transportation for both raw materials and the sale of the finished product. The firm will reduce production at higher cost plants elsewhere.

202. "Wallboard Scrap is "Gold" for North Carolina Recycler", Matt Ewadinger, and Kathleen Gray, Recycling Works (newsletter of the NC Recycling Business Assistance Center), Volume 4, Number 1, March 1998, pages 1 and 7; "Wallboard Scrap Moves up the Reuse Ladder", Matt Ewadinger and Kathleen Gray, BioCycle, May 1998, page 53

A firm in Chatham County, NC, Waste Reduction Products Corporation, has developed a successful business by making products from wallboard scrap discarded during construction, with a focus on the manufactured housing industry. Collection of the scrap is facilitated by the installation of a closed compactor box on the construction site, which both can hold twice as much drywall as an open-top container and protects the material from the weather. Because recycling is less expensive than landfilling, generators are saving up to \$1,000 a week, according to Gary Sutton, director of operations of the firm. The drywall is separated into gypsum powder and the paper backing. The powder is then pelletized or made into other products, for use in home gardening, lawn care, golf course maintenance, spill absorbents for industry, animal waste management and cat litter. The firm anticipates expanding into at least three other states, with expansion targeted for 1999. [See references 99 and 107.]

203. "Final Report. Recycling Gypsum Board for Agricultural Purposes", Bill Brey, BCF Drywall Recycling, October 31, 1996

A test was done for recovering gypsum drywall waste for agricultural purposes.

The first part of the project involved collecting the drywall. Initially, the drywall was retrieved from dumpsters that had mixed construction debris, but this proved to be too difficult. Next, a system was tried where the drywall was collected in containers separately from other material, with large signs indicating that it was drywall only. Except for lunch waste material, this resulted in clean drywall scrap.

Processing was initially done with an old farm chopper, but this was labor intensive and generated a considerable amount of dust. It was then moved to a tub grinder, which has worked satisfactorily, and five to six tons an hour can be processed, with the belief that improved efficiencies will allow 10 tons an hour to be processed.

Spreading was first done with a live bottom lime spreader, but bridging and dust made this unacceptable. A system was developed to use a trough with a tapered pan that could be added to the TMR mixer which both grinds and spreads the board.

Although some testing and evaluation was done of the impacts of the gypsum on the soil and plants, it is mostly anecdotal, and not based on hard data. For example, the plants looked better on the soil treated with gypsum. No data were provided on the application rates of gypsum to the fields. Further testing will be done by the engineering consultants to the project. Included in the project folder was the cover letter from the consultants of BCF Drywall Recycling to the Wisconsin Recycling Market Development Board for further studies as part of an early planning grant feasibility study (this study was done, but the information is considered proprietary by the RMDB). (Also see references 121, 123, 139, and 189.)

204 Door County, WI Ordinance 31-97, "Management and Prohibition of the Disposal of Drywall", effective January 1, 1998, 2 pages

Door County has prohibited the landfilling of drywall in their landfill and the placement of drywall at the curb for collection. This ordinance was developed after a drywall recycling facility was constructed in their county. [See references 121 and 123.]

205 Email message from Don Hess, don\_kathy@juno.com, April 10, 1998

Don Hess has been in the drywall contracting business for 15 years and is experimenting with grinding up drywall and for use in animal bedding.

206 Email message from Dan Wehrman, Wisconsin Department of Administration, wehrmd@mail.state.wi.us, February 4, 1998; personal communication from David Moyer, Celotex Corporation, June 5, 1998

Mr. Wehrman works on the procurement of recycled products for the state of Wisconsin. In his research, he has found a wallboard product by Celotex, phone (813)873-4027 that is made with 50% recycled gypsum.

In a faxed note, Mr. Moyer sent information on Celotex's products containing recycled material. This includes gypsum board, which uses 5% recycled post consumer newsprint and from 0 to 50% recovered utility gypsum, for a total recycled content of up to 55%.

207 "What's Happening in Gypsum Recycling", William Turley, C&D Debris Recycling, January/February 1998, pages 8-12

According to the article, gypsum drywall is an enigma, since those recycling it are often closed mouthed about how they handle it. Scrap gypsum is produced both during construction at a rate of about 1 pound per square foot of the structure as well as some 2 million tons per year of off-spec drywall generated at the manufacturing plants. Barriers for recycling include its weight and bulkiness, as well as competition from other sources of gypsum, including Flue Gas Desulfurization (FGD), which produces desulphogypsum (DSG). Gypsum must also be processed dry, as wet gypsum becomes very goeey, and the paper must be removed for most of the products that are to be made of the gypsum. Finally, there is the contamination from demolition projects, including painted wallboard. At best, the gypsum recycling market is at an embryonic stage in most of the country.

The article includes a chart of 10 potential uses for gypsum as compiled by the California Integrated Waste Management Board (see reference 199).

208 "Recycling Gypsum at the Construction Site", William Turley, C&D Debris Recycling, January/February 1998, pages 8-9

The US EPA has funded a program through the National Association of Home Builders to find a system for construction site drywall recycling as well as other materials. The state of Indiana will conduct tests to find a system that can go onto a construction site, crush up the wood, gypsum and perhaps concrete and other materials and then use the materials on-site. Four builders are working on this project in the Indianapolis area, and a report is expected in mid 1998. Four machines were tested, with varying levels of success.

The Gypsum Association Gypsumation newsletter of December 1997 highlights the results of tests for gypsum drywall recycling, with the following conclusions (also see item 163):

- the material should be pulverized to quickly disintegrate into the soil. This means that the pieces should be 1/2" or less in size.
- the pulverized material may be put on the top of the soil or mixed into the soil
- the material should be spread evenly over the entire lot if conditions permit application may be as much as 22 tons per acre
- gypsum board should be used only on lots that have adequate drainage and aeration
- Federal, state and local regulations should be considered

209 "Methods to Recycle Gypsum Wallboard", William Turley, C&D Debris Recycling, January/February 1998, page 10

Several systems are described to process gypsum drywall for recycling, including:

- leave the drywall outside and let it get wet. Drive over it with a front end loader or other equipment to break it up. Run it through a trommel with holes of 7/8" or smaller. The paper will separate and come out of the bottom of the trommel, while the gypsum will break up and pass through the screen. Smaller holes are used in the screen, along with magnets, if metal nails are present and need to be removed.
- use a horizontal rotor grinder with cutter bits to cut the gypsum against a set of stationary shearbars, followed by screening
- combine a specialized grinder with a flexible impaction system to remove the paper facing and then break down the material to product size. Use a magnet to remove metals and screen to desired size.
- use a 25 foot long drum to tumble the drywall to desired size. Process takes about 30 minutes at 7 rpm

210. "Star of a Recycling System", William Turley, C&D Debris Recycling, January/February, 1998, pages 16-19

At the Smink Afvalverwerking B.V. plant in the Netherlands for recycling C&D materials, the gypsum drywall is sent to landfill. Moreover, it is a problem in mixed loads, as it contaminates other materials, including wood and concrete and brick to be used in roadbase.

211 Wisconsin Recycled Products Clearinghouse, December 5, 1995; telephone conversation with Bill Wilson, Phoenix Resources, June 2, 1998

Phoenix Resources, 10313 Morse Lake Road, Alto, MI 49302, phone (616)891-9110 is listed in the Wisconsin Recycled Products Clearing house as making an absorbent product using 100% recycled material, including gypsum drywall.

Mr. Wilson's firm was making an absorbent out of gypsum drywall and other products, but is discontinuing this operation since the economics of recovering the drywall for agricultural uses is more economical. However, he has assisted other firms set up companies to process drywall for use as an industrial absorbent in both Rhode Island and on Long Island.

The gypsum is a better absorbent than a typical clay absorbent, although due to its white color, is not preferred by those facilities that do not clean up all the absorbent after a spill, since it is then very visible when tracked out of the spill area. Processing the drywall costs about \$30-\$35 a ton using his process, which is a modification of existing, off-the-shelf equipment. The paper is not removed in the operation.

Currently, his operation in Michigan provides the drywall to farmers for their use on their fields. There is no processing done -- the clean construction drywall is simply kept separate on the jobsite and delivered to farmers, who either allow it to become wet, or moisten it with liquid manure. The farmers then add the wet and softened drywall to their manure spreaders and spread it over their fields.

In Michigan, most drywall is made from local deposits of gypsum, which has approximately a 20% level of lime in the form of calcium carbonate. Thus, the pH level of the drywall is relatively high and the farmers' major benefit from using drywall scrap is from the liming value. Farmers have been using the gypsum/lime material for over 100 years, when the deposits were first mined in Michigan in the 1800's. Typically, the gypsum/limestone mixture is put on the fields at up to 4 times the rate that lime would be applied.

Mr. Wilson is willing to help others in setting up gypsum recovery operations, either to process the gypsum for absorbent or other products or for farmers to spread on their fields, as he believes that drywall should not be landfilled.

212. Gypsum & Drywall Recycling Category, Recycler's World, <http://www.recycle.net/recycle/Minerals/gypsum/index.html>, December 12, 1997

Under gypsum, this webpage lists specifications for various types of drywall scrap, trade associations, publications, traders and recyclers and recycling and waste processing equipment manufacturers.

213. Gypsum & Drywall Recycling Category, The Recycler's Exchange, Recycler's World, <http://www.recycle.net/recycle/Minerals/gypsum/xv080500.html>, December 12, 1997

The web pages of Recycler's World include a material exchange service. In December 1997, there were two listings of companies wanting gypsum drywall for recycling, one in southeast Pennsylvania, the other in Jakarta, Indonesia.

214. Email from Susan Chana, Director of Government and Regulatory Affairs, Gypsum Association, [schana@gypsum.org](mailto:schana@gypsum.org) or [gypsum@erols.com](mailto:gypsum@erols.com), December 15, 1997

Ms. Chana is interested in information on gypsum drywall recycling. She works for the national trade association of gypsum manufacturers.

215. Telephone conversation with Carol Vincent, All Seasons, PO Box 42, Nevada, IA 50201, (515)382-6020, February 23, 1998

They grind up reject drywall at wallboard manufacturers for recycling by the manufacturer in the Fort Dodge area of Iowa and the Sweetwater area of Texas. They remove some of the paper by screening. They have more material than the manufacturers can use and are looking at other opportunities for recycling the scrap.

216. Email message on GRN Recycle, <http://grn.com/grn/mail/archive/0297.html>, June 5, 1997

In response to a question, Fred Friedman of the Research Library of EPA describes the use of gypsum for some agricultural purposes and in compost.

St. Johns River Power Park in Jacksonville, FL, a utility, is selling gypsum to farmers for use in composting and in animal bedding. It has been particularly selling to peanut farmers and to some extent to watermelon farmers. The gypsum is a by-product of the air pollution control equipment at the utility.

Gypsum from drywall was tested in compost and in direct agricultural application by two graduate students at SUNY.

More information on gypsum use in compost and direct agricultural application can be obtained on the Clean Washington Center web page and their reports, including the report on Construction, Demolition, Landclearing Debris Research Assessment by GBB of Falls Church, VA in 1995.

217. Literature from Andela Tool & Machine, Inc., December 16, 1997, May 21, 1998 and May 28, 1998

Andela has manufactured a system to recycle gypsum drywall. They will be testing the system in early 1998 and will produce a video which will be available for distribution by the summer of 1998.

According to the literature, the Andela system is totally enclosed, measuring 8' wide by 9' 6" high and 40' long. It begins with an infeed conveyor belt, an impact separator, an intermediate conveyor belt and a trommel screen. The system produces a fine gypsum (1/8" minus), a coarse gypsum (1/2" minus) and paper. With one operator, the system can process 10 tons or 20 cubic yards of material an hour.

In tests done at a facility in Columbus, Ohio, they have been able to reduce paper content to less than 5% with a 1/2" screen and 1% with a 1/4" screen. The system is able to handle wet gypsum drywall if it is processed in combination with dry wallboard.

Three contacts on gypsum recycling are:

Ben Gordon  
Good Riddance Inc  
211 Alplaus Avenue  
Alplaus, NY 12008  
(518)399-7583 phone  
(518)399-7584 fax

Has a prototype Andela system and has investigated the markets for drywall recycling.

Doug Van Fossen and Dave Kindle

Agricycle  
1685 Woodland Avenue  
Columbus, Ohio 43219  
(614)257-1941 phone  
(614)257-1916 fax

Have researched agricultural uses of gypsum and will soon take delivery of an Andela system.

Mark Burger  
Burger Consulting Services  
PO Box 354  
Brewerton, NY 13029  
(315)676-5057 phone and fax.

Mr. Burger did his MS thesis on gypsum drywall recycling and is continuing to be involved in this area.

218. "As Acid Rain Disappears, So Does Sulfur in Soils", Paris Reidhead, newspaper article, unknown newspaper, unknown date (provided by Andela Tool & Machine)

The author is a field crops consultant and notes that from the 1930's to 1960's, farmers had been receiving a free source of sulfur from the emissions of coal burning facilities. However, with the removal of sulfur from these emissions to reduce the problems of acid deposition on waterways, farmers in the state of New York now often need to add sulfur.

Besides the direct benefits that sulfur provides to plants, sulfur also provides better availability of selenium and the crops in New York are now showing a deficiency of this micro-nutrient.

Sulfur can be added to the soil in a variety of forms, including calcium sulfate (gypsum).

219. "Benefits Derived From Soil Application of Drywall Wastes", Edwin H. White and Mark E. Burger, Report, No. 1, 1993 2 pages (provided by Andela Tool & Machine)

An estimated 82,000 tons of gypsum drywall waste are generated annually in the state of New York and can be used as a soil amendment to treat clay, sodic (high salt) soil or calcium-poor soils. It will also add sulfur to the soil.

Plants that can benefit from gypsum include:

- Flowers - clematis, lilacs, irises, delphiniums, alyssum stock, candy-tuft, nasturtium, tulips, gladioli, roses, camellias and gardenias
- Landscape plants - evergreens, rhododendrons, mountain laural, pin oak, sweet gum and flowering dogwood
- Vegetables - cabbage, broccoli, cauliflower, radishes, turnips, kale and onions

Gypsum loosens clay soil by aggregating clay particles, treats sodic soils by leaching sodium, reduces nitrogen loss to the atmosphere in compost piles, and can clear muddy water in ponds by aggregating soil particles. [also see references 1d and 54]

220. "Republic Paperboard to Add Capacity", Bruce Geiselman, Waste News, May 25, 1998, page 1

Republic Paperboard Co is developing a 220,000 recycled gypsum-grade paperboard plant in Lawton, Oklahoma, with production scheduled to begin in late 1999. Part of the production will be used at Republic's gypsum plant in Duke, OK, which is doubling in size to 1.2 billion square feet annually.

221. Home page of New West Gypsum, <http://www.nwgypsum.com/>, May 25, 1998

New West Gypsum has processed over one million tons of drywall scrap for recycling, including over 850,000 tons back to wallboard manufacturers. Their system not only removes the paper from the drywall, but is also capable of dealing with a variety of extraneous materials in the input stream, including vinyl, dimension lumber, metal, plastic and cardboard. Although the plants that use their recovered scrap usually use 15-20% recycled material, one wallboard mill has been able to make drywall with nearly 33% recycled content in a test run. The paper is also recovered in the New West Gypsum process.

Prior to their process, the most significant process for handling scrap was the Norba Crushing system.

222. Email message from Mark Sondeen, [mrs9y@virginia.edu](mailto:mrs9y@virginia.edu), June 3, 1998

Mr. Sondeen is working to assist a firm that uses gypsum board as a fire proofing material for safes to develop a market for their production scrap.

223. Internet search for gypsum sites in Germany, January, April and June 1998.

Several sites were found for German companies that make gypsum wallboard and similar products, Sites found include the following:

<http://www.bauinfor.de/4gips.htm> Listed 7 companies in Germany that manufacture gypsum products. Site could no longer be accessed in June 1998.

<http://avagmbh.com/OHA/firmen/steine.htm> Lists stone and earth material industries, including gypsum products ranging from dental apparatus to art gypsum to building materials to ceramic gypsum. For building materials, 5 firms are listed, including several not on the previous list.

<http://www.lafargegips.de> Site for information on Lafarge Gips GmbH, one of the manufacturers of gypsum building products in Germany.

In their downloadable brochure, chapter 3 shows the process of making gypsum drywall, and shows in the flowline where material is recycled, while chapter 4 is on environmental protection and recycling. The company both recycles production scrap, grinding it to less than 30 mm, as well as using synthetic gypsum from air pollution scrubber systems. An email note was sent, asking if the paper must be removed from the wallboard before it is recycled and if they accept clean construction scrap (see reference 231).

<http://www.mack.de> Site of Gipsweke Mack GmbH, a German manufacturer of gypsum building products. Wallboard products can be recycled, and the company will take back scrap from the jobsite, provided that no building waste is mixed in with the wallboard material. The company also works to recycle the packaging material associated with their products and uses environmental friendly packaging.

<http://www.rigips.de/> Home page of Rigips. In one of the press releases, it announces the introduction of several new gypsum wallboard and decking materials and note that they are environmentally friendly and 100% recyclable.

Another press release describes the construction of a demonstration home in later 1996 and early 1997 near Berlin using gypsum wallboard next to a similar home using traditional masonry construction. The house with gypsum wallboard was quicker to construct, at a lower cost, and provides for greater living area. Some goals of the demonstration project is to address questions of the quality, fire proofing, sound proofing, heating needs and wind proofing of the wallboard house and acceptance by the public.

[http://www.csd.de/profil/pm\\_ubp/recygid.htm](http://www.csd.de/profil/pm_ubp/recygid.htm) Tells of the recycling of materials to make gypsum drywall with the use of scrap paper using the Schenck production systems, but does not discuss recycling the scrap drywall.

[http://www.hagebau.de/hagebaumark/tips\\_und\\_tricks/gk\\_platten/](http://www.hagebau.de/hagebaumark/tips_und_tricks/gk_platten/) Has tips and tricks for the do-it-yourselfer in using gypsum drywall and similar products for walls and decks, but does not discuss recycling.

224. Web page of BPB Rigips, <http://www.rigips.de/>, January 1998 and June 1998; email messages from Karin Melder of Rigips, [KMelder@rigips.de](mailto:KMelder@rigips.de), May 26, 1998 and June 5, 1998

Rigips is a German firm that manufactures gypsum products, such as wallboard, both from natural gypsum as well as from synthetic gypsum, such as is produced from air pollution control equipment.

According to Ms. Melder, the firm recycles its production scrap by grinding it into small pieces and re-incorporating it into new gypsum products. The paper is not removed in this recycling process.

They do not take scrap from outside sources, and she is not aware of any uses of gypsum scrap for agricultural uses in Germany.

The homepage also offers some software for the design and use of gypsum wallboard, decking and similar materials, but I could not get it to download onto my computer.

225. "Utilization of Crushed Gypsum Drywall Waste for Potato Production in Wisconsin. Progress Report", Richard Wolkowski, Department of Soil Science, University of Wisconsin-Madison, February 16, 1998 (also see item 185)

A field research study was done at three locations to compare the response of potatoes to calcium fertilization, both from crushed wallboard scrap and commercial gypsum. Sites were located in Antigo silt loam at Antigo, Plainfield sand at Hancock and Vilas sand at Rhinelander.

Four replications were done of a control with no gypsum, and applications of 100, 300 and 500 pounds of Ca per acre using both crushed wallboard scrap and commercial fertilizer. The material was broadcast and disced into the soil. Size distributions are not provided in the report. In addition, all sites had 50 pounds per acre of potassium sulfate added preplant to remove the potential confounding response of sulfur from the gypsum applications.

The potato planted was Snowden in the Antigo and Vilas soils, and Russet Burbank in the Plainfield soil. Standard potato production practices were used.

Measurements included leaflet nutrient concentration and soil test level at flowering, yield and grade of harvested tuber, nutrient concentration of the periderm (peel) of the harvested tubers, incidence of hollow heart, and soft rot susceptibility of the harvested tubers.

For leaflet tissue, the addition of gypsum had little effect, except for sulfur measurements in the Plainfield and Vilas soils and calcium content in the Vilas soil (all measurements increased).

For the soils, the calcium levels increased in the Antigo silt loam and the sulfur increased in the Antigo and Vilas soils. pH was reduced in the Vilas sand, but this was not viewed as acidification, but instead, a replacement of H<sup>+</sup> ions with Ca ions on the cation exchange sites of the clay particles, thus putting more H<sup>+</sup> ions into the soil solution, where the pH is read. No other parameters were affected by the gypsum.

For total yield and grade, no significant differences were detected in any of the treatments. Yields were very good in terms of both total weight and grade.

For the nutrient concentration in the periderm, the impact was moderate, with a slight increase in sulfur at all locations, no changes in calcium in the Plainfield sand, and increased calcium at the other two sites. In the Vilas sand, the level of Mg decreased with increased levels of gypsum.

Hollow heart tests, along with dry matter content, were done on the US1A tubers. The only statistically significant difference was in the Vilas sand, which also had the lowest levels of calcium in the soil tests.

Finally, for soft rot, there was no statistically significant difference in soft rot at any of the sites, although there was a numerical reduction in soft rot in the Vilas sand. There were substantial mechanical problems with the equipment in conducting this test, which led to considerable variability in the readings.

The researcher also concludes that wallboard scrap is at least equivalent in effectiveness with commercial gypsum fertilizer and did not negatively affect crop growth and yield.

226. "Indiana to Try Recycling Plan", David Clancy, Waste News, June 29, 1998, page 24

Ten Indianapolis builders are participating in a pilot project to recover construction and demolition debris, including gypsum drywall. The project, which received \$169,000 in funding from the builders and several agencies, will include grinding up construction drywall for use as a fertilizer. In some cases, the gypsum will be tilled into the soil at the construction site. The project is expected to last six months, with a final report in January, 1999.

Sponsoring agencies include the National Association of Home Builders, the US EPA, and the Indiana Department of Environmental Management, with Carla Barrett as the IDEM contact.

227. "Construction Recycling Getting off the Ground in Northern Michigan", Sharon Leiter, C&D Debris Recycling, November/December 1997, pages 18-21

Construction Waste Recycling is a hauler of waste from the construction industry in Traverse City, Michigan. Waste materials are source separated at the job site, facilitating recycling. Drywall is said to be the largest component of building waste on a weight basis and is recycled by being remanufactured into new drywall by Georgia Pacific at Grand Rapids, MI.

228. "Builder's Waste Recycling", C&D Debris Recycling, November/December 1997, page 19

Builder's Waste Recycling in Traverse City, Michigan is able to recycle about 90% of the construction waste it receives. Drywall is a problem. While some farmers will use it for their soils, most is landfilled.

229. "Recipe for Success Includes Mixing Recycled C&D Products", James McElvenny, C&D Debris Recycling, November/December 1997, pages 22-23

For C&D recycling to be successful, new value-added products must be developed for using the recoverable materials. For drywall, one project in Nevada combined waste gypsum and compost to generate a material for use to prevent soil erosion. The gypsum can act as a cementitious, plaster-like material for ditch lining and embankments, using wood fiber as a strengthening agent. At the same time, seedlings can penetrate the mixture and, although the gypsum has a neutral pH, the mixture is said to be especially advantageous in areas with an acidic pH, such as where pine needles are prevalent.

230. "Beyond Biomass", William Turley, C&D Debris Recycling, November/December 1997, pages 10-11

Weaver Industries, based in Fresno, California, has five facilities processing wood and other materials for recycling. Gypsum drywall is among the materials recycled; it is processed for use as a soil amendment by farmers, and has been very successful and well received.

231. Email message from Svenja Beuermann of Lafarge Gips GmbH, Germany, June 30, 1998, email address [Svenja.Beuermann@LAFARGE-GYPSUM.lafarge.com](mailto:Svenja.Beuermann@LAFARGE-GYPSUM.lafarge.com)

In response to questions sent via email, Ms. Beuermann said that Lafarge does recycle wallboard scrap back into new gypsum. They mainly use plant scrap, but have recycled construction site scrap if collected properly. In their recycling process, they do not need to remove the paper from the drywall. (Also see reference 223.)

232. "The Utilization of Recycled Sheetrock (Refined Gypsum) as a Litter Material for Broiler Houses", C. L. Wyatt and T. N. Goodman, Poultry Science, Volume 71, No. 9, pp 1572-1576, 1992

Day-old broiler fowls were raised on 3 types of litter material: 13 cm fir wood shavings, 13 cm refined gypsum (recycled sheetrock) or 9 cm refined gypsum topped with 4 cm fir shavings. Litter material had no significant influence on chick mortality, feed conversion, condemnations and incidences of leg abnormalities to 41 days of age. Body weight gain was significantly lower for chicks reared on refined gypsum than for the other treatments at 21 days of age, but by day 41 no differences were observed among treatments. Percentage litter moisture was significantly lower for refined gypsum than for the wood shaving treatments at 21 and 41 days, although on a weight basis the gypsum contained the same amount of or more water. Litter material had no influence on room or brooding temp. Although it is quite dusty initially when placed in the house, refined gypsum can be used for bedding, as a base with wood shavings. [Published abstract]

233. "Stachybotrys atra Growth and Toxin Production in Some Building Materials and Fodder under Different Relative Humidities", M. Nikulin, et. al, Appl. Environ. Microbiol., Volume 60, number 9, pp. 3421-3424, September 1994

Growth of *Stachybotrys atra* and its toxin production on some building materials and in animal fodder were studied at relative humidities ranging from 78 to 100%. Toxins were detected by biological assays and chemical methods. Strong growth of the fungus and presence of macrocyclic trichothecenes, mainly satratoxins G and H, were detected on wallpaper and gypsum boards and in hay and straw at saturation conditions. [Published abstract]

234. "Possible Relationship of Succinate Dehydrogenase and Fatty Acid Synthetase Activities to *Aspergillus parasiticus* (NRRL 5139) Growth and Aflatoxin Production", C. L. Reding and M. A. Harrison, Mycopathologia, 127(3):175-81, September 1994

Fatty acid synthetase (FAS) activity measured over time corresponded to aflatoxin B1 biosynthesis by *Aspergillus parasiticus* grown in minimal salts sucrose medium. Succinate dehydrogenase (SDH) activity, our primary metabolism indicator, decreased as FAS activity increased demonstrating that as primary metabolism slows, secondary metabolism and subsequently aflatoxin production begins. Fungal biomass, as measured by chitin, increased up to day 13 then stabilized. Calcium, potassium, magnesium, manganese, zinc, and a combination of these minerals were tested to determine their effect in culture on FAS and SDH activities. Cultures grown in broth supplemented with zinc had greater FAS activity and produced more aflatoxin B1 when compared to the unsupplemented control. To determine if enzyme activity in a complex substrate is altered due to mineral composition, peanuts were cultivated with gypsum (calcium sulfate) supplementation. The peanuts grown had higher calcium content but less zinc. All peanuts grown in

gypsum treated fields had less aflatoxin produced on them when compared to unsupplemented peanuts. Also, FAS activity was lower and chitin content was less when compared to the unsupplemented control peanuts. The FAS activity observed in these experiments indirectly suggests that the FAS complex may be responsible for producing the precursor for aflatoxin synthesis. However, additional information is needed to validate this hypothesis. [Published abstract]

235. "Control of Common Scab (*Streptomyces aureofaciens*) of Potato (*Solanum tuberosum*) by Soil Treatment with Chemicals", A. Singh and D. V. Singh, *Crop Research (Hisar)*, 9(2): 330-333, 1995

An experiment was conducted during 1987-88 and 1988-89 to study the efficacy of 12 chemicals, each in two doses, was evaluated as soil treatment for the control of common scab of potato (*S. aureofaciens*) at Kanpur in pot experiments. The best control of the disease was obtained by soil application of Gypsum (25 g and 12.5 g/pot), followed by Brassicol (250 and 125 mg/pot), Thiram (250 and 125 mg/pot) and Dithane M-45 (250 mg/pot) with corresponding increase in yield. Comparatively poor results were obtained with both the doses of Blue Copper-50, Hexaferb, Ziram, Brestan-60, Captan, Apron, Topsin M, Bengard and the lower dose (125 mg/pot) of Dithane M-45. [Published abstract]

236. "Effect of Phosphorus Fertilization and Gypsum on Potato (*Solanum tuberosum* L. cv. *Aracy*) Yield", C. R. D. A. Moraes, M. A. R. Alvarenga, and W. R. Maluf, *Ciencia e Pratica*, 16(4): 475-480, 1992

This study was carried out in the experimental field of the Horticulture sector at Escola Superior de Agricultura de Lavras. The purpose was to evaluate the effects of increasing levels of phosphorus fertilizer, coupled with calcium and sulphur supply through gypsum, on tuber yield. Randomized complete blocks in a 4 times 4 factorial scheme with four levels of phosphorus fertilizer (0, 200, 400, 600 kg of  $P_2O_5$  per hectare) supplied as triple superphosphate, and four levels of gypsum (0, 200, 400, 600 kg per hectare) were used in there replicates. Cultivar Aracy was used and number of tubers per plant, average tuber weight and tuber yield were evaluated. It was concluded that triple superphosphate increased tuber number per plant up to the estimated value of 470 kg of  $P_2O_5$  per hectare and on tuber yield when applied at the dosage of 200 kg of  $P_2O_5$  per hectare. On the other hand, increasing levels of  $P_2O_5$  decreased the average tuber weight. Gypsum had no effect in any of the traits evaluated. [Published abstract]

237. "Effect of Sulfur, Calcium, and Boron on Tissue Nutrient Concentration and Potato Yield", U. C. Gupta and J. B. Sanderson, *Journal of Plant Nutrition*, 16(6): 1013-1023, 1993

Field studies were conducted over three years on Podzol soils in Prince Edward Island (P.E.I. (Canada)) on the effect of sulfur (S), calcium (Ca), and boron (B) fertilization on tissue nutrient concentration and potato (*Solanum tuberosum*) yield. Leaf tissues were sampled at 10% bloom and again two weeks later for S, Ca, and B analysis. In the absence of S fertilization, S deficiency symptoms, as evidenced by lighter green foliage were found. The mean tuber yield response due to S addition was 1.1 (SE 0.40) t/ha. Addition of S either as gypsum or magnesium sulfate was effective in overcoming the S deficiency symptoms and in increasing the S concentration in the leaves. Calcium and B additions did not affect the tuber yields. While Ca applications were ineffective in increasing the Ca concentration in the leaf tissue, B applications significantly increased the leaf tissue B concentration in both samplings. The interaction effects between S, Ca, and B were not significant on any of the components tested. Data indicated that 0.25 to 0.27 and 0.28 to 0.32% S in potato leaves were in the S deficiency and sufficiency range, respectively. This is the first documented case of S deficiency in the field in P.E.I. Potatoes and possibly other crops should be monitored for S-deficiency symptoms and S levels in plant tissues should be recorded to detect any trends. [Published abstract]

238. "Effect of Surface Applications of Lime, Gypsum and Phosphogypsum on the Alleviating of Surface and Subsurface Acidity in a Soil Under Pasture", C. J. Smith, et. al., *Australian Journal of Soil Research*, Vol 32, Iss 5, pp 995-1008, 1994

Changes in the chemistry of an acidic grey massive earth soil in response to various ameliorant treatments (gypsum and phosphogypsum in the presence or absence of lime) were investigated in a subterranean clover-based pasture in the southern highlands of New South Wales. Lime, gypsum, and phosphogypsum, or lime in combination with gypsum and phosphogypsum were broadcast at 2500 kg/ha on the surface of the soil in May 1990. Pasture production was determined and the soil was sampled to 25 cm depth, 6 and 18 months after treatment application. Surface soil pH was increased to 6-1 by the application of lime, gypsum plus lime and phosphogypsum plus lime treatments in the 0-5 cm depth interval, but remained unchanged when gypsum or phosphogypsum was used alone. Calcium chloride extractable aluminium increased down the soil profile under all treatments to 10-15 cm, but was highest in the gypsum treatment at depth. The application of phosphogypsum increased the 0.01 m  $CaCl_2$  extractable fluoride in the surface 5 cm from 26 to 43  $\mu M$ . In contrast, fluoride concentrations were decreased to between 5.3 and 7.3  $\mu M$  in the lime, gypsum plus lime and phosphogypsum plus lime treatments. Gypsum and phosphogypsum decreased the concentration of  $Al_3^+$  in solution and on the exchange sites in the 0-5 cm depth interval. However, the effectiveness of the amendments to reduce toxic  $Al_3^+$  concentrations were confined to the surface 5 cm. The concentration of aluminium and the activity of  $Al_3^+$  in the 0-5 cm soil layer at both soil samplings were decreased by the amendments. Lime, and gypsum or phosphogypsum in combination with lime, were the most effective treatments for reducing the activity of  $Al_3^+$ . The activity of  $Al_3^+$  increased with depth in all treatments. The pH and activity of  $Al_3^+$  measured in the 0.01 m  $CaCl_2$  extracts plot near the gibbsite solubility line and suggest that Al solubility was controlled by this mineral. Exchangeable Ca in the 0-5 cm soil layer was significantly increased by the application of lime whereas exchangeable aluminium was decreased by lime, gypsum and phosphogypsum. There was no significant change in exchangeable cations other than Al below the surface 5 cm which suggests limited leaching of lime, gypsum and phosphogypsum in the profile within the 18 month study period. Pasture yield was significantly increased by the addition of lime and was related to the decrease in the activity of  $Al_3^+$  in the surface soil. [Published abstract]

239. "Gypsum", Ronald Balazik, 1998 Mineral Commodity Summaries, US Geological Survey, January 1998, 2 pages

For 1997, US demand for gypsum was an estimated 26.3 million tons, which included:

Mine production	17 million tons
Byproduct	1.4 million tons
Imports	8.1 million tons

The average FOB price of crude gypsum at the mines was \$7.10 a ton in 1997, while calcined gypsum had an average price of \$20.30 a ton, FOB the mines. There were 61 mines in 20 states, with the lead producing states being Oklahoma, Texas, Iowa, Michigan, Nevada, California, and Indiana.

More than 2/3 of the production was for drywall and plastic products, with about 5 million tons used for cement, 2 million tons for agricultural applications and small amounts of high-purity material for a wide range of industrial processes, including smelting and glass making.

For the period of 1993 to 1997, wallboard production has remained flat, at from 22.5 to 24 billion square feet a year.

The use of byproduct material is expected to increase at an accelerated rate, as several large wallboard plants which will only use byproduct gypsum are under construction in the US. Only a relatively small amount of gypsum wall is recycled. (Also see references 17, 18 and 24)

240. Web page of the Gypsum Association, <http://www.gypsum.org>, July 1, 1998

This web page is for the US and Canada trade association of gypsum firms. It was started in January of 1998, and includes:

- a list of their 13 member firms and links to their web pages
- media releases
- sections for
- architects and engineers
- contractors and builders
- distributors and suppliers
- code enforcement officials
- a detailed list of available industry statistics available from the association. The statistical reports range from one page annual summaries (available for a fee of \$8.75) to 120 page multi-year reports available for \$165.

241. Survey of web pages of gypsum firms from the links of the Gypsum Association, July 1, 1998

Ten to the 13 members of the Gypsum Association have web pages. These sites were visited to review their information, including their recycling programs. Only one --Lafarge -- told of recycling scrap drywall. Email messages were sent to each of the other firms, inquiring if they take scrap construction drywall for recycling or can provide information on other recycling opportunities.

Celotex Corporation's web page has a short description of its involvement in using recycled materials, including sugar cane fiber by-products and recycled newsprint in their products since 1921, but not on the recycling of scrap drywall.

Lafarge Gypsum notes that they have two production facilities in the northeastern US, and both have the ability to recycle gypsum board.

National Gypsum describes their use of recycled paper for the facing and backing of their drywall and that several of their plants will use synthetic gypsum from coal air pollution control systems.

Republic Gypsum Company uses recycled paper for the facing on their drywall.

Temple-Inland uses both recycled paper for the facing of their drywall and uses synthetic gypsum from air pollution control systems. Temple's drywall will be used to build the Green House which was given as the national prize of America Recycles Day in 1997.

The remaining firms do not have any information on recycling. (Also see reference 223 for a similar survey of firms in Germany, and reference 200 for a firm in Norway.)

242. Responses from email questions to webpages of members of the Gypsum Association (also see reference 32 for a 1994 survey)

*Celotex Corporation*

Email message from Dave Moyer, Celotex, [Dave\\_Moyer@celotex.com](mailto:Dave_Moyer@celotex.com), July 7, 1998

Celotex does occasionally recycle scrap drywall, however most of the current efforts are on recycling waste drywall already at the plant sites. It is usually cost prohibitive to recycle scrap drywall from construction projects due to the transportation costs. If done, the paper does not need to be removed. It helps. For more details contact Celotex at Ft. Dodge, IA 1-800-247-1720

*G-P Gypsum*

Telephone call from Scott Rois, Environmental Manager, G-P Gypsum, (404)652-7177, July 1, 1998

Mr. Rois said that G-P Gypsum does accept construction scrap drywall for recycling but not demolition or remodeling scrap. Unprocessed drywall is accepted at no payment or fee, while there is a payment of about \$4 a ton for crushed and ground drywall. They currently buy scrap gypsum from brokers. Paper does not need to be removed; in the drywall manufacturing process, paper is typically added to the core to increase its strength. He noted that a number of states are moving to ban gypsum drywall from landfills, given the large volume of waste from construction and demolition projects. Besides remanufacture into drywall, two other methods of handling construction scrap are to place it in an empty exterior wall cavity during the construction project and to incorporate it into the soil at the building site. The National Association of Home Builders has literature on these uses.

G-P Gypsum acquired Domtar Gypsum in April 1996. [Domtar has had a long history in using recycled drywall scrap to make new drywall. See, for example, references 27, 29, 32, 64, 75, 101, and others.]

#### *James Hardie Gypsum*

Email from Rob Davies, Robd@accessone.com, of James Hardie Gypsum, July 2, 1998

In response to my inquiry through the company Internet site, Mr. Davies noted that they are not currently accepting scrap from jobsites although they have in the past and will again. Currently their plant in Washington State is going through a remodel and they can't accept scrap from jobsites.

When they do accept scrap drywall, they charge for this service, with the fee worked out with the sales department. They can accept drywall with paper, but remove it during their recycling process.

#### *Lafarge Gypsum*

Not surveyed, since web page said that they take scrap back for recycling

#### *National Gypsum*

Email message from Bob Ek, Manager, Technical Service, Bobek@worldnet.att.net, July 13, 1998

National Gypsum does not take back scrap. They have no way of recycling the wallboard once it leaves their plant. Some internal scrap is recycled back into product if it was taken directly off the line. Other product is used to make risers.

#### *PABCO Gypsum*

Email from Steven Jones, PABCO Gypsum, Steven.Jones@paccoast.com, July 6, 1998

Mr. Jones noted that PABCO does not accept scrap drywall from construction projects for recycling.

#### *Republic Gypsum*

No response yet.

#### *Temple-Inland Forest Products*

Email from Jim Rush, Temple Inland, JRush@templeinland.com, July 15, 1998, and Bruce Schrade, Temple Inland, BShrader@templeinland.com, July 16, 1998

Technically, the firm can recycle wallboard. However, they only have the capacity to recycle their internally generated scrap. They currently do not have an urban recycle program. There are several problems in trying to recycle scrap materials, that they have not been able to overcome, including the cost, removal of paper and contamination concerns

#### *United States Gypsum*

Phone conversation with Frank May, US Gypsum, (312)606-3770, July 7, 1998

US Gypsum does not accept scrap drywall from construction sites at this time although they do recover some internal plant scrap, which is about 1 to 2% of total production. Several challenges include the accumulation and transportation of the drywall scrap and contamination concerns. Contamination concerns include both non-drywall material -- both from the jobsite and midnight dumpers -- and the need to remove paper from the drywall before it is recycled. While some US Gypsum products have paper added to the core to improve strength, the quantity of paper must be limited in order to maintain fire ratings. An additional problem is the handling of the removed paper -- it is difficult to recycle because it will include some attached gypsum.

#### *Westroc Inc.*

Email message from Peter Mayer, Technology Development Manager, BPB Westroc, pmayer@westroc.com, July 10, 1998

All BPB Westroc facilities recycle off spec gypsum board and two facilities recycle scrap from construction sites. Material from construction sites is received by an independent gypsum scrap recycling company called New West Gypsum located New Westminster, BC and Burlington, Ontario. New West crushes the board and screens out most of the paper. Their plants were designed for processing gypsum rock and have no facilities for crushing and screening. Also, their fire rated products limit the amount of paper content in the board core.

BPB Westroc has expertise in recycling systems and can provide a specification for recycle material.

We are only able to recycle gypsum waste that is free from other construction debris. We therefore can only accept new construction waste and not demolition waste.

There is also a maximum limit of moisture. Their plants were designed to process rock that has a moisture content below 5%.

For an assessment of the capability of developing a program to accept construction debris from a specific location, Mr. Mayer asked for the total tonnage of new construction gypsum waste being considered and its location. We require this information to assess this opportunity.

243. Web site of US Gypsum, <http://www.usg.com/msds>, July 1, 1998. In a search on May 24, 2001, the site address was now [http://www.usg.com/Search/13\\_0\\_search.asp](http://www.usg.com/Search/13_0_search.asp)

As part of its web pages, US Gypsum provides the Material Safety Data Sheets for its products, providing extensive information.

244. "Dealing with Gypsum", Curt Harler, *Recycling Today*, August 1998, pages 36-44

Gypsum is said to be one of the toughest fractions of C&D debris to recycle. One form of gypsum recycling is the use of the gypsum that is produced as a by-product from the air pollution control systems of coal-fired power plants.

About 15 million tons of gypsum drywall is consumed annually and about 12% ends up as waste. This accounts for about 64% of all scrap gypsum generated, with demolition accounting for another 14%, manufacturing adding 12% and renovation 10%.

EPA is researching gypsum recycling in cooperation with groups, such as the National Association of Home Builders and one technique for recovery is to grind up the scrap and add it to the soil at the building site. While manufacturers will use some scrap in making new drywall -- especially internal scrap-- little building scrap is used due to transportation costs and the need to remove the paper. Demolition scrap offers additional problems.

In Western Canada, gypsum is often banned from landfills due to the formation of nuisance or toxic products, in eastern Canada, there are no bans on landfilling. However, both parts of the country have recycling programs, including gypsum manufacturers who accept scrap gypsum for making new drywall. In Europe, C&D recycling is mandated by 2010, and some countries are making significant progress.

In the US, recovery of drywall includes reuse of construction scrap, recovery for agricultural purposes, conversion into stucco, use as a bulking agent in sludge handling, mixing with wood chips for animal bedding, grinding into a powder for marking athletic fields, absorbing grease in mechanics' shops and as an inert material in flea powder. Also under study is the use of gypsum for landfill cover.

245. "New Wallboard Plants Will Use Gypsum from Scrubbed Exhaust", *Engineering News-Record*, July 6, 1998, page 25

The first plants in the US designed to make wallboard entirely from synthetic gypsum from flue gas desulfurization are now under construction, with facilities going up in Alabama, Tennessee and Pennsylvania. The main advantage of these plants is the quality of the gypsum -- higher than quarried material. However, it has a moisture content of 12%, and needs to be dried and is somewhat more abrasive than natural gypsum, requiring changes in plant design.

A further advantage is for the generators of the material, this converts a landfilled material into a product that can now be sold.

246. "Demonstration of Land Application of Crushed Gypsum Wallboard Waste for Alfalfa. A Final Report Prepared for the Wisconsin Department of Natural Resources Waste Reduction and Recycling Grant Program and Dane County Department of Public Works", Richard Wolkowski, Department of Soil Science, University of Wisconsin-Madison, August 12, 1998, 11 pages [also see references 159, 182 and 193]

Because of the large quantity of gypsum drywall scrap landfilled, and the potential for this material to be used as a fertilizer due to both the Ca and especially the S, a three year test was done at four locations in Wisconsin on the impact that the application of ground scrap gypsum would have on alfalfa. Alfalfa was chosen because of its high S need, the deficiency of S in Wisconsin soils and the high sulfur contained in the gypsum.

Ten alternative applications were used, including controls of no wallboard or S fertilizer up to an application of 36 Mg/ha.

While there was a trend of increased yields at the highest level of application at three of the four sites, it was not a statistically significant difference. The stand (the number of stems per area) was negatively affected at a statistically significant level at one site at applications less than the maximum application. In addition, there were increased levels of calcium and sulfur in the forage, and decreased levels of other cations, especially magnesium. Soil pH was decreased at high levels of application, which seemed to be caused by a salt reaction from the gypsum. The levels of Ca and S increased in the soil, while the level of Mg decreased. No other significant change in soil nutrients was detected.

An analysis of the gypsum showed that it had major plant nutrients found in gypsum were Ca and S, with considerably lower amounts of Mg. The only other beneficial plant nutrient was boron (B). A 10 Mg/ha application of gypsum would supply about 0.43 kg/ha B, which is close to the agronomic recommendation for B. Other metals content was very low.

The study concluded that the application of gypsum wallboard at modest rates does not appear to have a deleterious impact on alfalfa production. Three concerns identified were:

1. the depression of measured pH, that could lead to the application of unnecessary lime

2. a depression of Mg in the soil and the suppression of the uptake of Mg, which could lead to a deficiency of Mg in the plant, especially in sandy soil, where Mg is already low
3. animal health problems related to the feeding of low Mg, high Ca forages

It was recommended that application should be limited to 2 Mg/ha on sands and loamy sand soils and 5 Mg/ha on loams, silt loams and heavier textured soils. One application every three years should be adequate to supply S to the crop.

247. Email message from Bengt Ahlgren, ProFund AB, Sweden, profund@algonet.se, August 6, 1998

Bengt Ahlgren is researching methods to provide the most efficient and cheapest way of treating swine manure to prevent odor and to raise the nitrogen content, and is interested in the use of gypsum drywall to treat swine manure.

248. Email message from Bill Carter, Recycling Section, Texas Natural Resource Conservation Commission, WCarter@tnrcc.state.tx.us, October 8, 1998

In response to my inquiry for information on drywall recycling projects, Mr. Carter sent the following information via email.

There was a venture in the early 1990's to establish a drywall recycling industry. It put all its eggs in the basket of a statewide ban on landfill disposal of drywall which of course never materialized. A company was set up, equipment was designed and demonstrated, a video was produced, etc., but it never went into commercial production. If you want the name of the company or other background on its efforts, please let me know -- I just can't call it to mind right now.

At least 2 major composters in Texas actively accept drywall scrap along with clean wood scrap. One of the composters, Malcolm Beck of Garden Ville, Inc. (San Antonio, 210/651-6115), has looked into recovering gypsum from scrap wallboard and bagging it for horticultural purposes, but I don't believe he has yet put the idea into operation. The other composter who takes lots of wallboard is Robert Dow of Silver Creek Materials (Fort Worth, 817/246-2426).

Our predecessor agency produced a document on gypsum wallboard recycling around 10 years ago, but it's out of print and I can't find a copy. Most likely very dated. If you have a strong interest in it, let me know and I'll try to track it down.

249. "An evaluation of elemental sulfur-sewage sludge combinations and waste gypsum as sulfur sources", Sulewski, Gavin D., Masters Thesis. Univ. Saskatchewan. Saskatoon. SK. 101 pages, 1996

Sulphate release of waste gypsum was studied under field conditions at Star City, SK using canola as the test crop. Yield and sulfur uptake were assessed at three rates of sulfur (20, 40, 80 kg S/ha) on a Gray Luvisolic soil. Based on crop sulfur uptake data, wallboard gypsum was often comparable to ammonium sulfate. The waste gypsum sources provided significantly lower sulfur use efficiency at 20 kg S/ha than ammonium sulfate; however no difference was observed at 40 and 80 kg S/ha.

250. "Power Play. Wallboard Plant to Use Gypsum Made from Ohio Site's Residues", Waste News, February 8, 1999, page 5

The Lafarge Corporation is spending \$90 million to build a gypsum wallboard plant in Silver Grove, KY, which will use synthetic gypsum produced as a residue from the air pollution control system of the coal burning Wm. H. Zimmer Generating Station in Moscow, Ohio. With a capacity to produce 900 million square feet of gypsum wallboard a year, the plant will be the largest single-line gypsum wallboard producer in the US. In addition, Lafarge will also use synthetic gypsum from the power plant in cement productions in four regional facilities.

251. "Building Boom Means Wallboard Shortage, Higher Prices", Milwaukee Journal-Sentinel, n.d. on Internet, ca. March 17, 1999; "Drywall shortage crimping builders .Worsening supply leads to rising prices and delays in delivery", Dan Benson, Milwaukee Journal Sentinel, March 21, 1999; "Drywall Hard to Get and Costing More", Roger Gribble, Wisconsin State Journal, March 18, 1999, page 1

The national building boom has both caused a shortage in the supply of drywall and a dramatic increase in prices. One Milwaukee area dealer said that the current shortage is the worst he has seen the market supply in 31 years. Where before it might take two days to order and receive a load of drywall, it can now take a month. Some stores are limiting the amount that customers can buy. And where it might have previously cost \$9 a sheet, it now costs \$11 a sheet. In the Madison, WI area, prices have increased from between 25% and 60% from a year ago, and another 10% increase is expected next month. Drywall factories are reported to have been operating at full capacity for several months. The firms have not been able to afford to expand their facilities, however, due to asbestos-related lawsuits on other products. (Also see price articles #94 and 95.)

252. "Gipsaffald ... Deponi eller ...?", Ren Viden, March 1999, page 3

Danogips A/S, a Danish producer of gypsum building products, has sent out an offer to several communities and waste organizations to work with them to recycle post consumer gypsum drywall. The firm is already recycling scrap drywall at its factories in both Hobro and Vojens. The drywall must be clean, free of other building waste, including wood, screws, metal, fiberglass, plastic wall paper, etc. There is a charge of 200 kroner per tonne. The contact for more information is Carl Erik Bech, Danogips A/S, telephone 36 15 90 00. {Note: A search was made for an internet site for Danogips, but none was found.}

The next issue of Ren Viden will have an additional article on gypsum waste.

253. Email message from Vidar Olsen, Technical Manager, Norgips, email address vidaro@norgips.no, March 22, 1999

The plasterboard industry in Scandinavia has formed a group to look into the coming problem of what to do with waste drywall either from new building sites or from demolition. The authorities have set an aim for reducing scrap for landfill by 50% in the next 4 years. So even if most of the scrap drywall today goes to landfill, in the future this will be a restricted possibility. Norgips participated in a project to collect and recycle drywall scrap.

However, due to long transportation distances, it is not economical -- and probably not environmentally beneficial -- to transport the drywall back to the factory from long distances away. They are thus looking at alternatives and are searching for information on the use of gypsum for sewage treatment and the composting of organic municipal waste.

254. "C&D Markets Build upon Base", Anne Claire Broughton, Recycling Today, March 1999, pages 60-70, 94

According to this article "... numerous C&D debris recycling programs across the country are beginning to target gypsum wallboard for recycling." Ben Gordon, president of Construction Debris Recycling Inc. of Colony, NY, the market outlook for high quality gypsum is positive. However, he notes that the economics of recycling drywall depends on the alternative cost for landfilling, and that with low landfill costs, it is necessary to be both very efficient and have a nearby market. Among end uses, gypsum is suitable for blending in soil products and as use as an oil absorbent. His company currently processes construction drywall scrap and hopes to get involved with post-consumer drywall in the near future.

In the Los Angeles area, there are more than 145 companies that recycle C&D debris. According to Kelly Ingalls, senior management analyst for the Los Angeles Bureau of Sanitation Citywide Recycling Division, there is a demand for gypsum, so recycling it makes sense.

255. Email message from Richard Anthony, San Diego, CA, ranthopw@co.san-diego.ca.us, June 10, 1998

Rick Anthony noted that in California, gypsum is used to mark playing fields (chalk marks) on grass and can be used for football, soccer etc. It is better than herbicide or burning the fields with gasoline. Parent operated sports programs are big all over and field marking is a perennial cost.

256. Email message from Suzanne Savanick, Minnesota Office of Environmental Assistance, suzanne.savanick@moea.state.mn.us June 11, 1998,

Suzanne Savanick noted that Empire Organic Greenhouses in Rosemount, MN is using wallboard as a soil amendment and a firm known as SKB is considering using wallboard to change the pH in their new composting facility.

257. "Scoping Report into the Viability of Plasterboard Recycling, Waste Not Auckland, prepared for Auckland Regional Council, September 7, 1998, 8 pages

In the Auckland, NZ region, some 19,000 tonnes of gypsum plasterboard are landfilled annually, including some 18,000 tonnes from construction and demolition and 1,000 tonnes from a manufacturing plant. In a landfill, it both uses up valuable space and has the potential to generate toxic hydrogen sulfide gas, while also representing a loss of valuable natural resources.

This report has 6 objectives:

1. Gather background information on gypsum, its properties and uses.
2. Determine the current costs of gypsum.
3. Determine the remilling costs to recycle the product.
4. Determine the current market for gypsum.
5. Determine the potential market for gypsum.
6. Determine the actions required to realize the potential market

The major use of gypsum in New Zealand is for plasterboard, and an estimated 50,000 -80,000 tonnes a year.

Cement manufacturers also use a large quantity of gypsum as a retarder, and an estimated 50,000 tonnes are used annually.

The use of gypsum as a soil conditioner is minimal in New Zealand. Soils are generally acidic and lime is used for its neutralizing effect.

Other uses of gypsum, such as Plaster of Paris, dental molds, etc, are very minor.

In New Zealand, gypsum must be imported, with some coming from Mexico and Thailand, and the bulk of material used for wallboard manufacture coming from Australia, with a cost of some \$40 a tonne. At garden stores, a 10 kg bag of gypsum sells for about \$10 to \$13, or \$1000 - \$1300 a tonne. Bulk gypsum for agricultural use sells for around \$250 to \$320 a tonne, exclusively of delivery.

Adams Landscaping of Auckland is proposing to accept scrap drywall for recycling at a fee of \$30 a tonne, which is half the landfilling cost of \$60 a tonne. The company proposes to grind up and screen the material and then sell the material to manufacturers for recycling. They believe

that their cost of processing will be about \$15 a tonne -- excluding storage and disposal of residues -- and that they can sell the recovered material at about a third of the cost of importing gypsum.

Winstones, the New Zealand manufacturer of plasterboard, has set a specification of reusing gypsum to make wallboard of a particle size of 0.75 inch and a maximum paper content of 2%.

The two cement manufacturers of New Zealand have also been contacted for their specifications for gypsum for use as a retarder and it appears that the ground and screened recovered gypsum could meet their requirements.

For the agricultural marketing of gypsum, it is recommended to focus both on those crops that could benefit from gypsum (such as potatoes) as well as those areas with clayey soils for which gypsum could provide valuable treatment.

The options for marketing remilled gypsum are therefore as follows:

- Sell the material direct to cement manufacturers as per their specifications. This has the added advantage as it decreases the amount they need to import and does not take any business from Winstones.
- Sell the material to Winstones as per their specifications for Plasterboard.
- Sell the material to Winstones as per their specifications for Soil conditioners.
- Sell direct to farmers from the yard (e.g. price decrease will open up other markets such as Potato crops).
- Sell to agricultural/horticultural suppliers (e.g. Fruitfed, Wrightsons).
- Package on site and market/sell to garden centers and chains such as The Warehouse (who have a policy of stocking recycled products).
- Sell to a company such as Living Earth who may then combine it with an existing product such as compost, potting mix, or bark mixtures (these combinations have proven to be a successful mix).

The report recommends that work proceed on the recovery of scrap drywall for both the manufacture of plasterboard and as a cement retarder at this time, and forego pursuing the agricultural uses at this time, since the "...the issues are relatively complex, and much work is still required which is not justified at this time."

258. "Agricultural Uses of Phosphogypsum, Gypsum, and Other Industrial Byproducts", R. F. Korcak, pp 120-126 in Agricultural Uses of Municipal, Animal and Industrial Byproducts, US Department of Agriculture, Agricultural Research Service, Conservation Research Report No. 44, 1998, 135 pages. On the Internet through <http://www.ars.usda.gov>

This summary includes a page and a half on gypsum, referencing over 20 other reports. It notes that gypsum has both physical and chemical benefits, including increasing infiltration, reduced root impedance and reduced restriction of hardpans, increase subsoil C and reduced exchangeable Al. However, there can be negative effects as well and the chemistry of gypsum in the soil system is not yet completely understood. A soil test for determining the level of gypsum that can be applied has been proposed, but not yet standardized.

259. "USDA opens New Compost Facility", US Department of Agriculture news release, October 20, 1998. On the Internet at <http://www.ars.usda.gov>

The USDA has opened a new composting research station at its Beltsville, MD research facility. Included will be the testing of adding drywall to compost mixtures in cooperation with the Gypsum Association of Washington, DC and the National Association of Home Builders Research Center in Upper Marlboro, MD.

260. Phone conversation with wastewater treatment staff at the Wisconsin Department of Natural Resources, March 25, 1999

In response to my telephone inquiry on the use of gypsum in wastewater treatment -- both municipal and industrial -- the staff discussed this potential and could not give any examples of this use, nor any information that would point to any known benefits

261. Phone conversation with Jon Schellpfeffer, Assistant Director, Madison Metropolitan Sewerage District, March 25, 1999

In response to my telephone inquiry on the use of gypsum in wastewater treatment, Mr. Schellpfeffer said that the staff did not know of any role it might have. While it may be used as a flocculent for other purposes, its low solubility would limit its usefulness for sewage treatment. It may have a use as a component in the production of "artificial soil", however.

262. "Trash or Cash Commodity? It's All in the Blend", Agricultural Research, July 1996, pages 9-10

This publication is from the Agriculture Research Service of the USDA and highlights the upcoming research of Ronald Korcak to test the use of drywall scrap as a soil amendment or to compost with other materials. (Also see references 163 and 258.)

263. "Stopping Erosion with Gypsum and PAM", Agricultural Research, September 1997, pages 19 and 20

L. Darrell Norton of the National Soil Erosion Research Laboratory (NSERL) in West Lafayette, IN is studying the potential of gypsum to reduce soil erosion. Because gypsum reduces soil surface sealing and improves water entry, it is believed that soil erosion

can also be reduced. PAM (polyacrylamide) -- a material used in water treatment as a flocculent -- also has a use in stabilizing soil. Tests are proceeding on using both gypsum and PAM under a variety of situations.

Along with the erosion control benefits of gypsum, the NSERL scientists also found that crop yields were improved. Further tests will be done on the benefits of gypsum for wheat, corn and soybeans in several eastern states.

264. Email from Frank Wentzel, Recycling Coordinator for Citrus County, FL, frank@fiber-net.com, March 24, 1999

Mr. Wentzel has just received a state grant to develop drywall recycling methods for our area. At present he is leaning toward using recovered drywall in the manufacture of new drywall and in the production of portland cement.

265. "N.Y. Facility Accepts Drywall and Shingles", Recycling Today, April 1999, page 36; "N.Y. Facility Accepts Drywall and Shingles", C&D Recycler, Summer 1999, page 8

Construction Debris Recycling Inc of Colonie, NY is processing drywall and roofing shingles to make a variety of products. Their process was developed over a four year period by a local waste hauler and recycler along with Andela Tool & Machine company. The drywall is used for a variety of end markets, including agricultural soil amendment and industrial spill absorption material. The firm is charging for processing the materials, about 35% less than the competing landfills.

266. Email message from Joyce Harms, Recycling Commodity Consultant to the Wisconsin Recycling Market Development Board, email jwharms@execpc.com, April 7, 1999

As part of a national conference on the recycling of construction and demolition debris, Ms. Harms visited a facility that is recycling scrap drywall by composting it with wood and horse manure. The firm is Thelin Recycling Company, 5225 Thelin St., Fort Worth, TX 76115, phone (817)926-5626; contact is Michael J. Hill.

267. Email message from Vidar Olsen, Technical Manager, Norgips, email address vidaro@norgips.no, April 7, 1999

At Norgips, a Norwegian manufacturer of drywall, they recycle all of their scrap from production, together with some waste from building sites, back into new products. At the present time, they have the possibility of using a maximum of 6% clean drywall into new plasterboard. They have not yet tried to mix in demolition waste because of the lack of a good solution for separating the gypsum from the paper and surface treatment, and thus are not sure of the quality of the raw-material. (Also see reference 253.)

268 Email message from Duane Roskoskey, Michigan Department of Environmental Quality, Waste Management Division, E-Mail: Roskoskd@state.mi.us, phone: 517-335-4712

Mr. Roskoskey has compiled a list of companies that manufacture equipment for processing drywall for recycling, with the following list as of June 10, 1998:

Recycling Dimensions (mobile job-site machine)  
2600 W. Sahara Ave. #116-293  
Las Vegas, NV 89102  
(800) 884-8814 (ask for Cal)

Premier Gear & Machine Works (plant equipment)  
1700 N. W. Thurman  
Portland, OR 97209  
(503) 227-3514

Concept Products Corp. (Shred-All) (mobile job-site machine)  
Paoli Corporate Center  
16 Industrial Blvd., Suite 110  
Paoli, PA 19301  
(610) 722-0830

Andela Tool and Machine, Inc. (plant equipment)  
493 State Route 28  
Richfield Springs, NY 13439  
(315) 858-0055  
Web site: www.recycle.net/andela

Gyp-Pak<sup>TM</sup> Container, Inc. (mobile job-site machine)  
c/o Trebor Marketing Services  
26 Hampton Lane  
Fairport, NY 14450  
(716) 223-4005

New West Gypsum (plant equipment)  
Byron Harker  
1321 54<sup>th</sup> Ave.

Fife, WA  
(206) 922-9343

GP Research, Ltd. (plant delaminator)  
% Jim Dooley  
Federal Way Office  
1911 SW Campus Dr. #545  
Federal Way, WA 98023-6641  
(253) 838-3496

269. "Evaluation of the Potential for Composting Gypsum Wallboard Scraps", fact sheet by Clean Washington Center, October 1997, on the Internet at <http://www.cwc.org/briefs/construction.html#882577016>, 2 pages

The Clean Washington Center contracted with E&A Environmental Consultants, Inc., to examine the feasibility of recycling gypsum wallboard scrap as a bulking agent in a composting process. The goals of a bulking agent can include providing porosity, balancing the carbon-nitrogen ratio, and absorbing excess moisture.

In the experiments, four mixtures were made of gypsum, yard material and sewage sludge (biosolids). The mixtures were composted for 8 weeks, and data were gathered on porosity, temperature, oxygen, moisture, odor, decomposition, pH and visual factors. After the process was complete, the material was tested for calcium, boron and organic matter and the amount of degradation of the paper from the drywall was noted, with the smaller pieces nearly completely degraded and the larger (approximately 2 inch diameter) pieces having about a 40% degradation.

It was concluded that the use of ground gypsum as a bulking agent works satisfactory and can help to prevent odors in composting yard materials.

270. Evaluation of the Potential for Composting Gypsum Wallboard Scraps. Final Report, E&A Environmental Consultants, Inc., for The Recycling Technology Assistance Partnership (ReTAP), Clean Washington Center, Report CDL-97-4, 100 pages

The purpose of this project was to evaluate the potential of composting scrap gypsum wallboard from construction and demolition projects in combination with sewage sludge and yard debris. Specific objectives included:

Evaluate the composting process for its:

- Ability to break down paper
- Reduction of the volume of material
- Impact on the sulfur and calcium levels in the final product
- Impact on product salinity and pH
- Production of ammonia and sulfur products in the exhaust gas during composting
- Ability to utilize gypsum in composting

Develop recommendations for demonstration scale testing, including:

- Most suitable bulking materials and initial mix ratios
- Appropriate detention time
- Aeration system sizing
- Process monitoring and testing requirements
- Wallboard process to control dust
- Establish bulking materials and composting controls that provide the most effective breakdown of wallboard scrap

Develop information for full scale conceptual design and cost estimates for:

- Mass balance
- Detention time
- Processing equipment needed
- Process control strategy

The project tested four mixes of the sewage sludge, yard debris and gypsum, composting these materials for a period of 8 weeks in a 21 cubic foot insulated container with aeration equipment. Materials were initially mixed with a cement mixer. The volumetric mix ratios selected were:

Mix design		Sewage sludge	Yard Debris	Gypsum
1		1	3	0
2		1	1.5	1.5
3		1	2	1

4		1	2.5	0.5
---	--	---	-----	-----

The goal of the mix designs was to have the proper characteristics for porosity (<1200 lb/cy), moisture content (50-60%), available carbon (produce temperatures to reduce pathogens), nutrient content (C:N ratio near 30:1), and pH (between 6 and 7.5).

Data collection for each mix included the following parameters:

- Gypsum content
- Paper degradation
- Volume and weight reduction
- Heat generation
- Energy generation
- Ammonia volatilization and sulfur gas generation (odor impact)
- Product quality
- Volatile solids reduction

The composting process was controlled by programmable logic computers, which recorded the temperatures within the bins and controlled aeration blowers. The goal for temperature control was to have three consecutive days where temperatures were maintained at 55° C to meet EPA pathogen reduction criteria, followed by a reduction to 40 to 50° C to optimize organic matter degradation.

Two trials were done for the tests, primarily because the first trial was unable to get the temperatures in mixes 3 and 4 up to the required level due to excessive moisture.

Data provided in the report includes temperatures, a chart of airflows and oxygen content, ammonia and dimethyl sulfide generation rate curves and a bar chart on the reduction in the weight of the paper from the drywall. For odor, the control had higher levels of ammonia than the mixes with gypsum added. For sulfur compounds, there was no discernible trend. One of the wallboard mixes had higher levels of dimethyl sulfide generation than the control and two of the wallboard mixes had lower levels of dimethyl sulfide generation than the control. In none of the cases was odor a problem.

After the composting process, the material was screened with a screen size of 3/8". The screened compost was also tested for over 20 parameters. The amount of gypsum in the overs and final product were as follows:

Mix	Overs	Compost
1	0	0
2	45%	57%
3	38%	48%
4	15%	30%

While some parameters increased with increased levels of gypsum -- especially calcium and sulfur -- other parameters were not affected at all, such as boron. Still others, such as aluminum, manganese and zinc, were lower in the gypsum mixes than in the control. The report concludes that the wallboard gypsum could be readily used in most compost end-use applications, and that the levels of gypsum could be a benefit in some circumstances.

271. "Innovative Drywall Composting", Grant application by Okaloosa County, FL to the Florida Department of Environmental Protection, 1999, on the Internet at <http://www2.dep.state.fl.us/waste/programs/igg99/index.htm>, 9 pages

Okaloosa County, Florida requested a \$100,000 grant from the state of Florida for a drywall recycling project in cooperation with the Elgin Air Force Base, the Okaloosa Building Industry Association, and the University of Florida Institute of Food and Agricultural Sciences.

The project will test both in-vessel and traditional windrow composting of drywall and yard debris. The drywall will be ground prior to composting, and it is expected that existing equipment will be suitable for this purpose. Odor problems from the composting of drywall are believed to be controllable with in-vessel composting, using the technology of Ag-Bag Environmental. For windrow composting, it is expected that hydrogen sulfide gas will be produced, but that the production can be minimized by frequent turning to keep the pile from going anaerobic. The goal is to provide the finished compost to peanut farmers in the county, and there are more than 4,500 acres of peanut grown in the county.

The timeline for the project is to be completed within one year. The results will be shared with Putnam and Citrus Counties and the New River Solid Waste Association [see the next two reviews].

272. "Gypsum Drywall Recycling Program", Grant application by Putnam and Citrus Counties, FL to the Florida Department of Environmental Protection, 1999, on the Internet at <http://www2.dep.state.fl.us/waste/programs/igg99/index.htm>, 10 pages

Citrus County has had odor and environmental complaints from citizens concerning a landfill that accepts construction and demolition debris, and this may be due to the production of hydrogen sulfide from the decomposition of drywall in the site.

This project requested a \$260,000 grant to study the potential to recycle drywall in three stages:

Stage 1 - study the feasibility of collecting drywall in the two counties, and review existing drywall recycling systems elsewhere

Stage 2 - plan and implement a collection system for drywall in the two counties

Stage 3 - study and develop markets for the recovered drywall among manufacturers in Florida to make new drywall, which should be a much higher valued end product than compost or land application

An industry advisory group will help guide the project.

It is anticipated that the drywall would be generated at construction sites and collected either in a separated form as well as commingled with other materials. A reduced tipping fee will be charged for separated material. It is expected that the drywall will be processed by crushing and screening and a mobile grinder will be purchased at a cost of approximately \$100,000.

The project report is to be finished within 12 months of the project start. Dr. Tim Townsend of the University of Florida will prepare the report for this project as well as the project for Okaloosa County and the project for the New River Solid Waste Association.

273. "Recycling of Recovered Gypsum Drywall by Land Application", Grant application by the New River Solid Waste Association to the Florida Department of Environmental Protection, 1999, on the Internet at <http://www2.dep.state.fl.us/waste/programs/igg99/index.htm>, 10 pages

A grant of just under \$193,000 is requested by the New River Solid Waste Association for a project to collect, process and reuse gypsum drywall as a soil amendment and other applications, such as road base, a grease absorbent and for odor control. The New River Solid Waste Association includes Baker, Bradford and Union Counties, Florida.

The project will collect gypsum drywall scraps through a free drop off at the regional landfill. A grinder with a screen specifically designed for drywall will be purchased or leased, and the material that will be produced will be both sorted as either fine (1/8" minus) and coarse (1/2" minus).

The material will be tested for four purposes:

1. A soil amendment for both nutrient values (calcium and sulfur) as well as physical improvement (improve infiltration and root penetration in acidic subsoils)
2. An amendment for animal bedding and manure to control moisture and odor and for sludge and yard debris composting
3. A grease absorbent in maintenance and kitchen operations, replacing cat litter
4. A road base material, either by itself or with clayey soils

The final project report is expected in April, 2000.

274. Phone conversation with Joyce Harms, consultant to the Wisconsin Recycling Market Development Board, May 14, 1999, (414)385-9449

The conversation was about two projects to compost gypsum drywall with other materials.

In the first project, an on-going operation of Thelin Recycling Company, 5225 Thelin St., Fort Worth, TX 76115, phone (817)926-5626, Joyce visited this facility as part of a September 1998 construction and demolition debris recycling conference. The process mixes chipped wood, horse manure and ground drywall together in windrows, to which moisture is added. The material takes about 18 months to break down. This process had been in operation for 2-3 years at the time of her visit. The contact is Michael J. Hill.

In the second project, Zblewski Brothers, LLC of Plover, WI has applied for a grant from the Recycling Market Development Board (RMDB) to recycle both shingles and drywall. The firm already makes wood mulch and does composting of materials and proposes to mix in the drywall with chipped wood, compost the mixture and then screen it. The mixture would then be sold to farmers as a soil amendment. The farmers like the small processed wood, since the soil in that part of the state is very sandy and the wood helps to build up the moisture retention capacity of the soil. The gypsum is helpful because of both keeping the compost loose, serving as a bulking agent and adds nutrients to the soil for potato farmers. The proposal of the Zblewski Brothers was brought to the RMDB at their April 30, 1999 meeting, but was held over pending requests for more information.

275. "Ohio Nursery Tests Compost Made from Gypsum", Resource Recycling, September 1999, page 10

According to the Ohio Solid Waste Reporter, Barnes Nursery, Inc. of Huron, Ohio is conducting a pilot project to compost the paper from gypsum drywall.

276. "Reclaiming Acid Mine Soil with Drywall and Manure, David Munn and Frank Murray, BioCycle, October 1999, pages 59-60

Researchers at the Ohio State University Agricultural Technical Institute tested the use of gypsum drywall and cow manure in improving crop yields on acid mine soil. Pot tests were done using drywall rates of 0g, 10 g, 20 g and 30 g per kilogram of acid mine soil, first growing rye, followed subsequently by two crops of corn.

For the rye, the gypsum produce a significant positive result, including a linear increase in Ca concentration and plant dry material with increasing levels of gypsum.

For the corn, the first crop (which was grown in a cool greenhouse and had small yields), there was an increase in yield with increased amounts of gypsum, but the results were not significant. For the second crop, there was also an increased yield with increased amounts of gypsum and the results were significant.

Tests of the soil showed a positive correlation between gypsum addition and soil pH and a negative correlation between gypsum application and the quantity of exchangeable acidity. The researchers concluded that there appears to be a displacement of Al ions by Ca ions.

277. "Union City, California. 86 Percent of C&D Debris Recycled", BioCycle, November 1999, page 18

As part of a 95 home development, a Union City, CA builder contracted for the recycling of its construction debris. The recycler -- Green Waste Recovery of San Jose, CA -- collected 161 tons of gypsum drywall, which was turned into a soil amendment. Other collected materials included 631 tons of wood, 116 tons of dirt, asphalt and concrete and 62 tons of metal.

278. "Hancock County, Indiana. Recycling C&D Debris On-Site", BioCycle, November 1999, page 22

A pilot project was done last year to demonstrate the benefits and economic competitiveness of on-site recycling of construction debris from the building of homes. Wood, drywall and cardboard -- which made up 70-75 of the total debris -- were ground up using a small, mobile shredder. The wood was shredded to generally a less than 2 inch size, while the gypsum essentially processed into dust. The materials were then used either as mulch or as a soil amendment. The process was found to be less expensive than landfilling of the material, but there were problems with the unattractiveness of the mulch and the lack of availability of the wood mulch for erosion control during foundation and backfill work. The project was sponsored by the Indiana Department of Environmental Management and the US EPA.

279. Patent 3,673,095. Oil and Grease Absorbing Composition Comprising Sphagnum Moss, Calcined Gypsum and Perlite, from Internet site <http://www.patents.ibm.com>

This patent was granted in 1972 to Ralph M. Archer of Portland, OR, for an oil and grease absorbent using sphagnum moss as the major ingredient and calcined gypsum as a minor ingredient to act as a fire retardant.

280. Patent 3,820,970. Less Dusty Granular Gypsum Product and Process, from Internet site <http://www.patents.ibm.com>

This patent was granted in 1974 to the United States Gypsum Company, Chicago, IL, for a compaction-granulation process of producing less dusty gypsum granules.

281. Patent 4,048,337. Gypsum Dust Diluents for Use in Pesticides and Fertilizing Products, from Internet site <http://www.patents.ibm.com>

This patent was granted in 1977 to Bruno Fabbian of Asigliano Veneto (Vicenza), Italy, for the use of gypsum in a granular or powder form to be used as a carrier for either pesticides or for leaf and soil fertilizers.

282. Patent 4,163,674. Process for Making a Synthetic Liquid Absorbent and Products Resulting Therefrom, from Internet site <http://www.patents.ibm.com>

This patent was granted in 1979 to the Oil-Dri Corporation of America, Chicago, IL, for the manufacture of gypsum granules for use as an absorbent for oil and grease, as an absorbent in pet toilet boxes, or as an absorbent that can be used to carry a chemical insecticide, herbicide or fungicide. The granules can also be used as a ground cover. It is said that gypsum as a naturally occurring mineral or as a powdered plaster is not suitable as an absorbent, but that by controlled processing, absorbent granules can be made that have properties that are substantially equivalent to those of absorbent clay granules. The granules are made from a mixture of between 15% water and 85% plaster to about 50% water and 50% plaster.

283. Patent 4,264,543. Process for Manufacturing Synthetic Gypsum Absorbent Granules, from Internet site <http://www.patents.ibm.com>

This patent was granted in 1981 to the Oil-Dri Corporation of America, Chicago, IL, for a process to manufacture granules made of gypsum using a rotating, incline disc machine. The granules are suitable for use as absorbents for oil, grease and other liquids, for animal toilet refuse as in cat boxes, and for serving as carriers for agricultural chemicals.

284. Patent 4,278,047. Absorbent for Animal Excreta, from Internet site <http://www.patents.ibm.com>

This patent was granted in 1981 to Sebastiano F. Luca of Berlin, Germany, for an animal toilet litter. Gypsum can be one of the ingredients, which increases the specific weight of the litter, and it is said that then the litter will not adhere to even very long-haired animal pelts.

285. Patent 4,570,573. Composition Useful as a Cat Litter, Plant Mulch or Grease and Oil Absorbent, from Internet site <http://www.patents.ibm.com>

This patent was granted in 1986 to Cincinnati Fiber Inc of Cincinnati, Ohio, for a mixture consisting of 60-94% paper and clay absorbent, 3-12% water and 1-35% gypsum as a neutralizing agent for use as a cat litter, plant mulch or grease and oil absorbent. The

gypsum is said to react with the urea in the pet urine to form a urea sulfate salt, thus preventing the breakdown of the urea into a number of products, including ammonia, which has an odor.

286. Patent 4,917,837, Gypsum-based Insecticide Pellets and Method of Manufacture, from Internet site <http://www.patents.ibm.com>

This patent was granted in 1990 to John L. Clarke, Jr., Riverside, IL, for the manufacture of a gypsum pellet with insecticide which provides for a time-release of the insecticide dependent on the size of the pellet. The pellets are formed under high pressure by a briquette-making machine.

287. Patent 5,980,627, Production of Commercially Useful Materials for Waste Gypsum Boards, from Internet site <http://www.patents.ibm.com>

This patent was granted in 1999 to Gaetan Marcoux of Candiac, Canada for a process to make products from waste gypsum. The process is described as follows:

- (a) grinding the waste gypsum boards to obtain particles having a substantially uniform size;
- (b) drying the particles obtained in step (a) to obtain moisture-free particles;
- (c) heating the moisture-free particles obtained in step (b) at a temperature of 128 to 162° C. to convert the calcium sulfate dihydrate to calcium sulfate hemihydrate and thereby obtaining particles containing calcium sulfate hemihydrate;
- (d) adding water to the particles obtained in step (c) to form a paste;
- (e) forming the paste obtained in step (d) into a shaped product; and
- (f) drying a shaped product obtained in step (e) at a temperature of 105 to 120° C. to obtain an absorbent or filler material

The materials is send to be suitable for use as an absorbent for oil, grease and chemicals on floors, in animal toilet applications, as carriers for chemicals, such as a pesticides and herbicides; as a filler for agricultural and horticultural applications; or can be mixed with adhesive agents, can be applied onto walls and/or floors to provide a decorative coating.

288. "Putting Sustainable Development into Practice: An Overview", Philip Bennett, Eurogypsum XXII Congress Conference Proceedings, The Hague, May 13-15, 1998, 1 page summary, and 6 page paper

Mr. Bennett is the Secretary-General of the trade organization Eurogypsum and in his summary paper notes that "Virtually all production of [gypsum] waste is now reusable in the industry's plants and there are several examples of the industry encouraging the collection and sorting of construction site gypsum scrap for recovery either for reuse in gypsum plants or for recycling for other uses."

In his main paper, it is noted that Europe has around 1 billion metric tons of gypsum reserves, but access to this material is increasingly difficult. Synthetic gypsum is limited to impurities and other quality problems and the supply may be in jeopardy in the future, especially if the use of coal as a fuel source declines or other means of desulfurization are put into use.

Eurogypsum subscribes to a policy of shared product responsibility.

[Also see web page <http://www.eurogypsum.org>.]

289. "Raw Materials Supply: Practising Conservation Without Starvation", Plev Ellis, Eurogypsum XXII Congress Conference Proceedings, The Hague, May 13-15, 1998, 1 page summary, and 13 page paper

Plev Ellis works for BPB Gypsum Industries Ltd of Dublin, Ireland. The summary paper notes the gypsum industry needs to implement a comprehensive and credible strategy that satisfies the concept of sustainable development.

Much of the main paper is directed at the issue of mining gypsum (including the protection of several "fairy forts" at mines in Ireland), and mine restoration. Reference is also made that the life cycle impacts of gypsum are very favorable, and a citation is given to a Swedish report, "A Life Cycle Assessment – A Comparison Between Three Different External Walls and Possible Improvements", Swedish Waste Research Council, AFR [Avfallsforskningrådet?], Dnr 507/92 Dos 210

290. "Raw Materials Gypsum in Europe: Potential Usage of Synthetic Gypsum other than FGD Gypsum", Emmanuale Geeraert and Guido De Lange, Eurogypsum XXII Congress Conference Proceedings, The Hague, May 13-15, 1998, 1 page summary, and 9 page paper

The authors work for GYPROC Benelux N.V. in Belgium. Europe uses about 30 million metric tons of gypsum a year, and the synthetic forms are not large enough to meet these needs. Future supplies from natural sources are also limited by urbanization and land use restrictions, while synthetic supplies are limited by logistical concerns and changes in energy policies that are aimed at reducing the use of coal.

Natural supplies of gypsum in Europe are estimated at about 800 million tons, and Western Europe extracted about 21 million tons in 1986.

Synthetic supplies for gypsum include the following, along with the production figures for Europe:

## Annual European

Source	Production
Flue gas desulfurization	8 million tonnes a year
Phosphogypsum	10 million tonnes a year
Titanogypsum	2 million tonnes a year
Citrogypsum	230,000 tonnes a year
Borogypsum	120,000 tonnes a year
Fluoroanhydrite	540,000 tonnes a year
Miscellaneous sources	Not given

However, except for the gypsum from flue gas desulfurization, relatively little of the other sources of gypsum are used by the gypsum industry, due to impurities or specification limitations. The supply of FGD gypsum is expected to peak within a few years, and, while phosphogypsum and titanogypsum are the most favorable additional sources, both industries are shutting down production capacity in Europe.

291. "Integrated Gypsum Waste Management: Prevention, Recycling and Disposal", Dr. Dietrich Molden, Eurogypsum XXII Congress Conference Proceedings, The Hague, May 13-15, 1998, 1 page summary, and 20 page paper

The author is from a German organization, Gebr. Knauf Westdeutsche Gipswerke. Eurogypsum's Gypsum Waste Management Task Group began in 1996 to work on intensifying the attention given to characterizing the disposal situation of gypsum waste, including an evaluation of activities and regulations in the member countries.

The amount of gypsum waste disposed of annually in Europe is estimated at about 5 million metric tons a year, about 2 to 2.5% of the 217 million tonnes of construction and demolition debris disposed of each year.

From a regulatory viewpoint, only Netherlands at this time has regulations on the recycling or take back of gypsum waste. France will require recycling of all production and construction gypsum waste by 2002.

Production waste is recycled in at least 50% of the production facilities in Europe, and the remaining plants will soon be constructing facilities to recycle production waste, with a typical cost of the additional equipment about ECU 1.5 million.

For wallboard from construction sites, little is being recovered due to the difficulties of quality.

From demolition sites, wallboard is often viewed as a contaminate to recyclers of building rubble. The wallboard is either landfilled, used for recultivating or filling of mines. Research is underway to thermally process the wallboard is underway.

Disposal costs for gypsum vary considerably, averaging between 2 and 40 ECU/tonne, but up to 412 ECU/t in an extreme case in Germany. [These prices seem to be for more than just gypsum waste.] While there are standards for levels of sulfates in drinking water, there are no known toxic effects from dissolved calcium sulfate, and, in Germany, gypsum is classified as having "in general does not endanger water".

It is recognized that the building industry is becoming more conscious of waste management issues and that it would be a marketing advantage for the gypsum industry if it could demonstrate the recycling possibilities for gypsum.

The paper lists publications from Germany, France, the Netherlands and Scandinavia on the reuse and recycling of gypsum.

[Also see web page <http://www.knauf.de/>]

292. "Recovery for Reuse of Gypsum Scrap from Construction Sites", Ir. Hans Scheepbouwer, Eurogypsum XXII Congress Conference Proceedings, The Hague, May 13-15, 1998, 1 page summary, and 14 page paper

The author is from NBVG [Nederlandse Branche Vereniging Gips, a trade association] in the Netherlands, which is recycling gypsum scrap from construction sites. The firm began its program to recycle this material after the Dutch government set a directive to reuse at least 80% of recyclable construction waste by 2000 and raised the disposal fee by up to 500% in order to stimulate recovery.

Three categories of gypsum waste were recognized – production waste, construction waste and demolition waste. Easiest to recycle is production waste, hardest is demolition waste. Most factories already recover their production waste, so NBVG decided to tackle the issue of construction waste, and developed a container for collecting this material on jobsites. Labeled the "4 in 1 container", it has separate, locked compartments for gypsum, paper, plastic and chemicals (such as polyurethane and primer). It is a closed container, which thus encourages separation of material and discourages contamination of materials.

Currently, the system is focusing on the recovery of gypsum block [which is used for partitions and tiles for certain ceiling constructions], although work is underway for the recovery of plasterboard scrap.

The association acts as a go between for the building contractors and the recycling company Jannes Vos, helping with the drawing up of contracts. It does not get involved in the day-to-day operation, which is directly between the builder and recycler.

The gypsum scrap is sent to one of three recycling plants in Holland operated by Jannes Vos, from which it is then shipped to the end markets. There are two end markets, Gyproc in Belgium and Lafarge in northern Holland, both of which calcinate the gypsum for reuse. Both plants charge to take the scrap gypsum.

At the time of the presentation, 74 of the NBVG containers were in use and of the estimated 7,000 tons of scrap gypsum block waste from construction sites, about 1,380 tons, or 20%, was recycled in a 12 month period.

The cost of having the container is said to be economical in comparison to taking waste to landfills. In addition, penalty fees for contaminated material makes the system self-regulating for providing clean material.

Future plans are to explore the recovery of other types of material, including plasterboard scrap. Depending on future government policies, the recovery of other types of gypsum waste, including demolition debris, may also be studied.

[Also see web page <http://www.avdint/avd-is/nbvg>]

293. "Plasterboard Recycling in Denmark", Karsten Ludvigsen, Eurogypsum XXII Congress Conference Proceedings, The Hague, May 13-15, 1998, 1 page summary, and 8 page paper

The author is with RGS 90 A/S in Denmark, which is working on systems for the recovery of gypsum plasterboard.

Denmark has an aggressive national program to divert materials from landfills and incinerators, and beginning in 1987, has imposed escalating national fees on landfills and incinerators to provide an economic incentive for diversion. In 1997, the fees for incinerators were DKK 210 per tonne for incinerators with heat and power recovery and DKK 260 for systems with only heat recovery, while landfills had a surcharge of DKK 335 per metric ton [as of March, 2000, there were 7.75 DKK per US dollar, so the DKK 335 per metric ton is equal to about \$39 per ton].

Local units of government have the overall administrative responsibility for solid waste management in Denmark, and are to ensure that the necessary treatment facilities exist and that the waste is delivered to these facilities. Treatment of waste has traditionally been in public sector hands, managed by corporations set up by the local units of government.

Construction and demolition debris is handled by an integrated system and recent data suggests that up to 80% is recycled. Typically, wastes are sorted at the source. The dominant materials being landfilled are plasterboard and ceramics, including an estimated 20-30,000 tons of plasterboard a year.

Denmark has two plasterboard manufacturers (Gyproc A/S and Danogips A/S), with domestic consumption estimated at about 10-120,000 tonnes a year and an equal amount exported. Both firms have done a number of research studies in recent years, and both firms have announced a system for the recovery of plasterboard from new construction. There are no plans to handle materials from remodeling and demolition sites until a way is found to remove the contamination. Because the economic, technical and environmental factors do not always allow for the recovery of plasterboard back into plasterboard, alternatives also need to be developed and the most promising appear to be agriculture and cement production. RGS 90 A/S has successfully tested the composting of plasterboard with garden and park debris and successful trials of agricultural use of plasterboard have also been done in Sweden.

RGS 90 A/S is currently investigating other options to recycle plasterboard within the construction industry, assessing the viability of each option with respect to the material sent to the Kalvebod Recycling Center in Copenhagen, which handled 750,000 tons of construction waste in 1997.

294. "Geo-Chemical Behaviour and The Environmental Impact of Gypsum Waste and Gypsum Plasterboard", Jean-Michel Schmitt & Pascal Viennot, Eurogypsum XXII Congress Conference Proceedings, The Hague, May 13-15, 1998, 1 page summary, and 23 page paper

The two authors work for the Geological Information Center of the École des Mines de Paris in France and carried out research on the impact of the land disposal of gypsum mixed with other demolition products at the request of the French National Gypsum Industry Union. Three goals were identified:

1. To understand the geo-chemical and bio-chemical processes involved with the disposal of gypsum debris.
2. To quantify the environmental impact, particularly on groundwater, of the disposal of gypsum debris.
3. To learn how to better manage gypsum debris disposal sites.

The study consisted of both a literature review as well as in-field tests at two disposal sites, the first where the waste is dry and in an aerobic environment and the second where some of the disposed material is constantly in the groundwater.

The two areas researched were the effect of the gypsum debris on air emissions and the effect of the gypsum debris on the groundwater.

For the air emissions, it was found that in aerobic conditions, the paper on the drywall contributed to carbon dioxide emissions. In conditions where there is considerable moisture and conditions are anaerobic, the decomposition also produced considerable hydrogen sulfide gas.

For the study of the potential groundwater impacts, an extensive modeling was carried out, looking at three main types of aquifers: (1) a free aquifer of the karstic type, which is contained in a calcareo-dolomitic series, (2) an aquifer in a red sandstone and oxidized series, which contains a siliceous cement, and (3), an aquifer in a sandstone series which contains pyrite. The leachate model uses two different initial concentration in the leachate - 1,500 mg/l of sulfate and 600 mg/l calcium for a site with a majority of gypsum waste, with these parameters determined by on-site analyses, and a diluted leachate of 300 mg/l for a site where gypsum is only a minority of the waste.

The simulation found that from the site with the waste being primarily gypsum the aquifer had an increase in sulfate levels of a maximum of 100 mg/l just down gradient of the disposal site. At 200 meters, the maximum increase was 60 mg/l, while at 500 m, the increase was less than 40 mg/l. For the diluted leachate, the increases were about 1/5 of the concentrated leachate. In addition, it was noted that the leachate did have a substantial impact on increasing the reduction potential of the aquifer, although this did not adversely affect water quality. Finally, the land disposal of gypsum, when accompanied by the disposal of organic material, did include the risk of the development and growth of sulfur-reducing bacteria, which must be controlled.

295. “Genanvendelse af gipsaffald [Recycling of gypsum waste]”, Ren Viden, Denmark, November 1999, page 23 [available on the Internet at <http://www.affaldsinfo.dk/>]

Gypsum waste from construction and demolition projects in Denmark is largely landfilled, and is one of the largest single waste streams disposed of in Denmark.

Several firms (Kalvebod Miljøcenter, I/S Vestforbrænding and RGS 90) are jointly working on a project with the gypsum industry to investigate possible methods to reuse gypsum waste. Contamination is a problem for recovery. The cement industry may be a potential market for recycling. [Also see references 293 and 296.]

296. “Genanvendelse af gipsaffald [Recycling of gypsum waste]”, Gunner Larsen, Vestforbrændings Blå serie nr. 40, September 1999, Copenhagen, Denmark, 18 pages

Several businesses (Vestforbrænding, RGS 90, the gypsum industry) and Copenhagen jointly did a research project for the recycling of gypsum waste.

According to the latest data, 80% of building waste is currently recycled in Denmark, with the primary construction material still being landfilled including gypsum waste. It is estimated that in the Copenhagen area alone, some 10,000 metric tons of gypsum waste is disposed. A large part of that is received by the Kalvebod Miljøcenter and at Vestforbrænding’s reuse station, from which it is then taken to approved disposal sites. This project was initiated to determine potential markets as well as barriers to the recovery of this material. Six main goals were identified:

- A. To characterize the material received at the two facilities by quantity, type and composition
- B. To establish a two part system for the receipt of material, with one part for clean material and the other for the remaining material
- C. To collect information on the experience of others both in and outside the country for the recycling of gypsum debris
- D. In cooperation with the gypsum industry, to evaluate the potential for reusing gypsum scrap in the manufacture of gypsum products and to sketch out the possible collection and handling systems to meet the industry’s requirements
- E. In cooperation with the cement industry, to evaluate the potential for using gypsum scrap in the manufacture of cement and to sketch out the possible collection and handling systems to meet the industry’s requirements
- F. To perform a cost/benefit analysis of the possible collection and handling systems

Gypsum drywall is produced by two firms in Denmark, Danogips A/S, which has two factories, and Gyproc A/S, which has one manufacturing plant. In 1998, some 110,000 – 120,000 tons of drywall were consumed in Denmark, and an equal amount was exported.

Drywall comes in three main types – normal interior with 0.02% fiberglass in the paper layer, hard wearing interior with 0.25% fiberglass in the gypsum, and exterior drywall with silicone oil in the gypsum and the paper cover impregnated with wax. For interior wall gypsum, typical data are:

Component	Wt Per Tonne
Industrial Gypsum	670 kg
Natural Gypsum	280 kg
Paper	50 kg
Accelerator	3 kg
Corn starch	3 kg
Fiberglass	0.2 kg
Additives	0.2 kg

The industrial gypsum is produced from the air pollution control equipment which removes sulfur from the emissions of coal burning facilities.

The amount of gypsum drywall available for recovery is broken down by sources of generation. Production scrap at the three plants is put at 15,000 tonnes in 1998, and is already recovered to make new drywall. The scrap at construction sites is estimated at 15-20% of consumption, or a minimum of 16,500 tonnes in 1998. The amount of demolition drywall produced is difficult to estimate, but will be increasing as time goes on and existing offices and buildings are renovated or demolished.

The experience of recycling gypsum was reviewed both by contacting industry within Denmark and by attending the 1998 conference of Eurogypsum. For the gypsum industry, the internal scrap is already recovered, while the recovery of external scrap requires that the material be clean of contaminants (metal, stone, ceramic, other hard materials, hessian [a burlap type of fabric], wire mesh, etc). It is would then need to be processed to have a minimum of paper and a particle size of 20-30 mm. If these specifications are met, up to 25% can be substituted for the raw gypsum, and thus, in Denmark, with production at 220,000-240,000 tonnes a year, the total recoverable is 55,000 – 60,000 tonnes a year.

Gypsum can also be used for agricultural purposes, and research has been done in Sweden on the value of gypsum as a fertilizer. In Denmark, RGS 90 A/S has done research on the composting of drywall with garden and park waste, with good results. As before, the gypsum needs to be free of contaminants, and this project did not research this area further, preferring instead to focus on reuse by the gypsum industry.

The cement industry also uses gypsum and can use drywall with some burnable contamination, such as the paper and tape, but free of metal, stone and similar contamination. There is one cement producer in Denmark, which makes 2.6 million tonnes of cement annually, using 103,000 tonnes of gypsum, including 58,500 tonnes of natural gypsum. Work is underway at the cement producer to look at cleaning up scrap drywall for use in the cement making process.

As part of this project, a two part receiving system was developed, one for loads of clean drywall, the other for loads of drywall that had tape, wire mesh, paint, etc on it. Because of the short time during which this research was being done, it was not possible to set up an economic incentive system to encourage customers to presort the drywall.

During the projects, 700 tonnes of drywall were received and none were completely clean. Visual control and removal of contaminants was necessary, and was done with a poly-grab crane. However, this was not entirely satisfactory, as it prevented seeing all contaminants. The comparative cost of handling the drywall for disposal and recycling were calculated as follows:

**Cost to Handle Drywall DKK/tonne**

Task	Landfillin g	Recycling
Handling	50	300
Transportation	40	80
Disposal	400	100
Total	500	480

Danogips is working on a system to recover drywall that will include a vacuum system to remove paper, a magnet to remove magnetic metal and the removal of other, large contaminants with visual inspection and removal.

For future activity, it is noted that gypsum, while the largest component of construction and demolition debris being landfilled, is not one of the priority materials of the Danish environmental agency, which is instead targeting materials that have a more significant environmental impact. However, the authors propose to continue their work, both in discussions with the gypsum industry for the recovery of drywall and with the Danish environmental agency for setting up the necessary administrative structure.

297. "Raleigh, North Carolina. Over 17 Projects for Recovery of C&D Debris", BioCycle, March 2000, page 24; February 4, 2000 news release of the North Carolina Department of Environment and Natural Resources, [http://www.p2pays.org/news/press\\_releases/2400.htm](http://www.p2pays.org/news/press_releases/2400.htm); personal correspondence with John Blaisedell of the NC DENR, March 28, 2000

The state of North Carolina is providing \$278,700 in grants for 17 public and private sector projects on C&D debris recovery, including three projects specifically on gypsum debris:

- "Gypsum Drywall Processing" establishes a gypsum recycling facility in Charlotte, N.C. The firm currently has a scrap drywall processing and manufacturing facility in Goldston, NC, and is planning to develop a smaller facility to handle scrap from construction sites. Processing will include crushing the drywall to a powder and removal of the paper. End use will be for a hydroseed mulch application. Contact is Gerry Sutton, Waste Reduction Products Corporation, Goldston, NC, (919) 898-4105.
- "Gypsum Recycling" establishes a recycling facility to process gypsum for agricultural uses in the Union County area. New construction scrap will be ground and screened to a fine mesh for land application. Contact is Steve Davis, Union Gypsum, Marshville, NC, (704) 624-2077.

· "Recycling Gypsum from C&D Debris" will expand an existing system for the collection, transportation, and recycling of gypsum from contractors in Orange County, with the work done by a Boy Scout Troop. Contact is Robert J. Kessler, Recycling for Youth Inc., Chapel Hill, NC, (919) 942-4830

Contact for the state program is John Blaisedell at the Department of Environment and Natural Resources at (919)715-6522, email [John.Blaisedell@ncmail.net](mailto:John.Blaisedell@ncmail.net)

298. Year 2000 Construction and Demolition (C&D) Debris, Grant Cycle, REQUEST FOR PROPOSALS, N.C. Department of Environment and Natural Resources, Division of Pollution Prevention and Environmental Assistance, [http://www.p2pays.org/financial/previous/c\\_d.pdf](http://www.p2pays.org/financial/previous/c_d.pdf), March 28, 2000

As part of the state's description of available financial assistance for construction and demolition debris, it is noted that Pitt County, NC is currently operating a program to encourage source separation of gypsum from its C&D waste stream. In the 1997 C&D Debris grant cycle, funding was used to add a drop-off station for gypsum wallboard. For more information contact Phil Dickerson, County Engineer, at (252) 830-6352.

299. "Wallboard Feeds the Soil. Can Waste Wallboard Find a Home on the Farm Rather than in the Dump", University of Wisconsin College of Agricultural & Life Sciences Quarterly, Summer 1999, page 12. Also on the Internet at [http://www.cals.wisc.edu/media/news/04\\_99/wallboard\\_alfalfa.html](http://www.cals.wisc.edu/media/news/04_99/wallboard_alfalfa.html). (Also see references 159, 182, 193 and 246.)

Research at the University of Wisconsin on using gypsum drywall as a fertilizer for alfalfa found neither a positive or a negative effect. Gypsum can provide both calcium and sulfur to the soil – along with other lesser nutrients – and sulfur is often beneficial to alfalfa, with deficient soils in Wisconsin having a recommendation for an application of up to 50 pounds per acre. With test applications of 1 to 16 tons of wallboard per acre, the yields of the alfalfa tended to increase with increased applications of the wallboard, but no statistically significant increases were noted. At the higher levels, there were some changes in soil chemistry, with the biggest concern being that the calcium in the gypsum displaced some magnesium, leaving some soils magnesium deficient.

The study concluded that gypsum from drywall was as effective as commercial gypsum as a fertilizer and that farmers who use drywall limit the application to 1 ton an acre for sands and loamy soils and 3 tons an acre on loams and heavier soils. An application every 3 to 4 years will generally be sufficient to provide forage legumes with sufficient sulfur.

300. Personal conversation with James Williams, Specialty Sales Representative, United States Gypsum Company, voice mail, (800)874-8880, extension 6654, email [jwilliams@usg.com](mailto:jwilliams@usg.com), April 7, 2000

Mr. Williams said that USG recycles all of its internally generated drywall scrap and accepts clean drywall scrap delivered to its plant for recycling at no charge and no payment. USG has developed its own, proprietary wet grinding system to process the scrap. Although some of the paper floats off in this process, no other special effort is made to remove the paper.

301. Web page of San Jose's Zanker Road Landfill gypsum efforts, <http://www.z-best.com/zankerrd/>, June 29, 2000

Gypsum wallboard is processed for recycling at this landfill. Generally, the scrapped material is received from contractors or separated from mixed loads. The gypsum wallboard is ground and then screened. The powered gypsum is removed and stored for sale to markets, which are not listed on the web page. The residual paper is added to the green waste composting process which adds calcium and sulfur to the finished compost.

302. Email message from Heidi Feldman, Public Education Coordinator, Monterey Regional Waste Management District, Marina, CA, 831/384-5313, email [hfeldman@mrwmd.org](mailto:hfeldman@mrwmd.org), June 2000

They add gypsum to both the compost and topsoil that they produce.

303. Email message from Stephen Grealy, [SKG@sdcity.sannet.gov](mailto:SKG@sdcity.sannet.gov), on [GreenYes@earthsystems.org](mailto:GreenYes@earthsystems.org) mailing list, June 29, 2000

It is noted that recycled drywall is not allowed in organic agriculture; his understanding is that this has to do with the glues/binders and the fumigants used in the drywall used in wet areas (e.g. bathrooms).

304. Patent 6,060,086. Drywall Recycling System. Resource Recycling, September 2000, page 23: web page <http://www.delphion.com/details?&pn=US06060086>, January 28, 2001

Ted Belanus and James Kramer of Brooklyn, Wisconsin have received a patent for the use of recovered drywall for use in farm barns to reduce bacterial counts, fly populations and odor. The material is applied at the rate of 3-10 g/square foot [patent does not say if 'g' stands for gram or gallon, but it appears to be gram].

305. "Drywall Improves the Compost Mix", BioCycle, September 1999, page 51

Tim Gunter of Maui Earth Products in Hawaii added 40 tons of gypsum drywall scrap to a windrow of vegetative material that was 14 feet wide and 100 feet long. The pile was turned with a Scarab turner and the drywall broke up into pebble sized pieces that passed through his 3/8" homemade screen. He notes that the gypsum would help with the clayey and high sodium soils on the island.

306. "Exploring Gypsum Drywall Recycling". Timothy Townsend and Chuck McLendon, Resource Recycling, December 2000, pages 34-39.

In Florida, several components of the construction and demolition stream are being recycled, including asphalt, concrete, metal, corrugated cardboard, and wood. However, drywall is not currently being recovered. The landfilling of drywall can cause environmental problems, with several lawsuits or remedial action being underway due to problems due to the generation of hydrogen sulfide gas.

The recovery of drywall focuses on material from new construction due to the problems of potential contamination from drywall in existing buildings. Recovery methods include:

Make new drywall	Competition from synthetic gypsum is a barrier
Farm application	Challenge is to educate farmers on the benefits of calcium and sulfur in drywall
Cement additive	Must have proper processing of the scrap drywall
Other prospects	New markets could include construction materials, grease absorber, cat litter

Several Florida counties have received innovative recycling grants to explore gypsum drywall recycling. Citrus County studied the use of drywall for making new drywall and as an additive in Portland cement. The New River Solid Waste Association was awarded a grant for the use of scrap drywall in agriculture and in the construction of roads. Okaloosa County received a grant to study the use of drywall in compost for peanut farming.

These projects will not finish until early 2001, but preliminary results have should the following issues to be important:

- Markets – the two most promising are agriculture and cement manufacture
- Processing – dust control and paper removal are key
- Collection and economics – the cost of collection for recycling and the competing cost of landfilling is a major barrier

Work is expected to continue to focus on the issue of setting up economical separation and collection systems.

Mr. Townsend can be reached at [ttown@ufl.edu](mailto:ttown@ufl.edu); Mr. McLendon can be reached at [cmclendon@rwbeck.com](mailto:cmclendon@rwbeck.com)  
[Also see references 264, 271-273]

307. Telephone conversation with Pete Runhaar, Green Valley Disposal, Waunakee, WI, (608)251-7878, February 19, 2001; DNR Letter to Pete Runhaar dated January 29, 2001

Green Valley Disposal has received state approval to use recycled gypsum drywall scrap from a commercial construction project for agricultural uses at a farm in Dane County, Wisconsin. However, approval excludes several types of drywall, including "greenboard", sheathing, water-resistant products and fire-resistant (Type X) products.

308. Gypsum Wallboard Recycling and Reuse Opportunities in the State of Vermont, Emma Marvin Waste Management Division, Vermont Agency of Natural Resources, August 4, 2000, 44 pages

On the Internet at <http://www.anr.state.vt.us/dec/wastediv/recycling/gypsum.pdf>

This report examines alternative methods for recovery gypsum drywall from new construction, evaluating the alternatives against eight criteria.

The alternatives evaluated are:

- Reuse through donation
- Reuse for resale
- Recycling back into drywall
- Soil amendment as a compost bulking agent or additive
- Agricultural land application
- Recreational land application
- On site land application
- Athletic field marker
- Animal/livestock bedding
- Cement production
- Facilitate sodium leaching
- Flea powder
- Grease/spill absorbent
- Mine reclamation
- Mushroom growing
- Odor reduction
- Water treatment

The criteria used for evaluation were:

- Processing impacts
- Transportation costs
- Storage requirements

- Disposal fees
- Regulatory concerns
- Competition from other products
- Stakeholders' motivations
- Environmental impacts and other considerations

For each alternative, a summary sheet is provided with information on the above criteria, with descriptions of tests, pilot projects or operating systems, where available.

It is estimated that about 7,500 tons of drywall scrap are produced a year in Vermont, with about 5,000 tons from new construction. The report does not make any recommendations on which of these options should be pursued, although the last nine are labeled in the table of contents as being low priority for Vermont.

309. Email messages from Jenna Kunde, WasteCap Wisconsin, WasteCap [jkunde@wastecapwi.org](mailto:jkunde@wastecapwi.org), April 10, 2001, May 15, 2001, June 27, 2001, and July 15, 2001

Because of state restrictions on using Type X drywall in a gypsum recovery project where the material is to be recovered for agricultural purposes due to the concern about the impact on the fiberglass on the soil biology, WasteCap Wisconsin has been leading an effort to have some research done of these effects. A researcher at the University of Wisconsin-Madison (Dick Wolkowski) has agreed to do this research pending funding, and DNR has approved the proposed method of study. The study will be based on the US EPA Earthworm Subchronic Toxicity Test (OPPTS 850.6200) with one control level and five levels of simulated application of drywall. The test will take about four weeks. (Also see reference 307.)

310. Mineral Commodity Summary, on the Internet at <http://minerals.usgs.gov/minerals/pubs/commodity/gypsum/>, accessed July 17, 2001

For 2000, the US consumption of gypsum is estimated by the US Geological Survey at 39.9 million tons, an increase from 27.9 million tons from 1996, for a 43% increase in four years. Over the same time period, crude gypsum production increased from 17.5 million tons to 25 million tons, while synthetic gypsum use rose from 2.5 million tons to 6.3 million tons. Wallboard production grew from 23.7 billion square feet to 35 billion square feet. It was noted that only a small amount of gypsum is recycled. About 5.5 million tons of gypsum were used in cement production in 2000, along with 4 million tons for agricultural applications. Other uses were minor.

The average mine price of gypsum has been relatively constant, and dropped from \$7.10 a ton in 1996 to \$7.00 a ton in 2000.

311. Tour of the University of Wisconsin Biotron, Madison, Wisconsin, August 13, 2001

A tour was given by Dr. Wolkowski of the research project to test the toxicity of Type X drywall on worms. The test is nearly complete, and there does not appear to be any adverse affect on the worms from varying levels of drywall as compared to the control. A report will be published when the work is finished. (Also see reference 309.)

312. Tour at the Helt Farm, Waunakee, Wisconsin, September 20, 2001

Green Valley is working with the Helt Farm to recover drywall from the Alliant Energy headquarters project for agricultural use. Drywall has been stockpiled at an old quarry at the farm and test equipment was brought in to grind it, using both a 3" screen and a 2" screen. A scheduled land application demonstration had to be postponed due to very wet weather and fields. The grinding operation went very smoothly, with a minimum amount of dust, which was probably due in part to the wet condition of the drywall. The grinding equipment firm noted that the drywall was easy to process and would provide little wear and tear on the equipment, greatly reducing maintenance. (Also see references 311, 309 and 307.)

313. "Recycling von Gipsplatten", Prof. Dr. Hans-Ulrich Hummel, Gebr. Knauf Westdeutsch Gipswerke, Iphofen, Germany, 6 pages. From the Darmstädter Massive Construction Seminar, October 1997. Accessed on the Internet at <http://www.b-i-m.de/Public/BVGips/damasemhummel.htm> on November 20, 2001. Email note from the author on November 26, 2001, at [Goetz.Irene@knauf.de](mailto:Goetz.Irene@knauf.de). "Von der Platte zur Platte", Prof. Dr. Hans-Ulrich Hummel, UmweltMagazine, March 1999, page 53

This paper summarizes the manufacture of gypsum drywall from a German perspective and includes two schematics of the production process.

The recovery of gypsum drywall is in part motivated by German law and regulations, which requires that the amount of construction waste in Germany must be reduced by 50% in 2005 as compared to 1995.

The quantity of scrap drywall produced annually in Germany is unknown. It is estimated that from demolition debris, drywall comprises 450,000 metric tonnes, or 1% of the 45 million tonnes generated. From the construction of buildings, 14 million tonnes of waste are produced, but a quantification of the amount of drywall scrap is not given. In addition, there is the scrap from manufacturing.

The author's employer, Knauf, has set up a process to recycle drywall scrap in accordance with the framework promoted by the LIFE program of the European Commission. In Knauf's process, the material is cut into small pieces and with applied pressure in a machine with a 20 tonne/hour capacity. The cardboard is largely separated from the drywall in this process. The material is then screened with a screen size of 25 mm (about 1 inch), with the overflows going back to the cutting and crushing process. The screened

material is then sent to a storage silo, and later to a milling machine, and ground to a smaller size, with the remaining paper removed. Finally, the gypsum is calcined and sold as plastering gypsum. The paper is recovered either for use in gypsum board or for other products.

In an email note from the author on November 26, 2001, it was learned that the system is currently operating and recovering drywall.

314. "Nedmalda gipsskiverester ett bra jordförbättringsmedel!" [Ground up gypsum scrap a good agricultural soil amendment!], Annika Henrikson, GyprocNytt, 1995-3, on Internet through search engine <http://www.gyproc.se/sok/index.html>, accessed December 10, 2001

In the 1994 and 1995, the Malmöhus, Sweden district residential company worked with Carl F AB of Malmö to test the use of ground up gypsum drywall as a soil amendment on winter oilseed rape [genus *Brassica*]. [Canola oil is a type of rape seed oil, with low levels of erucic acid.] They found dual benefits of both improving the soil – and a 20% increase in crop yields – as well as reducing the amount of material going to the landfill. A recommendation is for up to 2 tonnes of gypsum per hectare.

According to the research, the agricultural benefit of gypsum to winter oilseed rape is the sulfur, which had formerly been added to the soil from atmospheric deposition. It was also found that the heavy metal content of the drywall is very low.

Gypsum scrap can also be recycled back into drywall, but the environmental impacts of long transportation distances can outweigh the benefits of the recycling.

315. "Gipsrester – ett användbart material!" [Gypsum scrap – a reusable material!], Lotta Sigfrid, GyprocNytt, 1996-1, on Internet through search engine <http://www.gyproc.se/sok/index.html>, accessed December 10, 2001

Gypsum is a recyclable material and scrap drywall can be recycled back into drywall. But, it can also be reused in a variety of ways that avoids the environmental consequences of long distance hauling to drywall manufacturers.

At Gyproc's factory in Bålsta, 5,000 tons of scrap drywall can be recycled each year. This material comes from the Stockholm area as well as from the factory itself. How far the gypsum scrap can be economically transported depends on the value of the gypsum as well as the cost of alternative methods of handling. In the Malmö region, for example, the maximum transportation distance is about 190 km, with a truck load of about 25-30 tonnes.

Alternative methods of recovering gypsum scrap include:

- in liquid fertilizers
- in compost for mushroom growing
- as an agricultural soil amendment

In liquid fertilizers (such as waste from animal stalls), there is often a problem of ammonia emissions. Additives to reduce these emissions are relatively expensive and research at the agricultural university in Lund found that the use of gypsum along with superphosphate gave very good results. With some 8 million tonnes of liquid fertilizers produced in Sweden every year, this provides a possible outlet for 80,000 tonnes of gypsum scrap at a use ratio of 1 to 100.

The use of gypsum as a component of mushroom compost has been studied elsewhere – such as Holland – and a large mushroom grower uses gypsum scrap from the Gyproc factory in Bålsta. This producer can use up to 40 tonnes of gypsum a year. The gypsum provides for an improved physical stability, an improved water balance along with increasing the pH from 6.5 to 7.3.

As an agricultural soil amendment, gypsum has several benefits, including:

- adding sulfur to the soil
- improving the soil structure
- increasing aeration of the soil
- better moisture holding capacity
- stabilizing of pH values
- ability to bind up metals
- improve "sour" soils
- improve deep root systems
- improve the uptake of water and nitrogen by roots

316. "Lättbyggnadstekniken med gipsskivor gör stora framsteg inom byggandet!" [Light frame building technology with gypsum board provides large progress in the building trade! ], Lars-Göran Mattisson, GyprocNytt nr 1997-1, on Internet through search engine <http://www.gyproc.se/sok/index.html>, accessed December 10, 2001

Drywall consumption is shown at about 7 square meters per person per year in the US and Canada, and about 3.1 square meters per person per year in France, Norway and Sweden, the next highest consumers shown.

317. "Nasjonal handlingsplan for bygg- og anleggsavfall" [National Management Plan for Building and Factory Waste], jointly written by the organizations BNL, TELFO, MEF and PGL, February 15, 2001, accessed on the Internet on December 14, 2001 at <http://www.grip.no/okobygg/Nasjonal%20handlingsplan/Handlingsplan.doc>

In this Norwegian waste management plan, a goal has been set to recover 40% of all gypsum drywall waste by 2005, including recovery of drywall from demolition debris. Item number 17 on page 32 designates the responsibility for achieving this goal to two Norwegian firms, Norgips and Gyproc, would will work through the trade association ØkoBygg on the project known as "Gipsgjenvinning" [Gypsum recycling].

318. "Gips til gjenvinding" [Gypsum to recycling], Internet web page [http://www.danogips.dk/danogips\\_nf/genbrugsgips\\_nf.htm](http://www.danogips.dk/danogips_nf/genbrugsgips_nf.htm), accessed December 17, 2001

Several systems have been set up in Denmark to accept clean gypsum drywall for recycling, with the entire country covered. These systems include:

- Gips Recycling A/S, <http://www.gipsrecycling.dk>, which covers all of Denmark
- I/S Fælles Forbrænding, <http://www.isff.dk>, which covers Jylland
- RGS90, <http://www.rgs90.dk>, which covers Sjælland

The systems accept clean gypsum uncontaminated with wood, stone, concrete, glass, insulation, metal (including screws), etc. There is no mention of the costs or payments made for accepted material, nor what product or products the gypsum is recycled into. A search of these three sites did not find any reference to gypsum on the 2nd and 3rd sites, while the first site had no details of prices or uses. [Also see references 293, 295 and 296.]

319. "Sensitivity of Earthworms to Type X Gypsum Drywall Under Controlled Environmental Conditions", Richard Wolkowski and Ann Crosby, Department of Soil Science, University of Wisconsin-Madison, Madison, Wisconsin, 1 October 2001, 6 pages, accessed on the Internet at <http://www.wastecapwi.org/bulletin/drywallresults.htm> on January 24, 2002

As part of a project to recycle Type X drywall for agricultural purposes, the project directors were required to do a test of the impact of the drywall on soil organisms. The research on this part of the project was done at the University of Wisconsin-Madison using a recognized 28-day sensitivity test for earthworms. Two types of soils were used in the test, and five levels of dosages of gypsum drywall were tested, along with a control and one level of commercial gypsum fertilizer. Ten worms were used in each sample, and the number, weight and activity level of the worms was measured weekly. No differences were detected between any of the samples. [Also see reference 311.]

320. "Leading the Way to New C&D Markets", Jenna Kunde and Sonya Newenhouse, Resource Recycling, January 2002, pages 18-21

As part of the construction of the new 325,000 square foot corporate headquarters of Alliant Energy in Madison, Wisconsin, the drywall was recycled for agricultural use. Comprising an estimated 20% of the waste stream, drywall is commercial construction is second only to wood in quantity. After initially getting approval from the state environmental regulatory agency for the land application of regular drywall, it was recognized that the material being used was Type X drywall, which has a small amount of fiberglass added to provide an increased fire rating. In order to recycle this material, additional tests needed to be done of the environmental impact of the fiberglass and drywall on soil organisms, and an earthworm sensitivity test was done at the University of Wisconsin-Madison. The test showed no significant impact on the earthworms and approval for land application of this material was granted. Several grinders were tested for processing the material at a local farm and the ground material was applied by the farm at the rate of 1 to 2 tons per acre. [Also see references 319, 312, 311, 309 and 307.]

321. Field notes of Elke Roggenstein, UW-Madison Engineering Construction Management program intern with the Dane County, Wisconsin Department of Public Works, of a tour of the Knauf drywall production facility, Iphofen, Germany, January 2002, along with company literature

The Knauf firm was established in 1932 with a focus on gypsum processing and currently has 7,500 employees in facilities around the world, with 1,000 employees in Iphofen.

The recycling of drywall back began as a method to handle production scrap and to save the cost of landfill disposal, which is approximately 1000 Deutsche Mark per metric tonne, or over \$500 per US ton. In 1998, the European Union LIFE program initiated a measure to encourage the recycling of drywall, and this spurred further efforts, including recycling construction scrap drywall. The final report of this project is entitled Abschlußbericht zum Projekt. Aufbereitungsanlage für Gipskartonplattenabfälle von Baustellen und aus der Produktion, [Final Report on the Project. Processing Facility for Gypsum Drywall Waste from Building Sites and from Production], Prof. Dr. Hans-Ulrich Hummel, LIFE96/ENV/D/237, 1 August 1996 – 31 July 1998, 30 pages.

A two-step process is used to recycle drywall. In the first step, the delivered scrap is shredded in a machine with a capacity of 20 t/hour, with an ideal mix to use equal amounts of dry and moist drywall. Pressure is applied during the shredding process, which helps to remove the paper backing and then the material is dried. Next, the material is screened with a screen size of 25 mm. Overs go back to the shredder, while the unders are stored in a silo.

In the second step, the materials is fed onto a conveyor belt and mixed with grinding stones in a rotating drum. The material is further reduced in size and more paper is removed and screened material is sent to ovens for processing either to be used to make drywall (oven temperature about 160 C) or into material to make self-leveling floors (oven temperature about 600 C). All paper in both steps is recovered for use in drywall backing.

The Iphofen facility produces about 800 million square meters of drywall a year, and about 10% of the raw material comes from the recycling process, while 90% comes from pollution control systems for coal burning plants (synthetic gypsum).[Also see reference 313]

322. Mineral Commodity Summary, on the Internet at <http://minerals.usgs.gov/minerals/pubs/commodity/gypsum/>, accessed June 4, 2002

For 2001, the US consumption of gypsum is estimated by the US Geological Survey at 33.2 million tons, an increase from 29.5 million tons from 1997, for a 12.5% increase in four years. Over the same time period, crude gypsum production increased from 17.5 million tons to 18.8 million tons, while synthetic gypsum use rose from 2.5 million tons to 6.1 million tons. Wallboard production grew from 23.7 billion square feet to 29.6 billion square feet. It was noted that "a portion" of gypsum is recycled. About 3.8 million tons of gypsum were used in cement production in 2001, along with 2 million tons for agricultural applications. Other uses were minor.

The average mine price of gypsum has been relatively constant, increasing from \$7.11 a ton in 1997 to \$8.46 a ton in 2001.

Also see reference 310.

323. "Gipsaffald skal genanvendes!" [Gypsum Waste Should be Recovered!]", Ren Viden, Volume 2, 2002, page 7, accessed on the Internet on June 14, 2002 at <http://www.affaldsinfo.dk/user/723/2691.pdf>

In Denmark, some 65,000 metric tons of gypsum waste are produced annually, with approximately 13% scrap of the gypsum used in construction. Gypsum recycling is a new activity in Denmark, with the scrap collected in containers, crushed and then made into new gypsum. The current goal is to collect 30-40,000 tonnes a year. The firm Gips Recycling A/S is setting up a nationwide system to recover gypsum and has developed a special collection container as shown in the article. The firm has a mobile crusher, with a capacity of 30 tonnes an hour, and the gypsum is crushed down to 10-15 cm. It is then passed by a magnet and milled down to smaller size, with contaminants removed. Typically, the contaminants amount to about 15-20% of the inflow. One of the economic advantages of this system is the saving of landfill fees, which are significant. More information can be obtained from Gips Recycling A/S, <http://www.gipsrecycling.dk>, e-mail: [gr@gipsrecycling.dk](mailto:gr@gipsrecycling.dk). [Also see [http://www.danogips.dk/danogips\\_nf/genbrugsgips\\_nf.htm](http://www.danogips.dk/danogips_nf/genbrugsgips_nf.htm)]

324. Meeting with staff of USG Corporation, US EPA, Bill Turley of the Construction Materials Recycling Association and WasteCap Wisconsin, July 19, 2002, Chicago, IL

The meeting was initiated by Paul Ruesch of Region V of EPA to discuss ways that might be taken to facilitate the recovery of scrap drywall, in part by sponsoring a central clearinghouse of information. Paul was aware of a number of on-going projects to research recovery of drywall, but that this and other information is not being efficiently disseminated. There was agreement that the focus is on the recovery of drywall from new construction; there are too many concerns vis-à-vis contamination to consider the recovery of demolition drywall at this time. Paul noted that EPA is getting a substantial number of complaints from the disposal of drywall leading to the release of hydrogen sulfide emissions, including from construction and demolition debris landfills.

The staff of USG noted that the company does not endorse any specific method of drywall recovery because the environmental and safety issues have not been addressed to the point where they believe that they can make a recommendation. The company is working hard to recover more scrap drywall to make new drywall, but there are both technical and economic challenges, with the economics constrained by low gypsum prices, low landfill prices and the energy cost to transport scrap to a manufacturing plant. It was noted that USG make an agricultural gypsum; this was the first product of USG when it was created 100 years ago. On the issue of the fiberglass in Type X drywall, it was noted by Charlie Byers, Manager, Product Safety, that the fiberglass is a textile grade, and due to its large size, is not considered as respirable and therefore has not been labeled as carcinogenic. It was also noted that there is still uncertainty about the carcinogenic nature of finer-sized fiberglass, with IARC changing their rating from a possible carcinogen to a non-classified material in 2001 and NTP still listing the fine-size fiberglass as carcinogenic. This, however, does not apply to the fiber size used in Type X drywall.

325. "Environmental Issues. Drywall and Building Panels. Green?", Power Point Presentation of Rik Master, USG Corporation, July 25, 2002

This is a 38 slide presentation, and includes the following:

- gypsum has a very low embodied energy per ton, compared to other construction materials, such as aluminum (30 times as much), steel (5 times as much), plastics (5 times as much), glass (3 to 4 times as much) and concrete (twice as much)
- for the embodied energy, the breakdown is typically about 80% is from manufacturing, 15% from raw material transportation, about 4% from board transportation and about 1% from raw material mining
- for the recycling of drywall, the energy of backhaul exceeds the energy saved with a transportation distance of 200-500 miles
- in residential construction, about 20% of the drywall becomes waste; in commercial construction, about 2% becomes waste

USG currently can regrind dunnage drywall, without removal of paper, up to 10% by weight with new core slurry. If the paper is removed, USG could use 100% of reground material. Last year USG used over 30,000 tons of pre-site dunnage gypsum at our plants, Nation wide. All of the paper backing used for USG drywall is recycled material. According to a report of the National Association of

Home Builders (NAHB), the scrap drywall generated at a typical homesite could be safely applied to a plot of land 1/8th acre in size if processed<sup>326</sup>. "From Hero to Bum in Less than a Heartbeat", Jack Beardwood, MSW Management, July/August 2002, pages 68-72

Maui Earth Composting of Hawaii is grinding up gypsum drywall and recovering it as a soil amendment.

327. "With Business Booming, It's Time to Take Another Look at C&D", Chuck McLendon, Timothy G. Townsend, and Kimberly M. Cochran, MSW Management, July/August 2002, pages 50-53

In Florida, drywall is estimated to comprise about 6% of the weight of C&D debris, although it is noted that the composition of C&D waste can vary greatly by region, and in Florida, can range from 5% to 15%. The decomposition of drywall in landfills can produce odors in some circumstances, which has led to increased interest in the recovery of the material and the Florida Department of Environmental Protection has recently issued a number of grants to Florida counties for drywall recycling. The major barriers to the recovery of drywall including the low cost of disposal as well as the low cost of virgin gypsum.

Compiled by

John Reindl, Recycling Manager  
Dane County Department of Public Works  
August 19, 2002  
reindl@co.dane.wi.us

(Note: a former version of this bibliography has been placed on the North Carolina Pollution Prevention webpage at <http://www.p2pays.org/ref/02/01827.htm>)