

**Collecting, Processing and Building with Recycled/Reclaimed Construction Waste
WDNR Waste Reduction and Recycling Demonstration Grant No. 07-05
Final Report (October 31, 2008)**

Noble Earth Technologies, Inc. (Noble Earth) is pleased to present this final report for the Wisconsin Department of Natural Resources (WDNR) Waste Reduction and Recycling Demonstration Grant Project No. 07-05. The project work began on January 1, 2007 and was substantially completed by August 31, 2008. During that 20-month period the project goals of collecting, processing and building with a wide range of recycled/reclaimed waste construction materials were met or exceeded. Successes and challenges were experienced along the way, as is the nature of a demonstration grant project. Both are presented in this report with the overall conclusion that reuse of many waste construction materials is not only very possible, but it can be economically viable as well.

While reviewing this report, please be aware that the grant project scope of work changed from what was presented in the original grant application. As reported before, the changes to the scope of work, as detailed below, were positive and essential changes that reflected changes in the real estate market and the advancement of construction waste recycling that occurred in Dane County during 2007 and 2008. The specifics regarding the changes to the grant project scope of work were originally detailed in the First Interim Report (dated April 2, 2007) and were discussed and subsequently approved by Candice Sovinski (WDNR) around the time of her formal WDNR site visit on April 19, 2007. Additional clarification of the changes to the grant project scope of work were reported in the Second Interim Report (dated July 2, 2007). Although the scope of work changed, it is important to note that a vast majority of the intent of the original scope of work was still successfully accomplished and for about 7% less cost to the WDNR than what was originally proposed. The full overview of the implementation of the changed scope of work is provided in this report.

1.0 BACKGROUND INFORMATION

Listed below is a summary of the original three parts of WDNR Grant Project No. 07-05, prior to the changes to the scope of work:

Recycle the Waste – Conduct construction waste recycling at building sites within the Waterford Glen subdivision and setup a centralized waste recycling collection area there.

Process the Waste - Transform the waste materials collected at the centralized waste recycling collection area, within the Waterford Glen subdivision, into reusable building materials.

Build with the Processed Waste - Use the transformed reusable building materials, along with new materials, to build a >61% recycled content unit, at the centralized collection area in the Waterford Glen subdivision.

The three parts of WDNR Grant Project No. 07-05 are described in more detail in the original grant application submitted by Noble Earth to the WDNR dated August 1, 2006 (see Appendix A). During consideration of Noble Earth's original grant application, the WDNR contacted Noble Earth to discuss extending the schedule of the original grant application from 12 months to 20 months. At that time, obtaining recycled construction materials from sources other than just the proposed Waterford Glen neighborhood in Fitchburg was also approved. These changes were approved by the WDNR, as detailed in Noble Earth's October 31, 2006 submittal, because of the significant decrease in housing starts that had occurred during the last half of 2006. The decrease in housing starts was projected to possibly continue into 2007 and, indeed, further decreases in housing starts occurred throughout 2007 and 2008. The decline of housing starts in 2007 and 2008 was exacerbated by what has been referred to as the "housing mortgage meltdown" which reached a critical mass during Summer 2007 and has resulted in a record number of housing foreclosures and a very slow residential real estate market (see Appendix C for articles). The extended schedule and approval to obtain recycled materials from outside of the Waterford Glen neighborhood gave Noble Earth more flexibility to complete the grant project given fewer houses were being built in Waterford Glen than was originally

expected. It should be noted that there was no increase in WDNR funding as a result of the extension in project completion time or the expansion of the allowable sources for reusable material collection.

The First Interim Report (dated April 2, 2007 – see Appendix A) for the grant project presented the successes and challenges that had occurred during the first three months of the grant project. The successes for the project are detailed in Section 2.0, The challenges are detailed in Section 2.0, Item 1 and Section 3.0. Further issues and clarifications were presented within a document prepared for the April 19, 2007 formal WDNR meeting/tour at Noble Earth's recycled material collection and storage facility (see Appendix A). Based on the challenges experienced, and alterations that were needed to the proposed grant activities, the changed scope of work was agreed to by Candice Sovinski in emails from April 4, 2007 through April 30, 2007.

The changes to the scope of work, as presented in the First Interim Report, can be summarized as follows:

Recycle/Reuse the Waste – Conduct construction waste recycling and construction material reuse from various building and deconstruction sites at multiple subdivisions, demolition projects and waste material collection facilities. Specifically target the recycling efforts on materials that can be recycled and/or reused for the planned construction project(s). Setup a centralized waste recycling collection area.

Process the Waste - Transform the waste and reusable building materials collected at the centralized waste recycling collection area into reusable building materials. The centralized waste recycling collection area did not need to be located within the Waterford Glen subdivision.

Build with the Processed Waste - Use the transformed recycled and reusable building materials, along with new materials, to build a >61% recycled content Shop Addition, at the centralized collection area, outside of the Waterford Glen subdivision, and a possible >61% recycled content house close to the centralized collection area.

The first important change to the scope of work was that the collection, processing and building of the >61% recycled content unit did not have to occur in the Waterford Glen subdivision. The second change was that only the recycled/reusable materials that were needed for the building project(s) needed to be collected/processed. The third change was that the >61% recycled content unit did not have to be located in Waterford Glen, and the end product did not have to be a house. A large Shop Addition and possible house were approved instead. The reasons these changes were needed are discussed in this report. It should be noted that with these changes the overall project costs were significantly decreased. The changes resulted in the project being completed, as noted above, approximately 7% below budget, despite being conducted over a 20-month period instead of the original proposed 12-month period.

2.0 PROJECT ACCOMPLISHMENTS

The actions completed to implement the revised project scope of work are provided below. Each of the numbered headings corresponds with the original scope of work action items, which did not need to change significantly, despite the changed scope of work. Photographs, from many of the activities listed below, are attached to this report. Additional information is also presented in Appendix A and Appendix B.

1. Prepare the final solid waste management plan. Coordinate with the developer for project implementation.

Samuel Cooke, of Noble Earth, contacted and met with Shaun Wilson (Development Associate with Gorman & Co. for Waterford Glen) regarding recycling of construction waste within the Waterford Glen neighborhood (5300 block of Lacy Road in Fitchburg, WI) during January 2007. The complete project narrative for WDNR Grant Project No. 07-05 was provided to Mr. Wilson for his review. Mr. Wilson replaced Rob Christlieb, who left Gorman & Co. Rob Christlieb is the author of Gorman's collaboration letter that was in Noble Earth's August 1, 2006 WDNR grant application. Mr. Wilson stated that Gorman &

Co was interested in the concept of the grant, but there would be some restrictions placed on any activities involving collecting, processing and/or building with waste materials within the subdivision. Mr. Wilson also said that Noble Earth should contact Mr. Ken Heim, one of the original residents of the Waterford Glen neighborhood, regarding its proposal for recycling, processing and building at Waterford Glen. Mr. Cooke contacted Mr. Heim who requested information and a two-week time period to review the information. A complete project narrative for WDNR Grant Project No. 07-05 was sent to Mr. Heim. Mr. Cooke contacted Mr. Heim after the two weeks, at which time Mr. Heim indicated that he also had reservations about the proposal.

Concerns were raised by the Mr. Heim, acting as the neighborhood representative, regarding the possibility of a decline in neighborhood aesthetics should the collection and processing of waste materials be conducted at a centralized site within the Waterford Glen neighborhood. Some of this activity would be allowed to occur on a neighborhood lot but not to the scale that was anticipated to complete the project. In addition, Mr. Heim raised concerns about the perception of using the waste materials to produce what he referred to as a "Garbage House," despite it meeting the required building codes and assurances that the building materials are essentially the same as new materials. Mr. Heim was also concerned about possible negative market response to that individual house or to the neighborhood if the project were conducted in Waterford Glen. This response was completely different than what had been originally discussed with Mr. Christlieb of Gorman & Co. Consideration of these concerns led to the changed scope of work and an expansion in the flexibility of the project scope. Ultimately, that increase in flexibility led to a more diverse and successful project.

After these issues were discussed with the WDNR and initial approval was given to consider alternatives to Waterford Glen, other waste material collection sites had to be considered, inspected and evaluated. These sites included warehouse space, light industrial park leased space and Noble Earth's shop location at 5335 Lacy Road. In addition, other building sites had to be considered, including lots in the Swan Creek subdivision and two properties owned by Samuel Cooke, the owner of Noble Earth. After researching these options, the 5335 Lacy Road location was selected for the waste material collection/processing site, and the two properties owned by Samuel Cooke were selected for the building sites.

2. Setup the materials collection site.

As indicated above, the materials collection site was setup at 5335 Lacy Road, which is the location of Noble Earth's workshop and storage facility. This location is immediately east of the Waterford Glen neighborhood. The material collection site was setup at 5335 Lacy Road and not within the Waterford Glen neighborhood as a result of the discussions presented in Item No.1, above. In addition, Samuel Cooke contacted the City of Fitchburg Building Inspection Department. Mr. Cooke met with Mr. John Crook (City of Fitchburg Building Inspector) about issues regarding the proposed collecting, processing and building with waste materials in the City of Fitchburg. Mr. Crook indicated that as long as the City of Fitchburg ordinances were followed and building codes were complied with, the work could take place. Mr. Crook also confirmed that jurisdiction for construction issues within Waterford Glen were not only exercised by the City of Fitchburg but also, to a certain extent, by Gorman & Co, the neighbors and the Waterford Glen Architectural Control Committee.

The 5335 Lacy Road material collection site continued to be used for recycled and reusable building material collection and processing through the end of the project.

3. Coordinate with the builders and present the solid waste management plans.

During 2007 and through August 2008, solid waste management plans, collection/recovery arrangements and/or agreements were presented and/or discussed with numerous site owners, builders, business owners, etc. The result of those discussions or presentations was that waste materials have been collected from >64

different building project locations or collection sites. The number “64” was important because that is the number of sites that were going to be built in Waterford Glen, as proposed in the original grant application. It should be pointed out that not everyone that Noble Earth personnel talked with agreed to allow waste material collection from his/her construction site or facility. The agreements that were made were with a wide range of sources. For example, there are agreements for collection of select waste materials from sites ranging from single lot residential construction projects to a 67-unit condominium development. In addition, waste materials were collected from individuals through notices provided on the Madison Stuff Exchange website and from individuals who had heard of this project through word-of-mouth. Photographs are also attached to this report, which show some of the collection locations. Details regarding the locations where the largest amount and/or most unique materials were collected are as follows (Note: The fact that the organizations listed below assisted with this demonstration project is not a representation that they have an open policy of wholesale or retail recycled material sales to the general public):

Residential Building Sites (Lumber, Engineered Panels, Headers, Drywall) – During 2007 and 2008, select waste building materials were collected from 56 different condominium and single-family home building sites. The arrangement with most sites was that Noble Earth personnel could take discarded lumber (cut off 2”x 4” through 2”x 12” dimensional lumber), oriented strand board (OSB) and other discarded items from the on-site dumpster. Special arrangements were coordinated for pickup of certain items. For example, a 22 ft long 2”x 14” LVL beam was obtained from a building site. The LVL beam had a slight twist in it and had not been used during construction. The beam was then cut where the slight twist made its bend and the LVL was perfect for use as the header over a garage door opening and a personnel door opening in the Shop Addition.

Bruce Company, aka Second Season Recycling (Lumber, Engineered Panels, Timbers, etc.) - A solid waste management plan was presented to and approved by the Bruce Company for wood recovery at their Verona and east Madison waste wood collection facilities (see Appendix B). That solid waste management plan was first implemented during March 2007 and periodically throughout the waste collection phase of the project. A substantial quantity of recycled reusable building materials were recovered via this plan including, for example, 6”x 6” wood timbers which were dismantled from large pallets that were going to be landfilled because the large steel bolts that held the pallets together might damage the Bruce Company’s grinder. Noble Earth used these wood timbers for the Shop Addition stud walls. 2”x 4” dimensional lumber was obtained from long pallets. This wood sometimes was SPF 2 (Spruce, Pine Fir No. 2) grade but most of the time was either HT KD (heat treated, kiln dried) stamped or was not graded. The pallets were dismantled and denailed to obtain the lumber. This material was pre-inspected and selected for use as blocking, bracing and truss web members, as designed by a structural engineer. Discarded ¾” structural plywood was collected and used for the Shop Addition’s mono truss gusset plates. Oriented strand board (OSB) that was structural graded and between 7/16 and 9/16 inches thick was also collected at this site for use as sheathing and roof decking (see Photographs).

Apple Tree Fitchburg, LLC (Lumber and Fill Material) - A solid waste management plan was discussed and approved by Apple Tree – Fitchburg, LLC for wood and fill material recovery at their Fitchburg development called “The Crossing”. The first part of the plan, for obtaining dimensional lumber, was first implemented during July 2007 and again in September 2007. A significant quantity of long pieces of 2”x 4” and 2”x 6” waste lumber was obtained from “The Crossing”. The second part of the plan was implemented during November 2007, when approximately 2,110 tons of waste fill material were hauled from “The Crossing” to the Noble Earth house site. The fill material was used at the proposed house construction site to increase the site elevation. The fill material was hauled less than 0.2 miles. This arrangement worked out symbiotically because Apple Tree would have had to haul the fill material much farther away to dispose of it at a much higher cost. At the same time, although waste fill material was not absolutely necessary for the Noble Earth house construction site, the fill material raised the elevation of the site, which was desirable.

Sorenson's Tree Service (Lumber and Beams) – During November 2007, 100% of the trees, brush and other site clearing waste that would normally have been just removed from the house construction property area and burned by Sorenson's Tree Service was able to be reused. The large limbs and trunks were taken to a local lumber mill (Wood Cycle in the Town of Oregon) and sawed into silver maple and black walnut timbers (8" x 8" and 4" x 4") and one-inch thick maple lumber for the house construction project (see Photographs). Smaller limbs and hollow trunks were sawed up for home heating firewood, to be used on-site. Branches and brush were chipped and used on-site for landscaping mulch.

County Materials – During the first quarter of 2008, a sizable quantity of concrete block from production overruns that were still usable, was found within 5 miles of the waste material collection site. This block is normally stockpiled by County Materials and then crushed or even disposed of in a landfill because the "overrun blocks" were small quantities of different specialty colors. The size of the block that was most prevalent was 12-inches wide, which was larger than the 8-inch wide stem wall design. However, only the larger block was available in the quantity needed to build the Shop Addition stem wall. Since the reusable block was only available in a range of different colors (e.g., red, brown, dark tan, dark grey, etc.) and with a mixture of split-faced block and smooth-faced block, it was slated for use below grade where uniformity of color and surface did not matter. Uniform smooth-faced grey block was designated for use above grade where it would be visible (see Photographs).

Wingra Redi-Mix – During the first quarter of 2008, efforts went into finding a way to have a high-recycled content building foundation. Typically, foundation walls in Wisconsin are poured concrete. The highest recycled content concrete was found through Wingra Redi-Mix, which contained 5% slag and fly ash. Although the slag and fly ash can replace up to 50% of the Portland cement (cementitious material) in the concrete mix that amount of slag and fly ash only amounts to a 5% recycled material content for the total concrete mix (Wingra Redi-Mix Concrete Mix No. 722 or 745). So, the 5% recycled content concrete was used for the foundation footing and the 100% reclaimed concrete blocks were used for the foundation stem wall in order to decrease the amount of new concrete required (see also County Materials, above).

Chase Lumber – During May/June 2008 the investigation for a high recycled/reused content roof included meetings and literature searches regarding the percent of recycled content in the various steel, aluminum, plastic, fiberglass panel and asphaltic roof coverings from various sources. Although there is significant recycled content in new roofing materials that would fully satisfy requirements for recycled content in other building projects, the scope of this project was to maximize the reuse of materials that are either already discarded or were going to be discarded due to obsolescence or other reasons. Reuse of pre-used steel roofing was considered because there was access to the weathered steel roofing from an old barn in the Town of Oregon. However, Noble Earth learned that Chase Lumber had some obsolete three-tab asphalt shingles that were over five years old and were not part of their stock that was being offered for normal sale. The bundles had sat outside and had partially fused together within their plastic packaging. These shingles were destined to be discarded, if they were not going to be used. Noble Earth found a way to separate the shingles that were bound together and in June 2008 obtained 100 bundles of the shingles, which was more than sufficient for the Shop Addition roof.

City of Fitchburg - Waste flood control sand was obtained from a City of Fitchburg site for reuse in the Shop Addition high thermal mass bed (a heat retention component of the Shop Addition). The higher than normal precipitation during early June 2008 necessitated the precautionary use of sand bags for a residence located approximately 2 miles from the Shop Addition project. The floodwaters never actually came in contact with the sandbags and, therefore, the sand within the sand bags was not at risk for any health related contamination issues. A total of 49 sandbags were picked up and transported to the building site where the sand was removed from the bags in such a way that the sandbags themselves

would be able to be reused. The approximately 2,000 lbs of sand were used as part of the high thermal mass bed beneath the southwest portion of the Shop Addition (see Photographs).

Barn in the Town of Oregon - During June 2008 Noble Earth began taking down a two-story barn building that the owner no longer needed and planned to burn. 1"x 12" cedar barn boards, of various lengths, were recovered from the exterior of the barn along with the 1"x 2.5" battens that were present between the 1"x 12" boards. This effort was important because of the high quality of materials obtained and the reduction in the amount of material slated for burning (see Appendix B and Photographs).

Other Material Collection Sites – Throughout the project there were other sites where materials such as pea gravel, bricks, drywall, rebar and other materials had either been discarded or were not going to be used by their owner. These materials were collected and processed for use as building materials for the grant project. In total, a good cross-section of waste material reuse sources was part of this demonstration project to demonstrate the range of sources available for recycled and reusable materials.

As indicated above, photographs from most of the activities listed above are attached to this report.

4. Setup waste material collection at each building site.

Noble Earth recovered waste materials from >64 building and other waste recovery sites in Fitchburg, Madison, Oregon, Edgerton, Sun Prairie and Verona. It should be noted that >95% of the waste construction materials were obtained from within 5 miles of Noble Earth's collection facility. This was accomplished, as detailed above, by removing select reusable materials, primarily concrete block, dimensional lumber, OSB, bricks, timbers, fill materials and gravel from whatever central construction waste collection container or other collection areas that were located at each of the sites. Noble Earth's pickup truck and trailer could complete most waste material collection and hauling. In some cases the volume or weight of the materials necessitated that they be delivered to the collection site by larger trucks. Contractors and individuals have also dropped off reusable building materials (dimensional lumber and OSB) at Noble Earth's collection facility but >95% of the time the materials were picked up by Noble Earth.

5. Implement the regular collection and site inspection staffing at the sites.

Noble Earth accomplished this by periodically collecting from the containers and collection areas described in Item Nos. 3 and 4, above.

6. Develop public relations materials.

The following public relations items or presentations were prepared and/or conducted:

- A PowerPoint presentation on this grant project was delivered at the University of Wisconsin – Madison, School of Engineering on March 22, 2007 (coordinated through Professor Michael Oliva).
- A presentation that included aspects of this grant project was delivered at Oregon High School on May 3, 2007 (coordinated through teacher Peter Kritsch).
- Noble Earth designed, built and staffed an exhibit at the Building Material Reuse Association (BMRA) Conference held from May 14-16, 2007 at the University of Wisconsin – Madison Union (coordinated through Forest Products Laboratories). The exhibit was prepared specifically for the WDNR demonstration grant project and included a full scale structural display using a wide variety

of 100% reused building materials (e.g., 6"x 6" beams, 2"x 10" headers and a framed stud wall using various non-structural 2"x 4" members as well as recycled content insulation). A picture of the display is included with the photographs.

- A newspaper article on the BMRA Conference and reuse of waste building materials was written by Noble Earth personnel and printed in the Fitchburg Star on June 28, 2007.
- A presentation on some of the aspects of proposed construction waste material reuse was given to the City of Fitchburg Plan Commission on July 17, 2007 and to the Fitchburg City Council on July 24, 2007. The presentation to the Plan Commission and the Council resulted in the approval of Resolution R-77-07 in support of the project. The City of Fitchburg's Resource Conservation Commission has been periodically updated on the project's progress during 2007 and 2008.
- Noble Earth staff attended the Greening the Heartland conference from September 12 – 14, 2007 at the Monona Terrace Conference Center in Madison. Many of the details and some documentation regarding the WDNR grant project were shared with multiple green-building professionals.
- Noble Earth staff attended the U.S. Green Building Council's (USGBC's) Greenbuild Conference on November 7 & 8, 2007 in Chicago, IL. Many of the details and some documentation regarding the WDNR grant project was shared with multiple green-building professionals.
- A presentation on the reuse of recycled building materials to be implemented during the construction phase of this project was delivered to a group of neighbors and City officials (i.e., Alderpersons) at a meeting of the East Fitchburg Neighborhood Association on December 6, 2007.
- The grant project was written up on March 31, 2008 and was entered as part of Isthmus Publishing's "Get Green Challenge" with publicity of the project's goals and methods, through the Isthmus, being the main purpose.
- An article, with the title: "Recycling To The Max" was prepared by an editor/reporter who interviewed me about the project. His article was presented on the front page of the May 29, 2008 Fitchburg Star newspaper with pictures of one of the 100% recycled content stud walls and the trusses built from reused lumber and recovered plywood.
- During the October 9, 2008 WasteCap Wisconsin R3 Awards Ceremony, with many representatives from the building construction, waste recycling and waste reuse industries present, a very brief synopsis of the WDNR grant project was given when one of Noble Earth's staff accepted one of the R3 awards (Outstanding Volunteer 2008).
- The final report, with photographs, will be posted on Noble Earth's website during November 2008: www.nobleearthtech.com
- It is anticipated that, once the solar panels are installed on the roof of the Shop Addition, many of the aspects of the demonstration grant project will be discussed with individuals/groups through the MREA Solar Tour and other events for years to come.

7. Collect waste materials and process them at the material collection sites.

Collection of residential construction waste has occurred at over 64 residential building sites and waste recovery locations that, for the most part, are located in or very close to Fitchburg. The materials collected at these sites for reuse include concrete blocks, dimensional lumber, engineered lumber, cardboard, drywall, bricks, metal, vinyl siding scraps, bottles/cans, insulation, polystyrene and concrete. Some of the most notable waste materials collected and processed are as follows (see also the attached pictures):

Waste Materials Collected/Processed and/or Used During 2007 and 2008

- An estimated six tons of reusable wood were collected during the Bruce Company wood recovery events. All of the material was transported to Noble Earth's central collection facility in Fitchburg for denailing and other processing.

- A total of 3.5 tons of bricks have been obtained for use in the house project. An estimated one-ton of bricks was collected from a deconstruction project in Madison on May 26, 2007. These bricks each required removal of mortar using a hammer or air chisel and subsequent wire brush cleaning. In addition, another estimated 2.5 tons of bricks were acquired from an Edgerton demolition site.
- An estimated 11.2 tons of reclaimed pea gravel was obtained from a building site in Madison during July 6 - 8, 2007.
- A total of ten tons of reusable wood was obtained from sources other than the Bruce Company. An estimated one-ton of wood was obtained from "The Crossing" and approximately nine tons of wood was obtained from other sources since the start of waste material collection.
- 34.6 tons (68,720 lbs) of crushed recycled concrete (1" with fines) was purchased from Wingra Stone for the Noble Earth house construction site in 2007 (not purchased using any grant funds).
- An estimated 2,110 tons (4,220,000 lbs) of waste trench spoils was reused from "The Crossing" at the Noble Earth house construction site during late Fall 2007.
- A total of 28 tons (56,040 lbs) of reclaimed concrete block (805 total blocks) for the Shop Addition foundation stem wall was obtained during January 2008. These blocks, from County Materials in Fitchburg, are usually either crushed for fill material or discarded, as they are production overruns of special colors for specific customers. This saved 21 yd³ (approximately 42 tons) of new concrete.
- 152.6 tons (219,600 lbs) of crushed recycled concrete (1" with fines) were purchased from Wingra Stone for use on the Noble Earth Shop Addition foundation stem wall and floor area backfill, base course and high thermal mass area during 2008 (not purchased using any grant funds).
- 3.1 tons (3,100 lbs of slag and 3,100 lbs of fly ash) of recycled slag and recycled fly ash were incorporated into the concrete mix used for the Shop Addition. This included the concrete used for the foundation footings (8 cu yds) during January 2008. This same mix of recycle content concrete (Wingra Redi-Mix No. 722) was also used for filling the concrete block vertical rebar voids (5 yds³) and for filling the horizontal rebar channels in the foundation stem wall bond beam blocks during March 2008. A slightly different mix, which still contained approximately 5% slag and fly ash (Wingra Redi-mix No. 745), was used for the 18.5 yd³, 4,000-psi concrete floor for the Shop Addition during July 2008.
- 1.6 tons of 6"x 6" posts/beams, 2"x 4", 2"x 6" and 2" x 10" dimensional lumber were processed, in addition to the other waste wood discussed above, to completely frame 100% of the stud walls and a majority of the trusses used for the Shop Addition. See Appendix B for truss design information.
- A 110 lb, 21.5 ft long 14"x 2" Microlam engineered header was collected from a Waterford Glen duplex project (after the building was complete and with permission from the contractor), which had been discarded due to a slight twist.
- 1.6 tons of oriented strand board (OSB), the equivalent of sixty 4' x 8' x ½ inch sheets, were collected and processed from various waste collection sites to completely sheath the exterior vertical walls and roof deck of the Shop Addition.
- 3.8 tons of roof shingles (100 bundles - enough for over 30 squares of roofing) were obtained from Chase Lumber in Sun Prairie as obsolete and were eventually to be discarded (3.2 tons have been used on the Shop Addition roof).
- 5.6 tons of 8"x 8" timbers, 4"x 4" timbers and 1" thick lumber was milled from what is normally thought of as waste Silver Maple trees. The Silver Maple trees had to be removed from the proposed building site due to their hollow trunks and proximity to the building. Many trees were left at the property, but some had to be removed because they were hollow and leaning over residences at a neighboring new development ("The Crossing"). Silver Maple is normally not cut up into timbers and lumber as the species is a type of soft hardwood and tends to have gaping holes within the limbs and trunk wood. The tree removal company only wanted to haul the trees to their large burn pile where they would have been burned. Most individuals consulted, who were familiar with wood milling, did not want to work with Silver Maple because of the chance of gaping holes. However, as the limbs and trunks were milled, what actually was produced was desirable lumber

and timbers, with minimal holes. Once again, the depth of this demonstration project was further expanded by taking a material that is normally burned or used for firewood – Silver Maple trees – and making a useful building material from it. The timbers and lumber is planned to be used for the interior of the house.

- 1 ton of sand was obtained from uncontaminated flood control sand bags collected from a site in Fitchburg. This material was used in the high thermal mass bed in the Shop Addition.
- 1 ton of 1-inch thick barn boards were obtained from a barn in the Town of Oregon. An estimated 800 board feet of barn boards were removed from the outside walls of the barn. The barn was scheduled, by its owner, to be burned after the recovery of materials. Other materials from the barn were either unusable because of possible animal odor issues or the wood beams had some evidence of powder post beetles.
- Relatively small quantities of rigid foam insulation, vapor barrier, waste fiber insulation and larger pieces of waste drywall were also collected and reused on this project.

The total amount of recycled/reclaimed/reused materials that has been collected/processed, as of the end of the project, is an estimated 2,373 tons. This includes stockpiled materials not included in Item 8, below.

8. Build a >61% recycled content unit within the development. (Instead of the House, from the April 2, 2007 Interim Report Scope of Work Changes: Build a >61% recycled content Shop Addition).

A 75% recycled content Shop Addition was built using the materials collected for this project (see Figures). A chronological account of the Shop Addition construction is included with the photographs. A more detailed description of the technical considerations is included in Section 4.0. The total amount of recycled and new materials, as well as the percentage of recycled content in the building projects, is as follows:

Noble Earth Shop Addition:

Recycled materials:

• Crushed concrete (fill for foundation, base & thermal mass)	305,300 lbs
• Concrete blocks (805 reused block in foundation)	56,040 lbs
• Pea gravel (leveling the base of the trenches)	22,400 lbs
• Shingles (Obsolete 3-tabs that were to be discarded)	5,470 lbs
• Fly ash and slag in concrete (the 5% recycled content)	3,660 lbs
• Wood (6x6s, LVL and dimensional lumber for framing)	3,360 lbs
• Wood (1/2 inch OSB sheathing for walls and roof deck)	3,240 lbs
• Sand (from flood control sand bags, reused as thermal mass)	1,980 lbs
• Structural plywood (60% of mono/common truss gusset plates)	1,230 lbs
• Wood (2x4s and 3/4" plywood for making partial mono trusses)	1,170 lbs
• Wood (2x10s for foundation footing forms)	895 lbs
• Dimensional Lumber (2x4 mono/common truss webs)	750 lbs
• Doors & Windows (3 doors and 6 windows total)	530 lbs
• Siding (30% recycled content cement fiberboard siding)	390 lbs
• #5 Rebar (324 ft for wall dowels, footing verticals, etc.)	340 lbs
• Plastic sheeting (to cover curing concrete)	<u>25 lbs</u>
TOTAL weight of recycled materials used, as of 10/31/08	406,780 lbs

New materials utilized:

• Concrete (95% non-recycled content of 31.5 yds ³ of concrete)	121,210 lbs
• Concrete blocks (30 new corners and 60 new bond beam)	6,330 lbs
• Purchased pitch girders and hip roof trusses	1,960 lbs
• Siding (70% non-recycled content cement fiberboard siding)	1,300 lbs
• Glazing (insulated glass, supports and frames for greenhouse)	950 lbs
• Structural plywood (40% of the truss gusset plates are new)	915 lbs
• FSC Certified Lumber (truss top & bottom chord members)	715 lbs
• Underlayment felt, staples and Ice/Water Shield for roof	475 lbs
• Garage Doors (one standard and one with 90% thermal glass)	400 lbs
• Miscellaneous New Materials (fascia, soffit, nails, screws, etc.)	400 lbs
• #4 Rebar (500 ft for footings & bond beam)	335 lbs
• Polystyrene insulation (32 panels for R-15 foundation insulation)	160 lbs
• Nails and glue (500 10d nails/mono truss; low VOC glue)	145 lbs
• Nails and glue (340 10d nails/partial mono; low VOC glue)	105 lbs
• Roofing nails, step flashing, roof tar and rolled flashing	75 lbs
• Hangers (structural hangers required for truss support)	<u>40 lbs</u>
TOTAL weight of new materials used, as of 10/31/08	135,515 lbs

TOTAL (recycled and new Shop Addition materials = 271 tons) 542,295 lbs
Percent Recycled Materials in Shop Addition 75%

Noble Earth House:

Recycled/Reclaimed materials:

• Waste trench spoils (used as non-structural fill)	4,220,000 lbs
• Crushed concrete (fill for driveway approach)	68,720 lbs
• Timbers and lumber milled from on-site trees (not used yet)	11,250 lbs
• Barn boards from old barn recovery effort (not used yet)	2,000 lbs
• Recycled wood chips in erosion control socks ((7) 8" socks)	<u>385 lbs</u>
TOTAL weight of recycled materials used, as of 8/31/08	4,302,355 lbs

New materials utilized:

• Crushed limestone (required erosion control tracking pad)	128,500 lbs
• 18" diameter culvert, angles & culvert wing walls	450 lbs
• Erosion control fence ((3) 100' fences)	<u>100 lbs</u>
TOTAL weight of new materials used, as of 8/31/08	129,050 lbs

TOTAL (recycled and new House materials: 2216 tons) 4,431,405 lbs
Percent Recycled Materials in House project, as of 8/31/08 97%

GRAND TOTAL RECYCLED MATERIALS*	2,354 tons
GRAND TOTAL NEW MATERIALS	132 tons
TOTAL PERCENT RECYCLED MATERIALS	95%

* Approximately 19 tons of recycled/reclaimed materials are stockpiled for future use on the house project.

9. Document and share the results of this project.

Documentation, in the form of this report, as well as the conference display documentation, presentations and other items discussed in No. 6, above, has been prepared. As indicated above, this report will be posted on Noble Earth's website (www.nobleearthtech.com) beginning in November 2008.

3.0 PROJECT CHALLENGES

Several project challenges, and the ways those challenges were overcome, were discussed in detail within Section 1.0 and Section 2.0 - Item No.1, above. In summary, those challenges had to do with the unpredicted slump in housing starts during 2006-2008 and the 2007/2008 "mortgage meltdown" that resulted in many fewer residences being built in Waterford Glen than had originally been anticipated. In addition, resistance on the part of the Waterford Glen representatives to have this project conducted within Waterford Glen resulted in Noble Earth's request to change the original scope of work to a more flexible scope of work. That flexibility meant that collection of waste building materials, processing of waste materials or building a >61% recycled content unit were no longer required to be done exclusively in Waterford Glen.

At the same time as the above was happening, Noble Earth found that the Bruce Company planned to operate a commingled construction waste recycling facility servicing Dane County. The facility was located within about 5 miles of Noble Earth's waste collection site. The fact that the Bruce Company was going to be recycling construction waste meant that Noble Earth would not need to solve the challenge of actively recycling all construction waste from the building sites. Instead, Noble Earth could focus on collecting and processing the material needed for the building project. Furthermore, Noble Earth personnel discovered that with the waste wood exposed to weather, etc. its use in a house, without heat-treating the wood first, was not recommended. So, the project building focus was changed to the construction of a Shop Addition. The reason a Shop Addition was the solution is that a shop is not occupied and therefore the lack of heating/cooling reduces the amount of consideration and chance for mold growth. The construction of a house, if it were to occur at all, was delayed with some preliminary material collection occurring during the Shop Addition construction project. Ultimately, the WDNR determined that the collection, processing and construction of the Shop Addition met all of the goals of the grant project. Near the end of the project, Noble Earth proposed a time extension to continue building the Noble Earth house but the WDNR determined that was not necessary.

Since the formal acceptance by the WDNR of the proposed scope of work changes, during April 2007, there were no further challenges that were insurmountable. One particular challenge that was overcome during the second quarter 2008 was finding sources of waste materials for the high thermal mass bed, detailed below.

Waste Street Sweeping Material for the High Thermal Mass Bed

A high thermal mass bed is a way to store heat, usually solar generated heat, within a volume of structural fill material below the area that is to be heated. The concept behind this is that if a large enough mass of material can be heated by circulating solar-heated fluid through it during the summer then that heated material would be available to provide heat to the space above it during the winter. The high thermal mass bed designed for use with the Shop Addition was 32 inches deep and had a vapor barrier with 4 inches of rigid foam insulation (R-20) on the bottom and sides of the 23 ft long by 15 ft wide area. On top of the 4 inches of rigid foam insulation was a 24-inch deep volume that needed to be filled with sand, or its equivalent. The sand material would be the medium where the heat would be stored in the summer and then slowly released over the winter. Three different waste materials were considered to replace the clean sand that normally is used for this purpose: waste street sweeping material; crushed recycled concrete fines; and used flood control sand bag material.

Municipalities in Wisconsin, including the City of Fitchburg, are accumulating large amounts of waste street sweeping material. Typically, waste street sweeping material is primarily made up of sand, sediment, organic matter and debris. Arrangements were made with the City of Fitchburg to run a trial that included separating the organic matter and debris from the sand and sediment. The result of the trial separation was that between 10% and 80% of this waste material is organic matter and debris (depending upon time of year and collection location). The five yds³, which was separated for the trial, had approximately 15% organic matter and debris.

There was some concern, based on prior studies and documentation regarding reuse of this material, that there may be contaminants at higher than desirable concentrations in the City of Fitchburg's waste street sweeping material. A composite sample was collected from the portion of Fitchburg's approximately 50,000 yd³ pile that had been stockpiled during the 2007/2008 street sweeping season. The composite sample was collected on May 26, 2008 and was analyzed for Diesel Range Organics (DRO), Chloride, Toxicity Characteristic Leaching Procedure (TCLP) Metals and Particle Size Distribution. The summary results from the analytical testing of the composite sample are shown below. The complete lab report is in Appendix B.

Waste Street Sweeping Material Analytical Testing Results

Analytical Parameter	Result	Standard
Diesel Range Organics	207 mg/kg	100 mg/kg*
TCLP Arsenic	0.01 mg/L	5.0 mg/L**
TCLP Barium	0.77 mg/L	100 mg/L**
TCLP Cadmium	0.0019 mg/L	1.0 mg/L**
TCLP Chromium	<0.0053 mg/L	5.0 mg/L**
TCLP Lead	<0.0069 mg/L	5.0 mg/L**
TCLP Selenium	0.0091 mg/L	1.0 mg/L**
TCLP Silver	<0.0017 mg/L	5.0 mg/L**
TCLP Mercury	<0.10 ug/L	0.2 mg/L**
Chloride	50.7 mg/kg	N/A

* NR 720 (WDNR) standard for residual contaminant levels based on protection of groundwater. Note: For sites with petroleum contamination where contaminated soils and soils below the contaminated soil for a depth of 3 meters have a hydraulic conductivity of 1x10⁻⁶ cm/s or less, the cleanup standard is a concentration in soil that may not exceed 250 mg/kg.

** 40 CFR 261.24 (EPA) Standard for determining hazardous waste toxicity through the toxicity characteristic leaching procedure (TCLP) analytical test.

As shown above, the composite street sweeping material sample result exceeded the WDNR "cleanup standard" for diesel range organics at the generic residual contaminant level of 100 mg/kg, as specified in NR 720. The sample results also showed that the TCLP RCRA metals were all below the applicable EPA standard for hazardous waste toxicity. There were detectable concentrations of TCLP RCRA metals and Total Metals in the composite sample. The presence of chloride was expected, and the fairly low concentration was not a concern relative to the proposed confined usage of the material.

A particle size distribution test was also run on the sample with those results indicating that the amount of material passing through the 200 mesh screen was 10.9% which exceeds the maximum of 5% given as the standard suitable for fine aggregate in concrete (standard given by Shawn Triller of Wingra Redi-Mix). Another standard for fine aggregate in asphalt concrete indicated that 0 to 10% was allowed to pass the 200 mesh screen and 0 to 20% was allowed to pass the 100 mesh screen (sample result was 17.2 % passed the 100 mesh screen). The asphaltic concrete specification appears to be more in line with the results of the composite street sweeping material sample, at least more so than the concrete specification.

With the contamination present in the waste street sweeping material, an alternative fine granular waste material stream was sought and found through reusing crushed recycled concrete screening fines and uncontaminated waste flood control sand.

4.0 TECHNICAL EVALUATION

The collection, processing and building with recycled/reclaimed waste building materials required evaluation to determine the most efficient way to handle, process and then utilize the materials. An evaluation of each material was important because the considerations of safety, quality, structural integrity and aesthetics were in play. Each of these considerations was evaluated independently, for each of the potential recycled/reclaimed materials. This was necessary because if any one of these characteristics (safety, quality, structural integrity and aesthetics) failed to meet specifications and expectations for any of the recycled/reclaimed materials then that material was no longer considered for reuse.

In fact, there were a number of materials that were evaluated but were determined to not be eligible for reuse in the building construction phase of the project. Examples of materials that did not make the cut, so to speak, include: 1) Ground cardboard for use as an insulation material, 2) Discontinued or discarded vinyl for use as siding, 3) Pre-used galvanized metal sheets as roofing panels, 4) Contaminated flood control sand as fill, as fine aggregate in concrete or fine aggregate in asphalt, 5) Waste street sweeping material for use as fill, as fine aggregate in concrete or as fine aggregate in asphalt, 6) Recycled shingles as asphalt, 7) Finger jointing of small pieces of dimensional lumber for structural and non-structural uses, and 8) Dimensional lumber (2x4s or 2x6s) as the primary structural members in the Shop Addition's stud walls.

As necessary, based on possible concerns about a waste materials' reuse, experts were contacted, analytical tests were run and pilot testing was conducted. For example, since there was a concern about the structural integrity of dimensional lumber in the stud walls Noble Earth consulted with an architect (Lou Host Jablonski with Design Coalition in Madison, WI) and structural engineer (Kurt Straus, P.E. with Structural Integrity in Middleton, WI) and obtained detailed design information for its limited reuse. Another example was concerns about possible lead paint contamination of the barn boards and several possible contaminants in the waste street sweeping material. As a result of that concern, analytical testing was performed on representative samples of those materials. Yet another example is that Noble Earth wanted to evaluate large-scale collection and processing of dimensional lumber. So, a pilot scale dimensional lumber collection and processing trial was conducted, in collaboration with the Bruce Co. See Appendix A and B for details regarding these issues.

For the recycled/reclaimed waste building materials that were collected, processed and used in the construction of the Shop Addition (or are stockpiled for use on the house project), the following are some technical considerations:

- **Fill Material** - Crushed recycled concrete is a material that Noble Earth would highly recommend for most fill applications, except high capacity load bearing applications. Noble Earth used crushed recycled concrete as material to backfill around the foundation, as base course for the floor and recycled concrete screening fines were used instead of sand in the high thermal mass bed. Depending upon the load that is delivered, it is mostly crushed grey concrete but it can also have crushed bricks, tile, blocks and an occasional small piece of glass or debris. The variation of different colors may be an aesthetic consideration for some but for most fill applications it is a great material to work with.
- **Foundation** – Concrete is normally a mixture of Portland cement, fine aggregate, coarse aggregate and water. The amount of each component is critical and varies, depending on the mix recipe that is designed to, for example, yield a specified strength of concrete. Noble Earth personnel had been told

that a 50% recycled content concrete could be used for the building foundation. What we had not been told, prior to being educated on the proportional makeup of concrete, is that the 50% recycled content (slag and fly ash) was not 50% of the total mass of the concrete but was actually 50% of the cementitious material (Portland cement). This meant that, since the cementitious material in the concrete ordered by Noble Earth was a total of 10% of the entire concrete's mass, the recycled content was actually only 5%. However, the presence of slag/fly ash in the concrete yields a stronger concrete. The only drawback is that the concrete takes slightly longer to initially set up and come to full strength, which can be an issue, particularly in cold weather or when a fast setup is required. When Noble Earth poured during cold weather the footings were insulated with loose hay, the trenches were covered with reclaimed plywood and the rigid foam sheets, that were going to be used around the perimeter of the foundation wall, and the covered trench was heated with several forced air propane heaters. This was probably overkill but the outside air temperature averaged in the teens.

- **Framing I** – (Reuse of wood has many issues, which cannot be covered adequately in this report. The information presented here is for summary purposes only) For 2x4 and 2x6 dimensional lumber, the biggest issue for reuse of the material in a structural capacity is the grading, all other issues being equal. Most of what is available for reuse either does not have a grade stamp or is graded at a grade level that is below what is necessary for structural applications. Dimensional lumber that is not graded cannot be used as a replacement for graded dimensional lumber. Noble Earth looked into the cost of having our collected lumber manually graded and the cost was unreasonably prohibitive. Instead we worked with an architect and a professional structural engineer. The structural engineer designed the trusses and stud walls, assuming that the lowest grade and strength of lumber would be used. This resulted in what many believe was an over-design of the trusses and stud wall but the structural integrity of the building is assured. A second set of considerations had to do with the available lengths and quality of the reclaimed dimensional lumber. Most of what is available for reuse is either fairly short or, if it is of a reasonable length, it could have a quality issue such as twisting, cupping, bowing, stains, etc. It should be noted that a slight twist or some staining does not render the lumber unusable. If the lumber is twisted or bowed then shorter straight lengths can be cut from the longer lumber. The third main set of considerations is the extra labor involved with finding, collecting, processing, sorting, storing, retrieving and reusing the dimensional lumber. There is no doubt that significant additional labor is required to achieve more than just a low level of dimensional lumber reuse. When dimensional lumber is available of a quality that is high enough to warrant the additional effort, then pry bars and denailing tools are used. Noble Earth used a variety of different pry bars to separate lumber and then most of the nails could be removed using a pneumatic denailer (e.g., Nail Kicker) which quickly drives an exposed nail either out of a piece of lumber or the nail becomes more accessible. The fourth main consideration has to do with exposure of the lumber to moisture, mold or other contaminants. Obviously, since waste wood has usually been exposed to the weather then it has likely been exposed to some moisture, etc. If that is the case then the retrieved lumber should be kept reasonably dry when stored and be careful not to use lumber that has diminished in quality, as there would be structural and contamination issues that cannot be reconciled.
- **Framing II** - Timbers and lumber milled from trees removed during the initial site clearing of a construction project does take extra time and effort but it is also likely to be economically advantageous (see Section 5.0). Depending on the species of trees, it is very possible to get beautiful timbers and high-grade No. 1 and 2 select lumber. Noble Earth took large tree limbs and trunks to a local saw mill because they also operate a wood drying operation using solar heat for drying. However, some saw mill operators have portable saw mills that can be contracted to come to where the tree limbs and trunks are and saw them there. Depending upon its eventual use, the newly sawn lumber should be stickered (~1"x 1" pieces of wood between lumber layers) and stacked in a dry location or taken to a wood drying kiln for drying.
- **Sheathing** – Noble Earth found that waste pieces of oriented strand board (OSB), which are the ubiquitous panels used on almost every residential building project, have many uses. Not only can OSB be used as sheathing but the small pieces were used for ground cover in muddy areas, shims for

½ inch or larger voids, cover over a new concrete floor to avoid damaging the surface, etc. It should be noted that repeated exposure to moisture is one of the main issues that render OSB unusable. Noble Earth also found that most of the various angled and different sized pieces, which are discarded from a typical construction site, are very time consuming to reuse. Finding pieces that were big enough to be readily reusable was another issue. The larger pieces of OSB were definitely available but not as frequently as the many smaller pieces. However, there is such a large quantity of OSB that is discarded, finding plenty of larger pieces was not a problem and Noble Earth was able to sheath the entire exterior and roof deck of the Shop Addition with 100% discarded larger sized pieces of OSB. As indicated in Framing I, above, removal of nails and staples was an issue as well.

- **Roofing** – Finding discontinued roofing material that is still usable may be viewed as a unique and infrequent situation but it is possible. The use of older, discontinued shingles or reused metal roofing does not sacrifice quality but does save money, with a similar level of effort expended.
- **Siding & Exterior** – Reuse of recovered bricks can be accomplished two ways. One way is to acquire and clean the bricks yourself and the other way is to acquire already cleaned bricks. Cleaning the bricks is a somewhat tedious process using an air chisel to chip most of the mortar from the brick, then using a rock hammer to scrape remaining mortar, followed by a stiff wire brush to finish the cleaning. Noble Earth found that if the bricks with mortar on them are soaked under water overnight, prior to cleaning off the mortar, the mortar comes off quicker and more completely with less effort.
- **Concrete Floor** – Use of recycled content concrete, with 5% slag & fly ash content, is discussed above – see “Foundation”. The concrete floor was poured on a hot summer day, which can sometimes be a problem with the concrete setting up too quickly. The slower setup of the recycled content concrete was found to be an advantage in that situation.
- **Windows & Doors** – With such a reasonable cost for doors and windows from the Habitat ReStore, it deserves serious consideration. Noble Earth knew, based on the design, the range of rough openings that would be possible for the windows and doors in the building. Over the time period when the foundation and initial rough framing were being done Noble Earth personnel found six new vinyl windows and three doors at the ReStore, that were perfect for the project. The size of the Habitat ReStore’s windows and doors then dictated the final rough opening framing dimensions. Some of the doorframe jambs had to be ripped to size but that was relatively easy, using a circular saw.
- **HVAC** – The ability to use relatively large quantities of crushed recycled concrete screening fines to store solar generated heat during the summer and release it during the fall/winter was a discovery that Noble Earth made in the middle of the construction project. Had this been included in the original design and allowed for during the excavation/fill work the cost of implementing this would have been less. Noble Earth still needs to evaluate how this works in assisting with the space heating needs of the Shop Addition but the potential for energy savings for decades to come is more than compelling to try this method out.
- **Drywall** – Reuse of waste pieces of drywall for interior wall finishing is anticipated but, as of the end of the grant project, has not been completed yet. Of all the waste material reuses this one might be the most impractical and difficult to implement since the main cost of a drywall project is the labor to install the drywall and then mud and tape the joints. The use of waste pieces of drywall would necessitate an increased number of joints, which would increase the amount of mudding and taping.
- **Interior finishing** – Dimensional lumber and trim milled from site-clearing trees is anticipated but, as of the end of the grant project, has not been completed yet. However, given the right bits and a router with a router table this is expected to significantly decrease the window and door trim material cost.

One more technical consideration that was taken for granted on this project, but is important to mention, is that comprehensive construction waste recycling was performed on this project. Over 99% of the waste generated on this project was recycled or reused. The waste materials that were recycled at a 100% rate were: Wood, waste shingles, tarpaper, cardboard, concrete, concrete blocks, metal, paper, insulation, polystyrene, cans/bottles. When drywall installation is accomplished the waste generated will also be recycled. The only

material not recycled/reused was some very muddy plastic sheeting, unrecyclable plastic packaging (e.g., shingle packaging), empty tubes of caulk, empty tubes of construction adhesive, empty stain cans, a few dry stain rags and floor sweepings. Lunch debris was also kept to a minimum by bringing whatever lunch and water that was brought to the site in reusable containers. The crew at work on this project was not only committed to waste construction material reuse but also not generating much new construction waste ourselves. An estimated 5 tons of project-generated waste was recycled/reused from this site. The cost of recycling was <\$50 on this project.

5.0 ECONOMIC EVALUATION

Documentation of the economic impact of collecting, processing and building with recycled/reclaimed materials was one of the most important administrative aspects of this demonstration grant project. Fulfilling on the project goal of constructing a >61% recycled content building from reclaimed waste building materials was thought to be an entirely reachable goal. However, the challenge was to see if the goal could be reached economically. The working definition of whether the project was economically viable or not came down to comparing how much it cost to collect/process/build with the recycled and reused materials with purchasing and building with new materials. Assuming that the quality of the final product was the same, if the total cost to collect/process/build with a recycled or reused material was the same or less than the total cost of purchasing and building with new materials then that recycled or reused material was considered to be economically viable. Meaning it had a better chance of being used on a larger scale basis. As shown in the far right column “Difference of Recycled vs. New” in the table below, some recycled/reused materials were more economically viable than new materials, some were not as economically viable as new materials and others were equal. Both the unit cost comparisons and the total project cost comparisons are presented in the tables below.

Table 5-1: COMPARISON OF UNIT COSTS OF RECYCLED/REUSED VS. NEW MATERIALS

Description of Construction Phase Or Type of Building Material	Quantity of Material	Cost Recycled (Including acquisition)	Cost New Mat'l (Including cost of material only)	Difference of Recycled vs. New
Fill Mat'l (recycled concrete)	105.35 tons	\$10.23/ton	\$10.23/ton	Equal
Fill Mat'l (trench spoils or clean fill)	2110 tons	\$0/ton	\$2.00/ton	>500% less
Fill Mat'l (flood control sand)	1 ton	\$50/ton	\$10.23/ton	490% more
Fill Mat'l (reclaimed pea gravel)	2.5 tons	\$124/ton	\$55/ton	225% more
Foundation (12" deep concrete blks)	805 blocks	\$0.77/block	\$1.60/block	52% less
Foundation Concrete (footings/blk fill)	13 cu yds	\$123.70/cu yd	\$130.05/cu yd	5% less
Framing (dimensional lumber)	Various	\$3,545.00	\$2,262.00	57% more
Trusses (18 ft & 11 ft span)	40 Trusses	\$64.75/truss	\$41.38/truss	57% more
Sheathing (equivalent to 4x8 OSB)	60 Sheets	\$10.80/sheet	\$6.80/sheet	59% more
Roofing shingles (asphaltic 3 tabs)	100 bundles	\$5.25/bundle	\$12.50/bundle	58% less
Siding (reclaimed barn boards)	800 Brd ft	\$0.90/Brd ft	\$1.50/Brd ft	40% less
Concrete floor (4,000 psi)	18.5 cu yds	\$123.70/cu yd	\$130.05 /cu yd	5% less
Windows/Doors	Various	\$180/unit	\$665/unit	73% less
High Thermal Mass Bed	24.29 tons	\$10.23/ton	\$10.23/ton	Equal
Bricks (Chicago Pink - exterior)	2,000 bricks	\$0.52/brick	\$0.54/brick	3% less
Maple Timbers	495 Lin ft	\$3.35/L.F. (avg)	\$9.07/L.F. (avg)	63% less
Maple Lumber (1" thick)	1,800 Brd ft	\$1.12/B.F.	\$3/B.F.	63% less

Table 5-2: COMPARISON OF TOTAL PROJECT COSTS OF RECYCLED/REUSED VS. NEW MATERIALS

Description of Construction Phase Or Type of Building Material	Quantity of Material	Cost Recycled (Including acquisition)	Cost New Mat'l (Including cost of material only)	Difference of Recycled vs. New
Fill Mat'l (crushed recycled concrete)	105.35 tons	\$1,077.00	\$1,077.00	Equal
Fill Mat'l (trench spoils or clean fill)	2110 tons	\$0.00	\$4,220.00	>500% less
Fill Mat'l (flood control sand)	1 ton	\$50.00	\$10.23	490% more
Fill Mat'l (reclaimed pea gravel)	2.5 tons	\$310.00	\$138.00	225% more
Foundation (12" deep concrete blks)	805 blocks	\$620.00	\$1,290.00	52% less
Foundation Concrete (footings/blk fill)	13 cu yds	\$1,608.00	\$1,690.00	5% less
Framing (dimensional lumber)	Various	\$3,545.00	\$2,262.00	57% more
Trusses (18 ft & 11 ft span)	40 Trusses	\$2,590.00	\$1,655.00	57% more
Sheathing (equivalent to 4x8 OSB)	60 Sheets	\$650.00	\$410.00	59% more
Roofing shingles (asphaltic 3 tabs)	100 bundles	\$527.50	\$1,253.00	58% less
Siding (reclaimed barn boards)	800 Brd Ft	\$720.00	\$1,200.00	40% less
Concrete floor (4,000 psi)	18.5 cu yds	\$2,288.00	\$2,406.00	5% less
Windows/Doors	Various	\$1,620.00	\$5,973.00	73% less
High Thermal Mass Bed	24.29 tons	\$239.80	\$239.80	Equal
Bricks (Chicago Pink - exterior)	2,000 bricks	\$1,050.00	\$1,080.00	3% less
Maple Timbers (8"x 8" & 4"x 4")	495 Lin ft	\$1,653.00	\$4,495.00	63% less
Maple Lumber (1" thick)	1,800 Brd ft	\$2,020.00	\$5,400.00	63% less
TOTAL		\$20,568.30	\$34,799.03	40% less

The data shown in the tables with boldface font, is for the more economically viable recycled materials. So, for example at the bottom of the tables, for the TOTAL to be “40% less”, the cost of acquiring, transporting, processing and/or purchasing all recycled materials is 40% less than the cost of purchasing and transporting all comparable new materials. It should be noted that as the cost of new materials fluctuates up or down, the percent difference will obviously change. The cost of lumber, for example, is currently at a ten year low so if the cost of lumber continues to decrease, the economic justification for using recycled/reused dimensional lumber will continue to be unjustified. However, if the cost of new lumber increases significantly (e.g., when 8’ long 2”x 4”s cost >\$3.10 each), then the economic justification for using recycled/reused dimensional lumber could change to be less expensive than purchasing new material.

In addition to the cost comparison data above, the actual costs for the Shop Addition project have been tabulated, are in the attached Tables. The table with the costs actually spent on the project construction is titled “5335 Lacy Road Shop Addition Actual Project Construction Costs” There is also an estimate prepared through RS Means CostWorks software that provide a “usual and customary” cost estimate for comparison with the actual costs. The cost estimation data used was updated for 2008 and is specific to the Madison, Wisconsin area. This table is titled “ Noble Earth Technologies, Inc. – WDNR Grant Project 07-05 High Recycled Content Shop Addition Project at 5335 Lacy Road, Fitchburg, WI”. The actual cost for the Shop Addition project was \$53,958 (\$39.79/sq ft). The RS Means CostWorks cost estimate for the Shop Addition project, not including any contractor overhead or profit, was \$54,660 (\$40.28/sq ft). If you include the normal estimated contractor overhead and profit, markups and other estimated add-ons for contractors, the estimate is \$75,390 (\$55.55/sq ft). In other words, if you built the same Shop Addition building with new materials it would cost between \$54,660 and \$75,390 whereas Noble Earth built the Shop Addition building for \$53,958. That is 1% to 40% higher to build by traditional methods with new materials with an average of 20% higher.

The actual costs and the estimated “usual and customary” costs are presented to show the savings that are possible by using the lower cost recycled/reclaimed materials. Overall, the materials that yielded cost savings exceeded the materials with higher labor costs (see tables, above, for details). The materials that save money, even with acquisition and processing labor factored in, are shown as bold in the above tables. Some of the recycled construction materials, such as framing, trusses and sheathing, cost substantially more (between 57% to 59% more) to acquire, process and build with the waste wood materials compared with the cost of acquiring and building with new materials. However, overall there was a significant cost savings by using all of the recycled/reclaimed materials that were used. If the cost of building materials increases then the cost savings from using recycled/reclaimed materials would increase as well.

6.0 LARGE SCALE IMPLEMENTATION

The three basic arguments given by most contractors or builders as to why they might not use recycled or reused materials on a larger scale are economics, quality and effort. Use of recycled or reused materials is generally thought to take significantly more labor time, which increases the project costs. Builders and contractors generally assume that the increase in labor cost would be more than the material cost savings. In addition, contractors/builders generally don’t want to take a chance on getting called back on a project due to a building material or quality related failure. The continued use of new building materials that are of uniform quality, size, price and can be delivered right to the construction site, ready to be used, is a compelling argument, when presented that way, against large scale waste building material reuse.

However, based on the economic evaluation in Section 5.0, and the experience of building with the recycled content and reused materials, the building phases listed below could easily utilize recycled content or reused construction materials without sacrificing quality while, at the same time, actually saving project costs and doing so with only moderate to no extra effort:

- **Fill Material** - Crushed recycled concrete comes in a wide range of particle size distributions, costs the same as similar fill materials and compacts well with no extra effort.
- **Foundation** - Recycled content concrete (5% slag & fly ash) costs less than its alternative because as much as 50% of the Portland cement is replaced by the slag/fly ash with no extra effort, since it is mixed by the concrete supplier. The presence of slag/fly ash yields a stronger concrete. The only drawback is that the concrete does take slightly longer to initially set up and come to full strength.
- **Framing I** - Graded and ungraded dimensional lumber used as bracing and blocking material saves money with minimal extra effort. More than this level of reuse is probably not economically viable. However, if the price of lumber goes up then increased reclaimed material use is worth reconsidering.
- **Framing II** - Timbers and lumber milled from trees removed during the initial site clearing provides a significant economic advantage to simply selling the trees with moderate extra effort, especially if timbers and specialty wood finishes are part of a future building project.
- **Sheathing** - Waste pieces of oriented strand board (OSB) have many uses. Reuse at the current building site or carrying larger scraps to the next building site will save money for a relatively moderate amount of effort. More than this level of reuse is probably not economically viable. However, if the price of OSB goes up then increased reclaimed material use is worth considering.
- **Roofing** – When available, the use of older, discontinued shingles or recycled content metal roofing does not sacrifice quality but does save money at the same level of effort.
- **Siding & Exterior** - Recovered bricks are reused in many situations, especially in areas of the country with less freeze/thaw conditions, and their use saves money with the same level of effort.
- **Concrete Floor** – Recycled content concrete (5% slag & fly ash – see “Foundation” above) costs less than its alternative and results in a stronger concrete with no extra effort.

- **Windows & Doors** – If a single window or door is needed, chances are it can be found at a Habitat ReStore for little extra effort and significant cost savings.
- **HVAC** – Installing solar panels and a high thermal mass heat absorption bed, made of crushed recycled concrete fines, yields energy savings for decades. However, there is significant cost & effort.
- **Drywall** – Reuse at the current building site or carrying larger pieces of scraped drywall to the next building site saves money for a relatively moderate to medium amount of effort. More than this level of reuse is probably not economically viable.
- **Interior finishing** – Dimensional lumber and trim milled from site-clearing trees is economical for a moderate to medium amount of effort. Consider doing this one if you are a craftsman who likes to work with wood.

If just the items listed above that took no extra effort and cost less than the new alternative were implemented, contractors and builders would save money, and hundreds of thousands of tons of material per year would be diverted from disposal at landfills. Since most of the items listed above save money on a construction project, and most require moderate to no extra effort, it makes sense to at least consider implementing some or all of them.

7.0 CONCLUSIONS AND FINAL RECOMMENDATIONS

Since work began on WDNR Grant Project No. 07-05 there has been a steady stream of recovered waste materials collected and processed (e.g., concrete block, waste fill material, dimensional lumber, engineered lumber, timbers, bricks, rebar, roofing, structural fill material and gravel). Waste building materials were collected from more than 64 sites and, after processing, a 75% recycled content Shop Addition was constructed (the goal was >61% recycled content). Given the evaluation of the project's technical effectiveness, detailed in Sections 2.0 and 4.0, and the economic evaluation, detailed in Section 5.0, this project has been an overall success.

Some highlights from the project technical information and economic evaluation include:

- The total amount of recycled construction waste materials that have been collected and/or used on the building projects is an estimated 2,373 tons.
- >95%, by weight, of the waste building materials collected and used for this project were found within 5 miles of Noble Earth's collection site.
- The materials that were used on the project, that were 100% recycled/reclaimed from construction waste, were as follows: fill material, foundation stem wall, stud wall framing, webbing for the mono trusses, exterior wall sheathing, roof deck sheathing, roofing and windows/doors.
- The overall labor cost to collect, transport, process and/or purchase all of the waste building materials was \$20,570 while the estimated cost of comparable new material was \$34,800. So, on this project, the recycled materials, overall, were 40% lower in cost than the comparable new materials. The \$20,570 cost includes the labor for acquisition, transport and processing of the recycled materials.
- The actual cost for the Shop Addition building project was \$53,958 (\$39.79/sq ft – see Tables for details). The RS Means CostWorks cost estimate for the Shop Addition project, not including any contractor overhead or profit, was \$54,660 (\$40.28/sq ft – see Tables for details). If you include the normal estimated contractor overhead and profit, markups and other estimated add-ons for contractors, the estimate is \$75,390 (\$55.55/sq ft – see Tables for details). In other words, if you built the same Shop Addition building with new materials it would cost between \$54,660 and \$75,390 whereas Noble Earth built the Shop Addition building for \$53,958. That is 1% to 40% higher to build by traditional methods with new materials, with the average being 20% higher.
- A steady stream of project challenges were worked out and overcome, as detailed in Section 3.0.

Given the amount of waste material diversion and usage on this one grant project (a total of 2,373 tons), the extrapolated impact and environmental effects from the widespread implementation of the recommendations provided in Section 6.0 would be significant. It is projected that it could result in the recycling and reuse of hundreds of thousands of tons of construction waste per year, just in Wisconsin. Noble Earth recommends a full implementation of construction waste recycling and recycled/reclaimed waste material reuse throughout Wisconsin.