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Proposal Title:
ENVIRONMENTAL PERFORMANCE MEASURES FOR RENEWABLE BUILDING MATERIALS WITH ALTERNATIVES FOR IMPROVED PERFORMANCE – Phase II

By: CORRIM (The Consortium for Research on Renewable Industrial Materials)

Targeted Research Area

America's future and quality of life depends on the sustainable management and wise use of natural resources such as our nation's forests. Home centers and wood distributors have come under pressure to identify and sell only environmentally preferable products. Government organizations are developing guidelines for environmentally preferable products in order to direct the massive purchasing power of the government toward similar objectives. Unfortunately the availability of quality data to use in developing guidelines or identify preferred products is far behind these attempts. One viable tool for attaining such a goal is Life Cycle Inventory (LCI) and Life Cycle Assessment (LCA) – understanding all the inputs and outputs of the growth, use, manufacturing, and disposal of forest products and their substitutes. With LCI information on products, particularly as they are used in building systems, one can assess environmental burdens and identify preferable alternatives and make changes that can lead to improved performance. Negative impacts can be mitigated and opportunities can be capitalized upon for the best use of wood and other products.

The American Forest and Paper Association's environmental performance research agenda under "Agenda 2020" included support for an updated analysis of the energy and environmental efficacy of renewable building materials and the cost effectiveness of environmental performance improvements with the ultimate objective of reducing environmental releases and energy requirements.

The Consortium for Research on Renewable Industrial Materials (CORRIM), a group of 15 research institutions and a number of member companies was formed in 1996 to conduct research on the environmental performance of wood materials and to develop LCI/LCA information on wood used in construction. Analyzing the flow of resources from the forest or mine pits to products, buiildings and ultimately disposal is a complex undertaking that is just now in the early stages of producing valid results. CORRIM developed a Research Plan that included 22 research modules and a protocol for carrying out the research (CORRIM 1998). Research on the first few modules has progressed resulting in an Interim Research report on the findings in 2002 and a Final Research Report that is now undergoing professional review (Bowyer et.al 2002 and 2004).

Introduction and Executive Summary

This proposal builds on the CORRIM Phase I research effort which is nearing completion. Phase I has developed Life-Cycle Inventory (LCI) data for structural products used in residential construction from two supply regions, the Pacific Northwest (PNW) and Southeast (SE), and developed Life-Cycle Assessments (LCAs) for the structure of buildings in Atlanta (a warm climate) and Minneapolis (a cold climate). The LCI database on lumber, plywood, oriented

strandboard (OSB), glulam, laminated veneer lumber (LVL), and I-joists for these two supply regions characterizes all the inputs and outputs for manufacturing these products starting from forest regeneration through manufacturing including the impact of all primary fuels. This comprehensive database will become a part of the USLCI database, a government supported project managed by DOE to collect properly reviewed LCI information on a wide range of products. Summary outputs of the LCI data are provided in the form of an LCA for environmental performance indices (energy, carbon, air & water pollution, solid waste, material use efficiency and forest biodiversity) for residential structure framing alternatives. The ATHENA Institute, a cooperator on the project provides a model, the Environmental Impact Estimator model (EIE) to integrate the bill of materials for residential designs and incorporates a wide range of non-wood product and design assemblies that are used in construction. The LCA includes wood and steel designs in Minneapolis and concrete and wood in Atlanta as well as designs that include within-wood substitutes such as OSB vs. plywood and I-joists vs. dimension lumber. The Phase I project successfully tested the implementation of a set of published research guidelines that supported integrating life cycle impacts across different products from cradle (regeneration) to grave (final disposal). The Phase I report demonstrates generally lower environmental burdens when more wood products are used in construction including substantial reductions is the use of fossil energy sources.

This proposal extends the Phase I research plan to include forest resource coverage for Northeast/Northcentral (NE/NC) and the Inland West and to insure the consistency with comparable Canadian data. By including lumber and OSB in these regions it essentially provides for complete coverage of structural products used in housing across the US. This database will then provide complete coverage for the primary LCI data for the softwood products used in housing for entry into the emerging multi-material USLCI database being coordinated by DOE-NREL.

Table 1 summarizes the coverage provided by Phase I and the extensions planned in Phase II contingent upon adequate funding.

Table 1. Summary of Phases I & II

Subject	Phase I Completed	Phase II Planned
Study Period	2000-2003	2004-2006
Forest Resources Module	Southeast, PNW	+ NC/NE, Interior West,
Houses	Atlanta , Minneapolis	+California/SW, Seattle/NW
Wood products	Lumber (regional), Plywood, OSB, LVL, glulam, I-joist	+ Lumber (all regions), OSB, Particleboard, treated wood and adhesives(a critical input)
Non-wood	Concrete, steel	Concrete, steel
Housing design	Residential – single-dwelling	+ Residential single, condo and subassemblies
….		
Forest Management	Fertilization, thinning	partial cutting

Several non-structural high volume products (particleboard, MDF and hardwoods) used in housing interiors and industrial applications will be included along with an analysis of the adhesives used in these and other wood products. A hardwoods forest resource module will be developed in conjunction with the NE/NC forest resource coverage module. Phase I demonstrated substantial performance differences across housing designs. Phase II will include analysis for a range of construction subassemblies appropriate for substitute materials in different regions as essential building blocks for understanding the impact of different design/material combinations. While the analysis of products frequently stops with LCI, a summary LCA will be provided for each component making up a wall or floor subassembly. Analysis of completed single family housing will be extended to include other high volume locations (Southwest or Southern California and PNW) and to alternative structures (low rise condo or apartment) providing a more complete analysis of construction variability and opportunities for improved environmental performance.

In addition to the geographic extension which will expand the Phase I coverage of forest resources and lumber from the two main supply regions to all regions, Phase II will extend the residential designs in regional coverage and to the low rise multiple-residence condos. Product coverage will also be extended to several non-structural products that have high volume use for interior use.

A summary description for each project module is provided below. This proposal includes non-federal matching support of 20% by the participating research institutions with the goal of extending the direct industry contribution to at least 25%.

Primary Investigators:

Bruce Lippke, CORRIM President, U. of Washington
Jim Wilson, CORRIM VP and chair of stage of processing modules, Oregon State University
Dave Briggs, chair for research protocols and guidelines, U of Washington
John Perez-Garcia, chair of integration analysis, U of Washington
Leonard Johnson, chair for forest resource modules
Kenneth Skog, chair for US Forest Products Lab participation
Bryce Stokes, chair for USFS Research participation
Bo Kasal, chair for construction alternatives, North Carolina State University
Pat Huelman, co-chair for construction and thermal analysis , University of Minnesota
Paul Winistorfer, chair for energy use, maintenance and disposal, Virginia Tech State U.
Wayne Trusty, LCI integration in structures, ATHENA Institute

Member Research Institutions, partners and key advisors:

U. of Idaho, U. of Washington, U. of Minnesota, Washington State U., Mississippi State U., North Carolina State U., Oregon State U., Virginia Tech State U., Louisiana State U., Purdue U.,

FORINTEK (CA), ATHENA Institute (CA), APA-The Engineered Wood Association, Western Wood Products Association, Composite Panel Association, USFS Forest Products Laboratory, USFS Research and Development. Memberships or affiliations are anticipated with Yale U., U. of Maine, U. of Wisconsin, and Penn State U. in order to extend the geographic coverage for Phase II.

Models and Databanks:
LCI data for products and stages of processing are developed in SimaPro, a professional software data analysis package designed for life cycle analysis, licensed from Pre' Consultants, Amersfoort, Netherlands. Product LCI's are developed (1) for mill processing of products including a report on purchased fuels which is used as the input to other models that directly compute the LCI impacts associated with purchased fuels, (2) including the impacts of those fuels, and (3) including user defined transportation hauls from producer to user. This provides ultimate flexibility in using the LCI data. For the LCA data on housing structures, the product LCI data is imported to the Environmental Impact Estimator (EIE) model developed and maintained by the ATHENA Sustainable Materials Institute, Ottawa, Canada, a cooperator with CORRIM on the research. The EIE is commercially available software for simulating building construction to generate LCI and environmental impact measures. CORRIM's use of the EIE has been supplemented by a more detailed analysis of biofuels which are of particular importance to wood based product uses. LCI data developed by CORRIM and other industries is also being made available by the Dept. of Energy, NREL, in a USLCI Database so that data developed under a common set of standards for a wide range of primary products is availbe to users.

Schedule: Stage of processing resource module drafts available June 15, 05; products Dec. 15, 05; assemblies, housing and integration analysis June 15, 06, reviewed and published by December 15, 06.

Research Module Descriptions:

(Module 1) Forest Resource II: Northeast/Northcentral (NE/NC), and (Module 2) Inland West

Summary Statement: Research is needed to synthesize data on the environmental and energy impact of providing timber and logs for the manufacture of products used in construction applications for the NE/NC and Inland West supply regions, building off of the work already completed in Forest Resources I modules for PNW & SE.
A comprehensive analysis of the impact of forest resource management from stocking through the delivery of logs to manufacturing operations is needed. This analysis should consider all pertinent inputs and outputs, including development of a life-cycle inventory analysis of environmental and energy measures for comparison to the use of other resources or management alternatives. The analysis should include a range of management alternatives and their impact on harvest, forest inventory, carbon sequestration, forest structure distributions and linked habitat indices, and other co-products of forest management. The resultant data and analysis should facilitate

identification of cost effective strategies for reducing the impacts of forest production on the environment or to meet existing or proposed environmental requirements.

Objective and Output of Module:

- Provide environmental, energy and resource data on the growth, management, harvesting and reforestation of timber for a range of management intensity scenarios for the NE/NC and Inland West supply regions of the United States.
- Develop case studies to represent a typical range of forest management objectives and stand and site conditions.
- Provide environmental performance measures including indices of stand structure diversity and habitat for each of the case study scenarios.
- Provide inputs for the Processing and Biomass modules from the case study scenarios.
- Provide LCI data for harvesting for the USLCI database project

Justification:

Removal of wood biomass from the forest and the activities associated with growth, removal, and re-establishment of trees need careful analysis to determine the total life-cycle impacts and sustainability of the use of biomass-based products. Life-cycle impacts are not stationary and will change over the next 100 years based on both past and prospective technologies, evolving forest management procedures and population demands. Time becomes a critical element of this analysis since the period from initial planting or forest establishment to removal can range from five years for short rotation intensive culture to 100 years or more for selectively managed natural forests. Inputs and outputs of the life-cycle process include both quantitative and qualitative measures of the environment and timber removed. To some, the qualitative (largely environmental) factors are of great importance to the life-cycle impacts of utilizing wood biomass and, to the degree possible, these factors need quantitative descriptions developed. Understanding the time dependent linkages between technology changes and management practices and their effects on these factors is essential to improve forest management alternatives that enhance the critical environmental features, but are also cost effective.

Research Statement:

Research is needed to identify harvest and forest management technologies that enhance critical environmental factors (environmental design systems) associated with forest management alternatives that are designed to produce timber. This will be done by characterizing the life-cycle inputs and outputs of representative forestry operations for both softwoods and hardwoods that are used in the construction and finished interiors of buildings. A wide variety of forest management and harvesting options currently exist, but the total environmental and economic impacts of these options over the life cycle of the forest are not well understood. A limited number of scenarios, representing the range of environmental and timber objectives, will be structured and analyzed through models

developed and tested in Phase I for the SE and PNW supply regions. These options could include:

(1) A base scenario representative of current management strategies.

(2) High timber output at low cost, while maintaining low environmental impacts—a scenario likely to involve areas intensively managed for timber and will involve such forest management activities as fertilization, thinning, harvest regeneration cuts and reforestation through planting.

(3) High outputs of environmental factors at low cost, but with continued production of timber—a scenario likely to involve selective removals of trees to maintain health, diversity and density of the forest. Activities such as thinning, snag and debris retention could be involved to achieve a desired level of structure diversity and mix of species.

(4) No forest management with no entries for wood removal—a control scenario that while perhaps unlikely, reflects the impact of no man-made or historic disturbances

(5) Post-fire regeneration – a possible scenario of interest in the inland west.

Outputs will be developed from existing models and synthesized to provide an indication of the life-cycle impacts of this range of forest operations. Some of these outputs are measurable in conventional units of measurement. Some environmental outputs will need to be expressed as indices comparable to the input values. All measures will be developed or calculated as responsive to selected management alternatives and primary resource inputs.

Inputs:

Stand structure and location as described by slope classification, site classification moisture relationship (wet or dry site), age classification (even aged, uneven aged, mature) and species mix. Analysis will be restricted to a distinct number of cases that represent the most common combination of conditions of a region.

Harvesting options with a regional average transport distance to the processing point and the harvest system selected from mechanized or non-mechanized, ground-based, cable or aerial harvesting system, or alternative harvesting technologies. The harvesting system selected will also be matched to options on road location and density.

Natural disturbances with associated risk factors for wildfire, insect and disease, wind and storm damage, and floods and related slope instability. Impact and costs of mitigation and control measures will also be noted.

Forest management treatments to existing forest stands to include thinning, pruning, fertilization, herbicide and pesticide treatments, harvest prescription, debris and snag retention and reforestation.

Pre-treatment measurements of environmental factors that to the degree possible include: water quality index, water quantity outflow per acre, an air quality index for factors related to fire, snags and down woody material, fuel loading, a biological diversity index as measured by a habitat index and stand structures (diameter, trees per acre, canopy, etc.), carbon storage per acre, and volume of standing biomass per acre.

Cost basis (simplified/standardized tax accounting) to include material costs, labor costs, cost of capital, and taxes.

Product options and values to include outputs in lumber grades, pulp wood grades and engineered products.

Harvesting inputs for harvest and transport to gate of processing, including energy requirements per acre by option, and other materials used.

Outputs:

Output tables of stand level variables will be expressed on a per acre basis. Outputs that do not lend themselves to per acre expressions will be expressed as a regional impact. Some outputs will stand by themselves as measures of impact from forest operations. In these cases they will be compared to values and indicators before treatment and when appropriate to a baseline scenario. Others will serve as input to the processing modules of the project. The outputs include the following:

Product volumes by quality, product, and species categories
Energy used by form
Carbon balance
- amount released and amount stored
- input to products

Water quality and quantity measurements
Air emissions
Biological diversity index as measured by habitat and stand structure
Production costs
Economics from marketed products to include cost and net present value, and to the degree practical, estimates of jobs.

Procedures:

The combination of forest stand conditions and treatment options in any given region are infinite. The first step in analysis for this module will be to develop a fixed number of options for analysis based on the alternatives defined earlier and stand and slope conditions typical of a region. Phase I of the module has analyzed conditions in the Pacific Northwest and Southeast United States. Phase II will consider a similar range of conditions appropriate to the Inland West and Northeast/North central United States. These will represent the most likely scenarios to meet timber market and environmental objectives and will also reflect a range of treatment options from no management or recovery from a site to intensive management. The site and stand conditions will also be limited to reflect those most likely to be selected for removal of biomass material. A select number of case studies will be developed for each region.

Existing models and spreadsheets developed in Phase I will be used to develop relationships before and after treatment. The Landscape Management System with regional growth models can be used to predict growth and yield of the biomass over time, to predict watershed impacts, and to assess fire risk in forest stands. Other work has been done in some regions to develop indicators of habitat and biological diversity. Where necessary, additional indicators can be developed from model output. Results of these models will be synthesized to develop output tables for a selected number of treatment options and locations.

Important outputs characterizing the impact of technology management alternatives will be the amount and quality of timber for markets, carbon stored and input to product flows, energy used by form, measures of biodiversity (habitat indices and stand structures), net present value to the landowner, jobs, tax receipts, expenditures, and capital requirements. These will establish a life-cycle footprint for each management alternative as a function of time.

Preliminary budget plan:	***External funds***	***Institution match***
NE/NC softwood supply	***$30,000***	***$10,000***
NE/NC hardwood supply	***$21,000***	***$7,000***
Inland West softwood supply	***$30.000***	***$10,000***
Model Extensions	***$15,000***	***$5,000***

(Module 3) Processes II for NE/NC lumber, (Module 4) for Inland West lumber and (Module 5) for NE/NC OSB

Summary Statement: Research is needed to synthesize data on the environmental, energy, and resource impact of manufacturing structural wood products such as softwood lumber, and oriented strand board (OSB), used in the construction of residential and light commercial structures.
A comprehensive life-cycle inventory analysis is needed of the environmental, energy, and resource impacts of wood use as a structural material and as an alternative to other materials. The study should address the impact from the resources entering the manufacturing operations through to the shipping of the product, considering all pertinent inputs and outputs. The specific products and related processes that need to be analyzed are softwood lumber and oriented strand board. The analysis will provide a parallel assessment like the analysis provided for similar products in the SE and PNW regions developed in the Phase I Research. The degree to which findings are similar at the machine center level will be identified so that future updates can concentrate on areas of change. The resultant data and analysis should facilitate identifying cost effective strategies for reducing the impacts of processing and product use on the environment.

Objective and Output of Module:

- Provides environmental, energy, and resource impact data on the manufacture of softwood lumber, and oriented strand board (OSB), in the NE/NC and Inland West regions.
- Provides input data for the Structural Modules
- Provides benchmark data for these products that will enable future comparison of process improvements or to new processes
- Shows fossil versus biomass fuel dependency
- Provides a measure of resource use efficiency
- Provides data for the USLCI database

Justification:

Over half of all forest products manufactured go into residential and light commercial construction resulting in a number of short and long term environmental performance impacts. A major portion of these products consists of structural building materials in the form of softwood lumber or, oriented strand board (OSB). The emphasis of this module will be on the life-cycle analysis of the manufacture of these materials based on resources from NE/NC or Inland West softwood and hardwood regions. The assessment of these materials will be used as inputs to the Structures module, which assesses structural units of walls, floors, and roofs composed of various building materials from individual supply regions. Ultimately these units will be combined in the Structures II module to analyze the impacts of completed residential and light commercial structures and their subassemblies.

Research Statement:

Research is needed to synthesize from available sources impacts resulting from the use of structural wood components in residential and light commercial building. The intent of this research is to document the environmental performance impacts of manufacturing structural materials that will be used as components in comparative structural units of floors, roofs, and walls. Data will be collected and analyzed on the production of solid lumber and, OSB, for two regions of the country–NE/NC and Inland West. Environmental, energy, materials, and economic data related to the production of these products will be collected in a manner consistent with the new CORRIM II protocol for measuring life-cycle impacts, while also being able to provide cost/benefit analysis comparisons between alternatives.

Inputs:

Raw materials (type, amount, and cost)
Ancillary materials (adhesives, wax, oils, antifreeze, packaging)
Water
Energy (type and source)
Capital
Labor
Transportation

Outputs:

Emissions to air, land and water (CO, CO_2, CH_4, NO_x, SO_2, particulate, VOC, HAP, formaldehyde)
Energy (purchased and biofuel sourced)
Solid waste
Materials (products and co products)
Transportation

Procedures:

Primary data will be used for wood products processing for the structural materials, while secondary data will be used for alternative materials such as steel, concrete, and plastic. Primary data will be developed for resins and adhesives in another module of this project. The study will be conducted for all inputs and outputs from the raw material coming into the process, to a manufactured product shipped to its use destination. Impact analysis data from the Forest Resources modules will be used as raw material inputs to the manufacturing operation. Analysis of the selected processes will be done not only by product, but by machine center within a process as well. Examples of machine centers include such manufacturing steps as sawing, planning, hot pressing, drying, and energy production. Choosing the machine center approach has several benefits. First of all, it will save time and effort when analyzing other operations that have the same or similar machine center in their operation such as machine centers in different regions. Secondly, information from machine centers will enable the analysis of new products and processes based on known machine centers such as the impact from different co product allocations for biofuel. Information gathered using this approach should prove useful in examining process modifications and determining the amount of reduction in environmental, energy and resource impacts that may be realized through processing and product changes.

Preliminary budget plan:	***External funds***	***Institution match***
NE/NC softwood lumber	***$30,000***	***$10,000***
NE/NC OSB	***$30,000***	***$10,000***
Inland West softwood lumber	***$30,000***	***$10,000***

(Module 6) Medium Density Fiberboard, MDF, (Module 7) Particleboard, (Module 8) Resins and Adhesives

Summary Statement: Research is needed to synthesize data on the environmental, energy, and resource impact of manufacturing medium density fiberboard (MDF) and particleboard used in furniture and interior finishing of light commercial structures. The research needs to be extended to include adhesives as important input materials.
A comprehensive life-cycle inventory analysis is needed of the environmental, energy, and resource impacts of wood use in medium density fiberboard and particleboard including the role of resins and adhesives. The study should address the impact from the

resources entering the manufacturing operations through to the shipping of the product, considering all pertinent inputs and outputs. The analysis will provide a parallel assessment like the analysis provided for similar products in the SE and PNW regions developed in the Phase I Research. The degree to which findings are similar at the machine center level will be identified so that future updates can concentrate on areas of change. The resultant data and analysis should facilitate identifying cost effective strategies for reducing the impacts of processing and product use on the environment.

Objective and Output of Module:

- Provides environmental, energy, and resource impact data on the manufacture of medium density fiberboard (MDF) and particleboard
- Provides environmental, energy, and resource impact data on the manufacture of resins and adhesives as important inputs to the process
- Provides input data for other wood uses
- Provides benchmark data for these products which will enable future comparison of process improvements or to new processes and in particular to provide data to update previous LCIs that relied on foreign or secondary data for information on adhesives
- Shows fossil versus biomass fuel dependency
- Provides a measure of resource use efficiency
- Provides LCI data for the USLCI database project

Justification:

Several wood products that are not generally used in the structural shell of buildings are of substantial volume and consume residuals (co products) from other product processes. Although the wood resources are relatively cheap, they carry substantial environmental burdens from their production process, and the regional affect of fuels and electricity for adhesive and panel production can be significant. By completing these modules in conjunction with the adhesives module it should be a natural extension of the methods developed in the Phase I Research for other products. The emphasis of this module will be on the life-cycle analysis of the manufacture of these materials. The assessment of these materials will be used as inputs to furniture, cabinets and other building interior applications. Also, the data on environmental impact of adhesive production can be used to update analysis of structural wood products such as plywood, OSB, glulam, I-joists and LVL done in Phase I using non-US data as a secondary source. Ultimately these units will be combined in structural modules to analyze the impacts of completed residential and light commercial structures and their subassemblies including interior finishing and remodeling applications.

Research Statement:

Research is needed to synthesize from available sources impacts resulting from the use of MDF and particleboard in building interiors and furniture and the use of adhesives in these products and a broader range of wood products. The intent of this research is to document the environmental performance impacts of manufacturing components that are

frequently used in furniture and building interiors and the resins and adhesives used in a broader range of products. Environmental, energy, materials, and economic data related to the production of these products will be collected in a manner consistent with the new CORRIM II protocol for measuring life-cycle impacts, while also being able to provide cost/benefit analysis comparisons between alternatives.

Inputs:

Raw materials (type, amount, and cost and relationship to other primary wood products)
Ancillary materials (adhesives, wax, oils, antifreeze, packaging)
Water
Energy (type and source)
Capital
Labor
Transportation

Outputs:

Emissions to air (CO, CO_2, CH_4, NO_x, SO_2, particulate, VOC, HAP, formaldehyde), land, water
Energy (purchased and biofuel sourced)
Solid waste
Material (products and co products)
Transportation

Procedures:

Primary data will be used for wood products processing, and as a companion project primary data will be available for adhesives that are important input materials to the production process. The LCIs for adhesives will be unique in that only a few companies produce essentially all the UF, MUF, PF, and PRF adhesives, and only one or two additional companies produce PMDI. These companies have willingly offered to assist with data collections. The plastics industry is doing some work in this area and may also be willing to participate. The completed LCIs would be compared to the LCIs from the European and Canadian databases that were used in Phase I for the plywood, OSB, LVL, glulam, and I-joist LCIs. Should there be a major difference in these databases, the Phase I models for composite structural products would be updated. The study will be conducted for all inputs and outputs from the raw material coming into the process, to a manufactured product shipped to its use destination. Impact analysis data from the Forest Resources modules and other wood product and co product processes will be used as raw material inputs to the manufacturing operation. Analysis of the selected processes will be done not only by product, but by machine center within a process as well. Examples of machine centers include such manufacturing steps as hot pressing, blending, trimming, drying, energy production and emissions mitigation. Choosing the machine center approach has several benefits. First of all, it will save time and effort when analyzing other operations that have the same or similar machine center in their operation such as machine centers in different regions. Secondly, information from machine centers will enable the analysis of new products and processes based on known machine centers such as the impact from different co

product allocations for biofuel. Information gathered using this approach should prove useful in examining process modifications and determining the amount of reduction in environmental, energy and resource impacts that may be realized through processing and product changes.

(Module 6) Medium Density Fiberboard, MDF, (Module 7) Particleboard, (Module 8) Resins and Adhesives

Preliminary budget plan:	***External funds***	***Institution match***
Particleboard	***$30,000***	***$10,000***
MDF	***$30,000***	***$10,000***
Resins and Adhesives	***$60,000***	***$20,000***

(Module 9) Treated wood LCI

Summary Statement: Research is needed to synthesize the data on the environmental, energy, and resource impacts of treated wood used in housing and industrial applications.

A comprehensive life-cycle inventory analysis is needed of the impacts of treated wood used in housing and industrial applications in comparison with other materials. The study should address the impact from the resources entering the manufacturing process through the shipping of the finished product and consider all pertinent inputs and outputs. Treated wood products that should be considered include wood used in the foundation of housing and light construction, decks, termite barriers, railroad ties, cooling towers, marine structures, utilities, and bridges, but need not be limited to these materials. The resultant data and analysis should facilitate the identification of cost effective strategies for reducing the impacts of processing and product use on the environment. The 3 or 4 most common current or emerging compounds will be covered.

Objective and Output of Module:

- Provides environmental, energy, and resource impact data on the manufacture of treated wood products including foundations for housing and light construction, decks, termite barriers, railroad ties, cooling towers, marine structures, utilities, and bridges foundations, decks, pallets, utility poles, piling, and railroad ties.
- Provides benchmark data for these products that will enable future comparisons with process improvements or with new processes.
- Identifies the role of wood preservation in recycling chemical waste products generated by other industries.
- Shows fossil fuel versus biomass fuel dependency.
- Provides a measure of resource use efficiency
- Provides LCI input data for the US LCI database

Justification:

Industrial products represent nearly 50% of the total volume of preservative treated wood produced each year. These products are primarily treated with creosote, pentachlorophenol, or one of the inorganic arsenicals. All of these materials have come under scrutiny from the Environmental Protection Agency and their use is tightly controlled to minimize the potential risks during treatment and use. Treated products are

also used extensively in homes as termite and moisture barriers and for decks or other exposed applications. The preservatives CCA and ACZA (copper napthenate) can be used in the permanent wood foundation (PWF) offering a potential alternative material to all-concrete. Other preservatives to consider are: ACQ, Cu Azole, disodium octaborate tetrahydrate (Tim-bor), and ZnBorate. The three or four most common current or emerging compounds will be examined. Treated products should include OSB, plywood, lumber, and decking materials for attached decks. Some aspects would be regionalized because of wood species (southern pine and Hem-fir) and regional building codes and practices (the south uses more borate treated wood and has a larger use of the PWF, and the use of ammonia based preservatives in the Northwest).

The data from this module will be used as inputs in the analysis of residential and light frame structures and their subassemblies. They will be used directly in the analysis of some large industrial products such as poles, and docks.

Research Statement:

Research is needed to synthesize from available sources the environmental impacts resulting from the production of treated wood employed in industrial and housing applications. The intent of this research is to document the impact of manufacturing materials that will be used in applications such as housing, decks, water-cooling towers, bridges, electric transmission or distribution lines, docks, railroads, and other large-scale exposed applications. Data will be collected and analyzed on chemical production, impregnation processes, internal waste handling procedures and disposal of treated or untreated wood products at the end of their useful life. Data will be regionalized to the extent necessary. Environmental, energy, materials and economic data related to the production of these products will be done in a manner consistent with the new CORRIM II protocol for measuring life-cycle impacts while also providing cost/benefit analysis comparisons with alternatives.

Inputs:

Raw materials (types and amounts)
Ancillary materials (coatings, fasteners)
Water or oil (solvent)
Energy (types and sources)
Capital
Labor
Transportation
Disposal

Outputs:

Material (products/byproducts)
Emissions to air, land, water (CO, CO_2, NH_4, Cu, Cr As, polycyclic aromatic hydrocarbons, pentachlorophenol)
Solid waste (sludge, sawdust, older treated wood)
Waste energy by source
Transportation

Procedures:
The study will assemble available data on all inputs and outputs from the raw material coming into the process to manufactured products ready for shipping. Industrial inputs related to the production of preservative components will be particularly important, but the possible inputs from waste mitigation strategies and other aspects of treatment mandated by Federal regulations should not be overlooked. Primary data will be used for assessing the impacts of production of treated and untreated industrial products, while secondary data will be used for comparative materials such as steel, concrete, fiberglass or plastic. The data will be analyzed on a process basis for treated wood products rather than on an individual commodity basis. This approach should minimize duplication of data and assist in the identification of process changes that can reduce environmental, energy and resource impacts.

Preliminary budget plan:	***External funds***	***Institution match***
Treated wood	***$60,000***	***$20,000***

(Module 10) Structural Components and Subassemblies

Summary Statement: Research is needed to synthesize data on the environmental, energy, and resource impact of different designs for constructing residential and light commercial structures using wood and other products.
The life-cycle assessment of residential structures completed in Phase I for wood, concrete and steel framing in a cold and warm climate showed much greater energy consumption in the common assemblies in the structure than in the alternative framing systems suggesting a much more comprehensive analysis of building design alternatives is needed. The study should address the impact of a wide range of subassemblies used in buildings including alternative designs for each subassembly that might be used in a given region. The scope of the study should include all pertinent inputs and outputs associated with the construction of these subassemblies. The resultant data and analysis should facilitate identifying cost effective strategies for reducing the impacts on the environment of constructing residential and light commercial buildings.

Objective and Output of Module:

- Provides environmental, energy, and resource impact data on the manufacture of floor, wall, and roof assemblies for residential and light commercial structures and the contribution of each product component
- Provides environmental, energy, and resource impact data on the manufacture of representative single residential structure designs comprised of floor, wall, and roof components
- Provides benchmark data for these products which will enable future comparison

of process improvements or to new processes
- Shows fossil versus biomass fuel dependency
- Provides a measure of resource use efficiency
- Provides data on structural assemblies to complement the primary product data in the USLCI database project

Justification:

Individual components (i.e., joists, studs, sheathing, etc.) are combined structurally to form various "subassemblies" such as floors, walls, and roofs. Floors and roofs can be comprised of individual components (e.g., joists or rafters) or of other systems (e.g. trusses). These subassemblies are combined to form a structural system. An understanding of the environmental impacts in producing structural components and their contributrion to the impacts of structural subassemblies is an essential step in the development of environmental performance measures and the identification of cost effective ways to improve environmental performance for structures.

Inputs:

Solid wood products
- lumber
- glued laminated lumber
- wood trusses

Composite wood products
- LVL
- composite I-beams
- plywood
- OSB
- particleboard

Other essential materials
- connectors (nails, bolts, glues)
- gypsum
- insulation

Type of construction
- site-constructed

Governing design criteria
- energy efficiency
- architectural
- structural

Transportation

Labor

Capital

Outputs:

Based on available data, several typical (representative) designs will be analyzed in detail. The analysis will yield the following data:

Quantity of the individual components required
Comparative energy consumption and other environmental performance impacts during the construction and life expectancy of the assembly
Relative cost of alternatives considered

Procedures

The first step in the analysis will be an evaluation of available components that can be substituted and the relative quality, environmental performance, life expectancy and cost of these components. The second step will be the evaluation of all assemblies (floors, walls, roofs, foundations) comprised of the aforementioned components, again including an assessment of the relative quality, environmental performance, life expectancy and cost. The results will be reported for each component and assembly type category discussed above. Regional categories may be introduced if such factors are deemed significant.

Preliminary budget plan:	***External funds***	***Institution match***
Comparisons for substitutable components	***$21,000***	***$7,000***
Analysis of alternative subassemblies	***$30,000***	***$10,000***
Identification of improvement alternatives	***$21,000***	***$7,000***

(Module 11) Residential construction location and multi-unit differences

Summary Statement: Research is needed to synthesize data on the environmental, energy, and resource impact of different building design s for constructing single and multi residential and light commercial structures using wood and other products as an extension to the Phase I analysis of single family structures in a cold and warm climate.
The life-cycle assessment of residential structures completed in Phase I for wood, concrete and steel framing in a cold and warm climate demonstrated that design changes would have a major impact. Design structures for a PNW and SW or Southern California climate are needed. Similarly designs for multi-family apartment or condo units are needed. The scope of the study should include all pertinent inputs and outputs associated with the construction of these subassemblies. The resultant data and analysis should facilitate identifying cost effective strategies for reducing the impacts on the environment of constructing residential and light commercial buildings.

Objective and Output of Module:

- Provides environmental, energy, and resource impact data on a range of structures representative of the range of single and multi-family designs in the US
- Identifies design changes for improved environmental performance
- Shows fossil versus biomass fuel dependency

Justification:

Environmental performance impacts for buildings are very design sensitive requiring an analysis of a range of design alternatives that are appropriate for different regions as well as for single and multi-unit use. An understanding of these differences is an essential step in the identification of cost effective ways to improve environmental performance.

Inputs:

- Solid wood products
  - lumber
  - glued laminated lumber
  - wood trusses
- Composite wood products
  - LVL
  - composite I-beams
  - plywood
  - OSB
  - particleboard
- Other essential materials
  - connectors (nails, bolts, glues)
  - gypsum
  - insulation
- Type of construction
  - site-constructed

- Governing design criteria
  - energy efficiency
  - architectural
  - structural
- Transportation
- Labor
- Capital

Outputs:

Based on available data, several typical (representative) designs will be analyzed in detail. The analysis will yield the following data:

- Quantity of the individual components
- Quality of the structural assembly
- Energy consumption and other environmental performance impacts during the construction and life expectancy of the assembly
- Relative cost of alternatives considered

Procedures

The analysis will parallel the Phase I Research for single family buildings in a cold and warm climate extending the designs to include other regions where designs are significantly different, in particular for the Southwest and Northwest. Designs will also be extended to include multi-family units. Environmental performance comparisons will be developed using modules such as ATHENA and SimaPro developed in the Phase I Research.

Preliminary budget plan:	***External funds***	***Institution match***
Southern CA and PNW single family design impacts	***$21,000***	***$7,000***
Multi-family design impacts for several regions	***$30,000***	***$10,000***
Integration and improvement alternatives	***$21,000***	***$7,000***

(Module 12) Cradle to gate integrated LCI/LCA's for easier use

Phase I reviews have identified that those interested in direct use of product LCI's cannot easily assess a transportation grid for consistent use. This module will provide a user friendly access to the product LCI's developed in Phase I and ultimately Phase II. This becomes in effect an integrated product LCI module. We will explore extending this to intermediate LCA's for specific uses of the material based on module 10a and perhaps 10b and c.

Preliminary budget plan:	***External funds***	***Institution match***
Cradle to gate LCI for Phase I products	***$21,000***	***$7,000***
Cradle to gate LCI for Phase II products	***$21,000***	***$7,000***
Cradle to gate LCA for Phase I and II products	***$30,000***	***$10,000***

(Module 13) Canadian wood data review/workshop

We should review and incorporate Canada supply regions BC coast, BC Inland, and Eastern Canada on a consistent basis with other regions. This will require a joint review with ATHENA on the data and assumptions. In theory, we should be close to consistency short of environmental measures at the landscape level. A funded review workshop could identify any differences that need to be flagged and perhaps adjusted or otherwise identified as future needs.

Preliminary budget plan:	***External funds***	***Institution match***
Canadian wood data review and workshop	***$20,000***	***0***

PROJECT COST BUDGET SUMMARY

Module 1-13 Budget Subtotal	**$602,000**	***$194,000***

(Module 1) Forest Resource II: Northeast/Northcentral (NE/NC), and (Module 2) Inland West

Preliminary budget plan:	***External funds***	***Institution match***
NE/NC softwood supply	***$30,000***	***$10,000***
NE/NC hardwood supply	***$21,000***	***$7,000***
Inland West softwood supply	***$30.000***	***$10,000***

Model Extensions	***$15,000***	***$5,000***
Subtotal	***$96,000***	***$32,000***

(Module 3) Processes II for NE/NC lumber, (Module 4) for Inland West lumber and (Module 5) for NE/NC OSB

Preliminary budget plan:	*External funds*	*Institution match*
NE/NC softwood lumber	***$30,000***	***$10,000***
NE/NC OSB	***$30,000***	***$10,000***
Inland West softwood lumber	***$30,000***	***$10,000***
Subtotal	***$90,000***	***$30,000***

(Module 6) Medium Density Fiberboard, MDF, (Module 7) Particleboard, (Module 8) Resins and Adhesives

Preliminary budget plan:	*External funds*	*Institution match*
Particleboard	***$30,000***	***$10,000***
MDF	***$30,000***	***$10,000***
Resins and Adhesives	***$60,000***	***$20,000***
Subtotal	***$120,000***	***$40,000***

(Module 9) Treated wood LCI

Preliminary budget plan:	*External funds*	*Institution match*
Treated wood	***$60,000***	***$20,000***

(Module 10) Structural Components and Subassemblies

Preliminary budget plan:	*External funds*	*Institution match*
Comparisons for substitutable components	***$21,000***	***$7,000***
Analysis of alternative subassemblies	***$30,000***	***$10,000***
Identification of improvement alternatives	***$21,000***	***$7,000***
Subtotal	***$72,000***	***$24,000***

(Module 11) Residential construction location and multi-unit differences

Preliminary budget plan:	*External funds*	*Institution match*
Southern CA and PNW single family design impacts	***$21,000***	***$7,000***
Multi-family design impacts for several regions	***$30,000***	***$10,000***
Identification of improvement alternatives	***$21,000***	***$7,000***
Subtotal	***$72,000***	***$24,000***

(Module 12) Cradle to gate integrated LCI/LCA's for easier use

Preliminary budget plan:	*External funds*	*Institution match*
Cradle to gate LCI for Phase I products	***$21,000***	***$7,000***
Cradle to gate LCI for Phase II products	***$21,000***	***$7,000***
Cradle to gate LCA for Phase I and II products	***$30,000***	***$10,000***

(Module 13) Canadian wood data review/workshop

Preliminary budget plan:	*External funds*	*Institution match*
Canadian wood data review and workshop	***$20,000***	***0***
Module 1-13 PROJECT Budget Subtotal	***$602,000***	***$194,000***
Other joint project budget items under admin control:		
Reviews	*$20,000*	*0*
Software ATHENA & SimaPro	*$30,000*	*0*
Web maintenance and Streaming video presentations	*$30,000*	*0*
Audit (end of project)	*$6,000*	*0*
Reports, page charges and distribution	*$20,000*	*0*
Admin, accounting, meeting prep, presentations	*$38,000*	*0*
Travel centrally controlled	*$45,000*	*0*
Admin Subtotal	***$189,000***	***0***
Total Project and Admin Cost	***$791,000***	***$194,000***

Phase II Target Sources of funds:		
USFS (FY03+)	$479,000	55%
Industry contribution Phase II	$220,000	25%
Subtotal cash sources	$699,000	
Institution match	$170,000	20%
Grand Total	$869,000	100%

Budget Gap:
The current project budget exceeds the planned funding sources by $92,000 which will be closed by either supplemental funding, eliminating several of the lowest priority projects, or perhaps a scope modification to projects not yet ready for startup.

Schedule: 2 years + reviews
Extended deliverables to Phase I: June 05
Phase II resource module draft: June 05
Phase II product module draft: December 05
Phase II housing and assembly drafts: June 06
Reviewed final reports: Dec 06

Other projects with supplemental funding and candidates for a housing extension that has been proposed by FPL or are deferred for a Phase III :

1. **Hardwood Floors**: The Hardwoods association has expressed an interest in developing an LCI, for flooring. This might be in comparison to other flooring products that have sufficient secondary data sources. A Forest Resource module to support it is included. Scott Bowe, U. of Wisconsin has obtained funds for this project. The funds for the flooring module are not included here although support for this is assumed.

2. **Factory built housing:** Will require separate surveys of the subassembly and final assembly construction process. This might be one of the explicit roles for the FPL fund raising for housing analysis that is not totally integrated into this proposal.

3. **R-code effectiveness:** should be evaluated for a subset of designs featuring different materials. This has not been emphasized but could be incorporated in the structures comparisons. Since it is sort of a trial and error analysis it may not be that cheap if more than a few structures are evaluated. It could become another extension component in the FPL housing analysis.

4. **Closing up the building**: To make the modeling more complete we could close up the building more completely including more than the shell, i.e. interior features. The ATHENA model has these capabilities now but we need to determine how to build them into our data collection effort so that we use what is available. This could be an implicit part of the Structures comparisons.

5. **Durability**: Given the basic information provided in Phase I, providing product/construction designs that are more durable should show substantial environmental benefits. Concentrating on the completed structure as we have, we were not able to show such differences. Bob Leichti, David Rosowsky, and Scott Kent have been working on building designs and durability issues at OSU and have expressed interest in pursuing this project. FPL has a history of product durability research that may provide a basis for incorporating durability more directly. UWA analysis of building life (Module L) showed longer lives than frequently reported. Their approach could be extended to incorporate the impact of improvements and maintenance.

6. **Developing Sustainable Management/LCI indices:** Similar to vitamin and diet information on the cereal box top, a sustainability index has been of interest to the building materials distributors. If developed for wood, the non-wood substitutes would have to provide the same information. Earlier interest by retailers may have lost steam with the recession.

7. **Comparisons with other studies are possible:** There is newly released information in Europe and New Zealand. LCI's often consider different system boundaries, use different energy sources, and end-use products, and are difficult if not impossible to compare. Nevertheless, to have a report clarifying these differences, and presenting the data for direct comparison where possible, would be very useful to the LCI community and the industries they represent.

8. **Siding:** There was a request for an LCI of cement impregnated fiber siding comparison to other siding. Siding is a big market. This area may deserve more attention.

9. **Infrastructural uses in Phase III** (bridges, docks, tunnels)

10. **Remodeling and interior uses:** much could be done with the proper survey information

11. **Use of new and more experimental materials and designs which frequently hit the press, particularly recycled products.**